THE RELATIONSHIP BETWEEN HEALTH POLICIES, MEDICAL TECHNOLOGY TREND, AND OUTCOMES: A perspective from the TECH Global Research Network[†]

by
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Abstract

Although technological change is a hallmark of health care world-wide, relatively little evidence exists on whether changes in health care differ across the very different health care systems of developed countries. We present new comparative evidence on heart attack care in seventeen countries showing that technological change—changes in medical treatments that affect the quality and cost of care—is universal but has differed greatly around the world. Differences in treatment rates are greatest for costly medical technologies, where strict financing limits and other policies to restrict adoption of intensive technologies have been associated with divergences in medical practices over time. Countries appear to differ systematically in the time at which intensive cardiac procedures began to be widely used and in the rate of growth of the procedures. The differences appear to be related to economic and regulatory incentives of the health care systems and may have important economic and health consequences.

1. - Introduction

The continuous increase in the cost of the health care services recorded over the last two decades in many countries has raised major concerns among policy makers, who have been forced to adopt new restrictive measures in order to reduce the public budget deficits. Most of the OECD countries have been involved in such practices, with the EU governments that have been particularly sensitive to this issue, given the strict requirements imposed on their budgets by the Maastricht Treaty signed in 1991.

There is a widespread consensus about two main causes for the sharp increase in health care services utilisation and expenditures: population aging, and the use of new and more intensive medical treatments. The ongoing change in the age structure of the industrialised countries is dramatic and is leading to a substantially higher proportion of older people. Population aging is particularly pronounced in many European countries, especially in Germany, Italy and France. Particularly remarkable is the increase among the oldest old: in the year 2030, many countries will have almost twice as many elderly over age 85 as now. There are several distinct processes that are causing these dramatic changes. From 1950 to 1980, life expectancy at birth increased by about 7.2 percent on average in the countries of the Organisation for Economic Cooperation and Development (OECD), while fertility in the industrialised countries declined to below replacement level. The effects of both processes sum to what is commonly termed "double aging" of the industrialised countries.

The scientific progress made in the health sector during the last 25 years is another distinct factor related to rising health care costs. In virtually all developed countries, health care costs are rising and population health and life expectancy are improving. Technological change, perhaps the most salient feature of the health care industry, may be a major contributor in these worldwide trends. Yet many previous studies have shown that

medical treatment differs substantially around the world. If *changes* in medical treatment also differ across countries, then policies that affect technological change may have important implications for both the nature and magnitude of medical expenditure growth and for improvements in health.

The combined effect of technology and aging population will lead to an unprecedented increase in cost for health care services. In the United States, Shoven *et al.* (1994) have estimated from 1990 to 2040 an increase of 125%, from $78 billion to $176 billion, compared to an increase in the population of only 27,5%.

As a result, one of the most crucial problems that all countries will face in the near future is the financial sustainability of health programs. In fact, with an aging population that receives increasingly sophisticated and expensive technological treatments, some countries are already experiencing long queues for health care, and it is conceivable to envision a point in which financial sustainability will not be assured and access to care will be further limited.

In response to this international issue, the global Technological Change in Healthcare (TECH) network (a network of researchers from 17 developed countries) was formed to conduct medical technology trend analyses with detailed healthcare data. As first step, the research activity has been organized to analyse changes in heart attack care (acute myocardial infarction, or AMI), an important health problem for populations worldwide, with the aim of providing insights into the determinants and consequences of medical technology changes over time. We chose to focus initially on patients hospitalised with heart attacks, for several reasons. Heart attack is a well-defined clinical condition around the world. Inpatient data, which are the most reliable data in most countries, are relatively complete sources of information on acute care for heart attacks. Knowledge of effective heart attack treatments has changed much in recent years; clinical trials and other data from the United States and other countries suggest that changes in medical

practices may account for a large part of the improvements in outcomes (Kessler and McClellan, 2002). Thus, if differences in technological change exist across countries, they are likely to show up in inpatient care for heart attack. We can assess directly whether, and how, differences in the economic and regulatory incentives underlying national policies appear to influence technological change. Finally, though confounders may remain, we can more directly evaluate the association between medical treatment differences and expenditure and health outcome differences for patients with these illnesses in each country.

Studies in the United States and a few European countries have demonstrated enormous variation in treatment patterns from region to region within individual countries, as well as differences at a point in time across countries. Aside from early stage work in several affiliated projects, and the nearly completed OECD Ageing projects, we are not aware of other studies providing an international comparison of the effects of the intertwined factors of technological changes, aging populations, socio-economic status, health policies, and health expenditures.

We have analysed the consequences of different technology adoption and diffusion patterns among a number of developed countries on health outcomes and health expenditures for different subgroups of society. In addition, we have developed protocols for extending these studies to other major clinical conditions that also influence quality and quantity of life.

The results reached so far shed some light on several major topics relevant to the current policy debates in the health sector, including *i)* how do different health care policies influence technological change, *ii)* what are the implications for health care costs, *iii)* what are the implications for the length and quality of life of individuals with heart disease, *iv)* do different policies influence which patients receive treatments, and the costs and outcomes that they experience? By providing quantitative and qualitative answers to these questions, and by developing methods that can be applied to many other common health care

problems experience worldwide, we will be able to provide insights for the management of technology in society within the health care sector.

2. - The Unresolved Issues in International Comparisons of Health and Health Care Systems

Apart from the increasing number of elderly, many investigators have hypothesised that technological change is responsible for most of the substantial real growth in expenditures experienced by virtually all countries in recent decades; yet direct empirical evidence on this question is limited, especially outside of the American context. Moreover, the role of medical care in explaining the improvements in health outcomes of older populations worldwide is unresolved. This lack of evidence is a crucial issue for policies on aging and health. If economic and regulatory incentives influence technological diffusion patterns, then national health policies may have dynamic, long-term consequences for the productivity of health care systems that are far more important than short-term, cross-sectional differences.

