Gaming the Liver Transplant Market

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The liver transplant waiting list is designed to allocate livers to the sickest patients first. Before March 1, 2002, livers were allocated to patients based on objective clinical indicators and subjective factors. In particular, a center placing a prospective transplant recipient in the intensive care unit (ICU) leads to a higher position on the liver transplant waiting list. After March 1, 2002, a policy reform mandated that priority on the liver transplant waiting list no longer be influenced by whether the patient was in the ICU. I show that after the reform, ICU usage declined most precipitously in areas with multiple transplant centers. I find no evidence that pervasive manipulation in the most crowded liver transplant markets distorted the allocation of livers away from the intended prioritization of the sickest patients first. It appears that centers in areas with multiple competitors manipulated the waiting list to ensure that the sickest patients received a liver. (*JEL* I11, D73, I18, L22)

1. Introduction

It is well known that competition can lead to many socially desirable outcomes such as lower prices, higher productivity, and less deadweight loss. Although often socially beneficial, competition can also spawn unethical strategic choices that harm many of a firm's stakeholders and the greater public welfare (Staw and Szwajkowski 1975; Shleifer 2004). Business stealing, predatory pricing, sabotage, and dishonesty can spread across firms as strategic responses to increased competition. These responses may yield private benefit to the firm at the expense of other stakeholders.

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A key mechanism that drives the relationship between competition and unethical firm strategies is that firms are unable to commit to ethical behavior. In many interactions, if all firms could commit to eschew unethical strategies, then collectively, they would be better off. However, if all the other firms are behaving ethically, then there are enormous incentives for any one firm to behave unethically. This generates a race to the bottom where the lack of commitment that leads many firms to behave unethically oftentimes leaves all of them collectively worse off.

Uncovering evidence of ethically dubious strategies is quite difficult because these practices are usually hidden under a veil of secrecy. Firms intentionally hide unethical practices from public view to avoid legal and market-based sanctions of their strategic behavior. To study the impact of competition on unethical behavior, I use a focused empirical study of the liver transplant market that uses particularly rich data, substantial variation in competition, and a shift in policy to overcome many of the hurdles in studying the relationship between competition on unethical firm behavior.

Approximately 6000 transplants are performed annually, and, on average, 2500 people die while waiting for a liver.[1] There is substantial variation in the number of transplant centers across markets; some markets have only one firm, whereas other markets have multiple participants. Prior to March 1, 2002, a major determinant of whether a patient would obtain a liver was whether he/she was in the intensive care unit (ICU). Patients in the ICU jumped to the top of the priority list regardless of how sick they actually were. There is considerable anecdotal evidence, suggesting that to obtain livers for their patients, the transplant centers created faux-ICUs where relatively healthy people were put in the ICU to strategically advance their positions on the waiting list. After March 1, 2002, the allocation of livers changed to a system where livers were allocated solely on clinical indicators of sickness. ICU status was no longer a factor in determining whether a patient obtained a liver or not. This policy resulted in, if anything, an increase in the sickness of the average patient at transplant and a dramatic discontinuous decrease in the number of patients who were in the ICU at the time of their transplant. This seemingly contradictory behavior is consistent with centers strategically misrepresenting the health of their patients prior to the policy reforms.

Using the policy change to examine changes in ICU admission behavior, I find that after the policy change, the use of the ICU decreased more in markets with more firms. I also find that after the policy change, the percentage of relatively healthy people in the ICU decreased most in the areas with more firms. This suggests that the threshold sickness level for admitting a patient to the ICU increases most dramatically after the policy reform in the areas with more firms. Although this overly aggressive use of the ICU was certainly costly in and of itself, it is unclear whether this distorted the allocation of livers to patients. I find no evidence that after the policy change, patients were sicker at the time of transplant in markets where multiple centers compete. This

1. See Figure 1.

suggests that the strategic use of the ICU by centers competing with each other was offsetting. It appears that each competing center used the ICU to move their sickest patients to the top of the list and had a negligible overall impact on the rank ordering of patients waiting for a liver. Although certain specifications are not always significant, overall the consistency of the results highlights an association between competitive pressures and the gaming of the transplant system.

This article proceeds as follows: Section 2 reviews the relevant literature. Section 3 describes the relevant institutions and some qualitative evidence. Section 4 develops the hypotheses. Section 5 discusses the identification strategy and summarizes the sample. Section 6 explains the empirical strategy. Section 7 presents the results. Section 8 concludes.

2. Prior Literature

There has been some prior literature on the impact of competition on ethical behavior.[2] Staw and Szwajkowski (1975) and Shleifer (2004) present a straightforward argument on how competition can increase unethical behavior. They define unethical behavior as "a behavior that is morally sanctioned by the larger community but can improve firm performance." Unethical behavior on the part of competitors forces the firm to behave unethically even if the firm places some value on ethical behavior.[3]

There have been various approaches to the empirical study of the impact of competition on unethical behavior. Hegarty and Sims (1978) provide some of the first evidence linking competition to unethical behavior in the laboratory setting. They find a strong result indicating that competition increases unethical behavior, but the laboratory setting is of concern when trying to generalize the results. In contrast, in a survey of sales person behavior, Dubinsky and Ingram (1984) find no significant evidence of competition influencing ethical behavior. It is difficult to take this work as definitive due to the difficulties that are pervasive in using surveys in this area. Cai et al. (2007) find a positive association between increases in competition and an increase in tax avoidance activity among Chinese manufacturers. This article is similar to Cai et al. in that both empirical studies show the importance of competition as an explanation of unethical behavior. The current study is distinctive because many of the factors that suggest self-regulation can work are absent in the work of Cai et al. on Chinese manufacturers.

2. There is an exceptionally large literature on ethics in business, which is beyond the scope of this article. See Ford and Richardson (1994), Loe et al. 2000, and Trevino et al. (2006).

