Why has longevity increased more in some U.S. states than others?

Frank R. Lichtenberg

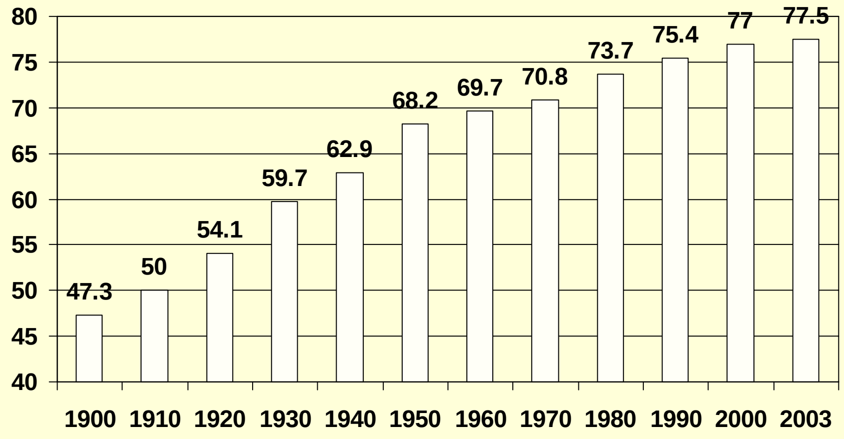
Columbia University and
National Bureau of Economic Research
frank.lichtenberg@columbia.edu
2008

Magnitude and value of U.S. longevity increase

- During the twentieth century, U.S. life expectancy at birth increased by almost 30 years (63%), from 47.3 years in 1900 to 77.0 years in 2000.
- Nordhaus (2002) estimated that, “to a first approximation, the economic value of increases in longevity over the twentieth century is about as large as the value of measured growth in non-health goods and services”.
- Murphy and Topel (2005) observed that “the historical gains from increased longevity have been enormous. Over the 20th century, cumulative gains in life expectancy were worth over $1.2 million per person for both men and women. Between 1970 and 2000 increased longevity added about $3.2 trillion per year to national wealth, an uncounted value equal to about half of average annual GDP over the period.”

2

Figure 1
U.S. life expectancy at birth, 1900-2003



3

Variation across states

- The rate of increase in longevity has varied considerably across U.S. states since 1991.
- This paper examines the effect of medical innovation (changes in drug vintage), behavioral risk factors (obesity, smoking, and AIDS incidence), and other variables (education, income, and health insurance coverage) on longevity using longitudinal state-level data.
- This approach controls for the effects of unobserved factors that vary across states but are relatively stable over time (e.g. climate and environmental quality), and unobserved factors that change over time but are invariant across states (e.g. changes in Federal government policies).
- We also analyze interstate variation in productivity (output per employee) growth, and in the growth of per capita medical expenditure (total, and by type).

4

Regions vs. diseases

- In previous studies, I have examined the effect of medical innovation on health and longevity by analyzing longitudinal *disease-level* data.
- See, for example, Lichtenberg, Frank, “The Impact of New Drugs on U.S. Longevity and Medical Expenditure, 1990-2003: Evidence from Longitudinal, Disease-Level Data,”*American Economic Association Papers and Proceedings*, forthcoming May 2007.
- A potential problem with that approach is that use of newer drugs may have cross-disease spillover effects: using newer drugs for one disease may either increase or decrease mortality from other diseases (in part due to “competing risks”).
- Such spillovers could be either negative or positive.
  - For example, using a newer drug to treat cardiovascular disease might reduce cardiovascular mortality but increase life-years lost due to cancer.
  - On the other hand, using a newer drug to treat depression and other mental disorders might lead to better management of cardiovascular disease. This study avoids the spillover problem by taking a different approach: analysis of longitudinal *state*-level data.
- There is no reason to expect there to be interstate spillover effects.