One major reason for the lack of evidence in this area thus far is the major challenge of accessing enough clinical details using available "macro" and "micro" data to evaluate the consequences of different health care systems. Part of the significant contribution of the TECH network is the identification of these limitations, which are discussed in the following sections.

2.1 - Limitations of Aggregate or "Macro" Statistics in Assessing Health Care Productivity

Most comparative studies across multiple countries are based on aggregate or "macro" statistics such as per-capita medical spending, gross domestic product (GDP) share devoted to health care, life expectancy, mortality rates from common diseases, and general surveys of population functional status and health. These statistics permit many useful international comparisons, but they leave many critical policy issues unresolved – particularly issues

related to changes in expenditures and health. For example, the OECD and other international organisations annually document large differences in aggregate per-capita spending on health care across developed countries. In addition, medical spending has increased enormously in the past 25 years, commonly doubling or tripling. Using estimates from Newhouse (1993), Schieber, Poullier and Greenwald (1994), noted that substantial real expenditure growth occurred in most OECD countries, at least through the 1980s.

Standardised measures of population health, such as life expectancy in middle or old age or disability-adjusted life expectancy (Murray and Lopez, 1996) also differ substantially across countries. These health measures have generally improved greatly in the recent decades of worldwide growth in real medical expenditures, particularly at older ages as confirmed by OECD. But these aggregate measures of population health show little relation to the differences in health care spending just described. Many important confounding factors -- cultural, and genetic differences, as well as differences in public health, educational, and income redistribution policies that lead to behavioural differences -- have been cited as reasons for the absence of any clear correlation.

Since aggregate statistics provide little direct evidence on the factors responsible for expenditure growth and health improvements, they are unable to resolve policy questions related to the productivity of the health care system. The likely cause for expenditure growth is derived from indirect evidence: at least in the United States, all factors other than technological change that might contribute to expenditure growth seem able to explain only a small fraction of increases (Newhouse, 1992). Population aging has been and remains an important policy concern, yet even in the most rapidly-aging countries it accounts for real growth rates of about one percent per year, much lower than most observed medical expenditure growth rates. Per-capita income has increased as a result of economic growth, and other factors such

as competition and insurance generosity may have changed as well, but the medical spending increases are far greater than can be explained by all of these determinants of spending combined. Because technology consists of particular drugs, devices, and labour inputs that differ from disease to disease, it is not possible to summarise effects in aggregate statistics. Instead, many comparative studies have provided somewhat more direct evidence on real increases in the quantities of medical services consumed based on national counts of such "high-tech" treatments as MRI scanners and catheterisation labs, and measures of the aggregate use of these procedures (e.g., Schieber, Poullier and Greenwald (1994)). Do technology and diffusion patterns also differ across countries, and if so, what policies might play a role? Do differences, in turn, have important consequences for health care expenditure growth? For health improvements, the importance of technological change is more difficult to assess due to confounding factors. And it is virtually impossible using only counts of procedures or measures of the availability of devices, without linking their use more directly to changes in health for the conditions that they are intended to treat.

Thus, "macro" international comparisons have provided some important though indirect evidence to support the view that differences in technology use across countries are important explanations for differences in the magnitude and growth of health expenditures. But many important issues involving technological change, its determinants, and its consequences remain unresolved. Are expenditure growth rates similar across countries, as Newhouse (1993) preliminary study suggested? If expenditure growth is more similar than expenditure levels across countries, is it because technological change is identical but prices differ? Or is it because the nature or magnitude of change in actual medical practice differs across countries? Does the less-costly country use new technologies less extensively? Or does it tend to adopt different kinds of technologies? Or does it follow medical practices in the more costly country with a lag? And

which health care policies are associated with these differences in technological change or expenditure growth? These questions about changes in health care resource use are very difficult to address with macro data alone. The relationship between trends in resource use and changes in health is even more elusive at the macro level. The absence of any clear relationship raises fundamental policy questions about whether some or all of the expenditure growth is worthwhile, and which of the highly diverse health policies across countries are most likely to encourage worthwhile changes in expenditures.

2.2 - Limitations of Previous "Micro", or Patient Level, Studies in Assessing Health Care Productivity

To overcome the shortcomings with "macro" international comparisons, several previous studies have compared clinical practices across countries for particular illnesses at the "micro" or patient level, and have speculated their health consequences, for two or several countries. We do not try to review all of these studies here. Instead, using two previous major large-scale international research efforts, such as the study by McKinsey Global Institute and the McKinsey Health Care Practice (1996) and the MONICA (Multinational MONItoring of Trends and Determinants in CArdiovascular Disease) Project, we illustrate some of the main conclusions from these comparisons. These studies are useful to illustrate key features of our research.

The study by McKinsey Global Institute and the McKinsey Health Care Practice (1996) was a detailed assessment of differences in medical practices and their consequences in three countries with quite different health care systems: the United States (US), the United Kingdom, and Germany. The study assessed the treatment of lung and breast cancer, diabetes, and gall bladder disease, based on medical practices around 1990. The investigators documented substantial differences in practices, with generally higher intensity of care (more treatments) in the US and Germany. They also documented higher prices for

clinician services in the United States. Through a combination of literature reviews of treatment effectiveness and actual data on patient outcomes in the study countries, as well as estimation of reasonable valuations of the outcomes, the investigators concluded that US productivity was better for cancer and gall bladder disease care. However, productivity of care for diabetes in the United Kingdom was better, because the multi-disciplinary teams used to treat diabetics did a better job of triaging patients with different types and severity of diabetes to the most appropriate level of care. Studies of other conditions, including heart disease, (e.g., Tu *et al.*, 1997) that have compared large populations with apparently similar health problems have found less evidence of differences in health outcomes despite substantially different practices across countries. Like most international comparisons, however, this study examined practices and their consequences at a point in time, raising the possibility that the differences across countries may be due to other country-specific factors.