3. This is part of the more general argument that ethical behavior is endogenous to social circumstances. For example, see Milgram (1963) and Trevino et al. (2006). Scalet (2006) provides an intriguing argument that it might not always be optimal to design institutions to solve ethical behavior induced by competition.

There is a limited economics literature studying the impact of the opportunity to engage in business stealing practices on market entry. These articles demonstrate in a variety of settings that free entry can be inefficient when the entrant's business plan is to steal incumbent's business rather than generate new value.[4]

There are also sets of studies in the health-care literature that look at the impact of incentives on ethical behavior. Dafny (2005) provides a useful framework for dividing this literature into two areas: nominal responses to incentives and real responses. The work on nominal responses focuses on how price changes in reimbursement rates provide incentives for hospitals to change their diagnosis. This behavior essentially redistributes wealth from the insurance providers to the hospital without providing additional services. Additionally, many articles find that as the relative reimbursement rates for treatments change, hospitals respond by moving to more lucrative diagnoses (Carter et al. 1990; Psaty et al. 1999; Silverman and Skinner 2004; Dafny 2005).[5]

This literature also studies how real responses, such as treatment choices, are affected by financial incentives. In an influential article, Gruber and Owings (1996) show that an increase in reimbursements for cesarean sections is associated with an increase in the number of cesarean sections performed by obstetricians. Cutler (1995) and Gilman (2000) additionally find evidence of a positive association between reimbursement rate and procedure intensity, as measured by length of stay or number of procedures performed. However, the results are not ubiquitous. Dafny (2005) finds little evidence of increases in reimbursements leading to changes in length of stay, procedure volume, or survival rates.

This article contributes to the literature in two ways. First, the ethical dilemma is much more intense in liver transplants than in other markets. Second, few of these studies look at the impact of competition on ethical behavior.[6] One could easily imagine that when the potential for harm is high, a relatively small number of hospitals could find ways to cooperate so as to avoid giving a liver to a relatively healthy patient. Professional codes of ethics and not-for-profit organizational status are major factors that could push these centers to cooperate. This article shows that even with a limited number of competitors and muted incentives, many centers act unethically.

Finally, Scanlon et al. (2004) also has a study similar to mine looking at the association between competition and the gaming of the heart transplant market. They study a policy change in 1999 that made it more difficult to move patients to the top of the heart transplant waiting list. In 3 years prior to 1999,

4. Examples from this literature include Hsieh and Moretti (2003), Berry and Waldfogel (1999), and Davis (2006).

5. Vaughn (1983) provides a detailed case study on Medicare fraud that is related to this empirical literature.

6. There is a literature on how hospital competition influences other outcomes (health, costs, etc.). See Dranove et al. (1992), Kessler and McClellan (2000), and Kessler and Geppert (2005).

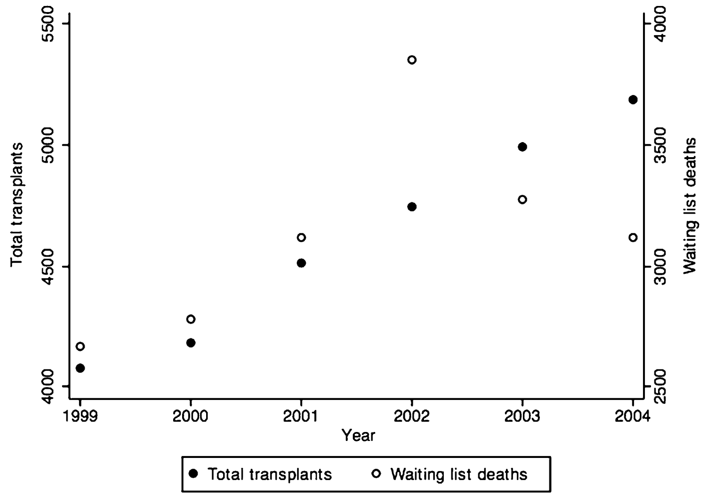

Figure 1. Data Obtained from UNOS STAR File.

they find a cross-sectional association between the number of transplant centers in an area and the probability that a patient was listed in the most serve need category at the time of transplant. After 1999, when listing a patient in the top priority became less subjective, the cross-sectional association between the number of firms in the market and percentage of patients in the most serve need disappeared. Though their study of hearts is similar to my study of livers in the basic setup, there are two crucial distinguishing factors in this article: (1) My article uses individual clinical-level data on how sick the patient was at the time of the transplant. This enables me to establish whether the aggressive use of the ICU influenced the final allocation of livers to patients. Because Scanlon et al. (2004) were using aggregate data, they were not able to say anything about whether manipulation of patient status on the heart transplant waiting list actually influenced the final allocation of organs. Additionally, I am able to show that manipulation was in fact used on sicker patients. (2) I use monthly level data and a panel approach that allow me to control for a variety of confounding effects not addressed by Scanlon et al. (2004). Using a richer set of controls, area-specific time trends, and regional time-varying fixed effects allows for a more convincing display that the observed changes in behavior are attributable to the policy change and not to heterogeneous area-specific trends over time.

