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CHALLENGES TO REGULATORY DECENTRALIZATION:
LESSONS FROM STATE HEALTH TECHNOLOGY REGULATION

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ABSTRACT

Policymakers often prefer decentralized regulation to central planning because decentralization allows them to better reflect the views of local residents, encourage experimentation, and evaluate various regulatory approaches. These advantages can be undermined, however, when the regulations of one government are affected by those of another. To examine the implications of such externalities, we consider the case of state certificate of need laws (CON), which require providers within the state to obtain licenses before adopting various types of health care technology. In particular, we analyze the cross-border effects of these laws on the number and location of magnetic resonance imaging providers. We find a large effect on the location of providers near borders between unregulated and regulated states. These results provide examples of some of the limitations of using states as policy laboratories as well as the ability of states to use state laws to reflect their local preferences. The results may also help explain conflicting studies on whether and why CON regulation may have failed to control costs and quantity.

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1. Introduction

Americans have debated which level of government, federal or state, ought to wield regulatory powers since the founding of the United States. The difficulty in "aligning responsibilities and fiscal instruments with the proper levels of government," (Oates, 1999), has meant that regulatory powers have shifted among different levels over time. This is true for fiscal policy, banking, housing, and job training just to name a few regulated domains. In the recent debates over national health care reform, politicians, judges, and voters have considered whether the federal government or the state is the most appropriate level to regulate various aspects of health care.

The arguments for centralized regulation or decentralization and devolution come not only from deeply held political and historical commitments, but also from the advantages and disadvantages of regulating at various levels of government. Centralization can help states overcome collective action problems (Cooter and Siegel, 2010), and provide superior resources such as money, manpower, and expertise. On the other hand, local and state regulators may be better positioned than the federal government to reflect the preferences of their citizens; it is also widely thought that a decentralized system allows states to serve as laboratories, testing various policies so that all levels of government can learn from the experiments. However, whether decentralization provides these benefits -- in particular whether states can control their own regulatory environments or serve as effective policy laboratories -- depends on a degree of isolation from the policy choices of other governments, including other state governments (Greve, 2001).

This paper analyzes state Certificate of Need Laws (CON) −licensing regimes that restrict the adoption and modification of health technology by existing providers and new entrants–with two questions in mind. The first question relates to the possibilities of federalism for policy experimentation − does state-based technology regulation affect the provision of that technology in neighboring states? The second is a question about the health policy potential of the example − how, if at all, do such regulatory spillover effects influence the provision of medical care? To answer these questions, we examine the effects of CON regulation on the location of free-standing Magnetic Resonance Imaging (MRI) providers. We ask whether MRI providers disproportionately locate in unregulated states in counties that border states regulated by CON licensing laws.

Our approach to evaluating CON is novel in important respects. First, rather than asking whether CON affects the total number of providers in a state, we ask whether CON affects provider location within a local market. A finding that providers strategically locate within markets suggests that differences between neighboring states with different regulatory regimes may be overstated by the prior research. Second, we employ a novel strategy for estimating the effects of CON, one that recognizes that a state's decision to adopt or retain CON regulations can be as much a reaction to provider supply as a cause of future provider supply. Previous research, which largely compares various outcomes in regulated to unregulated states, has not adequately addressed this challenge. By focusing on the cross-border effects of technology regulation across counties within a state, we control for state-level differences. Third, previous research has largely focused on capital and labor intensive technologies such as percutaneous coronary interventions (PCI) and open heart surgery. These technologies are typically provided in hospitals, which are likely to seek a CON for these services and unlikely to respond to regulation of an individual technology by relocating. On the contrary, free-standing MRI providers comprise a relatively fluid market for analysis of the potential effects of technology regulation.

Our results show a sizeable and statistically-significant cross-border effect of CON regulation on the location of MRI providers. Among counties located on state borders where one state regulates MRI entry and the other state does not, there is more likely to be an MRI provider in the unregulated county than in the regulated county. Moreover, we link the effect to the relative ease of travelling across state borders because we find the difference between regulated and unregulated border counties to stem almost exclusively on state borders that are *not* separated by rivers, borders that are presumably easier for potential patients and staff to cross.

These results point to several conclusions. First, they suggest that where state regulations have externalities on other states, states may not serve as effective sites to evaluate the effectiveness of those regulations. In this case, the differences between the number of providers in regulated and unregulated states may be the result of regulation within a state, the spillover effects of regulation, and unrelated factors. Second, if, as we argue, our results provide a more accurate measure of the effects of entry regulation on health technology provision than previous research, policymakers who wish to control technology diffusion may wish to reconsider entry regulation like CON, particularly if it can be done at the federal level. Finally, future health technology assessments on outcomes like spending and quality in neighboring states should account for the cross-border effects of regulation.

The paper proceeds as follows. Part 2 outlines the purposes and history of CON legislation and summarizes previous research. Part 3 describes our data and the descriptive statistics. Part 4 describes our empirical framework for estimating the cross-border effects of CON regulation, reports the results, and describes limitations of the analysis. Part 5 concludes.

2. Health Planning and Certificate of Need Regulation: Background and Previous Research

Certificate of Need (CON) laws require health care organizations to obtain permits from a state regulatory agency before building new health care facilities, offering new medical services, or acquiring certain medical technology. Although the first CON laws were implemented in New York in 1964 and a few other northeastern states shortly thereafter, such programs have their roots in earlier federal health planning efforts, such as the 1946 Hospital Survey and Construction Act (The Hill-Burton Act), meant to increase access to care, improve quality, and control costs (Hamilton, 1986). The premise of capital investment restrictions such as CON restrictions was that in markets for health care -- markets characterized by failures that make price competition an untenable method for providing an efficient level of care -- regulation controlling the supply of medical providers and health care services would prevent excess capacity, duplicative and unnecessary service provision caused by provider-induced demand, and spiraling costs (Finkler, 1985).

Virtually every state adopted CON requirements in response to two federal statutes -- the Social Security Act of 1972 (which conditioned Medicare and Medicaid payments on reviews for large capital expenditures) (Section 1122, 1972), and the 1974 National Health Planning and Resources Development Act (which offered financial incentives for states to establish review procedures for new clinical services, inpatient technology acquisition, and capital expenditures greater than $150,000). Early state CON requirements applied to inpatient hospital services, but in the 1980s many states expanded their CON regimes to control the growth of ambulatory services such as diagnostic imaging.

After 1986, when President Regan signed the law repealing the National Health Planning Act, many states eliminated some or all of their CON requirements based on evidence that the planning authorities had proved "costly to the Federal Government, in the last analysis without benefit, and even detrimental to the rational allocation of economic resources for health care." (Yakima Valley, 2011). Even more recently, in 2004 the Federal Trade Commission and the U.S. Department of Justice urged the remaining states with CON requirements to "reconsider whether these programs best serve their citizens' health care needs," in large part because of their failure to contain costs and anticompetitive risks. (U.S. Federal Trade Commission, 2004).

Previous research comparing the experiences of regulated to unregulated states has largely concluded that CON has been ineffective at limiting supply, controlling costs, or improving quality. (Conover and Sloan, 1998). The earliest research on the effects of CON on costs, investments, and service diffusion in hospitals generated disparate results. However, in sum, it suggested that capital expenditure controls such as CON did not constrain costs, but may have limited the supply of beds within individual hospitals (Salkever, 2000). For example, Salkever and Bice (1979) studied the effects of regulation in those states that were early adopters of CON programs and found no conclusive evidence that CON had effects on costs or quality. Other early studies on the effects of CON, such as one by Sloan and Steinwald (1980), were inconclusive but determined that the evidence was not strong enough to demonstrate that CON programs controlled hospital costs.

Later studies were similarly mixed. Some found that CON increased costs (Lanning, Morrisey and Ohsfeldt 1991; Antel, Ohsfeldt and Becker 1995), while another found that CON programs reduced per-capita acute care spending by 5 percent, but did not affect total per-capita spending, suggesting that providers responded to cost-containing regulation by increasing costs elsewhere (Conover and Sloan 1998).

The few studies concerning ambulatory services such as diagnostic imaging were conducted soon after regulation of outpatient and free-standing medical services was implemented. These studies examine technology diffusion rates. For example, using data from the American College of Radiology, Hillman and Schwartz (1985) conducted telephone interviews with MRI installers and employees in the marketing departments of MRI manufacturers to track all the early adoption of MRI conducted through CON applications; they found that MRI diffused more slowly than Computed Tomography (CT) in free standing facilities, and concluded that Medicare's prospective payment system and CON regulations explained the difference. Steinberg et al. (1985) made similar claims, as well as identifying clinical, technical, and other economic issues as the reason that MRIs diffused comparatively slowly with only 108 machines in place by the end of 1984.