An important, relevant exception is the World Health Organisation's MONICA Project, a major international epidemiological effort to document and understand possible national differences in reductions in death rates from ischemic heart disease (Tunstall-Pedoe *et al.*, 1998 and 2000). Reduction in mortality from ischemic heart disease (IHD), of which heart attacks are an important component, is by far the most important source of overall mortality declines in developed countries in recent decades (Uemura and Pisa, 1988). MONICA implemented careful and consistent methods for capturing all fatal out-of-hospital coronary disease events, as well as all hospital admissions for coronary events (including both heart attacks and less severe forms of IHD), and has reported many important findings. First, the study confirmed the importance of a substantial decline in heart disease event rates over time in explaining the falling mortality rates from heart disease. Second, the study also documented substantial reductions in mortality

among patients who reached the hospital alive. Both of these findings suggest an important role for technological change in explaining improved population health. Primary and secondary prevention of heart disease is the goal of pharmaceutical treatment to reduce blood pressure, cholesterol levels, and the workload of the heart, and these medications have become much more widely used over the past 20 years.

However, these findings also illustrate why it may be difficult to discern the impact of medical treatment and especially changes in medical treatment even in disease-specific mortality trends. Public health measures such as advertising campaigns, behavioural changes such as reduced smoking, and other non-medical factors may plausibly be more important contributors than treatment to the declines in IHD event rates that appear to account for the bulk of mortality reductions worldwide. The medications involved in prevention comprise only a small share of medical care and changes in resource use in the treatment of heart disease. In contrast, the hospital treatments for patients who reach the hospital alive are more representative of the bulk of health care resource use. But the third major finding of the MONICA project illustrates the limited importance of these treatments in contributing to the total mortality trends: the bulk of heart disease deaths are out-of-hospital deaths. Because the role of the health care system in preventing these deaths is limited (Heidenreich and McClellan, 1998), and because innovations in pre-hospital medical care have also been limited, it is perhaps not surprising that the aggregate health care spending levels and growth rates appear to have little relationship to the levels or declines in heart disease death rates documented in MONICA.

3 - Innovative Aspects of TECH Global Research Network

To address the limitations of previous works, the TECH Network has implemented a number of innovative approaches. First, an important advancement of our research is on the design of data collection protocols and standardised collaborative analyses of

changes in medical care and health outcomes at the "micro" level, across many countries.

Second, recent studies have put considerably more direct evidence on the importance of technological change, though most of it is confined to the United States (e.g., Shapiro and Wilcox (1999), Cutler and McClellan (1998), and Cutler *et al.* (1998)) Using a "micro" focus, Cutler *et al*. (1998) demonstrate that most expenditure growth in heart attack care is associated with the adoption of new treatments and the diffusion of intensive treatments; prices for particular treatments usually fall over time. Little comparable evidence exists for other countries, and comparative data studies within the TECH network aim to fill this gap.

Third, our understanding of the role of economic and regulatory influences on technological change is more speculative. Weisbrod (1991) argued that the kinds of incentives that economists often evaluate in a static context may have far more important dynamic consequences than static ones. For example, many studies (e.g., Newhouse, 1993) have documented that a generous fee-for-service reimbursement system, in which patients and providers receive third-party reimbursement for all treatments used, results in more intensive treatment and higher health care costs. But fewer studies have assessed whether such "low-powered" reimbursement incentives create an incentive environment that encourages excessive or low-valued technological innovation in medicine. McClellan (1997a, 1997b) argue that technological change in the U.S. Medicare program appears consistent with its low-powered incentives for the use of intensive procedures. TECH analyses extend the evidence on this question beyond a single country by comparing technological change in the care of similar patients in many different countries.

Fourth, longitudinal cross-country comparisons at the micro level appear to be an essential foundation for understanding how health policy may affect the contribution of technological change to health improvements and medical expenditure growth, and thus

to guiding future policies to improve the welfare of populations worldwide. By examining not only the effects of incentives on technological change, but also the associated changes in health outcomes and expenditures, TECH is providing evidence about the consequences of different incentive systems for changes in health care productivity. The longitudinal perspective of TECH also allows us to "difference out" important but relatively fixed differences across countries that might otherwise confound such cross-country comparisons of medical expenditures and outcomes.

Finally, our research builds upon the work undertaken by both the McKinsey study and the MONICA WHO study in several important ways. First, the TECH databases contain longitudinal data from patient discharge records from almost all participating country, instead of the registry-based data used by MONICA or cross-sectional data used by McKinsey. Analyses of outcomes after AMI in selected countries have shown that national data differs from local MONICA data. Unlike data from the MONICA project, data collected by the TECH research network incorporate *1)* at least a one-year follow-up when linked, longitudinal data are available, *2)* patients over 65 as well as patients under 65, and *3)* large geographic areas, in many cases the entire country. In addition, the time frames covered by each study differ: MONICA ended its official data collection in 1992 while the TECH study is gathering more current in a number of countries. Furthermore, while MONICA is mainly an epidemiological study, this project incorporates methodologies from different disciplines, such as sociology and economics, when studying the regulatory and reimbursement systems in countries and socio-economic characteristics of patients, to explain the differences existing in health technology adoption and health outcomes at country level. This research will complement MONICA's focus on public health, and build on productivity studies like the analysis by McKinsey that have sought to compare resource use and evaluate the role of economic and

regulatory incentives in influencing medical productivity. By adopting a longitudinal perspective with a focus on trend analyses across a number of countries, the TECH network aims to provide insights into the causes and consequences of differences in medical practice, and especially technological change. Because of the detailed data, our approach includes the ability to evaluate various population groupings, by age or other meaningful categories.

In the sections that follow, we discuss and illustrate in more details our approach to address these problems.

4. - The Methodology used

Since the motivating goal of TECH research and similar efforts is to help policy makers in designing policies that can foster appropriate adoption and diffusion of new technologies with the aim of improving patient health outcome without undo cost pressure, we have organized an ambitious research agenda. The first phase is focused on a specific prevalent health condition with major mortality and quality of life effects: Acute Myocardial Infarction or more commonly, heart attack (AMI). The second phase of the project explores the feasibility of extending our methodology to other areas, especially cardiovascular disease prevention, acute coronary syndromes and AMI complications.