3. Institutional Background

In the United States, the demand for liver transplants exceeds the supply of available livers. Figure 1 shows that the number of liver transplants has risen steadily to approximately 6000 transplants per year. Figure 1 also shows that

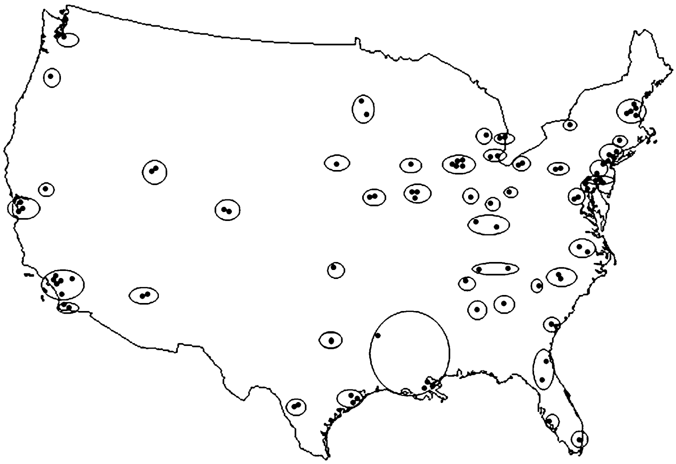

Figure 2. OPO Boundaries and Center Locations are for All Centers Active from March 1, 2001, to March 1, 2003.

there is still a significant gap, as more than 2000 people die each year waiting for a liver. Occasionally, part of a liver can be given from a living donor to a patient in need, but the risk associated with this procedure is high. More than 95% of all liver transplants come from deceased donors.

Liver transplants are performed by more than 100 centers in the United States, and each center is part of a hospital. The procurement and distribution of deceased donor livers are handled by geographically designated Organ Procurement Organizations (OPOs).[7] The OPOs are not run by specific hospitals, and each center is a member of only one OPO. When an OPO obtains a liver suitable for transplant, the centers within the OPO have first priority to that organ. Between March 1, 2001, and February 28, 2002, approximately 74% of livers stayed in the OPO where they were donated and 94% stayed within the same region.[8] Despite the high stakes involved in liver transplant, there is considerable variation in the probability of getting a liver across different parts of the country. During the period of March 1, 2001, to February 28, 2002, there were considerable differences in the ratio of severely ill patients to available livers across different OPOs.[9] The 25th percentile OPO had a monthly average of 1.12 severely sick patients for each liver, whereas the 75th percentile OPO had a ratio of 2.53 severely sick patients for each liver.[10] Given the high stakes involved, there would be strong incentives

7. Figure 2 shows a map that illustrates the distribution of centers and OPOs.

8. These 11 regions were chosen by UNOS. This differs from the standard convention of four regions in the United States. These numbers only vary minimally before and after the MELD policy change. After the policy change, the probability that a liver is shared outside the OPO increases by about 1.5%.

9. The definition of what constitutes a severely sick patient is given in Section 6.

10. Trotter and Osgood (2004) also show that there are large cross-sectional differences in liver scarcity across OPOs.

for a patient to move across the country to an area with less liver scarcity. Intuitively, two factors seem to limit sick patients from sorting across the country to compete away this variation: financial constraints and attachment to home hospitals. It is often difficult to move away from your home to swait for another liver. People who are in poor health often do not have the financial resources to relocate across the country. Insurance may not cover procedures at hospitals located further away from your home. Finally, some individuals may be unaware of these differences and or have other attachments to local healthcare providers.

The boundaries of the OPOs that limit national sharing of organs are maintained in part for political reasons; areas with a relatively good supply of organs are reticent to share them with other parts of the country. Within each OPO, there are a variety of market structures; some OPOs only have one center that provides liver transplants, and others have multiple transplant centers. When a patient needs a liver, they join the waiting list that is specific to a particular center. Although a patient can be listed at multiple centers for a liver transplant, during the sample period, this occurred approximately 4% of the time. There are certain compatibility concerns based on blood type. The matching requirements tend not to be as severe as those for kidney transplants.

Centers have discretion in the organs that they accept. When a center decides whether to accept or decline an organ, there are no hard guidelines. Centers make decisions on whether to accept a lower quality organ today based on the expected probability of receiving a higher quality organ sometime in the future (Howard 2002; Alagoz et al. 2007). The conclusions of these models and from practice is that people who are very sick are more likely to receive a marginal organ since the cost of waiting is exceptionally high.

The goal of the allocation system since the mid-1990s until today has been to prioritize the sickest individuals first. This is certainly not the only welfare criteria that could be used for allocation policy.[11] During the period of study, the stated goals of the program did not change, but the ways in which the allocation scheme meant to implement those goals did. Prior to March 1, 2002, livers were allocated on both objective and subjective criteria.[12] Priority was determined on the basis of a discrete aggregation of clinical scores[13] and waiting list time. Since the scoring system was not continuous, this leads to many patients being clumped together in terms of priority. Time on the waiting list was used to distinguish between these patients and became one of the most important factors in determining who received a liver and who did not.[14] The rules at the time stated that if a patient was in the ICU, they would move up the

11. Currently, in kidney transplants, there is a substantial debate over changing the kidney allocation scheme to one based on net lifetime benefit, where kidneys go to those who would benefit the most from them.

12. See the Institute of Medicine's (1999) report for a detailed discussion of the allocation prior to the policy change. In the interest of space, I am only able to give a very brief overview.

13. This aggregation was called the Child-Turcotte-Pugh scoring system.

14. Unfortunately, prior research has shown that time on the waiting list was a poor predictor of patient health.

list ahead of anyone who was not in the ICU. Being moved into the ICU meant being moved ahead of those who had been on the waiting list longer but were not in the ICU. Once in the ICU, livers would then be allocated to patients based on a discrete aggregation of clinical scores and then on the basis of how long they have been in the ICU. Patients within an OPO had first priority, but there was a system in place to promote limited regional sharing. If there were no patients who required continuous medical care (either in the hospital or at a facility close to the hospital), then a liver would be moved outside of the OPO. This policy leads to about a fourth of the livers moving outside of their home OPO.

