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PHARMACEUTICAL INNOVATION AND LONGEVITY GROWTH IN 30 DEVELOPING AND HIGH-INCOME COUNTRIES, 2000-2009

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ABSTRACT

I examine the impact of pharmaceutical innovation, as measured by the vintage (world launch year) of prescription drugs used, on longevity using longitudinal, country-level data on 30 developing and high-income countries during the period 2000-2009. I control for fixed country and year effects, real per capita income, the unemployment rate, mean years of schooling, the urbanization rate, real per capita health expenditure (public and private), the DPT immunization rate among children ages 12-23 months, HIV prevalence and tuberculosis incidence.

The estimates indicate that life expectancy at all ages and survival rates above age 25 increased faster in countries with larger increases in drug vintage (measured in three different ways), ceteris paribus, and that the increase in life expectancy at birth due to the increase in the fraction of drugs consumed that were launched after 1990 was 1.27 years—73% of the actual increase in life expectancy at birth.

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I. Introduction

Longevity increase is increasingly recognized by economists to be an important part of economic growth and development.[1] Economists also recognize that, in the long run, the rate of economic "growth…is driven by technological change that arises from intentional [research and development (R&D)] investment decisions made by profit-maximizing agents" (Romer (1990)). According to the National Science Foundation (2012), the medical devices and substances industries are the most research intensive industries in the economy. In 1997, "medical substances and devices firms had by far the highest combined R&D intensity at 11.8 percent,…well above the 4.2-percent average for all 500 top 1997 R&D spenders combined. The information and electronics sector ranked second in intensity at 7.0 percent."

In principle, technological change could be either disembodied or embodied in new goods. Solow (1960) hypothesized that most technological change is embodied: to benefit from technological progress, one must use newer, or later vintage, goods and services. Bresnahan and Gordon (1996) argued that "new goods are at the heart of economic progress," and Hercowitz (1998, p. 223) also reached the "conclusion…that 'embodiment' is the main transmission mechanism of technological progress to economic growth."

When technological progress is embodied in new goods, the welfare of consumers (and the productivity of producers) depends on the *vintage* of the goods (or inputs) they purchase. Solow (1960) introduced the concept of vintage into economic analysis.[2] Solow's basic idea was that technical progress is "built into" machines and other goods and that this must be taken into account when making empirical measurements of their roles in production. A number of econometric studies (Bahk and Gort, Hulten, Sakellaris and Wilson) have shown that manufacturing firms using later-vintage equipment have higher productivity.

I hypothesize that the health and longevity of a population depends on how technologically advanced the medical goods (including drugs) and services its members use are.

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[1] See e.g. Nordhaus (2003) and Murphy and Topel (2006). Murphy and Topel estimated that, over the 20th century, cumulative gains in U.S. life expectancy were worth over $1.2 million per person for both men and women. Between 1970 and 2000, increased U.S. 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] This was one of the contributions to the theory of economic growth that the Royal Swedish Academy of Sciences cited when it awarded Solow the 1987 Alfred Nobel Memorial Prize in Economic Sciences.

Furthermore, how technologically advanced a medical good or service is depends on its *vintage*, defined as its year of invention or first use.[3]

This study will examine the impact of pharmaceutical innovation, as measured by the vintage of prescription drugs used, on longevity using longitudinal, country-level data on 30 developing and high-income countries during the period 2000-2009. The analysis will be based on data drawn from several reliable databases: data on the utilization of over 89,000 pharmaceutical products from the IMS Health MIDAS database; life tables produced by the World Health Organization; and indicators of socioeconomic status, health expenditure, risk factors, and other variables from three World Bank databases and the OECD Health database.

Longevity growth is likely to depend on the vintage (hence quality) of non-pharmaceutical as well as pharmaceutical goods and services, so it would be ideal to include measures of the vintage of medical devices and procedures as well as measures of drug vintage in models of disability days. But measuring the vintage of medical devices and procedures is much more difficult than measuring drug vintage. Some evidence (described later in this article) indicates that non-pharmaceutical innovation is not correlated across countries or diseases with pharmaceutical innovation, so that excluding non-pharmaceutical innovation will not bias estimates of the effect of pharmaceutical innovation on longevity. Moreover, there are good reasons to think that pharmaceutical innovation has a greater impact on health outcomes than non-pharmaceutical innovation.[4] First, the number of people exposed to pharmaceutical innovation tends to be much larger than the number of people exposed to other types of medical innovation: for example, in 2007, 62% of Americans consumed prescription drugs, while only 8% of Americans were admitted to hospitals.[5] Second, pharmaceuticals are more research-intensive than other types of medical care: in 2007, prescription drugs accounted for 10% of U.S.

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[3] According to the Merriam Webster dictionary, one definition of vintage is "a period of origin or manufacture (e.g. a piano of 1845 vintage)". http://www.merriam-webster.com/dictionary/vintage.

[4] Ford et al (2007) estimated that 47% of the decline between 1980 and 2000 in the age-adjusted U.S. death rate for coronary heart disease was due to "treatments," 24% was due to reductions in total cholesterol, and 20% was due to reductions in systolic blood pressure. Many of the treatments identified by Ford et al were pharmaceutical treatments, and pharmaceuticals (e.g. statins) probably also played an important role in reducing cholesterol and blood pressure.

[5] Source: Medical Expenditure Panel Survey, 2007 Full Year Consolidated Data File. Lichtenberg (2013a) found that therapeutic procedure innovation increased the life expectancy of Western Australia hospital patients (whose mean life expectancy was about 10 years) by 2 to 3 months between 2000 and 2007. Since the fraction of the population that is hospitalized is fairly low, the implied contribution of hospital procedure innovation to aggregate longevity growth is fairly modest—much smaller than estimates (reviewed below) of the contribution of pharmaceutical innovation to aggregate longevity growth.

health expenditure (Center for Medicare and Medicaid Services (2013: Table 2)), but more than half of U.S. funding for biomedical research came from pharmaceutical and biotechnology firms (Dorsey et al, 2010). Much of the rest came from the federal government (i.e. the NIH), and new drugs often build on upstream government research (Sampat and Lichtenberg, 2011).

A number of previous studies have examined the impact of pharmaceutical innovation on longevity. Several types of econometric studies have been performed. Some studies used patient-level data, to investigate the following question: do patients using newer drugs live longer than patients using older drugs, controlling for their demographic characteristics (age, sex, race, income, education, etc.), medical conditions, behavioral risk factors, and other variables?[6] Other studies used longitudinal state-level data, to investigate whether life expectancy increased more rapidly in (U.S. or German) states experiencing more pharmaceutical innovation, controlling for changes in income, education, and other variables.[7] Other studies (e.g. Lichtenberg (2013c)) used longitudinal disease-level data, to determine whether life expectancy has increased more rapidly for people with diseases experiencing more pharmaceutical innovation.[8] I will compare estimates from this study to estimates obtained from previous studies (which were almost entirely based on data from high-income countries).

In Section II, I postulate a model of longevity as a function of drug vintage and other variables. I also consider why the increase in drug vintage is likely to vary across countries, describe the other variables I will control for, and briefly review some of the literature about the determinants of longevity. In Section III, I discuss the measurement of longevity and pharmaceutical innovation. Descriptive statistics are presented in Section IV. Empirical results are presented in Section V. Implications of the estimates are discussed in Section VI. The final section provides a summary.

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[6] Lichtenberg et al (2009) studied the impact of pharmaceutical innovation on longevity using patient-level data on elderly residents of Quebec, and Lichtenberg (2013b) studied this issue using patient-level data on elderly Americans.

[7] Lichtenberg (2011) studied the impact of pharmaceutical innovation on longevity using longitudinal state-level U.S. data, and Lichtenberg (2012) studied this issue using longitudinal state-level German data,

[8] In the studies based on patient-level and longitudinal state-level data, pharmaceutical innovation was measured by the mean *vintage* (FDA approval year) of drugs. In the studies based on longitudinal disease-level data, pharmaceutical innovation was measured by the *number* of drugs previously approved to treat a disease. Vintage is a superior measure of pharmaceutical innovation, since longevity should be more strongly related to drugs actually used than it is to drugs that are potentially available (i.e. previously approved).

II. A model of longevity

I hypothesize the following model of longevity:

$$LONGEVITY_{ct} = \beta\ VINTAGE_{ct} + \gamma\ Z_{ct} + \alpha_c + \pi_t + \varepsilon_{ct} \quad (1)$$

where

$LONGEVITY_{ct}$ = a measure of longevity in country c in year t
$VINTAGE_{ct}$ = a measure of the vintage of prescription drugs used in country c in year t
Z_{ct} = a vector of other attributes (e.g. income, education, risk factors, health expenditure) of country c in year t
α_c = a fixed effect for country c
π_t = a fixed effect for year t
ε_{ct} = a disturbance

The country fixed effects control for unobserved determinants of longevity that vary across countries but are constant (or very stable) over time; the year fixed effects control for unobserved determinants of longevity that change over time but are invariant across countries. Eq. (1) is a difference-in-differences model: a positive and significant estimate of β would signify that countries with larger increases in vintage had larger longevity increases, controlling for changes in other included attributes.

As explained below, there are only two years (2000 and 2009) for which data on LONGEVITY and VINTAGE are both available. Versions of eq. (1) may be written for each of these two years:

$$LONGEVITY_{c,2000} = \beta\ VINTAGE_{c,2000} + \gamma\ Z_{c,2000} + \alpha_c + \pi_{2000} + \varepsilon_{c,2000} \quad (2)$$

$$LONGEVITY_{c,2009} = \beta\ VINTAGE_{c,2009} + \gamma\ Z_{c,2009} + \alpha_c + \pi_{2009} + \varepsilon_{c,2009} \quad (3)$$

When we subtract eq. (2) from eq. (3), the country fixed effects vanish:

$$\Delta LONGEVITY_c = \beta\ \Delta VINTAGE_c + \gamma\ \Delta Z_c + \Delta\pi + \Delta\varepsilon_c \quad (4)$$

where, for example, $\Delta LONGEVITY_c = LONGEVITY_{c,2009} - LONGEVITY_{c,2000}$ and $\Delta\pi = \pi_{2009} - \pi_{2000}$. Eq. (4) indicates that the 2000-2009 *change* in longevity in country c depends on the change in drug vintage and the changes in other determinants of longevity in country c.

In eq. (4), pharmaceutical innovation (the change in drug vintage) is treated as exogenous with respect to longevity growth. If we were examining the relationship between pharmaceutical innovation and longevity growth at the global level, "reverse causality" (from longevity growth to pharmaceutical innovation) might pose a serious problem. An increase in longevity increases the number of consumers of (or size of the market for) pharmaceutical products, especially the number of elderly consumers; as shown in Figure 1, pharmaceutical consumption rises sharply with age. As previous investigators (Acemoglu and Linn (2004), Cerda (2007)) have shown, increases in market size tend to induce more drug development. But most countries are "small open economies"[9] with respect to pharmaceutical innovation: they participate in international trade of pharmaceutical products, but are small enough that they have little effect on global drug development. Civan and Maloney (2006) found that global drug development depends only on the size of the U.S. market, not the sizes of markets in other high-income or developing countries; Lichtenberg (2005a) obtained similar results. Longevity growth in most countries (even countries with large populations such as Indonesia and Mexico) is therefore likely to have a negligible effect on the number of new drugs used by their residents.

Sources of international variation in drug vintage growth. There are several reasons why the increase in drug vintage (ΔVINTAGE) is likely to vary across countries. Danzon et al (2005) demonstrated that both the probability and timing of the launch of a new drug in a country depends on the expected price of the drug (which is influenced by the regulatory environment) and the size of the market. They analyzed the effect of price regulation on the timing of launches in 25 major markets, including 14 EU countries, of 85 new chemical entities (NCEs) launched between 1994 and 1998. Their results indicated that countries with lower expected prices or smaller expected market size have fewer launches and longer launch delays, controlling for per capita income and other country and firm characteristics. Controlling for expected price and volume, country effects for the likely parallel export countries are significantly negative.[10]

[9] http://en.wikipedia.org/wiki/Small_open_economy

[10] Each NCE's expected price and market size in a country are estimated using lagged average price and market size of other drugs in the same (or related) therapeutic class. We estimate a Cox proportional hazard model of launch in each country, relative to first global launch. Only 55% of the potential launches occur. The US leads with 73 launches, followed by Germany (66) and the UK (64). Only 13 NCEs are launched in Japan, 26 in Portugal and 28 in New Zealand. Because a low price in one market may 'spill-over' to other markets, through parallel trade and external referencing, manufacturers may rationally prefer longer delay or non-launch to accepting a relatively low price.