For the AMI analysis, we have organized our work in six tasks related to each other as shown in Fig. 1. Task 1 characterizes the existing structure of regulations, financing, health care organization and competition in each country over the past decade, and hypothesize how these might affect health care technology adoption and diffusion. Task 2 deals with measures of health care technology intervention trends. The main objective of this task is to find reliable methods to describe these differences in a quantitative manner and to analyse the different treatment patterns for AMI patients across the participating countries. This is a very important task that involves the derivation of a new methodology to work with data from homogeneous patients

groups at international level. Based on the results obtained from task 2, in task 3 we determine mortality rates following hospital admission for AMI, studying and comparing *a)* mortality rates in each of the participating countries, and *b)* within each country, trends over time in mortality rates. We also investigate the relationship between the use of health care technology for the treatment of acute AMI and the outcomes of care in different countries, as measured by mortality rates; in this way we can also investigate on the relationship between *rates of change* over time in the use of technologies and *rates of change* over time in mortality rates. In task 4, as in the first three tasks, we document variations across countries in AMI expenditure levels and trends by decomposing micro level health care expenditure trends into relative cost and quantity trends. In addition, based on data from task 2 and task 3, we assess the impact of differences in expenditures on the up-take of new health care technologies across different health care systems. Then, based on results from task 1 through 4, we assess the relative importance of unit costs and quantity provision on population health controlling for regulatory environment. In task 5, based on additional data and information gathered from the previous work packages, we study how accessibility to new technologies, expenditures and health outcomes can vary according to patient socio-economic status (sex, education, race, income/poverty, etc.) for the treatment of hearth attack. Differences in socio-economic status and their effects on treatments are reinforced by restrictions in the public health care financing and by the increasing privatisation process of the health care sector witnessed in several OECD countries.

Information collected from task 1 through task 5 are then used in task 6 to explore the effects of regulation and incentives in health care systems on the diffusion of medical technology, and to discuss the potential policy implications of these findings. Understanding of this process will serve to inform several important policy issues.

The remaining three tasks (7-9) explore the feasibility of extending our methodology to cardiovascular disease prevention, acute coronary syndromes and AMI complications. The focus in task 7 on a specific health event (and ICD-9 code) enables a clean and valid comparative study. Cardiac events and their treatment include several further issues, which might affect the incidence, treatment and outcomes in the countries' AMI patients. Furthermore, during this phase we discuss the opportunity to enlarge our methodology to other sectors. Other forms of coronary heart disease (e.g., unstable angina and other acute coronary syndromes), stroke, breast cancer, and other cancers are possible candidates.

In particular, task 7 is relevant to the diffusion of technology and the determinants thereof -- in this case the diffusion of an emerging technology in coronary care -- the use of highly efficacious lipid-modifying agents in the primary prevention of CHD. It may be predicted that a considerable reduction in the clinical expression of acute coronary syndromes and hence of invasive cardiology will result from the successful management of hyperlipidemia through primary prevention. Incentives in the health care systems, regulatory policies and cost considerations will strongly affect large-scale penetration of statins into the non-symptomatic population. Most current recommendations indicate use in patients at high risk (20-30%) of an event over the next 10 years - a restriction that overwhelmingly favours care of the elderly, while neglecting the younger population. Task 7 is closely linked to tasks 1-6, as well as to task 8 and 9, which explores outcomes of failed primary prevention.

Task 8 focus on the management of acute coronary syndromes (ACS). Task 8 will explore the extent to which methods developed for task 2 can be adapted for study of a related and increasingly prevalent variant of heart disease, acute coronary syndrome. The final goal of this task is to develop a protocol for obtaining administrative data that can make valid comparisons across countries of trends in the use of technology

for the management of ACS (other than definite heart attack). In this way we can compare and contrast results obtained for heart attack trends with those obtained for other ACS patients. Task 8 will also provide data that may allow extension of the exploration of inequalities which is the focus of task 5.

In Task 9 we try to assess how the management of congestive heart failure (CHF) is affected by the regulatory environment and financing of healthcare. In fact, as more patients survive after an AMI, the natural history of the disease results in increased prevalence of CHF in European countries. Overall, CHF represents between 5-10% of all hospital admissions and 1-2% of total health expenditures in EU countries. There is evidence that an appropriate ambulatory management of CHF patients can reduce the number of adverse events, for which hospital readmissions are a good marker.

5. - The data used.

To the extent possible, teams used nationally representative micro-level data sources—covering at least a large geographic area of each country—rather than reports from particular, possibly non-representative institutions.

Most countries were able to provide national data or data from large regional databases for the analysis. U.S. data include all elderly, non–health maintenance organization (HMO) beneficiaries with new heart attacks, and all heart attack patients in California. Canadian data are from three provinces, as described in the text. U.K. data are from the Oxford region and Scotland. Several centers provided data from the MONICA project: Swiss data are from several prefectures surrounding Lausanne, and Italian data are from the Friuli region. Both of these samples are confined to the non elderly. Australian data are from the states of Western Australia (Perth and surrounding areas) and Victoria. Only two countries did not have approximately representative regional or national data. French data are from all public and non-profit private hospitals, which

represent about two-thirds of heart attack stays. Japanese data are from a selected sample of six large, academically oriented hospitals. All other research teams analysed national data sets.

We have developed and applied consistent methods for conducting micro-level analyses, including standardized cohort and variable definitions and population weights[1]. In particular, we have created a data collection protocol according to which all countries/teams have produced their cohorts of AMI patients. All participating countries feature administrative and other data that rely on ICD-9 or ICD-10 diagnosis codes, or on country-specific coding systems for which our principal diagnoses of interest (AMI, ischemic heart disease, congestive heart failure, etc.) have already been converted to these international standards. For most participating countries, we will use longitudinal patient data, allowing us to identify reliably a patient's first admission with AMI as well as treatment and outcomes of the initial and subsequent admissions. For countries without longitudinal data, we will construct "denominator" AMI population estimates from admissions with a primary diagnosis of a new AMI, and use both initial and subsequent (ICD-9 code 410.x2) AMI admissions to construct treatment rates.

