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Private and Social Returns to R&D: Drug Development and Demographics]

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Abstract

Investment in intangible capital—in particular, research and development—increased dramatically since the 1990s. However, productivity growth remains sluggish in recent years. One potential reason is that a significant share of the increase in intangible investment is geared toward consumer products such as pharmaceutical drugs with limited spillovers to productivity. The researchers document that a significant share of R&D spending in the U.S. is done by pharmaceutical firms and is geared to developing drugs for the older patients. Increased life expectancy and quality of life among the elderly increases welfare but may not be reflected in estimates of total factor productivity.

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Over the last few decades business investment has shifted away from physical capital (machines, structures) and toward intangible capital (software, intellectual property), (Alexander and Eberly, 2018; Crouzet and Eberly, 2019). Despite this increase in intangible investment, measured productivity growth has been sluggish (Gordon, 2016, 2018). Yet if productivity is measured as a Solow Residual – the residual output net of the contribution of capital and labor – this represents a puzzle: if intangible investment has increased so much, why is it not reflected in higher output and higher measured productivity growth?[1]

Here, we present one possible resolution: a significant share of this increased intangible investment is geared towards medical R&D targeting older patients. To the extent that these patients are no longer in the labor force, their improved health and well-being would be welfare-enhancing but not directly productivity-improving.[2]We explore this point in several steps.

First, we show that pharmaceutical firms account for an increasing share of the total R&D spending in the economy. In the 1970s, U.S. pharmaceutical firms accounted for less than 3% of the overall R&D spending in the economy. Today, that share has risen to approximately 10%, and their share among manufacturing firms has risen from 8% to 35%.[3]

Second, we show that much of this increased spending is geared towards developing drug candidates targeting ailments typically afflicting older patients. Using detailed data on firms' drug development pipelines, we show that a significant share of drug candidates under development are treating diseases that disproportionately affect patients that have exited the labor force (over 65 years old). By exploiting between-firm heterogeneity in the profile of

[1]Intangible capital might be expected to increase measured productivity both because it is under-measured in the capital stock and also because of direct contributions to productivity, say through R&D.

[2]Our analysis follows the traditional definitions of national output and income. Improvement in health would lead to an increase in more heterodox measures of national income (Nordhaus, 2003) but not in productivity growth.

[3]During this period, U.S. pharmaceutical firms also account for an increased share of R&D spending among all publicly listed firms (7% to 25%). Though our sample is restricted to the largest firms in the economy, these firms account for the bulk of R&D spending in the economy—approximately two-thirds.

firms' drug development strategies, we can obtain an estimate of the fraction of overall R&D spending by pharmaceutical firms that is geared towards developing drugs targeting specific groups. We find that the share of expenditures allocated to treating diseases common in the over-65 year group has increased by more than 50% since 2000. Though much of our analysis is focusing on the post-2000 period, many of the trends we document are also present in the pre-2000 sample (Acemoglu and Linn, 2004).

Our estimates suggest that about a third of total R&D spending by pharmaceutical firms is geared towards those aged 65 and over. While prolonging life expectancy and improving quality of life, these investments in R&D have little effect on measured productivity and output growth. Male life expectancy at birth in the U.S. increased from 70 years in 1980 to 76.3 years in 2018. However, the effective retirement age for men has been hovering around 66 since 1980 and has risen only slightly to 67.9 by 2018, while the statutory retirement age increased from 65 to 66. Absent a significant change in retirement patterns, it is unlikely that R&D spending targeting seniors will directly enhance the labor force and hence output growth (Fernald, Hall, Stock, and Watson, 2017; Goodhart and Pradhan, 2020).

