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THE EFFECT OF U.S. HEALTH INSURANCE EXPANSIONS ON MEDICAL INNOVATION

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ABSTRACT

I study the channels through which health insurance influences medical innovation. Following Medicare and Medicaid's passage, I find that U.S.-based medical-equipment patenting rose by 40 to 50 percent relative to both other U.S. patenting and foreign medical-equipment patenting. Within the United States, increases in medical-equipment patenting were most dramatic in states where the Great Society insurance expansions were largest and in which there were large baseline numbers of physicians per resident. Consistent with historical case studies, Medical innovation's determinants extend beyond the potential revenues associated with global market size; a physician driven process of innovation-while-doing appears to play a central role. An extrapolation of the evidence suggests that the last half century's U.S. insurance expansions have driven 25 percent of recent global medical-equipment innovation. In a standard decomposition of health spending growth, this insurance-induced innovation accounts for 15 percent of the long run rise in U.S. health spending in hospitals, physicians' offices, and other clinical settings.

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"It is naturally to be expected, therefore, that some one or other of those who are employed in each particular branch of labour should soon find out easier and readier methods of performing their own particular work, whenever the nature of it admits of such improvement."

-Adam Smith (1776)

"Learning is the product of experience. Learning can only take place through the attempt to solve a problem and therefore only takes place during activity."

-Kenneth Arrow (1962)

The advance of medical technology underlies both the costs (Newhouse, 1992; Chandra and Skinner, 2012) and benefits (Cutler and McClellan, 2001; Cutler, Rosen, and Vijan, 2006; Murphy and Topel, 2003) of modern medicine. The economics literature says little, however, about the processes through which these advances occur. Research on medical equipment and devices speaks more directly to the causes of diffusion across providers than to the sources of development.[1] Studies of medical innovation's causes have focused primarily on pharmaceuticals.[2]

The development of medical equipment is conceptually quite distinct from the development of pharmaceuticals. Pharmaceuticals are associated with the labors of large enterprises attuned to global markets. By contrast, much medical-equipment innovation

[1]Several recent papers address the responsiveness of technology adoption to the incentives created by insurance arrangement (Acemoglu and Finkelstein, 2008; Clemens and Gottlieb, Forthcoming; Freedman, Lin, and Simon, 2012). Baicker and Goldman (2011) provide an overview of equally relevant research on the demand side effects of insurance, which includes notable papers by Manning et al. (1987), Finkelstein et al. (2012), and Finkelstein (2007).

[2]In the tradition of directed technical change (Acemoglu, 1998), several interesting sources of variation in potential market size have been linked to research and development efforts in the context of pharmaceuticals. These sources include inoculation policy (Finkelstein, 2004), shifts in population demographics (Acemoglu and Linn, 2004), variation in willingness to pay (De Mouzon, Dubois, Scott Morton, and Seabright, 2011), the introduction of Medicare Part D (Blume-Kohout and Sood, 2008), and variation in effective patent life driven by the difficulty of establishing a treatment's efficacy (Budish, Roin, and Williams, 2013). In the environmental context, several studies have linked increases in energy prices to quickened development of energy-saving innovations (Jaffe, Trajtenberg, and Romer, 2005; Popp, 2002; Aghion, Dechezleprêtre, Hemous, Martin, and Van Reenen, 2012).

has local foundations. While patients self administer most medications, medical equipment must integrate into procedures performed by practitioners. Historical case studies find that these practitioners are essential to the innovative process (Roberts, 1988).

In Section 2 I model the empirically relevant content of medical innovation's distinguishing characteristics. The model first emphasizes that capitalizing on innovation requires clearing regulatory barriers and integrating into existing styles of medical practice. These hurdles point to a role for national markets; familiarity with regulators and physicians' practice norms improves an innovator's odds of successfully integrating into a market. Second, I emphasize the importance of local patient demand. In the spirit of Arrow (1962), the productivity of innovative effort depends on physicians' experience working with technologies at the existing frontier. This *innovating-while-doing* phenomenon links innovation to local flows of comprehensively insured patients. All factors considered, the model shows how insurance arrangements may influence innovation through global, national, and relatively local channels.

I investigate medical innovation's determinants by estimating the effect of the Great Society health programs on patenting activity. I first find that, following Medicare and Medicaid's introduction, U.S.-based medical-equipment patenting increased by 40 to 50 percent more than both other U.S. patenting and foreign medical-equipment patenting (see Section 4). The occurrence of such a large, differential increase in patenting activity implies central roles for medical innovation's national and local determinants. This core result is robust to a range of methods for controlling for more general, U.S.-specific trends towards health-sector innovation.[3]

[3]In addition to standard robustness exercises, this includes confirmation of Acemoglu, Cutler, Finkelstein, and Linn's (2006) finding that Medicare and Medicaid had no effect on pharmaceutical innovation. Medicare and Medicaid's coverage of pharmaceuticals was limited in these programs' early years, allowing estimates of their effect on pharmaceutical patenting to function as placebo test. Ordinary least squares regression models, count models, and a synthetic control framework (Abadie and Gardeazabal, 2003; Abadie and Hainmueller, 2010) deliver consistent results.

I assess the relevance of relatively local factors by analyzing variation in the increases in medical innovation that occurred within the United States. The evidence points to an important role for innovation-while-doing. I find that expansions in U.S. medical-equipment patenting were largest where there were large baseline numbers of physicians per capita and large Medicare- and Medicaid-induced insurance expansions (see Section 5). Furthermore, these local factors most strongly predict increases in patents for which innovation-while-doing is most plausibly relevant. This most prominently includes patents associated with surgery, a vocation in which mastery is tightly linked to experience (Chandra and Staiger, 2007). Local factors do not predict shifts towards patenting in diagnostic imaging equipment, which is more closely linked to the efforts of large-scale manufacturers.[4]

The paper's remaining analysis considers the influence of U.S. insurance expansions on long-run trends in innovation and health expenditures. By quantifying local and national mechanisms through which insurance expansions operate, the analysis can place a lower bound on the total effect of insurance expansions on medical innovation.[5] The distance between the estimated bound and the total impact depends primarily on the extent to which foreign innovators responded to the markets created by Medicare and Medicaid. The evolution of health-sector patenting across sub-groups of foreign countries provides suggestive evidence on the importance of foreign-innovator responses. I find that the spread between the growth of U.S.-based medical-equipment patenting and foreign medical-equipment patenting becomes increasingly large as I restrict the sample of foreign countries to those more culturally removed from the United States. Health-sector patenting in non-European, non-English speaking countries may provide

[4]I thank Loren Baker for suggesting this division of the data.

[5]Movement of physicians across countries could shift the bound in the opposite direction; if relevant, the observed expansion in U.S.-based medical innovation would capture substitution across space in addition to any aggregate increase. This seems unlikely, however, on the horizon over which the observed effects unfold.

the most reasonable counterfactual for estimating the total effect of U.S. insurance expansions. Extrapolating to more recent years, I estimate that U.S. insurance expansions increased U.S.-based medical-equipment patenting by around 50 percent. This increase accounts for 25 percent of recent global medical-equipment innovation.

Accounting decompositions of health spending typically attribute two-thirds of long run growth to the development of new technologies (Newhouse, 1992; Chandra and Skinner, 2012). I conclude by using my estimates to decompose technology's contribution into an insurance-induced component and a counterfactual component. Weisbrod (1991) emphasizes that insurance can create incentives for innovation focused primarily on either quality enhancement (without regard for cost) or on cost reduction (at a given level of quality). The predominance of fee-for-service reimbursements over the time period under study makes insurance-induced innovation a potentially important driver of rising costs. I estimate that the effect of U.S. insurance arrangements on medical innovation accounts for around 15 percent of the rise in U.S. spending in hospitals, physicians' offices and other clinical settings over the last half century.

1 U.S. Insurance Expansions and the Markets for Medical Technologies

This section characterizes the effect of the mid-to-late 20th century rise of U.S. health insurance on consumer exposure to out-of-pocket costs. With the insurance of this era primarily involving cost-plus, fee-for-service reimbursement for providers, these expansions can be viewed as unambiguous increases in the ranks of comprehensively insured patients and in the size of U.S. markets for new health care technologies. As emphasized in the following section, it is particularly relevant that U.S. physicians are well reimbursed for engaging with treatments at the technological frontier.

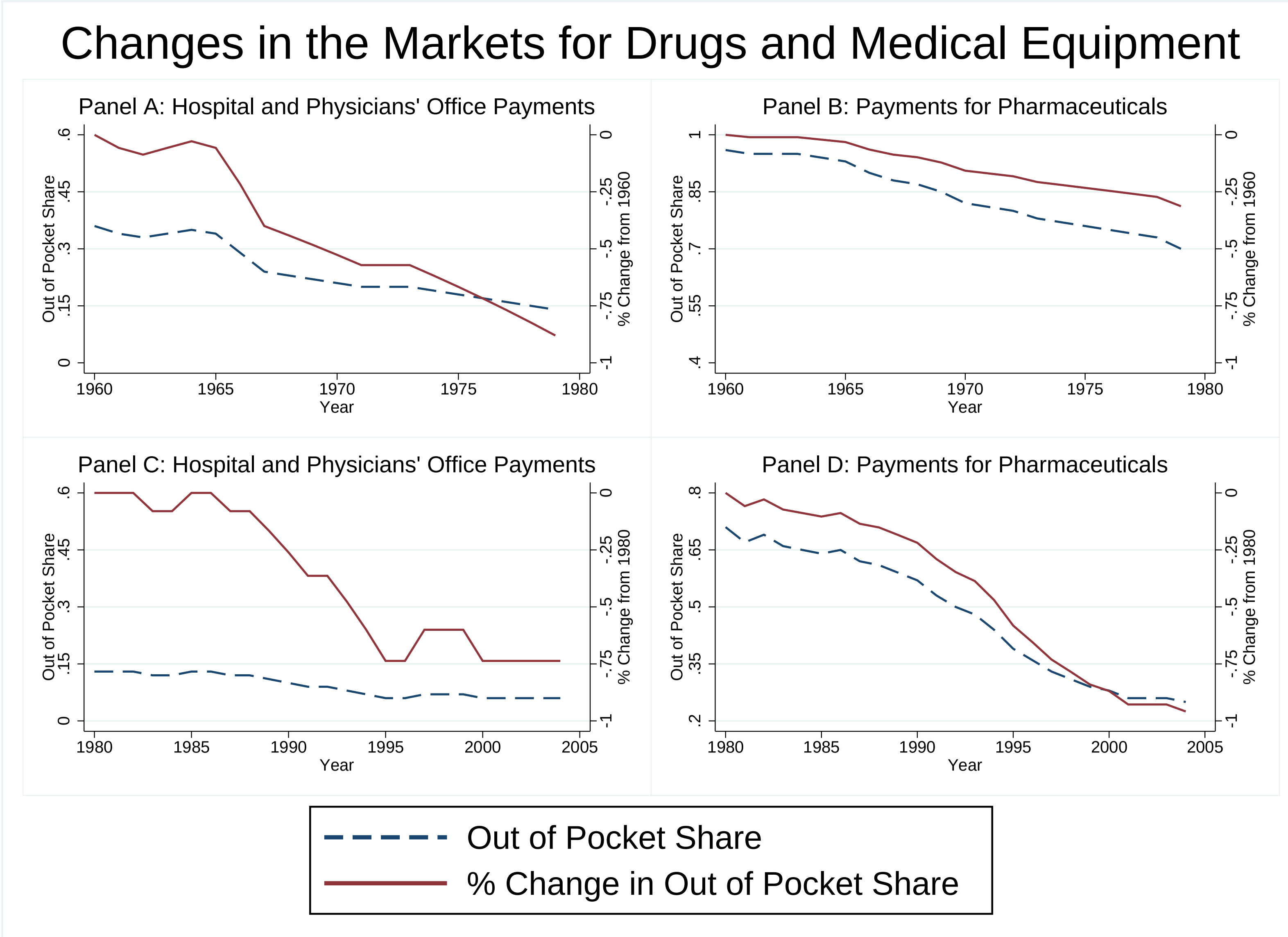

Figure 1: **Declines in Exposure to Out of Pocket Medical Costs:** All series were constructed by the author using the historical National Health Expenditure data reported by the Center for Medicare and Medicaid Services (CMS). Percent changes are calculated as $\frac{\text{Current Year - Base Year}}{(\text{Current Year + Base Year})/2}$, with 1960 serving as the base year in Panels A and B and 1980 serving as the base year in Panels C and D.

In parallel with the later empirical analysis, I consider consumer exposure to the costs associated with hospitals and physicians' offices separately from their exposure to the cost of prescription drugs. Panel A of Figure 1 shows the fraction of spending at hospitals and physicians' offices that consumers paid out of pocket from 1960 to 1980.[6] It also reports the percentage change in this share from 1960 to each of the subsequent years. The implementation of Medicare and Medicaid resulted in a large, nearly immediate decline in this share, by 40 percent, from 1965 to 1967. By 1970 it had declined by more than 50 percent. Declines continued over subsequent years, approaching 90 percent by 1980, in part reflecting the expansion of Medicaid to the disabled and to those on Supplemental Security Income in 1972.

Panel B reports series similar to those in Panel A, but for consumer exposure to the cost of prescription drugs. The percent change in the out-of-pocket share for prescription drugs is much smaller than it was for spending at hospitals and in physicians' offices. The change approaches a 25 percent reduction by 1980, with a reduction of less than 15 percent from 1960 to 1970. By as late as 1980, consumers remained exposed to an average of 70 percent of the cost of their prescription drugs.

Panels C and D report the same series as Panels A and B, but for the period extending from 1980 to 2005. This period saw substantial declines, in percent terms, in exposure to the cost of health spending in both of the relevant environments. The out-of-pocket share for spending in hospitals and physicians' offices declined from an already low base of 15 cents on the dollar to roughly 5 cents on the dollar. For prescription drugs, the out-of-pocket share declined from around 70 cents on the dollar to 25 cents on the dollar, with the most dramatic movement taking place during the early 1990s.

[6]This section's figures were constructed using data on total and out-of-pocket health spending from the National Health Expenditure accounts reported by the Centers for Medicare and Medicaid Services (CMS).

2 Implications of Market Size and Innovation-While-Doing for Medical Innovation

2.1 What We Know About Medical Innovation

This section presents a model of medical innovation that both motivates and is explored by the later empirical analysis. The model draws on an existing literature on the innovative process in the medical-equipment sector. Highlighting crucial distinctions between medical-equipment and pharmaceutical innovation, Roberts (1988) summarizes the relevant literature as follows:

> [My] personal experience, supported by the few relevant studies on innovation, indicates that... innovation in medical devices is usually based on engineering problem solving by individuals or small firms, is often incremental rather than radical, seldom depends on the results of long-term research in the basic sciences, and generally does not reflect the recent generation of fundamental new knowledge. It is a very different endeavor from drug innovation, indeed.

The research referenced by Roberts includes several studies by Shaw (1985, 1986, 1991). In a sample of 34 medical-equipment innovations, Shaw finds that just over half (18) stemmed from physician-produced prototypes while an additional third (11) involved direct transfer of an initial idea from a physician to a manufacturer.[7] Shaw (1986) further reports that two-thirds of these innovations were ultimately developed through a process of "multiple and continuous user-manufacturer interaction." The extensiveness of local insurance coverage, which determines physicians' incentives to work at

[7]In these studies, physicians were thus at minimum responsible for idea generation in more than 80 percent of the innovations.

the frontier of existing technologies, thus exerts significant influence over the innovative process.

Von Hippel (1976) finds a similar phenomenon of "user dominated innovation" in studies of innovation in scientific instruments. His analysis considered major innovations in Gas Chromatography, Nuclear Magnetic Resonance Spectrometry, Ultraviolet Spectrophotometry, and Transmission Electron Microscopes. Across these areas, Von Hippel (1976) finds that 80 percent of major innovations were due predominantly to the efforts of practitioners rather than manufacturers.[8] For present purposes, innovation in scientific instruments speaks most directly to innovation in diagnostic imaging equipment. While the presence of patients is less central here than in the context of surgical equipment, national market factors remain quite relevant.

2.2 A Model of Innovation by Entrepreneurial Physicians

Suppose that devotion of effort towards innovation involves a binary choice on the part of physicians. They differ in terms of a physician-specific cost of engaging in such effort, c_i, distributed according to pdf $g(c)$ with full support on the interval $[\underline{c}, \bar{c}]$. The benefit of attempting to innovate depends on the size of the markets new innovations can reach and on their probability of successfully reaching them. Market size is driven by the number of comprehensively insured patients, D, and by the potential revenues associated with each patient, R.

The probability of successful innovation has two components. First, the physician must have a potentially patentable idea. To capture the importance of "innovation while doing," the arrival rate for patentable ideas, θ, is an increasing, concave, differentiable

[8]Recent case studies of "radical innovation projects" in medical equipment technology by Lettl, Herstatt, and Gemuenden (2006) find a similar pattern of practitioner dominance. Other recent studies in the relevant literature include Chatterji, Fabrizio, Mitchell, and Schulman (2008) and Chatterji and Fabrizio (2011).

function of the number of well-insured patients per physician, $\frac{D_s}{N_s}$, where N is the number of physicians and the subscript s is associated with a particular state (or other geographic region).[9] Second, after an idea arrives it must be successfully brought to market. This process faces multiple hurdles, including country-specific regulators like the FDA and the need for the idea to successfully integrate into physicians' practice styles. These issues point to potential differences in the probability that innovations by U.S.-based and foreign physicians will successfully reach U.S. markets. I describe these probabilities as $\lambda^{US,US}$ and $\lambda^{F,US}$, with $\lambda^{US,US} > \lambda^{F,US}$ indicating that U.S.-based innovators have a higher probability of successfully tapping U.S. markets than do foreign innovators.

