The Effect of Resident Work-hour Reform on Hospital Productivity

Jose Manuel Fernandez*

The University of Louisville

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Abstract

A policy limiting the amount of hours a medical resident can work has a direct effect of raising the cost of production, but potentially has several indirect effects including decreasing medical research. In this article, I offer new empirical evidence on the effect such a policy has on hospital input choices, output, and research. Two econometric techniques, difference in difference and nonparametric estimation, are used to identify the policy's treatment effect. On average, the work hour policy increases total cost, payroll cost, and hospital beds, but decreases the number of residents per bed. Further, these effects are concentrated in smaller hospitals (<500 beds) where hospital resources are more strained. Larger hospitals enjoy production increases in spite of increases in production cost. Lastly, the policy decreases the amount of NIH funding for research, but this decrease is not statistically significant.

keywords: Medical Residents; work hour reform; hospital productivity

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*Department of Economics, College of Business, University of Louisville, Louisville, KY 40292, E-MAIL: jose.fernandez@louisville.edu, PHONE: 502.852.4861, FAX: 502.852.7672

1. Introduction

In this article, I provide new empirical evidence of the effect a medical resident work hour limitation has on hospital output, input, and research. On May 1, 2003 the Council of Teaching Hospitals restricted the maximum number of hours worked by a resident to 80 hours a week. This seldom studied input in hospital production commands a large amount of public resources. In 1998, $5.6 billion in NIH grants and $5.9 billion in Medicare funds were given to teaching hospitals across the nation to conduct medical research and train new physicians, respectively. Medical residents serve a dual purpose in teaching hospitals as students and physicians. The benefits of having medical residents are two-fold in that residents are a low cost substitute for experienced physicians in patient care and they allow experienced physicians to focus on medical research. The direct cost of educating residents is entirely subsidized through federal programs such as Medicare, but an indirect cost of using medical resident also exist. Due to their limited experienced, medical residents have a higher propensity to order unnecessary medical tests and provide diagnoses at less efficient rates than experienced physicians. Overall, medical residents have a net benefit on hospital production (else teaching hospitals would not exist).

Limiting the number of hours a medical resident can work has an ambiguous affect on hospital production. For hospitals that have residents working above the limit, the new policy essentially increases the cost of having a resident, producing two opposing effects. First, residents will see less patients causing production to fall. Hospitals may respond by increasing the number of experienced physicians or decreasing the number of beds. If a hospital increases the number of physicians it must substitute away from research, but these new inputs are more efficient than the residents they replace. Therefore, the new physicians can see more patients and order less medical tests per patient.

To answer the question of how hospitals respond to the policy change one needs to compare how hospitals' change their input mix before and after the policy versus no change in policy over the same time period. I utilize the New York 405 Code of 1989 as a natural

experiment to answer this question. The paper employs a difference-in-difference approach to evaluate the effect of the policy on hospital inputs, costs, and research. A semi-parametric model is also used to estimate the effect of the policy on hospital production.

The New York 405 Health Code limits the number of work hours for medical residents to a monthly average of 80 hours per week. The change in work hours was initiated for fear of an increase in medical errors due to "sleep deprivation." While no current evidence supports that a work hour limitation leads to a decrease in medical errors (see Howard et. al, 2004), there has been little attention given to the possible effects this policy would have on hospital productivity. I study the effect work hour reform has on hospital input (nurse, physicians, beds, and residents) and output (inpatient days, NIH grants, total cost) decisions.

The economics literature on medical residents is concentrated in the choice of medical specialization (Arcidiacono and Nicholson, 2003; Nicholson and Souleles, 2002; Nicholson, 2003), but little research is available on the role of medical residents as hospital inputs. Early studies use a Cobb-Douglas hospital production function to estimate the relationship between the inputs and number of patients served (Lave, 1970; Reinhardt, 1971). Both models recognize that physicians and medical residents are two separate inputs and treat them as such in the production function. Jensen and Morrisey (1986) overcome some of the functional restriction of the Cobb-Douglas by using a Translog production function. The Translog function incorporates second-order and interaction terms, which are absent in the Cobb-Douglas model. The authors find the elasticity of substitution between physicians and nurses to be close to zero and the marginal product of the last medical resident to not be statistically different from zero. The model of hospital production in this study departs from the previous literature in two ways. First, the model relaxes structural constraints placed upon the estimation of the hospital production function by a fully parameterized model. Physicians and medical residents enter the production function non-parametrically to allow for richer non-linear effects on hospital production. Secondly, the model introduces instruments for the hospital inputs to remove simultaneity bias ignored by previous studies.

The remainder of the paper is organized in the following fashion. Section 2 summarizes the events leading to the restriction in medical resident work hours. Section 3 develops the empirical model of hospital production. Section 4 describes the estimation strategy. Section 5 gives a description of the data. The results of the estimation are described in Section 6. Section 7 concludes the paper with a concise description of the results and provides suggestions for public policy.