The most recent CON research has focused on a few hospital-based services, particularly invasive cardiac treatments, and has also generated mixed results. Cutler et al. (2010) concluded that the removal of CON in Pennsylvania was welfare neutral; in that case, increased entry into cardiac surgery led to a redistribution of patients to higher quality surgeons, an effect that approximately offset the losses due to increased fixed costs. Studies of the effects of CON on the volume of cardiac services typically found that the average number of procedures performed per hospital in states without cardiac CON was significantly lower than in regulated states (Ho 2004; Vaughan-Sarrazin et al., 2002). Comparing outcomes in regulated to unregulated states, Vaughan-Sarrazin and colleagues (2002) also found lower mortality in regulated states. Popescu and colleagues found that patients in regulated states were less likely to need revascularization services than those in unregulated states (2006). Moreover, Ho (2007) demonstrated that the number of hospitals offering intensive cardiac services (coronary artery bypass grafting and PCI) was lower in states with CON than in others. And CON was associated with fewer PCIs per capita (Ho, 2007). In her most recent work, Ho (2009) used a difference and difference approach that substantiated some of her earlier findings. She analyzed states that discontinued CON between 1989 and 2002 and found no change in utilization rates after the elimination of regulation (Ho, 2009). Some researchers have considered the effects of CON on access, for example finding that the loosening of CON rules was associated with increased access to cardiac care for African-Americans as well as with reductions in health disparities (Delia et al 2009).

Our research differs from this previous work in at least three important respects. First, to our knowledge there is no previous research on the causal effects of CON on practice location, and our work is the first account of the spillover effects of CON regulation across regulatory regimes. Second, previous research largely evaluated CON by comparing the experiences of regulated to unregulated states, an approach unlikely to provide accurate estimates of the effects of CON because, among other reasons, those states that retained CON regulations are probably different from those that did not in ways that are both relevant to current health technology markets and difficult to control for with available quantitative measures. By focusing on the cross-border effects of technology regulation we can account for state-specific factors using the other counties within states.

Third, although ambulatory services such as imaging are likely to be more responsive to entry regulation than are more expensive, hospital-based services such as cardiac treatment, existing research focuses on the latter. Imaging services are neither tied to a hospital location nor do they require hiring and retaining highly-credentialed physicians. A new cardiac catheterization laboratory (in the range of $3 million and up[1]) also costs more than an MRI machine (depending on the power of the unit, an MRI costs between roughly $1 to $3 million dollars, and the price of a common whole-body scanner -- a 1.5 tesla unit -- is $1.25 million) (Cosmus and Parizh, 2011).

Moreover, hospital-based technologies are provided to relatively sick patients, those who are either inpatients or likely have more limited ability to travel compared to patients seeking diagnostic imaging at a free-standing center. On the contrary, even though increased travel for patients may be costly, patients can more easily travel to free-standing MRI offices, which can be located anywhere one can site a trailer, particularly with the development of compact scanners. As a result of these differences, MRI providers can be relatively nimble in their responses to regulation and competition. We assume that the relative ease of entry on the supply side and patient travel on the demand side makes MRI markets good markets in which to consider responsiveness to state technology regulation.

3. Data and Descriptive Statistics

3.1 Data

Determining whether a state regulates health technology adoption is difficult. State laws and related regulations appear in different types of statutes and are enforced by different agencies (for example, departments of state health planning, public health, health and human services) depending on the state, and once found the statutory language is often ambiguous. The laws vary

[1] Costs range depending on the type of equipment, including whether it is new or used. The most recent New York applications for new laboratories that we could find were roughly $3.5 million. Mount Sinai hospital requested the purchase of two new labs for a total of $7,139,016 (New York Department of Health, 2010) and Orange Regional Medical Center requested one new lab for $3,462,325 (New York Department of Health, 2008).

a great deal in terms of which services and equipment are covered by CON. Moreover, even when licensing laws are on the books, regulators may not enforce those laws. This means that the secondary sources listing state regulatory regimes, the sources upon which most empirical research relies, may be unreliable.

We assembled an original dataset regarding state CON laws for all states except Alaska and Hawaii. First, we surveyed current statutes and regulations to determine which states had CON for MRI. At least two lawyers and a law student reviewed each state's statutes. To determine whether state regulators actively enforced their CON for MRI, we conducted further research to confirm our designations, mainly by contacting regulators by phone or email in almost every state we designated as having, at least, a general CON program (i.e., states with CON for any major technology, even if the written laws did not appear to apply to diagnostic imaging).[2] Figure 1 identifies states with CON for any service, CON for MRI, and no CON as of 2012. The states with CON for MRI are concentrated in the Northeast and Midwest.

We also assembled a dataset containing virtually all free-standing MRI facilities in the continental United States by using address lists from the websites of the two agencies that accredit MRI facilities -- American College of Radiology (ACR) and Intersocietal Accreditation Commission (IAC). We believe we have close to a universe of these facilities because all outpatient imaging providers, including both practitioners and facilities, were required by the Medicare Improvement for Patients and Providers Act of 2008 to obtain accreditation from one of three CMS-designated accreditation organizations, including the ACR and the IAC, by

[2] We contacted regulators by phone or electronic mail in all but twelve states. Additional research makes us confident that we classified those states correctly because there we found corroborating evidence – such as an updated state website that suggested an active regulatory program or such as press reports or website evidence that showed the state had discontinued their regulatory programs many years ago.

January 1, 2012 to be reimbursed by Medicare for the technical component of various imaging procedures including MRI.[3] The third organization, the American Hospital Association, accredits hospitals and, therefore, is unlikely to include freestanding facilities. After removing duplicates, we identified 6104 facilities and their locations from the ACR and an additional 662 from the IAC. We then used their addresses to collapse the dataset to the county level and constructed two MRI county-level variables: the number of MRI providers in each county and whether the county had any free-standing MRI providers.

We identified counties that lie along state borders using spatial joins in ArcGIS (using ArcGIS v10). We identified borders separated by rivers using a visual identification of major rivers on the border. County-level demand and supply side controls came from the 2012-2013 Area Resource File (AHRF) (US Department of Health and Human Services).

3.2 Descriptive Statistics

We describe our constructed county-level dataset in Table 1 by whether the county is in a non-CON (unregulated) or CON (regulated) state. There are 2.5 MRI providers per county in non-CON counties and 1.6 in CON counties. However, more people live in unregulated counties; therefore, when normalized by each million people in the county, there are more providers in CON counties (11.4 providers per million people in non-CON counties and 11.7 providers per million people in CON counties). There are also about an equal number of counties with at least one MRI in regulated and unregulated counties (Unregulated = 36.8% v. Regulated = 36.7%).

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[3] Medicare Improvements for Patients and Providers Act of 2008 122 Stat. 2532Section 135, codified at 42 U.S.C.A § 1395m (e). For the definition of provider see Social Security Act §1861(d). The term "supplier" means, unless the context otherwise requires, a physician or other practitioner, a facility, or other entity (other than a provider of services) that furnishes items or services under Medicare.

We do not draw conclusions as to whether the quantity of MRI providers in these counties is influenced by their regulatory environment because these counties are quite different in some respects. On the one hand, as shown in Table 1, they are similar in terms of some demographic characteristics associated with health status and health care use, such as age (population > ages 18-64 is 59.7% in regulated counties v. 58.1% in unrelated counties; population >64 is 14.9% in regulated counties v. 15.6% in unregulated counties), education (population >25 years with college education is 13.0% in regulated counties v. 14.3% in unregulated counties), and median household income ($42,574 in regulated counties v. $44,903 in unregulated counties). However, unregulated counties are quite different from regulated counties in other respects; they have larger populations (Mean=109,092 in unregulated counties v. 82,569 in regulated counties), are less dense (164 people per square mile in unregulated counties v. 358 in regulated counties), more rural (measured by non-metro and rural classifications), and have more hospital beds per population (374 beds per 100,000 in unregulated counties v. 325 in regulated counties.).