Bringing the above factors together, the expected benefit of innovation to a U.S.-based physician in state s is $\theta(\frac{D_s}{N_s})W$, where $W = \lambda^{US,US} D^{US} R^{US} + \lambda^{US,F} D^F R^F$. Physician i attempts innovation if $c_i < c^* = \theta(\frac{D_s}{N_s})W$, which is true for fraction $p = \int_{\underline{c}}^{c^*} g(c)dc$ of physicians. Expected innovation in state s, normalized into per capita terms, is thus:

$$I_s = \frac{p_s N_s \theta(\frac{D_s}{N_s})}{\text{Pop.}_s}. \tag{1}$$

This paper is primarily concerned with the effect of U.S. insurance expansions on the course of medical innovation. A U.S. insurance expansion can be described by a differential change in D^{US} of which fraction ρ_s occurs in state s. The effect of the insurance expansion on expected innovation in state s is:

$$\frac{dI_s}{dD^{US}} = \underbrace{\frac{dp_s}{dD^{US}} \frac{N_s}{\text{Pop.}_s} \theta(\frac{D_s}{N_s})}_{\text{New Entry Into Innovation}} + \underbrace{p_s \frac{N_s}{\text{Pop.}_s} \theta'(\frac{D_s}{N_s}) \frac{\rho_s}{N_s}}_{\text{Change in Incumbent Productivity}}, \tag{2}$$

[9] Regarding the concavity of the innovation-while-doing curve, Arrow (1962) writes "A second generalization that can be gleaned from many of the classic learning experiments is that learning associated with repetition of essentially the same problem is subject to sharply diminishing returns." The relevance of patient flows creates a conceptual link between this paper's emphasis on innovation-while-doing and Malani and Philipson's (2011) analysis of the availability of participants in clinical trials.

where $\frac{dp_s}{dD^{US}} = g[\theta(\frac{D_s}{N_s})\lambda^{US,US}R^{US} + \theta'(\frac{D_s}{N_s})\frac{\rho_s}{N_s}W]$.[10] The change in innovation can be written more completely as:

$$\frac{dI_s}{dD^{US}} = \underbrace{g\lambda^{US,US}R^{US}\frac{N_s}{\text{Pop.}_s}\theta^2}_{\text{Market Size Effect}} + \underbrace{\frac{g\theta'\rho_s\, W\theta}{\text{Pop.}_s} + \frac{p_s\theta'\rho_s}{\text{Pop.}_s}}_{\text{Innovation-While-Doing Effect}}. \tag{3}$$

The first term of the above expression can be characterized as a pure market-size effect; higher potential revenues induce more entry into innovation. The latter two terms reflect changes associated with innovation-while-doing. The first of these captures the portion of entry into innovation that is driven by the rise in productivity associated with the increase in the number of well-insured patients per physician. The second piece captures a rise in the productivity of incumbent physician innovators.

To compare changes in the United States to those abroad, note first that $\rho_s = 0$ for foreign physicians. For ease of comparison, momentarily consider a U.S. state and foreign country for which baseline N_s, population, $\theta(\frac{D_s}{N_s})$, and the local value of the density, g, are the same. This simplifies the differential effect of a U.S. insurance expansion on innovation in U.S. state s relative to the foreign country f to:

$$\Delta_{s,f} = \underbrace{[\lambda^{US,US} - \lambda^{F,US}]gR^{US}\frac{N_s}{\text{Pop.}_s}\theta^2}_{\text{Differential Market Size Effect}} + \underbrace{\frac{g\theta'\rho_s\, W\theta}{\text{Pop.}_s} + \frac{p_s\theta'\rho_s}{\text{Pop.}_s}}_{\text{Innovation-While-Doing Effect}}. \tag{4}$$

The differential has two components. First, it includes a differential market-size effect driven by differences in the probability of successfully reaching U.S. markets (the λ terms). Second, the differential includes the entire innovation-while-doing effect. Section 4 presents estimates of this differential effect of U.S. insurance expansions on U.S. medical innovation relative to foreign medical innovation.

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[10]The analysis implicitly takes place within a short-to-medium run over which the supply of physicians, N, is fixed.

The model also has implications for variation in the size of the effect of U.S. insurance expansions on innovation across regions of the United States. Looking back to equation (3), there are two comparative statics of interest. First, changes in medical-equipment innovation are unambiguously increasing in the extent to which an insurance expansion affects coverage in each state: $\frac{d^2 I_s}{dD^{US} d\rho_s} > 0$. The local impact of the insurance expansion, ρ_s, matters exclusively through the innovation-while-doing effect. This factor should be particularly important for innovation associated with surgery, where experience is tightly linked with mastery of the relevant devices and techniques (Chandra and Staiger, 2007). It should be of limited importance for the development of new diagnostic imaging equipment, which is more closely tied to the efforts of large-scale manufacturers.

Second, shifts in innovation are likely, though not necessarily, increasing in the number of physicians per capita, $\frac{N_s}{\text{Pop}_{\cdot s}}$. Note first that physicians per capita enters directly into the market size effect. This reflects the fact that a given increase in the fraction of physicians attempting innovation, $\frac{dp}{dD^{US}}$ from equation (2), results in a larger increase in per capita innovation when there is a larger base of physicians. The innovation-while-doing curve creates an additional force pointing towards a positive cross-partial with respect to the baseline number of physicians per capita. More specifically, a low baseline number of patients per physician places the state on a steeper portion of the innovation-while-doing curve.[11] Arrow's (1962) summary of existing evidence points to the learning curve's sharp concavity as one of its most notable characteristics.

[11]While the cross-partial is ultimately of indeterminate sign, the factors suggesting a positive cross-partial are likely to dominate. For example, the local value of the density, g, could be smaller, larger, or the same size in regions with high and low baseline numbers of physicians per capita. *A priori*, there are no obvious reasons why this and other relevant factors would work in the direction of a negative cross partial between baseline physicians per capita and increases in medical innovation.

3 A Framework for Estimating the Effects of Medicare and Medicaid's Origins on Medical Innovation

This section describes my empirical approach for using the origins of the Great Society health programs to estimate the effect of U.S. health insurance expansions on medical innovation. Exposition of the estimation framework is facilitated by first describing the data set used in the analysis.

3.1 The NBER Patent Database

The analysis utilizes the NBER Patent Database, which contains several relevant pieces of information on all patents granted by the U.S. Patent and Trademark Office (USPTO) from 1963 to 1999 (Hall, Jaffe, and Trajtenberg, 2001). The first relates to the classification of each patent to technological categories and sub-categories. The patents are grouped into 6 broad technological categories, of which category 3 encompasses most health-sector patents, and 36 technological sub-categories. The sub-categories are sufficiently narrow to allow health-sector patents to be divided into those related to prescription drugs and those related to the medical equipment underlying the practice of medicine in hospitals and independent outpatient settings.

Throughout the analysis, I group sub-categories 31 and 33, which contain Drug and Biotechnology patents respectively, to characterize patenting associated with pharmaceutical innovation. I group sub-categories 32, 39, and 44 to characterize patenting associated with innovation in medical equipment. Sub-category 32 contains all Surgical Equipment patents, including historic developments associated with arterial catheterization and stent technology (Fogarty, 1969; Palmaz, 1988; Wall, 1993). Sub-category 39 is a relatively small category of Miscellaneous Drugs & Medicine patents associated with dentistry, optometry, and prosthetic devices. Although sub-category 44, Nuclear

& X-rays, is not included in the broader Drugs and Medical technological category, it contains innovations involving magnetic resonance imaging (MRI) scanners, computed tomography (CT) scanners, and a variety of advances in X-ray technology (Damadian, 1974; Ledley, 1975).[12]

The NBER Patent Database also reports the location of each patent's primary filer. When the primary filer is located in the United States, the database reports his or her state of residence; when located abroad, it reports his or her country of residence. Table 1 presents summary statistics describing the patenting activity of U.S.- and foreign-based patenters as I group them for subsequent regression analysis. I have aggregated relatively small U.S. states on the basis of census regions, leaving a total of 32 geographic units in the United States.[13] The aggregation reduces the noise associated with proxying for the relative intensity of innovative effort on the basis of small samples of patents. It further allows me to construct a balanced panel of regions without losing data when taking logarithms or expressing the intensity of medical innovation relative to other innovation using shares.

The years referenced in Table 1 describe the year in which each patent was granted. The NBER Patent Database reports information on the application year for all patents starting with those granted in 1967. This is unfortunate because the application year clearly comes closer than the grant year to representing the time at which each innovation occurred. I use the later years of the database to estimate the average lag between filing years and grant years. This lag averages 2.3 years for health-sector patents and is

[12]It also includes relatively exotic cost drivers including a series of patents related to the systems of proton beam therapy discussed by Baicker and Chandra (2011).

[13]The aggregate of small Western states, for example, joins Alaska, Hawaii, Idaho, Montana, Nevada, New Mexico, and Wyoming, while leaving California, Colorado, Oregon, and Washington as distinct entities. In addition to four region-specific aggregates of small U.S. states, I have created two aggregates of relatively small foreign countries. These aggregates are not included in most specifications because I do not have reliable data for constructing a control for GDP per capita across these countries. Inclusion of these aggregates has essentially no effect on specifications that leave out this control variable.

Table 1: **Patent Distributions and Other Summary Statistics**

	(1) Foreign Countries	(2) US States
Fraction Med. Equipment	0.0245	0.0300
	(0.00856)	(0.0100)
Fraction Phamaceutical	0.0297	0.0137
	(0.00928)	(0.00926)
Fraction Chemicals	0.269	0.219
	(0.0645)	(0.112)
Fraction Computing And Electric	0.190	0.188
	(0.0496)	(0.0725)
Fraction Mechanical	0.272	0.261
	(0.0324)	(0.0612)
Fraction Other	0.214	0.288
	(0.0524)	(0.0624)
GDP Per Capita (10000s)	1.788	2.107
	(0.404)	(0.254)
Uninsured Elderly	NA	0.746
		(0.119)
Physicians Per 1000 Res. (1965)	NA	1.408
		(0.312)
Change in State Gov. Health Spending	NA	141.2
		(81.05)
Observations	6	32

Note: All patent shares were constructed by the author using the NBER Patent Database for years 1963 through 1979. Following the classification system described by Hall, Jaffe, and Trajtenberg (2001), medical patents include technological category 3 and sub-category 44. I decompose this into pharmaceutical patents, which include sub-categories 31 and 33 (Drugs and Biotechnology), and Medical Equipment patents, which include sub-categories 32, 39, and 44 (Surgical Equipment, Miscellaneous Drugs & Medical, and Nuclear & X-rays). Chemicals corresponds to technological category 1, Computing to category 2, Electronics to all sub-categories of category 4 but sub-category 44, Mechanical to category 5, and Other to technological category 6. GDP per capita comes from the Penn World Tables and regional accounts of the Bureau of Economic Analysis. Uninsured Elderly comes from Finkelstein (2007). Physicians per 1,000 state residents in 1965 comes from the 1967 Statistical Abstract of the United States. The change in state government health spending (taken from 1962 to 1972) comes from the Census of Governments. The 32 US state units include four regional aggregates, namely Small Western (MT, ID, WY, HI, AK, NV, and NM), Small Northeastern (ME, VT, NH, RI, DC, WV, and US territories), Small Central (ND, SD, KS, NE, UT), and Small Southern (AR, AL, MS, KY, and SC). The foreign countries are Canada, the UK, France, Switzerland, the Netherlands, and Japan.

relatively stable within the years covered by the database.[14] Significant impacts of Medicare and Medicaid on the patents appearing in the database would thus be expected no earlier than with those granted around 1968.

In most of the analysis presented below, I aggregate groups of years to further reduce the noise associated with observations based on small numbers of patents. Accounting for the lag between patent filing and granting, I typically treat the period running from 1963 to 1968 as the pre-Great Society period, with 1969 to 1974 describing the short- to medium-run post-Great Society period and 1975-1980 describing the post-Great Society long run.

3.2 Estimation Framework

In my initial analysis, the estimating equations take the following basic form:

$$\begin{aligned} \text{Health Share}_{s,t} = {} & \beta_1 \text{Post Great Society}_t \times \text{US State}_s \\ & + \beta_{2_s} \text{State}_s + \beta_{3_t} \text{Period}_t + X_{s,t}\gamma + \varepsilon_{s,t}, \end{aligned} \tag{5}$$

where US State_s is an indicator equal to one for all observations associated with U.S. states, $State_s$ is a state- or country-specific fixed effect, $Period_t$ is a time effect, and $X_{s,t}$ is a vector of time varying controls, typically including a measure of each area's per capita income. $Health\ Share_{s,t}$, the outcome of interest, is the fraction of all patents filed in state s during period t that are associated with a particular portion of the health sector. β_1 is an estimate of the differential change in this health-sector share in the U.S. states relative to foreign countries. All standard error estimates allow for arbitrary serial correlation across the errors associated with each geographic unit. The standard error estimates

[14] Popp, Juhl, and Johnson (2004) note that, more generally, the lag between patent filing and granting can vary substantially due, among other factors, to the volume of patents submitted to the USPTO at any given time.

change little, declining slightly, when I allow further for arbitrary correlation across the errors associated with each country at each point in time.[15] For inference purposes, the assumption that observations associated with different U.S. states are statistically independent thus proves to be innocuous.

It is known that, for several reasons, patent counts can be poor measures of differences in levels of innovative activity across time, sectors, and countries (Trajtenberg, 1990a). The number of patentable ideas generated by a given amount of research effort may, for example, may vary due to the number of innovations on the horizon of a sector's technological frontier or to sector-specific changes in patent law. The financial motivation for patenting any given innovation can also vary with the nature of a sector's technical frontier.[16] Such developments are accounted for by the inclusion of time effects since they apply with equal weight to foreign and domestic innovators. Also relevant is that there has been a secular increase in the share of total USPTO-granted patents that are filed by foreigners (see Panel A of Appendix Figure A.1).[17] Analysis of within-state and within-country patent shares eliminates this secular trend. Equation (5) is motivated by the fact that, in spite of these challenges, changes in the health-sector share of patents by U.S.-based innovators net of changes in the health-sector share of patents by foreign innovators can nonetheless capture relative changes in the direction of innovative activity.

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[15]The latter adjustment allows for correlation across the errors associated with the US states at each point in time. I implemented two-way clustering using Stata's "cluster2" command, which was developed for the analysis in Petersen (2009). The cluster2 command could only be implemented using an unweighted version of the baseline specification. The claim regarding the relative sizes of the standard errors associated with two- and one-way clustering holds whether the specifications are run using annual observations or observations aggregated in multi-year time periods.

[16]Moser (2011), for example, finds that patenting became relatively popular in the late 19th century chemicals industry when the publication of the periodic table made secrecy a poor means of restricting access to intellectual property.

[17]International patent filing has long been common practice, as highlighted elsewhere by Moser and Voena (2012) and (Moser, Bilir, and Talis, 2011). Patent-granting has had some degree of standardization across countries as far back as the signing of the Paris Convention in 1883.

I also estimate the effect of Medicare and Medicaid on patent counts using log-linear, poisson, and negative binomial count models. When estimating count models, the issues discussed in the previous paragraph are controlled for using a triple-difference methodology. The log-linear model of patent counts appears below:

$$\begin{aligned}\ln(\text{Patent Count})_{c,s,t} = {} & \gamma_1 \text{Post Great Society}_t \times \text{US State}_s \times \text{Medical Equipment}_c \\ & + \gamma_{2_{s,t}} \text{State}_s \times \text{Period}_t + \gamma_{3_{t,c}} \text{Period}_t \times \text{Category}_c \\ & + \gamma_{4_{s,c}} \text{State}_s \times \text{Category}_c + X_{s,t}\theta + \varepsilon_{c,s,t}. \end{aligned} \tag{6}$$

Patent $\text{Count}_{c,s,t}$ describes the number of patents granted in technological category c, in state s, during period t. The coefficient γ_1 is an estimate of the differential evolution of U.S. medical-equipment patenting relative to other U.S.-based patenting net of any changes in foreign medical-equipment patenting relative to other foreign patenting. I present results aggregating the patent categories into Medical Equipment and All Other patents. The analysis yields similar results when I aggregate more finely to the 36 technology sub-categories.

The origins of Medicare and Medicaid provide a compelling natural experiment in part because there was little impact on incentives for the invention of new pharmaceuticals. Consequently, they resulted in a substantial change in incentives for one type of health-sector innovation and not for another. I thus estimate equations (5) and (6) separately for medical equipment and pharmaceutical patents, using the estimated effect on pharmaceutical patenting as a falsification test. I also run specifications in which I include the pharmaceutical share as an element of the vector of control variables. This can be interpreted as a direct control for any state- or country-specific shifts in patenting towards the health sector broadly construed.

An issue that affects the interpretation of the estimates is the extent to which foreign innovators joined U.S. innovators in responding to changes in the size of U.S. health care markets. Some foreign response is surely expected, since innovations are marketable on a world-wide basis. β_1 captures the innovation-while-doing and differential market size effects characterized in equation (4) in section 2. It is, quite literally, an estimate of the differential change in health-sector patenting as a share of total patenting among residents of U.S. states relative to residents of foreign countries. I further consider the difference between Medicare and Medicaid's differential and total impacts in Section 7.

