The Relationship Between Technology Availability And Health Care Spending

Attempts to address technology availability and rising costs could end up badly misguided if implications for quality are not considered.

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ABSTRACT: We analyze the relationship between the supply of new technologies and health care utilization and spending, focusing on diagnostic imaging, cardiac, cancer, and newborn care technologies. As anticipated by previous research, increases in the supply of technology tend to be related to higher utilization and spending on the service in question. In some cases, notably diagnostic imaging, increases in availability appear associated with incremental utilization rather than substitution for other services. Policy efforts to assess and manage the availability of new technologies could benefit society where the additional spending produced by new services is not associated with strong quality improvements.

It is commonly accepted that advances in technology have been one of the most important drivers of health care spending growth over the past several decades, if not the most important driver.[1] As costs continue to rise, interest in policy efforts that would address spending growth by influencing technology advancement is a natural response.[2]

Technology advancement encompasses many costly activities, from basic science to product development to adoption, making the entirety of the relationship between technology advancement and spending multifaceted and sometimes difficult to understand clearly. One point at which many of the relevant issues crystallize and are frequently discussed is the placement of new equipment into service. This paper addresses questions of technology and spending from this

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perspective, reporting on a series of analyses that investigate the relationship between the availability of specific technologies and equipment, on the one hand, and health care use and spending, on the other. We consider a range of technologies, from outpatient diagnostic imaging to inpatient radiation oncology facilities, linking measures of technology supply to spending for both elderly and nonelderly populations and examining whether changes in availability are related to changes in use and spending.

We report on relationships between technology availability and spending at several levels, from spending on the particular technology in question to overall health care spending. Building on previous literature, our results highlight important relationships between the availability of individual technologies and spending. Even taken individually, the availability of some specific technologies is associated with sizable spending growth. Our results also highlight the fact that measured relationships can vary when spending at different levels is assessed. While our results suggest that individual technologies are closely related to specific types of spending, they are also consistent with the view that technological change more broadly has an even stronger relationship with overall spending.

It is important to stress that costly advances in medical technology need not be "bad" for society if they produce comparable or greater benefits. While some have questioned the extent to which high medical spending in the United States has produced benefits in a broad sense, other recent work has suggested that some technological advances have produced important net benefits for society even after their substantial costs are taken into account.[3]

While recognizing the difficulty of cleanly identifying all of the causal relationships in this area, we hope that these analyses reinforce important relationships that are part of the U.S. health care system and should continue to be part of policy discussions.

Analyzing Health Care Technology And Spending

We conducted a series of analyses that related a range of measures of technology availability to associated spending measures.[4] While in principle health care technologies can encompass everything from new strategies for organizing data to scientific advances in genetics to hospital equipment, here we examine the effects of infrastructure-intensive capabilities involved in diagnostic imaging and in the treatment of cardiac patients, cancer patients, and newborns. Specifically, we looked at the effects of changing availability of magnetic resonance imaging (MRI) and computed tomography (CT) scanners, cardiac catheterization facilities, percutaneous transluminal coronary angioplasty (PTCA) facilities, coronary artery bypass graft (CABG) facilities, hospitals with implantable cardioverter defibrillator (ICD) capabilities, cardiac intensive care units (CICUs), neonatal intensive care units (NICUs), radiation oncology facilities, and positron emission tomography (PET) scanners. We compiled measures of the availability of these services by metropolitan statistical area (MSA) by year for the period 1998–2001 using American Hospital Association (AHA) surveys, Medicare claims, and data on diagnostic imaging from Verispan LLC.

We aimed to select technologies that have the potential to be important cost drivers because they are themselves costly or are used in the treatment of patients with serious and expensive conditions.[5] We also are constrained to examine technologies for which appropriate data are available during the study time period.

Nationwide, the availability of most of these technologies has risen over time, particularly diagnostic imaging. Moreover, the extent of changes in technology availability varies across MSAs: Some areas expand and contract over time, and some expand or contract faster than others. Exhibits 1 and 2 illustrate these changes over time and across states, respectively.