These differences between the counties in regulated and unregulated states may be related to the reasons that states decided to either retain or eliminate CON regulation after federal incentives for regulation were repealed in 1986. For example, the decisions may have been determined, at least in part, by the number of providers in the state. Thus it is difficult to determine whether the regulation itself may have an influence on the number of providers or whether other factors may be driving the differences in the number of providers. On the one hand, CON regulations were meant to restrict entry, suggesting that if they worked as intended then regulated counties would have fewer providers than unregulated counties. On the other hand, the presence of a CON regulation may also be the result of some set of unobservables. For example, the reason a CON state becomes a CON state may be related to some propensity to seek medical care. Alternatively, those states that retained CON regulations after changes in federal policy made it possible to repeal them without penalty may have done so because of a sense among regulators that there are too many providers, suggesting that regulated counties may have more providers than unregulated counties, even if the regulations effectively restricted entry.

Given the difficulty of determining how a state's regulatory regime affects differences in the number of providers in regulated compared to unregulated states, we have employed an estimation approach that does not rely on such differences. Because CON regulations are state rather than county regulations, the factors that contributed to whether a state retained regulation should not be reflected in differences between counties within the state. We take advantage of this observation to test whether a state's CON regulation affects the location of MRI providers within that state and across the border in neighboring states depending on whether there is also CON regulation in the neighboring state.

4. Empirical Framework and Results

4.1. Empirical Framework

We hypothesize that a provider considering serving a population in a regulated area would prefer to locate the business in a nearby unregulated location if one is available as long as travel costs from the regulated area is minimal. We make this assumption because opening a new imaging center in a regulated state can add additional costs to starting a business in terms of the financial costs to assemble a CON application, time costs of waiting for approval, and uncertainty regarding whether a potential competitor with a CON license would challenge the application. But these costs are weighed against the benefits to providers in locating where there is unmet demand for care, demand that may be greater in markets where licensing costs can be easily avoided. Based on this assumption, and the assumption that a state's choice to adopt (or not repeal) CON regulation for MRIs has little to do with the differences between the counties within a state, we compare the numbers of providers among various types of counties -- considering not only whether the county is regulated but where it is located in terms of other counties with the same or different regulatory regimes. We emphasize that we are not looking to test whether CON regulations can reduce the total number of MRIs; rather we focus on the marginal influence of CON near state borders.

Our setup for this hypothesis relies on our classification of counties based on whether they sit on the border of the state and on whether the regulatory regime across that border is the same or different. Thus we defined a county as a border county if it touches another state or as an interior county if the county does not touch another state border or, if it is on a state border, it does not touch another state. For border counties we classified them into two types: a border county that faces the same regulatory regime in the state across the border ("border_same") and a border county that faces a different regulatory regime in the state across the border ("border_change").

We test whether border_change counties differ from other types of counties in their supply of MRI providers. Specifically, we test whether unregulated border_change counties have more MRI providers than CON border_change counties. In contrast to general comparisons between CON and non-CON states, we construct comparison groups that should difference out any unmeasured confounding factors between CON and non-CON states. For example, border counties that do not face a regime change provide a useful comparison group as it controls for general differences between CON and non-CON states as well as any specific differences that can be attributed to border counties. We also use the number of MRI providers in interior counties as an alternative way to benchmark the changes that occur between CON and non-CON border counties with regime change.

We offer here a more formal description of this empirical strategy. We test the effect of CON regulation using two measures of MRI location. The first is the number of providers per million people in the county. Because the majority of counties have no MRI providers at all -- the modal number of providers in counties that have any MRI is 1 -- we also estimate these effects on the existence of any MRI provider in the county.

We estimate the following equations:

(1) $\text{MRI/million}_i = \beta_o + \beta_1\text{Border\_change}_i \text{ *CON} + \beta_2\text{Interior}_i \text{ *CON} + \beta_3\text{Border\_change}_i + \beta_4\text{Interior}_i + \beta_5\text{CON} + \beta_6\text{Pop}_i + \beta_7\text{MedSupply}_i + e$

(2) $\text{E(Any MRI Provider)} = \beta_o + \beta_1\text{Border\_change}_i \text{ *CON} + \beta_2\text{Interior}_i \text{ *CON} + \beta_3\text{Border\_change}_i + \beta_4\text{Interior}_i + \beta_5\text{CON} + \beta_6\text{Pop}_i + \beta_7\text{MedSupply}_i + e$

where (1) estimates the number of MRI providers per million people in a county (MRI/million) and (2) estimates an indicator of any MRI provider in the county (E(Any MRI Provider)). We estimate both models using Ordinary Least Squares (OLS) with robust standard errors.[4]

[4] The binary outcome of Any MRI provider was also estimated using a Probit model where the magnitude of the effects were converted to marginal effects with all control variables set at their means. Because estimates were so close to the OLS estimates, we did not report them. They are available from authors upon request.

CON represents whether a county is regulated or unregulated. In addition to the Border_change and Interior variables that measure the number of providers in different types of counties as described above, we also include control variables for the counties to adjust for any remaining imbalance between the differences in counties that may not be differenced out in the difference-in-difference framework, including variables that may well affect demand or supply of services. Pop includes population and population squared of the county in which the provider is located, the population density (county inhabitants per square mile), and categorical variables using the 2013 rural-urban continuum codes (we classified whether the county is in a metropolitan area, a non-rural non-metropolitan area, or whether the county is rural). Pop also includes the percent of the county living in poverty, the percentage of adults (18-64 years) old, the percentage of adults 65 years of age and older (and, therefore, eligible for Medicare), and the percent of adults in the county with college degrees. MedSupply represents the number of hospital beds per 100,000 in the county.

Our primary hypothesis is that $\beta_1 < 0$, the coefficient on the variable interacting being in a regulated state being located on a state borders where contiguous counties across the state border have different regulatory regimes, which would suggest that MRI providers are more likely to locate on the unregulated (non-CON) side of a state border when the choice is available to them in a local market, controlling for the behavior of MRI providers in state border markets where contiguous counties across state borders have the same regulatory regime .

We also test an alternative control group –interior counties – as $\beta_1 - \beta_2 < 0$ -- which allows us to examine the same effect as above, but now using the difference in the number of providers in interior counties as a control. This alternative control is presumably more representative of a county's regulatory regime as the location is less likely to be affected by regulations in other states.

This set up also allows us to look at the single difference within unregulated states. A finding that $\beta_3 > 0$ would suggest that, for unregulated counties on state borders, there are more MRI providers in counties that are contiguous with counties in regulated states (border_change counties) than in counties that are contiguous with counties in other unregulated states (border-same counties). A finding that $\beta_3 - \beta_4 > 0$ would suggest that there are more MRI providers in unregulated counties on state borders that are contiguous with counties in regulated states (border_change counties) in interior counties in unregulated states.

Since our hypotheses that providers' higher likelihood of locating near a regulated state when locating in an unregulated state is related to tapping into unmet need in the regulated state, this higher likelihood will be a function of the cost of traveling over the state border, all else equal. If we add a river boundary as an additional cost of travel, all else equal, then we would expect our findings to be stronger where there is a land boundary than where there is a river boundary between states with different regulatory regimes.[5] In effect, we use the existence of the river as a proxy for the ease of travel over state borders.

To implement this approach, we estimate:

(3) $\text{MRI/million}_i = \beta_o + \beta_1\text{Land\_border\_change}_i * \text{CON} + \beta_2\text{River\_border\_change}_i * \text{CON}$

$+ \beta_3\text{River\_border\_same}_i * \text{CON} + \beta_4\text{Interior}_i * \text{CON} + \beta_5\text{Land\_border\_change}_i +$

[5] The location and size of the bridges necessary to cross rivers are an important professional concern of city planners and traffic engineers because of the central role they play in access and the economy. (Levinson and Krizek, 2008).

β_6River_border_change$_i$ + β_7River_border_same$_i$ + β_8Interior$_i$ + β_9CON + β_{10}Pop$_i$ + β_{11}MedSupply$_i$ + e

(4) E(Any MRI Provider) = β_o + β_1Land_border_change$_i$ *CON + β_2River_border_change$_i$ *CON + β_3River_border_same$_i$ *CON + β_4Interior$_i$ *CON + β_5Land_border_change$_i$ + β_6River_border_change$_i$ + β_7River_border_same$_i$ + β_8Interior$_i$ + β_9CON + β_{10}Pop$_i$ + β_{11}MedSupply$_i$ + e

Where the equations are the same as equations (1) and (2) with the separation of borders into two types, River and Land. These equations, then, allow the average border effect in the first two equations to be separated into the effects within each of these two types of borders.