4 Effects of Medicare and Medicaid on Innovation in the United States Relative to Foreign Countries

Panels A and B of Figure 2 present the patent data underlying subsequent estimates of equation (5); the panels of Appendix Figure A.1 do the same for equation (6). The figure shows the evolution of medical-equipment and pharmaceutical patents as shares of total patents, plotting separate series for U.S.-based innovators and foreign innovators. Panel A shows that, during the early-to-mid 1960s, medical-equipment patents made up a modestly smaller share of total patents by U.S.-based innovators than of those by foreign innovators. While the foreign share is stable through the early 1970s, the U.S. share rises by around 1 percentage point (from a base of just over 2 percentage points) from 1966 to 1970, surpassing the foreign share for the first time in 1969. The U.S. share stabilizes at between 0.6 and 1.0 percentage point higher than the foreign share from 1970 through 1980. As noted previously, there is, on average, a 2.3 year lag between health-sector patent filing and granting during the years of the NBER patent database for which both of these pieces data are available. The late 1960s surge in U.S.-based medical equipment patenting thus occurs when one would expect an initial Medicare-and Medicaid-induced change in patenting activity to reveal itself in the data.[18] Panel A of Figure 3 shows that neither this basic pattern nor the magnitude of the relative shift in U.S. medical-equipment patenting are affected by re-weighting the foreign countries to more closely match the pre-Great Society level of the U.S. share. A more complete synthetic control analysis can be found in Appendix 2.

Panel B of Figure 2 shows the evolution of pharmaceutical patenting, for which incentives were not directly affected by Medicare and Medicaid. The pharmaceutical share of patents granted to U.S.-based and foreign innovators move similarly over most of the relevant time period. The surge in U.S.-based medical equipment patenting thus does not appear to have been associated with a more general increase in health-sector innovation in the United States. If anything, it appears that foreign patenters were faster than their U.S.-based counterparts to participate in the surge in pharmaceutical patenting that began during the late 1970s. Panel B of Figure 3 shows that, like the medical equipment result, this placebo result continues to hold when the synthetic control procedure is applied.

4.1 Difference-in-Differences Estimates of the Effect of Medicare and Medicaid on Medical-Equipment Patenting

Table 2 presents estimates of equation (5) in which observations are weighted according to each state or country's share of all USPTO-granted patents over the sample period. The results indicate an increase in U.S. medical-equipment patenting relative to foreign medical-equipment patenting (as shares of total patents) of roughly 1.1 percentage points over the medium run and 1.5 percentage points over the longer run. The standard errors,

[18] The timing is consistent with a delay of one to two years during which an initial wave of post-Medicare innovative efforts translate into patentable ideas, with an additional two to three years between patent filing and patent granting.

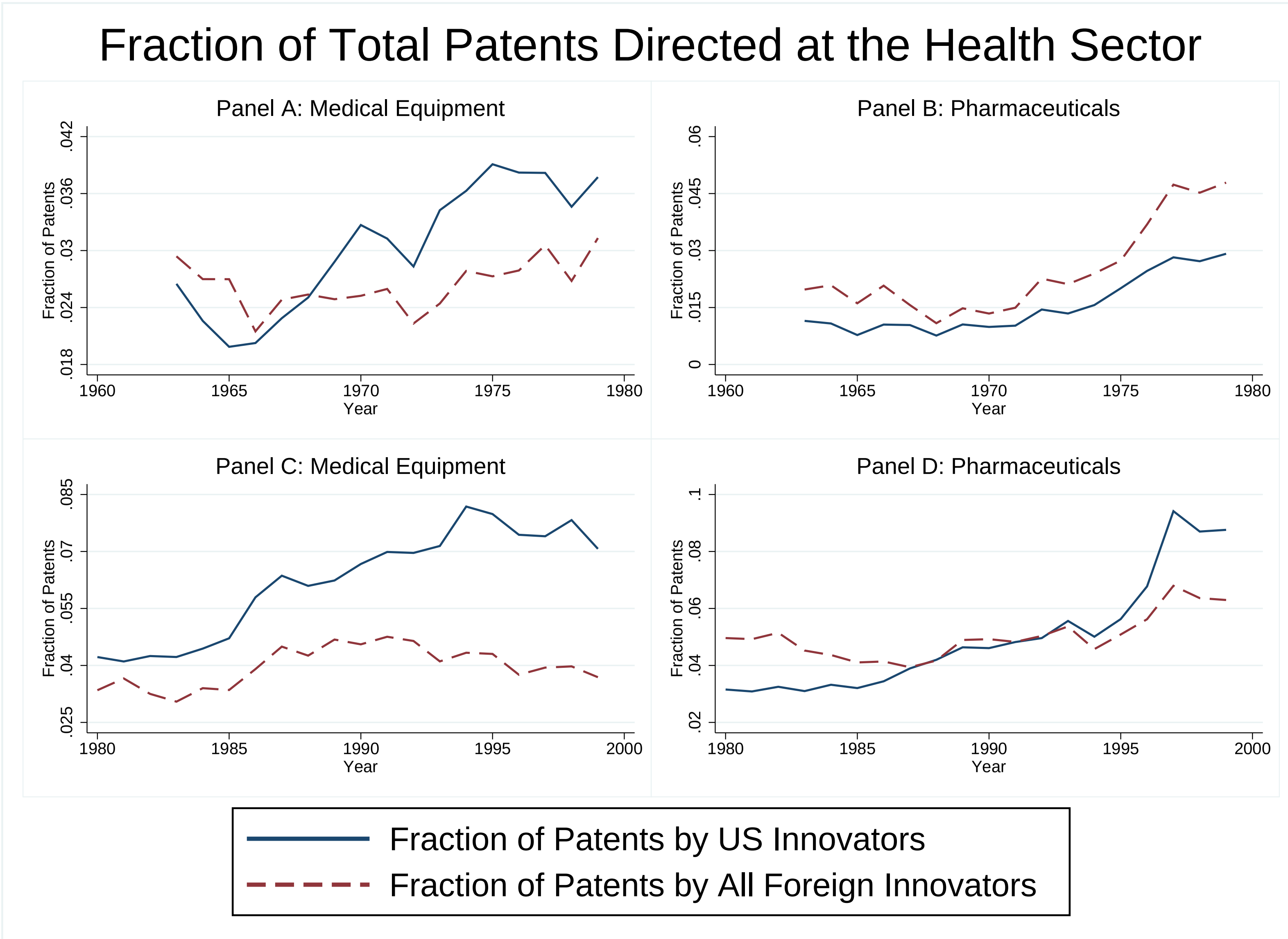

Figure 2: **Fraction of Patents Directed at the Health Sector (U.S. vs Foreign):** Series were constructed by the author using data from the NBER Patent Database (Hall, Jaffe, and Trajtenberg, 2001). A description of the system for classifying Medical Equipment and Pharmaceutical patents can be found in the note to Table 1. The years in the figure refer to the year in which each patent was granted. In later years of the patent database, grant years lag filing years by an average of 2.3 years for health-sector patents (roughly 2.0 years for patents more generally).

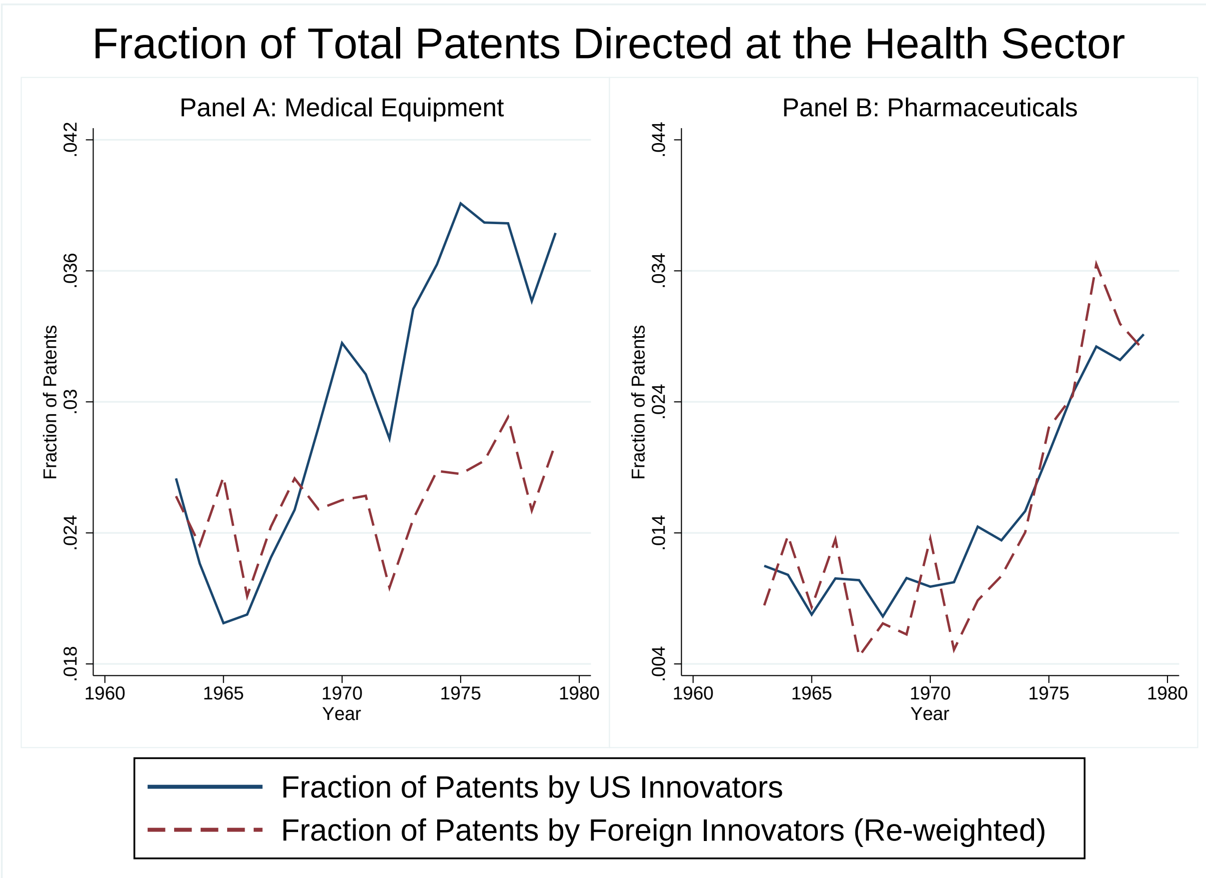

Figure 3: **Fraction of Patents Directed at Medical Equipment (U.S. vs Foreign):** Series were constructed by the author using data from the NBER Patent Database (Hall, Jaffe, and Trajtenberg, 2001). A description of the system for classifying Medical Equipment and Pharmaceutical patents can be found in the note to Table 1. The years in the figure refer to the year in which each patent was granted. In later years of the patent database, grant years lag filing years by an average of 2.3 years for health-sector patents (roughly 2.0 years for patents more generally). In Panel A, country-level aggregates of foreign patents have been re-weighted to more closely match the levels and changes in the U.S.'s pre-Medicare medical-equipment share of total patents using Abadie, Diamond, and Hainmueller's (2011) "synth" package. Panel B is similarly constructed, with pharmaceutical patent shares being the outcome of interest. Pharmaceutical patenting can be viewed as a placebo test because, with few exceptions, pharmaceuticals were not initially covered by Medicare.

which allow for arbitrary autocorrelation within each state or country over time, show these point estimates to be highly statistically distinguishable from 0. In unweighted versions of these specifications, the standard errors change little, decreasing marginally, when I further allow for arbitrary correlation patterns across the errors associated either with each year or with each country at a point in time.[19] The confidence interval for the estimate of the medium-run impact of Medicare and Medicaid on medical-equipment patenting ranges from 0.60 to 1.5 percentage points.

The result in column 2 shows column 1 to be robust to controlling for changes in each state or country's GDP per capita over time. GDP per capita enters positively, and at a level that, in this specification, is statistically distinguishable from 0. This result is consistent with a role for the forces emphasized by Hall and Jones (2007) and Jones (2011), who argue that demand for life-extending health innovations will rise faster than demand for innovations in other areas as income increases. Column 3 expresses the result from column 2 in log terms. The result implies that, controlling for changes in income per capita, the medical-equipment share of patents in the U.S. states rose by 40 to 50 percent more from the mid-1960s to the 1970s than did the medical-equipment share of patents by innovators in foreign countries.

The remaining columns of Table 2 provide evidence that the results discussed above are not driven by a more general shift in U.S. patenting towards the health sector. Column 4, which can be interpreted as a falsification test, shows that, relative to foreign patenting, the share of U.S. patents directed at pharmaceuticals did not change following Medicare's implementation. Over the longer run it appears that, if anything, the U.S. pharmaceutical share declined relative to the foreign pharmaceutical share, although the

[19]The latter adjustment involves allowing for correlation across the errors associated with the US states at each point in time. I implemented two-way clustering using Stata's "cluster2" command, which was developed for the analysis in Petersen (2009). I only compare the one- and two-way clustered standard errors for unweighted specifications because cluster2 does not allow for weights.

Table 2: **Change in Fraction of Patents Directed At Medical Equipment: Post Great Society**

	(1) Equip Share	(2) Equip Share	(3) Ln(Eq Share)	(4) Rx Share	(5) Equip Share	(6) Equip Net Rx
US State × 1968 to 1974	0.0106**	0.0114**	0.3812**	0.0029	0.0114**	0.0085**
	(0.0023)	(0.0017)	(0.0633)	(0.0028)	(0.0015)	(0.0030)
US State × 1975 to 1980	0.0152**	0.0164**	0.5473**	-0.0066	0.0165**	0.0230*
	(0.0021)	(0.0027)	(0.0746)	(0.0117)	(0.0031)	(0.0112)
GDP Per Capita (10000s)		0.0171*	0.2900	-0.0341	0.0176	0.0512
		(0.0082)	(0.2524)	(0.0308)	(0.0107)	(0.0303)
Fraction Pharmaceutical					0.0130	
					(0.1202)	
R^2	0.931	0.936	0.949	0.838	0.936	0.885
N	114	114	114	114	114	114
Number of Clusters	38	38	38	38	38	38
Weighted	Yes	Yes	Yes	Yes	Yes	Yes
Period FE	Yes	Yes	Yes	Yes	Yes	Yes
State And Country FE	Yes	Yes	Yes	Yes	Yes	Yes
Base Period	1963 to 1968	1963 to 1968	1963 to 1968	1963 to 1968	1963 to 1968	1963 to 1968

Note: **, *, and + indicate statistical significance at the 0.01, 0.05, and 0.10 levels respectively. The table reports coefficients from ordinary least squares estimates of equation (5). In columns 1, 2, and 5 the dependent variable is the fraction of total patents that are categorized as Medical Equipment patents. In column 3 the dependent variable is the natural logarithm of this fraction. In column 4 the dependent variable is the fraction of total patents that are categorized Pharmaceutical patents. Finally, in column 6 the dependent variable is the fraction of total patents that are categorized as Medical Equipment patents minus the fraction categorized as Pharmaceutical patents. A description of the classification system can be found in the note to Table 1. Relatively small U.S. states are grouped into regional aggregates as described in the note to Table 1, where readers can also find a list of the foreign countries included in the sample. Observations are weighted according to each state or country's average share of all patents in the database over the sample period. Standard errors, reported beneath each point estimate, allow for arbitrary autocorrelation across the errors associated with the observations for each U.S. state or foreign country. The standard errors in unweighted versions of these specifications change little, typically decreasing marginally, when I allow further for arbitrary correlation patterns across the errors associated with each year or associated with each country at a point in time. Data sources are described in the note to Table 1.

relevant coefficient is estimated with low precision. Column 5 shows that controlling directly for the pharmaceutical share has no impact on the baseline result. The pharmaceutical share enters positively, but its coefficient is not estimated precisely. In column 6 the dependent variable is expressed as the medical-equipment share net of the pharmaceutical share. The estimated effect of Medicare and Medicaid is, once again, statistically and economically indistinguishable from the baseline result in column 2. The point estimates are statistically significantly different from 0, but are less precisely estimate than the result from column 2.

4.2 Robustness within the Shares Estimation Framework

Results presented in Appendix Tables A.1 through A.4 further explore the robustness of the baseline estimates. Table A.1 shows that the results in Table 1 are robust to running each regression without weighting each state or country's observations for their contribution to the total count of patents during the sample period. Table A.2 shows the implications for various weighted and unweighted specifications of utilizing the full sample available when not controlling for state and country income per capita.[20] The resulting coefficients are moderately smaller than in the baseline. This is most noticeable for estimates of Medicare and Medicaid's relatively long run effect, which is just above 0.9 percentage point in the weighted specifications and 1.1 to 1.2 percentage points in the unweighted specifications.

Table A.3 shows that the baseline specification from Table 2's column 2 is not significantly altered by shifting the year that separates the base period from the period representing the medium-run after Medicare and Medicaid's implementation. The "medium run" effect becomes moderately smaller as it is made to start closer to 1965. It declines

[20]The additions to the sample include two aggregates of small countries for which there is, individually, relatively little patent data, as well as Germany, for which the East-West partition resulted in incomplete income reporting by the Penn World Tables for the 1960s.

monotonically from 1.2 percentage points in the baseline specification, which ends the base period in 1968, to 0.9 percentage point when the base period ends in 1965. The results suggest that the full effect of Medicare on the distribution of patents emerges several years after its implementation, consistent with empirically realistic lags for both the development of patentable ideas and the granting of patents once they have been filed.[21]

Table A.4 shows that the results in Table 2 are robust to estimating equation (5) using annual observations rather than observations aggregated to the level of 5 and 6 year periods. Estimation on annual observations allows me to control directly for a differential U.S.-specific trend towards medical-equipment patenting. Controlling for such a trend has no appreciable impact on the baseline results. Columns 1 through 3 of Table A.4 make use of the full sample of annual observations while columns 4 through 6 impose a balanced-panel requirement. Panel balance becomes relatively stringent when working with annual observations rather than with observations that aggregate patent data over several years. This restriction only modestly affects the results.

4.3 Robustness to Estimation of Count Models

Tables 3 and 4 present estimates of count models that take the form of equation (6). In both tables, the results include a log-linear model of patent counts along with comparable poisson and negative binomial models. Table 3 presents estimates of the effect of Medicare and Medicaid on medical-equipment patenting while Table 4 presents falsification tests for an effect of Medicare and Medicaid on pharmaceutical patenting.