2. Background

In 1984, an 18-year old woman died from an apparent adverse reaction to the medicine given to her while in a New York City hospital. The court ruled that the excessively long work hours of the resident in care of this patient were to blame.

> In October 1987, the Ad Hoc Advisory Committee on Emergency Services of New York State Department of Health adopted the following recommendations as a result of the court hearing:

- 24 hour supervision of acute care inpatient units by experienced attending physicians
- Improved working conditions and greater ancillary support for residents
- 12-hour work limits for residents and physicians in emergency departments in areas other than the emergency room
- a scheduled work week for residents not exceeding an average of 80 hours per week over a four-week period and not exceeding 24 hours consecutively, with at least one 24 hour period of nonworking time per week (Conigliaro et. al., 1993).

These regulations are known as the New York State Health Code Section 405 Regulations and were implemented on July 1, 1989. In May 2003, the Council of Teaching Hospitals adopted these same regulations, nationalizing the policy. The American Medical School

Association (AMSA) has lobbied for resident hour reform, and, at this time, has bills in both the House of Representatives and the Senate. The role of medical residents should be of interest to policy makers because the wages and education given to the residents is funded through Medicare/Medicaid.

Medical resident work reform is also a concern in the international arena. The international community has taken a lead in labor reform for medical residents through the introduction of work hour restrictions as described in Table 1. Denmark has the most stringent restriction at 45 hrs/wk, and is followed by the European Union at 48 hrs/wk. The least stringent restriction is found in Australia at 75 hrs/wk, which is still more conservative than the current restriction in the United States of 80 hrs/wk.

3. Data

The data are from four sources: the American Hospital Association (AHA), US Census 5% Public Use Microdata Samples (PUMS), National Institute of Health (NIH), and Centers for Medicare & Medicaid Services (CMS). The AHA data provides annual hospital characteristics on the number of inpatient days, physicians, medical residents, registered nurses, licensed nurses, hospital beds, and other cost characteristics. A sample of both teaching and non-teaching hospitals is obtained for the years of 1987 and 1991. The starting year, 1987, is selected because it is sufficiently before the enactment of Section 405 in 1989 that the hospitals would not have adjusted their production decisions in anticipation of the law. Due to legislative changes in the medicare/medicaid fee schedule for teaching hospitals that occurred in 1992, the year 1991 is selected as the end date of the natural experiment.

These two samples provide a two-year panel dataset. The number of inpatient days is selected as a measure of output for each hospital. Inpatient days are not a perfect measure of production because they cannot be considered a completely homogenous good. Hospitals provide a wide range of services different costs and levels of quality. Therefore, the level of care is not completely captured by the number of inpatient days. As Jensen and Morrisey

(1986) suggests, the case mix index is used to re-weight the number of inpatient days per hospital. The case mix index is a weighted sum of Medicare cost for different diagnostic services in a hospital. These sums are then normalized into an index where the average cost of health care service receives a value of 1. The level of care is captured by the cost of providing the service. Each hospital with a Medicare provider number is assigned a case mix value. Multiplying the case mix value by the number of inpatient days allows one to adjust output between hospitals into a more homogenous good. The case mix index is highly correlated with itself from year to year with a correlation coefficient of .97. Therefore, the 1992 case mix index is used to substitute the case mix indices of 1987 and 1991, which is not available.[1]

Descriptive statistics regarding hospital output, input, and research funds are found in Table 2. The variables of interest are relatively stable within both samples, but all the variables appear to decrease between the pre- and post period. On average between groups, New York hospitals produce more inpatient days, have more employees and beds, but receive less research funds and pay physicians less than hospitals in the rest of the nation. Respectively, the number of physicians and residents is at least three and two times as large in New York as in the control group. Given the large investment in these hospital inputs, medical resident work hour reform is an important topic within the state of New York.

4. Econometric Model

4.1 Difference-in-Differences Model

The difference-in-differences approach identifies a treatment effect by comparing changes in a variable of interest within a treatment group pre- and post-treatment relative to the same variable within a control group. Presumably, the control group captures changes in the variable of interest in the absence of the treatment. To evaluate the effect of a work hour policy on hospital input, output, and research choices, I utilize the 1989 adoption of

[1] Case Mix Index Source: Centers for Medicare & Medicaid Services

the New York State Health Code Section 405 as the treatment. Hospitals in the state of New York serve as a treatment group, while all other teaching hospitals are viewed as the control group. Only hospitals in the state of New York undergo treatment over the study period. All other teaching hospitals do not adopt the work hour policy until 2003. I utilize a matched data set of teaching hospitals in 1987 and 1991 compiled by the American Hospital Association to estimate the following equation

$$\ln Y_{91h} - \ln Y_{87h} = c_1 + c_2 NY_h + (\omega_{91h} - \omega_{87h})$$

where Y (inpatient days, residents, physicians, nurses, research funds, and hospital cost) is the variable of interest, NY is a dummy variable equal to 1 for hospitals in New York and zero otherwise, and the policy's treatment effect is captured by the parameter c_2. Differencing the dependent variable by hospital removes any unobserved hospital specific time-invariant variables, thus reducing the omitted variable bias. The results of this estimation exercise are found in Table 3.

