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THE IMPACT OF NEW LABORATORY PROCEDURES AND OTHER MEDICAL INNOVATIONS ON THE HEALTH OF AMERICANS, 1990-2003: EVIDENCE FROM LONGITUDINAL, DISEASE-LEVEL DATA

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ABSTRACT

This study examines the effect of the introduction of new laboratory procedures and other medical goods and services on the health of Americans during the period 1990-2003. We hypothesize that, the more medical innovation there is related to a medical condition, the greater the improvement in the average health of people with that condition. To test this hypothesis, we estimate models of health outcomes using longitudinal disease-level data. We measure innovation in five types of medical procedures or products: pathology & laboratory procedures, outpatient prescription drugs, inpatient prescription drugs, surgical procedures, and diagnostic radiology procedures.

We examine two kinds of (inverse) indicators of health: mortality and disability. The mortality indicator we analyze is the mean age at death of people whose underlying cause of death is medical condition i. The disability measures we analyze are the fraction of people with medical condition i who (1) missed work, or (2) spent one or more days in bed, due to that condition.

Our estimates indicate that conditions with higher rates of lab and outpatient drug innovation had larger increases in mean age at death, controlling for other medical innovation rates and initial mean age at death. The 1990-1998 increase in mean age at death attributable to use of new lab procedures is estimated to be about 6 months. This is 42% of the total increase in mean age at death (1.18 years) in our sample of diseases. New laboratory procedures introduced during 1990-1998 are estimated to have saved 1.13 million life-years in 1998. Expenditure per life-year gained from new lab procedures is estimated to be $6093. Treatments that cost this amount are generally considered to be quite cost-effective.

In the analysis of disability, when we don't control for the initial level of disability, we find that conditions with higher rates of lab and outpatient innovation had greater declines in the probability of missing work during 1996-2003. This suggests that the use of new laboratory procedures reduced the number of work-loss days in 2003 by 42 million. When we control for initial disability, the inverse relationship between lab innovation and disability changes disappears. This is because there is a significant inverse relationship between initial health and the extent of laboratory innovation. But due to errors in measuring initial health, controlling for this variable may cause the impact of innovation on health to be underestimated.

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Economists believe that the development of new products is the main reason why people are better off today than they were several generations ago. In their 1993 book, *Innovation and Growth in the Global Economy*, Grossman and Helpman argued that "innovative goods are better than older products simply because they provide more 'product services' in relation to their cost of production." In their 1996 book, *The Economics of New Goods*, Bresnahan and Gordon stated simply that "new goods are at the heart of economic progress." And in a recent paper, *Measuring the Growth from Better and Better Goods*, Bils (2004) makes the case that "much of economic growth occurs through growth in quality as new models of consumer goods replace older, sometimes inferior, models."

New goods do not emerge *ex nihilo*. They are usually the result of investment in research and development (R&D). National Science Foundation data reveal that the medical equipment and supplies industry is one of the most research-intensive industries in the economy. As Figure 1 indicates, the ratio of R&D expenditure to sales is two and a half times as high in this industry as it is in the average American industry.

In this paper I will examine the impact of a subset of the new products generated by this industry—clinical laboratory products—on the longevity and quality of life of Americans. FDA data indicate that, in the last decade, about 100 of these new products have been introduced. I hypothesize that these new products have improved the quality of information physicians and patients have about patients' medical conditions, and have therefore enabled more appropriate and effective treatment of those conditions. This may be illustrated by two new kinds of tests: HIV tests, and genetic tests related to dosing of a widely prescribed anti-blood clotting drug.

For almost two decades, HIV tests had two glaring flaws. They did not detect the earliest stage of infection, when people are more likely to spread the virus. They also took days to produce results, and many people never returned to learn whether they were infected. New generations of tests can largely eliminate either the long waiting time for results, or the failure to find early infections (but not both) (New York Times (2005a)).

About two million Americans take warfarin (Coumadin) each day to help prevent blood clots because of problems like a heart attack, an abnormal heart rhythm, a stroke or major surgery. Establishing a proper dose of warfarin as patients start taking the drug is

one of the peskiest problems in medical practice. Misjudgments in doses can critically affect the clotting mechanism, leading to potentially fatal bleeding. At present, doctors rely on costly blood tests that must be repeated frequently over a period of months to adjust the dose to ensure that the drug will work safely. But a recent study suggests that it may be possible to develop a standard genetic test that would allow doctors to quickly and precisely choose a safe starting dose of warfarin (New York Times (2005b)).

This study will examine the effect of the introduction of new laboratory procedures and other medical goods and services on the health of Americans during the period 1990-2003.

Econometric specification

We hypothesize that, the more medical innovation there is related to a medical condition, the greater the improvement in the average health of people with that condition. To test this hypothesis, we will estimate the following model, using longitudinal disease-level data:

$$H\_END_i - H\_BEGIN_i = \alpha + \sum_j \beta_j INNOV_{ji} + \gamma Z_i + \varepsilon_i \qquad (1)$$

where

H_END_i = a measure of the average health of people with medical condition i at the end of a period

H_BEGIN_i = a measure of the average health of people with medical condition i at the beginning of the period

$INNOV_{ji}$ = a measure of innovation of type j in the treatment of condition i during the period

Z_i = other attributes of medical condition i

We will measure innovation in five types of medical procedures or products (j = 1,…,5): pathology & laboratory procedures (henceforth referred to as lab procedures), outpatient prescription drugs, drugs administered by providers (e.g. chemotherapy; henceforth referred to as inpatient prescription drugs), surgical procedures, and diagnostic radiology procedures.