The results in Table 3 are readily compared with that from column 3 of Table 2, which showed that Medicare increased the log of medical-equipment's share of total patents by

[21]See Roberts (1988), quoted in some detail earlier in the paper, for a discussion of the short-horizon, non-revolutionary nature of most medical-equipment innovation.

Table 3: **Changes in Arrival Rates for Medical Equipment Patents**

	(1) Ln(Equip)	(2) Poisson	(3) Neg. Binom.
US State $\times$ Med. Equip. $\times$ 1969 to 1974	0.4268**	0.4229**	0.4229**
	(0.1375)	(0.0559)	(0.0559)
US State $\times$ Med. Equip. $\times$ 1975 to 1980	0.5824**	0.5485**	0.5485**
	(0.1607)	(0.0560)	(0.0560)
N	228	228	228
Number of Clusters	38	38	38
Period x Equipment FE	Yes	Yes	Yes
Period x State FE	Yes	Yes	Yes
State x Equipment FE	Yes	Yes	Yes
Base Period	1963 to 1968	1963 to 1968	1963 to 1968

Note: **, *, and + indicate statistical significance at the 0.01, 0.05, and 0.10 levels respectively. The table reports coefficients from regressions using the models described in the column headings. Column 1 reports estimates from a log-linear model of patent counts, column 2 from a poisson model, and column 3 from a negative binomial model. For the poisson model, the p-values for the Deviance Pearson tests of goodness-of-fit are 0.0070 and 0.0052 respectively, suggesting that the data are over-dispersed. Point estimates and standard errors are stable, however, when replacing the poisson model with the negative binomial model. The dependent variable in all three specifications consists of patent counts. Observations have been aggregated at the level of time periods (as in the regressions previously reported) geographic regions (again as in previous regressions) and patent categories. The patent categories are simply Medical Equipment and All Other, resulting in twice as many observations as in the regressions reported in previous tables. Standard errors, reported beneath each point estimate, allow for arbitrary autocorrelation in the errors associated with the observations for each US state or foreign country. Data sources are described in the note to Table 1.

Table 4: **Changes in Arrival Rates for Pharmaceutical Patents**

	(1) Ln(Equip)	(2) Poisson	(3) Neg. Binom.
US State × Pharma × 1969 to 1974	0.2134	0.0831	0.0545
	(0.2320)	(0.1304)	(0.1325)
US State × Pharma × 1975 to 1980	0.0275	0.1864	0.1413
	(0.4819)	(0.3683)	(0.3796)
N	228	228	228
Number of Clusters	38	38	38
Period x Pharma FE	Yes	Yes	Yes
Period x State FE	Yes	Yes	Yes
State x Pharma FE	Yes	Yes	Yes
Base Period	1963 to 1968	1963 to 1968	1963 to 1968

Note: **, *, and + indicate statistical significance at the 0.01, 0.05, and 0.10 levels respectively. The table reports coefficients from regressions using the models described in the column headings. Column 1 reports estimates from a log-linear model of patent counts, column 2 from a poisson model, and column 3 from a negative binomial model. For the poisson model, the p-values for the Deviance Pearson tests of goodness-of-fit are 0.0000 and 0.0000 respectively, strongly implying that the data are over-dispersed. Point estimates change modestly and standard errors are stable when replacing the poisson model with the negative binomial model. The dependent variable in all three specifications consists of patent counts. Observations have been aggregated at the level of time periods (as in the regressions previously reported) geographic regions (again as in previous regressions) and patent categories. The patent categories are simply Medical Equipment and All Other, resulting in twice as many observations as in the regressions reported in previous tables. Standard errors, reported beneath each point estimate, allow for arbitrary autocorrelation in the errors associated with the observations for each US state or foreign country. Data sources are described in the note to Table 1.

40 to 50 percent. All three of the models presented in Table 3 yield similar results; the evidence implies that Medicare and Medicaid increased the arrival of medical-equipment innovations within this same range of 40 to 50 percent. The poisson and negative binomial models are estimated with greater precision, reflecting superior fits of the data.

The results in Table 4 have implications similar to the result from Table 2's column 4. In no case is there statistically significant evidence for an effect of Medicare and Medicaid on U.S.-based pharmaceutical patenting. It remains the case, however, that estimates involving pharmaceutical patenting are sufficiently imprecise that large effects cannot be ruled out. This is particularly true for estimates of Medicare and Medicaid's medium-to-long run effect.

4.4 An Investigation of the Quality of Insurance-Induced Medical-Equipment Patents

The innovation literature highlights a need to use caution when translating observed shifts in patenting activity into impact-adjusted levels of innovation.[22] Best practice continues to draw on work by Trajtenberg (1990a), who found in the case of patents associated with computed tomography that there is "a close association between citation-based patent indices and independent measures of the social value of innovations in that field." Evidence on the effect of using citations to adjust for patent quality can be found in Table 5. The dependent variables in the regressions reported in Table 5 replace the dependent variables from Table 2 with citation-weighted patent shares. The Medical Equipment share, for example, is calculated as the sum of all citations received by a state's medical-equipment patents divided by the sum of all citations received by all of that state's patents. The results in Table 5 are little changed from those in Table 2.

Table A.5 presents additional evidence on patent quality; its results also describe Medicare's impact on patent quality as measured using patent citations. The results show a moderate, but statistically insignificant, increase in the mean number of citations associated with U.S.-based medical-equipment patents (relative to foreign medical-equipment patents). However, there was a moderate decline (on the order of one half of a standard deviation) in the ratio of mean citations for medical-equipment patents rela-

[22]For example, cross-sectional evidence reported by Moser (2011) shows that low quality (or less important) innovations are more likely to go unpatented than high quality innovations. It is thus important to consider the possibility that expansions in the markets for health technologies may, in part, have increased the rate of patenting for existing innovations rather than increasing total innovation.

Table 5: **Change in Fraction of Citation-Weighted Patents Directed At Medical Equipment**

	(1) Equip Share	(2) Equip Share	(3) Ln(Eq Share)	(4) Rx Share	(5) Equip Share	(6) Equip Net Rx
US State × 1968 to 1974	0.0122**	0.0131**	0.2428*	0.0031	0.0129**	0.0101*
	(0.0038)	(0.0044)	(0.0972)	(0.0022)	(0.0041)	(0.0045)
US State × 1975 to 1980	0.0174*	0.0187*	0.3351*	-0.0059	0.0192*	0.0246**
	(0.0066)	(0.0074)	(0.1555)	(0.0091)	(0.0078)	(0.0081)
GDP Per Capita (10000s)		0.0197	-0.0025	-0.0342	0.0223	0.0539*
		(0.0230)	(0.4529)	(0.0223)	(0.0228)	(0.0224)
Fraction Pharmaceutical					0.0757	
					(0.2301)	
R^2	0.897	0.900	0.923	0.838	0.900	0.887
N	114	114	114	114	114	114
Number of Clusters	38	38	38	38	38	38
Weighted	Yes	Yes	Yes	Yes	Yes	Yes
Period FE	Yes	Yes	Yes	Yes	Yes	Yes
State And Country FE	Yes	Yes	Yes	Yes	Yes	Yes
Base Period	1963 to 1968	1963 to 1968	1963 to 1968	1963 to 1968	1963 to 1968	1963 to 1968

Note: **, *, and + indicate statistical significance at the 0.01, 0.05, and 0.10 levels respectively. The table reports coefficients from ordinary least squares regressions. The dependent variables differ from those in Table 2 only in that each patent is now weighted by the number of future citations it had received as of 1999. For example, the Medical Equipment share is now calculated as the sum off all citations received by an area's medical-equipment patents divided by the sum of all citations received by all of an area's patents during the relevant time period. A description of the classification system can be found in the note to Table 1. Relatively small U.S. states are grouped into regional aggregates as described in the note to Table 1, where readers can also find a list of the foreign countries included in the sample. Standard errors, reported beneath each point estimate, allow for arbitrary autocorrelation in the errors associated with the observations for each US state or foreign country. Data sources are described in the note to Table 1.

tive to all patents.[23] As always, caution is warranted when translating shifts in patenting activity into absolute, impact-adjusted levels of innovation.

5 Within-U.S. Effects of Medicare and Medicaid on Medical Innovation

I next explore predictors of variation in the size of U.S. states' increases in medical-equipment patenting. The Great Society programs' most substantial impact was to alter incentives for health-sector innovation in the United States (as a whole) relative to foreign markets. At the same time, Section 2 highlighted the importance of local factors as drivers of medical innovation. Positive relationships between states' increases in medical-equipment patenting and proxies for equation (3)'s locally varying factors can thus contribute to the case that these mechanisms are truly at work. I explore the strength of the relevant relationships by estimating the following equation:

$$\triangle \text{Health Share}_s = \alpha_0 + \alpha_1 \text{Mechanism Intensity}_s + \varepsilon_s. \tag{7}$$

I estimate equation (7) on a sample consisting exclusively of the U.S. states. The coefficient α_1 describes the strength of the correlation between the size of states' expansions in health-sector patenting and proxies for the strength of the relevant mechanisms (represented by *Mechanism Intensity*$_s$).[24]

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[23]This ratio, which proxies for the quality of health-sector patents relative to all patents, would be the preferred measure if patent-citation norms change differentially across countries over time. Such changes cannot be distinguished from across the board changes in the relative quality of patents across countries.

[24]I refrain from advancing a causal interpretation of the estimates of α_1. However, the apparent simplicity of the estimation framework should not take away from the fact that, in a condensed fashion, it delivers estimates similar in spirit to those reported by Finkelstein (2007). I do not advance a causal interpretation largely because, as should become clearer below, the mechanisms of interest include features of the Great Society beyond the Medicare-induced changes in coverage rates for which variation is plausibly (conditionally) uncorrelated with other relevant factors. Directly relevant, for example, is the fact that the

I consider several variables that capture the mechanisms emphasized in Section 2. The first, *Physicians Per 1,000*, is a measure of physicians per 1,000 state residents in 1965; it captures the presence of the potential physician innovators emphasized throughout. The second, *Uninsured Elderly*, proxies for the size of the insurance expansion associated with Medicare. I take this measure directly from Finkelstein (2007), who tabulated regional survey estimates of pre-Medicare coverage rates among the elderly. The third, $\triangle$*State Health Spending*, describes the change in health spending (in 1000s of dollars per capita) by state governments from 1962 to 1972, which was driven primarily by states' integration into the Medicaid program.[25]

Two additional variables involve composites in which the initial three variables have been made comparable through standard normalization. The first of these, *Demand Side Composite*, captures the total size of the Great Society programs' demand-side impact. It does so by summing the standard-normalized versions of *Uninsured Elderly* and $\triangle$*State Health Spending*. The final variable, *Total Composite*, is the sum of all three standard-normalized variables; it is thus a relatively comprehensive measure of the Great Society programs' region-specific forces.

Table 6 reports estimates of α_1 when *Mechanism Intensity*$_s$ is represented by the variables discussed above. Columns 1 through 3 show that *Physicians Per 1,000*, *Uninsured Elderly*, and $\triangle$*State Health Spending* are each positively correlated with the size of states' shifts towards medical-equipment patenting. For the individual variables the strength of these correlations is modest.

Accounting for the potential mechanisms jointly, as in columns 4 and 5, yields sta-

mechanisms are not uncorrelated with one another, making it difficult to advance a causal interpretation for the coefficient associated with any one of them.

[25]The choice of years is driven in part by the relatively detailed information on sub-national government budgets made available through the Census of Governments, which occurs in years ending with 2 and 7. Using the change in spending through 1972 helps to fully account for the impact of Medicaid because 1972 was the first year during which states' Medicaid programs were required to cover individuals receiving Disability or Supplemental Security Insurance payments through Social Security.

Table 6: **Change in Fraction of Patents Directed At Medical Equipment: Mechanisms**

	(1) $\triangle$ Equip Share	(2) $\triangle$ Equip Share	(3) $\triangle$ Equip Share	(4) $\triangle$ Equip Share	(5) $\triangle$ Equip Share
Physicians Per 1,000	0.00553+			0.00602**	
	(0.00312)			(0.00219)	
Uninsured Elderly		0.00687			
		(0.00991)			
$\triangle$State Health Spending			0.01208		
			(0.00984)		
Demand Side Composite				0.00093**	
				(0.00033)	
Total Composite					0.00116**
					(0.00026)
N	32	32	32	32	32
Number of Clusters	32	32	32	32	32
R-Squared	0.126	0.031	0.055	0.225	0.196
Weighted	Yes	Yes	Yes	Yes	Yes
Base Period	1963 to 1968	1963 to 1968	1963 to 1968	1963 to 1968	1963 to 1968

Note: **, *, and + indicate statistical significance at the 0.01, 0.05, and 0.10 levels respectively. The table reports coefficients from ordinary least squares estimates of equation (7), which is a cross-sectional specification restricted to the sample of U.S. states. The dependent variable in each column is the change in the fraction of total patents that are categorized as Medical Equipment. The change is calculated from a pre-Great Society base using patents granted from 1963-1968 to a post-period using patents granted from 1969-1980. Relatively small U.S. states are grouped into regional aggregates as described in the note to Table 1. Observations are weighted according to each state's average share of all patents in the database over the full sample period. Standard errors, reported beneath each point estimate, are robust to heteroskedasticity. *Physicians Per 1,000* residents was taken from the 1967 edition of the Statistical Abstract of the United States; the data apply to 1965. *Uninsured Elderly* was taken directly from Finkelstein (2007) and varies at geographic units that are slightly more dis-aggregated than U.S. census divisions. $\triangle$*State Health Spending* is the change in state government spending (in 1000s of dollars per capita) on health (through Medicaid and direct spending to subsidize hospitals) as reported by the Census of Governments. *Demand Side Composite* is the sum of the standard-normalized versions of *Uninsured Elderly* and $\triangle$*State Health Spending*, while *Total Composite* is the sum of the standard-normalized versions of each of the first three variables.

tistically stronger results. In column 4, the composite of the demand-side changes associated with Medicare and Medicaid has a positive relationship with shifts towards medical-equipment patenting that is statistically significant at the 0.01 level. The coefficient implies that a state at the 95th percentile of the Great Society programs' demand-side effects experienced a shift towards medical-equipment patenting that exceeded the shift at the 5th percentile by 0.37 percentage point. This difference is roughly 1/4th of the baseline estimate from column 2 of Table 2.

The presence of an additional physician per 1000 residents, corresponding to the difference between the 5th and 95th percentiles, was associated with a shift towards medical-equipment patenting of an additional 0.6 percentage point. This amount is equal to nearly 1/2 of the baseline estimate from column 2 of Table 2. This coefficient is also statistically differentiable from 0 at the 0.01 level.

The coefficient on *Total Composite* has similar implications for the magnitudes of states' shifts towards medical-equipment patenting. This final variable predictively explains 20 percent of the variation in the size of shifts towards medical equipment patenting within the United States.[26] Graphical illustrations of the correlation between states' increases in medical-equipment patenting and the mechanism variables can be found in Figure A.2 in Appendix 1.

Table 7 provides further evidence for the relevance of the mechanisms emphasized above. It reports estimates equivalent to those from Columns 4 and 5 of Table 6, but separately for the sub-categories of medical-equipment patents. This is motivated by the fact that imaging equipment is relatively closely linked to the efforts of large-scale manufacturers, while innovation in surgical equipment and other medical devices is more

[26]It is worth noting that these results are robust to a variety of changes in the manner in which the variables are constructed. Taking the measure of physicians per 1,000 residents from different years, making reasonable alterations to the measure of changes in state government health spending, using Finkelstein's alternative measure of the size of Medicare's impact on coverage, and further adjusting for the elderly's share of each state's total population have negligible impacts on the presented results.

Table 7: **Change in Fraction of Patents Directed At Medical Equipment by Category: Mechanisms**

	(1) △ Surgery	(2) △ Surgery	(3) △ Misc.	(4) △ Misc.	(5) △ Imaging	(6) △ Imaging
Physicians Per 1,000	0.00354*		0.00202**		0.00046	
	(0.00139)		(0.00046)		(0.00137)	
Demand Side Composite	0.00073**		0.00019**		0.00001	
	(0.00020)		(0.00007)		(0.00019)	
Total Composite		0.00082**		0.00030**		0.00004
		(0.00019)		(0.00007)		(0.00012)
N	32	32	32	32	32	32
Number of Clusters	32	32	32	32	32	32
R-Squared	0.175	0.168	0.274	0.184	0.004	0.001
Weighted	Yes	Yes	Yes	Yes	Yes	Yes
Base Period	1963 to 1968	1963 to 1968	1963 to 1968	1963 to 1968	1963 to 1968	1963 to 1968

Note: **, *, and + indicate statistical significance at the 0.01, 0.05, and 0.10 levels respectively. The table reports coefficients from ordinary least squares estimates of equation (7), which is a cross-sectional specification restricted to the sample of U.S. states. The dependent variable in each column is the change in the fraction of total patents that fall into the sub-category of Medical Equipment patents that appears in the relevant column heading (Surgical Equipment, Miscellaneous Medical Equipment, or Diagnostic Imaging Equipment). The change is calculated from a pre-Great Society base using patents granted from 1963-1968 to a post-period using patents granted from 1969-1980. Relatively small U.S. states are grouped into regional aggregates as described in the note to Table 1. Observations are weighted according to each state's average share of all patents in the database over the full sample period. Standard errors, reported beneath each point estimate, are robust to heteroskedasticity. *Physicians Per 1,000* residents was taken from the 1967 edition of the Statistical Abstract of the United States; the data apply to 1965. *Uninsured Elderly* was taken directly from Finkelstein (2007) and varies at geographic units that are slightly more dis-aggregated than U.S. census divisions. △*State Health Spending* is the change in state government spending (in 1000s of dollars per capita) on health (through Medicaid and direct spending to subsidize hospitals) as reported by the Census of Governments. *Demand Side Composite* is the sum of the standard-normalized versions of *Uninsured Elderly* and △*State Health Spending*, while *Total Composite* is the sum of the standard-normalized versions of each of the first three variables.

tightly linked to practicing physicians. The latter categories of innovation are better categorized as the result of innovation-while-doing and thus, as discussed in Section 2, ought to be more responsive to the local features of insurance expansions. The data are consistent with this view. Both the baseline number physicians per capita and the impact of the Great Society health programs on local patient flows have much stronger relationships with surgical equipment and miscellaneous medical devices than with imaging equipment.