Hospitals view the work hour policy as an increase in the cost of production. This increase in cost causes hospitals to either decrease their demand for that input or substitute away from other activities (research and teaching) to cover the increase in cost. The difference-in-difference models provides treatment effect point estimates, which support this theory. On average, the demand for physicians and residents decreases and the demand for registered nurses, licensed practical nurses, and other staff increases. The results suggest hospitals are substituting away from high wage inputs to lower wage inputs. Research grants (including those used for training, fellowship awards, and R & D awards), on average, are found to be 55% less than those funds received by control hospitals, but this difference is not statistically significant. Total operating cost and payroll amounts are found to be 39%[2] and 45% higher, respectively, than those in the control group and are statistically significant at the 10% level. Further, the growth in hospital beds is estimated to be 55% higher in the

[2] From table 3: (.904)/(.904+1.431)

treatment group, but the number of residents-per-bed is 30% lower than teaching hospitals in the the control. Both estimates are found to be statistically significant at the 5% level. The decrease in residents-per-bed also decreases the amount of indirect medical education (IME) reimbursement. As stated in Nicholson and Song (2001), the DRG price a hospital receives for admitting a Medicare patient increases linearly with the hospital's resident to bed ratio (R/K)

$$IME\ Payments = 1.16\,(R/K)\,DRG * Q \tag{1}$$

where IME payments are determined by equation (1), Q refers to the number of medicare patients admitted, and 1.16 is a multiplier determined by the federal government. The IME payment formula provides an incentive for hospitals to close beds, but the work hour policy leads to an increase in the number of beds in spite of this incentive. Therefore, revenue generated by residency programs decreases as a result of the work hour policy.

Using hospital beds as a proxy for hospital size, I explore how the treatment effect varies given hospital size. A Gaussian Kernel function is used to estimate the treatment effect conditional on the number of hospital beds in 1987, which serves as a proxy for hospital size. The sample of hospitals is divided into two sub-samples of treatment hospitals and control hospitals. The kernel function is applied on these two sub-samples. The results indicate that the work hour policy primarily affects smaller hospitals (beds <150), see Figure 1a and 1b. In the case of hospital beds, smaller hospitals are found to increase the number of beds available in response to the policy, but as hospital size increases the percent change in the number of hospitals beds decreases and becomes negative for hospitals with greater than 400 beds.

[insert Figure 1]

Hospitals costs also increase disproportionately in smaller hospitals than larger hospitals. Larger hospitals have access to many more resources allowing them flexibility in their

input mixture. Larger hospitals are able to respond by more efficiently scheduling residents and physicians (i.e. night float systems). Smaller hospitals do not have enough house staff to cover resident hours. Therefore, the size of the auxiliary staff (registered nurses, nurse practitioners, licensed practical nurses, and lab techs) increases to meet the work hour requirements. The difference-in-differences methods serves as a useful tool to identify treatment effects using a "black box" approach. In the following section, a semi-parametric model is used to estimate hospital production and identify any changes in the production function associated with the policy.

4.2 Semi-parametric Model

The hospital production function is defined semi-parametrically as the sum of a linear function and a non-specified function, $g(\cdot)$

$$\log Y_{it} = X_{it}\theta + D_{it}\gamma + g(P_{it}, R_{it}, PL_{it}) + \varepsilon_{it} \quad (2)$$

where (i) and (t) index hospital and time. The inputs of the $g(\cdot)$ function are the number of physicians (P), the number of residents (R), and a policy dummy variable (PL). The policy dummy variable takes the value of 1 after Section 405 has been made law and zero otherwise. The first term in equation (2) is a Translog function of the remaining labor inputs, which include the number of registered nurses (RN) and the number of licensed nurses (LPN). The dependent variable (Y) is the hospital output measured as the total number of inpatient days. The regression constant α represents a productivity constant. The second term, $D_{it}\gamma$, contains dummy variables for each hospital type (community hospital, veteran affairs, non-profit, religious, etc). The error term, ε_{it}, is assumed to have a mean of zero and a standard deviation of σ^2.

Specifying the production function in this manner has several advantages. First, the

relationship between physicians and residents is isolated from the other inputs. Physicians and medical residents are close substitutes, but have a unique relationship in that physicians serve as instructors to medical residents. Second, the non-specified function allows for flexibility in the substitution patterns of these inputs, which could be constrained with a fully parametrized model. The relationship between registered nurses and licensed nurses is not the focus of the research, but is still important to capture. A Translog function is used to capture the effects of nurses on production.

$$X_{ist}\theta = \theta_1 + \theta_2 \left[\log(RN) \log(LPN)\right] + \theta_3 \left[\log(RN)\right]^2 + \theta_4 \left[\log(LPN)\right]^2 \tag{3}$$

The Translog function incorporates second order terms and interaction of the inputs allowing more flexibility than the traditional Cobb-Douglass model.