The rate of pharmaceutical innovation varies across diseases. Therefore, even if the drugs used to treat a given disease were the same in different countries, heterogeneity of countries with respect to the nature of diseases afflicting the population would cause the increase in drug vintage to vary across countries. Moreover, due to physician practice variation, the drugs used to treat a given disease are likely to be different (and to change at different rates) in different countries.

Other potential determinants of longevity. I will control for a number of other country attributes that some previous studies have indicated may be important determinants of longevity:

- income (real per capita GDP in constant 2000 US$)
- unemployment rate
- education (mean years of schooling, 15+, total)
- urbanization rate
- real per capita health expenditure (public and private)
- DPT immunization rate (% of children ages 12-23 months)
- risk factors (HIV prevalence (% of population ages 15-49) and tuberculosis incidence)

Although the effects on longevity of at least some of these variables might seem obvious, the effects of some of them are theoretically ambiguous, or there is mixed evidence about their effects. I briefly review some of this evidence below.

Real income. Cutler, Deaton and Lleras-Muney (2006) observed that, "in both the time-series and the cross-section data, there is a strong correlation between income per capita and mortality rates, a correlation that also exists within countries, where richer, better-educated people live longer." However, based on their review of the literature, they "downplay direct causal mechanisms running from income to health," and "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." Deaton and Paxson (2004)'s examination of patterns of mortality, income, and income inequality in the United States and in Britain since 1950 did "not suggest any simple relationship between income growth and the decline in mortality, nor between income inequality and mortality rates. In the United States, the period of slowest income growth saw substantial accelerations in the rate mortality decline." Lichtenberg (2010, 2012) found no correlation and in some cases a negative correlation across states between income growth and longevity growth, both in the U.S. and in Germany.

Unemployment rate: Mean income tends to decline when the unemployment rate rises. Therefore, if income had a positive effect on longevity, one would expect mortality rates to rise when the unemployment rate rises. But Ruhm (2005) has shown that the death rate rises during periods of low unemployment rates, and it falls when the unemployment rate goes up.

Education. More educated people tend to have longer life expectancy. In 2007, the life expectancy at age 25 of Americans with bachelor's degree or higher education was about 9 years longer than that of Americans with no high school diploma (Source: National Health Interview Survey Linked Mortality File, http://www.cdc.gov/nchs/data/hus/2011/fig32.pdf). However, cross-sectional correlations between longevity and either income or education may substantially overestimate the effect of socioeconomic status per se on longevity. For example, the positive correlation between income and longevity may reflect the effect of health on income ("reverse causality") as well as the effect of income on health. Almond and Mazumder (2006) argue that, "although it is well known that there is a strong association between education and health, much less is known about how these factors are connected, and whether the relationship is causal." Lleras-Muney (2005) provided perhaps the strongest evidence that education has a causal effect on health. Using state compulsory school laws as instruments, Lleras-Muney found large effects of education on mortality. Almond and Mazumder (2006) revisited these results, noting they were not robust to state time trends, even when the sample was vastly expanded and a coding error rectified. They employed a dataset containing a broad array of health outcomes and found that when using the same instruments, the pattern of effects for specific health conditions appeared to depart markedly from prominent theories of how education should affect health. They also found suggestive evidence that vaccination against smallpox for school age children may account for some of the improvement in health and its association with education.

Urbanization: Leon (2008) disputes the largely negative view in the epidemiological and public health literature of the population health impact of cities and urbanization in the contemporary world.

Risk factors. Although a rise in the *incidence* of HIV would be expected to reduce longevity, one would not necessarily expect an inverse correlation between HIV *prevalence* and

longevity.[11] Advances in the treatment of HIV/AIDS are expected to increase survival (longevity) of AIDS patients, hence the number of people living with HIV (prevalence).

The World Bank Health, Nutrition and Population (HNP) database contains some data on other risk factors, such as the number of malaria cases reported, diabetes prevalence, and smoking prevalence. Unfortunately, data on these risk factors is missing so frequently that it is infeasible to include them in the longevity models we estimate, or to investigate their correlation with pharmaceutical innovation. However, more complete data on the following risk factors are available for OECD countries from the OECD Health database:

- BMI_GT25: Overweight or obese population, self-reported, % of total population
- BMI_GT30: Obese population, self-reported, % of total population
- TOBACCO: Tobacco consumption, % of population aged 15+ who are daily smokers
- ALCOHOL: Alcohol consumption, liters per capita (15+)

To determine whether growth in these risk factors was correlated across countries with pharmaceutical innovation (growth in VINTAGE), we estimated models of the following form, using annual data during the period 1999-2009:

$$\ln(RISK_{ct}) = \gamma\ POST1990\%_{ct} + \alpha_c + \pi_t + \varepsilon_{ct} \qquad (5)$$

where RISK = BMI_GT25, BMI_GT30, TOBACCO, or ALCOHOL, and POST1990% is the quantity-weighted-mean fraction of pharmaceutical products sold in country c in year t that were launched after 1990.[12] Eq. (5) was estimated by weighted least squares, weighting by POP_{ct} (the population of country c in year t); disturbances were clustered within countries. The results are shown in Table 1.

The increase in drug vintage was not correlated across OECD countries with the growth in obesity, tobacco use, or alcohol use. It was significantly *positively* correlated with growth in the fraction of the population that was either overweight or obese (whose mean value was 54%), but Flegal et al (2005) concluded that "overweight [is] not associated with excess mortality." Therefore, failure to control for these variables in the longevity growth equation (eq. (4)) is unlikely to bias estimates of the effect of pharmaceutical innovation on longevity growth.

Non-pharmaceutical medical innovation. I hypothesize that the health and longevity of a population depends on how technologically advanced the non-pharmaceutical as well as

[11] The World Bank publishes data on HIV prevalence, but not on HIV incidence.
[12] Measurement of POST1990% will be described in detail below.

pharmaceutical medical goods and services its members use are. Unfortunately, non-pharmaceutical medical innovation is much more difficult to measure than pharmaceutical innovation. However, data on one important type of non-pharmaceutical medical innovation—advanced imaging equipment—is available for OECD countries during the period 1999-2009 from the OECD Health database. Two indicators contained in that database are the number of Computed Tomography (CT) scanners and the number of Magnetic Resonance Imaging (MRI) units per million population.[13] To investigate the correlation across countries between the diffusion of pharmaceutical and non-pharmaceutical medical innovations, we estimated models of the following form, using annual data during the period 1999-2009:

$$\ln(IMAGE_{ct}) = \gamma\ POST1990\%_{ct} + \alpha_c + \pi_t + \varepsilon_{ct} \qquad (6)$$

where IMAGE = the number of CT scanners, the number of MRI units, or the sum of the number of CT scanners and MRI units, all defined per million population.[14] Eq. (6) was estimated by weighted least squares, weighting by POP_{ct}; disturbances were clustered within countries. The results are shown in Table 2.

The increase in drug vintage is positively correlated across OECD countries with growth in the number of MRI units per million population. However, it is negatively correlated with growth in the number of CT scanners per million population, and it is not significantly correlated with growth in the overall quantity of advanced imaging equipment (CT + MRI) per million population.

Lichtenberg (2013c, Appendix 2) used longitudinal disease-level measures of non-pharmaceutical and pharmaceutical medical innovation for the U.S. during the period 1997-2007 to assess whether rates of pharmaceutical and non-pharmaceutical medical innovation are correlated across diseases. He measured the fraction of non-drug and non-imaging outpatient and inpatient medical procedures performed that were ‘‘new’’ (post-1991) procedures, by

[13] The U.S. Centers for Medicare and Medicaid Services classifies both CT and MRI procedures as “advanced imaging” (as opposed to “standard imaging”) procedures in its Berenson-Eggers Type of Service (BETOS) health care procedure coding system. See http://www.cms.gov/Medicare/Coding/HCPCSReleaseCodeSets/BETOS.html Lichtenberg (2010) found that life expectancy increased more rapidly in U.S. states where the fraction of Medicare diagnostic imaging procedures that were advanced procedures increased more rapidly, and Lichtenberg (2012) found that the age-adjusted mortality rate declined more rapidly in German states with larger increases in the per capita number of CT scanners.

[14] On average, there were almost twice as many CT scanners as there were MRI units during the period 1999-2009 (sample mean values are 22 and 14 per million people, respectively), but the number of MRI units increased more rapidly.

disease and year; a ‘‘new’’ procedure was defined as a procedure whose code did not exist in 1991. His estimates indicated that the rate of pharmaceutical innovation was uncorrelated across diseases with rates of innovation in imaging and other procedures. This suggests that failure to control for non-pharmaceutical medical innovation in the longevity growth equation (eq. (4)) is unlikely to bias estimates of the effect of pharmaceutical innovation on longevity growth.

III. Measurement of longevity and pharmaceutical innovation

Longevity measurement. Beginning with the year 1999, the World Health Organization (WHO) began producing annual life tables for all Member States. These life tables form the basis of all WHO's estimates about mortality patterns and levels worldwide. Life tables have been developed for all Member States for the reference year 1990, 2000 and 2009 starting with a systematic review of all available evidence from surveys, censuses, sample registration systems, population laboratories and vital registration on levels and trends in under-five and adult mortality rates. WHO applies standard methods to the analysis of Member State data to ensure comparability of estimates across countries.

I will analyze two types of measures contained in the WHO life tables: life expectancy at different ages (0, 25, 45, 65), and survival from age a_0 to age a_1 (birth to 25, 25 to 65, 65 to 75, and birth to 75). Life expectancy at a given age reflects mortality (or survival) at all subsequent ages. For example, life expectancy at birth depends on mortality rates among the elderly. I examine age-specific survival rates as well as life expectancy because the effect of pharmaceutical innovation on survival rates may vary across age groups. As shown in Figure 1, which is based on data from Denmark, utilization of prescription drugs rises sharply with age: per capita consumption of medicines by people age 75-79 is over 10 times that of people age 25-29. The effect of pharmaceutical innovation on survival rate of young people may be much smaller than its effect on the survival rate of older people; it may even be zero.

Pharmaceutical innovation measurement. I construct three alternative measures of pharmaceutical innovation from the IMS Health MIDAS database, which provides annual data on the quantity (number of “standard dose units”) of every prescription drug product sold in each

country during the period 1999-2010.[15] The database also indicates the molecules (active ingredients) contained in each product, and the world launch year of most molecules (world launch years of some (apparently very old) molecules are unknown). The three alternative measures are:

$POST1990\%_{ct}$ = the quantity-weighted fraction of products sold in country c in year t that were launched after 1990

$POST1980\%_{ct}$ = the quantity-weighted fraction of products sold in country c in year t that were launched after 1980

$LAUNCH\_YEAR_{ct}$ = the quantity-weighted-mean launch year of products sold in country c in year t

The methodology used to construct these measures is described in Appendix A.

IV. Descriptive statistics

Descriptive statistics (population weighted) for 30 countries on the levels of variables in 2000 and 2009 are shown in Table 3. (Complete data on longevity, pharmaceutical use, and other variables, by country and year, are shown in Appendix Tables 1, 2, and 3, respectively.) The first part of the table shows statistics on longevity. Life expectancy at birth increased by 1.6 years, from 74.1 to 75.7 years, between 2000 and 2009. In 2000, life expectancy at birth ranged from 56.3 years in South Africa to 81.3 years in Japan. Life expectancy at age 65 increased by 0.8 years, on average. The probability of surviving from birth to age 75 increased from 59.8% in 2000 to 63.2% in 2009. Most of that increase was due to an increase in the probability of surviving from age 65 to age 75.