6 Late 20th Century Developments in Medical Innovation

Panels C and D of Figure 2 show the evolution of health-sector patenting from 1980 to 1999. Recall from Panels C and D of Figure 1 that this was a period during which consumer exposure to the cost of both pharmaceuticals and care provided in hospitals and physicians' offices declined substantially. Figure 2 shows that, relative to the health-sector's share of foreign patents, U.S. patenting of both medical equipment and pharmaceuticals rose over this time period. The rise of U.S. pharamceutical patenting was particularly sharp during the 1990s, reflecting the rise of the U.S. biotechnology industry. During this period, the U.S. medical-equipment share rose by 2 percentage points relative to the foreign share and the U.S. pharmaceutical rose by 3.4 percentage points.

Appendix Tables A.6 and A.7 shows these late 20th century movements in patenting activity to be statistically differentiable from 0. It is important to emphasize that there was no sharp natural experiment during this period, only a gradual, continuing decline in consumer exposure to out-of-pocket costs. Consequently, the estimates cannot be viewed as causal estimates of the effect of any particular change in insurance arrangements. Rather, the estimates can be characterized as descriptive summaries of the evolution of patenting in the United States relative to foreign countries. Appendix Tables A.8 through A.9 provide evidence that these late 20th century increases in U.S. health-sector patenting did not come at the expense of patent quality.

As already emphasized, it would be erroneous to describe the results in Tables A.6 and A.7 as causal estimates of the effect of an insurance expansion. Nonetheless, they contribute additional evidence to the overall argument that U.S. insurance expansions played an important role in shaping the course of medical innovation. To see why, recall that the panels of Figure 1 describe 4 episodes in the evolution of cost sharing in U.S. health-care markets. These panels are mirrored by the panels of Figure 3, which show the equivalent episodes in the history of health-sector patenting. U.S. patenting shifted substantially more towards the health sector than did foreign patenting during all 3 of the episodes during which cost sharing declined substantially. During the 1 episode during which cost sharing changed little, namely the pharmaceuticals market of the 1960s and 1970s, U.S. and foreign patenting moved nearly in parallel.

7 Cross-Country Breakdowns by Cultural Closeness to the United States

Estimating the total size of the effect of U.S. insurance expansions on health-sector innovation requires establishing an appropriate counterfactual. As emphasized previously, the regression estimates have described the differential evolution of U.S. health-sector patenting relative to foreign health-sector patenting. To the extent to which foreign patenters have joined U.S. patenters in responding to the incentives associated with U.S. markets, these estimates constitute a lower bound on the total effect of U.S. insurance expansions. Figure 4 provides suggestive evidence on the potential importance of the relevant spillover effects.

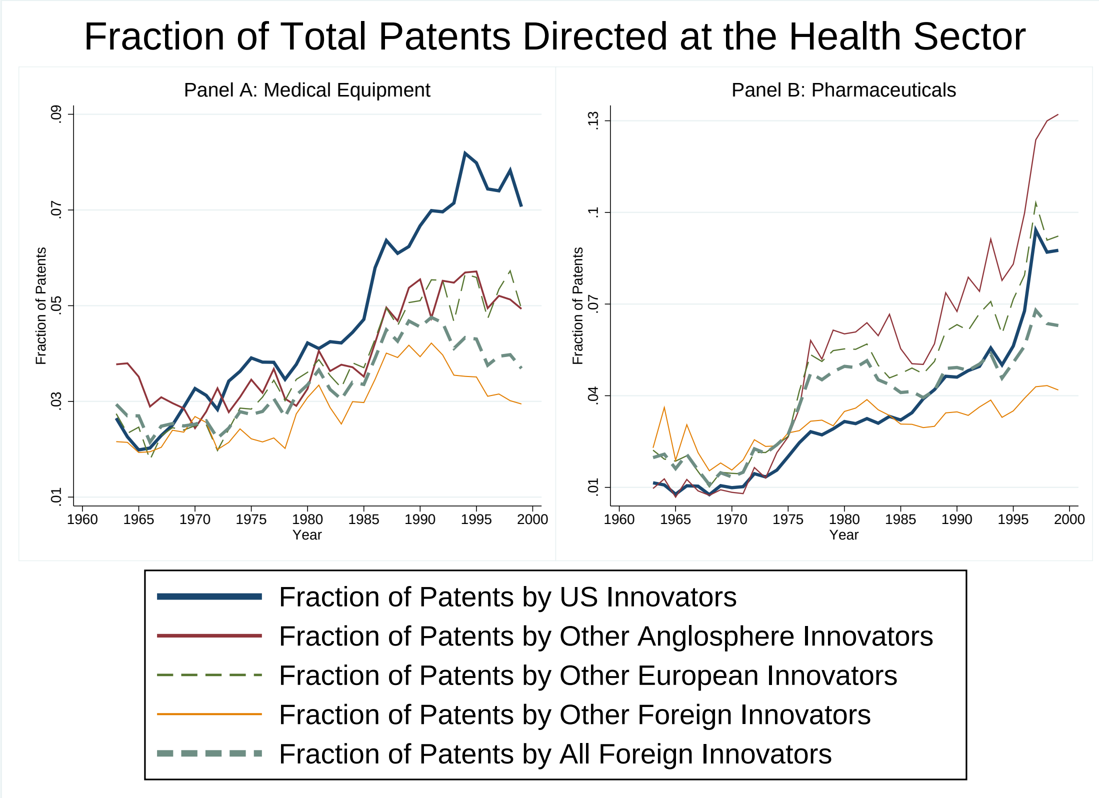

Figure 4: **Fraction of Patents Directed at the Health Sector (U.S. vs Foreign Country Groups):** Series were constructed by the author using data from the NBER Patent Database (Hall, Jaffe, and Trajtenberg, 2001). Patents are classified as coming from the Anglosphere if the patenter lives in Canada, Australia, Great Britain, or Ireland. "Other European" innovators are those from European countries that are not included in the Anglosphere. A description of the system for classifying Medical Equipment and Pharmaceutical patents can be found in the note to Table 1. The years in the figure refer to the year in which each patent was granted. In later years of the patent database, grant years lag filing years by an average of 2.3 years for health-sector patents (roughly 2.0 years for patents more generally).

Figure 4 displays the patent shares seen in Figure 2, but with a finer disaggregation of foreign patenters. Specifically, I divide foreign patenters into 3 groups: patenters in English speaking countries (the Anglosphere), patenters in non-English speaking European countries, and patenters elsewhere in the world (a category dominated by patents filed by residents of Japan). The categories are meant to roughly capture degrees of cultural closeness to the United States, which should correlate with each patenter's inclination towards, and ease of marketing (or dealing with regulators) in, the United States.[27] If

[27]In the language of the model from section 2, it is natural to expect $\lambda^{US,US} > \lambda^{Anglo,US} > \lambda^{Euro,US} >$

foreign patenters are responding to changes in the size of U.S. markets, such responses should be largest among the English speakers and smallest among those outside of both Europe and the Anglosphere.

The figure shows that health-sector patenting's share of total patents rose more dramatically in English-speaking countries and other countries in Europe than elsewhere in the world. From the mid-1960s through the late-1990s, the medical-equipment share of patents rose from roughly 3 percent of all patents to 5 percent of all patents in English-speaking countries and other countries in Europe (relative to a rise from just above 2 percent to just over 7 percent in the United States). Elsewhere in the world, this share rose from roughly 2.5 percent to just over 3 percent after peaking at a high of 4 percent during the late 1980s.

Patenters in the Anglosphere exceeded U.S.-based patenters in terms of their pharmaceutical share, which rose from 1 percent to nearly 13 percent relative to an increase from 1 percent to nearly 9 percent in the United States. Other European patenters have pharmaceutical shares similar to that in the United States. Innovators elsewhere in the world had a pharmaceutical share of just over 4 percent during the late 1990s.

The data are suggestive that the patenting of innovators outside of Europe and the Anglosphere may provide a reasonable counterfactual for the path of U.S. patenting in the absence of its insurance expansions. There is, of course, a great deal of uncertainty associated with establishing this counterfactual. Appendix 3 presents a calibration of the role of U.S. health insurance expansions as a driver of innovation and health expenditures. The calibration draws on the existing literature and the current paper's analysis. While the exercise requires many caveats, my best estimate is that U.S. insurance expansions are responsible for roughly 25 percent of recent global medical equipment

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$\lambda^{Other,US}$. The potential-market-size effect is declining in cultural distance from the United States. The differential between U.S.-based patenters and "Other" foreign patenters should thus come relatively close to characterizing the total effect of U.S. insurance expansions on U.S.-based medical innovation.

innovation. This innovation would have driven roughly 15 percent of the increase in U.S. health spending in hospitals, physicians' offices, and other clinical settings from 1960 to 2010.

8 Conclusion

This paper provides estimates of the effect of insurance on broad aggregates of medical innovation. The evidence suggests that Medicare and Medicaid significantly increased U.S.-based medical-equipment patenting. While extrapolation involves considerable uncertainty, my best estimate is that the effects of U.S. insurance expansions on innovation account for 25 percent of recent, worldwide medical-equipment patenting. The forces of directed technical change (Acemoglu, 1998), and thus of government's influence as a maker of markets for technologies (Kremer, 2002; Acemoglu, Aghion, Bursztyn, and Hemous, 2012), appear quite strong in this context.[28]

The evidence highlights the importance of medical innovation's local and regional determinants. In particular, the relevance of the skills and insights of experienced practitioners (Arrow, 1962) implies a central role for local flows of well-insured patients. Consequently, medical innovation's economic determinants extend beyond the potential revenues associated with global market size.

The relevance of local factors may be important for predicting the Patient Protection and Affordable Care Act's (ACA) implications for innovation. Taxing medical device manufacturers reduces their profitability, likely discouraging innovation. By increasing the ranks of insured patients, however, the ACA's coverage expansions may increase the productivity of physicians' innovative efforts. The latter effect depends on both the size

[28]See also Glennerster, Kremer, and Williams (2006) and Berndt, Glennerster, Kremer, Lee, Levine, Weizsäcker, and Williams (2007) for discussions of market making in the context of vaccine policy. The welfare implications of insurance-induced pharmaceutical innovation are further assessed by Lakdawalla and Sood (2009) and Gailey, Lakdawalla, and Sood (2010).

of the coverage expansion and the comprehensiveness of the coverage it involves. Generous payment rates encourage health care providers to adopt and innovate upon new technologies, while low reimbursements do not (Freedman, Lin, and Simon, 2012). Until the composition of ACA-induced coverage changes is better known, the law's implications for aggregate medical innovation remain highly uncertain.

In many industries, technological advance is associated with cost-reducing productivity gains. A striking feature of medical innovation has been its tendency to expand the frontier of quality rather than reduce cost. Paying providers on a cost-plus basis encourages innovation of precisely this form. Reforms that shift from fee-for-service models towards bundled payments will tend to increase the rewards for innovation of the cost-conscious variety. Medicare reforms may have particularly strong effects on these incentives as a result of linkages between Medicare and private insurers' payment models (Clemens and Gottlieb, 2013). As emphasized by Weisbrod (1991), the structure of physician payment may be as important as its generosity on this particular score. Estimating the influence of bundled payments and managed care arrangements on medical innovation's productivity- and quality-relevant characteristics is a natural priority for future research.

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Appendix 1: Supplemental Figures and Tables

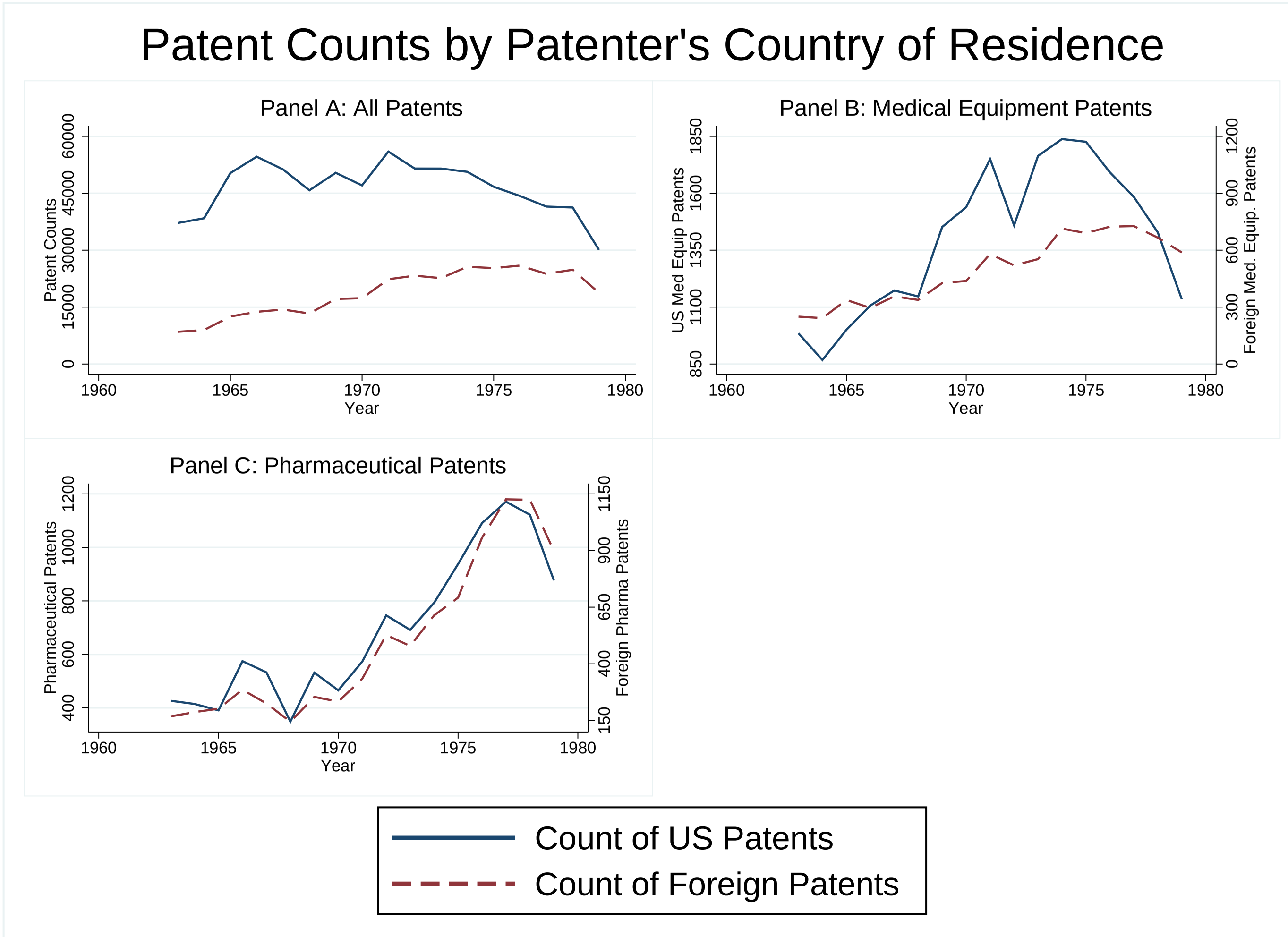

Figure A.1: **Total and Health Sector Patent Counts (U.S. vs Foreign):** Series were constructed by the author using data from the NBER Patent Database (Hall, Jaffe, and Trajtenberg, 2001). A description of the system for classifying Medical Equipment and Pharmaceutical patents can be found in the note to Table 1. The years in the figure refer to the year in which each patent was granted. In later years of the patent database, grant years lag filing years by an average of 2.3 years for health-sector patents (roughly 2.0 years for patents more generally).