Olley and Pakes (1996) recognize that firms choose their level of production and the number of inputs simultaneously, thus, inputs are econometrically endogenous. A suitable instrument would be correlated with input choices, but uncorrelated with hospital output. Hospitals within the same local area compete in the local labor market when choosing inputs. Hospital are assumed to play a simultaneous move game when choosing inputs; therefore, hospitals make input decisions conditional on the input decisions of their competitors. For this reason, competitor input choices serve as suitable instruments for hospital input choices. Wage data is used as a second instrument. Mean physician wages by SMSA are collected from the 5% Census PUMS data for the years on 1980 and 1990. Wages in 1987 and 1991 are then extrapolated from these endpoints.

4.3 Estimation strategy

The challenge of estimating this production function is simultaneously handling the endogeneity of the inputs and estimating the non-specified function, $g(\cdot)$. A two staged least squares approach with weights (2SLSW) is used to estimated the model. As proposed

by Ichimura (1993), the non-specified function for each hospital is assigned a numerical value by solving equation (1) for $g(\cdot)$.

$$\widetilde{Y}_{it} \equiv \log Y_{it} - X_{it}\theta - D_{it}\gamma - \varepsilon_{it} = g\left(P_{it}, R_{it}, PL_{it}\right)$$

A multivariate Gaussian kernel function is used to estimate $g(\cdot)$. The bandwidths for each input (Physicians, Residents, and Policy) are equal to their respective standard deviation.

$$\text{(4)} \qquad \widehat{g}\left(P_{it}, R_{it}, PL_{it}\right) = \frac{\sum_{j \neq i} \widetilde{Y}_{jt} K(P_{jt}, R_{jt}, PL_{jt})}{\sum_{j \neq i} K(P_{jt}, R_{jt}, PL_{jt})} = \sum_{j \neq i} \widetilde{Y}_{jt} w_{jt}$$

$$\text{(5)} \qquad \widehat{g}\left(P, R, PL\right) = W\widetilde{Y}$$

Considering the kernel function does not contain any parameters to be estimated, the weights, w_{jt}, can be written in matrix notation as seen as in equation (5). Each predicted value of $g(\cdot)$ is a weighted sum of the production residual $\widetilde{Y}$.

I replace the non-specified function $g(\cdot)$ in equation (2) with the predicted value $\widehat{g}(P, R, PL) = W\widetilde{Y}$. I then solve for the dependent variable, which reveals a simple linear regression model.

$$V = \widetilde{X}\begin{bmatrix}\theta \\ \gamma\end{bmatrix} + u$$

$$V = (I - W)\log Y \qquad \widetilde{X} = (I - W)[X \;\; D] \qquad u = (1 - W)\varepsilon$$

Assume an appropriate set of instruments Z. Two stage least squares techniques are used to remove the endogeneity in X.

$$\widehat{X} = Z(Z'Z)^{-1}Z'\widetilde{X}$$

The weighted 2SLS estimator gives consistent estimates of $\begin{bmatrix}\widehat{\theta} \\ \widehat{\gamma}\end{bmatrix} = (\widehat{X}\,'\widetilde{X})^{-1}\widehat{X}\,'V$.

5. Results

The performance of the semi-parametric model is compared against a Cobb Douglas Production function. The results of the Cobb Douglas production function are located in Table 4. The production inputs, physicians and medical residents, are interacted with the state and policy dummy variables to identify the policy's effect on production. The estimated coefficients are interpreted as production elasticities. In the production of both inpatient days and adjusted inpatient days (case mix index * inpatient days) the input choices are found to be endogenous via the Hausman test with a level of significance equal to 5% and 1%, respectively. The OLS estimates are found to be biased towards zero.

The estimated coefficient in the two-stage least squares equations provide evidence that the policy primarily affects the production capabilities of physicians and residents. The coefficient on the policy dummy variable alone is not found to be statistically different from zero, but the policy-input interaction terms are. As a result of the policy, a 1% increase in the number of physicians increases the number of inpatient days by 11% more than physicians in the control group; and a 1% increase in the number of residents decreases inpatient days by 7% more than residents in the control group. These results are in stark contrast to the estimates provided by OLS where changes in production elasticities for physicians and residents as a result of the policy are -2.4% and 2.5%, respectively. These estimates imply that the policy has the opposite effect than those found using the instrumental variables estimates.