1 Drug Expenditures by Age

Our argument that increased intangible investment is geared towards medical treatments targeting the elderly hinges on the notion that seniors demand more medical care, a fact that is well documented in the literature (Gruber and Levy, 2009; Pashchenko and Porapakkarm, 2016; Meara, White, and Cutler, 2004; Cravino, Levchenko, and Rojas, 2020). Older people tend to consume more pharmaceutical drugs than younger people because they are more likely to have multiple chronic medical disorders, such as high blood pressure, diabetes, or arthritis. Moreover, the drugs used by older people for chronic disorders are taken for long periods of time. According to Ruscin and Linnebur (2018): "Almost 90% of older adults regularly take at least 1 prescription drug, almost 80% regularly take at least 2 prescription drugs, and 36% regularly take at least 5 different prescription drugs...Women typically take more drugs than men. Older people who are frail, hospitalized, or in a nursing home take the most drugs. Nursing home residents are prescribed an average of 7 to 8 different drugs to take on a regular basis."

We use the Medical Expenditure Panel Survey (MEPS) to illustrate the cost of drug consumption by age. The MEPS program is run by the Agency for Healthcare Research and Quality at the U.S. Department of Health & Human Services, and tracks data on health services use and cost for a large nationally representative sample of households. We use the MEPS data to match drugs to age cohorts.

We use the years 1996 through 2015 of the MEPS data, covering between 22,000 to 38,000 patients, depending on the year of the survey. Using MEPS's *Total Payment* and *Clinical Classification Code* variables, we calculate an elderly expense share for each medical condition. By matching drugs to their medical condition and medical conditions to their age distributions, we can calculate a drug's elderly expense share. We term "elderly drugs" those drugs with an expense share greater than the elderly population share (ages 65 and above).

Drugs targeting older patients generate significant revenues for pharmaceutical companies. As an illustrative example, consider Lipitor—a statin used to lower cholesterol in the blood—which was first approved in 1997 and has contributed to Pfizer's revenue $143 billion since 1999. Using MEPS, we aggregate expenditures on Lipitor by age groups from 1997, the first year in which Lipitor was introduced, until 2011, the year in which it went off patent. As Figure 1 demonstrates, Lipitor has been prescribed mostly to patients older than 45 with the share of prescriptions to those in the 65+ age group accounting for more than 40% of total prescriptions.

Figure 2a plots per capita drug expenditure (in 2015 dollars) for four different age groups: (1) ages 0-24; (2) ages 25-44; (3) ages 45-64; and (4) ages 65 and up. As the figure illustrates, per capita drug expenditure is increasing in age. For example, in 2015 the per capita drug expenditure for the 65+ age cohort was $2,531, compared to $1,758 for those in the 45-64 age cohort. Moreover, per capita expenditure increased dramatically from $1,668 in 2000 to $2,531 in 2015 for those in the 65+ age cohort.

The increase in drug expenditure per capita was driven mostly by an overall increase in drug cost, rather than an increase in the number of drugs.[4] Figure 2b depicts the evolution of drug cost (in 2015 dollars) by age groups from 1995 to 2015. As the figure shows drug costs increased significantly during the period. The average cost per drug for people age 65 and over was $242 in 1996 but increased to $472 by 2015. This trend is consistent with the fact that the service expenditures (particularly health) of older households has tended to rise over time (Cravino et al., 2020). In the next section we argue that R&D efforts are focused on such drugs that treat chronic conditions among the elderly.

2 The Evolution of R&D of the Pharmaceutical Industry

A significant share of intangible investment in recent years has been made by pharmaceutical firms. Figure 3 plots the ratio of R&D expenses made by pharmaceutical firms to total R&D expenses by publicly traded firms in the U.S.

As Figure 3 shows, pharmaceutical firms share of R&D among all Compustat firms increased from less than 10% in the early 1970s to 24% in 2018. Most of the increase in pharmaceutical's R&D took place during the 1990s and the first decade of the 21st Century. Though our sample is restricted to the largest firms in the economy, these firms account for approximately two-thirds of total R&D spending in the economy.[5] Five out of the ten largest

[4]The number of drugs prescribed per person increased from 2.4 in 2000 to 2.6 in 2015.

[5]In 2019, U.S. publicly listed firms in Compustat collectively accounted for $444.4 billion of R&D spending compared to $669.1 billion total R&D spending in NIPA.