Increase in life expectancy at birth 1991-2004, by state

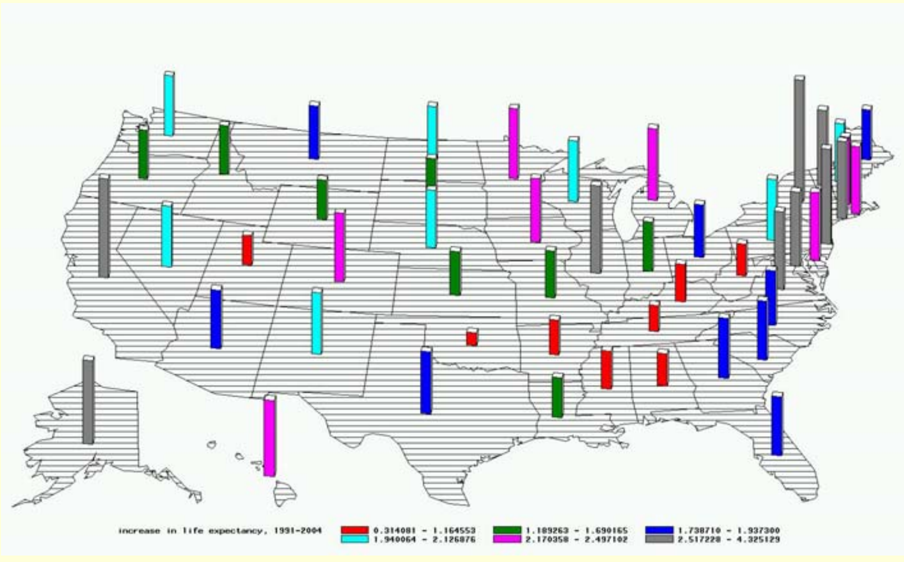


Figure 3
Conceptual framework

- Use of medical innovations
  - Vintage of Medicaid Rx's
  - Vintage of Medicare drug treatments
- Behavioral risk factors
  - AIDS incidence
  - BMI
  - Smoking
- Health insurance coverage
- Per capita income
- Educational attainment
- Use of other innovations
- State fixed effects
- Year fixed effects

⇒

- Life expectancy
  - At birth
  - At age 65
- Productivity
- Per capita medical expenditure
  - Total
  - By type of service

7

Role of medical innovation

- While longevity is probably influenced by a number of factors, medical innovation—the use of new medical goods and services—is likely to play a pre-eminent role in explaining recent U.S. longevity growth.
- Economists believe that the development of new products is the main reason why people are better off today than they were several generations ago.
- Grossman and Helpman (1993) argued that "innovative goods are better than older products simply because they provide more 'product services' in relation to their cost of production."
- Bresnahan and Gordon (1996) stated simply that "new goods are at the heart of economic progress."
- Jones (1998) argues that "technological progress [is] the ultimate driving force behind sustained economic growth" (p.2), and that "technological progress is driven by research and development (R&D) in the advanced world" (p. 89).
- 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."

8

Scientific advance and technical progress as ultimate determinant of health?

"While there is no consensus about the causal mechanisms, we tentatively identify the application of scientific advance and technical progress (some of which is induced by income and facilitated by education) as the ultimate determinant of health...We downplay direct causal mechanisms running from income to health."

The Determinants of Mortality
David M. Cutler, Angus S. Deaton, and Adriana Lleras-Muney
NBER Working Paper No. 11963
Issued in January 2006

9

Embodied technological progress

- Solow (1960) argued that "many if not most innovations need to be embodied in new kinds of durable equipment before they can be made effective. Improvements in technology affect output only to the extent that they are carried into practice either by net capital formation or by the replacement of old-fashioned equipment by the latest models…"
- We hypothesize that innovations may be embodied in nondurable goods (e.g. drugs) and services as well as in durable equipment.