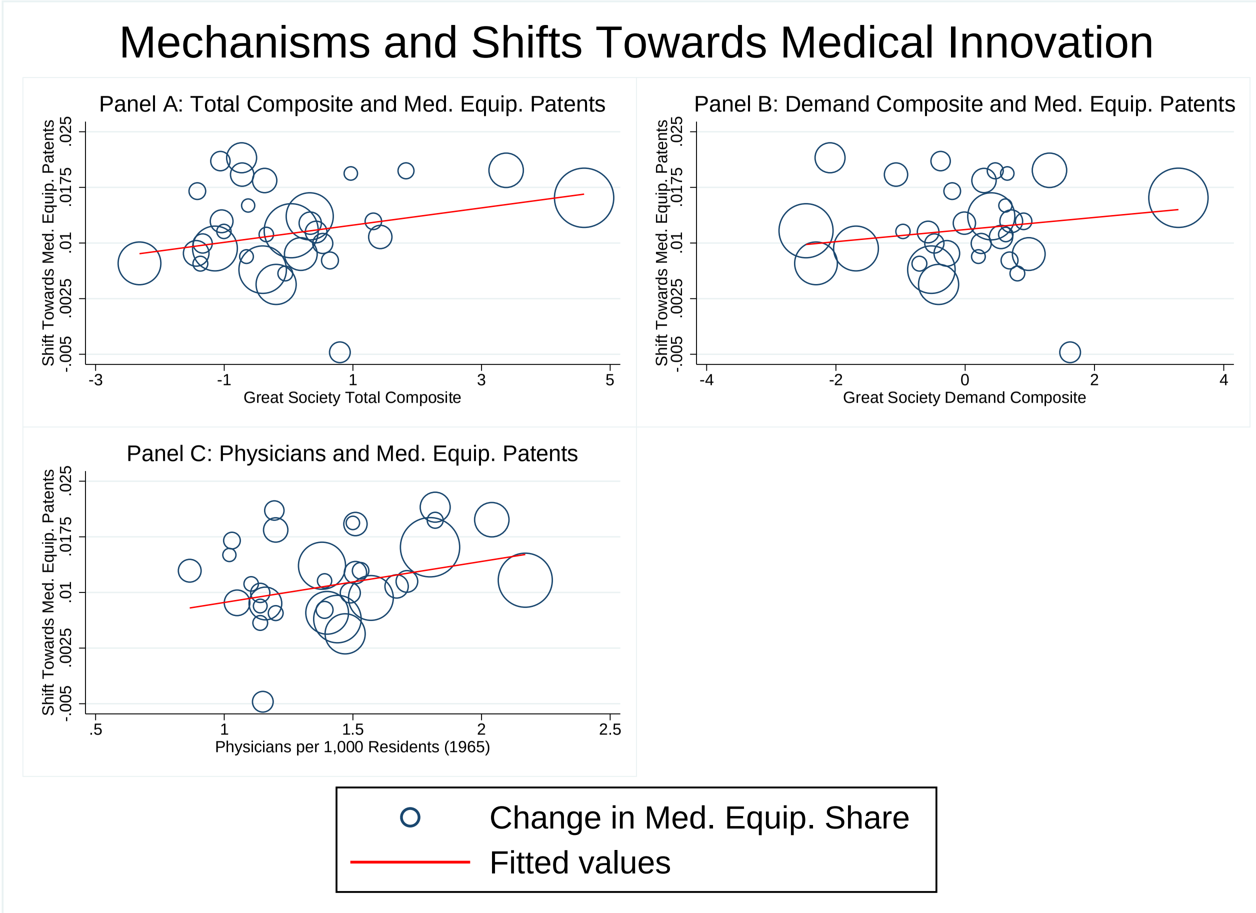

Figure A.2: **Correlations between Mechanism Proxies and Increases in Medical-Equipment Patenting:** The shifts towards medical-equipment patenting were constructed by the author using data from the NBER Patent Database (Hall, Jaffe, and Trajtenberg, 2001). A description of the system for classifying Medical Equipment patents can be found in the note to Table 1. Observations represent U.S. states and state aggregates, again constructed as described in the note to Table 1. The Total Composite, Demand Composite, and Physicians per 1,000 Residents (in 1965) variables were constructed as described in the note to Table 3. Physicians per 1,000 Residents comes from the 1967 edition of the statistical abstract of the United States. The Demand Composite is the sum of two standard-normalized variables; the first proxies for the state-level impact of the origin of Medicare, while the second proxies for the state-level impact of the origin of Medicaid. The Total Composite is the sum of the Demand Composite and a standard-normalized version of the variable describing the number of Physicians per 1,000 Residents. Observations are weighted by each state's contribution to the total number of patents appearing in the database over the sample period. R-squared statistics associated with the best fit lines in Panels A, B, and C are 0.196, 0.077, and 0.126 respectively.

Table A.1: **Change in Fraction of Patents Directed At Medical Equipment: Unweighted Regressions**

	(1) Equip Share	(2) Equip Share	(3) Ln(Eq Share)	(4) Rx Share	(5) Equip Share	(6) Equip Net Rx
US State × 1968 to 1974	0.0105**	0.0115**	0.4009**	0.0004	0.0114**	0.0110**
	(0.0024)	(0.0019)	(0.0994)	(0.0031)	(0.0018)	(0.0027)
US State × 1975 to 1980	0.0154**	0.0165**	0.5749**	-0.0138+	0.0177**	0.0302**
	(0.0024)	(0.0026)	(0.1014)	(0.0077)	(0.0032)	(0.0077)
GDP Per Capita (10000s)		0.0219**	0.1684	-0.0249	0.0241*	0.0467*
		(0.0078)	(0.3060)	(0.0216)	(0.0094)	(0.0221)
Fraction Pharmaceutical					0.0875	
					(0.1161)	
R^2	0.915	0.921	0.926	0.853	0.923	0.905
N	114	114	114	114	114	114
Number of Clusters	38	38	38	38	38	38
Weighted	No	No	No	No	No	No
Period FE	Yes	Yes	Yes	Yes	Yes	Yes
State And Country FE	Yes	Yes	Yes	Yes	Yes	Yes
Base Period	1963 to 1968	1963 to 1968	1963 to 1968	1963 to 1968	1963 to 1968	1963 to 1968

Note: **, *, and + indicate statistical significance at the 0.01, 0.05, and 0.10 levels respectively. The table reports coefficients from ordinary least squares regressions. In columns 1, 2, and 5 the dependent variable is the fraction of total patents that are categorized as Medical Equipment Patents. In column 3 the dependent variable is the natural logarithm of this fraction. In column 4 the dependent variable is the fraction of total patents that are categorized Pharmaceutical Patents. Finally, in column 6 the dependent variable is the fraction of total patents that are categorized as Medical Equipment Patents minus the fraction categorized as Pharmaceutical Patents. A description of the classification system can be found in the note to Table 1. Relatively small US states are grouped into regional aggregates as described in the note to Table 1, where readers can also find a list of the foreign countries in included in the sample. Standard errors, reported beneath each point estimate, allow for arbitrary autocorrelation in the errors associated with the observations for each US state or foreign country. The standard errors change little, decreasing marginally, when I allow further for arbitrary correlation patterns across the errors associated with each year or associated with each country at a point in time. Data sources are described in the note to Table 1.

Table A.2: **Change in Fraction of Patents Directed At Medical Equipment: Sample w/o Income Control**

	(1) Equip Share	(2) Equip Share	(3) Ln(Eq Share)	(4) Equip Share	(5) Equip Share	(6) Ln(Eq Share)
US State × 1968 to 1974	0.0081**	0.0081**	0.2768**	0.0085**	0.0084**	0.3220**
	(0.0022)	(0.0024)	(0.0763)	(0.0022)	(0.0023)	(0.0910)
US State × 1975 to 1980	0.0091+	0.0091+	0.2938	0.0113**	0.0117**	0.4136**
	(0.0049)	(0.0048)	(0.1864)	(0.0034)	(0.0035)	(0.1307)
Fraction Pharmaceutical		0.0110			0.0407	
		(0.1237)			(0.1014)	
R^2	0.908	0.908	0.920	0.904	0.904	0.914
N	123	123	123	123	123	123
Number of Clusters	41	41	41	41	41	41
Weighted	Yes	Yes	Yes	No	No	No
Period FE	Yes	Yes	Yes	Yes	Yes	Yes
State And Country FE	Yes	Yes	Yes	Yes	Yes	Yes
Base Period	1963 to 1968	1963 to 1968	1963 to 1968	1963 to 1968	1963 to 1968	1963 to 1968

Note: **, *, and + indicate statistical significance at the 0.01, 0.05, and 0.10 levels respectively. The table reports coefficients from ordinary least squares regressions. In columns 1, 2, 4, and 5 the dependent variable is the fraction of total patents that are categorized as Medical Equipment Patents. In column 3 and 6 the dependent variable is the natural logarithm of this fraction. A description of the classification system can be found in the note to Table 1. Relatively small US states are grouped into regional aggregates as described in the note to Table 1. The sample differs from the sample described in Table 1, and utilized in Table 2 and Table A.1 in that it is not restricted to countries for which there is reliable data on income per capita in each period. This adds Germany, which suffers from income-reporting issues during some years of its division into East and West, as well as 2 aggregates of small countries for which there is, individually, relatively little patent data. Standard errors, reported beneath each point estimate, allow for arbitrary autocorrelation in the errors associated with the observations for each US state or foreign country. In the unweighted specifications the standard errors change little, decreasing marginally, when I allow further for arbitrary correlation patterns across the errors associated with each year or associated with each country at a point in time. Data sources are described in the note to Table 1.

Table A.3: **Change in Fraction of Patents Directed At Medical Equipment: Robustness To Changing Base Period**

	(1) Equip Share	(2) Equip Share	(3) Equip Share	(4) Equip Share	(5) Equip Share
US State × Medium Run	0.0089**	0.0108**	0.0115**	0.0121**	0.0120**
	(0.0028)	(0.0027)	(0.0026)	(0.0024)	(0.0022)
US State × Long Run	0.0139**	0.0143**	0.0138**	0.0131**	0.0123**
	(0.0030)	(0.0030)	(0.0028)	(0.0025)	(0.0022)
GDP Per Capita (10000s)	0.0113**	0.0066**	0.0035	0.0022	0.0040*
	(0.0024)	(0.0021)	(0.0021)	(0.0022)	(0.0019)
R^2	0.729	0.739	0.751	0.760	0.757
N	656	656	656	656	656
Number of Clusters	39	39	39	39	39
Weighted	Yes	Yes	Yes	Yes	Yes
Period FE	Yes	Yes	Yes	Yes	Yes
Year FE	No	No	No	No	No
State And Country FE	Yes	Yes	Yes	Yes	Yes
Balanced Panel	No	No	No	No	No
Base Period	1963 to 1965	1963 to 1966	1963 to 1967	1963 to 1968	1963 to 1969

Note: **, *, and + indicate statistical significance at the 0.01, 0.05, and 0.10 levels respectively. The table reports coefficients from ordinary least squares regressions. Specifications differ in terms of their specification of the "Medium Run" post-Medicare period. In each column this period begins immediately following the base period listed in the table's final row. The medium run ends in 1974 in all cases. In all columns the dependent variable is the fraction of total patents that are categorized as Medical Equipment Patents. A description of the classification system can be found in the note to Table 1. Relatively small US states are grouped into regional aggregates as described in the note to Table 1, where readers can also find a list of the foreign countries included in the sample. Observations are weighted according to each state or country's average share of all patents in the database over the full sample period. Standard errors, reported beneath each point estimate, allow for arbitrary autocorrelation in the errors associated with the observations for each US state or foreign country. Data sources are described in the note to Table 1.

Table A.4: **Change in Fraction of Patents Directed At Medical Equipment: Annual Observations w/ Trend Controls**

	(1) Equip Share	(2) Equip Share	(3) Equip Share	(4) Equip Share	(5) Equip Share	(6) Equip Share
US State × 1968 to 1974	0.0121**	0.0120**	0.0112**	0.0108**	0.0108**	0.0073**
	(0.0024)	(0.0024)	(0.0036)	(0.0023)	(0.0026)	(0.0024)
US State × 1975 to 1980	0.0131**	0.0131**	0.0114**	0.0154**	0.0152**	0.0090
	(0.0025)	(0.0026)	(0.0039)	(0.0021)	(0.0022)	(0.0053)
GDP Per Capita (10000s)	0.0022	0.0014	0.0079*	0.0009	-0.0015	0.0089*
	(0.0022)	(0.0040)	(0.0037)	(0.0022)	(0.0044)	(0.0038)
Linear Trend		0.0001			0.0003	
		(0.0003)			(0.0003)	
US-Specific Trend			0.0002			0.0006
			(0.0004)			(0.0004)
R^2	0.760	0.760	0.786	0.810	0.810	0.843
N	656	656	656	357	357	357
Number of Clusters	39	39	39	21	21	21
Weighted	Yes	Yes	Yes	Yes	Yes	Yes
Period FE	Yes	Yes	No	Yes	Yes	No
Year FE	No	No	Yes	No	No	Yes
State And Country FE	Yes	Yes	Yes	Yes	Yes	Yes
Balanced Panel	No	No	No	Yes	Yes	Yes
Base Period	1963 to 1968	1963 to 1968	1963 to 1968	1963 to 1968	1963 to 1968	1963 to 1968

Note: **, *, and + indicate statistical significance at the 0.01, 0.05, and 0.10 levels respectively. The table reports coefficients from ordinary least squares regressions. The dependent variable is the fraction of total patents that are categorized as Medical Equipment Patents. A description of the classification system can be found in the note to Table 1. Relatively small US states are grouped into regional aggregates as described in the note to Table 1, where readers can also find a list of the foreign countries included in the sample. Observations are weighted according to each state or country's average share of all patents in the database over the full sample period. Standard errors, reported beneath each point estimate, allow for arbitrary autocorrelation in the errors associated with the observations for each US state or foreign country. In unweighted versions of these specifications the standard errors change little, decreasing marginally, when I allow further for arbitrary correlation patterns across the errors associated with each year or associated with each country at a point in time. Data sources are described in the note to Table 1.

Table A.5: **Post Medicare Changes in the Mean Citations of Patents by US Patenters**

	(1) Health Patent Citations	(2) All Patent Citations	(3) Relative Citations
US State × 1968 to 1974	0.5186	0.2123	-0.1683+
	(0.3650)	(0.1659)	(0.0996)
US State × 1975 to 1980	0.6402	0.3879	-0.2828+
	(0.6239)	(0.3397)	(0.1421)
GDP Per Capita (10000s)	0.8417	0.8735	-0.4197
	(1.9600)	(0.9527)	(0.4268)
R^2	0.929	0.981	0.728
N	114	114	114
Number of Clusters	38	38	38
Weighted	Yes	Yes	Yes
Period FE	Yes	Yes	Yes
State And Country FE	Yes	Yes	Yes
Base Period	1963 to 1968	1963 to 1968	1963 to 1968

Note: **, *, and + indicate statistical significance at the 0.01, 0.05, and 0.10 levels respectively. The table reports coefficients from ordinary least squares regressions. In column 1 the dependent variable is the mean number of citations associated with each medical-equipment patent. In column 2 the dependent variable is the the mean number of citations associated with all patents. In column 3 the dependent variable is ratio of the medical-equipment and all-patent citation means. A description of the patent classification system can be found in the note to Table 1. Relatively small US states are grouped into regional aggregates as described in the note to Table 1, where readers can also find a list of the foreign countries included in the sample. Observations are weighted according to each state or country's average share of all patents in the database over the full sample period. Standard errors, reported beneath each point estimate, allow for arbitrary autocorrelation in the errors associated with the observations for each US state or foreign country. Data sources are described in the note to Table 1.

Table A.6: **Change in Fraction of Patents Directed At Medical Equipment: Late 20th Century**

	(1) Equip Share	(2) Equip Share	(3) Equip Share
US State × 1986 to 1990	0.0061+	0.0061+	0.0064+
	(0.0034)	(0.0033)	(0.0033)
US State × 1991 to 1995	0.0177**	0.0174**	0.0183**
	(0.0055)	(0.0057)	(0.0061)
US State × 1996 to 1999	0.0223**	0.0222**	0.0236**
	(0.0066)	(0.0066)	(0.0064)
GDP Per Capita (10000s)		-0.0016	-0.0012
		(0.0122)	(0.0133)
R^2	0.918	0.918	0.918
N	152	152	144
Number of Clusters	38	38	36
Weighted	Yes	Yes	Yes
Period FE	Yes	Yes	Yes
State And Country FE	Yes	Yes	Yes
Anglosphere?	Yes	Yes	No
Base Period	1980 to 1985	1980 to 1985	1980 to 1985

Note: **, *, and + indicate statistical significance at the 0.01, 0.05, and 0.10 levels respectively. The table reports coefficients from ordinary least squares regressions. The dependent variable is the fraction of total patents that are categorized as Medical Equipment patents. A description of the classification system can be found in the note to Table 1. Relatively small U.S. states are grouped into regional aggregates as described in the note to Table 1, where readers can also find a list of the foreign countries included in the sample. Observations are weighted according to each state or country's average share of all patents in the database over the full sample period. Standard errors, reported beneath each point estimate, allow for arbitrary autocorrelation in the errors associated with the observations for each U.S. state or foreign country. Data sources are described in the note to Table 1.

Table A.7: **Change in Fraction of Patents Directed At Pharmaceuticals: Late 20th Century**

	(1) Pharma Share	(2) Pharma Share	(3) Pharma Share
US State × 1986 to 1990	0.0140**	0.0141**	0.0152**
	(0.0033)	(0.0034)	(0.0034)
US State × 1991 to 1995	0.0174*	0.0181+	0.0226*
	(0.0077)	(0.0093)	(0.0096)
US State × 1996 to 1999	0.0373+	0.0375+	0.0467**
	(0.0201)	(0.0205)	(0.0170)
GDP Per Capita (10000s)		0.0040	0.0067
		(0.0213)	(0.0226)
R^2	0.844	0.844	0.846
N	152	152	144
Number of Clusters	38	38	36
Weighted	Yes	Yes	Yes
Period FE	Yes	Yes	Yes
State And Country FE	Yes	Yes	Yes
Anglosphere?	Yes	Yes	No
Base Period	1980 to 1985	1980 to 1985	1980 to 1985

Note: **, *, and + indicate statistical significance at the 0.01, 0.05, and 0.10 levels respectively. The table reports coefficients from ordinary least squares regressions. The dependent variable is the fraction of total patents that are categorized Pharmaceutical patents. A description of the classification system can be found in the note to Table 1. Relatively small U.S. states are grouped into regional aggregates as described in the note to Table 1, where readers can also find a list of the foreign countries included in the sample. Observations are weighted according to each state or country's average share of all patents in the database over the full sample period. Standard errors, reported beneath each point estimate, allow for arbitrary autocorrelation in the errors associated with the observations for each U.S. state or foreign country. Data sources are described in the note to Table 1.