We relate changes in the availability of the technologies to measures of spending on those technologies, related technologies, and health care in general. We examine spending patterns in the commercially insured population under age sixty-five using data from a large national group health plan that has approximately three million covered lives per year from all fifty states. Ninety-four percent of these people are in preferred provider organization (PPO)–like arrangements, with 6 percent in point-of-service (POS) plans. Benefit designs do not vary

EXHIBIT 1
Availability Of Selected Technologies, 1999 And 2001

	Average number per state	
Technology	**1999**	**2001**
Freestanding CT units[a]	19.0	27.0
Facilities with freestanding CT[a]	17.6	25.6
Hospitals with CT[b]	42.8	42.0
Freestanding MRI units[a]	27.5	44.7
Facilities with freestanding MRI units[a]	24.0	37.8
Hospitals with MRI[b]	30.5	31.4
Hospitals with CABG[c]	19.2	19.4[d]
Hospitals with cardiac catheterization[c]	38.7	38.5[d]
Hospitals with ICD[c]	15.6	15.9[d]
Hospitals with PTCA[c]	21.2	21.8[d]
Hospitals with CICU[b]	22.0	21.9
Hospitals with NICU[b]	14.4	14.8
NICU beds[b]	279.0	285.0
Hospitals with radiation oncology facility[b]	18.2	19.1
Hospitals with PET[b]	4.0	7.5

SOURCES: See below.
NOTES: CT is computed tomography. MRI is magnetic resonance imaging. CABG is coronary artery bypass graft. ICD is implantable cardioverter defibrillator. PTCA is percutaneous transluminal coronary angioplasty. CICU is cardiac intensive care unit. NICU is neonatal ICU. PET is positron emission tomography.
[a] Verispan (1999–2001).
[b] American Hospital Association (AHA) annual surveys (1999–2001).
[c] Centers for Medicare and Medicaid Services (Medicare) (1999–2000).
[d] Data for 2001 are not available; data shown are for 2000.

EXHIBIT 2
Geographic Variation In Technology And Outpatient Spending, 1998–2001

	Number of freestanding MRI units[a]		Number of hospitals with PTCA[b]		Percent change in outpatient spending for commercial plan population, 1999–2001		
State	2001	Percent change, 1999–2001	2000	Percent change, 1998–2000	Overall population	Diagnostic imaging population	Cardiac care population
US	45	133	22	6	23	19	21
AK	2	100	2	0	33	24	24
AL	36	80	24	9	14	11	18
AR	10	100	18	29	18	18	14
AZ	48	71	26	8	28	26	28
CA	234	32	123	4	27	22	20
CO	34	113	19	6	30	23	36
CT	25	108	7	0	24	12	3
DC	5	400	5	25	20	15	21
DE	15	114	1	−50	8	8	24
FL	292	79	60	3	18	17	20
GA	57	111	16	−6	22	15	18
HI	0	0	5	0	15	2	−20
IA	7	133	16	14	23	17	30
ID	6	500	3	0	21	15	10
IL	86	72	61	9	17	9	15
IN	42	110	33	6	23	19	30
KS	17	89	14	0	29	26	42
KY	27	93	18	6	24	20	12
LA	25	79	41	8	22	17	28
MA	43	39	14	8	30	22	27
MD	66	38	12	33	20	15	12
ME	26	1,200	3	50	27	20	7
MI	21	40	28	0	17	10	−1
MN	37	28	16	14	25	21	16
MO	34	143	36	0	21	18	18
MS	7	133	14	−13	25	19	15
MT	4	33	5	0	16	9	13
NC	34	79	24	4	25	22	22
ND	2	100	8	14	7	8	4
NE	3	200	10	0	30	21	14
NH	3	0	6	20	31	24	35
NJ	133	46	17	21	29	24	25
NM	7	40	5	0	28	27	46
NV	19	27	9	−10	35	33	45
NY	263	25	33	3	18	11	8
OH	85	89	45	10	26	18	24
OK	13	63	18	29	25	21	29
OR	33	50	12	0	22	19	30
PA	143	47	57	2	20	15	7
RI	10	900	2	0	37	20	23
SC	25	257	15	15	21	17	9
SD	2	0	3	0	26	24	5
TN	25	25	29	12	16	13	16
TX	175	88	102	1	22	20	19
UT	6	200	12	20	21	18	21
VA	29	53	23	5	20	16	20
VT	0	0	1	0	29	29	27
WA	35	59	27	8	25	23	26

EXHIBIT 2
Geographic Variation In Technology And Outpatient Spending, 1998–2001 (cont.)

	Number of freestanding MRI units[a]		Number of hospitals with PTCA[b]		Percent change in outpatient spending for commercial plan population, 1999–2001		
State	2001	Percent change 1999–2001	2000	Percent change 1998–2000	Overall population	Diagnostic imaging population	Cardiac care population
WV	18	100	26	4	22	16	6
WI	5	150	5	0	28	21	39
WY	5	150	2	0	36	34	79

SOURCES: See below
NOTES: US is the U.S. average. MRI is magnetic resonance imaging. PTCA is percutaneous transluminal coronary angioplasty. Commercial plan population is nonelderly population, and spending is per member per month.
[a] Verispan (1999–2001).
[b] Centers for Medicare and Medicaid Services (Medicare) (1998–2000).

substantively across areas. We also examine spending in the Medicare population, using data on a 10 percent national random sample of senior fee-for-service (FFS) Medicare beneficiaries. For spending measures derived from both sources, we use total paid claim amounts plus any required patient copayments, deductibles, or coinsurance amounts for inpatient, outpatient, and physician claims. Because of data limitations, we do not include pharmaceuticals in any of our spending measures. Where applicable, our spending measures include both professional and facility spending.