We will examine two kinds of (inverse) indicators of health: mortality and disability. The mortality indicator we will analyze is the mean age at death of people whose underlying cause of death is medical condition i. Data on mean age at death (and the number of deaths), by cause, were obtained from the Multiple Cause-of-Death Mortality Data from the National Vital Statistics System of the National Center for Health Statistics. Each record in the micro data is based on information abstracted from death certificates filed in vital statistics offices of each State and District of Columbia. Causes of death were coded according to the International Classification of Diseases, Ninth Revision 1979-1998. The average number of records (deaths) per year is about 2.3 million.

The disability measures we will analyze are the fraction of people with medical condition i who (1) missed work, or (2) spent one or more days in bed, due to that condition. These data were constructed from the Medical Conditions files of the 1996 and 2003 waves of the Medical Expenditure Panel Survey (MEPS).

Eq. (1) will be estimated via weighted least-squares, where the weight is equal to the mean number of observations from which the dependent variable was computed ($(N\_BEGIN_i + N\_END_i)/2$). In the mortality analysis, the weight is the mean of the number of 1990 and 1998 deaths due to underlying cause i. In the disability analysis, the weight is the mean of the number of records in the 1996 and 2003 Medical Conditions files associated with condition i. The data are consistent with the hypothesis that the variance of $(H\_END_i - H\_BEGIN_i)$ is inversely proportional to $((N\_BEGIN_i + N\_END_i)/2)$. Figure 1 depicts the relationship across conditions between the 1990-1998 change in the mean age at death and the mean number of deaths. The variance of the change in the mean age at death is much lower for conditions causing a larger number of deaths.

Measures of innovation in the treatment of a condition during a period were constructed as follows:

$$INNOV_{ji} = \sum_p FREQ_{pji}\, NEW_p / \sum_p FREQ_{pji} \qquad (2)$$

where

$FREQ_{pji}$ = the number of times procedure p of type j was performed on patients with diagnosis i in the last year of a period

NEW_p = 1 if the CPT code for procedure p was established by the AMA after the beginning of the period
= 0 otherwise

Data on utilization of medical procedures and products, by diagnosis ($FREQ_{pji}$), were obtained from the MEDSTAT Marketscan database. MEDSTAT contains data on outpatient and inpatient services (procedures) and outpatient prescriptions of hundreds of thousands, or even millions, of individuals. Each outpatient and inpatient service record contains one procedure code (usually a CPT code), one or more ICD-9 diagnosis codes, and the amount paid for the procedure. Hence, we can compute the frequency of procedures performed (and expenditure), by CPT code and ICD-9 code, in each year (1990-2003).

The year in which CPT codes for laboratory, surgery, and radiology procedures were first established by the American Medical Association was determined from the AMA's publication *CPT Assistant Archives 1990-2003*. To illustrate the data contained therein, here is information about the first seven hematology and coagulation procedures (a subset of lab procedures) listed:

CPT code and description	**Year CPT code was established**
85002 Bleeding time	Pre-1990
85004 Blood count; automated differential WBC count	2003
85005 Blood count; basophil count, direct	Pre-1990
85007 Blood count; blood smear, microscopic examination with manual differential WBC count	Pre-1990
85008 Blood count; blood smear, microscopic examination without manual differential WBC count	1993
85009 Blood count; manual differential WBC count, buffy coat	Pre-1990
85012 Blood count; eosinophil count, direct	Pre-1990

A similar method was used to determine the vintage of drugs administered by providers (e.g. chemotherapy), which are also reported in outpatient and inpatient services files. However the codes for these procedures are not CPT codes established by the AMA, and the dates the codes were established are not reported in *CPT Assistant Archives 1990-2003*. These codes are Healthcare Common Procedure Coding System

(HCPCS) Level II Codes.[1] We used Multum's Lexicon database (http://www.multum.com/Lexicon.htm) to determine the active ingredients of the drugs corresponding to each of these HCPCS Level II Codes. We used data from the Drugs@FDA database (http://www.fda.gov/cder/drugsatfda/datafiles/default.htm) to determine the year in which each active ingredient was first approved by the FDA.

MEDSTAT outpatient prescription drug claims do not include diagnosis codes, so we used a different source of data on outpatient prescription drugs that links prescriptions written with diagnoses: the National Ambulatory Medical Care Survey (NAMCS).

Sample characteristics

We have data on utilization of medical procedures and products during the period 1990-2003. However, the sample period for the mortality analysis is restricted to 1990-1998, and the sample period for the disability analysis is restricted to 1996-2003.

The initial year for the mortality analysis is 1990 because the data on the dates at which CPT codes were established are left-censored: if a CPT code was established before 1990, we can't determine the year in which it was established. The final year is 1998 because the disease classification system used to code underlying cause-of-death for deaths that occurred after 1998 is different from that used to code underlying cause-of-death for deaths that occurred earlier and from that used to code patient diagnoses in MEDSTAT, NAMCS, and MEPS.