Table A.8: **Change in Fraction of Citation-Weighted Patents Directed At Medical Equipment**

	(1) Equip Share	(2) Equip Share	(3) Equip Share
US State × 1986 to 1990	0.0214*	0.0213*	0.0225*
	(0.0093)	(0.0092)	(0.0092)
US State × 1991 to 1995	0.0310*	0.0299*	0.0306*
	(0.0119)	(0.0120)	(0.0134)
US State × 1996 to 1999	0.0195+	0.0193+	0.0190
	(0.0114)	(0.0111)	(0.0124)
GDP Per Capita (10000s)		-0.0062	-0.0063
		(0.0191)	(0.0206)
R^2	0.888	0.888	0.888
N	152	152	144
Number of Clusters	38	38	36
Weighted	Yes	Yes	Yes
Period FE	Yes	Yes	Yes
State And Country FE	Yes	Yes	Yes
Anglosphere?	Yes	Yes	No
Base Period	1980 to 1985	1980 to 1985	1980 to 1985

Note: **, *, and + indicate statistical significance at the 0.01, 0.05, and 0.10 levels respectively. The table reports coefficients from ordinary least squares regressions. The dependent variables differ from those in Table 4 only in that each patent is now weighted by the number of future citations it had received as of 1999. For example, the Medical Equipment share is now calculated as the sum off all citations received by an area's medical-equipment patents divided by the sum of all citations received by all of an area's patents during the relevant time period. A description of the classification system can be found in the note to Table 1. Relatively small US states are grouped into regional aggregates as described in the note to Table 1, where readers can also find a list of the foreign countries included in the sample. Standard errors, reported beneath each point estimate, allow for arbitrary autocorrelation in the errors associated with the observations for each US state or foreign country. Data sources are described in the note to Table 1.

Table A.9: **Change in Fraction of Citation-Weighted Patents Directed At Pharmaceuticals**

	(1) Pharma Share	(2) Pharma Share	(3) Pharma Share
US State × 1986 to 1990	0.0158**	0.0158**	0.0175**
	(0.0042)	(0.0044)	(0.0040)
US State × 1991 to 1995	0.0154	0.0157	0.0205+
	(0.0101)	(0.0108)	(0.0109)
US State × 1996 to 1999	0.0179	0.0179	0.0237
	(0.0161)	(0.0162)	(0.0147)
GDP Per Capita (10000s)		0.0014	0.0043
		(0.0195)	(0.0206)
R^2	0.865	0.865	0.862
N	152	152	144
Number of Clusters	38	38	36
Weighted	Yes	Yes	Yes
Period FE	Yes	Yes	Yes
State And Country FE	Yes	Yes	Yes
Anglosphere?	Yes	Yes	No
Base Period	1980 to 1985	1980 to 1985	1980 to 1985

Note: **, *, and + indicate statistical significance at the 0.01, 0.05, and 0.10 levels respectively. The table reports coefficients from ordinary least squares regressions. The dependent variables differ from those in Table 5 only in that each patent is now weighted by the number of future citations it had received as of 1999. For example, the Pharmaceutical share is now calculated as the sum off all citations received by an area's pharmaceutical patents divided by the sum of all citations received by all of an area's patents during the relevant time period. A description of the classification system can be found in the note to Table 1. Relatively small US states are grouped into regional aggregates as described in the note to Table 1, where readers can also find a list of the foreign countries included in the sample. Standard errors, reported beneath each point estimate, allow for arbitrary autocorrelation in the errors associated with the observations for each US state or foreign country. Data sources are described in the note to Table 1.

Appendix 2: Exploration of Synthetic Control Methods

This appendix presents further results involving the synthetic control method used for the re-weighting of control units for Figure 3. The appendix includes consideration of inference in the synthetic control context. It is important to note that inference of the sort considered below makes inefficient use of the context's data. One could critique the empirical context as being a setting in which there is effectively one treated unit, namely the United States. The data, however, appear to reject this view. This conclusion is driven by the results obtained when using a two-way clustering procedure to calculate standard errors; allowing for arbitrary correlation across all observations within the United States at each point in time has no material impact on the estimated standard errors. Observations across regions of the United States thus appear to be effectively statistically independent. Collapsing the United States into a single unit fails to make use of valuable information. Nonetheless, it may be worth exploring practical issues that arise in the context of synthetic control inference, as these issues may arise in more general settings.

The inference problem can be characterized in the following terms. Inference requires estimating the distribution of shocks to which the treated units would have been subject had they not additionally been subject to the treatment. If the relevant shocks are small, then one may be able to reject the hypothesis that moderately sized treatment-effect estimates arose by chance from the underlying process. This characterization of inference is particularly apt in settings in which a single sample unit has been subjected to the treatment. In such settings, inference requires placing the estimated treatment effect on a counterfactual distribution of shocks constructed using the outcomes associated with control units.

Inference is particularly difficult in a synthetic control context like that considered here because there are relatively few countries from which substantial numbers of patents were filed with the USPTO. This is important because the analysis involves using patent filings as a proxy for innovative effort. Variation in this proxy, and by extension in its changes over time, thus involves both true differences in innovative effort and noise associated with the conversion of innovative effort into patents. A distribution of shocks estimated using small numbers of patents will thus exhibit greater variance than a distribution of shocks estimated using large numbers of patents. In the current setting, this will result in overly conservative inference because far fewer patents are associated with the control units than with the United States.

Appendix Figure A.3 displays unadjusted, country-level changes in medical equipment's share of each country's USPTO-granted patents. Panel A shows that U.S. patenting shifted towards medical equipment by 1.2 percentage points from its average from 1963-1968 to its average from 1969-1979. This exceeds the increases taking place in any of the foreign countries, whose patent-weighted average change was just over 0.1 percentage point. The remaining panels show that, looking across the technological subcategories that contribute to the medical-equipment aggregate, the U.S. had the largest increase in surgical-equipment patenting, the second largest increase in patenting in diagnostic equipment, and is in a pack at the top of the distribution of changes in miscellaneous medical-equipment patenting. Because there are only 9 control units, however, it is difficult to feel confident that their changes fully characterize the distribution of shocks to which these units were exposed.

Appendix Figure A.4 shows results from synthetic-control estimation. The figure shows the distribution of placebo treatment effects obtained when assigning treatment status to each of the control-group countries/units individually. The true synthetic control estimate, in which the United States is appropriately declared the treatment unit, is 1 percentage point. This far exceeds the mean of the 9 placebo estimates, which is quite close to 0. As with the raw changes shown in Figure A.3, the true estimate

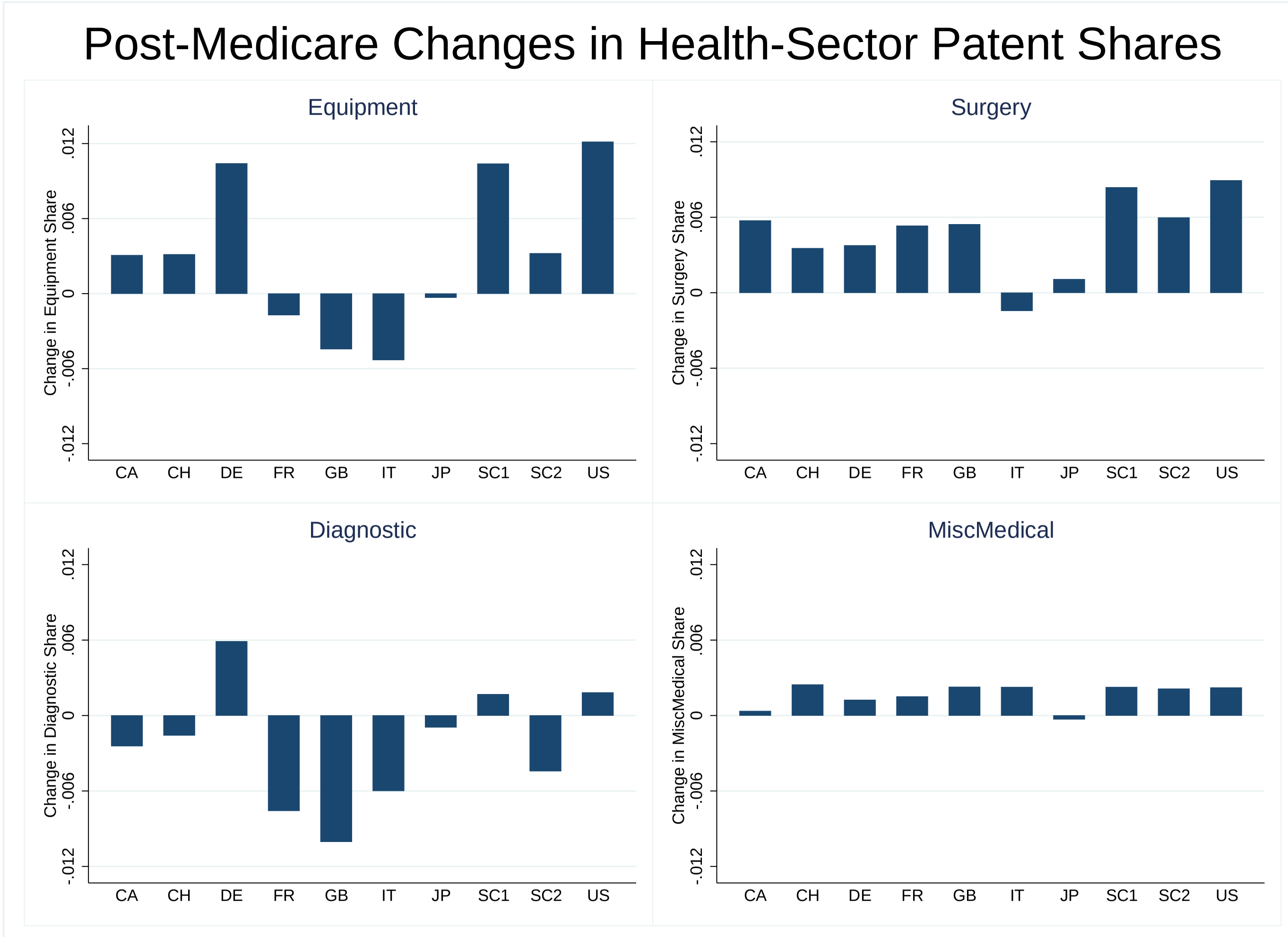

Figure A.3: **Post-Medicare Changes in Health-Sector Patent Shares:** Series were constructed by the author using data from the NBER Patent Database (Hall, Jaffe, and Trajtenberg, 2001). Surgery (sub-category 32), Diagnostic (sub-category 44), and MiscMedical (sub-category 39) sum to Equipment. Changes are constructed as the change in each country's average medical equipment share from 1963-1968 to 1969-1979. CA corresponds to Canada, CH to Switzerland, DE to Germany, FR to France, GB to Great Britain, IT to Italy, JP to Japan, SC1 to an aggregate of all countries with fewer than 15,000 patents in the entire database, SC2 to an aggregate of countries with between 15,000 and 30,000 patents in the entire database, and US to the United States. All patents in the NBER Patent Database over the relevant time period are incorporated into the figure.

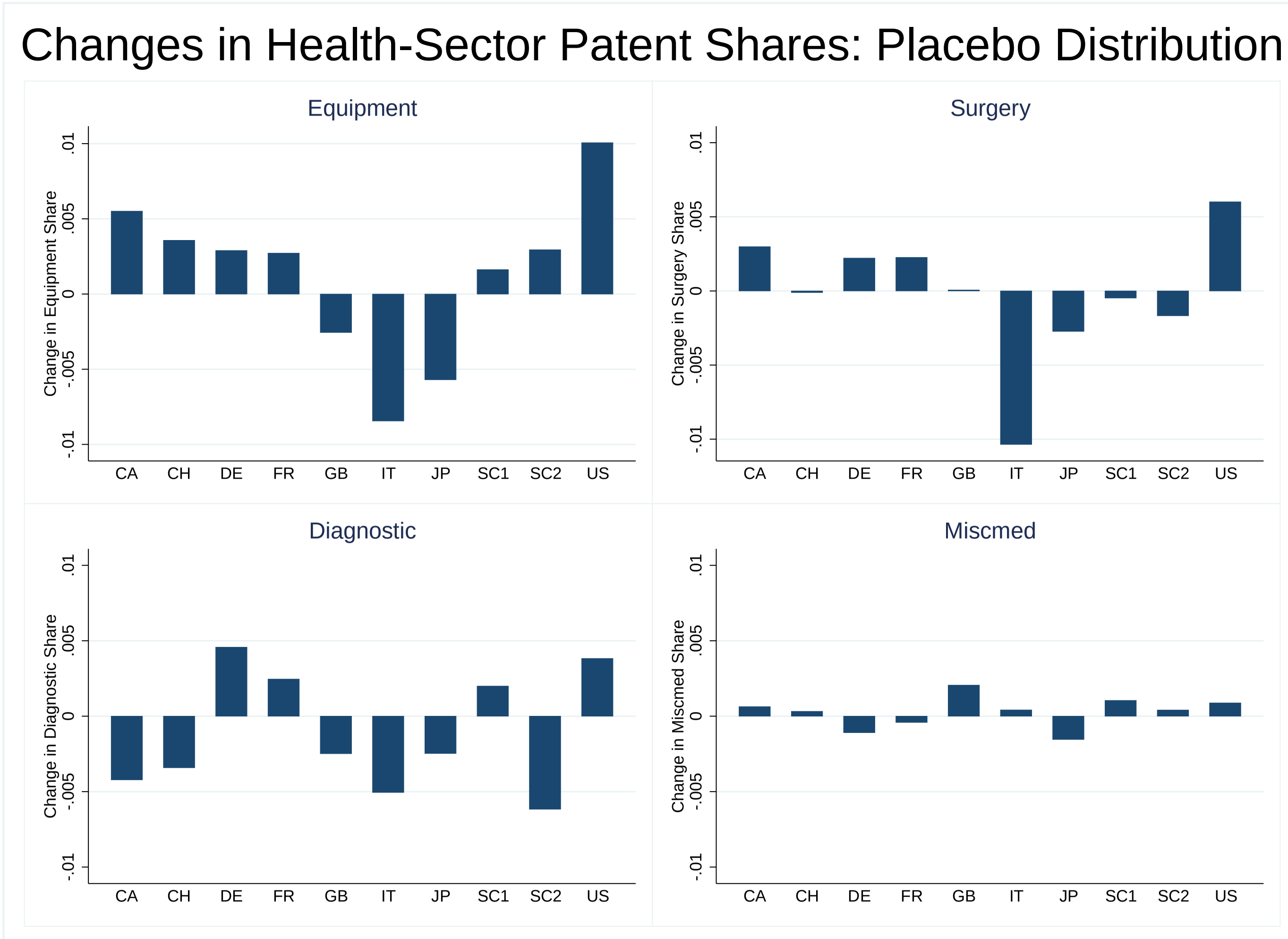

Figure A.4: **Synthetic Control Placebo Estimates of Post-Medicare Changes in Health-Sector Patent Shares:** Series were constructed by the author using data from the NBER Patent Database (Hall, Jaffe, and Trajtenberg, 2001). Each bar presents an estimate of the relative change in medical-equipment patents (from 1963-1968 to 1969-1979 for the indicated country relative to other countries. The estimates are, in each case, relative to a synthetic control constructed by re-weighting the remaining countries to match the levels and changes in the "treatment" country's pre-Medicare medical-equipment share. Estimates for all countries other than the United States can thus be viewed as placebo estimates, while the estimate for the United States is an estimate of the effect of Medicare on Medicaid on patenting by U.S.-based innovators relative to foreign innovators. The full list of country acronyms is described in the note to Figure A.3.

exceeds all placebo estimates, in this case by a moderately large margin. Across the sub-categories of medical equipment, the true synthetic control estimate is the largest for surgical equipment, second largest for diagnostic equipment and third largest for miscellaneous medical equipment.[29] The economic magnitude of the true estimate continues to look substantial relative to the placebo estimates. Nonetheless, it remains difficult to assess what constitutes a reasonable estimate of the underlying distribution of idiosyncratic shocks to the medical equipment patent share.

As suggested by Abadie and Hainmueller (2010), I use the panel aspect of the data to generate a fuller characterization of the relevant distribution of shocks. Specifically, I construct a distribution that describes changes in the control units' medical equipment shares relative to the contemporaneous changes experienced by the remaining sample units. That is, I characterize the shock associated with country j in period t as

$$\text{Med. Shock}_{j,t} = \triangle\text{Med. Share}_{j,t-(t-1)} - \frac{1}{N-1}\sum_{s\neq j}\triangle\text{Med. Share}_{s,t-(t-1)}, \tag{8}$$

where N is the total number of countries in the sample. For the observations used to construct this distribution to be plausibly independent, their base periods must be non-overlapping. I thus implement this approach with periods describing changes from 1963-1968 to 1969-1979, 1969-1974 to 1975-1975, from 1975-1979 to 1980-1989, and from 1980-1985 to 1986-1995.

I report the distribution of Med. $\text{Shock}_{j,t}$ in Figure A.5. The true US estimate of 0.0102 is illustrated by the dashed black line. The mean of the distribution of shocks is -0.001 while the standard deviation is 0.005. Among the 36 shocks in the distribution, one is marginally larger than the true US estimate. Using the "permutation test" style

[29]Note that the estimates associated with the sub-categories do not add to one because the synthetic control procedure is re-run in each case, generating new sets of weights across the potential "donor" units in the control group.