The system was criticized for creating numerous incentives and opportunities to manipulate who gets a liver. Centers could put potential patients on the waiting list years before they would actually need a liver so as to inflate their waiting time. Many of the subjective indicators could also be manipulated. For example, one of the subjective indicators transplant centers were required to measure was the severity of ascites, which is an accumulation of fluid in the abdomen. Without an invasive surgery, measurement of this condition is subjective and left considerable discretion to the centers.[15]

Crucially, putting someone in the ICU improved their priority status, even over those who had more time on the waiting list. There was some anecdotal evidence that ICU admission was being used strategically. The most salient case involved the University of Illinois' liver transplant program in the highly competitive Chicago liver transplant market. It was claimed that "according to the Chicago Tribune, some of the patients [in the ICU] at the University of Illinois Medical Center spent weekends at home, one acted the part of a clown at a blood drive, and another was at a restaurant having dinner when he got word that a suitable liver had been located. Authorities alleged that one patient on the list was not even eligible for transplantation" (Murphy 2004).[16] Centers could use the ICU strategically by admitting patients who were not critically ill so as to move them ahead on the list. The University of Illinois was eventually fined 2 million dollars by Medicare for this abuse of the transplant system.

In response to these problems, the United Network for Organ Sharing (UNOS) completely changed the allocation policy by instituting the Model for End-Stage Liver Disease (MELD) allocation policy.[17] The MELD policy was instituted on March 1, 2002. The MELD allocation policy for livers is based on a linear combination of three clinical indicators: serum bilirubin, International normalized ratio, and serum creatinine. These factors combined to create a continuous MELD score that is strongly associated with severity of liver disease. Higher MELD scores reflected higher expected mortality rates for a patient with end-stage liver disease absent a transplant. After the policy

15. In response, it is widely believed that most centers gave almost everyone a high score. The data to confirm this observation unfortunately do not exist.

16. Also, see *Transplant News (November 30, 2003)*.

17. For more details on the policy change and some of its direct effects, see Freeman (2003), Freeman et al. (2002), Trotter and Osgood (2004), and Wiesner et al. (2003).

change, waiting list time and ICU status were no longer considered in the allocation of livers. Priority was now based on clinical indicators that came from blood tests, which are markedly more difficult indicators to manipulate.

4. Empirical Tests

Using the logic of Staw and Szwajkowski (1975) and Shleifer (2004), I propose a simple framework for analyzing the impact of competition on strategic misrepresentation in the liver transplant market. Prior to the policy change within an OPO with multiple competitors, it is sensible to believe that strategic use of the ICU by centers to move patients ahead on the list can be a rational outcome, absent the ability to commit to ethical strategies. If one center in an OPO decided not to engage in strategically using the ICU, that center would face the prospect of losing opportunities to perform liver transplants. More centers should lead to more competition. After the policy change, the impact of competition on strategic use of the ICU should be eliminated. This leads to the following hypothesis:

Hypothesis 1. After the policy change, the rate of ICU usage should decrease more in OPOs with more centers.

A natural point of concern is that areas with more competitors may also have sicker patients on average. If the patients are sicker in more competitive areas, then hypothesis 1 could be true without strategic manipulation. This can be addressed in a number of ways. First, it is possible to control for the underlying number of sick patients on the waiting list. Second, I can construct an objective clinical measure of illness at the time of transplant. This measure can be used to examine what the threshold for admission to the ICU was. If strategic manipulation was present prior to the policy change, then in competitive areas, there would be a higher likelihood that relatively healthy patients would be in the ICU at transplant. If the policy change eliminated the incentives for this behavior, then we have the following hypothesis.

Hypothesis 2. After the policy change, the MELD scores of patients transplanted from the ICU should increase more in OPOs with more centers.

Finally, it is important to know whether distortions to the sickest first prioritization were more likely in OPOs with more firms. Consider a hypothetical OPO with two centers. Suppose that both centers were equally aggressive in admitting their sickest patients to the ICU prior to the reform. The sickest patients would be moved into the ICU and consequentially to the top of the list. Though the ICU was being used excessively, the sickest patients would still receive livers regardless of the attempt to manipulate the list. After the reform, the ICU would be used less aggressively, relatively healthy patients would be kept out of the ICU, but the average level of sickness of patients at the time of transplant should remain unchanged. Empirically, I would expect to observe that the change in the average patient's MELD scores at the time of transplant induced by the policy reforms would not be influenced by the number of centers in an OPO. Alternatively, if the centers were using the ICU to move relatively healthy people ahead of sicker people on the list, I would expect the average level of sickness of patients at the time of transplant to increase after the reforms.

5. Data and Sample Selection

The data for this project come from a comprehensive database on every liver transplant performed in the United States from the middle of 1987 to the end of 2008 maintained and provided free of charge from the UNOS. These patient-level data include observations when (1) a patient registers for the waiting list, (2) a patient gets a transplant, and (3) if a patient dies. In these data, there is clinical information sufficient to create a MELD score for each patient,[18] identification of the center where the patient was wait listed and received their transplant at, when they were wait listed and transplanted, demographic data, cause of liver disease, and whether they were in the ICU or not at transplant. From these data, I was able to incorporate the identity of the OPO with each center based on data publicly available on the UNOS Web site. Even though the data are at the patient level, all the data are collapsed to the OPO/Month level or the center/Month level.

To study the impact of the change in allocation policy, I restrict the sample to 1 year before and 1 year after the policy shift. I use the identifiers provided in the data set to define a center. One exception to this is the case of children's hospitals. Pediatric liver transplants performed at a children's hospital are done in conjunction with a team at a hospital that performs adult liver transplants. For example, in Chicago, both Northwestern Memorial Hospital and Children's Memorial Hospital are in the Northwestern University system. The transplant teams in both these hospitals work together and the surgeons at both institutions are Northwestern faculty members. For the 17 children's hospitals in the data set, I searched to find what adult transplant program they were affiliated with and merged the two together as one center.

Another difficulty with the data was that there were many observations where the MELD score could not be computed because one of the three clinical indicators was missing. To address this problem, I created predicted MELD scores at transplant when one or two of the clinical factors were missing. Though this is not desirable, it provides a useful way to incorporate more than 98% of the data into the analysis. The remaining observations where no MELD score could be computed for a transplant recipient were dropped.