The disease classification system used to code underlying cause-of-death for deaths that occurred in the United States during 1979-98, and to code patient diagnoses in MEDSTAT, NAMCS, and MEPS data, is the Ninth Revision of the International Classification of Diseases (ICD-9). The Tenth Revision of the ICD (ICD-10) was used to

[1] Level II of the HCPCS is a standardized coding system that is used primarily to identify products, supplies, and services not included in the CPT codes, such as ambulance services and durable medical equipment, prosthetics, orthotics, and supplies (DMEPOS) when used outside a physician's office. Because Medicare and other insurers cover a variety of services, supplies, and equipment that are not identified by CPT codes, the level II HCPCS codes were established for submitting claims for these items. The development and use of level II of the HCPCS began in the 1980's. Level II codes are also referred to as alpha-numeric codes because they consist of a single alphabetical letter followed by 4 numeric digits, while CPT codes are identified using 5 numeric digits. See http://www.cms.hhs.gov/medicare/hcpcs/codpayproc.asp

code underlying cause-of-death for deaths that occurred in 1999 and later years. The ICD-9 and ICD-10 classification systems are quite different. The ICD-9 system has a 4-digit numeric structure and about 5,000 categories for classifying cause-of-death. The ICD-10 system has a 4-digit alphanumeric coding structure and about 8,000 categories for classifying cause-of-death. Comparison of ICD-9 and ICD-10 shows that new chapters have been added to the ICD, old chapters have been rearranged, causes of death have been regrouped, and titles have changed. As a result of these changes, the two classification schemes are different enough to make direct comparisons of cause-of-death difficult.[2]

The sample period for the disability analysis is restricted to 1996-2003, because 1996 was the first year in which the MEPS was conducted.

We will analyze data at the 3-digit ICD-9 level.[3] We exclude medical conditions due to injury and poisoning (ICD-9 codes 800-999). The models we estimate will be based on data on about 400 diseases.

Descriptive statistics

Table 1 shows data on procedures performed in 1998, by type and vintage. In 1998, the MEDSTAT data covered 92 firms. About 22 million outpatient and inpatient lab, surgical, drug, and diagnostic radiology procedures were performed on the people covered by these firms' health plans. The total cost of these procedures was $1.94 billion. About 22% of the laboratory procedures performed had CPT codes that were established by the AMA after 1990. The average cost of new lab procedures was only $1 higher than the average cost of old lab procedures ($24). For other types of procedures, the average cost of new procedures was 1.8 to 11.0 times as high as the average cost of old procedures. Lab procedures account for 60% of the total number of procedures performed, but only 17% of total expenditure on these procedures.

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[2] See http://wonder.cdc.gov/wonder/help/mort.html#Compressed%20Mortality%20File:%20ICD%20Revision

[3] For a list of 3-digit ICD-9 disease codes and names, see http://www.disabilitydurations.com/icd9top.htm.

About 1100 distinct lab tests (CPT codes) appear in the 1998 MEDSTAT data. Table 2 lists the 20 lab procedures performed in 1998 with the highest total cost. Table 3 lists the 20 post-1990 lab procedures performed in 1998 with the highest total cost.

Table 4 shows summary mortality and innovation statistics for the sample of 3-digit ICD-9 diseases during the period 1990-1998. Table 5 shows mortality and laboratory innovation data for the 30 largest causes of death. Note that the extent of laboratory innovation varied considerably across diseases. For some diseases, less than 16% of lab procedures were post-1990 procedures. In contrast, 33% of the lab procedures for prostate cancer, and 41% of the lab procedures for HIV, were post-1990 procedures.

Mortality results

Estimates of models of the 1990-1998 change in mean age at death are presented in Table 6. We estimated four different models. All models include five innovation measures (lab procedures, outpatient rx, inpatient rx, surgical procedures, and diagnostic radiology procedures), and the 1990-1998 change in the log of the number of deaths.

HIV is included in models 1 and 2, but excluded from models 3 and 4. As shown in Table 5, among high-mortality diseases HIV is an outlier in terms of both laboratory innovation and increase in mean age at death. It is therefore of interest to assess the sensitivity of the estimates to the inclusion of this observation.

Eq. (1) may be viewed as a special case of the following equation, in which the restriction $\pi = 1$ is imposed:

$$H\_END_i = \alpha + \sum_j \beta_j INNOV_{ji} + \gamma Z_i + \pi H\_BEGIN_i + \varepsilon_i \qquad (3)$$

or

$$H\_END_i - H\_BEGIN_i = \alpha + \sum_j \beta_j INNOV_{ji} + \gamma Z_i + (\pi - 1) H\_BEGIN_i + \varepsilon_i \qquad (4)$$

Inclusion of H_BEGIN in eq. (4) is referred to as “baseline adjustment”. Arguments can be made both for and against baseline adjustment. The argument for is that mean age at death may be subject to regression to the mean: diseases with high initial mean ages at death are likely to experience smaller increases in mean age at death ($\pi < 1$). If this is

true, and innovation is correlated with initial mean age at death, imposing the restriction $\pi = 1$ may result in biased estimates of the β's. In particular, if innovation is inversely related to initial mean age at death—there is more innovation for diseases with the worst initial health—then the β's may be overestimated.

In our sample, there is a significant inverse relationship between initial health (e.g. mean age at death) and the extent of laboratory and inpatient rx innovation: the rates of innovation (% of new procedures) are highest for diseases with the worst initial health. Initial health is uncorrelated with the rates of outpatient rx and diagnostic radiology innovation, and positively correlated with surgical innovation: there was more surgical innovation for diseases with high initial mean ages at death.

If H_BEGIN were measured without error, estimates of β_j's from the unrestricted model (4) would be more reliable than estimates from the restricted model (1). In practice, however, H_BEGIN is measured with error. In the presence of measurement error, the estimate of π is biased towards zero: the estimate of π will be significantly less than 1 even when true $\pi = 1$. Moreover, the bias will be transmitted to estimates of coefficients on other regressors that are correlated with H_BEGIN. In particular, coefficients on other regressors that are negatively correlated with H_BEGIN will also be biased towards zero.