R&D spenders in Compustat in 2010 were pharmaceutical firms.[6]

3 Pharmaceutical Drug Portfolios and R&D

We next document that an increased share of pharmaceutical R&D spending is geared towards developing drugs for older patients. To do so, we use detailed project-level data linked to therapeutic areas. This analysis is enabled by the Cortellis Investigational Drugs data, which includes information on the drug development histories of over 50,000 drugs (as of 2015). That information includes the development, milestones, clinical trial dates, and therapeutic indications. Two data matching steps allow us to link Cortellis drug candidates to Clinical Classification Codes (CCC) in the MEPS data. First, we map Cortellis indication codes to the International Classification of Diseases Ninth Edition codes (ICD9).[7] Next, we use the MEPS mapping between ICD9 codes and CCC.[8]

Armed with this map from drug-indication to CCC, we classify drug development activity by age buckets. We categorize each drug-indication that enters development by its corrosponding CCC's expense share in each age bucket. Recall that a given drug-CCC is classified as "elderly" if its CCC group's elderly expense share in MEPS is larger than the elderly population share. Figure 4 shows that throughout the 1995-2013 period "elderly drugs" represent more than half of the overall new drug development entry for preclinical projects. The flow of new elderly drug projects is also less volatile than other drugs—steadily rising throughout the period.

[6]The five pharmaceutical firms are Merck, Roche, Pfizer, Novartis and GlaxoSmithKline. In 2010 Merck had the highest R&D expenditures among all U.S. publicly listed firms in Compustat ($11.4 billion in 2012 dollars)

[7]We are grateful to Manuel Hermosilla, who worked with a medical billing professional to generate this data crosswalk.

[8]This data is available through the MEPS Github repository (https://github.com/HHS-AHRQ/MEPS). We matched the three digit ICD9 code from Cortellis to the first three digits of MEPS's five-digit ICD9 code. When an ICD9 code matched with multiple CCC codes, we randomly selected a single CCC code ensure a 1-to-1 mapping between ICD9 and CCC.

For each of the firms in Cortellis, we calculate the share of their drugs that target patients in the 45+ and the 65+ age groups, respectively. Next we match these age-cohort shares of drugs in development to Compustat by firm and year. This match gives us a measure of R&D share by age bucket, firm and year. We assume that the cost of drug development is similar across age cohorts and hence assign R&D expenses to age cohorts based on their total share in drug development.[9]

Panels A and B of Figure 5 plot the share of total pharmaceutical R&D attributed to the development of drugs for patients in the 45-64 and 65+ age groups, respectively. Over this time period, Panels A and B show that the R&D share increased by 10 to 15 percentage points in both age groups. Taken together, the development and age-specific expenditure trends suggest that the focus of both R&D investment and sales has shifted toward older patients over time.

4 Discussion and Conclusion

So far, we have shown that a significant share of intangible investment, specifically R&D expenditure, is geared towards treating medical conditions afflicting the elderly. To the extent that these seniors remain out of the labor force, their increased quality of life and life expectancy will not directly increase labor supply and output (via a supply mechanism). Hence, output metrics may not benefit from this type of R&D investment. Indirect mechanisms, however, could compensate. For example, if pharmaceutical R&D leads to longer or more productive working lives, output and even productivity may benefit from retaining the human capital of older workers (Fernald et al., 2017). Further research is needed to understand whether focusing innovation on older patients increases productive human capital or has

[9] To verify that this assumption is reasonable, we examine whether variation in R&D spending per drug in development is systematically related to the share of firms' drug portfolios targeting different age groups. Point estimates suggest that, if anything, firms developing drugs for older patients have higher R&D costs per drug candidate, though the differences are not always statistically significant.

other indirect benefits.