Construction of diagnosis, treatment, co-morbidity, outcome, and resource use variables will follow the standard procedures developed in our preliminary studies and are incorporated into our

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[1] See McClellan and Kessler (2002). Following previous validated studies in multiple countries, all research teams used a consistent case definition for AMI patients based on discharge data, applying the same exclusions to avoid cases unlikely to represent true new AMIs. See M.B. McClellan *et al*., "Trends in Intensive Procedure Use and Outcomes in the United States and Canada" (forthcoming). We have also compared co-morbidities and co-morbidity trends across countries, and have estimated multivariate models with and without various sets of co-morbidity control variables. See Tu *et al*. (2001). In general, these models show that after demographic adjustment, little to no difference exists between trend results estimated using models that account for co-morbidities and those without.

protocol already. For that research, we developed standard statistical programs for constructing all of these variables using ICD diagnosis codes and ICD-CM and CPT procedure codes. We constructed identically-defined variables for important high-tech treatments (catheterization, bypass surgery, angioplasty, primary angioplasty, stent use). We have developed similar shared programs for constructing covariates for common co-morbid diseases and for co-morbidity indices such as the Charlson index.

For countries able to link individual hospital records over time, our principal outcome measures include all-cause mortality (for countries able to link death records), in-hospital mortality (especially acute mortality), and readmissions related to specific cardiac complications at various time periods after AMI. The complication measures of principal interest are recurrent admissions with new AMIs and admissions for congestive heart failure (CHF) more than 30 days after the initial hospitalization. For countries that do not have longitudinal data, we will construct measures of outcomes from the initial hospital stay (e.g., CHF reported as a complication during the admission, and death at discharge); for comparability, we will construct analogous initial-stay measures from the countries with longitudinal data. All of this data when received will be thoroughly reviewed by the data manager at the coordinating centre.

These methods have enabled us to make cross-country comparisons with a degree of precision that has not been achieved before. Furthermore, in conjunction with methods developed by us, these data will enable investigators to estimate formal cross-country regression models assessing the effect of one or more aspects of health care systems on technology use and quality, *without actually pooling sensitive individual patient data*. We have then developed a methodology that will allow us to share such information without violating the privacy of the data itself. We will refer to this methodology as "sub-matrix method". Our method allows researchers to undertake formal cross-country regression analyses, while only sharing data in an aggregated

matrix form that has all individual-level information destroyed.[2] None of these standardized matrices contains any individual-level information because all the individual-level information has been summed together to form the cross-product matrices.

6. - Evidence on International Differences in the Causes, Nature, and Consequences of Technological Change

In this section we present and discuss the main findings of our ongoing research activity. In general, we find a great deal of technological change in most dimensions of acute heart attack care, in virtually all of the countries included in our analysis. However, technological change for heart attack care has differed in many ways across countries.

In order to have a better understanding of the causes, nature and consequences of technological change in the following section we present we have adopted a convenient taxonomy for both market and governmental forces as well as for definition of technological change. Here below we report on the consequences of these linkages between medical technology impediments and promoters for health care use and population health status. The results illustrate some clear relationships to health system characteristics, particularly for the case of intensive treatments for heart attack patients.

6.1 – Regulations, Financing, Health Care Organization and Competition

The following incentives reflect a review of the international and country-specific literature on economic influences on medical treatment, and extensive discussions with economists and other

[2] For simplicity, consider the problem of pooling data on across two countries for a single year, country A and country B. Some elementary matrix algebra shows that the OLS estimator of φ , $(X'X)^{-1}\ X'Y$, can be rewritten $(X_A'X_A + X_B'X_B)^{-1}\ (X_A'Y_A + X_B'Y_B)$ where X_A has k columns, one for each variable in the joint analysis, and NA rows, one for each individual patient in country A, and X_B is defined similarly. This has great importance. Simply by sharing four matrices -- $(X_A'X_A)$, $(X_B'X_B)$, $(X_A'Y_A)$, and $(X_B'Y_B)$ – investigators in either of the two countries can conduct a joint regression analysis.

participants in the research network (see table 1). We consider effects of health care payment systems, regulations, and a range of other economic and policy factors. Many of these factors have been the subject of cross-sectional studies, for example of the effects of co-payments or differences in physician payment on treatment choices. Following Weisbrod (1992) and others, we emphasize the *dynamic* consequences of these policies. For example, lower patient payments or more generous physician payments for a particular treatment may provide incentives to develop expanded uses of a medical treatment that would be less encouraged under different reimbursement systems. As a result, differences in health care incentives and regulations may have substantial dynamic implications.

Patient Payment Incentives. The out-of-pocket payments by patients when they use medical services are quite different in different nations. Patient payments range from trivial or nonexistent in countries like the United Kingdom and Sweden, to very high rates in some Asian countries. For example, many insurance plans in Korea reimburse only a fraction of the cost of hospital admissions, procedures, and drugs. Along these lines, a substantial proportion of health care expenditures in Taiwan (approximately 40 percent) historically were financed by out-of-pocket expenditures; however, this proportion declined dramatically after March 1, 1995, when Taiwan adopted a comprehensive National Health Insurance system (see below). Many of the countries with low patient payments in their "basic" public insurance systems have more or less extensive systems of private insurance, where patients are responsible not only for their premium payments but also for substantial co-payments when they use services. Australia provides a good example of this system, in which more than one-fifth of the population (largely those with higher demands for medical care) have private policies that provide coverage for a substantial amount of medical care.