We hypothesize here that $\beta_1 < 0$, the coefficient on the variable interacting being in a regulated state * being located on a state border separated by land where contiguous counties across the state border have different regulatory regimes. If $\beta_1 < 0$, this would suggest that MRI providers are less likely to locate on the regulated (CON) side of a state border when travel between the boundary is relatively easy since finding a bridge is unnecessary, when compared to the difference between CON and non-CON counties on land borders that face the same regulatory regime across their borders. As in initial specifications, we test alternative comparison groups, this time alternatives include the difference in river border counties with a regime change, $\beta_1 - \beta_2 < 0$ and the difference in interior counties, $\beta_1 - \beta_4 < 0$. As above, we also examine the coefficients within unregulated counties.

4.2. Results

In Table 2 the key dependent variables are described by the county types for our analysis strategy. Among the 3,100 counties, 1,138 are border counties. Among the 1,138 border counties, 394 face a change in regulatory regime at the border. Among the 394 facing a regulatory regime change, 234 are on a land border and 160 are on a river border. When broken down by CON and non-CON states, the split is fairly proportional except there are only 5 counties in CON states that are contiguous with a CON county and are separated by a large river on the state border.

As can be seen in Table 2, the raw comparison of MRI providers per million people in a county between regulated and unregulated states show very little difference (0.3). When broken down by border and interior counties the differences are still small and are only negative among border counties (-1.0), meaning that, among counties on state borders, there are fewer providers per million people in regulated than unregulated counties. However, also in the raw data, there are considerably larger differences among those counties that border counties in other states that have different regulatory regimes. Moreover, when broken down further by whether that border is a land or river border, we only see large differences among land borders. The same patterns appear in the raw data that measure whether there is any MRI provider in the county (a dichotomous variable).

We look at these relationships more formally in the regression analyses, reported in Tables 3 and 4. As shown in Table 3, Column 1, the key coefficient is -6.4. This suggests there are fewer MRI providers per million people in regulated counties that border counties in unregulated states than in unregulated counties that border regulated counties, after accounting for any differences between regulated and unregulated states in the number of providers in counties contiguous with cross-border counties with the same regulatory regime ($p<0.01$). As can be seen in Table 3, Column 2, after controlling from the demographic and market variables discussed above, the coefficient is nearly the same, -6.9 ($p<0.01$), suggesting that the control groups in our difference-in-difference analysis are highly robust. In Table 3, column 3, where we estimate whether there is any MRI provider in the county, the coefficient is -0.241 ($p<0.001$). Again, there is little change in the coefficient when control variables are added, as can be seen in Table 3, column 4. Finally, we note that the difference-in-differences all remain large and significant when compared to interior counties rather than to other types of border counties.

The results in Table 3, Row 3 show that there are 4.9 more MRI providers per one million residents in unregulated counties that border regulated counties than unregulated counties that border other unregulated counties. This result suggests that most of the difference we identify in the difference-in-difference results is driven by activity on the unregulated side of the border rather than fewer providers on the regulated side of the border.

When we account for the ease of travelling across state borders by introducing the distinction between state borders marked by rivers versus land, as described in equations 3 and 4 and reported in Table 4, we find that the border effects are considerably larger for land borders than river borders. Among border counties where the border is not a large river (land border counties), controlling for demographic and other county characteristics, and after differencing out the effects attributable to merely being on a border (i.e., regulated counties that border counties in other regulated states), there are 11.3 fewer MRI providers per million people in regulated counties bordering unregulated counties. (Table 4, Column 2, $P<0.01$).

In contrast to the large differences among land border counties contiguous with counties in states with different regulatory regimes, there is very little difference among corresponding counties separated by rivers. For regulated counties with river borders that border unregulated counties the corresponding difference is only -0.2 (SD=2.620). Given these results, if we subtract the coefficients measuring the effects of being on different types of borders from our key coefficient (the -11.3), our results remain large and robust. We note that because there are only 5 CON counties on borders that are contiguous with counties that both have the same regulatory regime and are separated by rivers, the coefficients on river_border_same*CON are unstable, but are not statistically significant when control variables are included (-2.14 [SD-4.16]).

We also find the same patterns when we use a dichotomous variable for the existence of any MRI provider in a county (Table 4, Columns 3 & 4). Again the results are large, demonstrating a decline of 0.32 in the proportion of counties with any MRI provider ($p<0.001$).

For ease of interpretation, we have reported the OLS results in the specifications using a dichotomous variable (Any MRI) on the left hand side. In sensitivity testing, we also applied a Probit specification, estimated at the mean of all the variables, which is more appropriate for dichotomous variables. The results are nearly identical to the main specifications.

4.3. Sensitivity Testing and Limitations

We perform sensitivity tests that focus on the significance of population for the results. As opposed to merely using several adjustments for population, some researchers may favor a model that weights the variables by population. Having applied the tests for determining whether regression weighting is appropriate advanced by Solon, Haider, and Wooldridge (2013), we concluded that the unweighted model is more accurate than the weighted model for several reasons: 1) we have tried to include a full universe of free-standing providers and, therefore do not need weights to account for a skewed sample in our descriptive statistics, 2) we have no reason to believe that the individual-level error terms within the groups of regulated or unregulated border counties are correlated because of some unobserved group-level factors (after all the border counties are in different states); to confirm our intuition, we tested for heteroskedasticity by regressing the squared residuals from the OLS equations on the inverse of the population variable for regulated and unregulated border counties (See a description of this modified Breusch-Pagan test in Solon, 2013). The results were not significant for the regressions testing MRI per population, although they were for the regressions testing whether a county had any MRI at all, and 3) we believe we have the universe of providers and, therefore, do not have endogenous sampling.

However, a fourth reason for weighting in this context is if we believe that CON regulations might have a greater or lesser effect in more populous counties, perhaps creating different thresholds for opening any provider site. Although Solon et al. caution that weighting may well not solve this kind of problem and, indeed, might make it worse, we have used population weights in sensitivity testing. In sum, the weighted results support our hypotheses that whether a county is regulated by CON for MRI affects the location of providers; however, many estimates are less precise (have higher standard errors) and show considerably smaller effects than those in our preferred specification. We report the descriptive statistics and all of the regression results in both unweighted and weighted form in the Appendix.

There are several limitations to our study. First, because panel data for MRI providers and legal regimes were not available, our study is based on cross-sectional estimates, both leaving open the possibility that there is some local difference that contributes to our results and limiting the generalizability of our results over time. We included several independent variables to address potential left out variable bias, but there may well be remaining bias. Second, because the data were unavailable, we were unable to account for the type or number of MRI machines used by each provider, nor were we able to account for the quantity of individual scans provided. Third, all of the states with active CON for MRI are in the Midwest and Northeast, leaving open the possibility that there are regional effects which we were unable to assess.

5. Conclusion

Technological advances, like those represented by the development of advanced diagnostic imaging, have made positive contributions to human health. But they have costs as well. Some of these costs are financial. Medical imaging has been identified as a prime example of an overused technology, contributing to unsustainable health care spending and growth in spending. (Medicare Payment Advisory Commission, 2005). More specifically, over the last decade physician imaging services has represented one of the fastest growing Medicare Part B costs (the Medicare program that pays for physician services); “From 2000 through 2006, Medicare spending for physician imaging services doubled from about $7 billion to about $14 billion—an average annual increase of 13 percent, compared to an 8 percent increase in spending for all Medicare physician-billed services over the same time period,” and two-thirds of which was billed for services performed in physician offices rather than hospitals. (GAO, 2008).

Not only total spending, but the large variation in prices for diagnostic scans suggests room for cost-control; in 2012, prices for MRIs in the United States varied a great deal with the 25^{th} percentile at $522, an average price of $1,121, and the 95th percentile at $2,871. (International Federation of Health Plans, 2013). Easily available websites for patients to compare prices by location shows similarly dramatic price differences. For example, NewChoiceHealth.com, which is an online clearinghouse that directs patients to providers, lists the average costs of procedures; In 2013, in Detroit, Michigan (a regulated state), the average cost of an MRI was $3,461; in Salt Lake City, Utah (an unregulated state) the average cost was $1,694 (NewChoice, 2013).

Other costs are harder to measure, but no less important. For example, the overuse of medical technology can have large, negative health effects. Chandra and Skinner (2012) colorfully explain, “there are specific uses of imaging with unequivocal value, but at the margin the value approaches zero or even becomes harmful given the risk of false positives, incidental findings unrelated to the original inquiry (“incidentalomas”) or risks of radioactive exposure;” They cite a study (Brenner and Hall, 2007), suggesting that “1.5 to 2 percent of all cancers in the United States were caused by CT radiation exposure.” Although the Food and Drug Administration states that “[t]here are no known harmful side-effects associated with temporary exposure to the strong magnetic field used by MRI scanner,” there are safety concerns associated with MRI use such as injuries caused by interactions between the MRI magnet and pacemakers, artificial limbs, and other objects that contain metal (U.S. Food and Drug Administration, 2013). There may also be risks associated with some of the contrast agents used in the procedure, particularly for patients with moderate to end-stage kidney disease (U.S. Food and Drug Administration, 2010). Preliminary evidence from a small study indicates that contrast agents may accumulate in the brain (Kanda et al., 2013).