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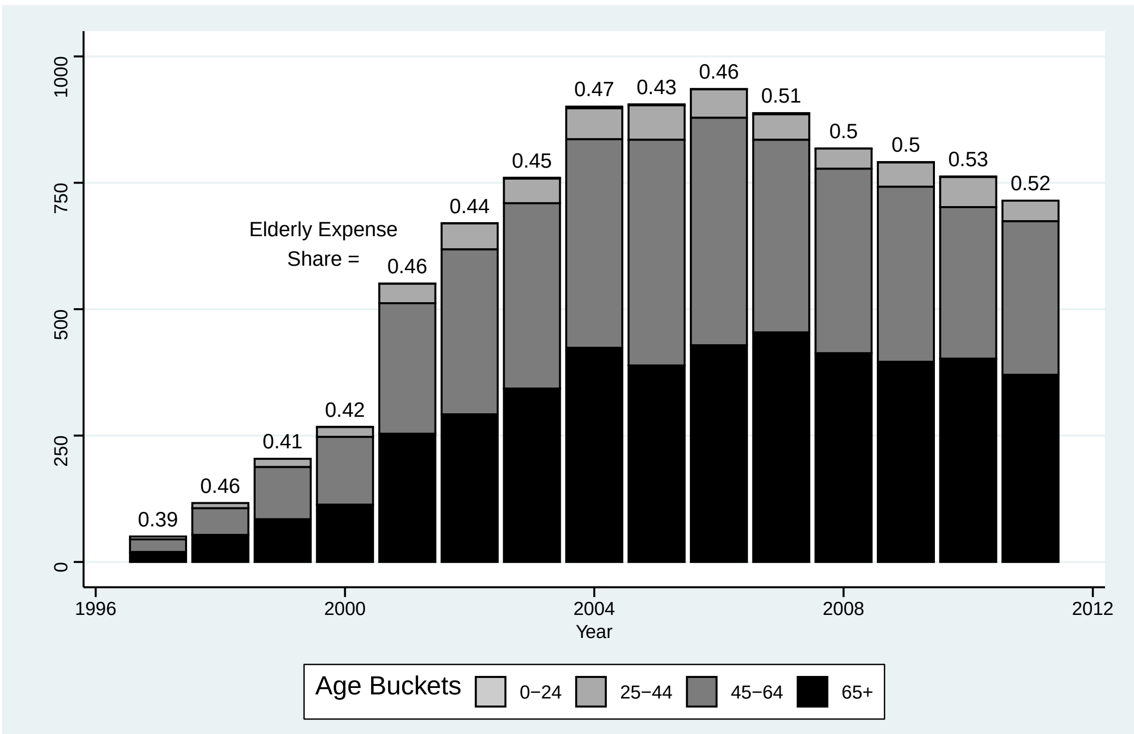
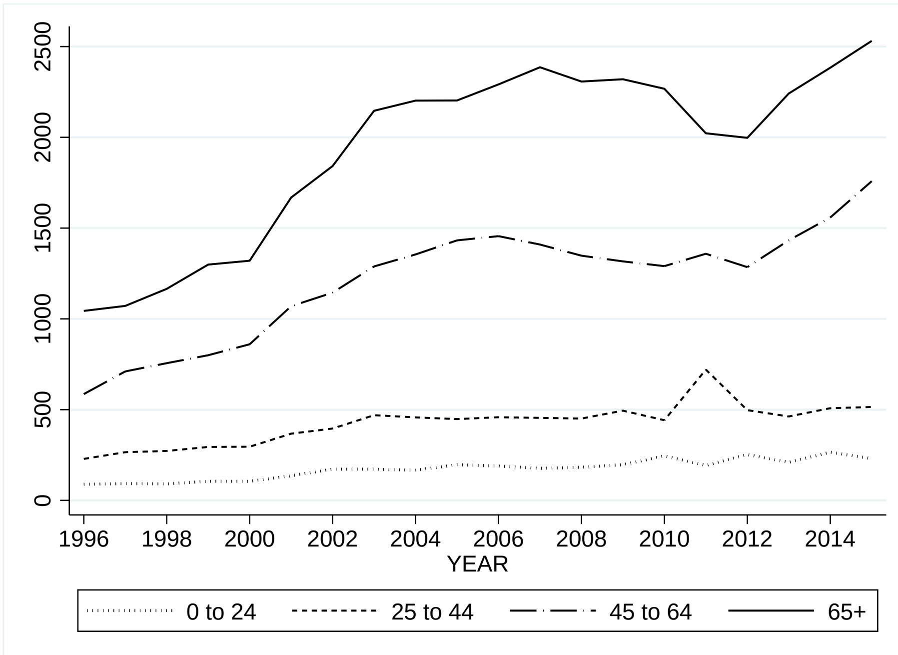
Figure 1: Lipitor expenditures over time