Previous investigators have recognized the potential pitfalls of baseline adjustment. Campbell and Kenny (2002) argued there "are instances when problems are actually created, instead of solved, by 'correction' for regression toward the mean." And Glymour et al (2005) concluded that

> In many plausible situations, baseline adjustment induces a spurious statistical association between [the treatment measure] and change in [outcome]. More generally, when exposures are associated with baseline health status, this bias can arise if change in health status preceded baseline assessment or if the dependent variable measurement is unreliable or unstable. In some cases, change-score analyses without baseline adjustment provide unbiased causal effect estimates when baseline-adjusted estimates are biased.

Models 1 and 3 do not control for initial health (mean age at death in 1990); models 2 and 4 do. The true effect of innovation on health may be bounded between estimates from models that don't and do control for initial health.

Consider the estimates of Model 1 in Table 6. The coefficients on laboratory, outpatient rx, and inpatient rx innovation are positive and highly significant: diseases with above-average rates of these types of innovation had above-average increases in mean age at death. The coefficient on diagnostic radiology innovation is only marginally significant (p-value = .16), and the coefficient on surgical innovation is not significant.[4] The positive coefficient on the 1990-1998 change in the log of the number of deaths indicates that diseases with larger percentage increases in the number of deaths tended to have larger increases in mean age at death.

Model 2 controls for initial mean age at death, and (like Model 1) is based on a sample including HIV. Not surprisingly, the coefficient on initial health is negative and highly significant: mean age at death increased more for diseases with low initial ages. Controlling for initial health has little effect on the outpatient rx coefficient. However, it reduces the magnitude of the lab innovation coefficient by about 50%, and the coefficient on inpatient rx innovation is no longer significant. The lab innovation coefficient is now significant at the 6% level.

Model 3 excludes HIV and does not control for initial health. The estimates are similar to the estimates of Model 1, but the coefficients on lab and outpatient rx innovation are about 20% smaller when HIV is excluded. Model 4 excludes HIV and controls for initial health. The estimates are similar to the estimates of Model 2.

To summarize the estimates, in all four models, the coefficients on lab innovation and outpatient rx innovation are positive and significant at at least the 6% level; in some models these coefficients are much more significant. Controlling for initial health reduces the magnitude and significance of the lab and (especially) the inpatient rx

[4] Measuring surgical innovation using CPT code changes may be problematic. Closer inspection of the data on surgical procedures reveals that some "new" procedures are probably just relabeled or reclassified old procedures, rather than true innovations. For example, the three procedures whose codes were added in 1997 which were most frequently performed in 1997 were 98940, 98941, and 98942, which correspond to different types of chiropractic manipulative treatment of the spine. Undoubtedly, this type of treatment was performed well before 1997. A new CPT code should therefore be considered a necessary condition for a medical innovation, but not a sufficient condition: all innovations have new CPT codes, but some new CPT codes are not innovations. The fraction of procedures with new CPT codes exceeds the fraction of truly innovative procedures, perhaps by a significant amount, and the degree of overstatement varies across diseases. In the future, I hope to develop a reliable method of distinguishing between truly innovative procedures and old procedures with new CPT codes.

innovation coefficients, but if poor initial health stimulates innovation, controlling for initial health may bias these coefficients downward.

Now we will assess the implications of the estimates of Model 2, which has the lowest lab innovation coefficient and the second lowest outpatient rx coefficient. As shown in Table 4, 20% of the lab procedures performed in 1998 were post-1990 procedures. The 1990-1998 increase in mean age at death attributable to use of new lab procedures is estimated to be 0.49 years (= 2.44 * 0.20). This is 42% of the total increase in mean age at death (1.18 years) in our sample of diseases. There were 2.31 million deaths in the U.S. in 1998. If each of the 2.31 million people who died in 1998 lived 0.49 years longer due to 1990-1998 laboratory innovations, then these innovations saved 1.13 million (= 0.49 * 2.31 million) life-years in 1998.

The following table shows U.S. laboratory revenues during the period 1997-2003[5]:

Year	U.S. Laboratory Revenues ($ Billions)
1997	$30.6
1998	$30.6
1999	$30.7
2000	$32.9
2001	$35.4
2002	$38.1
2003	$40.1

Total laboratory revenue was $30.6 billion in 1998. The data shown in Table 1 imply that 22.5% of 1998 expenditure on laboratory procedures was spent on post-1990 procedures. Hence, about $6.9 billion (= 22.5% * $30.6 billion) was spent on post-1990 lab procedures in 1998. Expenditure per life-year gained from new lab procedures is therefore $6093 (= $6.9 billion / 1.13 million life-years). Treatments that cost this amount are generally considered to be quite cost-effective.

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[5] Source: "Lab Industry Strategic Outlook 2005: Market Trends & Analysis" Author: Jondavid Klipp. Published in 2004 by "Washington G-2 Reports", New York, NY. In 2003, the distribution of revenue by type of lab was:

Hospital Labs	54%
Independent Labs	32%
Physician Office Labs	7%
Other (e.g. Nursing Home, Public Health)	7%

Due to the DRG reimbursement structure, estimation of revenues for hospital labs is difficult.

Disability results

Table 7 shows summary disability and innovation statistics for the sample of 335 3-digit ICD-9 diseases during the period 1996-2003. The disability statistics are based on a much smaller number of individual-level observations than the mortality statistics: the combined number of condition records in the 1996 and 2003 MEPS Medical Conditions Files with non-missing disability data is 182,689. The rate of lab innovation during 1996-2003 was similar to the rate of lab innovation during 1990-1998. Nineteen percent of the lab procedures performed in 2003 had CPT codes that were added after 1996. But the other rates of innovation were lower: 19% of outpatient rx's consumed in 1998 were for drugs introduced after 1990, but only 12% of outpatient rx's consumed in 2003 were for drugs introduced after 1996.