The next part of Table 3 shows statistics on pharmaceutical use. In general, medicines in use tend to be quite old. In 2000, the quantity-weighted mean world launch year of drugs was 1946.5, i.e. the average drug consumed was more than half a century old. Moreover, this

[15] The number of standard 'dose' units sold is determined by taking the number of counting units sold divided by the standard unit factor which is the smallest common dose of a product form as defined by IMS HEALTH. For example, for oral solid forms the standard unit factor is one tablet or capsule whereas for syrup forms the standard unit factor is one teaspoon (5 ml) and injectable forms it is one ampoule or vial. Other measures of quantity, such as the number of patients using the drug, prescriptions for the drug, or defined daily doses of the drug, are not available.

calculation excludes drugs with unknown world launch years, which tend to be quite old. The difference between the mean launch years of drugs used in 2000 in Indonesia (1928.0) and the Netherlands (1960.5) was over 32 years. The mean launch year of drugs increased by 4.7 years between 2000 and 2009. About 28% of the drugs consumed in 2009 had been launched after 1970; 18% had been launched after 1980, and 8% had been launched after 1990. Figure 2 depicts the quantity-weighted-mean fraction of products sold in 2009 that were launched after 1990 (POST1990%), by country. Figure 3 shows that there is a highly significant positive relationship across 26 countries between the number of new chemical entities launched during 1982-2001 and POST1980% in 2000.[16]

The remainder of Table 3 shows statistics on other variables included in out model of longevity. Mean real per capita GDP and years of schooling both increased modestly (by 4.4% and 5.8%, respectively) during the period 2000-2009. Mean real per capita health expenditure increased much more rapidly (by 32.0%).

Descriptive statistics (2009 population weighted) for 30 countries on 2000-2009 *changes* in variables are shown in Table 4. Coefficients of correlation between changes in two alternative measures of pharmaceutical innovation and changes in other variables in the longevity growth model are shown in Table 5. There is a significant correlation between the change in the fraction of post-1990 drugs (ΔPOST1990%) and just two variables: the log change in GDP per capita, and the change in urbanization rate. Both correlations are negative: countries with higher GDP growth had smaller increases in the fraction of post-1990 drugs. Table 5 also indicates that countries with larger increases in educational attainment had smaller increases in the quantity-weighted mean launch year of drugs consumed.

Table 6 shows the top 25 post-1990 molecules, ranked by number of standard units in 30 sample countries in 2010.

[16] Data on the number of new chemical entities (NCEs) launched during 1982-2001were obtained from Table 1 of Lichtenberg (2005b). Japan and Italy had the most NCEs launched (422); Malaysia had the fewest (122). The regression equation shown in Figure 3 indicates that the difference in NCEs (422 – 122) would be associated with a difference in POST1980% of .135 (= .0045 * 300). As shown in Appendix Table 2, the values of POST1980% in 2000 for Italy, Japan, and Malaysia were 20%, 22%, and 5%, respectively.

V. Empirical results

Estimates of the longevity change model (eq. (4)) are presented in Table 7. I analyze 8 different measures of the dependent (longevity change) variable: the change in life expectancy at birth and at ages 25, 45, and 65 (ΔLE0, ΔLE25, ΔLE45, ΔLE65, respectively), and the log change in the probability of survival from birth to 25, 25 to 65, 65 to 75, and birth to 75. For each dependent variable, I estimate two versions of the model: one in which ΔVINTAGE is the only regressor (in which the vector γ is constrained to equal zero), and one that includes the other potential determinants of longevity change (ΔZ) described earlier. I also include an additional regressor: the change in the log of the per capita *quantity* of prescription drugs (Δq_rx); ΔVINTAGE might be considered as the change in the average *quality* of prescription drugs.[17]

All equations were estimated by weighted least squares, weighting by 2009 country population. The data exhibit heteroskedasticity: the variance of ΔLONGEVITY is larger for small countries than it is for large countries. Heteroscedasticity can cause ordinary least squares estimates of the variance (and, thus, standard errors) of the coefficients to be biased, possibly above or below the true or population variance.[18] However, the weighted least squares estimates are not very different from ordinary least squares estimates.

In the models presented in Table 7, the measure of ΔVINTAGE is ΔPOST1990%. After presenting these estimates, I will present (in Table 8) estimates of longevity change models based on two alternative measures of ΔVINTAGE: ΔPOST1980% and ΔLAUNCH_YEAR.

In model 1 in Table 7, the dependent variable is the 2000-2009 change in life expectancy at birth, and the only regressor is ΔPOST1990%. The coefficient on this variable is positive and highly significant (p-value = 0.008), indicating that countries with larger increases in drug vintage had larger increases in life expectancy at birth. Model 2 includes the ten other potential determinants of longevity change discussed above. The coefficients on just two of these

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[17] Eminent philosophers and scientists have noted the importance of accounting for both quantity and quality. For example, in John Stuart Mill's theory of utilitarianism, both the quantity and the quality of the pleasures resulting from an action should be considered when making a moral judgment about it. Also, James Clerk Maxwell, the distinguished Scottish theoretical physicist, said the following**: "**It was a great step in science when men became convinced that, in order to understand the nature of things, they must begin by asking, not whether a thing is good or bad, noxious or beneficial, but of what kind it is? And how much is there of it? Quality and Quantity were then first recognized as the primary features to be observed in scientific inquiry."

[18] http://en.wikipedia.org/wiki/Heteroscedasticity

variables are statistically significant: countries with larger increases in unemployment had larger increases in life expectancy at birth (a finding consistent with those from some previous studies), and countries with larger increases in HIV prevalence had smaller increases in life expectancy. Controlling for the ten other potential determinants of longevity change *increases* the coefficient on ΔPOST1990% by about 32%. Figure 4 is a bubble plot of the correlation across countries between the 2000-2009 change in life expectancy at birth and ΔPOST1990%, controlling for changes in other variables.[19] It indicates that the strong positive correlation is not due to a small number of outliers.

Models 3-8 are similar to models 1-2, in which the change in life expectancy at birth is replaced by the change in life expectancy at age 25, 45, or 65. In all of these models, the coefficient on ΔPOST1990% is positive and highly significant (p-value $\leq$ .001). The only other coefficients that are statistically significant are on ΔHIV_prev in the ΔLE25 equation (model 4), Δhealth_expend in the ΔLE45 equation (model 6), and Δurban% in the ΔLE45 and ΔLE65 equations (models 6 and 8). Controlling for the ten other potential determinants of longevity change does not reduce the coefficient on ΔPOST1990% by more than 19%.

In model 9 in Table 7, the dependent variable is the 2000-2009 log change in the probability of survival from birth to age 25, and the only regressor is ΔPOST1990%. The coefficient on ΔPOST1990% is *negative* and significant. However, when we control (in model 10) for the ten other potential determinants of longevity change, the coefficient on ΔPOST1990% is far from statistically significant (p-value = .728). As discussed earlier, utilization of prescription drugs is much higher among the elderly than it is among young people, and only a small fraction of aggregate drug utilization is by young people. It is therefore not surprising that there is not a significant correlation between our measure of pharmaceutical innovation (which is based on drugs used by all age groups[20]) and the log change in the probability of survival from birth to age 25. There is a positive association between the log change in this probability and

[19] Figure 4 is a plot of the residuals from the population-weighted regression of ΔLONGEVITY on ΔZ against the residuals from the population-weighted regression of ΔPOST1990% on ΔZ.

[20] Unfortunately, the IMS MIDAS dataset does not contain any information about the age of pharmaceutical consumers, so it is not feasible to construct age-specific measures of pharmaceutical innovation. However, as Acemoglu and Linn (2004) showed, drugs in some therapeutic classes (e.g. antiinfectives) tend to be predominantly used by young people, whereas drugs in other therapeutic classes (e.g. antineoplastics) tend to be predominantly used by old people. Hence data on the therapeutic classes of drugs could be used to assign drugs to different age groups. This is a task for future research.

changes in per capita income, educational attainment, and the unemployment rate, and a negative association with the change in per capita health expenditure.

Models 11-16 are similar to models 9-10, in which the log change in the probability of survival from birth to age 25 is replaced by the log changes in the probability of survival from 25 to 65, 65 to 75, and birth to 75. When other potential determinants of longevity are included (in models 12, 14, and 16), the coefficient on ΔPOST1990% is positive and significant (p-value $\leq$ .020). Countries with larger increases in drug vintage had larger increases in the probability of survival from 25 to 65, 65 to 75, and birth to 75. The only other coefficients that are statistically significant are on ΔHIV_prev in the 25-to-65 and birth-to-75 survival equations (models 12 and 16), and Δurban% in the 65-to-75 survival equation (model 14).

In the models presented in Table 7, the measure of ΔVINTAGE is ΔPOST1990%. Table 8 presents estimates of coefficients on ΔVINTAGE in the longevity change model (eq. (4)) based on 2 alternative measures of ΔVINTAGE: ΔPOST1980% and ΔLAUNCH_YEAR. To conserve space, I do not report estimates of the coefficients on all of the covariates included in these models. To facilitate comparison, panel A of Table 8 reproduces the coefficients on ΔPOST1990% in models 2, 4,…,16 of Table 4. Panel B of Table 8 displays the corresponding coefficients on ΔPOST1980% when that variable is substituted for ΔPOST1990%. The coefficient on POST1980% is positive and significant (p-value $\leq$ .026) in all models except the model of the log change in the probability of survival from birth to 25. Panel C of Table 8 displays the corresponding coefficients on ΔLAUNCH_YEAR when that variable is substituted for ΔPOST1990%. Once again, the coefficient on ΔLAUNCH_YEAR is positive and significant (p-value $\leq$ .055) in all models except the model of the log change in the probability of survival from birth to 25.

As stated in the introduction, a number of previous studies have examined the impact of pharmaceutical innovation on longevity. Table 9 compares estimates of the marginal effect of drug vintage on longevity (ΔLONGEVITY/ΔLAUNCH_YEAR) from the present study (reproduced from Panel C of Table 8) with estimates from four previous studies.[21] This study's estimate of the effect of LAUNCH_YEAR on life expectancy at birth (.121) is similar to the estimate (.135) in Lichtenberg (2011), which was based on longitudinal U.S. state-level data. It

[21] Some previous studies did not provide estimates of ΔLONGEVITY/ΔLAUNCH_YEAR.

is about 33% lower than the estimate (.182) of the effect of LAUNCH_YEAR on mean age at death in Lichtenberg and Duflos (2008), which was based on longitudinal Australian disease-level data, and about 40% lower than the estimate (.208) of the effect of LAUNCH_YEAR on life expectancy at birth in Lichtenberg (2012), which was based on longitudinal German state-level data. This study's estimate of the effect of LAUNCH_YEAR on life expectancy at age 65 (.076) is similar to the estimate (.066) in Lichtenberg (2013b), which was based on cross-sectional patient-level data on elderly American community residents. Hence, this study's estimates of the marginal effect of drug vintage on longevity are similar to those in two previous studies, and smaller than those in two other studies.

VI. Discussion

The estimates in Tables 7 and 8 indicate that life expectancy at all ages and survival rates above age 25 increased faster in countries with larger increases in drug vintage (measured in three different ways), controlling for an extensive set of other factors. Now I will use those estimates to assess both (1) how much of the global growth in life expectancy was due to pharmaceutical innovation, and (2) the extent to which international differences in life expectancy in 2009 were attributable to differences in drug vintage.

As shown in Table 4, for the 30 countries in our sample, between 2000 and 2009 population-weighted mean life expectancy at birth increased by 1.74 years, and POST1990% increased by .050. The coefficient on POST1990% in model 2 of Table 7 is 25.36. This implies that the increase in life expectancy at birth due to the increase in the fraction of drugs consumed that were launched after 1990 was $\beta\ \Delta$POST1990% = 25.36 * .050 = 1.27 years. This is 73% of the actual increase in life expectancy at birth. Similar calculations can be performed for life expectancy at higher ages, and alternative measures of vintage. The results are shown in Table 10.

When either POST1990% or POST1980% is used as the vintage measure, the increase in life expectancy at age 25 due to the increase in drug vintage exceeds the actual increase in life expectancy at age 25. This is possible because HIV prevalence and urbanization increased (Table 3), and the estimates in Table 7 imply that these trends may have reduced longevity. Moreover, obesity has increased (at least in OECD countries), and previous research (Flegal et al

(2005)) indicates that this has also reduced longevity.[22] Although per capita income and educational attainment have also increased, there does not appear to be a consensus among scholars about the effects of these trends on longevity growth, and the estimates in Table 7 and in other studies suggest that they have not made a contribution to survival gains among adults.