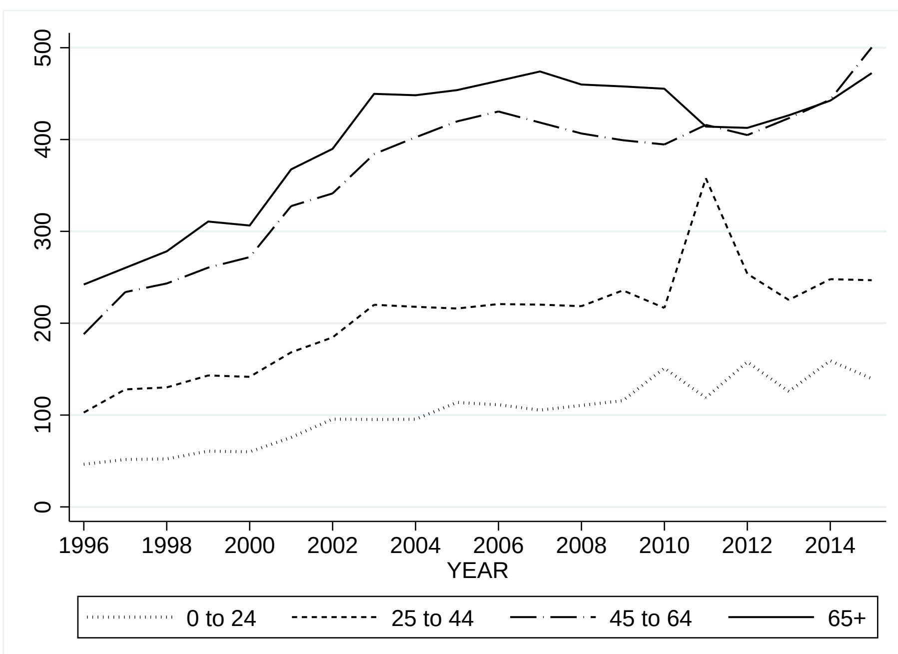
Note: The figure shows MEPS survey inflation adjusted expenditure on Lipitor over time for three different age buckets. Source: MEPS.

Figure 2: Per Capita Drug Cost by Age Buckets (in billion 2015 dollars)