The Affordable Care Act employs numerous methods to prevent inappropriate use of and slow the growth of spending on medical technology. These methods include various payment reforms to alter the financial incentives for medical practitioners and organizations to provide services, but they do not include direct regulation of technology through programs such as CON. Given the market failures endemic to health care markets, failures that undermine the ability of price competition to create an efficient level of production and consumption, the barriers to entry raised by CON were intended to control total costs by reducing the number of providers (a plausible outcome even if unit prices increase) and ensure quality through increasing volume among a limited number of providers. However, such regulation cannot succeed if providers can simply move to unregulated jurisdictions and direct their patients to follow them. Moreover, before concluding that direct regulation can or cannot be effective, one must consider types of cross-border effects of regulations we analyze here.

In the case of the one technology we analyze here, one that accounts for a great deal of medical spending, we find preliminary evidence that regulations influenced the location decisions of MRI providers across borders and, we speculate, the places where patients seek care. Therefore, previous efforts to evaluate CON that did not account for these effects may have misestimated the true effects of regulation. Although it is beyond the scope of our study to estimate the welfare effects associated with these spillovers, rigorous study of the private, health, and other costs such as travel time and quality of care is needed.

Beyond the implications for health policy, our results point to an important lesson, one generalizable to other types of regulation evaluation. In addition to the widely discussed political reasons for state versus federal regulation, policymakers should consider the effectiveness of state regulation given variation in its adoption. Moreover, to use states as valid policy laboratories, the experiments should not be affected by the experiments in the laboratory next door. In the case of Certificate of Need laws, we have found some evidence of just that kind of contamination.

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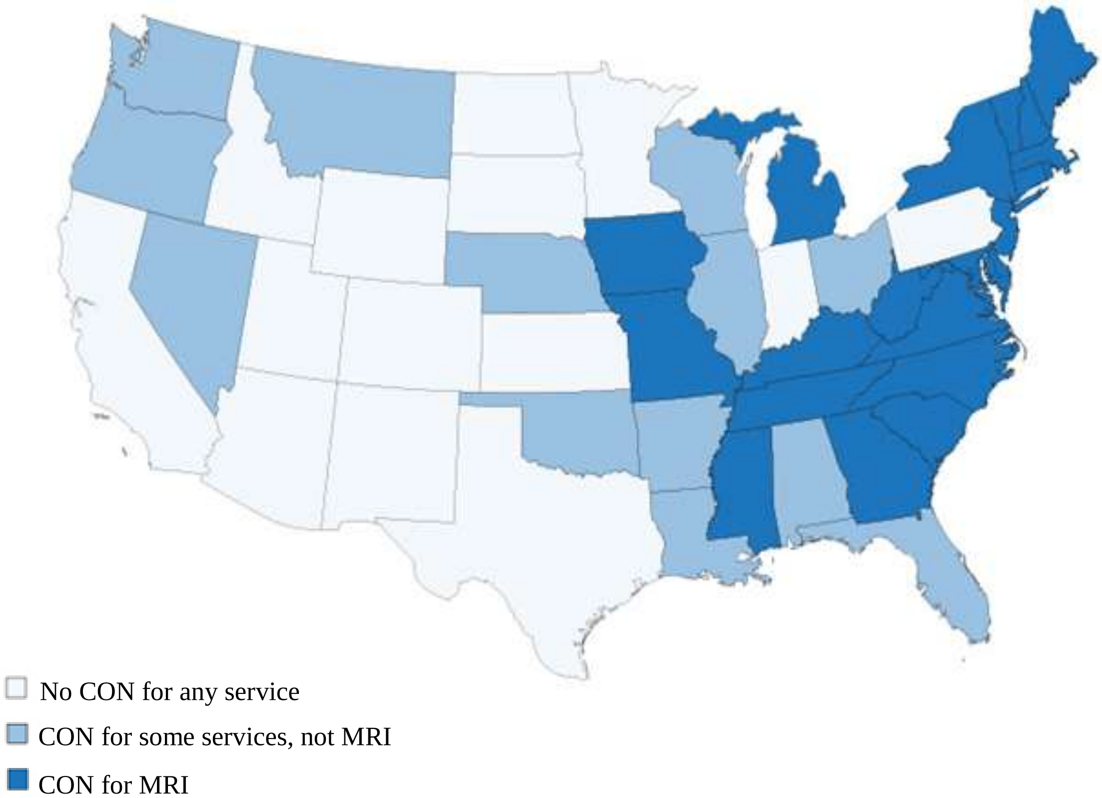
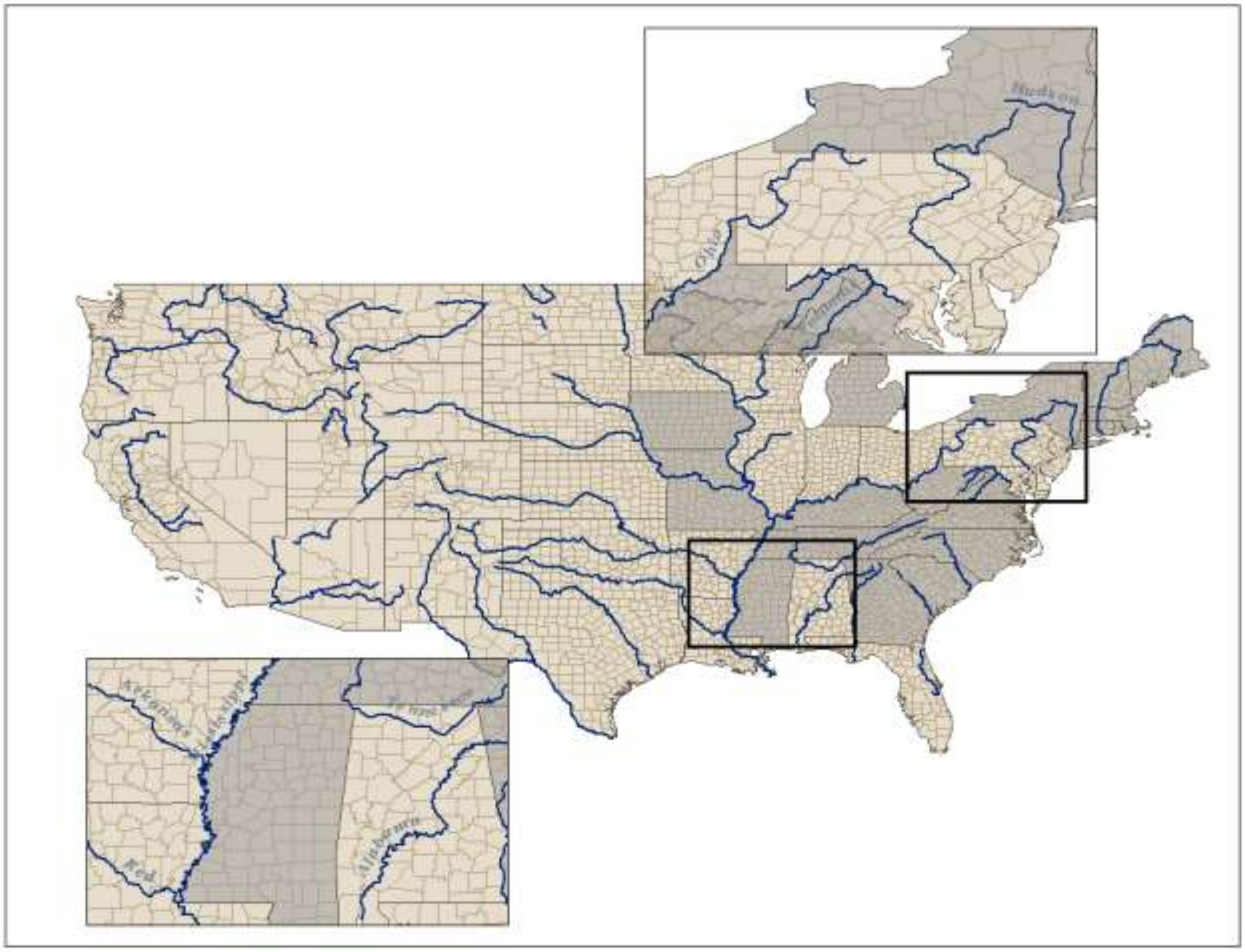
Figure 1. State Certificate of Need Laws, 2012



SOURCES: The designations in this figure are from the authors' primary research including: a 48-state survey of state statutes and regulations, confirmed by interviews with state regulators in departments of health, bureaus of health planning, CON offices, or other relevant state offices.