Estimates of the increase in life expectancy attributable to pharmaceutical innovation based on the POST1980% vintage measure are similar to, but slightly smaller than, estimates based on the POST1990% vintage measure. Estimates based on the LAUNCH_YEAR vintage measure are considerably smaller—less than half the size of estimates based on the POST1990% vintage measure. This may be due to the fact that world launch dates of many (old) molecules are unknown, so that LAUNCH_YEAR is a much noisier measure of vintage than POST1990% or POST1980%.[23]

To assess the extent to which international differences in life expectancy in 2009 were attributable to differences in drug vintage, we will compare the top 5 countries (ranked by POST1990% in 2009), as depicted in Figure 2, with the bottom 5 countries (ranked by the same criterion). As shown in Table 11, the difference between these groups in POST1990% was 0.13. Since the coefficient on POST1990% in model 2 of Table 4 is 25.36, this implies that the difference between these two groups in life expectancy at birth due to the difference in the fraction of drugs consumed that were launched after 1990 was $\beta \Delta$POST1990% = 25.36 * .13 = 3.4 years. This is 37% of the actual difference (9.1 years) between these two groups in life expectancy at birth.

VII. Summary

This study examined the impact of pharmaceutical innovation, as measured by the vintage of prescription drugs used, on longevity using longitudinal, country-level data on 30 developing and high-income countries during the period 2000-2009. The analysis was based on data drawn from several reliable databases: data on the utilization of over 89,000 pharmaceutical products from the IMS Health MIDAS database; life tables produced by the World Health

[22] Ford et al (2007) found that increases in body-mass index and the prevalence of diabetes increased the number of U.S. deaths from coronary disease by 8% and 10%, respectively, during the period 1980-2000.
[23] Measurement error in the vintage measure is likely to bias its coefficient in eq. (4) towards zero.

Organization; and indicators of socioeconomic status, health expenditure, risk factors, and other variables from three World Bank databases and the OECD Health database.

The difference-in-differences estimation approach controlled for unobserved determinants of longevity that varied across countries but were constant (or very stable) over time, and for unobserved determinants of longevity that changed over time but were invariant across countries. I also controlled for a number of time-varying country attributes that some previous studies have indicated may be important determinants of longevity: real per capita income, the unemployment rate, mean years of schooling, the urbanization rate, real per capita health expenditure (public and private), the DPT immunization rate among children ages 12-23 months, and some risk factors (HIV prevalence and tuberculosis incidence).

I analyzed two types of measures contained in the WHO life tables: life expectancy at different ages (0, 25, 45, 65), and survival from age a_0 to age a_1 (birth to 25, 25 to 65, 65 to 75, and birth to 75). The estimates indicated that life expectancy at all ages and survival rates above age 25 increased faster in countries with larger increases in drug vintage (measured in three different ways), controlling for an extensive set of other factors. The increase in drug vintage was the only variable that was significantly related to all of these measures of longevity growth. Controlling for all of the other potential determinants of longevity did not reduce the vintage coefficient by more than 20%.

My measures of pharmaceutical innovation (which are based on drugs used by all age groups) were not related to the change in the probability of survival from birth to age 25. This is not surprising, since utilization of prescription drugs is much higher among the elderly than it is among young people, and only a small fraction of aggregate drug utilization is by young people.

Due to data limitations, certain risk factors (obesity, tobacco use, or alcohol use) could not be included in the model, but I showed that the increase in drug vintage was not correlated across OECD countries with the growth in these risk factors. It was also not correlated with a measure of non-pharmaceutical medical innovation: the growth in the overall quantity of advanced imaging equipment (CT scanners and MRI units) per million population.

I used the estimates of the longevity growth model to assess both (1) how much of the global growth in life expectancy was due to pharmaceutical innovation, and (2) the extent to which international differences in life expectancy in 2009 were attributable to differences in drug vintage. For the 30 countries in our sample, between 2000 and 2009 population-weighted mean

life expectancy at birth increased by 1.74 years. The estimates indicate that the increase in life expectancy at birth due to the increase in the fraction of drugs consumed that were launched after 1990 was 1.27 years—73% of the actual increase in life expectancy at birth. Some estimates imply that the increase in life expectancy at age 25 due to the increase in drug vintage exceeds the actual increase in life expectancy at age 25. This is possible because HIV prevalence and urbanization increased, and our estimates imply that these trends may have reduced longevity. Moreover, obesity has increased (at least in OECD countries), and previous research indicates that this has also reduced longevity. Although per capita income and educational attainment have also increased, there does not appear to be a consensus among scholars about the effects of these trends on longevity growth, and our estimates and those in some other studies suggest that they have not made a contribution to survival gains among adults.

To assess the extent to which international differences in life expectancy in 2009 were attributable to differences in drug vintage, I compared the top 5 countries (ranked by drug vintage in 2009) with the bottom 5 countries (ranked by the same criterion). Life expectancy at birth in the top 5 countries (Netherlands, Greece, Italy, Portugal, Spain) was 9.1 years higher than it was in the bottom 5 countries (Morocco, Egypt, Colombia, Thailand, Indonesia). My estimates imply that 37% (3.4 years) of this difference was due to the difference in drug vintage.

In recent years, several emerging economies, including India, Argentina and the Philippines, have passed laws placing strict limits on pharmaceutical patents, and Brazil and Thailand have been issuing compulsory licenses for AIDS drugs for years under multilateral agreements that allow such actions on public health grounds (Harris and Thomas, 2013). While such policies may benefit patients in those countries in the short run, in the long run, they are likely to diminish incentives for new drug development, particularly because sales in emerging markets like Brazil and China are expected to account for 30 percent of global pharmaceutical spending by 2016, up from 20 percent in 2011, according to IMS Health. The evidence presented in this paper indicates that reduced investment in pharmaceutical innovation would have adverse long-term effects on longevity.

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Appendix A

Pharmaceutical innovation measurement

In this Appendix I describe the construction of measures of pharmaceutical innovation from the IMS Health MIDAS database, which provides annual data on the quantity (number of "standard dose units") of every prescription drug product sold in each country during the period 1999-2010.[24] The database also indicates the molecules (active ingredients) contained in each product, and the world launch year of most molecules (world launch years of some (apparently very old) molecules are unknown).

I use a two-step procedure to measure pharmaceutical innovation.[25] The first step is to measure the vintage of each "international product":[26]

$$PROD\_YEAR_p = \frac{\Sigma_m\, INGRED\_OF_{pm}\, LAUNCH\_YEAR_m}{\Sigma_m\, INGRED\_OF_{pm}}$$

where

$PROD\_YEAR_p$ = the vintage of product p, i.e. the (mean) launch year of the active ingredient(s) of product p

$INGRED\_OF_{pm}$ = 1 if product p contains molecule m[27]
= 0 otherwise

$LAUNCH\_YEAR_m$ = the world launch year of molecule m

[24] The number of standard 'dose' units sold is determined by taking the number of counting units sold divided by the standard unit factor which is the smallest common dose of a product form as defined by IMS HEALTH. For example, for oral solid forms the standard unit factor is one tablet or capsule whereas for syrup forms the standard unit factor is one teaspoon (5 ml) and injectable forms it is one ampoule or vial. Other measures of quantity, such as the number of patients using the drug, prescriptions for the drug, or defined daily doses of the drug, are not available.

[25] In this methodology, a new molecule is considered an innovation, but a new combination of existing molecules is not. The IMS Health MIDAS database identifies the world launch years of new molecules but not of new combinations of existing molecules. Food and Drug Administration (2013) data indicate that during the period 1990-2004, the number of new molecules approved in the U.S. was over 5 times as large as the number of new combinations (431 vs. 79). Moreover, the number of new "priority-review" molecules approved in the U.S. was over 30 times as large as the number of new priority-review combinations (183 vs. 6). "Priority-review" products are those believed to offer "significant improvement compared to marketed products in the treatment, diagnosis, or prevention of a disease"; "standard-review" products "appear to have therapeutic qualities similar to those of one or more already marketed drugs."

[26] There are over 89,000 international products. ($\Sigma_m\, INGRED\_OF_{pm}$) = the number of active ingredients of product p. About 28% of standard units are for combination drugs.

[27] There are approximately 5600 molecules. IMS provides world launch dates for about 1600 of these molecules.

The second step is to measure the quantity-weighted-mean launch year of products sold in country c in year t:

$$LAUNCH\_YEAR_{ct} = \frac{\Sigma_p Q_{pct} PROD\_YEAR_p}{\Sigma_p Q_{pct}}$$

where

$LAUNCH\_YEAR_{ct}$ = the quantity-weighted-mean launch year of products sold in country c in year t

Q_{pct} = the quantity (number of standard dose units) of product p sold in country c in year t

The world launch year of some molecules is not known. But it is safe to assume that molecules with missing world launch years are generally old molecules, e.g. that they were not launched after 1990.[28] Therefore it is useful to define the following binary variable:

$POST1990_m$ = 1 if $LAUNCH\_YEAR_m > 1990$
= 0 if $LAUNCH\_YEAR_m \leq 1990$ or $LAUNCH\_YEAR_m$ is unknown

An alternative measure of the vintage of each "international product" based on this binary measure is:

$$POST1990\%_p = \frac{\Sigma_m INGRED\_OF_{pm} POST1990_m}{\Sigma_m INGRED\_OF_{pm}}$$

where

$POST1990\%_p$ = the fraction of product p's active ingredients that were launched after 1990

An alternative measure of the mean vintage of pharmaceuticals consumed in a country in a given year is:

$$POST1990\%_{ct} = \frac{\Sigma_p Q_{pct} POST1990\%_p}{\Sigma_p Q_{pct}}$$

[28] The quantity-weighted-average fraction of products with molecules with missing launch years declined from 31.6% in 1999 to 27.5% in 2010. The quantity-weighted-average fraction of products with molecules with missing launch years varies considerably across countries: it exceeds 40% for Thailand, the Philippines, and Indonesia, and is below 16% for Greece, Sweden, and the Netherlands.

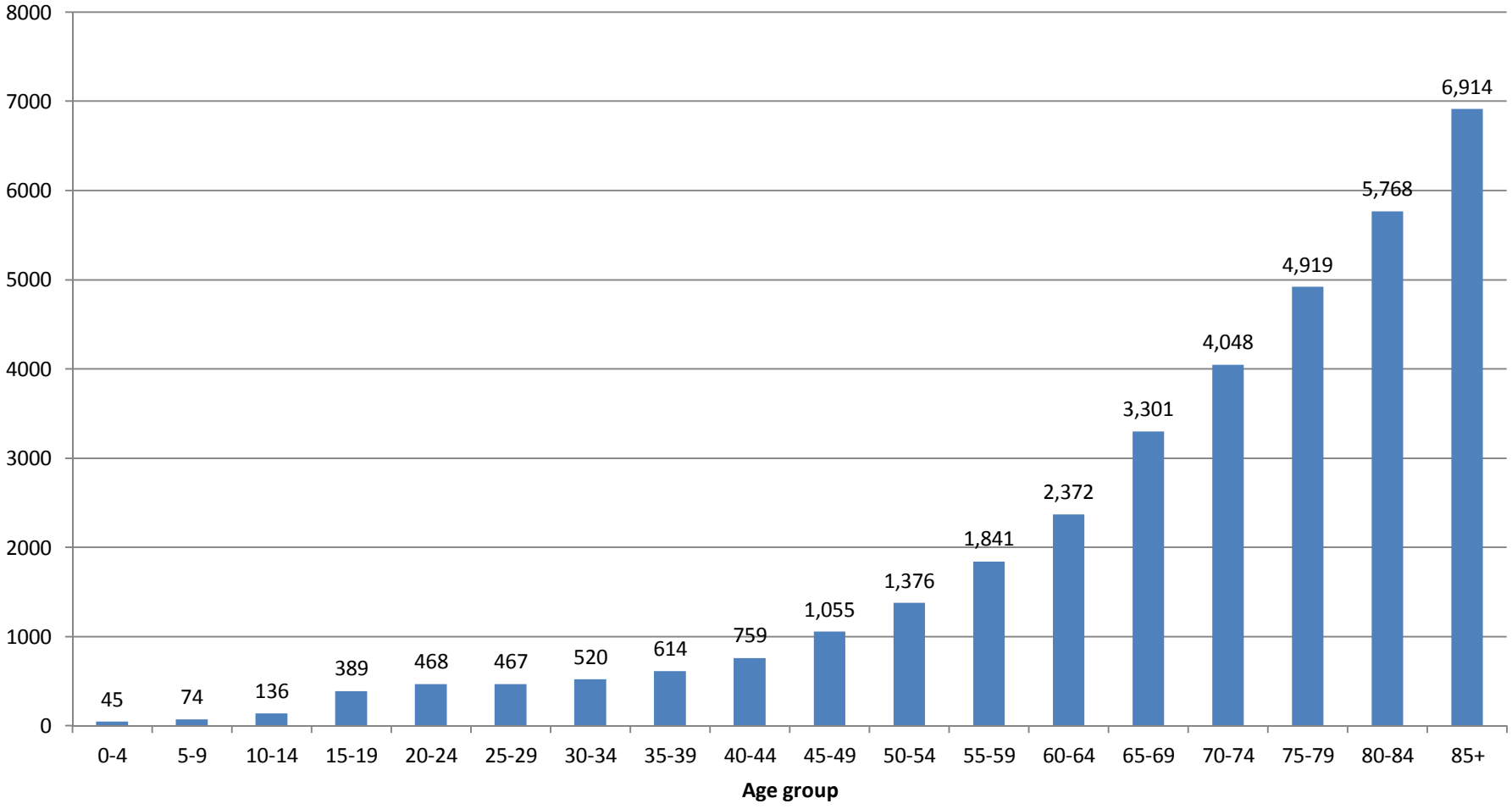
where

$POST1990\%_{ct}$ = the quantity-weighted-mean fraction of products sold in country c in year t that were launched after 1990