10

Measuring vintage

The general definition of vintage we will use is:

$$vint_{it} = \frac{\Sigma_p \; freq_{pit} \; vint_p}{\Sigma_p \; freq_{pit}}$$

where

$vint_{it}$= the mean vintage of products and services used in state i in year t

$freq_{pit}$= the frequency of use of product or service p in state i in year t

$vint_p$= the vintage (year of first use) of product or service p

11

- In principle, we would like to measure the vintage of all drugs, all other medical goods and services, and even all other products and services. Unfortunately, this is not possible.
- We will measure:
  - the mean vintage of outpatient prescription drugs paid for by the state's Medicaid program
  - the mean vintage of drugs administered by providers (e.g., chemotherapy) to Medicare beneficiaries.
- The number of prescriptions paid for by Medicaid is very large: according to the Medical Expenditure Panel Survey, in 1997, Medicaid paid for about 201 million prescriptions—11% of all U.S. prescriptions. Moreover, we show that the extent of utilization of new drugs in the Medicaid program is strongly correlated with the extent of utilization of new drugs in general: the vintage of non-Medicaid (and all) rx's tended to increase more in states with larger increases in the vintage of Medicaid rx's.

12

- Drugs administered by providers are quite different from self-administered drugs, and Medicare pays for a substantial fraction of the former.
- In 2004, Medicare paid providers $7.6 billion for performing 522 million pharmaceutical procedures.
- Medicare data on the frequency of use of non-pharmaceutical services (e.g. lab and surgical procedures) are also available.
- However, due to asymmetries in FDA regulation, determining the vintage of non-pharmaceutical medical services is far more difficult than determining the vintage of pharmaceutical products and procedures.

13

Top 20 active ingredients contained in 2004 Medicaid prescriptions, ranked by number of prescriptions

active_ingredient	number of prescriptions
acetaminophen	48,661,138
hydrochlorothiazide	35,027,596
risperidone	31,534,553
levothyroxine sodium	29,278,356
amoxicillin (as trihydrate)	26,065,616
hydrocodone bitartrate	25,832,307
clonazepam	16,976,543
ethinyl estradiol	16,452,694
clavulanate potassium	16,295,635
fluticasone propionate	15,435,753
clarithromycin	13,826,324
lisinopril	13,678,282
verapamil hydrochloride	13,241,735
amitriptyline hydrochloride	12,650,203
erythromycin ethylsuccinate	11,849,113
trandolapril	11,730,763
ranitidine hydrochloride	11,421,621
fluoxetine hydrochloride	11,394,072
metformin hydrochloride	11,328,717
furosemide	10,908,503

14

Top 20 active ingredients contained in 2004 Medicare drug treatments, ranked by total services count

active_ingredient	TOTAL_SERVICES_COUNT
sodium chloride	55,426,498
mycophenolate mofetil	47,917,499
tacrolimus	43,062,403
heparin	36,659,665
oxaliplatin	27,314,244
cyclosporine	21,892,673
dexamethasone sodium phosphate	19,764,089
botulinum toxin type A	14,661,255
prednisone	10,913,119
infliximab	9,943,030
imiglucerase	9,010,483
triamcinolone acetonide	7,856,756
alpha-1 proteinase inhibitor	6,631,202
dolasetron mesylate	6,215,073
dextrose	6,185,437
sirolimus	5,822,688
bacteriostats	5,507,020
granisetron hydrochloride	5,324,628
cyanocobalamin	5,247,190
ondansetron hydrochloride	5,223,916

- Since we will not control for the vintage of non-pharmaceutical medical services, and the latter may be correlated with drug vintage, the drug vintage coefficients we estimate may to some extent reflect the effect of other medical innovation as well as the effect of drug innovation.
- The coefficients could also reflect the effect of *non-medical* innovation, e.g. consumer use of information technology. We will attempt to control for the latter by estimating some models that control for the percent of state residents who use a computer at home.

Adjusting for state-specific changes in the distribution of disease

- If there have been state-specific *changes* in the distribution of disease, and drug vintage is correlated with disease severity (e.g., newer drugs tend to be for less severe diseases), the coefficient on drug vintage could be biased.
- However, we can eliminate any potential bias by constructing an alternative (fixed-weighted) index of drug vintage.

17

Potential reasons for interstate variation in the rate of increase of drug vintage

The rate of increase in drug vintage may vary across states due to both interstate differences in the types of diseases afflicting the population, and differences in the drugs used to treat given diseases.