Provider Payment Incentives. Countries also differ enormously in their provider payment systems. We considered two principal dimensions in which payment methods and changes in payment methods for hospitals, physicians, and other health care providers may differ: the *level* of payment ("average" payment generosity), and the *responsiveness* of payment to the use of more costly treatments for a patient ("marginal" or incremental payment generosity). Countries in our study vary enormously in these incentives. For hospital reimbursement, systems range from global budgets with relatively high (Canada) and low (United Kingdom, Denmark) average payments per bed or admission, to fee-for-service systems with relatively high (United States, for its "traditionally" insured and preferred-provider populations) and low (Japan, Korea) payment levels.(7) Other countries use intermediate systems, ones that respond to some extent (or for some kinds of treatment only) to the use of more costly treatments. For example, Australia and Taiwan now rely on diagnosis-related group systems for hospitals, which are "prospective" payments that differ in amount based on the diagnoses and technologies used to treat a patient (McClellan, 1997). Sweden offers a unique combination of systems, in which some districts reimburse hospitals on the basis of global budgets, and some reimburse hospitals with a DRG system. These countries also differ substantially in their average payment rate.

Payment systems for physicians also differ widely, in ways that differ from hospital reimbursement systems. For example, Canada pays physicians on a fee-for-service basis, so that more intensive treatments lead to more reimbursement (up to a cap), while "traditional" Medicare in the United States features a relatively more generous fee-for-service system. Physicians in Japan and Korea are also reimbursed largely on a fee-for-service basis. At the opposite extreme, physicians in Finland and Sweden are salaried. In between, the United Kingdom use a "fee-for-patient" (capitation) reimbursement system, again with quite different

average payment levels. The level and responsiveness of payments for drugs, devices, and other medical services also differ across countries. Reimbursement for thrombolytic drug treatment of heart attack (discussed in detail below) illustrates the range of drug payment incentives. At one extreme, Belgium offers virtually unrestricted fee-for-service reimbursement for use of all thrombolytics. In contrast, Taiwan provides fee-for-service reimbursement for thrombolytics only under certain conditions, and Sweden finances most inpatient drugs through global hospital budgets.

Technology Regulation. Countries differ equally widely in their regulation of medical technology and the use of various medical treatments. Our reviews of technology regulation suggested that countries differed primarily in two broad types of regulation: "macro" regulation of the adoption or aggregate level of use of medical technologies, and "micro" regulation of the use of medical technologies in particular cases. At the *macro* level, countries such as Canada and the United Kingdom strictly review and limit the capabilities of providers to perform costly, intensive medical procedures. These government regulations generally affect "high-tech" medical technologies such as MRI scanners, cardiac catheterization labs, and open-heart surgery facilities. At the opposite extreme, countries including Japan, Korea, Taiwan, and the United States have little or no macro-regulation of technological capabilities. In between, countries including Belgium, France, Italy, and Australia regulate intensive technological capabilities on a limited basis, for example in public hospitals but not the large number of privately-owned hospitals.

Micro regulation of technology use in individual patients, particularly the use of costly technologies, occurs on a more limited worldwide basis. The pre-approval requirements, second opinion requirements, and other features of utilization review that

are a major part of managed care in the United States are well known. However, other countries have also begun to regulate technology use at the micro level. For example, the province of Ontario uses a relatively detailed clinical evaluation system to prioritize its waiting lists for bypass operations and other procedures that are subject to "macro" regulation. The United Kingdom and Denmark also have "gatekeeper" requirements, involving pre-approval by a patient's primary physician, for visits to specialists and other intensive services to be covered.

Hospital Ownership. Our participating countries also differ in the ownership of their health care facilities. In Denmark, Finland, and Sweden, hospitals and other facilities are publicly owned. However, these countries differ in the level of government with institutional control, ranging from the national government to local municipalities. Many countries, including Australia, France, Taiwan, and the United States, have mixed systems of hospital ownership, and also differ in the extent to which private ownership is for-profit or nonprofit. Countries such as Japan and Korea rely relatively heavily on for-profit ownership, even of teaching hospitals.

Competition. Countries differ in the extent to which their populations have effective choices among medical providers and health insurance plans. For its non-elderly population, the United States has a high degree of choice and thus competition at the health plan level. Other countries, including Japan and Switzerland, also have some freedom of choice of health plans. At the opposite extreme, universal government-funded health insurance programs such as those in Canada, Denmark, the United Kingdom, and Sweden have no choice in primary insurance plans, and (in some of these countries) only limited choices in supplemental private insurance policies. Many countries with little choice of insurance plans, such as France,

Korea, and the United Kingdom, do have considerable freedom of choice among health care providers.

Physician Supply. Many countries, including some that do not regulate technology use strictly or rely on public payment systems, strictly regulate their supply of health professionals. Regulations may affect both the total supply and their distribution across specialties. Countries with relatively strict limits include the United Kingdom; countries with relatively little regulation include Israel, and the United States.

Other Factors. Virtually all research teams suggested that the factors listed above were likely important determinants of technological change in their countries. Research teams in some particular countries also noted some additional factors. Investigators from several countries mentioned the importance of public and private policies on the provision of information about providers and the effectiveness of medical technologies. For example, press coverage of waiting lists was mentioned by investigators in Israel, and Sweden as having altered government policy about allocation of resources to the provision of intensive cardiac procedures; direct advertising to patients in the United States may have similar effects on diffusion of the use of certain prescription drugs. Information provided to physicians and hospitals on such topics as the effectiveness of treatments (e.g., policy initiatives to educate doctors on treatment effectiveness in the United Kingdom) and on how their practices differed from those of their peers was noted as an important determinant of treatment changes in some countries. However, many more research teams reported that such information provision was likely to become a more important determinant of medical practice in the future, with further improvements in data collection systems on medical practices and outcomes.

6.2 – A convenient taxonomy of technological change[3]

For a better exposition of our findings we divide technological change into three main categories: changes in *high-tech* care, *low-tech* care, and the *appropriateness* of medical care.