Estimates of models of the 1996-2003 change in the fraction of people who missed work or had bed days due to a condition are presented in Table 8. We estimated models both excluding and including the level of disability in 1996. All models include five 1996-2003 innovation measures (lab procedures, outpatient rx, inpatient rx, surgical procedures, and diagnostic radiology procedures), and the 1996-2003 change in the log of the number of people with the condition.

In Model 1, the dependent variable is the 1996-2003 change in the fraction of people who missed work, and we don't control for the level of disability in 1996. The coefficient on lab innovation is negative and significant at the 2% level, and the coefficient on outpatient rx innovation is negative and significant at the 6% level. This implies that *conditions with higher rates of lab and outpatient innovation had greater declines in the probability of missing work during 1996-2003*. Lab innovation during 1996-2003 is estimated to have reduced the probability of missing work in 2003 by .0092 (= 0.048 * 0.19). The average probability of missing work during this period was about 13%, so this represents about a 7% (= .0092 / .13) reduction in the probability of missing work. The CDC estimates that there were about 598 million work-loss days in 2003 (Lethbridge-Çejku and Vickerie (2005, Table 17)). This suggests that *the use of new laboratory procedures reduced the number of work-loss days in 2003 by 42 million* (= 7% * 598 million).

In Model 2, the dependent variable is the 1996-2003 change in the fraction of people who had any bed days, and we again don't control for the level of disability in 1996. The lab innovation coefficient is somewhat smaller, and is significant at the 7% level. This suggests that conditions with higher rates of lab innovation during 1996-2003 had greater declines in the probability of having bed days.

Models 3 and 4 control for the level of disability in 1996. When we control for initial disability, the lab and drug innovation coefficients are all statistically insignificant. In this sample, as in the mortality sample, there is a significant inverse relationship between initial health and the extent of laboratory innovation: the % of new lab procedures is higher for diseases with the highest initial rates of missed work and bed days. Due to errors in measuring initial health, controlling for this variable may cause the impact of innovation on health to be underestimated.

Summary

This study has examined the effect of the introduction of new laboratory procedures and other medical goods and services on the health of Americans during the period 1990-2003. We hypothesized that, the more medical innovation there is related to a medical condition, the greater the improvement in the average health of people with that condition. To test this hypothesis, we estimated models of health outcomes using longitudinal disease-level data. We measured innovation in five types of medical procedures or products: pathology & laboratory procedures, outpatient prescription drugs, inpatient prescription drugs, surgical procedures, and diagnostic radiology procedures.

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Our estimates indicated that conditions with higher rates of lab and outpatient drug innovation had larger increases in mean age at death, controlling for other medical innovation rates and initial mean age at death. The 1990-1998 increase in mean age at

death attributable to use of new lab procedures is estimated to be about 6 months. This is 42% of the total increase in mean age at death (1.18 years) in our sample of diseases. New laboratory procedures introduced during 1990-1998 are estimated to have saved 1.13 million life-years in 1998. Expenditure per life-year gained from new lab procedures is estimated to be $6093. Treatments that cost this amount are generally considered to be quite cost-effective.

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Figure 1
The relationship across conditions between the
1990-1998 change in the mean age at death and the mean number of deaths