Suppose that

$\Delta V_i = \Sigma_d \text{ share}_{di} \, \Delta V_d$

where

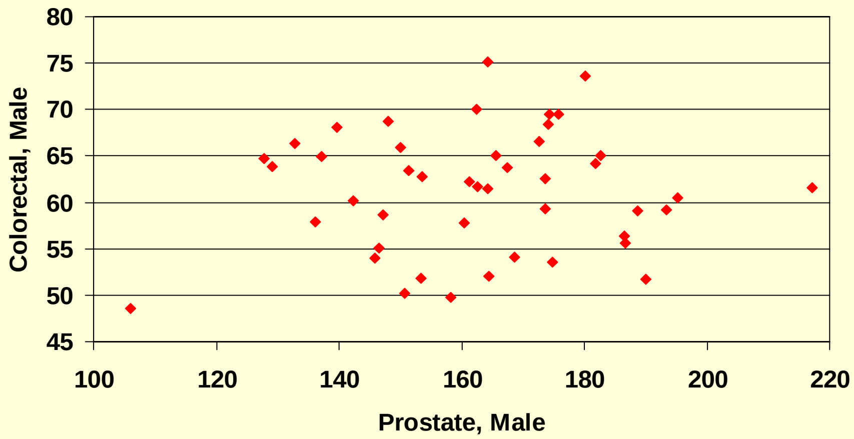
ΔV_i= the increase in the mean vintage of drugs in state I

share_{di}= the fraction of state i's residents who have disease d

ΔV_d= the increase in the mean vintage of drugs to treat disease d

18

Figure 4
Annual incidence rates (cases per 100,000) of prostate and colorectal cancer, males, 2002, by state



The correlation across states between these two incidence rates is not significantly different from zero (p-value = 0.61).

19

Potential reasons for variation in the rate of increase of drug vintage

- Due to medical practice variation, the increase in the mean vintage of drugs to treat any given disease is likely to vary across states.
- Medical practice variation is a well-documented phenomenon: there are 2514 citations for this term in the PubMed database.
- The Dartmouth Atlas of Health Care Project (Wennberg (2006)) has demonstrated “glaring variations in how health care is delivered across the United States.”

20

Econometric model

We will investigate the effects of drug vintage, behavioral risk factors, and other variables on life expectancy, productivity, and medical expenditure by estimating models of the following form:

$$Y_{it} = \beta X_{it} + \alpha_i + \delta_t + \varepsilon_{it}$$

(1 = 1,…,50; t = 1991,…,2004)
where Y is one of the following variables:
LE_{it} = life expectancy at birth in state i in year t
$LE65_{it}$ = life expectancy at age 65 in state i in year t
$productivity_{it}$= the log of gross state product per employee in state i in year t
$expend_{it}$= the log of per capita medical expenditure, total or by type of service, in state i in year t

21

Explanatory variables

X includes all of the following variables:
$vint\_medicaid\_rx_{it}$= the mean vintage of Medicaid prescriptions in state i in year t
$vint\_medicare\_rx_{it}$= the mean vintage of Medicare drug treatments in state i in year t
$income_{it}$= the log of per capita personal income in state i in year t
edu_{it}= an index of mean educational attainment of residents of state i in year t
$health\_cov_{it}$= the % of residents covered by health insurance in state i in year t
bmi_gt25_{it}= the % of residents with BMI > 25 in state i in year t
now_smoke_{it}= the % of residents who are current smokers in state i in year t
$aids_{it-2}$= the number of AIDS (Acquired Immune Deficiency Syndrome) cases reported per 100,000 population in state i in year t-2
α_i and δ_t represent state fixed effects and year fixed effects, respectively.

Eq. (1) will be estimated by weighted least squares (WLS), weighting by pop_{it}, state i's population in year t.