High-Tech Changes. We define high-tech treatments as those with high fixed costs for provision, or high marginal costs with each use. An example of a high fixed-cost technology is cardiac catheterisation, a technique for imaging the interior of the arteries which provide blood to the heart muscle. The high fixed-costs of cardiac catheterisation include hiring specialised personnel (not only interventional cardiologists, but also specialised nurses and cath technicians) and purchasing substantial specialised equipment (e.g., cath tables and fluoroscopic imagers). The provision of open-heart (bypass) surgery also requires substantial fixed investments, and is also expensive to perform on a per-case basis. Each case requires substantial specialised surgeon, cardiologist, and nurse input, as well as costly supplies like blood products and heart-lung bypass filters and tubing. In the results presented in subsequent chapters, we find very large effects of differences in incentives on trends in the use of high-tech procedures in heart attack care. For example, Israel increased marginal reimbursement rates for bypass surgery in 1989 in response to public dissatisfaction with long waiting lists; immediately after marginal reimbursement rose, the number of bypass procedures rose dramatically. More generally, countries that use fixed payment systems and countries that regulate the diffusion of high-tech capabilities tightly have much less growth in the use of high-tech procedures over time, so that treatment involving high-tech services such as catheterisation, angioplasty, and bypass surgery across countries has diverged substantially. Payment levels also seem much less important for explaining the

[3] - The framework was designed to be applicable to the analysis of technological change for any health problem, not just heart attacks.

trends in high-tech procedure use than does the responsiveness of a payment system to increased use of high-tech procedures.

Low-Tech Changes. We define low-tech treatments as those with low fixed and marginal costs of use. Essentially, these are treatments that individual doctors or other health personnel could provide without the use of substantial input of labour, capital equipment, or materials. For example, clinical trials in the 1980s documented important survival benefits from the use of drugs such as aspirin and beta blockers soon after a heart attack. These drugs have been available for some time in generic versions. Though data on trends in the use of low-tech treatments are more difficult to obtain in many countries, especially over long time periods, results from our study suggest that differences in incentives across countries are not that important in explaining trends in low-tech treatments. For example, aspirin use has increased at relatively similar rates to very high levels in almost all of our countries over the past decade, and beta blocker use has also increased. The use of drugs found in clinical trials to be potentially harmful in heart attack care, including calcium channel blockers and lidocaine, have also declined in use by relatively similar magnitudes in most countries studied.

Changes in Expertise or Appropriateness. We characterise technological change not only in terms of changes in the use of various types of technology, but also in terms of changes in the *appropriateness* or experience with which such technologies are used. For example, two countries may have similar rates of use of catheterisation and aspirin, but if medical professionals in the first country do a progressively better job of targeting the technology to the patients who would most benefit from it, then the first country is likely to have better outcomes after heart attack. Judgments about changes in appropriateness or the skill of physicians using the technology require detailed medical data over time to assess these issues, and such data are not currently

available in most countries. However, many of the research teams were able to review research studies relevant to this question, and to identify better data for future studies. We suspect that differences in the appropriateness of technological change are important determinants of differences in outcome trends. However, in the current study we are only able to develop speculative evidence on this topic.

6.3 – The Nature and Magnitude of Technological Change

In this section we present the outcome consequences of the substantial differences in technological change across countries that are associated with differences in economic and regulatory incentives. We consider only health outcomes, especially mortality, leaving expenditure and resource use outcomes to future analyses.

Our analyses of differences in outcome trends suggest that the improvements in mortality after heart attack are large in most countries, and generally appear to be only modestly related to technological change, especially high-tech technological change. However, countries with greater high-tech changes had somewhat less growth in the occurrence of heart disease complications in the additional heart attack survivors, especially at older ages, suggesting that the more rapid growth in intensive treatments did have some consequences for patient quality of life. Even in our longitudinal analysis, other factors may explain the absence of a stronger relationship besides the lack of mortality benefits from greater high-tech changes in care.

Our analyses strongly suggest that the nature and magnitude of technological change are systematically related to the economic and regulatory incentives in a country's health care system. However, the way in which medical practices have changed has differed. For intensive procedures, we found three very different patterns of technological change. The United States and (based on more limited evidence) Japan and possibly France illustrated an early start/fast growth pattern: intensive procedures

tended to diffuse early, resulting in relatively high treatment rates in the overall population in any given time period. This pattern is also associated with relatively rapid diffusion for these countries' elderly populations.

A second pattern, late start/fast growth, involves relatively rapid diffusion of intensive technologies, but diffusion that starts later and thus from a lower "base rate." These countries show diffusion rates that are similar to U.S. rates, and indeed in some cases con-verge toward U.S. rates. But the overall intensity of treatment at any given time tends to be somewhat lower than in the United States because of the later start of diffusion (and, in the case of Canada, because the trend rate is somewhat slower than the U.S. rate). In addition, diffusion of procedures to elderly patients in these countries tends to be slower. Countries with this pattern include Australia, Belgium, most Canadian provinces (although their growth rates were somewhat slower than those of most other countries in this group), France, Italy, Singapore, and Taiwan.

The third pattern involves late start/slow growth: later adoption and slower diffusion throughout the decade. Countries with this pattern include the United Kingdom, most of the Scandinavian countries, and (at least on some measures) Ontario. No such systematic differences in trends were evident for relatively low-cost, easy-to-use drugs. In general, many drug treatments diffused widely in all developed countries, but the patterns of diffusion were not so clearly different. Drugs with very high costs, illustrated by tPA, showed differences in trends more like those observed for the intensive procedures.

In our ongoing work, we are conducting more comprehensive analyses of the extent to which these broad patterns of technological change are related to the underlying regulatory and economic incentives for providing medical treatments in each country. While much remains to be done, our results suggest that "supply side" incentives—particularly those affecting hospitals and, to a lesser extent, physicians—have an important

relationship to observed trends in costly treatments, including intensive procedures and certain very expensive drugs. Countries such as the United States and Taiwan with relatively "weak" supply-side restrictions on the adoption of intensive treatments—such as the provision of additional reimbursement to hospitals based on the treatments they provide, and limited regulatory restrictions on particular technology adoption decisions by hospitals—have relatively rapid growth rates.