There is growth in spending over time, and there is considerable variation in spending in different parts of the country. Exhibit 2 also illustrates the variation in the growth in outpatient spending for the entire commercially insured population we study, for patients with any diagnostic imaging claims and for patients with cardiac diagnoses, respectively.[6]

We conducted a series of regression analyses that examined the relationship between the amount of spending for different services and the availability of technology. In essence, these regression models were designed to ask whether spending increased more quickly in areas that had faster growth in the technologies than in areas with less rapid growth.[7] The results provide statistical evidence about the direction, size, and strength of any relationship between technology and spending. To illustrate the results, we computed the predicted size of the spending change associated with an increase in the availability of a technology by one unit per million population.[8]

It is tempting in analyses such as these to interpret the relationships between technology availability and spending as causal. It is, after all, plausible that the availability of more technology in an area causes more use of that technology in ways not unlike those by which the supply of other health care personnel is sometimes hypothesized to create its own demand. However, as in most studies of this type, we cannot rule out the possibility that unobserved confounders lead to observed relationships that are not causal. For example, if the populations of some areas have stronger preferences for using health care, then their general demand could drive both technology availability and spending. We attempt to control for important potential confounders, including state fixed effects, to mitigate this difficulty, but we cannot entirely eliminate it.

Three Relationships Between Technology Availability And Spending

■ **Technology-specific spending.** We begin by asking whether more availability of a given technology is associated with higher use of and more spending on that technology. Exhibit 3 summarizes key findings—specifically, the estimated percentage change in use of or spending on the given technology that our results indicate is associated with an increase of one unit per one million population. To illustrate, Exhibit 3 indicates that an increase of one freestanding (that is, nonhospital) MRI unit per million population is associated with an increase of 0.93 percent in per beneficiary spending on outpatient MRI among this commercially insured population.

The general pattern in our results is that more availability is associated with higher use and more spending. For diagnostic imaging, for both the commercial and Medicare plans, more availability of freestanding MRI facilities is associated with a higher number of outpatient MRI procedures per population and higher spending on outpatient MRI.[9] Taking the effects on the commercial and Medicare populations together and extrapolating based on average MRI spending, the percentage changes in spending we observe would mean that a one unit increase in the number of freestanding MRI units per million people is associated with an increase of about $32,900 per million beneficiaries per month, or approximately $395,000 per year.

Exhibit 3 also reports results from parallel analyses focusing on freestanding CT availability. Increases in freestanding CT units are significantly associated with increases in use of and spending on outpatient CT for both commercial plan and Medicare beneficiaries.

We next studied five technologies and capabilities that have roles in caring for cardiac patients. When we examine effects on use, for each technology we count the number of outpatient procedures plus the number of hospitalizations in which a given procedure was performed, among patients with a cardiac diagnosis. When we study spending, we compute the amount of spending on these procedures and hospitalizations among the same population.

In the commercial plan data, increases in the availability of cardiac catheterization labs are associated with increases in cardiac catheterization use and spending. Adding one hospital with a cardiac catheterization lab per million population is associated with an increase of 2.2 percent per beneficiary in the number of cardiac care hospitalizations that involve a cardiac catheterization procedure,

EXHIBIT 3
Relationship Between Technology Availability And Technology-Specific Use And Spending, 1998–2001

	Percent change			
	Commercial plan		Medicare	
Technology availability per million population	Tech-specific use	Tech-specific spending	Tech-specific use	Tech-specific spending
Freestanding MRI units[a]	0.93**	0.10**	0.21**	1.99**
Freestanding CT units[a]	1.26**	0.16**	0.42**	1.15**
Hospitals with cardiac catheterization[b]	1.21**	0.35	0.14**	−0.36
Hospitals with PTCA[b]	0.92	0.28	1.24**	1.49**
Hospitals with CABG[b]	1.17	0.15	1.13**	0.99
Hospitals with ICD[b]	0.32	0.02	4.00**	5.90**
Hospitals with CICU[c]	1.16	0.15	2.40**	3.06**
Hospitals with NICU[c]	2.56	0.42	–[d]	–[d]
NICU beds[c]	−0.04	−0.05	–[d]	–[d]
Hospitals with radiation oncology[c]	−4.45**	−0.22	−3.74**	−1.42**
Hospitals with PET in same MSA[c]	5.11	−0.05	–[e]	–[e]