Figure 2. State Borders with Major Rivers



SOURCES: Templates from ArcGIS. Original source for major rivers from ESRI, Rand McNally & Company, Bartholemew and Times Books, Defense Mapping Agency presently known as National Geospatial-Intelligence Agency.

Table 1. Descriptive Statistics

Variable	All Counties (N=3,100) Mean	All Counties (N=3,100) Std. Dev.	CON Counties (N=1,213) Mean	CON Counties (N=1,213) Std. Dev.	Non-CON Counties (N=1,887) Mean	Non-CON Counties (N=1,887) Std. Dev.
MRI Providers per million pop	2.17	7.15	1.63	4.92	2.52	8.26
Population	98,714	314,458	82,569	193,829	109,092	371,568
MRI Providers per million pop	11.6	21.0	11.7	24.5	11.4	18.5
Urban-rural classification: non-metro	0.44	0.496	0.427	0.495	0.448	0.497
Urban-rural classification: rural	0.211	0.408	0.186	0.39	0.227	0.419
Density: pop per square mile	240	1670	358	2515	164	710
Population below poverty line (%)	15.3	6.0	16.7	6.3	14.4	5.7
Median Household Income ($)	43,992	11,328	42,574	11,838	44,903	10,894
Population 18-64 years (%)	58.8	4.5	59.7	4.3	58.1	4.6
Population > 64 (%)	15.3	4.2	14.9	3.6	15.6	4.5
Pop >25 with College Education (%)	13.8	6.0	13.0	6.4	14.3	5.6
Hospital Beds (per 100,000 pop)	355	534	325	488	374	561

SOURCES: Authors' analysis of data on MRI providers from the American College of Radiology (2012) and Intersocietal Accreditation Commission, on rural and urban status from the Centers for Disease Control and Prevention, National Center for Health Statistics Urban-Rural Classification Scheme (2012), and, for the remaining measures, the US Department of Health and Human Resources, Health Resources Administration, Area Resource File (2010).

Table 2. MRI Providers by County Border Classification by Certificate of Need Status

	Number of counties				MRI per million population			Any MRI in county		
	Total	CON	Non-CON		CON	Non-CON	diff	CON	Non-CON	Diff
All counties	3,100	1,213	1,887		11.7	11.4	**0.3**	0.367	0.368	**0.001**
Border	1,138	452	686		10.8	11.8	**-1.0**	0.392	0.362	**-0.030**
Interior	1,962	761	1,201		12.3	11.3	**1.0**	0.352	0.371	**0.019**
				diff	**-1.5**	**0.5**	**-2.0**	**0.040**	**-0.009**	**-0.049**
Border										
Border change	394	209	185		10	15.3	**-5.3**	0.354	0.486	**0.132**
Border same	744	243	501		11.5	10.4	**1.1**	0.424	0.315	**-0.109**
				diff	**-1.5**	**4.9**	**-6.4**	**-0.07**	**0.171**	**0.241**
Border change										
land border	234	123	111		8.3	18.4	**-10.1**	0.309	0.541	**0.232**
river border	160	86	74		12.4	10.8	**1.6**	0.419	0.405	**-0.014**
				diff	**-4.1**	**7.6**	**-11.7**	**-0.110**	**0.136**	**0.246**
Border same										
land border	662	238	424		11.7	10.6	**1.1**	0.433	0.321	**-0.112**
river border	82	5	77		0.0	9.6	**-9.6**	0.000	0.286	**0.286**
				diff	**11.7**	**1.0**	**10.7**	**0.433**	**0.035**	**-0.398**

SOURCES: Authors' analysis of data on MRI providers from the American College of Radiology (2012) and Intersocietal Accreditation Commission, the Centers for Disease Control and Prevention, National Center for Health Statistics Urban-Rural Classification Scheme (2012), and the US Department of Health and Human Resources, Health Resources Administration, Area Resource File (2010).

Table 3. Regression Results for Border County Classification

	(1) MRI pop	(2) MRI pop	(3) Any MRI	(4) Any MRI
Border Change * CON	-6.431**	-6.929**	-0.241***	-0.238***
	[2.318]	[2.206]	[0.0624]	[0.0523]
Interior * CON	-0.0587	0.0389	-0.128**	-0.102**
	[1.787]	[1.577]	[0.0440]	[0.0357]
Border Change	4.915**	4.301**	0.171***	0.133***
	[1.728]	[1.661]	[0.0422]	[0.0366]
Interior	0.852	-0.0241	0.0560*	0.00672
	[0.983]	[0.956]	[0.0250]	[0.0203]
CON	1.044	1.230	0.108**	0.102**
	[1.371]	[1.314]	[0.0379]	[0.0312]
Control Variables	No	Yes	No	Yes
Constant	10.43***	-0.764	0.315***	0.247
	[0.835]	[7.645]	[0.0208]	[0.147]
Observations	3100	3100	3100	3100

NOTES: Regressions (1) and (2) estimated by ordinary least squares. Regressions (3) and (4) estimated with a linear probability model; corresponding Probit estimates produced similar results (available from authors). See data description in text for definitions, sources, and list of control variables. Standard errors in brackets. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 4. Regression Results for River and Border County Classification

	(1) MRI pop	(2) MRI pop	(3) Any MRI	(4) Any MRI
Land Border Chg*CON	-11.24***	-11.33***	-0.344***	-0.321***
	[2.928]	[2.824]	[0.0744]	[0.0644]
River Border Chg*CON	0.447	-0.195	-0.0988	-0.106
	[2.936]	[2.620]	[0.0875]	[0.0701]
River Border same*CON	-10.72***	-2.150	-0.398***	-0.102
	[2.490]	[4.162]	[0.0649]	[0.0891]
Interior * CON	-0.147	0.116	-0.131**	-0.0985**
	[1.838]	[1.625]	[0.0452]	[0.0368]
Land Border Change	7.802**	7.265**	0.220***	0.186***
	[2.370]	[2.288]	[0.0525]	[0.0466]
River Border Change	0.204	-0.501	0.0847	0.0367
	[1.986]	[1.775]	[0.0615]	[0.0500]
River Border same	-0.993	-0.883	-0.0350	-0.0411
	[2.231]	[2.101]	[0.0563]	[0.0453]
Interior	0.700	-0.160	0.0506	0.000400
	[1.052]	[1.019]	[0.0267]	[0.0215]
CON	1.133	1.143	0.112**	0.0982**
	[1.435]	[1.375]	[0.0394]	[0.0324]
Control Variables	No	Yes	No	Yes
Constant	10.58***	-1.300	0.321***	0.239
	[0.915]	[7.658]	[0.0227]	[0.147]
Observations	3100	3100	3100	3100

NOTES: Regressions (1) and (2) estimated by ordinary least squares. Regressions (3) and (4) estimated with a linear probability model; corresponding Probit estimates produced similar results (available from authors). See data description in text for definitions, sources, and list of control variables. Standard errors in brackets. * p < 0.05, ** $p < 0.01$, *** $p < 0.001$.

Appendix 1A: Descriptive Statistics, County level, UNWEIGHTED

Variable	All Counties (N=3,100) Mean	All Counties (N=3,100) Std. Dev.	CON Counties (N=1,213) Mean	CON Counties (N=1,213) Std. Dev.	Non-CON Counties (N=1,887) Mean	Non-CON Counties (N=1,887) Std. Dev.
MRI provider	2.173	7.151	1.633	4.918	2.520	8.256
Population	98,714	314,458	82,569	193,829	109,092	371,568
MRI providers per million	11.6	21.	11.7	24.5	11.5	18.5
Urban-rural classification: non-metro	0.440	0.496	0.427	0.495	0.448	0.497
Urban-rural classification: rural	0.211	0.408	0.186	0.390	0.227	0.419
Density: population per square mile	240	1,670	358	2,515	164	710
Population below poverty line (%)	15.3	6.0	16.7	6.3	14.4	5.7
Median household income ($ 2008)	43,992	11,328	42,574	11,838	44,903	10,894
Population 18-64 years (%)	58.8	4.5	59.7	4.3	58.1	4.6
Population > 64 (%)	15.3	4.2	14.9	3.6	15.6	4.5
Population > 25 with college education (%)	13.8	6.0	13.0	6.4	14.3	5.6
Hospital beds per 100,000 pop	355	534	325	488	374	561

SOURCES: Authors' analysis of data on MRI providers from the American College of Radiology (2012) and Intersocietal Accreditation Commission, on rural and urban status from the Centers for Disease Control and Prevention, National Center for Health Statistics Urban-Rural Classification Scheme (2012), and, for the remaining measures, the US Department of Health and Human Resources, Health Resources Administration, Area Resource File (2010).