Countries such as Canada, Sweden, Denmark, Finland, and Norway with stricter supply-side restrictions—such as global budgets for hospitals and central planning of the availability of intensive services— have considerably slower growth rates. The factors influencing diffusion of drug and other therapies are somewhat less clear-cut; their use is not strongly related to financial incentives. Since the costs of these treatments are relatively modest, it is possible that institutional and cultural forces as well as specific initiatives related to quality of care are primary determinants.

Policy conclusions about which of these diverse patterns of technological change are optimal depend on their consequences for patient health outcomes and costs of care in each country, and on the value placed on these outcomes by each country's population. However, it is clear that if high-quality care requires rapid innovation and diffusion of valuable high-cost as well as low-cost treatments, quality of care may differ greatly around the world, and national health policies may influence quality in important ways.

The formal evidence from clinical trials on the effects of such high-cost intensive procedures is and will likely remain limited. Especially in countries with relatively wide availability of intensive procedures, it has been difficult to find both adequate funding and adequate willingness among patients and providers to participate in randomisation for such major therapeutic decisions. Moreover, because providers' experiences and use of procedures change so rapidly, the results of randomised trials may be viewed

as having only limited relevance to current practice by the time they are published.

This seems to have been the case in trials of primary angioplasty. The early trials in the late 1980s and early 1990s showed no benefit over thrombolytic drugs, but these trials appear to have had almost no impact on the rate of diffusion of primary angioplasty. In contrast, more recent trials have shown at least a slight advantage (one percentage point or so case survival), at least in experienced centers.

Very recently, the development of complementary drugs and devices (stents) may have improved outcomes even more. Large differences in outcome trends between countries would not be expected even if differences in procedure rates were substantial. For example, if intensive procedures convey a nontrivial mortality benefit—say, two percentage points—then even when a difference of twenty percentage points in treatment rates emerges, the associated difference in the population mortality rate would be 0.4 percentage points. Of course, this does not necessarily imply that the more intensive procedures are not worthwhile; it simply implies that careful analysis of outcome trends and the factors influencing the trends is necessary. We are conducting more detailed analyses of short- and long-term outcome trends for heart attack patients in our participating countries, and our large sample sizes provide an opportunity to detect trend differences with a very high level of precision.

Conclusion

The findings presented illustrate that medical practices for heart attack care have changed dramatically around the world in the past decade. Treatment has become more intensive, with more use of potentially valuable medications and more use of intensive cardiac procedures.

However, it is possible that any differences due to intensive procedures may be overshadowed by trend differences in less intensive treatments, population characteristics, and other factors.

Our ongoing work also suggests that more rapid diffusion of intensive technologies has had clearer implications for health care costs. If the patterns we observe for heart attack care apply more generally, then they would suggest somewhat faster medical expenditure growth in countries with the two more rapid patterns of intensive technology diffusion compared to countries with the third, slower pattern. Moreover, the material and personnel costs ("prices") associated with the use of intensive treatments also differ greatly across countries; the countries with more rapid diffusion tend to have somewhat higher payments for these inputs.

Even if the consequences for outcomes imply that the more rapid technological change involving intensive procedures is worthwhile, other important unanswered questions remain. Do the patterns we have observed for trends in acute treatments also apply to preventive services and treatments for chronic illnesses? What are the equity effects of different patterns of technological change: Does more rapid diffusion tend to exacerbate or reduce differences in utilization across socio-economic groups, or are socio-economic differences in use of intensive treatments unaffected? Are differences in technological change by age and by gender consequential? Does the rate of technological change affect variations in medical practice and quality of care within countries? Do countries with similar overall patterns of technological change have different outcome and cost consequences, because of differences in quality and appropriateness of treatment in patients who undergo procedures? Virtually no evidence exists on these questions. They are important next steps for international studies on how health care changes over time, and how policies can affect these changes.

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Tab. 1
Differences in Economic and Regulatory Incentives for Technological Change in 1995

Type of Incentive	Strong Limit	Intermediate Limit	Weak Limit
Costs Borne by Patient	*Substantial out-of-pocket payments*:	*Some out-of-pocket payments and/or significant optional private insurance sector with premiums borne directly by patients:* France Switzerland	*Zero/very low patient payments for services:* Belgium Denmark Finland Israel Italy (for AMI patients) Sweden United Kingdom
Generosity of Payments to Hospitals (both *level* of payments and *responsiveness* of payments to intensity of treatment may differ; this table focuses on responsiveness)	*Fixed global budgets, more or less stringent:* Denmark Finland** Sweden** United Kingdom	*Some additional payments for the provision of more costly treatments:* Belgium France*** Israel Italy	*Fee-for-service payments:* Switzerland France (private hospitals)
Generosity of Payments To Physicians (both *level* of payments and *responsiveness* of payments to intensity of treatment may differ; this table focuses on responsiveness)	*Physicians are mainly salaried:* Denmark (cardiovascular doctors) Finland France (public hosp.) Israel Italy Sweden United Kingdom	*Some additional payments for the provision of more Costly treatments:*	*Fee-for-service:* Belgium France (private hospitals) Switzerland
"Micro" Technology Regulation (mainly involves costly "high-tech" procedures, and potentially expensive patients)	*Extensive reviews of individual treatment decisions:*	*Limited case-level review and/or "gatekeeping":* Denmark Israel United Kingdom	*Little or no case-level review:* Other countries
"Macro" Technology Regulation (includes regulation of physician supply)	*Strict regulation:* United Kingdom	*Intermediate regulation:* Belgium Denmark Finland France Sweden	*Little regulation:* Israel Italy Switzerland
continued			

Choice and Competition among Insurance Plans	*No choice (universal insurance):* Denmark Finland Italy Sweden United Kingdom	*Limited choice (e.g. in supplemental coverage):* Belgium France Israel Switzerland	*Substantial choice:*

Figure 1: Relationships between Work Packages