$POST1990\%_{ct}$ can be computed using data on all products, whereas $LAUNCH\_YEAR_{ct}$ can be computed only using data on products containing molecules with known launch years. We also calculated measures analogous to $POST1990\%_{ct}$ using different launch-year cutoff values, e.g. $POST1980\%_{ct}$ = the quantity-weighted-mean fraction of products sold in country c in year t that were launched after 1980.

Figure 1

Mean consumption of medicines (defined daily doses per thousand inhabitants per day), by age group, Denmark, 2011



Source: http://medstat.dk/en

Figure 2
Quantity-weighted-mean fraction of products sold in 2009 that were launched after 1990 (POST1990%) , by country

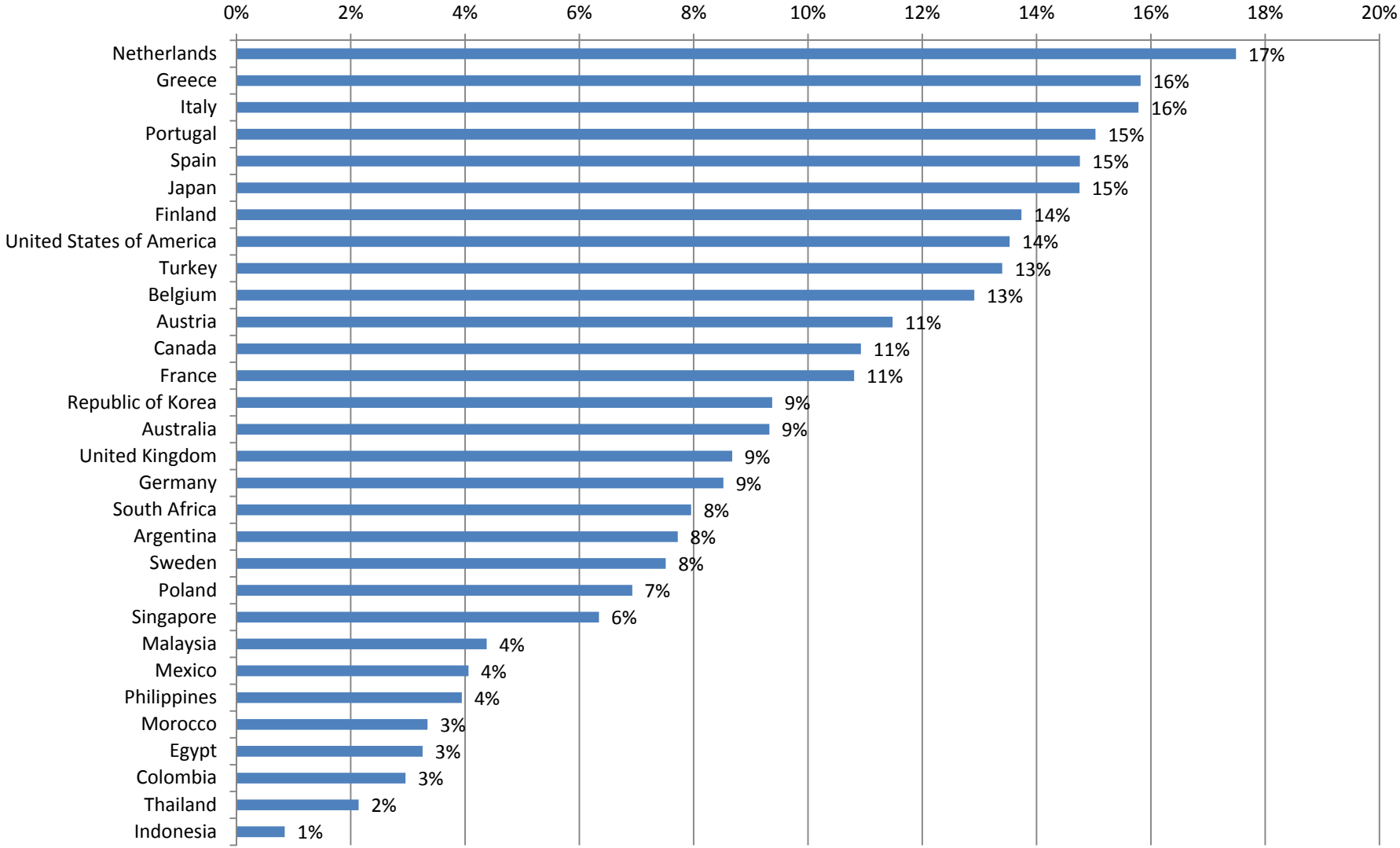


Figure 3

Relationship across countries between number of new chemical entities launched during 1982-2001 and POST1980% in 2000

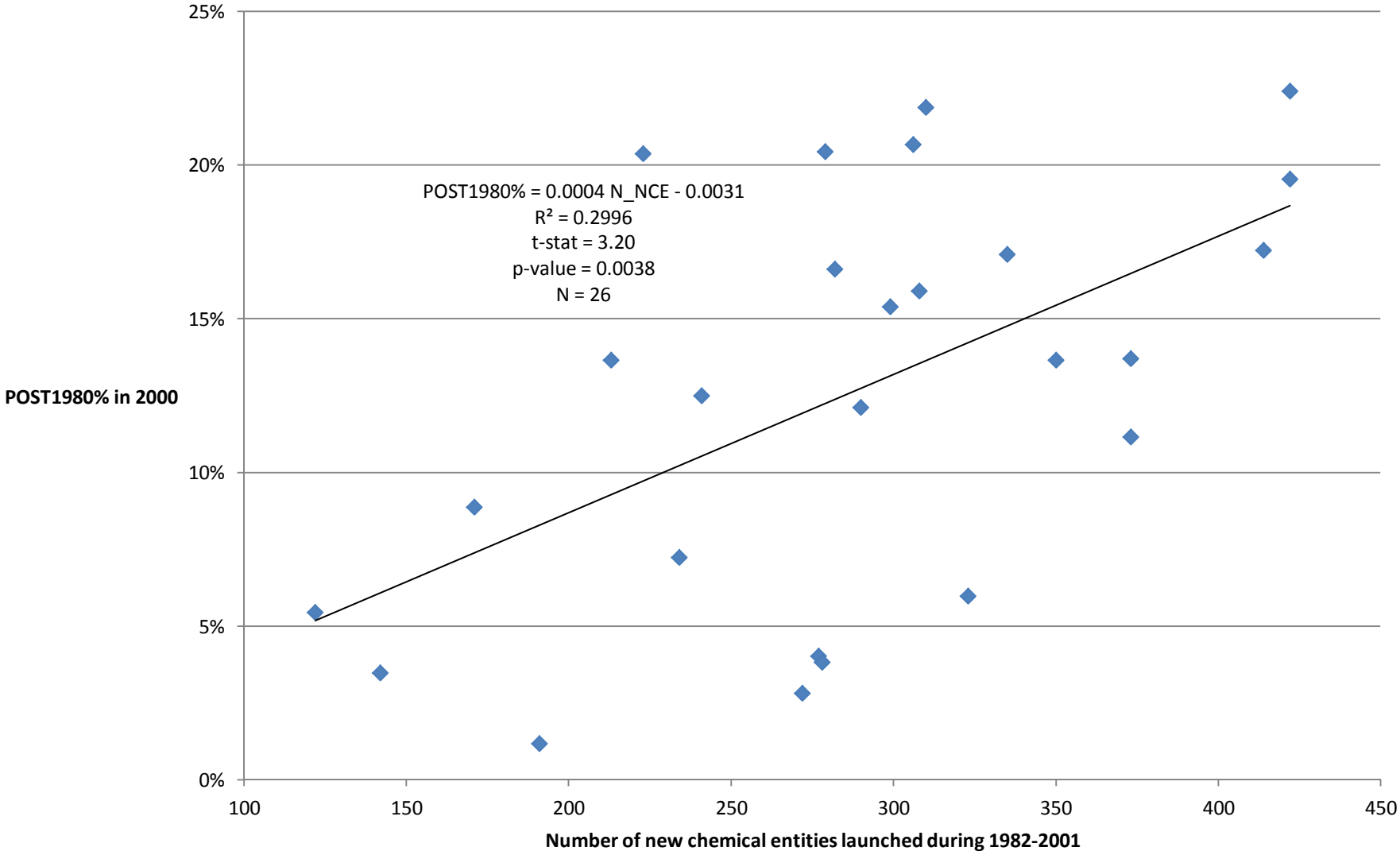
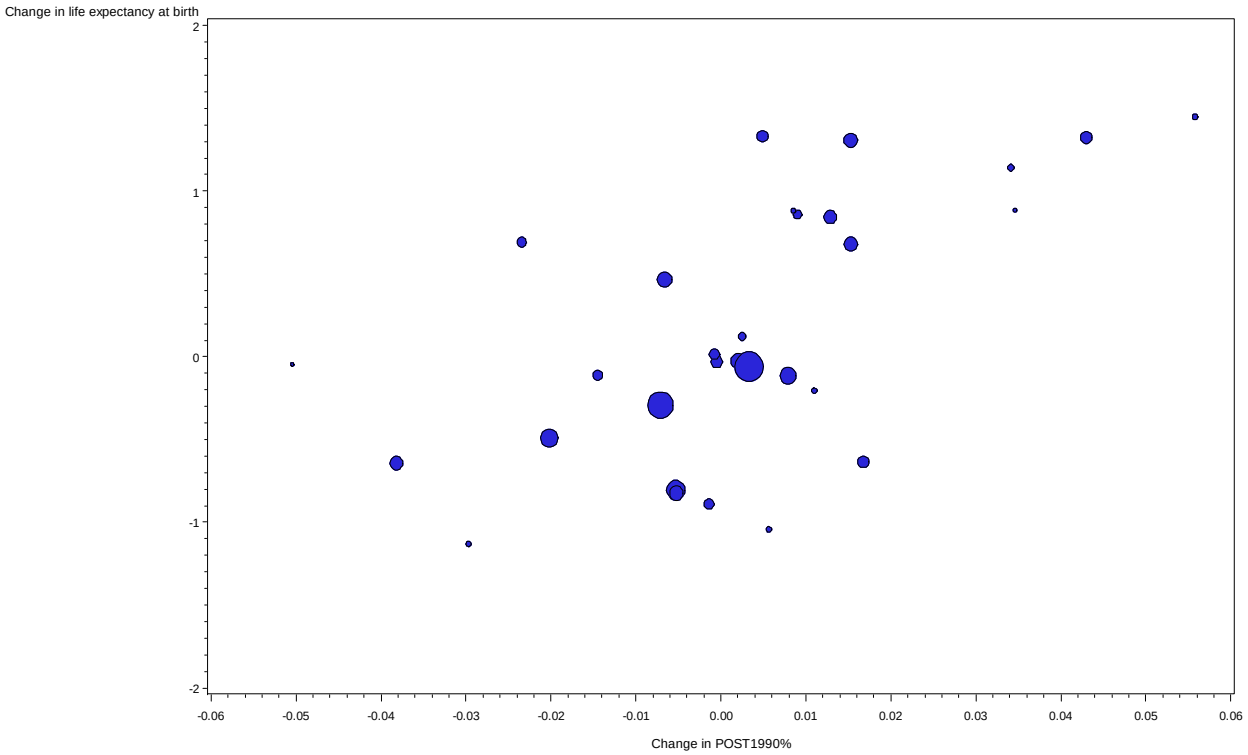


Figure 4

Correlation across countries between 2000-2009 change in life expectancy at birth and change in drug vintage, controlling for changes in income, unemployment rate, education, urbanization, health expenditure, immunization rate, HIV prevalence and tuberculosis incidence



Note: size of bubble is proportional to country population.