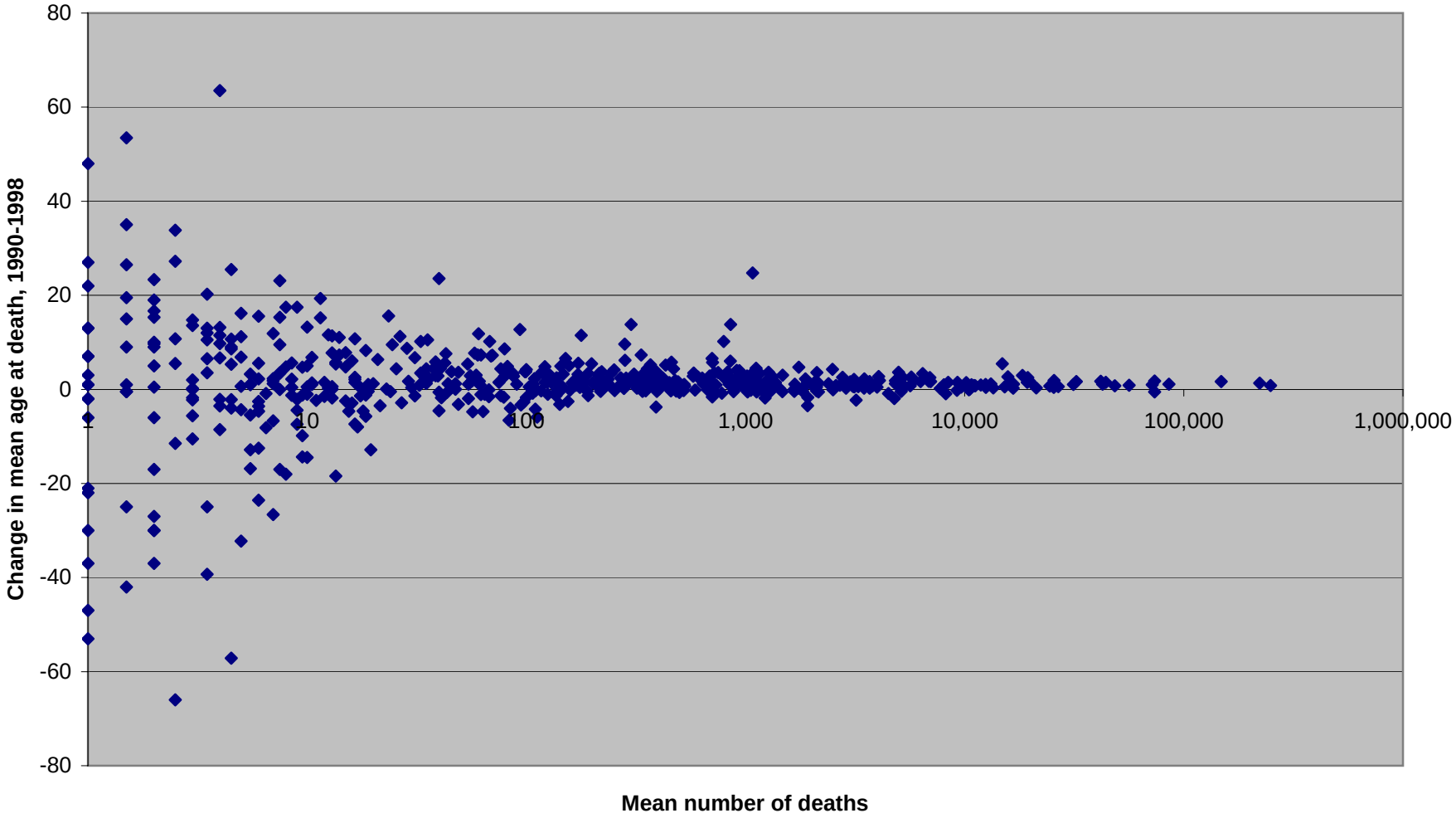

Table 1
Procedures performed in 1998, by type and vintage

type	post1990=0	post1990=1	all
	Number of procedures		
Pathology & laboratory	10,352,876	2,898,617	13,251,493
Drugs administered by providers	355,259	33,457	388,716
Surgery	4,206,445	539,415	4,745,860
Radiology--Diagnostic	3,689,574	120,960	3,810,534
	Total expenditure		
Pathology & laboratory	$249,408,303	$72,482,882	321,891,185
Drugs administered by providers	$19,097,036	$19,724,219	38,821,255
Surgery	$988,987,966	$232,978,135	1,221,966,101
Radiology--Diagnostic	$322,288,564	$39,734,802	362,023,366
	Average price		
Pathology & laboratory	$24	$25	$24
Drugs administered by providers	$54	$590	$100
Surgery	$235	$432	$257
Radiology--Diagnostic	$87	$328	$95

Table 2
20 lab procedures performed in 1998 with highest total cost

cpt	description	Number of procs.	Total cost	Avge. cost	year_added
88305	Level IV - Surgical pathology, gross and microscopic examinationAbortion - Spontaneous/MissedArtery,	421,385	$47,280,735	$112	pre-1990
80061	Lipid panelThis panel must include the following:Cholesterol, serum, total (82465)Lipoprotein, dire	558,944	$15,107,078	$27	pre-1990
85025	Blood count; complete (CBC), automated (Hgb, Hct, RBC, WBC and platelet count) and automated differe	713,426	$14,268,671	$20	pre-1990
84443	Thyroid stimulating hormone (TSH)	338,683	$10,455,861	$31	pre-1990
80054	Comprehensive metabolic panel This panel must include the following: Albumin (82040) Bilirubin, tota	398,899	$9,684,817	$24	1998
88307	Level V - Surgical pathology, gross and microscopic examinationAdrenal, ResectionBone - Biopsy/Curet	43,734	$7,610,713	$174	pre-1990
88304	LEVEL III - Surgical pathology, gross and microscopic examinationAbortion, Induced Abscess Aneurysm	106,460	$7,289,114	$68	pre-1990
80092	Thyroid panel This panel must include the following tests: Thyroxine, total (84436) Thyroid hormone	136,737	$6,802,368	$50	1993
85024	Blood count; hemogram and platelet count, automated, and automated partial differential WBC count (C	367,033	$6,763,304	$18	pre-1990
84153	Prostate specific antigen (PSA); total	186,778	$6,431,902	$34	1993
81000	Urinalysis, by dip stick or tablet reagent for bilirubin, glucose, hemoglobin, ketones, leukocytes,	647,439	$5,921,593	$9	pre-1990
88156	Cytopathology, smears, cervical or vaginal, (the Bethesda System (TBS)), up to three smears; screeni	353,172	$4,891,132	$14	1993
80049	Basic metabolic panel This panel must include the following: Carbon dioxide (82374) Chloride (82435)	185,322	$4,488,182	$24	1998
80050	General health panelThis panel must include the following: Comprehensive metabolic panel (80053) Bl	91,758	$4,288,761	$47	pre-1990
83036	Hemoglobin; glycated	180,492	$3,677,163	$20	pre-1990
80058	Hepatic function panel This panel must include the following: Albumin (82040) Bilirubin, total (8224	162,447	$3,541,755	$22	pre-1990
88150	Cytopathology, slides, cervical or vaginal; manual screening under physician supervision	218,682	$3,277,182	$15	pre-1990
87086	Culture, bacterial; quantitative colony count, urine	164,315	$3,023,076	$18	pre-1990
86588	Streptococcus, screen, direct	182,842	$2,658,488	$15	1993
85610	Prothrombin time;	216,645	$2,584,066	$12	pre-1990