6. Empirical Strategy

I compare how the number of firms in an OPO influences the key outcome variables: ICU usage rates, average sickness at the time of transplant,

18. Ocassionally, one component of the MELD score was missing. To make all the MELD scores comparable across individuals that component was interpolated.

percentage of healthy patients in the ICU, and share of patients in the ICU. This comparison is done in two ways: in the cross section and through a difference in differences approach. In the cross section, I look at how variation in the number of firms across markets impacts the outcomes before and after the policy change. One objection to this cross-sectional approach is that omitted fixed characteristics at the OPO level drives the results. To address this concern, I estimate how firms in competitive markets respond to the change in policy. If there was more strategic manipulation of the list in markets with more firms, then, for example, we would expect a decrease in the percentage of patients who were admitted to the ICU relative to less competitive markets.

To examine the impact of the number of firms on the different sets of outcomes in the cross section before and after the policy shift, I use the following specification at the OPO/Month level:

$$\text{Outcome}_{i,t} = \beta_1 \text{Firm Count}_i + \text{Month}_t + \varepsilon_{i,t}. \tag{1}$$

Here, firm count is the number of distinct centers active during the 2-year sample period in a given OPO. Although the count of the number of firms in an OPO is a crude measure of market competition, it has the advantage of being plausibly exogenous. One could use a Herfindahl index based on number of transplants performed, but the distribution of transplants is likely to be endogenously determined by the behaviors of moving patients into the ICU strategically. It also may be important to measure the presence of a small player in the market since they could threaten the positions of the other firms in the market. The Month variable is a fixed effect for each month in the sample, so the same calendar month in separate years have separate fixed effects. Region is a fixed effect that controls for 11 different parts of the country. These regions are approximately equal in size. This sentence has different font for some reason.

To partially obviate the concerns about using a cross-sectional approach, I employ a difference in differences estimation strategy:

$$\begin{aligned}\text{Outcome}_{i,t} = {} & \beta_1 \text{Firm Count}_i + \beta_2 \text{MELD era}_t \times \text{Firm Count}_i \\ & + \beta_3 \text{Controls}_{i,t} + \beta_4 \text{MELD era}_t \times \text{Controls}_{i,t} \\ & + \text{Month}_t + \text{OPO}_i + \varepsilon_{i,t}.\end{aligned} \tag{2}$$

Here, the identification of the impact of competition on the outcome of interest is measured by the β_3 parameter. This measures how OPOs with different numbers of firms respond to the policy change, where MELD era equals zero before the policy change and equals one afterward. Since there are dummies for each month, the main effect of MELD era is absorbed. If the cross-sectional results indicate an effect of competition on the outcome but there is no difference in the response to the policy shift, the evidence would be far less compelling. Since the variation in the market structure of the OPOs does not change over time when the OPO fixed effects are included, the parameter β_1 will be absorbed. However, the interaction effect is still identified.

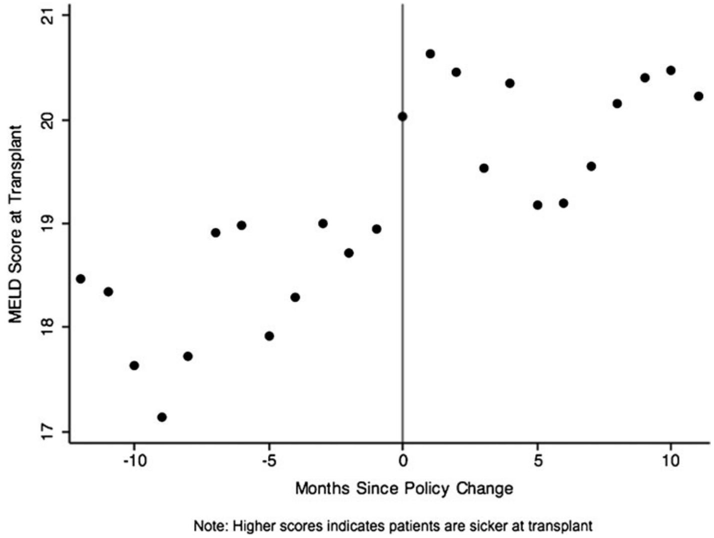

Figure 3. The Policy Change Occurred on March 1, 2002. MELD Scores are a Clinical Measure of Illness. Higher Scores Imply Sicker Patients. Scores are Compute from the UNOS STAR File.

To control for OPO-level characteristics that may confound the relationship between the firm count and the outcome, I construct several control variables at the OPO level. Sick ratio is a proxy for the scarcity of livers in a given OPO. To construct this variable, I compute the number of patients who died waiting for a transplant in a given month for every OPO and then divide by the cumulative waiting list size in the OPO. Though somewhat crude, this ratio captures in part the scarcity at the OPO level. I also create a monthly measure of the total number of transplants at the OPO level called OPO volume. This is included because it is possible that size of the OPO rather than the number of firms in the OPO might be driving the relationship between the firm count and the outcome of interest. To evaluate whether this is the case, it is important to control for the number of livers transplanted in the OPO and the interaction of that variable with MELD era. I also created a variable to capture the prestige of the medical center. This control measures the percentage of centers in an OPO that were listed in the 2002 U.S. News survey of hospitals as a top 25 center for digestive disease.[19] Finally, I use the waiting list data to construct a composite measure of the average age, median income, and percentage of minorities on the waiting list at the OPO level.[20] For the characteristics where there is no panel variation,[21] the main effect will be absorbed by the OPO-level fixed effect. However,

19. Using top 25 nephrology programs yields similar results.

20. This measure was constructed from the average characteristics of each person added to the wait list from January 1, 2000, to December 31, 2002.