SOURCES: See below.
NOTES: MRI is magnetic resonance imaging. CT is computed tomography. PTCA is percutaneous transluminal coronary angioplasty. CABG is coronary artery bypass graft. ICD is implantable cardioverter defibrillator. CICU is cardiac intensive care unit. NICU is neonatal ICU. Commercial population is nonelderly population. PET is positron emission tomography. MSA is metropolitan statistical area. Tech-specific use for diagnostic imaging is the total number of outpatient procedures for the given service. Tech-specific spending is outpatient spending for the given service. Tech-specific cardiac use measures the number of outpatient procedures plus the number of hospitalizations involving the service in question, among patients with a cardiac diagnosis. Tech-specific cardiac spending includes spending on outpatient services plus the total costs of hospitalizations that included these services, among patients with a cardiac diagnosis. Tech-specific cancer use is the number of outpatient services plus the number of hospitalizations involving the service among cancer patients. Tech-specific cancer spending includes spending on outpatient services plus the total costs of hospitalizations that included these services, among patients with a cancer diagnosis. Cancer patients are those with claims data evidence of having lung cancer, prostate cancer, colorectal cancer, breast cancer, ovarian cancer, or lymphoma/leukemia. Tech-specific use for newborns is the number of NICU days per newborn. Tech-specific spending is NICU spending among newborns.
[a] Verispan (1998–2001).
[b] Centers for Medicare and Medicaid Services (Medicare) (1998–2000).
[c] American Hospital Association (AHA) annual surveys (1998–2001).
[d] Not applicable.
[e] Unable to estimate because of low prevalence in the Medicare population.
** $p < .05$.

evaluated for the MSA with average availability of in-hospital cardiac catheterization. We observe relationships in the same direction for PTCA, CABG, ICD, and CICU measures, although the results are not statistically significant.

Results are stronger in the Medicare population. Greater availability of these technologies is significantly associated with higher use in all of the cases, and greater availability of PTCA, ICD, and CICU is associated with higher spending. The magnitudes of the relationships are relatively large. Evaluated at mean spending levels, adding one PTCA hospital per million population is associated with an increase in spending of about $1.3 million per 100,000 cardiac beneficiaries per year. Adding one ICD hospital per million population is associated with increases

"We find the strongest association between higher availability and more spending for freestanding diagnostic imaging."

in spending of about $1.1 million per 100,000 cardiac beneficiaries per year.

Results from analysis of the availability of NICUs and cancer care technologies produced less conclusive results, with limited statistical significance. These less-than-compelling findings could be related in part to the fact that there is comparatively less variation in the availability of these technologies during the research time period than was the case for cardiac and diagnostic imaging.

■ **"Category" spending and the potential for substitution.** An important component of the total effect of any technology on use and spending is the extent to which it substitutes for other technologies, reducing total utilization, or complements other technologies, tending to increase total utilization. We explored these relationships in several ways. First, we explored the relationship between expanding MRI availability and use of CT scanning. Although these are distinct technologies that can have distinct uses, one could expect MRI to act as a partial substitute for CT scanning. We estimated regressions similar to those above, examining the relationship between freestanding MRI and CT availability and outpatient CT use and spending. Our results show that increases in the availability of freestanding MRI, controlling for the availability of CT, are associated with increases in CT use. That is, this evidence does not suggest that MRI availability offsets CT use but rather seems to suggest the opposite.

Second, we investigated the potential for substitution between PTCA and CABG, two alternative treatments for patients with cardiac disease. In the commercially insured population, we did find evidence for substitution, in that higher availability of PTCA is associated with substantial reductions in use of and spending for CABG and vice versa. We also found higher CABG availability associated with lower PTCA use in the Medicare population. However, higher PTCA availability was associated with higher CABG use in this population.

Another way to study these effects is to consider the relationship between technology availability and spending in a broader category to which each specific technology pertains. For example, for freestanding MRI, we measure spending on diagnostic imaging procedures. For cardiac catheterization, we measure total spending on patients with cardiac conditions. These measures are designed to capture direct effects on spending as well as other indirect effects (for example, substitution). These analyses may be instructive, since they involve broader categories of spending than the technology-specific analyses discussed earlier, but the potential here for confounding is also greater. An additional issue is the relatively high correlation among many of our technology measures, so that the measured relationships might reflect not only the relationship between the availability of a specific technology and category spending, but also the relationships of other correlated technologies.

Exhibit 4 reports some results of these analyses. For diagnostic imaging category spending, we study total spending for outpatient MRI, CT, ultrasound, and x-ray procedures. In the commercial plan population, an increase of one unit per million in the availability of MRI equipment is associated with an increase of 0.33 percent in diagnostic imaging spending. This relationship is much larger than that observed for MRI spending alone, particularly noting that it is relative to the higher baseline spending level of diagnostic imaging spending rather than just MRI spending. Results for the Medicare population are consistent and somewhat larger. Results for CT availability are also similar.