22

Increase in fixed-weighted drug vintage index 1991-2004, by state

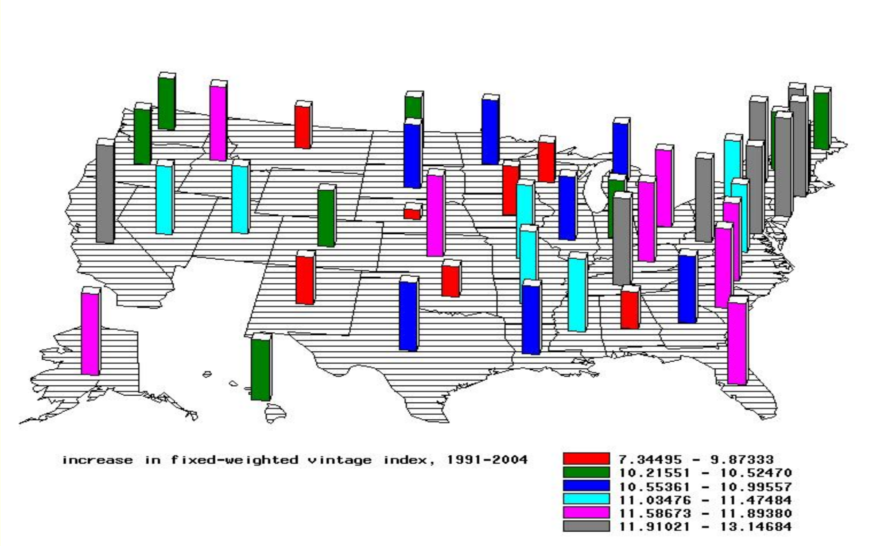
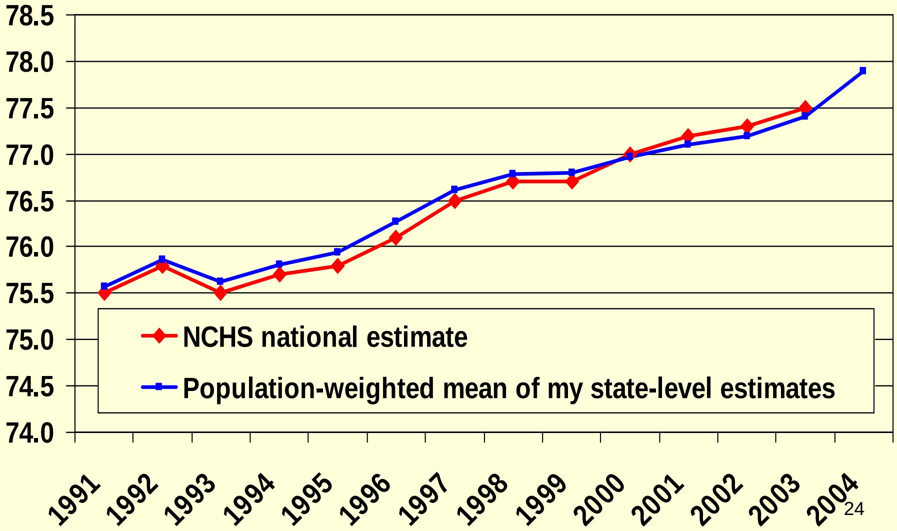


Figure 6
Comparison of population-weighted mean of my state-level estimates of life expectancy at birth to NCHS national estimate



24

Data sources

Life expectancy: Multiple Cause-of-Death Mortality Data from the National Vital Statistics System.

Population data: from CDC Wonder Bridged-Race Population Estimates.

Productivity and per capita income: Bureau of Economic Analysis Gross Domestic Product by State and State Annual Personal Income databases

Per capita medical expenditure: CMS Health Accounts by State database

Vintage of Medicaid prescriptions: CMS Medicaid State Drug Utilization files (700 files!) and Drugs@FDA database

Vintage of Medicare drug treatments: CMS annual Physician/Supplier Procedure Summary (PSPS) Master Files

Demographic characteristics and behavioral risk factors: CDC Behavioral Risk Factor Surveillance System (the world's largest telephone survey), and AIDS Public Information Data Set