21. The demographic characteristics and the center rankings.

Table 1. Summary Statistics

	Pre-MELD era	Post-MELD era
Total number of liver transplants	5221	5368
Percentage of patients coming from the ICU	24.38	13.38
Mean predicted MELD score at transplant	18.32	20.01
Percentage of patients with a predicted MELD score greater than or equal to 25 at transplant	21.96	26.15

when these controls are interacted with the MELD era dummy, this interaction is not absorbed by the OPO-level fixed effect.

There are further worries about specification (2) that could pollute the validity of the regressions. First, if there are different trends in the movement of the outcome variable of interest at the OPO level that could lead to an omitted variables bias. Although the month fixed effects absorb the common changes over time to the entire system, they do little to address changes at the OPO level. Although it would be ideal to add OPO-specific month effects, this would absorb all the variation to observe the parameter of interest β_3. One compromise is to allow for quadratic trends at the OPO level. I create a quadratic term for months centered at zero for March 2002 and going backward and forward 1 unit for each month difference. Though this imposes a quadratic structure on the trends, it is much less restrictive than not allowing for any OPO-specific time changes. In other specifications, I interact the variable sick ratio with the OPO fixed effects. The intention of this strategy is to estimate the β_3 parameter while flexibly controlling OPO-specific changes in the level of scarcity.

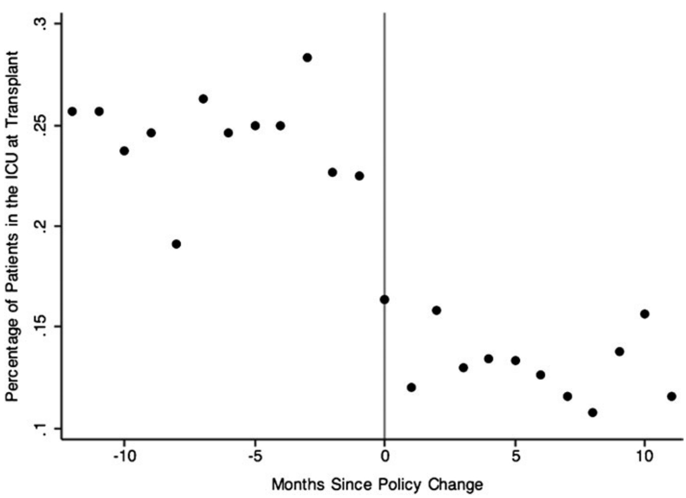

Figure 4. The Policy Change Occurred on March 1, 2002. Data Obtained from UNOS STAR File.

Table 2. Distribution of Firm Counts across OPOs

Number of centers	Frequency	Percentage
1	23	46
2	17	34
3	4	8
4	3	6
5	2	4
6	1	2
Total	50	100

As a robustness test, I include a specification that interacts MELD era and region[22] to further allow for flexible time effects across geographically connected OPOs. All the results are estimated using clustering at the OPO level. This addresses the problem of serial correlation without which the regression would assume that each observation is independent.

7. Results

7.1 Summary Statistics

In Figure 3, the average MELD score at transplant is computed on a monthly basis. It is difficult to determine whether there is a discontinuous jump in the average sickness at transplant, but it is clear that sickness of patients at transplant is increasing over time.

Prior to the policy change, the average MELD score was 18.32 and after the policy shifts, the average MELD score was 20.01 Table 1. Although the average sickness of patients at transplant was increasing over time, Figure 4 shows that there was a large discontinuous drop in ICU admissions. Intuitively, one would think the opposite: As patients are getting sick, they should appear in the ICU more on average. Strategic manipulation of the allocation process leads to the opposite conclusion, when the incentive to place a patient in the ICU decreases, the usage of the ICU decreases overall. This occurs despite the fact that patients are getting sicker over time.

In Table 2, the market structure of the 50 OPOs is described. Forty-six percent of the OPOs had only one transplant center, while 20% of the OPOs had more than three centers. This variation in the market structure over the 2-year sample period makes for an ideal sample to study the effects of increased competition on strategic manipulation. Tables 3 and 4 show that the difference in differences approach is seen in the unconditional data.

7.2 Hypothesis 1 Test

Table 5 presents the basic results on the percentage of transplanted patients who come from the ICU. The results are consistent with hypothesis 1. In column (1), the cross-sectional results from the year before the policy shift show a strong association between the number of firms in an OPO and the percentage

22. Recall that region is a UNOS designation for 11 distinct parts of the country.

Table 3. Difference in Differences Impact of MELD Reforms and Competition on the Percentage of Patients Transplanted from the ICU

	Pre-MELD era	Post-MELD era	Difference
Single-center OPO	0.138 (0.012)***	0.104 (0.010)***	0.034 (0.015)***
Multicenter OPO	0.268 (0.007)***	0.141 (0.005)***	0.127 (0.008)***
Difference	−0.130 (0.014)***	−0.037 (0.010)***	−0.092 (0.017)***

Data are at the OPO month level.
*, **, and ***Significant at the 10%, 5%, and 1% confidence levels, respectively.

of transplanted patients coming from the ICU. Column (2) shows the same regression for the year following the policy shift. The impact of the number of firms in an OPO has decreased and is no longer significant. Columns (3)–(6) show a variety of specifications estimating whether the difference between the firm count parameters in columns (1) and (2) is significant. Column (3) presents the most basic difference in differences specification to test the significance of the difference between the parameter estimates of firm count in columns (1) and (2). The parameter estimate of the interaction between MELD era and firm count suggests that for each additional firm, 3.6% less of the patients are in the ICU at transplant after the MELD policy shift. Taken together with Figure 4, this shows that the fall in the use of the ICU was most dramatic in areas with the strongest competition implying that competition was a strong driver of strategic manipulation. The specifications in columns (4)–(7) address the various threats to identification that revolve around OPO-specific time trends or omitted variables bias due to differences in the underlying degree of scarcity. The parameter estimate on the interaction between firm count and MELD era is quite stable across specifications and is always highly significant.