Table 3
20 post-1990 lab procedures performed in 1998 with highest total cost

cpt	description	Number of procs.	Total cost	Avge. cost	year_added
80054	Comprehensive metabolic panel This panel must include the following: Albumin (82040) Bilirubin, tota	398,899	$9,684,817	$24	1998
80092	Thyroid panel This panel must include the following tests: Thyroxine, total (84436) Thyroid hormone	136,737	$6,802,368	$50	1993
84153	Prostate specific antigen (PSA); total	186,778	$6,431,902	$34	1993
88156	Cytopathology, smears, cervical or vaginal, (the Bethesda System (TBS)), up to three smears; screeni	353,172	$4,891,132	$14	1993
80049	Basic metabolic panel This panel must include the following: Carbon dioxide (82374) Chloride (82435)	185,322	$4,488,182	$24	1998
86588	Streptococcus, screen, direct	182,842	$2,658,488	$15	1993
81001	Urinalysis, by dip stick or tablet reagent for bilirubin, glucose, hemoglobin, ketones, leukocytes,	143,869	$2,238,765	$16	1996
88142	Cytopathology, cervical or vaginal (any reporting system), collected in preservative fluid, automate	39,580	$1,312,214	$33	1998
80091	Thyroid panel This panel must include the following tests: Thyroxine, total (84436) Thyroid hormone	49,692	$1,195,475	$24	1993
86677	Antibody; Helicobacter pylori	29,555	$1,144,457	$39	1993
86003	Allergen specific IgE; quantitative or semiquantitative, each allergen	12,236	$1,142,655	$93	1994
81003	Urinalysis, by dip stick or tablet reagent for bilirubin, glucose, hemoglobin, ketones, leukocytes,	105,628	$1,086,876	$10	1993
88141	Cytopathology, cervical or vaginal (any reporting system); requiring interpretation by physician (Li	43,322	$991,082	$23	1998
82378	Carcinoembryonic antigen (CEA)	19,016	$778,445	$41	1993
86701	Antibody; HIV-1	32,618	$709,558	$22	1993
82105	Alpha-fetoprotein; serum	20,374	$657,742	$32	1993
83721	Lipoprotein, direct measurement; direct measurement LDL cholesterol	32,098	$599,652	$19	1993
87490	Infectious agent detection by nucleic acid (DNA or RNA); Chlamydia trachomatis, direct probe techniq	20,490	$577,064	$28	1998
80051	Electrolyte panelThis panel must include the following:Carbon dioxide (82374)Chloride (82435)Potass	30,626	$570,721	$19	1998
89250	Culture of oocyte(s)/embryo(s), less than 4 days;	591	$563,148	$953	1996

Table 4
Summary statistics, mortality sample

Variable	No. of observations	MEAN	STD	MIN	MAX
mean age at death in 1998	570	74.56	428.85	1	91
1990-1998 change in mean age at death	570	1.18	71.82	-66	63.5
1990-1998 log change in number of deaths	570	0.1	14.93	-1.79	2.58
post-1990 procedures/rx's as % of total procedures/rx's in 1998					
lab	570	0.20	2.88	0.00	0.60
outpatient rx	422	0.19	6.56	0.00	1.00
inpatient rx	497	0.08	8.89	0.00	0.83
diagnostic radiology	569	0.04	4.20	0.00	1.00
surgery	570	0.13	7.16	0.00	0.81

Note: Statistics are weighted by mean number of deaths in 1990 and 1998

Table 5
30 largest causes of death, 1990 and 1998

ICD-9 code and name	mean number of deaths, 1990 and 1998	1990-1998 change in mean age at death	Number of lab procedures in 1998	post-1990 lab procedures as % of total lab procedures in 1998
(414) Other forms of chronic ischemic...	248,781	0.8	106,318	19%
(410) Acute myocardial infarction	221,654	1.3	14,728	22%
(162) Malignant neoplasm of trachea, ...	148,001	1.7	33,196	16%
(436) Acute but ill-defined cerebrova...	85,468	1.1	10,271	15%
(429) Ill-defined descriptions/compli...	73,610	-0.6	14,411	18%
(496) Chronic airways obstruction, no...	73,503	1.7	19,182	23%
(486) Pneumonia, organism unspecified	71,834	1.0	24,942	17%
(250) Diabetes mellitus	56,252	0.8	533,601	19%
(153) Malignant neoplasm of colon	48,469	0.7	25,991	22%
(428) Heart failure	44,057	1.5	23,051	27%
(174) Malignant neoplasm of female br...	42,600	1.1	129,583	17%
(427) Cardiac dysrhythmias	41,830	1.7	75,205	19%
(185) Malignant neoplasm of prostate	32,307	1.7	30,621	33%
(199) Malignant neoplasm without spec...	31,362	1.1	7,149	22%
(157) Malignant neoplasm of pancreas	26,731	0.6	6,932	15%
(425) Cardiomyopathy	25,550	1.9	10,193	23%
(571) Chronic liver disease and cirrh...	25,520	0.4	22,709	19%
(402) Hypertensive heart disease	24,468	0.7	25,386	22%
(038) Septicemia	21,231	0.3	5,704	20%
(202) Othr malignant neoplasm of lymp...	19,797	1.7	35,796	14%
(331) Other cerebral degenerations	19,392	2.5	1,194	24%
(431) Intracerebral hemorrhage	19,327	1.5	1,219	26%
(042) Human immunodeficiency virus in...	18,338	3.0	34,958	41%
(290) Senile and presenile organic ps...	16,692	1.1	475	22%
(440) Atherosclerosis	16,669	0.2	5,894	19%
(492) Emphysema	16,638	1.1	2,107	24%
(441) Aortic aneurysm	16,375	0.6	2,369	23%
(424) Other diseases of endocardium	15,766	2.7	21,795	17%
(434) Occlusion of cerebral arteries	15,214	0.5	3,270	18%
(799) Other ill-defined and unknown c...	14,873	5.5	68,369	22%