Appendix 1B: Descriptive Statistics, WEIGHTED

	All Counties		CON Counties		Non-CON Counties	
Variable	**Mean**	**Std. Dev.**	**Mean**	**Std. Dev.**	**Mean**	**Std. Dev.**
MRI Providers/County	22.59	31.52	11.62	14.88	27.93	35.82
Pop. Per County	1,100,111	1,899,140	537,204	621,418	1,373,983	2,223,853
MRI Providers/million in county	22.01	14.52	19.78	15.90	23.10	13.67
% Counties Non-Metropolitan	0.15	0.35	0.18	0.39	0.13	0.34
% Counties Rural	0.02	0.13	0.03	0.16	0.01	0.11
Population Density	2,008	6,429	3,701	10,684	1,183	1,964
% Population Poverty 2008	13.26	5.05	13.74	5.61	13.03	4.73
Median Household Income ($2008)	54,289	14,148	53,603	15,987	54,622	13,151
% population 18-64 years	0.60	0.04	0.61	0.04	0.60	0.03
% population > 64	0.13	0.03	0.13	0.03	0.12	0.04
College Education	0.20	0.08	0.20	0.09	0.19	0.07
Hospital Beds Per County	315	248	349	310	299	210
N counties		3,100		1,213		1,887

SOURCES: Authors' analysis of data on MRI providers from the American College of Radiology (2012) and Intersocietal Accreditation Commission, on rural and urban status from the Centers for Disease Control and Prevention, National Center for Health Statistics Urban-Rural Classification Scheme (2012), and, for the remaining measures, the US Department of Health and Human Resources, Health Resources Administration, Area Resource File (2010).

Appendix 2A: MRI Providers in Unregulated v. Regulated County by Location, UNWEIGHTED

		Non-CON	CON
All counties	# Counties	1,887	1,2130
	Avg # of MRI Providers	2.5	1.6
	MRI Providers per million people	11.4	11.7
	% with any MRI	0.368	0.367
Interior Counties	# Counties	1,201	761
	Avg # of MRI Providers	2.8	1.5
	MRI Providers per million people	11.3	12.3
	% with any MRI	0.371	0.352
Borders with Same CON Laws on Both Sides	# Counties	501	243
	Avg # of MRI Providers	1.9	1.7
	MRI Providers per million people	10.4	11.5
	% with any MRI	0.315	0.424
Borders with Different CON Laws on Each Side	# Counties	185	209
	Avg # of MRI Providers	2.2	1.9
	MRI Providers per million people	15.3	10
	% with any MRI	0.486	0.354

Appendix 2B: MRI Providers in Unregulated v. Regulated County by Location, WEIGHTED

		Non-CON	CON
All counties	# Counties	1,887	1,213
	Avg # of MRI Providers	27.6	11.6
	MRI Providers per million people	23.1	19.8
	% with any MRI	0.895	0.818
Interior Counties	# Counties	1,201	209
	Avg # of MRI Providers	31.1	11.9
	MRI Providers per million people	23.2	19.8
	% with any MRI	.902	.803
Borders with Same CON Laws on Both Sides	# Counties	501	243
	Avg # of MRI Providers	23.9	8.5
	MRI Providers per million people	22.1	19.1
	% with any MRI	.878	.847
Borders with Different CON Laws on Each Side	# Counties	185	209
	Avg # of MRI Providers	10.6	8.5
	MRI Providers per million people	25.02	20.5
	% with any MRI	.879	.832

Appendix 3A: MRI Providers in Regulated v. Unregulated Border Counties: River v. Non-River Borders, UNWEIGHTED

		State borders not separated by river		State border separated by river	
Home County		Non-CON	CON	Non-CON	CON
Same CON Regime in Both States	Number MRIs	2.0	1.8	1.5	0.0
	MRI/million (mean)	10.6	11.7	9.6	0
	P(any MRI)	0.321	0.433	0.286	0
	N (counties)	424	238	77	5
Different CON Regime in Both States	Number MRIs	2.2	1.0	2.2	3.2
	MRI/million (mean)	18.4	8.3	10.8	12.4
	P(any MRI)	0.541	0.309	0.405	0.419
	N (counties)	111	123	74	86

Appendix 3B: MRI Providers in Regulated v. Unregulated Border Counties: River v. Non-River Borders, WEIGHTED

		State borders not separated by river		**State border separated by river**	
Home County		Non-CON	CON	Non-CON	CON
Same CON Regime in Both States	MRI/million (mean)	22.7	19.1	18.8	0
	P(any MRI)	0.882	0.848	0.853	0
	N (counties)	424	238	77	5
Different CON Regime in Both States	MRI/million (mean)	25.4	14.8	24.9	24.6
	P(any MRI)	0.883	0.723	0.874	0.911
	N (counties)	111	123	74	86

Appendix 4A: Number of MRI Providers and Any MRI Provider in Regulated and Unregulated County, UNWEIGHTED

	(1) MRI_Pop	(2) MRI_Pop	(3) MRI_Pop	(4) MRI_Pop	(5) Any MRI	(6) Any MRI	(7) Any MRI	(8) Any MRI	(9) Any MRI	(10) Any MRI
bdry_diff_neigh	4.915	3.683	-1.516	-2.711	0.110	0.470	0.072	-0.092	-0.256	-0.049
	1.728	1.638	1.545	1.457	0.037	0.159	0.024	0.037	0.156	0.030
interior	0.852	-0.511	0.793	-0.192	0.000	-0.054	-0.008	-0.089	-0.185	-0.035
	0.983	0.909	1.493	1.280	0.020	0.108	0.016	0.029	0.131	0.025
pop_home		0.000		0.000	0.000	0.000	0.000	0.000	0.000	0.000
		0.000		0.000	0.000	0.000	0.000	0.000	0.000	0.000
npop2		0.000		0.000	0.000	0.000	0.000	0.000	0.000	0.000
		0.000		0.000	0.000	0.000	0.000	0.000	0.000	0.000
nonmetro		-3.549		1.377	-0.199	0.876	0.133	0.003	0.576	0.110
		1.160		1.719	0.030	0.142	0.020	0.033	0.135	0.025
rural		-13.933		-5.233	-0.478	0.036	0.006	-0.192	-0.171	-0.033
		1.426		2.494	0.030	0.245	0.037	0.036	0.221	0.042
popdens		0.000		0.000	0.000	0.007	0.001	0.000	0.000	0.000
		0.001		0.000	0.000	0.002	0.000	0.000	0.000	0.000
perc_poverty08		-0.157		-0.317	0.000	-0.028	-0.004	-0.012	-0.024	-0.005
		0.101		0.235	0.002	0.016	0.002	0.003	0.017	0.003
med_hhincome		0.000		0.000	0.000	0.000	0.000	0.000	0.000	0.000
		0.000		0.000	0.000	0.000	0.000	0.000	0.000	0.000
page18_64		10.046		34.841	0.201	0.941	0.143	0.532	2.048	0.391
		8.112		25.891	0.194	0.982	0.149	0.287	1.288	0.247
page65		7.405		-84.085	-0.439	-0.856	-0.130	-2.999	-4.669	-0.892
		13.162		29.220	0.266	1.490	0.228	0.398	1.973	0.380
ed_col25		61.210		81.869	1.376	4.192	0.638	2.599	4.535	0.866
		9.281		19.963	0.208	1.046	0.158	0.284	1.324	0.257
hospbeds		0.000		0.011	0.000	0.000	0.000	0.000	0.000	0.000
		0.001		0.009	0.000	0.000	0.000	0.000	0.000	0.000
	10.425	1.071	11.470	12.549	0.148	-2.964		0.782	-1.482	
	0.835	7.350	1.088	14.741	0.170	1.050		0.270	1.183	
Included counties	no con	no con	CON	CON	NO CON	No CON	No Con	CON	CON	CON
Model	OLS	OLS	OLS	OLS	OLS	Probit	Probit Margin	OLS	Probit	Probit Margin
N (counties)	1,887	1,887	1,213	1,213	1,213	1,887	1,887	1,213	1,213	1,213

Appendix 4B: Number of MRI Providers and Any MRI Provider in Border Counties, Population Weighted