For cardiac technologies, we examine category effects by studying total spending for patients with cardiac diagnoses. Here, increases in the availability of cardiac services are most often associated with reductions in total spending on patients with cardiac diagnoses. This pattern might suggest some substitution of the measured technologies for other services contemporaneously, or use of these services might tend to reduce use of other future services.

EXHIBIT 4
Relationship Between Technology Availability And Category and Total Spending, 1998–2001

	Percent change			
	Commercial plan		Medicare	
Technology availability per million population	Category spending	Total spending	Category spending	Total spending
Freestanding MRI units[a]	0.33**	0.58**	0.33**	0.01
Freestanding CT units[a]	0.50**	0.67**	0.73**	0.33**
Hospitals with cardiac catheterization[b]	0.07	0.81**	−0.28**	0.01
Hospitals with PTCA[b]	−0.42**	0.73**	−0.25**	−0.28**
Hospitals with CABG[b]	−0.84**	0.53**	−0.21**	−0.26**
Hospitals with ICD[b]	−0.14	1.05**	0.42**	−0.03**
Hospitals with CICU[c]	−0.40	−0.25**	−0.05	0.07
Hospitals with NICU[c]	−2.80	−0.20**	–[d]	–[d]
NICU beds[c]	−0.38	0.03**	–[d]	–[d]
Hospitals with radiation oncology[c]	−0.49	0.08	0.06	0.28**
Hospitals with PET in same MSA[c]	0.79	1.12**	2.39**	1.63**

SOURCES: See below.

NOTES: MRI is magnetic resonance imaging. CT is computed tomography. PTCA is percutaneous transluminal coronary angioplasty. CABG is coronary artery bypass graft. ICD is implantable cardioverter defibrillator. CICU is cardiac intensive care unit. NICU is neonatal ICU. Commercial population is nonelderly population. PET is positron emission tomography. MSA is metropolitan statistical area. Category spending for diagnostic imaging includes all spending on outpatient MRI, CT, ultrasound, and x-ray among the entire population. For cardiac, newborn, and cancer technologies, category spending is total spending on patients in the related category. Results are from models that include one technology at a time.

[a] Verispan (1998–2001).

[b] Centers for Medicare and Medicaid Services (Medicare) (1998–2000).

[c] American Hospital Association (AHA) annual surveys (1998–2001).

[d] Not applicable.

** $p < .05$.

For NICUs, we studied relationships between availability and total spending for newborns. The estimated relationship is negative but statistically insignificant. For cancer, we examined total spending for cancer patients. In the commercial plan population, neither of the technology-specific measures was significantly associated with category spending, although increases in PET availability are associated with higher category spending in the Medicare population.

■ **Total health care spending.** Finally, we examined total spending measures, which include all spending for all inpatient, outpatient facility, and physician services for all patients in an area. Although the high potential for confounding in an analysis of such high-level measures makes drawing causal conclusions difficult, this kind of analysis could be instructive to the extent that each of our individual technology measures can be construed as capturing at least partially the broader level of technology availability in an area. These results could then be instructive in light of previous work underscoring the importance of the overall association between technological advancement and spending (Exhibit 4).[10]

In the commercial plan population, greater availability of technologies is associated with higher total spending in all but two cases. These effects tend to be quite large, and much bigger than the technology-specific relationships reported in Exhibit 3. This pattern is consistent with the view that in addition to reflecting the availability of a specific technology, these measures also reflect an overall higher level of technology availability that is associated with higher spending. In the Medicare population, results are more mixed, with increases in the availability of many technologies associated with increased spending, although, notably, not for cardiac technologies.

Discussion

■ **Technology availability is associated with higher spending.** We find that increases in the supply of specific technologies are frequently associated with increases in use of and spending on those technologies. Although many studies have identified advances in technology broadly as a major driver of health spending, this study links the availability of specific technologies to higher use and spending.

There are, however, a number of important nuances that should be noted as one considers approaches to containing rising health care costs that might target new technologies. First, relationships are not the same across technologies. We find the strongest association between higher availability and more spending for freestanding diagnostic imaging. We find much less evidence of such a relationship for NICUs and cancer technologies. It need not be that the availability of every new technology will be associated with higher use and spending. Some technologies might be easily amenable to expansions in their use with higher availability, while for other technologies the opportunities for use might be relatively fixed, so more of the technology cannot drive use as easily.