The case mix index is used to account for variation in medical intensity (simple versus difficult procedures) between hospitals. Jensen and Morrisey (1986) suggests multiplying inpatient days by the case mix index to capture variation in medical intensity between hospitals. After adjusting for medical intensity, the instrumental variables estimates show that the work hour policy leads to a decrease in physician production elasticity of -7.31% and an increase of 9.07% in resident production elasticity. Although the number of inpatient days increased via physician production after the policy, the increase in inpatient days is due to an

increase in less medically intensive procedures. The work hour policy leads to an increase in the number of medically intensive procedures performed by medical residents. By reducing the number of work hours for residents, each resident is exposed to fewer medical procedures. Medical residents are required to perform a minimum of certain types of difficult procedures to meet accreditation requirement. For example, family practice residencies programs require residents to deliver a minimum of 10 continuity patients to meet accreditation. These procedures become more scares as a result of the work hour limitation forcing more common procedures to be performed by the remaining house staff.

The semi-parametric model provides a robustness check for the Cobb-Douglas results. The estimated coefficients for the semi-parametric model are found in Tables 5 and 6. Eight different specification are used to capture the effect of the policy on production: (with and without hospital type fixed effects)x(with and without higher order terms for inputs)x(with and without instrumental variables). In all eight specification the policy dummy variable is found to be statistically indistinguishable from zero. Yet, a clear change within the production function is identified in the the nonparametric component, see figures 2 and 3. With the exception of larger hospitals, overall productivity is decreased by the policy as illustrated in figure 2. The reduction in productivity in concentrated among hospitals with fewer than 200 residents. Hospitals with more than 200 resident experience modest improvement in production perhaps as a result of more efficient scheduling practices. In figure 3, the change in adjusted inpatient days per resident is increasing with the number of physicians. This result reinforces the substitution patterns of medically intensive procedures from experienced physician to medical residents. Presumably, these procedures are move to resident in order to meet accreditation requirement in light of the limited availability of residents.

insert figures 2-3

On average, a physician's production elasticity decreases by -11% (-0.1270, -0.0992) with

respect to inpatient days, but increases by 9.3% (0.0778, 0.1096) with respect to adjusted inpatient days. Medical residents experience improvements in both types of output. The resident elasticity point estimate with respect to inpatient days (adjusted inpatient days) increased by 8.2% (6.05%) and is statistically significant at the 1% level. The semi-parametric model suggests that hospitals are substituting away (or possible upgrading from) lower Diagnostic Related Group conditions (DRG) toward higher reimbursement DRG conditions. The IV estimates of the production elasticities for registered nurses (RN) and licensed practical nurses (LPN) are comparable to those found in the Cobb-Douglas model. A 1% increase in the number of RN's increases production by 49% (.2869, .6985). In contrast to the Cobb-Douglas model, OLS estimates of elasticity in the semi-parametric model overstate an LPN's effect on production and understates the effect of an RN.

There exists two limitation in using a semi-parametric approach. First, a large dataset is needed to identify the nonparametric function. A one dimensional Gaussian kernel has slower than $\sqrt{n}$ convergences (a property of full parametric models). Next, a trivariate Gaussian kernel is used to estimate the unknown function. It is well established that as the number of dimension within the kernel increases, then the rate of convergences decreases (Beyers et. al, 1999). Considering the sample size of hospitals used in this context (n = 1184 with inpatient days and n=474 with adjusted inpatient days) the semi-parametric estimates lose precision due to the curse of dimensionality. Note, the IV estimates found in models (6) and (8), which both use higher order terms for RN's and LPN's, have standard errors substantially larger than the model. In both of these equations, only the coefficient on TIME is found to be statistically significant. Though useful for identifying changes in functional form, the reader should treat the point estimates found in models (6) and (8) with some reservation.

6. Conclusion

In this study I use the New York Section 405 health code, which limits the number of hours a medical resident can work, as a natural experiment to identify the effect of work hour limitation on production, input mix, and research. The article's finding suggest that the work hour limitation, while decreasing the number of inpatient days, increased the number of medically intensive procedures as accounted by the case mix index. The limitation on resident work hours forced smaller hospitals to increase the number of available beds, to increase the flow of medically intensive patients to medical residents, and allow less critical patients to be treated by cheaper inputs (eg. RN's and LPN's). In the case of larger hospitals, the loss of resident work hours has little ro no effect on inpatient days, but the number of adjusted inpatient days increased dramatically. The work hour limitation may have forced previously inefficient hospitals to improve scheduling practices. Both payroll and total operating costs are found to increase significantly. Research funding is estimated to decrease in every area, but none of the deductions are found to be statically different from zero. The resident elasticity on production increases as a result of the work hour policy. The production elasticity is defined as $\frac{\partial F}{\partial L}\frac{L}{F}$ where L is an input into production and F is the production function. Considering that the number of medical residents per hospital remain relatively stable throughout the study, the increase in the elasticity is a direct result of an increase in the marginal product of the last resident. On average, the marginal productivity of a medical resident in terms of (adj.) inpatient days increased as a consequence of the work hour policy, which is consistent with the theory of diminshing marginal returns.