	(1) MRI_Pop	(2) MRI_Pop	(3) MRI_Pop	(4) MRI_Pop	(5) any MRI	(6) any MRI	(7) any MRI	(8) any MRI
bdry_diff	3.051	0.203	1.409	-0.972	0.001	-0.005	-0.014	-0.051
	1.775	1.373	2.559	2.472	0.031	0.021	0.042	0.033
interior	1.039	-0.594	0.742	1.144	0.024	-0.021	-0.044	-0.070
	1.528	1.080	1.856	1.906	0.025	0.015	0.033	0.027
pop_home		0.000		0.000		0.000		0.000
		0.000		0.000		0.000		0.000
npop2		0.000		0.000		0.000		0.000
		0.000		0.000		0.000		0.000
nonmetro		-10.199		-2.248		-0.350		-0.152
		1.358		1.725		0.024		0.038
rural		-28.744		-13.156		-0.858		-0.489
		1.774		2.261		0.022		0.045
popdens		0.000		0.000		0.000		0.000
		0.000		0.000		0.000		0.000
perc_poverty08		-0.736		-0.035		-0.002		-0.015
		0.193		0.283		0.003		0.004
med_hhincome		0.000		0.000		0.000		0.000
		0.000		0.000		0.000		0.000
page18_64		-7.881		-24.054		-0.087		-0.171
		20.311		22.033		0.235		0.300
page65		73.644		18.707		-0.069		-2.822
		20.641		28.694		0.190		0.447
ed_col25		57.787		43.789		0.760		1.346
		12.028		15.689		0.133		0.207
hospbeds		0.006		0.011		0.000		0.000
		0.002		0.004		0.000		0.000
	22.119	38.677	19.074	19.621	0.878	0.937	0.847	1.559
	1.128	15.928	1.430	16.948	39.540	0.185	0.025	0.235
Included counties	No CON	No CON	CON	CON	NO CON	No CON	CON	CON
N counties	1,887	1,887	1,213	1,213	1,887	1,887	1,213	1,213

NOTES: All regressions are ordinary least squares and are weighted by population. Robust standard errors.

Appendix 5A: Number of MRI Providers/ Million and Any MRI Providers in a County, River v. Non-River Borders, UNWEIGHTED

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
	MRI Pop	**MRI pop**	**MRI Pop**	**MRI Pop**	**Any MRI**	**Any MRI**	**Any MRI**	**Any MRI**	**Any MRI**	**Any MRI**
nrbdry_diff	7.802	6.737	-3.441	-4.390	0.1675	0.665	0.101	-0.127	-0.448	-0.085
	2.369	2.246	1.720	0.620	0.0469	0.189	0.029	0.044	0.182	0.035
rbdry_diff	0.204	-1.447	0.650	-0.439	0.0052	0.091	0.014	-0.046	0.018	0.003
	1.986	1.765	2.164	1.980	0.0510	0.228	0.034	0.050	0.196	0.037
rbdry_same	-0.993	-1.139	-11.711	-3.858	-0.0450	-0.075	-0.011	-0.133	0.000	0.000
	2.230	2.102	1.106	4.710	0.0459	0.223	0.034	0.080	(omitted)	(omitted)
interior	0.700	-0.688	0.553	-0.265	-0.0066	-0.068	-0.010	-0.092	-0.190	-0.036
	1.052	0.964	1.507	1.303	0.0212	0.116	0.018	0.030	0.132	0.025
pop_home		0.000		0.000	0.0000	0.000	0.000	0.000	0.000	0.000
		0.000		0.000	0.0000	0.000	0.000	0.000	0.000	0.000
npop2		0.000		0.000	0.0000	0.000	0.000	0.000	0.000	0.000
		0.000		0.000	0.0000	0.000	0.000	0.000	0.000	0.000
nonmetro		-3.517		1.476	-0.1986	0.864	0.131	0.005	0.593	0.113
		1.161		1.720	0.0296	0.141	0.020	0.033	0.135	0.025
rural		-13.857		-5.188	-0.4767	0.010	0.001	-0.191	-0.161	-0.031
		1.426		2.491	0.0296	0.244	0.037	0.036	0.221	0.042
popdens		0.000		0.000	0.0000	0.008	0.001	0.000	0.000	0.000
		0.001		0.000	0.0000	0.002	0.000	0.000	0.000	0.000
perc_poverty08		-0.149		-0.310	-0.0001	-0.027	-0.004	-0.012	-0.023	-0.004
		0.102		0.237	0.0025	0.016	0.002	0.003	0.017	0.003
med_hhincome		0.000		0.000	0.0000	0.000	0.000	0.000	0.000	0.000
		0.000		0.000	0.0000	0.000	0.000	0.000	0.000	0.000
page18_64		11.491		33.396	0.2292	1.076	0.163	0.497	1.886	0.360
		8.135		26.138	0.1948	0.983	0.148	0.288	1.299	0.249
page65		7.736		-84.122	-0.4323	-0.844	-0.128	-2.996	-4.646	-0.887
		13.125		29.303	0.2650	1.497	0.227	0.397	1.980	0.381
ed_col25		59.950		82.709	1.3495	4.171	0.632	2.614	4.567	0.872
		9.292		19.943	0.2093	1.053	0.159	0.284	1.333	0.259
hospbeds		0.000		0.011	0.0000	0.000	0.000	0.000	0.000	0.000
		0.001		0.009	0.0000	0.000	0.000	0.000	0.000	0.000
	10.578	-0.042	11.711	13.353	0.1284	-3.087		0.800	-1.395	
		7.390	1.106	14.740	0.1709	1.056		0.269	1.190	
Included counties	No CON	No CON	CON	CON	No CON	No CON	No CON	CON	CON	CON
Model	OLS	OLS	OLS	OLS	OLS	Probit	Probit Margin	OLS	Probit	Probit Margin
N (counties)	1,887	1,887	1,213	1,213	1,887	1,887	1,887	1,213	1,208	1,208

Appendix 5B: Number of MRI Providers/ Million and Any MRI Providers in a County, River v. Non-River Borders, WEIGHTED

	(1) MRI_pop	(2) MRI_pop	(3) MRI_pop	(4) MRI_pop	(5) Any MRI	(6) Any MRI	(7) Any MRI	(8) Any MRI
nrbdry_diff	2.702	-0.162	**-4.345**	-5.465	0.001	0.007	**-0.125**	**-0.101**
	1.982	1.711	2.068	2.647	0.036	0.027	0.066	0.043
rbdry_diff	2.202	-0.714	5.488	2.980	-0.008	-0.025	0.062	-0.008
	2.863	1.931	3.234	2.838	0.044	0.028	0.037	0.036
rbdry_same	-3.858	-4.110	-19.111	-8.795	-0.029	-0.005	-0.848	-0.266
	2.298	2.134	1.434	3.843	0.062	0.043	0.025	0.108
interior	0.486	-1.181	0.704	1.236	0.020	-0.022	-0.046	-0.069
	1.633	1.144	1.859	1.905	0.026	0.016	0.033	0.027
pop_home		0.000		0.000		0.000		0.000
		0.000		0.000		0.000		0.000
npop2		0.000		0.000		0.000		0.000
		0.000		0.000		0.000		0.000
nonmetro		-10.229		-1.681		-0.350		-0.146
		1.359		1.712		0.024		0.038
rural		-28.704		-12.719		-0.859		-0.483
		1.772		2.260		0.022		0.045
popdens		0.000		0.000		0.000		0.000
		0.000		0.000		0.000		0.000
perc_poverty08		-0.754		-0.004		-0.002		-0.015
		0.194		0.258		0.003		0.004
med_hhincome		0.000		0.000		0.000		0.000
		0.000		0.000		0.000		0.000
page18_64		-7.873		-24.760		-0.077		-0.182
		20.369		21.931		0.235		0.292
page65		72.314		16.762		-0.068		-2.842
		20.798		28.324		0.193		0.447
ed_col25		57.539		44.859		0.753		1.358
		11.978		14.783		0.134		0.209
hospbeds		0.006		0.011		0.000		0.000
		0.002		0.004		0.000		0.000
	22.671	39.975	19.111	19.139	0.882	0.933	0.848	1.554
	1.266	15.966	1.434	16.272	0.024	0.186	0.025	0.230
Included counties	No CON	No CON	CON	CON	No CON	No CON	CON	CON
N counties	1,887	1,887	1,213	1,213	1,877	1,877	1,213	1,213

NOTES: All regressions are ordinary least squares and are weighted by population. Robust standard error.