Second, the effects of the diffusion of an individual technology on spending could be felt beyond use of and spending on that particular technology. New technologies that substitute for other services could themselves see increased spending but offset some of that with reductions in spending elsewhere. Or new technologies could complement other technologies and drive up use and spending in other areas as well. Although we did not attempt comprehensive analyses of these issues, our results suggest the potential for such a complementary effect for diagnostic imaging. Our analysis of cardiac services, however, suggests a potential substitution. One potential explanation concerns differences in the types of services and patients: It might be easier to increment diagnostic imaging procedures than cardiac procedures.

Third, prices may matter. In the commercially insured population we studied, a one-unit increase in the number of freestanding MRI machines per million is associated with a 0.93 percent increase in use of outpatient MRI but only a 0.10 percent increase in spending for it. This implies that prices for MRI are lower by about 0.83 percent in high-availability areas relative to low-availability areas, so that the effect of lower prices reduces the size of the relationship between availability and spending. Such a pattern is frequently observed in this commercially insured population. For some technologies, more availability could be increasing the amount of competition, leading to lower prices, although the potential for such an effect to produce meaningful impacts on spending could clearly vary across technologies. This effect, though, is not observed as commonly in the Medicare population, where the opposite pattern often occurs; this suggests that Medicare prices might be higher in areas with greater technology availability.

Fourth, context matters. Although our results for the commercial and Medicare populations are frequently similar, there are differences in the implied price dynamics just noted, and in other areas as well. This point highlights the fact that relationships identified for one population might not always hold for others. Differences across settings could arise for a number of reasons. In this case, for example, Medicare uses a relatively fixed pricing structure, whereas commercially insured patients are subject to a more flexible pricing structure.

As a general principle, these results should be viewed in the context of a long history of evidence suggesting that broad technology change is a key, perhaps the key, driver of health spending over time. In fact, our analyses of the relationship between our technology measures and overall spending are quite consistent with this evidence. Although we have examined only one specific aspect of technology expansion—growth in the supply of some new technologies—we believe that our results reinforce and amplify previous assessments of the importance of technological change and the need for continued attention to growth in technologies.

■ **Would reducing technology availability reduce spending?** Observing a relationship between greater technology availability and more spending, one is tempted to conclude that increases in technology availability cause increases in use and spending. It then requires but a small step to conclude that efforts to slow the

"The key question in evaluating increased use associated with new technologies is how the benefits compare to the costs."

rate at which new equipment is made available would slow spending growth. Such an interpretation is certainly plausible but warrants careful consideration, since other explanations are also possible, and the actual effect of policies will be nuanced.

Some previous research has associated increases in the availability of physicians and hospital beds in an area with increases in use of medical services, giving rise to the widely discussed, if not conclusively demonstrated, possibility that supply in some circumstances can create its own demand.[11] It seems possible that some of the technologies studied here could increase use through such a mechanism. If new equipment tends to be used once it is put in place, greater availability of technology could lead to use and spending that would otherwise not have occurred. Reductions in the availability of new technologies would then tend to reduce use of and spending for those technologies. (An important consideration, discussed below, is the extent to which the additional services produce important value for patients.)

It is also possible that associations between technology availability and spending arise for reasons that would not lead to the conclusion that reducing the availability of technology would reduce spending. One possibility is that other factors drive both greater use of technology and more spending. For example, some areas might have populations with a strong interest in purchasing health care. This could manifest itself as a climate in which health care providers find it profitable to buy new technologies. Although this would lead to greater availability of technology and higher spending in these areas, simply shutting off the supply of new technologies to the area need not reduce health care spending.

Another possibility is that some of the spending on the new technologies provides a means of compensating upstream technology development efforts, and is not solely compensating the equipment costs and variable costs associated with performing the procedures. Reducing availability would not reduce the costs for basic research and development (R&D) but would only spread these fixed costs over fewer machines and procedures.

This study, with its inherent methodological limits, cannot conclusively demonstrate the amount of savings that would be achieved if technology availability were reduced. We have included a number of controls for area characteristics and state fixed effects to attempt to control for bias from confounding, and we hope that this limits the extent to which the relationship we observe simply reflects underlying differences in characteristics. However, we recognize that changes over time in technology availability could also be confounded and that the controls we add, although they should be helpful, are unable to rule out this possibility. We lack the data to determine how much of the spending we observe is related to sunk upstream costs.

At the same time, we believe that the existence of relationships between technology availability and spending, and the reasonable possibility that at least some of this relationship arises when the adoption of new equipment spurs demand for incremental procedures, calls for continued attention. It would be difficult for any study to conclusively predict the effects of reducing technology availability; however, in the face of steeply rising health care costs, prudence dictates that careful consideration continue to be given to the role of technology adoption.

