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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.

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" [32].

According to the National Science Foundation [30], 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 [36] 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 [4] argued that "new goods are at the heart of economic progress," and Hercowitz [16], p. 223 also reached the "conclusion…that 'embodiment' is the main transmission mechanism of technological progress to economic growth."

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[1]See e.g. Nordhaus [31] and Murphy and Topel [29]. 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.

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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 [36] 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 [3], Hulten [17], Sakellaris and Wilson [34]) 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. 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 quality (hence vintage) 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. health expenditure [5], but more than half of U.S. funding for biomedical research came from pharmaceutical and biotechnology firms [11]. Much of the rest came from the federal government (i.e. the NIH), and new drugs often build on upstream government research [35].

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 [25]) 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 (A model of longevity), 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 (Measurement of longevity and pharmaceutical innovation), I discuss the measurement of longevity and pharmaceutical innovation.

[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.

[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. [13] 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 [23] 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.

[6]Lichtenberg et al. [27] studied the impact of pharmaceutical innovation on longevity using patient-level data on elderly residents of Quebec, and Lichtenberg [24] studied this issue using patient-level data on elderly Americans.

[7]Lichtenberg [21] studied the impact of pharmaceutical innovation on longevity using longitudinal state-level U.S. data, and Lichtenberg [22] 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).