Table 1

Estimates of eq. (5): $\ln(RISK_{ct}) = \gamma\ POST1990\%_{ct} + \alpha_c + \pi_t + \varepsilon_{ct}$

RISK measure	**average annual growth rate**	**γ**	**Z**	**Pr > |Z|**
BMI_GT25	1.10%	0.5779	3.02	0.0025
BMI_GT30	2.80%	0.0321	0.06	0.9546
TOBACCO	-1.70%	-1.2128	-0.76	0.4452
ALCOHOL	1.30%	1.3873	0.58	0.5649

Table 2

Estimates of eq. (6): $\ln(IMAGE_{ct}) = \gamma\ POST1990\%_{ct} + \alpha_c + \pi_t + \varepsilon_{ct}$

IMAGE measure	**average annual growth rate**	**γ**	**Z**	**Pr > |Z|**
CT	6.50%	-3.0439	-2.15	0.0313
MRI	18.60%	6.0763	2.66	0.0078
CT + MRI	9.30%	1.1257	0.78	0.4362

Table 3

Descriptive statistics (population weighted) for 30 countries: levels in 2000 and 2009

Statistic	MEAN		MIN		MAX	
Year	2000	2009	2000	2009	2000	2009
Life expectancy at						
Birth	74.1	75.7	56.3	54.5	81.3	83.1
Age 25	51.5	52.5	37.8	35.4	57.0	58.7
Age 45	33.1	34.0	25.1	25.1	37.7	39.4
Age 65	16.8	17.6	12.3	13.7	20.2	21.7
Probability of survival from:						
Birth to 25	96.5%	97.2%	88.4%	88.5%	99.1%	99.3%
25 to 65	81.0%	82.0%	53.0%	46.0%	89.0%	91.0%
65 to 75	75.0%	78.0%	57.0%	62.0%	85.0%	88.0%
Birth to 75	59.8%	63.2%	26.6%	25.3%	75.4%	79.3%
Pharmaceutical variables						
LAUNCH_YEAR	1946.5	1951.2	1928.0	1928.3	1960.5	1967.5
POST1970%	20.6%	27.8%	5.6%	8.3%	39.6%	49.8%
POST1980%	10.8%	18.2%	1.2%	2.6%	22.4%	34.5%
POST1990%	3.4%	8.4%	0.3%	0.8%	7.6%	17.5%
Per capita quantity of prescription drugs	773	848	129	145	1725	1744
Other variables						
GDP per capita (constant 2000 US$)	$15,684	$16,379	$773	$1,089	$36,789	$37,766
Health expenditure per capita (constant 2000 US$)	$1,559	$2,057	$15	$27	$4,704	$6,463
Public sector share of health expenditure	56%	58%	29%	36%	85%	80%
Unemployment rate	7.5	8.4	2.4	1.2	26.7	23.8
Prevalence of HIV, total (% of population ages 15-49)	0.7	0.8	0.1	0.1	16.1	17.8
Mean years of schooling, 15+	9.0	9.5	4.4	5.3	12.6	12.8
Incidence of tuberculosis (per 100,000 people)	79.6	85.0	5.5	4.4	576.0	971.0
Urban population (% of total)	66.0	69.4	31.1	33.7	100.0	100.0
Immunization, DPT (% of children ages 12-23 months)	88.4	92.2	71.0	63.0	99.0	99.0

Table 4

Descriptive statistics (2009 population weighted) for 30 countries: 2000-2009 changes

	MEAN	MIN	MAX
Change in life expectancy at			
Birth	1.74	-1.80	4.70
Age 25	1.17	-2.40	3.90
Age 45	1.07	-0.60	3.70
Age 65	0.92	-0.40	2.80
Log change in probability of survival from:			
Birth to 25	0.01	0.00	0.03
25 to 65	0.01	-0.14	0.07
65 to 75	0.04	-0.01	0.09
Birth to 75	0.06	-0.05	0.18
Pharmaceutical variables			
Change in LAUNCH_YEAR	4.85	-1.21	9.99
Change in POST1970%	0.07	0.01	0.15
Change in POST1980%	0.08	0.01	0.15
Change in POST1990%	0.05	0.01	0.11
Log change in per capita quantity of prescription drugs	0.17	-0.18	0.67
Other variables			
Log change in GDP per capita (constant 2000 US$)	0.15	-0.03	0.35
Log change in Health expenditure per capita (constant 2000 US$)	0.36	0.13	0.68
Change in Public sector share of health expenditure	0.02	-0.11	0.22
Change in unemployment rate	0.93	-7.90	7.50
Change in prevalence of HIV, total (% of population ages 15-49)	0.06	-0.50	1.70
Change in mean years of schooling, 15+	0.58	0.08	1.01
Change in incidence of tuberculosis (per 100,000 people)	3.24	-49.00	395.00
Urban population (% of total)	3.57	-0.44	10.58
Change in immunization, DPT (% of children ages 12-23 months)	3.89	-12.00	13.00

Table 5

Coefficients of correlation between 2000-2009 changes in measures of pharmaceutical innovation and changes in other variables in longevity model (2009 population-weighted)

	Coefficient of correlation with change in POST1990%	p-value		Coefficient of correlation with change in mean LAUNCH_YEAR	p-value
Log change in per capita quantity of prescription drugs	-0.120	0.529		0.071	0.711
Change in mean years of schooling, 15+	-0.238	0.206		**-0.386**	0.035
Log change in GDP per capita (constant 2000 US$)	**-0.590**	0.001		-0.308	0.097
Change in unemployment rate	0.150	0.429		0.192	0.309
Log change in health expenditure per capita (constant 2000 US$)	-0.296	0.113		-0.123	0.517
Change in public sector share of health expenditure	-0.300	0.107		-0.012	0.951
Change in immunization, DPT (% of children ages 12-23 months)	-0.017	0.931		-0.124	0.513
Change in prevalence of HIV, total (% of population ages 15-49)	0.106	0.579		-0.040	0.835
Change in incidence of tuberculosis (per 100,000 people)	0.051	0.789		0.026	0.891
Change in urban population (% of total)	**-0.549**	0.002		**-0.525**	0.003

Table 6

Top 25 post-1990 molecules, ranked by number of standard units in 30 sample countries in 2010

Molecule	World launch year	Millions of standard units in 2010
FLUTICASONE	1991	15,719
CIPROFLOXACIN	2002	10,969
ATORVASTATIN	1997	10,244
LOSARTAN	1994	7,046
VALSARTAN	1996	6,521
GLIMEPIRIDE	1995	6,285
PANTOPRAZOLE	1994	5,980
GABAPENTIN	1993	5,442
CLOPIDOGREL	1998	4,615
LEVOFLOXACIN	1993	4,454
ROSUVASTATIN	2003	4,401
LANSOPRAZOLE	1991	4,357
CARVEDILOL	1991	4,319
CANDESARTAN CILEXETIL	1997	3,851
DORZOLAMIDE	1995	3,592
ESOMEPRAZOLE	2000	3,511
TELMISARTAN	1998	3,465
LATANOPROST	1996	3,166
IRBESARTAN	1997	3,158
TAMSULOSIN	1993	3,056
OLMESARTAN MEDOXOMIL	2002	2,993
PIOGLITAZONE	1999	2,873
RABEPRAZOLE	1997	2,828
OLOPATADINE	1997	2,743
MONTELUKAST	1997	2,709

Table 7

Estimates of models of longevity change, 2000-2009

Model		**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Dependent variable		**change in life expectancy at**							
		Birth		**Age 25**		**Age 45**		**Age 65**	
Regressor	statistic								
ΔPOST1990% (change in quantity-weighted-mean fraction of products sold that were launched after 1990)	estimate	**19.150**	**25.358**	**26.994**	**27.202**	**27.276**	**23.088**	**21.509**	**17.429**
	t value	**2.867**	**3.194**	**4.527**	**4.594**	**7.013**	**4.035**	**7.778**	**3.821**
	prob > |t|	**0.008**	**0.005**	**0.000**	**0.000**	**0.000**	**0.001**	**0.000**	**0.001**
Δq_rx (change in log of per capita quantity of prescription drugs)	estimate		-0.564		-0.908		-0.893		-0.677
	t value		-0.542		-1.171		-1.191		-1.134
	prob > |t|		0.594		0.257		0.249		0.272
Δhealth_expend (change in log of real per capita health expenditure)	estimate		-0.045		1.918		**2.568**		1.913
	t value		-0.027		1.534		**2.126**		1.987
	prob > |t|		0.979		0.142		**0.048**		0.062
Δpublic_health% (change in public sector share of health expenditure)	estimate		-1.471		-2.163		-2.486		-1.822
	t value		-0.681		-1.343		-1.597		-1.468
	prob > |t|		0.505		0.196		0.128		0.159
Δgdp (change in log of real per capita GDP)	estimate		5.295		1.798		1.016		1.341
	t value		1.611		0.734		0.429		0.710
	prob > |t|		0.125		0.473		0.673		0.487
Δunemp (change in unemployment rate)	estimate		**0.159**		0.065		0.062		0.052
	t value		**2.755**		1.508		1.490		1.566
	prob > |t|		**0.013**		0.149		0.154		0.135
Δedu (change in mean years of schooling of people age 15+)	estimate		1.084		0.074		0.076		-0.131
	t value		1.866		0.171		0.181		-0.392
	prob > |t|		0.078		0.866		0.859		0.700
ΔDPT_immun (change in immunization, DPT (% of children ages 12-23 months))	estimate		-0.021		-0.030		-0.015		0.001
	t value		-0.648		-1.251		-0.659		0.073
	prob > |t|		0.525		0.227		0.518		0.943
ΔHIV_prev (change in prevalence of HIV, total (% of population ages 15-49))	estimate		**-3.462**		**-3.302**		-0.987		0.210
	t value		**-2.880**		**-3.682**		-1.139		0.304
	prob > |t|		**0.010**		**0.002**		0.270		0.764
ΔTB_inc (change in incidence of tuberculosis (per 100,000 people))	estimate		0.005		0.005		0.002		0.002
	t value		1.052		1.241		0.623		0.594
	prob > |t|		0.307		0.231		0.541		0.560
Δurban% (change in urban fraction of population)	estimate		-0.126		-0.107		**-0.126**		**-0.110**
	t value		-1.547		-1.771		**-2.154**		**-2.354**
	prob > |t|		0.139		0.094		**0.045**		**0.030**
Intercept	estimate	0.775	-0.246	-0.194	-0.383	-0.305	-0.503	-0.165	-0.298
	t value	1.974	-0.424	-0.552	-0.888	-1.333	-1.205	-1.016	-0.895
	prob > |t|	0.058	0.677	0.585	0.386	0.193	0.244	0.318	0.383

Note: N = 30. Weighted least squares estimates, weighting by 2009 population.