Panel A. Expenditures per capita

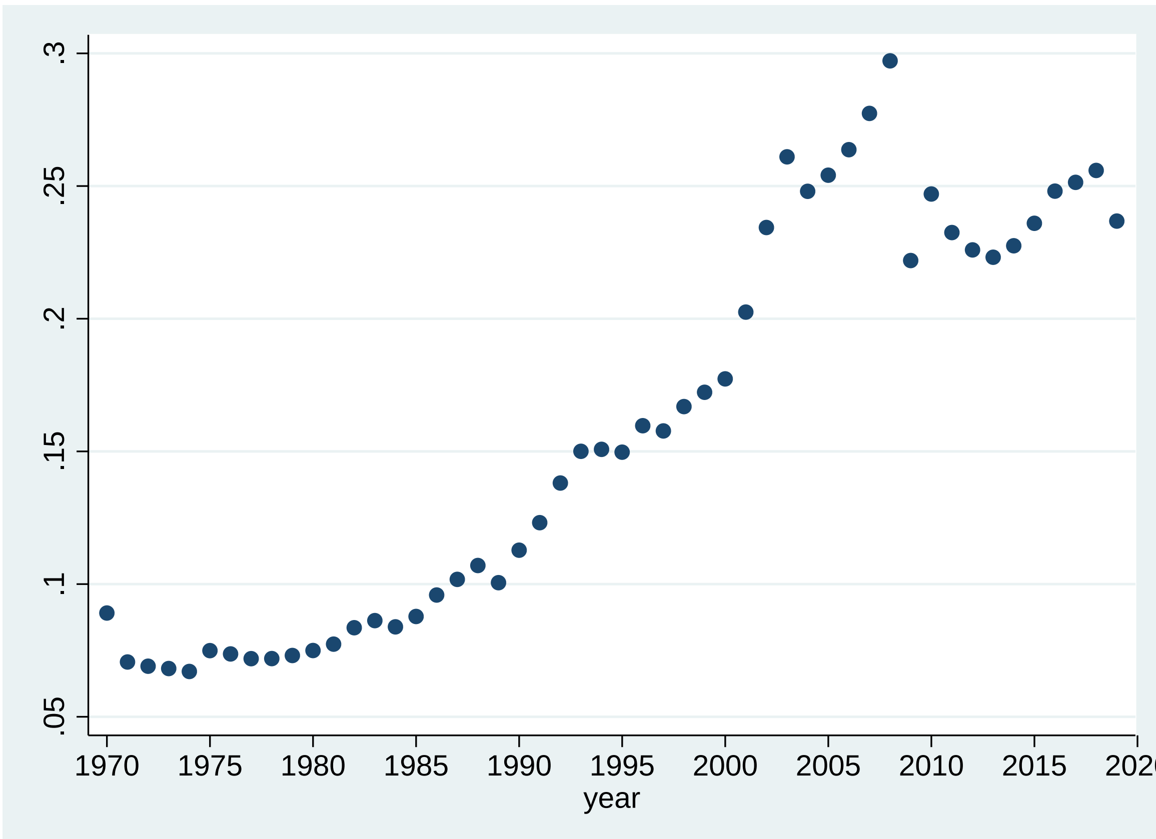


Panel B. Expenditures per drug



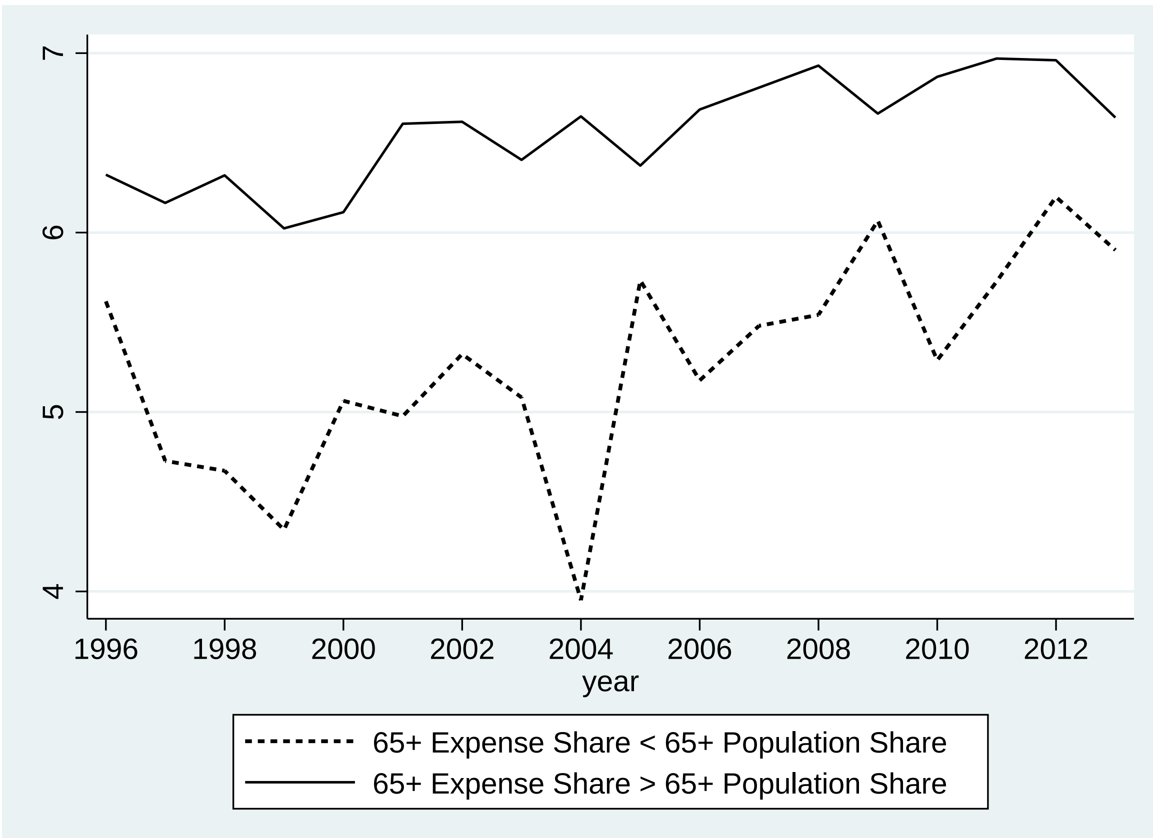
Note: The figure shows prescription drug inflation-adjusted expenditure per capita (Panel A) and per drug (Panel B) over time for four different age buckets. Source: MEPS.