25

WLS estimates of Equation 1 based on the fixed-weighted index of Medicaid drug vintage

column	1	2	3	4	5	6	7	8	9
Dependent variable	life expectancy		productivity	per capita medical expenditure					
	at birth	at age 65		drug	HH	NH	hospital	physician	total
vint_medicaid_rx	0.158	0.086	0.011	0.035	0.090	0.020	0.001	-0.040	-0.004
tValue	6.39	6.28	4.98	8.64	6.43	3.85	0.27	-8.69	-1.53
Probt	<.0001	<.0001	<.0001	<.0001	<.0001	0.0001	0.7867	<.0001	0.1264
vint_medicare_rx	0.034	0.011	0.000	-0.003	0.001	0.005	-0.003	-0.001	-0.001
tValue	5.09	3.02	0.79	-2.64	0.38	3.61	-3.33	-0.65	-1.53
Probt	<.0001	0.0027	0.4321	0.0085	0.7038	0.0003	0.0009	0.5142	0.1264
aids	-0.027	-0.009	-0.001	0.001	-0.002	0.000	0.002	0.002	0.002
tValue	-13.47	-7.90	-4.06	2.98	-1.80	0.94	6.32	6.37	8.64
Probt	<.0001	<.0001	<.0001	0.003	0.0728	0.3461	<.0001	<.0001	<.0001
bmi_gt25	-4.659	-2.408	-0.042	0.107	-0.789	0.493	-0.082	0.208	0.095
tValue	-5.31	-4.96	-0.53	0.74	-1.59	2.73	-0.68	1.26	1.02
Probt	<.0001	<.0001	0.5933	0.459	0.113	0.0064	0.4954	0.2065	0.3099

26

WLS estimates of Equation 1 based on the fixed-weighted index of Medicaid drug vintage (cont'd)

column	1	2	3	4	5	6	7	8	9
Dependent variable	life expectancy		productivity	per capita medical expenditure					
	at birth	at age 65		drug	HH	NH	hospital	physician	total
now_smoke	-3.182	-3.021	-0.191	0.283	-0.515	0.873	0.128	0.220	0.284
tValue	-3.18	-5.45	-2.11	1.71	-0.91	4.24	0.93	1.17	2.67
Probt	0.0016	<.0001	0.0351	0.0876	0.364	<.0001	0.3545	0.2426	0.0079
edu	0.029	0.001	-0.011	0.159	-0.264	0.064	0.058	0.164	0.108
tValue	0.16	0.01	-0.72	5.51	-2.66	1.76	2.39	4.98	5.77
Probt	0.87	0.995	0.4748	<.0001	0.0081	0.0787	0.0171	<.0001	<.0001
health_cov	1.455	0.595	0.141	-0.246	2.190	0.574	-0.227	-1.064	-0.416
tValue	1.60	1.18	1.72	-1.64	4.26	3.07	-1.81	-6.24	-4.31
Probt	0.1094	0.2366	0.0857	0.1011	<.0001	0.0022	0.0705	<.0001	<.0001
income	-1.679	-0.965	0.687	-0.040	0.749	-0.675	0.488	0.505	0.288
tValue	-2.67	-2.77	12.08	-0.39	2.10	-5.21	5.62	4.27	4.29
Probt	0.0079	0.0058	<.0001	0.6975	0.0362	<.0001	<.0001	<.0001	<.0001

27

Life expectancy estimates

- States in which the vintage of both self- and provider-administered drugs grew faster than average had above-average increases in life expectancy
- Life expectancy grew more slowly in states with larger increases (or slower declines) in AIDS, obesity, and smoking rates.
- The coefficients on educational attainment and health insurance coverage are not statistically significant.
- The coefficient on per capita income is *negative* and significant: states with high income growth had smaller longevity increases, *ceteris paribus*. This may be consistent with findings by Ruhm.
- Signs and significance of the coefficients in the life expectancy at age 65 equation are similar to those in the life expectancy at birth equation.

28

Productivity estimates

- States with larger increases in Medicaid drug vintage had faster productivity growth, conditional on income growth and the other factors in eq. (1).
- The increase in Medicaid drug vintage is estimated to have increased output per employee by about 1% per year.
- Much of this may be attributable to increased hours worked per employee. Based on a study of disease-level household survey data from the period 1982–1996, Lichtenberg (2005) concluded that pharmaceutical innovation reduced the number of work-loss days per employed person by 1.0% per year.