In addition to these findings, the paper presents a novel approach to estimate hospital production paying particular care to treating the endogenity problem of hospital inputs. By not removing the bias, previous studies have underestimated the marginal product of physicians and residents. A downward bias on the estimate of marginal product for physicians suggest that there exists a negative correlation between the number of medical residents and the hospital specific error in production. This correlation most likely arises from the dual

responsibilities of teaching residents and providing care found in teaching hospitals. Time spent teaching a medical resident is time not spent on productive activities. It is demonstrated that hospital inputs are endogenous; the use of doctors' wages and rival hospitals' input levels (defined as being within the same city) serve as uesful instruments for hospital inputs. The intuition arises from hospitals making output and input choices conditional on their competitors' choices of output and input.

The results have implications on how teaching hospitals will respond to a nationwide reduction on resident hours. The supply of less medically intensive procedure by hospitals will be reduced or delegated to outpatient clinics. There will be a rise in the participation level of medical residents in higher risk procedures. There will be a decrease in research (or research funding), but this result is not conclusive. From a demand perspective, disciplines, such as surgery, known for long hours will see an increases in demand for residency positions as a consequence of the policy. The work hour restriction should cause a decrease in the average number of hours worked by non-primary residents and should have little to no affect on the average hours worked by primary medicine residents.

The estimation strategy used here can be used to answer other questions about hospital an inputs. For example, what is the cost faced by hospitals to educate a resident? Teaching hospitals receive three sources of funding to educate novice physicians: direct medical education funds, indirect medical education funds, and hospital revenue. Resident wages are completely born by the federal government and the residual of the funds are used to offset teaching expenses. The cost held by hospitals is derived from wages needed to pay attendees (possibly lost research due to attendees substituting research for teaching) and differences in productivity levels between residents/physicians.

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Appendix: Tables and Figures

Tables

Table I: International Comparison of Resident Work Hour Limitations

Country	Total Duty Hours per Week	Max. Hours on Duty	Min. Rest Between Shifts
Australia	68 -75 hrs/wk	24 hrs	NA
Denmark	45 hrs/wk	NA	8-11 hrs
United Kingdom	72 hrs/wk	16 hrs	8-12 hrs
European Union	48 hrs/wk	8 hrs at Night	NA
Germany	56 hrs/wk	24 hrs	10 hrs
United States	80 hrs/wh	36 hrs	10 hrs
Netherlands	48 hrs/wk	24 hrs	10 hrs

Table II: Descriptive Statistics

	All Hospitals				New York			
Variables	1987		1991		1987		1991	
Beds	380.38	(238.85)	383.82	(230.93)	523.63	(315.47)	506.41	(301.80)
Inpatient Days (10000s)	12.57	(8.07)	10.79	(7.32)	20.73	(12.43)	16.54	(10.11)
Physicians	32.52	(67.78)	28.74	(66.27)	86.35	(95.90)	75.53	(87.38)
Residents	56.47	(104.32)	51.17	(92.14)	127.15	(161.94)	121.61	(144.47)
Registered Nurses	389.46	(312.66)	349.43	(267.45)	480.19	(367.95)	450.69	(338.43)
LP Nurses	61.16	(58.25)	64.48	(59.23)	66.08	(52.00)	62.52	(47.69)
Other	1162.94	(826.70)	1029.91	(740.93)	1599.52	(1114.67)	1438.35	(1012.37)
Total Cost ($100,000)	1069.78	(825.38)	734.93	(559.08)	1588.12	(1291.70)	1051.49	(825.32)
Payroll ($100,000)	505.04	(380.73)	357.00	(272.93)	846.12	(682.97)	558.24	(432.04)
Research Grant ($1,000)	20.173	(21.99)	23.079	(25.50)	29.627	(23.16)	3.0521	(23.52)
Training Grant	1344	(1771.00)	1468.89	(1939.54)	1760.3	(1651.71)	1776.578	(1692.10)
Fellowships	214.022	(298.24)	230.67	(271.12)	204.09	(184.69)	172.1873	(143.87)
R&D Grant	1500.6	(1724.95)	1266.34	(1493.62)	1452.46	(1250.15)	933.067	(1038.20)
Physicians Wages	54,466.04	(14,988.08)	68,242.56	(20,318.35)	50,844.88	(3,830.52)	66,647.67	(18,803.10)
N	1009				113			

Notes: Sources – American Hospital Association, NIH, 5% PUMS Census 1980-1990; Cost are in 1987 dollars; Standard deviation is in parentheses