Table 7

Estimates of models of longevity change, 2000-2009

Model		**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**
Dependent variable		**log change in probability of survival from**							
		birth to age 25		**age 25 to 65**		**age 65 to 75**		**birth to age 75**	
Regressor	statistic								
ΔPOST1990% (change in quantity-weighted-mean fraction of products sold that were launched after 1990)	estimate	**-0.118**	-0.019	0.422	**0.502**	**0.656**	**0.519**	**0.960**	**1.002**
	t value	**-2.438**	-0.353	1.958	**2.567**	**5.238**	**2.953**	**3.451**	**2.555**
	prob > |t|	**0.021**	0.728	0.060	**0.019**	**0.000**	**0.009**	**0.002**	**0.020**
Δq_rx (change in log of per capita quantity of prescription drugs)	estimate		0.006		-0.008		-0.007		-0.010
	t value		0.771		-0.318		-0.309		-0.189
	prob > |t|		0.450		0.754		0.761		0.852
Δhealth_expend (change in log of real per capita health expenditure)	estimate		**-0.030**		0.033		0.049		0.052
	t value		**-2.547**		0.789		1.330		0.633
	prob > |t|		**0.020**		0.440		0.200		0.535
Δpublic_health% (change in public sector share of health expenditure)	estimate		0.008		-0.034		-0.050		-0.076
	t value		0.521		-0.649		-1.037		-0.716
	prob > |t|		0.609		0.524		0.314		0.483
Δgdp (change in log of real per capita GDP)	estimate		**0.052**		0.021		0.070		0.142
	t value		**2.262**		0.254		0.955		0.873
	prob > |t|		**0.036**		0.802		0.352		0.394
Δunemp (change in unemployment rate)	estimate		**0.001**		0.001		0.002		0.005
	t value		**3.250**		0.929		1.698		1.681
	prob > |t|		**0.004**		0.365		0.107		0.110
Δedu (change in mean years of schooling of people age 15+)	estimate		**0.014**		0.010		0.005		0.029
	t value		**3.443**		0.696		0.411		1.015
	prob > |t|		**0.003**		0.496		0.686		0.324
ΔDPT_immun (change in immunization, DPT (% of children ages 12-23 months))	estimate		0.000		-0.001		-0.001		-0.002
	t value		0.738		-1.776		-0.827		-1.153
	prob > |t|		0.470		0.093		0.419		0.264
ΔHIV_prev (change in prevalence of HIV, total (% of population ages 15-49))	estimate		-0.009		**-0.114**		-0.005		**-0.129**
	t value		-1.118		**-3.861**		-0.189		**-2.166**
	prob > |t|		0.278		**0.001**		0.852		**0.044**
ΔTB_inc (change in incidence of tuberculosis (per 100,000 people))	estimate		0.000		0.000		0.000		0.000
	t value		0.530		0.313		1.389		0.854
	prob > |t|		0.603		0.758		0.182		0.404
Δurban% (change in urban fraction of population)	estimate		0.000		-0.002		**-0.005**		-0.007
	t value		-0.285		-0.783		**-2.734**		-1.657
	prob > |t|		0.779		0.444		**0.014**		0.115
Intercept	estimate	0.015	0.003	-0.008	-0.014	0.001	-0.003	0.008	-0.014
	t value	5.114	0.628	-0.647	-0.985	0.201	-0.228	0.477	-0.505
	prob > |t|	0.000	0.538	0.523	0.338	0.842	0.822	0.637	0.620

Note: N = 30. Weighted least squares estimates, weighting b

Table 8
Estimates of coefficients on ΔVINTAGE in longevity change model (eq. (4)) based on 3 alternative measures of ΔVINTAGE

Dependent variable		Vintage coefficient estimate	t Value	Pr > |t|
		A. Vintage measure = ΔPOST1990%		
change in life expectancy at	Birth	25.358	3.19	0.005
	Age 25	27.202	4.59	0.000
	Age 45	23.088	4.03	0.001
	Age 65	17.429	3.82	0.001
log change in probability of survival from	Birth to Age 25	-0.019	-0.35	0.728
	Age 25 to 65	0.502	2.57	0.019
	Age 65 to 75	0.519	2.95	0.009
	Birth to Age 75	1.002	2.56	0.020
		B. Vintage measure = ΔPOST1980%		
change in life expectancy at	Birth	16.247	2.50	0.022
	Age 25	17.519	3.38	0.003
	Age 45	13.673	2.70	0.015
	Age 65	9.972	2.48	0.023
log change in probability of survival from	Birth to Age 25	-0.012	-0.28	0.783
	Age 25 to 65	0.366	2.44	0.026
	Age 65 to 75	0.385	2.85	0.011
	Birth to Age 75	0.739	2.46	0.024
		C. Vintage measure = ΔLAUNCH_YEAR		
change in life expectancy at	Birth	0.121	2.05	0.055
	Age 25	0.130	2.66	0.016
	Age 45	0.102	2.21	0.040
	Age 65	0.076	2.10	0.050
log change in probability of survival from	Birth to Age 25	0.000	-0.08	0.938
	Age 25 to 65	0.003	2.09	0.051
	Age 65 to 75	0.003	2.33	0.032
	Birth to Age 75	0.006	2.10	0.050

Note: All models include the following covariates**:** **Δq_rx** (change in log of per capita quantity of prescription drugs); **Δhealth_expend** (change in log of real per capita health expenditure); **Δpublic_health%** (change in public sector share of health expenditure); **Δgdp** (change in log of real per capita GDP); **Δunemp** (change in unemployment rate); **Δedu** (change in mean years of schooling of people age 15+); **ΔDPT_immun** (change in immunization, DPT (% of children ages 12-23 months)); **ΔHIV_prev** (change in prevalence of HIV, total (% of population ages 15-49)); **ΔTB_inc** (change in incidence of tuberculosis (per 100,000 people)); **Δurban%** (change in urban fraction of population)

Table 9

Comparison of estimates of the marginal effect of drug vintage on longevity (ΔLONGEVITY/ΔLAUNCH_YEAR) with estimates from four previous studies

Study	Age group	Country	Period	Longevity measure	Methodology	ΔLONGEVITY/ ΔLAUNCH_YEAR
Previous studies						
Lichtenberg and Duflos (2008)	Entire population	Australia	1995-2003	Mean age at death	longitudinal disease-level	0.182
Lichtenberg (2011)	Entire population	USA	1991-2004	Life expectancy at birth	longitudinal state-level	0.135
Lichtenberg (2012)	Entire population	Germany	2001-2007	Life expectancy at birth	longitudinal state-level	0.208
Lichtenberg (2013b)	Elderly (65+) community residents	USA	1996-2000	Time till death	cross-section patient-level	0.066
Current study						
	Entire population	30 develop-ing and high-income countries	2000-2009	Life expectancy at birth	longitudinal country-level	0.121
	Entire population	30 develop-ing and high-income countries	2000-2009	Life expectancy at age 65	longitudinal country-level	0.076

Table 10

Estimates of the increase in life expectancy due to the increase in drug vintage

		Due to increase in drug vintage, based on vintage measure:		
2000-2009 increase in life expectancy at:	Actual	POST1990%	POST1980%	LAUNCH_YEAR
Birth	1.74	1.27	1.23	0.59
Age 25	1.17	1.36	1.33	0.63
Age 45	1.07	1.15	1.04	0.5
Age 65	0.92	0.87	0.76	0.37

Table 11

Comparison of the top 5 countries (ranked by POST1990% in 2009) with the bottom 5 countries (ranked by the same criterion).

	POST1990% in 2009	Life expectancy at birth in 2009
Top 5 countries (ranked by POST1990% in 2009): Netherlands, Greece, Italy, Portugal, Spain	16%	80.7
Bottom 5 countries: Morocco, Egypt, Colombia, Thailand, Indonesia	3%	71.6
Difference	13%	9.1

Appendix Table 1
Longevity data

			Life expectancy at age				Number of survivors per 100,000 births until age			
country	**year**	**population (millions)**	**0**	**25**	**45**	**65**	**25**	**45**	**65**	**75**
Argentina	2000	36.9	74.6	51.8	33.2	17.1	96,888	93,601	78,762	60,174
Argentina	2009	40.1	75.4	52.3	33.6	17.3	97,327	94,344	80,255	62,671
Australia	2000	19.2	79.8	55.8	36.8	19.1	98,600	96,481	88,014	73,053
Australia	2009	22.0	81.9	57.7	38.5	20.5	98,977	97,343	90,167	78,286
Austria	2000	8.0	78.4	54.3	35.3	18.2	98,660	96,577	85,570	69,381
Austria	2009	8.4	80.3	56.0	36.7	19.4	98,972	97,460	87,644	74,191
Belgium	2000	10.3	77.8	53.8	34.8	17.8	98,564	96,221	84,926	68,107
Belgium	2009	10.8	80.0	55.8	36.6	19.3	98,970	97,159	87,221	73,313
Canada	2000	30.8	79.4	55.3	36.1	18.8	98,699	96,848	86,932	70,789
Canada	2009	33.7	81.2	57.0	37.8	20.2	98,825	97,236	88,816	75,230
Colombia	2000	39.8	72.8	51.5	34.4	18.2	94,372	88,168	75,353	58,632
Colombia	2009	45.7	76.5	54.1	36.1	19.1	96,299	92,014	81,766	66,476
Egypt	2000	67.6	68.4	47.6	28.9	13.8	93,964	90,481	69,931	45,349
Egypt	2009	79.7	70.9	48.1	29.2	14.2	96,682	93,742	72,495	48,682
Finland	2000	5.2	77.7	53.5	34.6	17.7	98,798	96,125	84,570	68,141
Finland	2009	5.3	79.9	55.5	36.5	19.5	99,058	96,868	86,455	72,741
France	2000	60.8	79.3	55.2	36.3	19.5	98,726	96,192	85,176	70,748
France	2009	64.5	81.4	57.0	37.9	20.9	99,093	97,168	87,315	75,459
Germany	2000	82.2	78.3	54.1	35.0	18.0	98,818	96,742	85,339	68,171
Germany	2009	81.9	80.3	55.9	36.5	19.2	99,152	97,675	87,796	73,840
Greece	2000	10.9	78.2	54.2	35.0	17.5	98,595	96,606	87,062	70,822
Greece	2009	11.3	80.2	55.9	36.8	19.2	98,948	97,081	88,468	75,834
Indonesia	2000	213.4	67.9	48.0	29.7	13.9	92,510	88,495	71,185	47,710
Indonesia	2009	237.4	68.3	47.2	29.1	13.8	94,111	89,224	69,854	46,271
Italy	2000	56.9	79.4	55.2	36.0	18.5	98,828	97,013	87,865	72,398
Italy	2009	60.2	81.9	57.6	38.2	20.3	99,112	97,763	90,475	78,350
Japan	2000	126.9	81.3	57.0	37.7	20.2	99,030	97,363	88,606	75,363
Japan	2009	127.6	83.1	58.7	39.4	21.7	99,246	97,704	90,159	79,282
Malaysia	2000	23.4	71.6	48.1	29.7	13.9	97,574	93,658	74,738	49,272
Malaysia	2009	27.9	73.4	49.4	30.8	14.5	98,318	94,940	78,826	54,148
Mexico	2000	100.0	74.4	52.0	33.6	17.6	96,259	92,661	78,143	59,845
Mexico	2009	112.0	75.7	52.6	34.1	17.7	97,195	93,901	80,528	62,800
Morocco	2000	28.8	69.5	49.4	30.6	14.3	93,044	90,111	74,910	51,921
Morocco	2009	31.6	72.6	51.1	32.1	15.2	95,130	92,948	79,925	58,553
Netherlands	2000	15.9	78.1	54.0	34.7	17.4	98,801	97,061	86,375	68,547
Netherlands	2009	16.5	80.6	56.2	36.8	19.2	99,175	97,880	89,079	74,893
Philippines	2000	77.3	69.5	48.1	30.3	15.1	94,546	89,384	70,729	50,012
Philippines	2009	91.7	69.6	47.9	29.9	14.7	95,149	90,075	70,840	49,426