29

Per capita medical expenditure estimates

- a one-year increase in Medicaid drug vintage causes drug expenditure to increase by 3.5%
- use of newer drugs is also associated with increased expenditure on home health care and nursing home care
- use of newer drugs is associated with reduced expenditure on physicians
- The coefficients on both the Medicaid and Medicare drug coefficients in the total expenditure equation are insignificantly different from zero: states in which drug vintage has increased the most have not had above-average increases in overall medical expenditure. While use of newer drugs has increased some types of medical expenditure, it has reduced other types, and the expenditure reductions approximately offset the expenditure increases.
- This suggests that pharmaceutical-embodied technological change, like equipment-embodied technical change, is *non-neutral.*
- Increases in income, education, smoking, and the incidence of AIDS tend to increase per capita medical expenditure; expanded health insurance coverage reduces it.

30

- The Kaiser Family Foundation, citing Rettig, says that "advances in medical technology have contributed to rising overall U.S. health care spending."
- But in my study, the coefficients on both the Medicaid and Medicare drug vintage coefficients in the total expenditure equation are insignificantly different from zero. This indicates that states in which drug vintage has increased the most have not had above-average increases in overall medical expenditure. While use of newer drugs has increased some types of medical expenditure, it has reduced other types, and the expenditure reductions approximately offset the expenditure increases.
- Kaiser Family Foundation, "How Changes in Medical Technology Affect Health Care Costs," March 2007, http://www.kff.org/insurance/snapshot/chcm030807oth.cfm#front5
- Rettig, Richard A., "Medical Innovation Duels Cost Containment," *Health Affairs* (Summer 1994): 15.

31

Benefits vs. costs

- The *costs* of prescription drugs are well documented, and frequently discussed.
- While policy discussions sometimes allude to the *benefits* of drugs, descriptions of the benefits are often vague and qualitative, e.g. "prescription drugs are vital to preventing and treating illness and helping to avoid more costly medical problems."
- As a result, the costs tend to get a lot more attention than the benefits.
- That's why it is important to perform a careful, systematic assessment of the benefits as well as the costs of using newer drugs.
- Kaiser Family Foundation, "Prescription Drug Trends," http://www.kff.org/rxdrugs/upload/3057-05.pdf

32

Medical technology frontier

- In principle, there are two ways to improve the average quality of health care.
- One way is to give best-practice care to people who are currently receiving less than best-practice care (i.e., people who are below the frontier of medical technology).
- The other way is to improve best-practice care (i.e., shift the technological frontier).
- While moving from below the frontier to the frontier is desirable, the only way to achieve sustained improvements in health and longevity is to shift the medical frontier, by developing and using new medical goods and services.

33

Longevity growth accounting

Life expectancy at birth

- Life expectancy at birth increased by 2.33 years from 1991 to 2004.
- The estimates indicate that the growth in obesity and the growth in income both reduced the growth in life expectancy: if obesity and income had not increased, life expectancy at birth would have increased by 3.88 years.
- The increases in Medicaid and Medicare drug vintage account for 2.43 years (63%) of the “potential increase” in life expectancy.
- The declines in AIDS incidence and smoking account for 0.23 and 0.12 (6% and 3%) of the potential increase in life expectancy, respectively.
- About 1.1 years (28%) of the potential increase in life expectancy at birth is unexplained

34

Earlier period; other countries

- The results indicate that medical innovation accounted for most (about 2/3) of the increase in longevity in the U.S. during the period 1991-2004.
- Medical innovation probably accounted for a much smaller fraction of longevity increase during the 19th and early 20th centuries, and may also account for a smaller fraction of recent longevity increases in other countries.
- In a previous paper, I estimated that new chemical entity launches accounted for 40% of the 1986-2000 increase in longevity in 52 developed and developing 52 countries during the period 1982-2001.
- Lichtenberg, Frank, "The impact of new drug launches on longevity: evidence from longitudinal disease-level data from 52 countries, 1982-2001," *International Journal of Health Care Finance and Economics* 5, 2005, pp. 47-73.