Table 6
Estimates of models of 1990-1998 change in mean age at death

Model	**1**	**2**	**3**	**4**
HIV	included	included	excluded	excluded
age_{1990}		-0.05044		-0.05161
std. err.		0.00902		0.00962
t-stat.		-5.59		-5.36
p-value		<0.0001		<0.0001
lab innovation	4.73875	2.44398	3.81875	2.60478
std. err.	1.25634	1.2783	1.38762	1.36003
t-stat.	3.77	1.91	2.75	1.92
p-value	0.0002	0.0566	0.0062	0.0562
outpatient rx innovation	1.59764	1.49814	1.27713	1.57028
std. err.	0.60348	0.58181	0.63695	0.61799
t-stat.	2.65	2.57	2.01	2.54
p-value	0.0084	0.0104	0.0456	0.0114
inpatient rx innovation	1.25194	0.14881	1.21932	0.13099
std. err.	0.44078	0.46832	0.4405	0.47161
t-stat.	2.84	0.32	2.77	0.28
p-value	0.0047	0.7508	0.0059	0.7814
diagnostic radiology innovation	1.12984	1.08233	1.02536	1.1055
std. err.	0.80448	0.77529	0.80589	0.77899
t-stat.	1.4	1.4	1.27	1.42
p-value	0.161	0.1635	0.204	0.1566
surgical innovation	-0.1945	0.45884	-0.01637	0.43252
std. err.	0.53341	0.52712	0.54474	0.53307
t-stat.	-0.36	0.87	-0.03	0.81
p-value	0.7156	0.3846	0.976	0.4176
1990-1998 change in log no. of deaths	0.62402	1.00554	0.78101	0.97787
std. err.	0.2555	0.25549	0.27444	0.26776
t-stat.	2.44	3.94	2.85	3.65
p-value	0.015	<.0001	0.0047	0.0003
Intercept	-0.23337	3.91213	-0.03623	3.96179
std. err.	0.30767	0.79828	0.33244	0.81172
t-stat.	-0.76	4.9	-0.11	4.88
p-value	0.4486	<.0001	0.9133	<.0001
R-Square	0.0885	0.1557	0.0728	0.1362
dep. var. mean	1.17699	1.17699	1.16012	1.16012
weight	N_DEATH	N_DEATH	N_DEATH	N_DEATH
N	401	401	400	400

Table 7
Summary statistics, disability sample

Variable	No. of observations	MEAN	STD	MIN	MAX
% of people who missed work in 1996	335	0.13	172.83	0.01	1
1996-2003 change in % of people who missed work	335	-0.01	65.36	-0.46	0.43
% of people with bed days in 1996	335	0.14	164.51	0	0.79
1996-2003 change in % of people with bed days	335	-0.01	74.49	-0.46	0.48
1996-2003 change in log of no. of people with condition	335	0.12	764.96	-2.79	1.94
post-1996 procedures/rx's as % of total procedures/rx's in 2003					
lab	335	0.19	194.48	0	0.72
outpatient rx	335	0.12	98.03	0	1
inpatient rx	335	0.02	73.65	0	0.46
diagnostic radiology	335	0.02	61.44	0	0.56
surgery	335	0.07	181.25	0	0.81

Note: Statistics are weighted by mean of number of people with condition in 1996 and 2003

Table 8
Estimates of models of 1996-2003 change in % of people who missed work or had bed-days

Model	**1**	**2**	**3**	**4**
Disability measure	**Missed work**	**Any bed days**	**Missed work**	**Any bed days**
initial rate of disability			-0.18034	-0.19522
std. err.			0.02152	0.02443
t-stat.			-8.38	-7.99
p-value			<.0001	<0.0001
lab innovation	-0.04824	-0.04095	-0.00376	0.00601
std. err.	0.01985	0.02285	0.0188	0.02174
t-stat.	-2.43	-1.79	-0.2	0.28
p-value	0.0156	0.074	0.8417	0.7824
outpatient rx innovation	-0.07086	-0.06495	-0.02773	-0.0125
std. err.	0.03691	0.04249	0.03393	0.03947
t-stat.	-1.92	-1.53	-0.82	-0.32
p-value	0.0558	0.1274	0.4145	0.7518
inpatient rx innovation	0.05445	0.02185	0.01925	0.0611
std. err.	0.0481	0.05537	0.04391	0.05096
t-stat.	1.13	0.39	0.44	1.2
p-value	0.2584	0.6934	0.6614	0.2315
diagnostic radiology innovation	0.03827	-0.07427	-0.01819	-0.06693
std. err.	0.06242	0.07187	0.05712	0.06584
t-stat.	0.61	-1.03	-0.32	-1.02
p-value	0.5403	0.3022	0.7504	0.3101
surgical innovation	0.03326	0.0382	0.06655	0.0674
std. err.	0.02055	0.02366	0.01909	0.02198
t-stat.	1.62	1.61	3.49	3.07
p-value	0.1066	0.1073	0.0006	0.0023
1996-2003 change in log no. of conditions	-0.00411	0.00479	-0.01541	-0.00021393
std. err.	0.00501	0.00577	0.00475	0.00532
t-stat.	-0.82	0.83	-3.24	-0.04
p-value	0.413	0.4073	0.0013	0.968
Intercept	0.00421	0.00805	0.01548	0.01661
std. err.	0.00703	0.00809	0.00652	0.00749
t-stat.	0.6	1	2.37	2.22
p-value	0.5497	0.3202	0.0182	0.0272
R-Square	0.0475	0.0281	0.2159	0.1869
dep. var. mean	-0.00989	-0.00586	-0.00989	-0.00586
weight	N_COND	N_COND	N_COND	N_COND
N	335	335	335	335