Table III: Difference-in-Differences Results

Variables (% change)	Constant		NY		STD of Regression
Beds	.3890***	(0.07)	0.4781**	(0.22)	2.199
Inpatient Days	1.116***	(0.23)	1.086	(0.72)	7.26
Physicians	7.211***	(0.85)	-2.333	(2.69)	27.04
Residents	12.52***	(1.44)	-2.468	(4.55)	45.67
Physicians per Bed	331.7***	(42.15)	-209.73	(133.35)	1338.97
Residents per Bed	531.7***	(54.12)	-369.75**	(171.23)	1719
Registered Nurses	1.139***	(0.16)	0.616	(0.51)	5.153
LP Nurses	2.920***	(0.47)	0.837	(1.50)	15.059
Other	0.795***	(0.13)	0.577	(0.40)	3.967
Total Cost	1.431***	(0.16)	0.904*	(0.51)	5.137
Payroll	1.361***	(0.16)	1.102**	(0.52)	5.198
Research Grant	4.263*	(2.25)	-4.205	(7.13)	23.61
Training Grant	1.206***	(0.42)	-0.742	(1.29)	3.856
Fellowships	2.530***	(0.71)	-1.99	(2.16)	6.747
R&D Grant	-0.026	(0.18)	-0.197	(0.51)	1.59

Notes: Levels of significances - *** 1%; ** 5%; *10% ; SE in parentheses

Table IV: Cobb-Douglas Production Function Estimates

Cobb Douglas Production Function

DEPENDENT	INPATIENT DAYS				INPATIENT DAYS * CASE MIX			
	OLS		IV		OLS		IV	
Constant	5.721***	(.0525)	3.549***	(.7171)	5.908***	(.0851)	7.310***	(.6736)
log(Physician)	.0208***	(.0038)	.2039**	(.1094)	.0052	(.0051)	.0828**	(.0497)
log(Resident)	-.0542***	(.0046)	-.4344***	(.0716)	-.0433***	(.0071)	-.1189*	(.0692)
log(RN)	-.0330***	(.0123)	.4699	(.3196)	.1299***	(.0203)	.8721***	(.1632)
log(LPN)	.0485***	(.0039)	-.0160	(.0355)	.0487***	(.0054)	.0451	(.0389)
New York	.1432***	(.0477)	.2556	(.2887)	.3899***	(.0826)	.1722	(.2637)
Policy	.0512	(.0648)	-.0764	(.1735)	-.2133***	(.0953)	-.7509**	(.3211)
Time	-.0600***	(.0085)	.0093	(.0222)	-.1742***	(.0133)	-.1465***	(.0226)
Physician * Policy	-.0241	(.0190)	.1143*	(.0694)	-.0731***	(.0265)	-.5626***	(.1406)
Resident * Policy	.0250*	(.0144)	-.0698*	(.0372)	.0907***	(.0209)	.6753***	(.1554)
Physician * New York	-.0054	(.0142)	-.3177***	(.1190)	.0271	(.0229)	.6786***	(.1260)
Resident * New York	.0104	(.0113)	.2526***	(.0381)	-.0739***	(.0185)	-.6176***	(.1294)
no. observations	1184				532			
Hausman Test	31.23**				35.18***			

Level of significance: *** 1%; ** 5%; * 10%; SE in parentheses

Table V

SEMIPARAMETRIC ESTIMATION: INPATIENT DAYS

Variables	OLS				2SLS			
Model	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
LNLPN	0.5019***	0.1478	0.5681***	0.2465	0.0933***	-0.6931	0.0398	-0.6845
	(0.0226)	(0.1659)	(0.0259)	(0.1648)	(0.0474)	(10.7919)	(0.0419)	(3.5706)
LNRN	0.129***	0.3749***	0.1074***	0.3257***	0.4927***	6.1317	0.6214***	6.1839
	(0.0129)	(0.0780)	(0.0134)	(0.0779)	(0.1050)	(31.4913)	(0.1029)	(8.1507)
$LNLPN^2$		0.0545***		0.0484***		-0.1425		-0.3853
		(0.0173)		(0.0172)		(1.7042)		(0.6433)
$LNRN^2$		0.0384***		0.0383***		-0.5795		-0.6462
		(0.0081)		(0.0082)		(3.8744)		(1.0718)
LNLPN*LNRN		-0.0813***		-0.0754***		0.2912		0.5274
		(0.0157)		(0.0158)		(3.6838)		(1.2043)
New York	0.1686***	0.194***	0.168***	0.1888***	0.2174***	0.0992	0.2118***	-0.056
	(0.0536)	(0.0536)	(0.0536)	(0.0533)	(0.0605)	(0.9127)	(0.0527)	(0.3699)
Time	-0.0929***	-0.1063***	-0.0916***	-0.1057***	-0.1086***	-0.084	-0.0995***	-0.0044
	(0.0314)	(0.0313)	(0.0306)	(0.0304)	(0.0312)	(0.3812)	(0.0288)	(0.1824)
Policy	0.1	0.076	0.1013	0.0786	-0.0065	0.0598	0.0498	0.2119
	(0.0971)	(0.0964)	(0.0948)	(0.0935)	(0.1080)	(0.7650)	(0.0909)	(0.3416)
Hospital Type FE	no	no	yes	yes	no	no	yes	yes