35

Longevity growth accounting

Life expectancy at age 65

- life expectancy at age 65 increased by 1.29 years from 1991 to 2004.
- If obesity and income had not increased, life expectancy at age 65 would have increased by 2.15 years.
- The increases in Medicaid and Medicare drug vintage account for 1.19 years (55%) of the potential increase in life expectancy at age 65.
- The declines in AIDS incidence and smoking account for 0.07 and 0.12 (3% and 5%) of the potential increase in life expectancy, respectively.
- About 0.8 years (36%) of the potential increase in life expectancy at age 65 is unexplained.

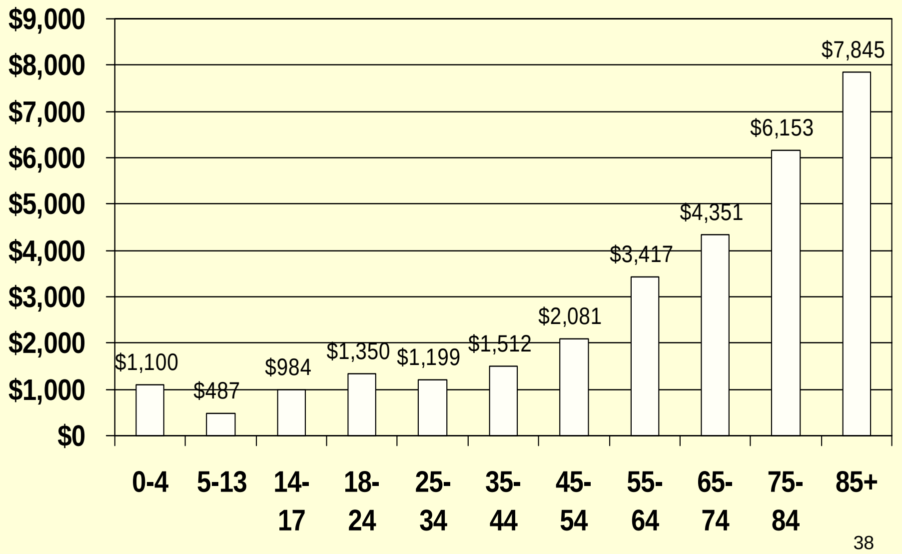
36

Lifetime medical expenditure

- Although use of newer drugs does not appear to have increased *annual* medical expenditure, it may have increased *lifetime* medical expenditure.
- The increase in the latter may be approximately equal to total medical expenditure during the 2.43 additional years of life attributable to increasing drug vintage.
- In 1996 mean medical expenditure of people age 75-84 was $6153—56% more than the mean medical expenditure of all Americans.
- This implies that the increase in lifetime medical cost per life-year gained from using newer drugs has been about $6153.
- Medical interventions that cost this amount are generally considered to be highly cost effective.

37

Figure 10
Mean medical expenditure per person in 1996, by age



38

Estimated effects of various factors on changes in U.S. life expectancy, 1991-2004

	Life expectancy (LE)	
	at birth	at age 65
Observed increase in LE	2.33	1.29
Contribution of factors reducing LE		
bmi_gt25	-0.70	-0.36
income	-0.86	-0.49
Total	-1.56	-0.85
Potential increase in LE	3.88	2.15
Contribution of factors increasing LE		
vint_medicaid_rx	1.80	0.98
vint_medicare_rx	0.63	0.21
aids	0.23	0.07
now_smoke	0.12	0.12
Total	2.78	1.38
Unexplained potential increase in LE	1.10	0.77

39

Cross-sectional longevity variance

- Differences in drug vintage explain some of the interstate variation in life expectancy, but the fraction of cross-sectional variance explained is smaller than the fraction of aggregate time-series variance (growth) explained.
- For example, the mean value of New Jersey's Medicaid fixed-weighted index of drug vintage is almost three years higher than the value of Tennessee's index. (These states used the newest and oldest drugs, respectively.) Our estimates imply that this difference would result in about a 6-month difference in life expectancy at birth. This is about 20% of the mean actual life expectancy differential (2.3 years) between the two states.

40