■ **Quality effects are an important consideration.** It is important to recognize the potential for benefits when evaluating technology. Higher spending need not be purely negative for society if the spending yields sufficient benefits. It is possible, even likely, that a large amount of health care spending does not produce higher quality. It is, nonetheless, also likely that some new technologies do produce value for patients. For example, some research argues that the benefits for society of several recent advances are substantial, and seemingly large enough to justify their large costs when compared with common cost-benefit benchmarks.[12] Perhaps the key question in evaluating increased use associated with the diffusion of new technologies is how the benefits compare to the costs. Any attempts to address the issue of technology availability and rising costs could end up badly misguided if implications for quality were not considered.

Policy Responses

Although providing detailed policy guidance is beyond the scope of our results, they do suggest some insights. Policy efforts should allow for the possibility that effects vary among technologies and that price dynamics and other aspects of the population and context can matter. It seems unlikely that appropriate one-size-fits-all approaches exist to address technology adoption. The most effective policy regimes will include serious technology evaluation and related efforts so that activities that would promote the growth of some technologies and retard others can be most effectively targeted.

Also, policy efforts should incorporate both the benefits and costs of new technologies. One typical argument is that a desire for high-technology care, coupled with the relatively low prices for medical care faced by well-insured consumers, tends to lead to the consumption of services whose value is much lower than the cost to society. However, effective price competition in health care markets, in which those receiving the benefits of services also have an appreciation for their cost, has the potential to reduce excess, inefficient use. For example, health plan policies that help consumers better identify the costs associated with their consumption choices, particularly for nonacute treatment decisions, may be effective policies to consider. In turn, these could affect the incentives associated with the purchase of new equipment.

In other cases, overuse could stem from individual consumers' and physicians' inability to identify the benefits of a new technology, so that they make individual choices that do not produce a collective set of socially optimal choices. Here, more generalized efforts could be warranted to assess the value of new technologies, disseminate information, and perhaps takes steps to collectively control the diffusion of new infrastructure and services.

Although we believe that this research emphasizes important points across a number of technologies and spending measures, these analyses do not encompass all technologies or angles of inquiry. Our measures do not include pharmaceutical spending. This study also focused on data from a relatively narrow time window and a specific portion of each technology's life cycle. Results from studies with longer or different time frames could vary. More broadly, technology advance includes research and other development efforts that could independently drive up spending, which we do not directly address.

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NOTES

1. See V. Fuchs, "Economics, Values, and Health Care Reform," *American Economic Review* 86, no. 1(1996): 1–24; J.P. Newhouse, "Medical Care Costs: How Much Welfare Loss?" *Journal of Economic Perspectives* 6, no. 3 (1992): 3–21; and B. Weisbrod, "The Health Care Quadrilemma: An Essay on Technological Change, Insurance, Quality of Care, and Cost Containment," *Journal of Economic Literature* 29, no. 2 (1991): 523–552.
2. See S. Heffler et al., "Health Spending Projections for 2002–2012," 7 February 2003, www.healthaffairs.org/WebExclusives/Heffler_Web_Excl_020703.htm (1 October 2003); and B.C. Strunk and P.B. Ginsburg, "Tracking Health Care Costs: Trends Stabilize but Remain High in 2002," 11 June 2003, www.healthaffairs.org/WebExclusives/Strunk_Web_Excl_061103.htm (1 October 2003).
3. Some analysts argue that spending may not produce benefits. See, for example, E.S. Fisher et al., "The Implications of Regional Variations in Medicare Spending, Part 1: The Content, Quality, and Accessibility of Care," *Annals of Internal Medicine* 138, no. 4 (2003): 237–287; E.S. Fisher et al., "The Implications of Regional Variations in Medicare Spending, Part 2: Health Outcomes and Satisfaction with Care," *Annals of Internal Medicine* 138, no. 4 (2003): 288–298; and J.E. Wennberg, E.S. Fisher, and J.S. Skinner, "Geography and the Debate over Medicare Reform," 13 February 2002, www.healthaffairs.org/WebExclusives/Wennberg_Web_Excl_021302.htm (1 October 2003). Other analysts suggest benefits. See, for example, D.M. Cutler and M.B. McClellan, "Is Technological Change in Medicine Worth It?" *Health Affairs* (Sep/Oct 2001): 11–29; D.M. Cutler and E. Meara, "The Technology of Birth: Is It Worth It?" NBER Working Paper no. 7390 (Cambridge, Mass.: National Bureau of Economic Research, 1999); and D.M. Cutler, M.B. McClellan, and J.P. Newhouse, "The Costs and Benefits of Intensive Treatment for Cardiovascular Disease," NBER Working Paper no. 6514 (Cambridge, Mass.: NBER, 1998).
4. A complete description of these analyses is available from the authors. Contact Laurence Baker at laurence.baker@stanford.edu; details are also available in L. Baker et al., "Final Report on the Relationship between Technology Availability and Health Care Spending," 5 November 2003, www.bcbs.com/research/healthcare_technology_&_spending.pdf.