Level of significance: *** 1%; ** 5%; * 10%; SE in parentheses

Table VI

SEMIPARAMETRIC ESTIMATION: ADJ. INPATIENT DAYS

Variables	OLS				2SLS			
Model	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
LNLPN	0.0818***	0.4867***	0.077***	0.4566***	0.0554	3.0584	0.0234	3.849
	(0.0184)	(0.1291)	(0.0188)	(0.1290)	(0.0582)	(4.3031)	(0.0615)	(4.5115)
LNRN	0.6428***	-0.6902*	0.6699***	-0.6333*	0.6943***	-2.302	0.706***	-1.5054
	(0.0373)	(0.3338)	(0.0409)	(0.3383)	(0.1827)	(6.1267)	(0.1710)	(5.5695)
$LNLPN^2$		0.0319***		0.0267**		0.0291		0.0159
		(0.0120)		(0.0122)		(0.1454)		(0.1849)
$LNRN^2$		0.1414***		0.135***		0.4304		0.4141
		(0.0319)		(0.0322)		(0.7314)		(0.6871)
LNLPN*LNRN		-0.0973***		-0.0877***		-0.5273		-0.6551
		(0.0247)		(0.0249)		(0.7941)		(0.8407)
New York	0.153*	0.183**	0.1663*	0.1818**	0.1947**	0.2032	0.2124***	0.1894
	(0.0866)	(0.0869)	(0.0873)	(0.0873)	(0.0860)	(0.1997)	(0.0821)	(0.2516)
Time	-0.166***	-0.1886***	-0.164***	-0.1812***	-0.1694***	-0.2*	-0.176***	-0.2056*
	(0.0486)	(0.0487)	(0.0486)	(0.0485)	(0.0483)	(0.1079)	(0.0465)	(0.1220)
Policy	-0.053	-0.1013	-0.0673	-0.1035	-0.1106	-0.2307	-0.1348	-0.2684
	(0.1268)	(0.1267)	(0.1258)	(0.1250)	(0.1232)	(0.2812)	(0.1150)	(0.3172)
Hospital Type FE	no	no	yes	yes	no	no	yes	yes

Level of significance: *** 1%; ** 5%; * 10%; SE in parentheses

Figures

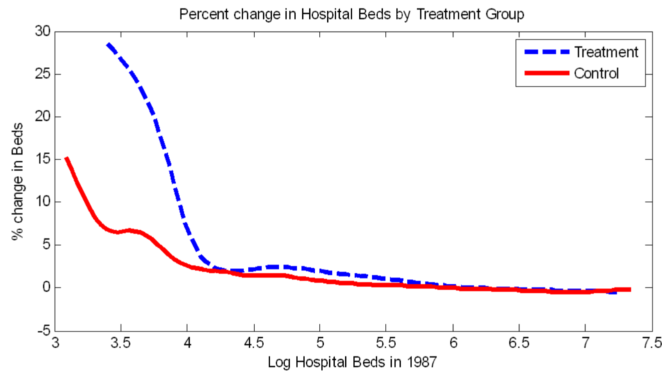

Figure 1a

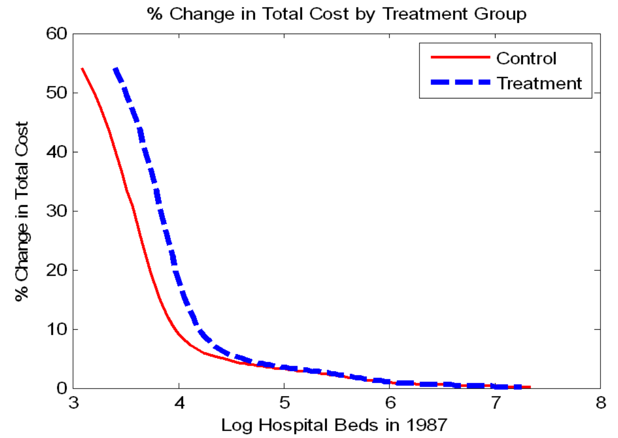

Figure 1b

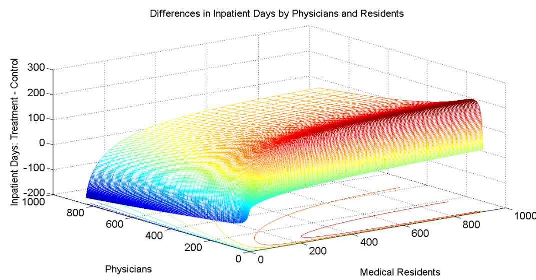

Figure 2

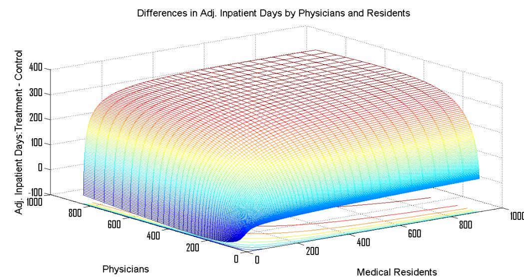

Figure 3

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