Figure 3: Pharmaceutical R&D as a fraction of Total R&D, 1970-2018



Notes: This figure displays the fraction of R&D expenditures of Compustat's pharmaceutical companies to total R&D expenditures by all Compustat firms from 1970 until 2018. Source: Compustat.

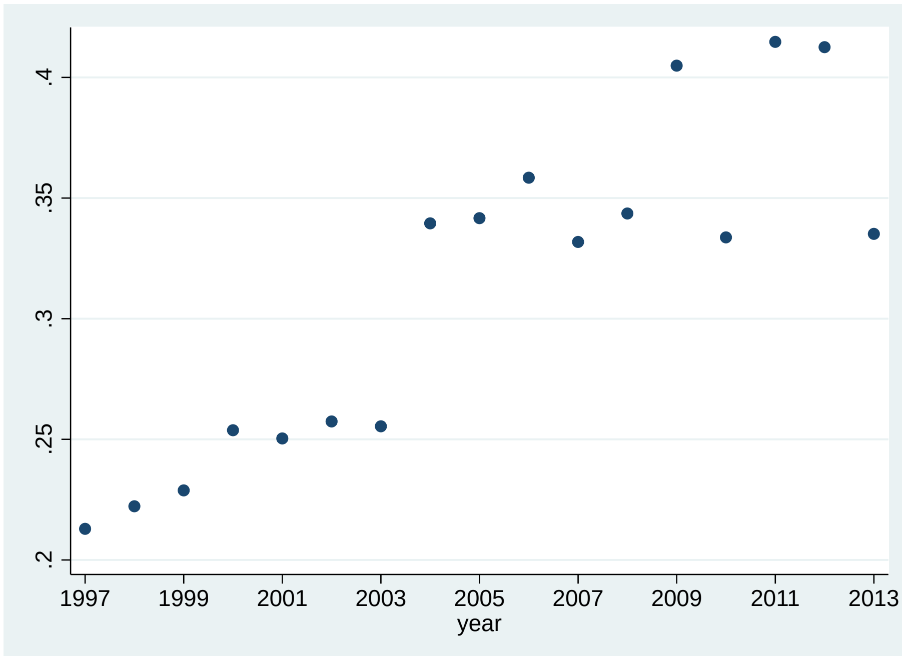
Figure 4: Drug Innovation: Flow of Drugs into Development



Notes: This graph shows the flow of new preclinical drug projects (in logs) into development. Elderly Expense Share is the percentage of a given Clinical Classification Code (CCC) expenditure spent by individuals in the 65+ age bucket. A given CCC is defined as an "Elderly Drug" if the Elderly Expense Share is larger than Elderly Population Share, and "Non-Elderly" otherwise. Source: MEPS and Cortellis.

Figure 5: R&D Expenses weighted by Drug Development Age Bucket

Panel A. Share of 45-64 age group



Panel B. Share of 65+ age group

Notes: This figure displays R&D expenditures of Compustat's pharmaceutical companies that is attributed to drug developments for individuals aged 45 to 64 (Panel A) and 65 or older (Panel B) from 1997 until 2013. Source: MEPS Cortellis and Compustat.