5. Support for the potential for these technologies to be associated with sizable costs comes from various sources. Literature supports the view that advanced care for high-risk newborns is very expensive. See CIGNA, *Corporate Cost of Poor Birth Outcomes and Infant Health in America: Everybody's Business* (Bloomfield, Conn.: CIGNA, 1992); and D.M. Cutler and E. Meara, "The Medical Costs of the Young and Old: A Forty-Year Perspective," NBER Working Paper no. 6114 (Cambridge, Mass.: NBER, 1997). MRI equipment is also very costly, both to purchase and to maintain and operate. See, for example, R.A. Bell, "Economics of MRI Technology," *Journal of Magnetic Resonance Imaging* 6, no. 1 (1996): 10–25; and Booz Allen Hamilton, "Medical Technology Cost Management Strategies," BCBSA Working Paper (Chicago: Blue Cross Blue Shield Association, 28 April 2003). Many of these technologies and services are also noted as important innovations in V.R. Fuchs and H.C. Sox, "Physicians' Views of the Relative Importance of Thirty Medical Innovations," *Health Affairs* (Sep/Oct 2001): 30–42.
6. Cardiac diagnoses are myocardial infarction, ischemic heart disease, congestive heart failure, and cardiac arrest/ventricular fibrillation.
7. For each person in the commercial plan and Medicare data, we linked data on the level of availability of the various technologies according to their MSA of residence and year. Non-MSA residents were grouped by state of residence and year. We estimated individual-level ordinary least squares (OLS) regression models in which the dependent variables are the measures of use and spending per person per month, and the key independent variables are our technology measures. In all of the spending models we use the logarithm of spending as the dependent variable, since the spending distributions are skewed. Technology availability measures are specified as number of units per population and are entered into the model using a quadratic formulation to allow for nonlinear relationships between increasing technology availability and use or spending (except in the case of PET scanners, where the independent variable is a dummy for the presence of a PET scanner in the MSA). The models include a dummy for sex, the person's age and age squared, and interactions between age and sex. The models also include area-level variables of per capita income; percentage of the population having less than nine years of education, having graduated from high school, and having graduated from college; the unemployment rate; the number of office-based nonfederal physicians per population; an analysis-dependent measure of related office-based nonfederal physicians per population (pediatricians in newborn analyses, radiologists in diagnostic imaging analyses, cardiologists in cardiac care analyses, and oncologists in cancer analyses); number of short-term general hospital beds per population; number of hospital outpatient and emergency department (ED) visits per population; the total area population; and area population density. We also include a measure of the average case severity in the person's MSA, based on APR-DRGs (3M Health Information Systems), dummy variables for years to control for time trends, and dummy variables for states to control for potentially unmeasured characteristics of state populations that do not change over time. The use of state fixed effects instead of MSA fixed effects reflects a modeling trade-off. The former would likely provide a stronger study design, but for some technologies, particularly cardiac technologies, it was not always possible to obtain stable estimates using MSA fixed effects, probably because of limited variation in technology availability over time within MSAs. We incorporated MSA-level fixed effects in several models where we could and found that the results were broadly consistent with those using state fixed effects, although the technology coefficients were sometimes lower. To maintain consistency in the presentation, we report all results using state-level effects. We evaluate the statistical significance of relationships using F-tests for the joint significance of the linear and quadratic technology regression coefficients.
8. Because our regression models allow for a nonlinear relationship between technology supply and spending, the size of the predicted changes varies with the level of technology. We compute the values shown in the paper at the average of the technology measure.
9. We focus in our analysis on freestanding MRI and CT units, which are units outside of hospitals, since these measures and those of outpatient use and spending are more accurate. We relate the availability of freestanding units to measures of MRI use and spending occurring in freestanding centers and hospital outpatient departments. Analyses using less precise measures of availability of, use of, and spending for inpatient diagnostic imaging produce results that are similar but statistically weaker.
10. See, for example, Fuchs, "Economics, Values, and Health Care Reform"; Newhouse, "Medical Care Costs"; and Weisbrod, "The Health Care Quadrilemma."
11. See, for example, C.E. Phelps, *Health Economics* (New York: HarperCollins, 1992), 210–216; R.G. Evans, "Supplier-Induced Demand," in *The Economics of Health and Medical Care*, ed. M. Perlman (London: MacMillan, 1974), 162–173; and V.R. Fuchs, "The Supply of Surgeons and the Demand for Operations," *Journal of Human Resources* 13 (1978 Supplement): 35–56.
12. See, for example, Cutler and McClellan, "Is Technological Change in Medicine Worth It?"