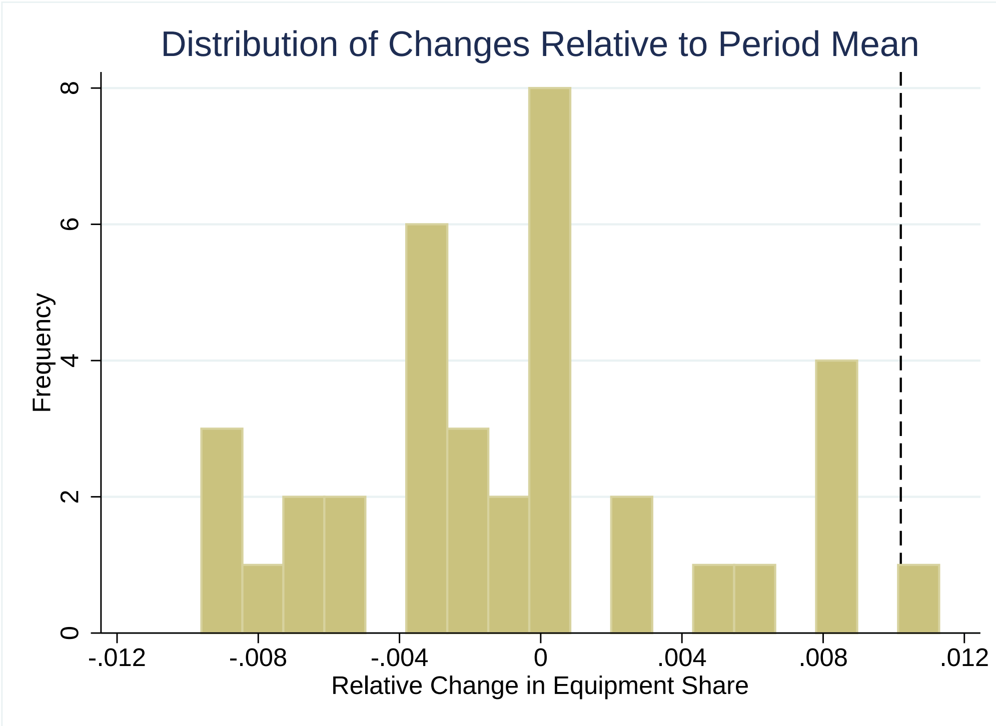

Figure A.5: **Distribution of Relative Changes in the Medical Equipment Share:** The figure shows the distribution of shocks defined by Medical Equipment Shock$_{j,t}$ $=$ $\triangle$Medical Equipment Share$_{j,t-(t-1)}$ $-$ $\frac{1}{N-1}\sum_{s\neq j}$ $\triangle$Medical Equipment Share$_{s,t-(t-1)}$. The time periods describe changes from 1963-1968 to 1969-1979, 1969-1974 to 1975-1975, from 1975-1979 to 1980-1989, and from 1980-1985 to 1986-1995. The true point estimate of 0.0102, associated with the change in United States from 1963-1968 to 1969-1979, is illustrated by the vertical, dashed black line.

of inference, the true estimate would be distinguishable from 0 at the conventional 0.05 level. As emphasized above, the shocks in the figure's distribution are constructed with far less patent data than the US point estimate. Consequently, the dispersion of the resulting distribution is overstated relative to the distribution of interest and inference will tend to be overly conservative.

Appendix 3: Calibrating the Effect of U.S. Insurance Expansions on Health Spending Growth

This appendix works through a calibration of the effect of insurance-induced technological development on the growth of U.S. health expenditures. Its first subsection presents a straightforward accounting framework for decomposing increases in health expenditures across several contributing forces. Its second subsection presents a calibration of the role of each force. The calibration draws on the existing literature in addition to the current paper's empirical results.

An Accounting Framework for Characterizing the Drivers of Health Spending Growth

Real per capita health spending, H, can be described as the product of a per-unit cost of care, P, and an average quantity of care consumed per person, Q. The average quantity per person can, in turn, be described illustratively as the product of the fraction of individuals, f, who can benefit from existing health-care treatments and technologies and the quantity of care, q, consumed by each of these individuals.

Our current interest is in the long-run effect of health insurance expansions on health care spending. This includes both its static impact on desired levels of consumption at a given state of technology and its dynamic impact on the treatments available at each point in time. I summarize insurance by the average coinsurance rate, c, faced by health care consumers. Demand at a point in time is $q_t = q(c_t)$. I write the state of the technical frontier as $f_t = f(t) + f_{\bar{c}}(\bar{c}_t)$, where $\bar{c}_t = \sum_{i=0}^{t} \lambda_i c_i$ is a weighted average of the current and past coinsurance rates. The term $f(t)$ describes a counterfactual, secular advance of health-technologies in the absence of changes in insurance arrangements. Establishing such a counterfactual was a principal aim of this paper's empirical work. That the remainder, insurance's dynamic effect, depends on the history of coinsurance rates reflects both that innovation does not occur instantaneously and that past innovations may remain relevant to the current technical frontier for some period of time.[30] At a point in time, health spending per capita can thus be expressed as:[31]

$$H_t = P_t q(c_t)[f(t) + f_{\bar{c}}(\bar{c}_t)]. \tag{9}$$

Differentiating per capita health expenditures with respect to time yields the following expression:

$$\frac{dH}{dt} = \frac{dP}{dt} fq + Pfq' \frac{dc}{dt} + Pq[\frac{df(t)}{dt} + f_{\bar{c}}' \frac{d\bar{c}_t}{dt}]. \tag{10}$$

In this accounting framework, changes in health expenditures per capita can be decomposed into 4 pieces. The first, $\frac{dP}{dt} fq$, reflects changes in input costs and productivity, including administrative loads. The second, $Pfq_c' \frac{dc}{dt}$, is the static effect of insurance ex-

[30]Expectations of future arrangements are relevant as well, and are implicitly assumed here to be driven by the past (Weisbrod, 1991).

[31]I have assumed away any effects of insurance arrangements on the per unit cost of care. I rule out one source of such effects to focus attention the long run. Large, short-run declines in coinsurance rates could drive up the per unit cost of care by increasing demand on a horizon over which the supply of physicians and nurses does not have time to adjust. I purposefully focus attention on a long run over which the labor market is in equilibrium. Insurance arrangements could also affect per unit costs by inducing cost-saving productivity advances. While such advances are clearly important, I follow Weisbrod in emphasizing that 20th century insurance expansions were largely associated with cost-plus financing arrangements, which do not provide incentives for cost-reducing changes in technology. Developments of this sort have not been in short supply, but are appropriately considered to be part of the counterfactual evolution of the per unit cost of care. A striking health-sector example involves the productivity revolution in diagnostic imaging with CT scanners as analyzed by Trajtenberg (1989, 1990b).

Given the limited role of consumers in medical decision making (Arrow, 1963) this accounting framework may appear to place an excessive emphasis on the role of demand. The quantity per patient, $q(c_t)$, need not be viewed solely as a reflection of consumer-driven demand, however; it could also be written as being a function of the system of provider reimbursements. Reflecting the prevailing reimbursement systems of the mid-to-late 20th century, I implicitly assume cost-plus reimbursement as a constant feature of the environment. Importantly, within a stable reimbursement environment, quantities will increase as cost sharing falls even if one models patients as passively accepting the recommendations their physicians. So long as physicians act, at least partially, as agents of their patients, their supply curves will have negative slopes with respect to *their patients'* out-of-pocket price.

pansions on demand for care. The remainder of any increases in spending are captured by the pieces of equation (4) that involve technical advances. This paper's empirical work informs a division of this remainder between the secular, counterfactual advance of technology in a stable insurance environment, $Pq\frac{df(t)}{dt}$, and the dynamic effect of insurance expansions, $Pqf'_{\bar{c}}\frac{d\bar{c}_t}{dt}$.

Estimating the Dynamic Effect of Insurance Expansions on U.S. Health Expenditures

This section uses the above accounting framework to estimate the contribution of insurance's dynamic effects to the growth of U.S. health expenditures. Panel A of Table A.10 presents the inputs used for my calibration of the effect of non-technological factors. The total increase in real per capita spending in hospitals, physicians' offices, and other clinical settings over the last half century was roughly $4,200 (from a base of roughly $700 in 1960 to $4900 in 2010). Estimates from Cutler and Ly (2011) and Pozen and Cutler (2010) suggest that $616 of this increase, or 15 percent, may be attributable to changes in administrative costs.[32] Newhouse (1992) highlights difficulties in attributing changes in spending to other aspects of per-unit cost like physician salaries. In short, it is difficult to disentangle prices and quantities since relatively high physician incomes (both historically and across countries) are also associated with the performance of relatively skill-intensive medical procedures. I follow Newhouse in not attributing spending growth to such factors.

I next calibrate the potential role of insurance's static effect on demand for care. An initial estimate of $335, or 8 percent, comes quite directly from calculations by Manning

[32]The estimate comes from a comparison of administrative costs in the United States and Canada. Absent reliable historical information on administrative costs in the United States, I essentially take current administrative costs in the relatively streamlined Canadian system as an estimate of U.S. administrative costs prior to the advance of insurance complexity over the last half century.

Table A.10: **Calibration of the Dynamic Effect of Insurance on Spending in Hospitals and Physicians' Offices**

Total Growth to Explain	\$4,197	National Health Expenditure Data
Panel A: Non-Technological Factors		
Spending Per Unit of Care	\$616	Cutler and Ly (2011); Pozen and Cutler (2010)
Small Static Demand Effect	\$335	Manning et al. (1987); Finkelstein et al. (2012); Newhouse (1992)
Large Static Demand Effect	\$1,006	Above plus Finkelstein (2007)
Panel B: Technology Residual		
	Small Static Effect	Large Static Effect
Technology Residual	\$3,246	\$2,576
Panel C: Scenarios for Allocating Residual between Counterfactual Technological Advance and the Dynamic Effect of Insurance		
Counterfactual Scenario	Due to Insurance	Features of Scenario
Scenario A:	30%	Counterfactual of non-European innovators; only recent innovations matter.
Scenario B:	17%	Counterfactual of non-European innovators; two decades of innovations matter.
Scenario C:	25%	Counterfactual of all foreign innovators; only recent innovations matter.
Scenario D:	12%	Counterfactual of all foreign innovators; two decades of innovations matter.
Panel D: Estimated Contribution of Insurance's Dynamic Effect		
Counterfactual Scenario	Small Static Effect	Large Static Effect
Scenario A:	\$978	\$776
Scenario B:	\$562	\$446
Scenario C:	\$823	\$653
Scenario D:	\$375	\$297

Note: Author's calculations using sources described in the table and results presented earlier in this paper. Further details of the calibration exercise can be found in the text.

et al. (1987). As summarized by Newhouse (1992), the Rand health insurance experiment found that "the effect of moving from an average coinsurance rate of 33 percent to a coinsurance rate of zero at a point in time is roughly a 40 to 50 percent increase in demand." The described reduction in coinsurance rates is quite similar to the decline in the out-of-pocket share for spending in hospitals and physicians' offices from 1960 to 2010, which was from 36 percent to 6 percent.[33] The moderate demand elasticities from the Rand and Oregon health insurance experiments are thus consistent with a modest role for static demand effects as drivers of increasing health expenditures. Finkelstein (2007) notes that large-scale insurance expansions may explain a larger share of spending growth than these estimates imply. Specifically, large scale expansions may have general equilibrium effects on the way hospitals and physicians organize their practice of medicine. In an alternative estimate of insurance's static effect, I allow such general equilibrium impacts to triple its size to $1,006.[34]

The calibration leaves a residual per capita spending increase of either $3,200 or $2,600 (77 or 61 percent of the total) to be explained by advances in health-care technology. Consistent with analysis by Newhouse (1992), Cutler (2004), and Chandra and Skinner (2012), these estimates attribute the lion's share of the rise in health expenditures to the advance of health technologies. Panels A and B of Figure A.6 provide suggestive evidence that such an allocation is reasonable, as they show tight relationships between expansions in health sector patents as shares of total patents and expansions in health spending as a share of GDP. Health spending in hospitals, physicians' offices, and other

[33]Applying a demand elasticity of -0.2 to the change in price of roughly 180 log points produces a similar, but somewhat smaller estimate.

[34]This is moderately smaller than Finkelstein's (2007) preferred calculation, which suggests that the static demand effect may account for as much as half of the increase in hospital spending. While general equilibrium effects are undoubtedly important, Finkelstein's estimate are sufficiently larger than all others that use of an intermediate value may be appropriate. Additionally, and consistent with industry-studies of medical-equipment innovation, this paper's results imply a short lag between Medicare's introduction and increases in medical-equipment innovation. Finkelstein's estimates of Medicare's effect on health spending through 1970 will thus incorporate, in small part, some effects of insurance-induced innovation.

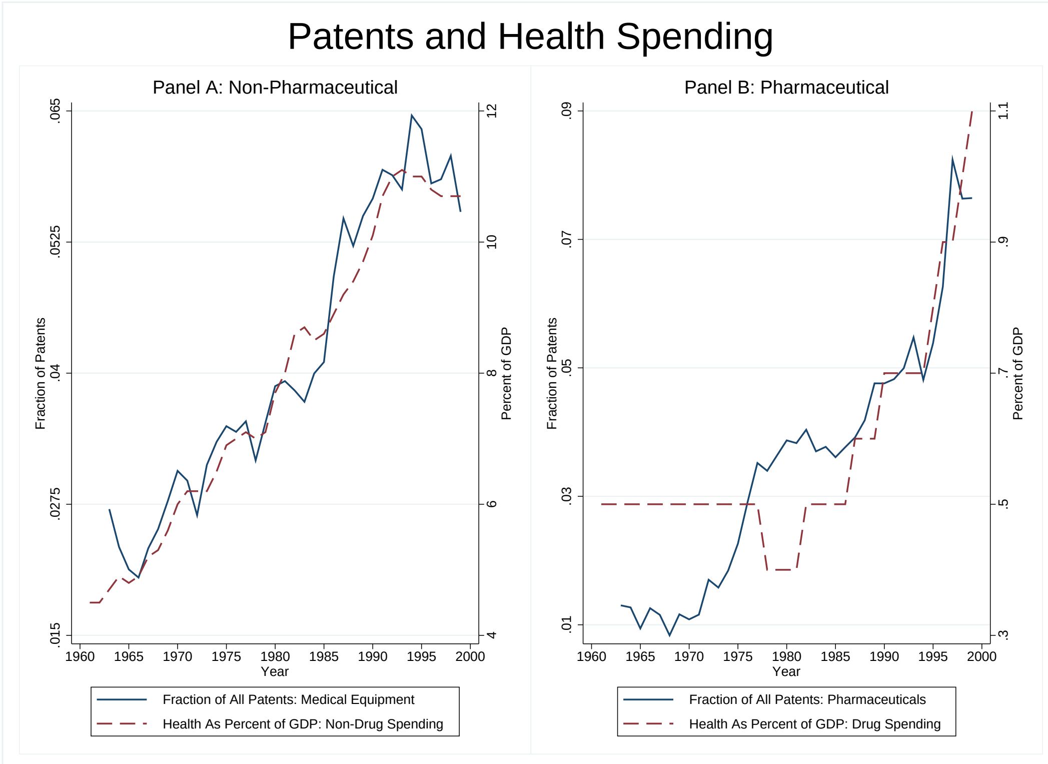

Figure A.6: **US Health Spending and Health-Sector Patenting Over Time:** The patent series were constructed by the author using data from the NBER Patent Database (Hall, Jaffe, and Trajtenberg, 2001). A description of the system for classifying Medical Equipment and Pharmaceutical patents can be found in the note to Table 1. The spending series were calculated using the historical National Health Expenditure data reported by the Center for Medicare and Medicaid Services (CMS). The spending series in Panel A describes all health spending that takes place in hospitals, physicians' offices, and other clinical settings. The spending series in Panel B describes health spending on pharmaceuticals only.

clinical settings moves quite tightly with medical-equipment patenting. Drug spending escalated significantly during the biotechnology patenting boom of the 1990s.

Table A.10's Panel C presents a range of estimates of the fraction of the residual health-spending growth that can be explained by the dynamic effect of insurance on incentives for innovation. The range reflects the possibilities implied by permutations of two coarse assumptions. The assumptions are required for a) estimating the counterfactual path of U.S. medical-equipment innovation that would have occurred in a world without its insurance expansions and b) translating this counterfactual path of innovation into current health expenditures.

I estimate the counterfactual level of medical-equipment innovation in two ways. The first takes the counterfactual to be the path of innovation among the non-English speaking, non-European countries. The second, which produces more conservative estimates of the effect of U.S. insurance expansions, takes the counterfactual to be the path of innovation among all foreign patenters. In both cases I assume that the United States accounts for half of global medical-equipment innovation. Worldwide patent data from the OECD show this to have been the U.S. share of all medical-equipment patents during the last years of the 20th century. U.S.-based innovators account for closer to 68 percent of all medical-equipment patents (61 percent of all patents) in the NBER Patent Database, but not all foreign health innovations are patented with the USPTO.

I also employ two assumptions for translating counterfactual paths of innovation into current health expenditures. The first is that only the 5 most recent years of innovation continue to affect current health expenditures. The second is that innovation from the prior two decades affect current health expenditures.

Scenario A takes the counterfactual to be the path innovation among the non-English speaking, non-European countries. It further assumes that only the last 5 years of innovation impact current health spending. In this scenario, I estimate that the dynamic effect of U.S. insurance expansions increased global medical-equipment innovation by 30 percent. When the static effect of insurance on health-care consumption is assumed to be relatively small, the results imply that insurance's dynamic effects explain about $1,000 of the $4,200 increase (nearly 25 percent) in real per capita spending at hospitals and physicians' offices. When the static effect of insurance is allowed to be relatively large, the dynamic effect can account for nearly $800 of the increase. Replacing the counterfactual with a counterfactual of patenting in all foreign countries reduces these estimates by about one sixth.

Assuming that a full two decades of medical-equipment patenting influence current health-care spending results in relatively conservative estimates of the dynamic effect of insurance. This assumption reduces the estimates of U.S. insurance expansions' contribution to global medical-equipment innovation by roughly 13 percentage points. Given the tight and nearly contemporaneous tracking of the series for medical-equipment patenting and spending in hospitals and physicians' offices (Figure A.6), this assumption may be less realistic than the assumption that current spending is driven by relatively recent innovations.

The estimates in Table A.10 highlight the high level of uncertainty associated with translating documented shifts in patenting activity into changes in health care spending. Additional considerations provide plausible arguments for either increasing or decreasing one's preferred estimate of the effect of U.S. insurance expansions on medical spending. Concern that the estimated shifts in patenting overstate shifts in impact-adjusted innovation, for example, would be cause for a downward revision. Concern that the counterfactuals fail to adequately account for effects of U.S. markets on foreign innovation would be cause for an upward revision.