7.3 Hypothesis 2 Test

Do more firms in an OPO lead to relatively healthier people being admitted and transplanted from the ICU? To operationalize this point, I look at the MELD scores of patients who were in the ICU at the time of transplant. In Table 6, column (1) suggests that prior to the MELD reforms, the MELD scores of patients coming from the ICU were lower in the more competitive areas. After

Table 4. Difference in Differences Impact of MELD Reforms and Competition on the MELD Scores of Patients in the ICU

	Pre-MELD era	Post-MELD era	Difference
Single-center OPO	29.35 (0.71)***	30.73 (0.85)***	−1.39 (1.10)
Multicenter OPO	26.00 (0.25)***	31.26 (0.32)***	−5.25 (0.40)***
Difference	3.34 (0.66)***	−0.52 (0.85)	3.86 (1.06)***

Data are at the OPO month level.
*, **, and ***Significant at the 10%, 5%, and 1% confidence levels, respectively.

Table 5. The Impact of Competition after the Reforms on the Percentage of Patients Transplanted from the ICU

	Percentage of patients in ICU at transplant						
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Firm count	0.047 (0.011)***	0.011 (0.008)	Absorbed	Absorbed	Absorbed	Absorbed	Absorbed
MELD era × firm count			−0.036 (0.007)***	−0.041 (0.014)***	−0.033 (0.014)**	−0.039 (0.017)**	−0.048 (0.016)***
Era	Pre-MELD	Post-MELD	Both	Both	Both	Both	Both
Region fixed effects	Yes	Yes	Absorbed	Absorbed	Absorbed	Absorbed	Absorbed
OPO fixed effects	No	No	Yes	Yes	Yes	Yes	Yes
Month fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Quadratic month term × OPO fixed effects	No	No	No	Yes	Yes	Yes	Yes
MELD era × OPO demographic and program prestige controls	No	No	No	No	Yes	Yes	Yes
MELD era × OPO sick ratio	No	No	No	No	Yes	Yes	Yes
MELD era × OPO volume	No	No	No	No	Yes	Yes	Yes
OPO fixed effects × OPO sickness ratio	No	No	No	No	No	Yes	Yes
MELD era × region fixed effects	No	No	No	No	No	No	Yes
Number of observations	580	584	1164	1164	1164	1164	1164
Number of clusters	50	50	50	50	50	50	50

Main effects are included in all specifications with interactions. SEs clustered at the OPO level.
*, **, and ***Significant at the 10%, 5%, and 1% confidence levels, respectively.

Table 6. The Impact of Competition after the Reforms on the MELD Score of Patients Conditional on Being in the ICU at Transplant

	MELD score for transplants from ICU						
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Firm count	−1.26 (0.42)***	0.79 (0.38)**	Absorbed	Absorbed	Absorbed	Absorbed	Absorbed
MELD era × firm count			1.39 (0.41)***	1.35 (0.63)**	1.27 (0.67)*	1.05 (0.76)	1.92 (1.11)*
Era	Pre-MELD	Post-MELD	Both	Both	Both	Both	Both
Region fixed effects	Yes	Yes	Absorbed	Absorbed	Absorbed	Absorbed	Absorbed
OPO fixed effects	No	No	Yes	Yes	Yes	Yes	Yes
Month fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Quadratic month term × OPO fixed effects	No	No	No	Yes	Yes	Yes	Yes
MELD era × OPO demographic and program prestige controls	No	No	No	No	Yes	Yes	Yes
MELD era × OPO sick ratio	No	No	No	No	Yes	Yes	Yes
MELD era × OPO volume	No	No	No	No	Yes	Yes	Yes
OPO fixed effects × OPO sickness ratio	No	No	No	No	No	Yes	Yes
MELD era × region fixed effects	No	No	No	No	No	No	Yes
Number of observations	383	323	706	706	706	706	706
Number of clusters	48	48	48	48	48	48	48

Main effects are included in all specifications with interactions. SEs clustered at the OPO level.
*, **, and ***Significant at the 10%, 5%, and 1% confidence levels, respectively.

the reform, the result reverses itself. The results from the difference in differences specifications in columns (3) and (4) conform to this intuition. I find that the inclusion of OPO control variables in columns (5) and (6) does not materially change the parameter estimates but reduces the significance of the estimates. Given the conservative clustering and the fact that some of the variables are such as OPO volume colinear with the number of firms in an OPO, this is not surprising. In specification (7), I find that including interactions for region fixed effects and post-MELD era reforms again yields significant results while the control variables are included. By including interactions between region and MELD era in this specification, I restrict the comparison across different firm counts to other OPOs within the region. It is reasonable to assume that geographically closer entities would make better control groups. Although the evidence is not perfect, it seems to point toward an association between the number of firms in an OPO and a post-MELD decrease in the likelihood that a relatively healthy person will be put in the ICU.

7.4 Implications for the Allocation of Livers

Table 7 shows basic results on the association between the number of firms and the change in the MELD scores of patients at the time of transplant. The impact of the policy reforms on the sickness levels of patients at the time of transplant is not influenced by the number of centers in an OPO. In specifications (1) and (4), I find that the interaction between the MELD reforms and the number of firms in an OPO yields a small and statistically insignificant result. From specification (4), the 95th percentile upper bound on the coefficient of interest is equal to 0.66. This implies that one additional center in an OPO would increase the average MELD score at transplant after the reform by at most 0.66.[23] Specifications (2), (3), (5), and (6) show further results using the percentage of transplants performed on those with very high MELD scores and the very low MELD scores. Although column (3) is significant, the more flexible specification used in column (6) eliminates the significance. Again, the results are very small in magnitude. Calculations using other specifications seen in Tables 5 and 6 yield similar results.

7.5 Robustness Tests

In Table 8, I show that relaxing the assumption of a linear structure on the firm count variable does not substantially change the results from Tables 5–7. In columns (1)–(3), I create a fixed effects for all possible numbers of centers in an OPO and regress it on all three of the prior outcomes.[24] In columns (4)–(6), I perform a similar analysis using specification (4) from Tables 5–7. I find that this relaxed functional form is consistent with the prior results.