Appendix Table 1
Longevity data

			Life expectancy at age				Number of survivors per 100,000 births until age			
country	**year**	**population (millions)**	**0**	**25**	**45**	**65**	**25**	**45**	**65**	**75**
Poland	2000	38.5	73.9	50.0	31.4	15.8	98,272	94,779	77,124	56,110
Poland	2009	38.2	75.7	51.6	32.8	17.1	98,623	95,683	79,323	61,205
Portugal	2000	10.2	76.6	52.8	34.3	17.2	98,211	94,845	83,596	66,486
Portugal	2009	10.6	79.4	55.1	36.1	18.8	99,010	96,839	86,848	73,230
Republic of Korea	2000	47.0	76.0	52.0	33.1	16.5	98,579	95,846	82,586	63,494
Republic of Korea	2009	48.7	80.2	55.9	36.8	19.3	98,984	96,994	88,210	74,350
Singapore	2000	4.0	78.4	54.0	34.7	17.4	99,060	97,373	86,774	68,010
Singapore	2009	5.0	81.7	57.2	37.7	19.9	99,302	98,165	90,277	75,899
South Africa	2000	44.0	56.3	37.8	25.1	12.3	88,367	69,850	46,502	26,556
South Africa	2009	49.3	54.5	35.4	25.1	13.7	88,512	64,004	40,518	25,262
Spain	2000	40.3	79.2	55.1	36.1	18.8	98,752	96,452	86,788	72,031
Spain	2009	45.9	81.6	57.2	37.8	20.2	99,176	97,704	89,319	77,195
Sweden	2000	8.9	79.8	55.4	36.1	18.5	99,060	97,538	88,336	72,938
Sweden	2009	9.3	81.3	56.8	37.5	19.6	99,270	97,939	90,050	76,554
Thailand	2000	63.2	67.7	45.6	29.9	14.9	95,102	84,864	66,531	46,424
Thailand	2009	68.7	69.9	47.1	29.9	14.5	96,443	89,447	71,437	50,389
Turkey	2000	63.6	69.9	48.9	30.4	14.3	94,217	90,626	74,322	51,279
Turkey	2009	71.8	74.6	51.7	32.7	15.8	96,977	94,703	82,052	61,567
United Kingdom	2000	58.9	77.9	53.8	34.7	17.5	98,743	96,703	85,714	67,188
United Kingdom	2009	61.8	80.2	55.9	36.8	19.3	98,976	97,061	87,961	73,617
United States of America	2000	282.2	76.9	53.2	34.4	17.9	98,169	95,263	82,413	64,632
United States of America	2009	306.8	78.5	54.7	35.9	19.2	98,311	95,588	84,024	68,639

Appendix Table 2
Pharmaceutical data

country	year	SU per 100,000	mean launch year	post1970%	post1980%	post1990%
Argentina	2000	40	1950.2	28%	14%	3%
Argentina	2009	50	1951.3	30%	19%	8%
Australia	2000	121	1951.4	22%	14%	4%
Australia	2009	152	1951.3	23%	17%	9%
Austria	2000	102	1952.1	27%	14%	5%
Austria	2009	113	1959.3	36%	23%	11%
Belgium	2000	109	1956.9	35%	17%	5%
Belgium	2009	114	1963.4	45%	29%	13%
Canada	2000	107	1950.3	25%	15%	6%
Canada	2009	158	1952.8	26%	19%	11%
Colombia	2000	25	1938.7	12%	4%	1%
Colombia	2009	23	1938.8	16%	8%	3%
Egypt	2000	26	1944.4	14%	3%	1%
Egypt	2009	42	1949.8	21%	9%	3%
Finland	2000	102	1953.5	28%	17%	5%
Finland	2009	114	1961.4	38%	30%	14%
France	2000	173	1952.2	24%	12%	3%
France	2009	154	1956.1	31%	21%	11%
Germany	2000	127	1950.1	22%	10%	3%
Germany	2009	131	1959.1	32%	21%	9%
Greece	2000	81	1959.7	37%	20%	6%
Greece	2009	123	1964.0	43%	30%	16%
Indonesia	2000	17	1928.0	6%	1%	0%
Indonesia	2009	24	1928.3	8%	3%	1%
Italy	2000	84	1955.3	35%	20%	6%
Italy	2009	85	1965.3	46%	32%	16%
Japan	2000	148	1958.6	35%	22%	6%
Japan	2009	174	1964.8	46%	34%	15%
Malaysia	2000	16	1946.1	16%	5%	1%
Malaysia	2009	18	1948.8	20%	11%	4%
Mexico	2000	29	1943.0	15%	6%	2%
Mexico	2009	24	1941.8	17%	10%	4%
Morocco	2000	17	1946.0	13%	3%	1%
Morocco	2009	23	1952.0	21%	9%	3%
Netherlands	2000	62	1960.5	37%	22%	8%
Netherlands	2009	76	1965.6	46%	34%	17%
Philippines	2000	13	1938.7	11%	4%	1%
Philippines	2009	14	1940.2	15%	8%	4%
Poland	2000	98	1950.4	25%	9%	1%

Appendix Table 2
Pharmaceutical data

country	year	SU per 100,000	mean launch year	post1970%	post1980%	post1990%
Poland	2009	113	1958.9	36%	21%	7%
Portugal	2000	88	1960.5	40%	20%	4%
Portugal	2009	102	1967.5	50%	34%	15%
Republic of Korea	2000	108	1941.8	16%	6%	1%
Republic of Korea	2009	127	1951.7	30%	21%	9%
Singapore	2000	40	1949.6	19%	9%	3%
Singapore	2009	49	1953.7	28%	17%	6%
South Africa	2000	27	1946.9	16%	7%	2%
South Africa	2009	45	1951.5	25%	17%	8%
Spain	2000	107	1959.6	36%	21%	6%
Spain	2009	115	1964.2	43%	30%	15%
Sweden	2000	106	1951.3	27%	16%	5%
Sweden	2009	126	1955.8	33%	23%	8%
Thailand	2000	34	1934.6	9%	3%	0%
Thailand	2009	55	1942.3	17%	9%	2%
Turkey	2000	30	1950.5	27%	12%	3%
Turkey	2009	60	1960.4	39%	25%	13%
United Kingdom	2000	114	1951.4	20%	11%	4%
United Kingdom	2009	137	1955.2	29%	21%	9%
United States of America	2000	125	1951.3	25%	17%	8%
United States of America	2009	124	1959.1	35%	26%	14%

Appendix Table 3
Other variables

country	year	GDP	real per capita health expenditure	public sector share of health expenditure	incidence of tuberculosis	immunization, DPT (% of children ages 12-23 months)	prevalence of HIV, total (% of population ages 15-49)	unemployment rate	urban fraction of population	mean years of schooling of people age 15+)
Argentina	2000	$7,696	$689	55%	40.0	83	0.4	15.0	90.1	8.4
Argentina	2009	$9,933	$946	66%	28.0	87	0.5	8.6	92.2	8.9
Australia	2000	$21,766	$1,748	67%	6.1	90	0.1	6.3	87.2	11.1
Australia	2009	$25,084	$2,189	64%	6.3	92	0.1	5.6	88.9	11.8
Austria	2000	$23,973	$2,385	77%	16.0	81	0.1	3.5	65.8	11.1
Austria	2009	$26,166	$2,886	74%	7.3	83	0.3	4.8	67.4	11.2
Belgium	2000	$22,697	$2,039	68%	14.0	95	0.2	6.6	97.1	10.3
Belgium	2009	$24,173	$2,620	74%	8.7	99	0.2	7.9	97.4	10.9
Canada	2000	$23,560	$2,084	70%	6.4	92	0.2	6.8	79.5	12.6
Canada	2009	$25,069	$2,858	66%	4.8	80	0.2	8.3	80.5	12.8
Colombia	2000	$2,524	$172	81%	43.0	79	0.9	16.2	72.1	7.7
Colombia	2009	$3,153	$239	71%	35.0	92	0.5	12.0	74.8	8.4
Egypt	2000	$1,476	$80	40%	26.0	98	0.1	9.0	42.6	6.5
Egypt	2009	$1,912	$92	43%	19.0	97	0.1	9.4	42.8	7.5
Finland	2000	$23,529	$1,702	71%	12.0	99	0.1	9.7	61.1	12.4
Finland	2009	$26,257	$2,375	77%	11.0	99	0.1	8.2	63.6	12.7
France	2000	$21,829	$2,199	79%	13.0	97	0.3	10.2	75.8	8.7
France	2009	$22,668	$2,696	75%	9.6	99	0.4	9.1	77.6	9.3
Germany	2000	$22,946	$2,360	80%	13.0	90	0.1	7.7	73.1	12.3
Germany	2009	$24,367	$2,857	73%	5.1	93	0.1	7.7	73.7	12.4
Greece	2000	$11,396	$898	60%	7.6	89	0.1	11.1	59.7	8.7
Greece	2009	$14,114	$1,492	63%	4.9	99	0.1	9.5	61.2	9.4
Indonesia	2000	$773	$15	37%	189.0	71	0.1	6.1	42.0	7.1
Indonesia	2009	$1,089	$27	49%	189.0	82	0.2	7.9	52.6	7.9
Italy	2000	$19,388	$1,563	73%	8.9	87	0.3	10.8	67.2	8.7
Italy	2009	$18,785	$1,772	78%	5.4	96	0.3	7.8	68.2	9.4
Japan	2000	$36,791	$2,829	81%	36.0	85	0.1	4.8	65.2	10.9
Japan	2009	$37,767	$3,592	70%	22.0	98	0.1	5.0	66.6	11.5
Malaysia	2000	$4,005	$127	52%	95.0	95	0.4	3.0	62.0	8.8
Malaysia	2009	$4,915	$225	47%	83.0	95	0.5	3.7	71.3	9.6
Mexico	2000	$5,817	$295	47%	32.0	97	0.3	2.6	74.7	7.6
Mexico	2009	$5,858	$379	48%	17.0	95	0.3	5.2	77.5	8.3
Morocco	2000	$1,272	$53	29%	109.0	95	0.1	13.6	53.3	4.4

Appendix Table 3
Other variables

country	year	GDP	real per capita health expenditure	public sector share of health expenditure	incidence of tuberculosis	immunization, DPT (% of children ages 12-23 months)	prevalence of HIV, total (% of population ages 15-49)	unemployment rate	urban fraction of population	mean years of schooling of people age 15+)
Morocco	2009	$1,797	$94	36%	92.0	99	0.1	10.0	56.4	5.3
Netherlands	2000	$24,180	$1,924	63%	9.6	97	0.2	2.7	76.8	10.6
Netherlands	2009	$26,247	$3,144	70%	7.2	97	0.2	3.4	82.4	10.9
Philippines	2000	$1,048	$36	48%	329.0	79	0.1	11.2	58.5	8.7
Philippines	2009	$1,307	$47	37%	280.0	87	0.1	7.5	65.7	9.3
Poland	2000	$4,454	$246	70%	33.0	98	0.1	16.1	61.7	9.1
Poland	2009	$6,332	$465	66%	23.0	99	0.1	8.2	61.3	9.8
Portugal	2000	$11,471	$1,015	73%	47.0	96	0.4	3.9	54.4	7.0
Portugal	2009	$11,591	$1,244	73%	29.0	96	0.6	9.5	60.1	7.9
Korea	2000	$11,347	$543	46%	79.0	97	0.1	4.4	79.6	10.4
Korea	2009	$15,463	$1,070	51%	95.0	94	0.1	3.6	81.7	11.2
Singapore	2000	$23,816	$668	45%	50.0	98	0.1	6.0	100.0	8.5
Singapore	2009	$28,932	$1,196	39%	36.0	97	0.1	5.9	100.0	9.1
South Africa	2000	$3,020	$256	40%	576.0	73	16.1	26.7	56.9	7.4
South Africa	2009	$3,692	$338	37%	971.0	63	17.8	23.8	61.2	8.1
Spain	2000	$14,422	$1,040	72%	23.0	95	0.4	13.9	76.3	7.4
Spain	2009	$15,539	$1,486	73%	17.0	96	0.4	18.0	77.3	8.1
Sweden	2000	$27,870	$2,295	85%	5.5	99	0.1	5.8	84.0	10.6
Sweden	2009	$30,838	$3,084	78%	6.2	98	0.1	8.3	84.6	11.1
Thailand	2000	$1,943	$66	56%	137.0	97	1.8	2.4	31.1	7.3
Thailand	2009	$2,531	$106	78%	137.0	99	1.3	1.2	33.7	7.9
Turkey	2000	$4,189	$207	63%	46.0	85	0.1	6.5	64.7	5.4
Turkey	2009	$4,969	$335	75%	29.0	96	0.1	14.0	69.1	6.1
UK	2000	$25,082	$1,767	79%	12.0	91	0.1	5.5	89.4	9.6
UK	2009	$27,645	$2,706	80%	13.0	93	0.2	7.7	90.0	10.2
USA	2000	$35,080	$4,704	43%	6.7	94	0.5	4.0	79.1	11.4
USA	2009	$36,706	$6,463	45%	4.4	95	0.6	9.3	82.0	11.5