23. A 0.66-point increase in a MELD score is approximately equal to a 0.3% increase in expected 1-year survival. This comes from a calculation performed by the author.

24. I use specification (3) from Tables 5–7.

Table 7. The Impact of Competition after the Reforms on the MELD Scores of All Patients Transplanted

	MELD score at transplant	Percentage with MELD score ≤25 at transplant	Percentage with MELD score ≤15 at transplant	MELD score at transplant	Percentage with MELD score ≤25 at transplant	Percentage with MELD score ≤15 at transplant
	(1)	(2)	(3)	(4)	(5)	(6)
Firm count	Absorbed	Absorbed	Absorbed	Absorbed	Absorbed	Absorbed
MELD era × firm count	−0.161 (0.156)	0.002 (0.007)	0.029 (0.010)***	−0.05 (0.36)	0.018 (0.018)	0.020 (0.022)
Era	Both	Both	Both	Both	Both	Both
OPO fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Month fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Quadratic month term × OPO fixed effects	No	No	No	Yes	Yes	Yes
Number of observations	1163	1163	1163	1163	1163	1163
Number of clusters	50	50	50	50	50	50

Main effects are included in all specifications with interactions. SEs clustered at the OPO level.
*, **, and ***Significant at the 10%, 5%, and 1% confidence levels, respectively.

Table 8. Alternate Specifications for Market Structure

	Percentage of patients in ICU at transplant	MELD score for transplants from ICU	MELD score at transplant	Percentage of patients in ICU at transplant	MELD score for transplants from ICU	MELD score at transplant
	(1)	(2)	(3)	(4)	(5)	(6)
MELD era × two firms	−0.064 (0.031)**	2.97 (1.83)*	0.30 (0.72)	−0.121 (0.062)**	2.08 (2.42)	1.15 (1.42)
MELD era × three or more firms	−0.060 (0.020)***	3.39 (3.58)	−1.14 (0.69)	−0.019 (0.062)	2.17 (7.29)	−0.23 (1.10)
MELD era × four or more firms	−0.146 (0.023)***	5.56 (2.27)**	−0.81 (0.49)	−0.179 (0.043)***	5.49 (2.46)**	1.21 (1.44)
MELD era × five or more firms	−0.106 (0.051)**	4.91 (1.95)**	−0.47 (0.48)	−0.176 (0.043)***	7.01 (2.71)**	−0.72 (2.30)
MELD era × six or more firms	−0.187 (0.015)***	6.91 (1.26)***	0.19 (0.48)	−0.157 (0.031)***	3.66 (2.08)*	−1.45 (0.90)
Number of firms dummies	Absorbed	Absorbed	Absorbed	Absorbed	Absorbed	Absorbed
OPO fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Month fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Quadratic month term × OPO fixed effects	No	No	No	Yes	Yes	Yes
Number of observations	1164	706	1164	1164	706	1164
Number of clusters	50	48	50	50	48	50

In columns (4)–(6), single-firm OPOs are the omitted category. SEs clustered at the OPO level.
*, **, and ***Significant at the 10%, 5%, and 1% confidence levels, respectively.

Finally, in unreported results,[25] I find that organ acceptance policies do not change after the MELD policy. Using age of the donor[26] as a proxy for organ quality, I find no effect on the interaction between firm count and MELD era using specifications similar to Tables 5–7. This issue is of concern since marginal organs often go to very sick patients. If after the MELD era OPOs with more firms became less likely to accept marginal organs, then transplants from the ICU would also go down. The evidence is not consistent with this explanation.

8. Conclusions

This article shows that the number of firms in the OPO appears to be robustly associated with increases in strategic behavior in the liver transplant market prior to the MELD reforms. The findings suggest that when centers are faced with opportunities to reallocate livers from the patients of other centers to their own patients, these opportunities were taken. I found that prior to the reforms, competition encouraged centers to use the ICU more often for patients who were relatively healthy. There was little evidence to suggest that this distorted the level of sickness of patients at transplant. This suggests that centers used the ICU to make sure that their sickest patients maintained a high priority on the waiting list. The aggressive use of the ICU in OPOs with many firms did not seem to significantly distort away from the intended policy of prioritizing the sickest patients first for a liver transplant.

One important issue to note is that these estimates should not be interpreted as a causal relationship between competition and ethical behavior. Although the policy change enables me to observe a change in gaming behavior, I do not have a good instrument for competition across OPOs. Although it is likely that many exogenous factors shaped the current market structure, it is difficult to isolate these factors in the form of an instrument.

Another issue to note is that there is considerable ambiguity in the welfare implications of the gaming of the liver list. Strategically manipulating the list for the benefit of a relatively healthy patient at the expense of a relatively sick, one could be welfare improving. An anecdotal observation among transplant surgeons is that patients often stay at their level of activity prior to transplant. So, if a patient was not working prior to transplant, anecdotally they do not return to work. By providing a liver to a patient sooner rather than later, the patient's benefit from the organ could be larger. However, if the sole purpose of strategically manipulating the list was to get healthier patients' livers, then we should not see such a strong association between the number of firms and gaming behavior. Examining these broader ethical issues of strategic manipulation is interesting but is beyond the capabilities of this article.

25. Results available upon request.

26. Although age is not a perfect proxy for organ quality, it is one of the proxies that is uniformly collected and easily observable. This is an important measure of quality in Howard (2002).

Further work is needed to assess how general these results are. In principle, similar findings to those in this article might be present where it is possible to strategically misrepresent some characteristic to gain access to a scarce resource. Allocating scarce physician time and admissions to college are two plausible areas where strategic misrepresentation of need or candidate quality could be increasing in competition for access to resources.

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