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The impact of diversification on task performance: Evidence from kidney transplant centers

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Abstract

Research Summary: Even when diversification is beneficial, entry into a new business can negatively affect the performance of the firm's existing business(es). We examine transplant centers that diversified from kidney transplants into liver transplants, focusing on how patient age can affect the costs associated with diversification. We find that diversification into liver transplants resulted in worsened quality performance in kidney transplants for younger patients, whose cases were less likely to be unexpectedly complex. For older patients, whose cases were more likely to have complications, the negative effect of diversification was offset. Our findings suggest that in health care the costs of diversification can be sensitive to patient characteristics, making focused organizations desirable when task complexity is low, while favoring diversified organizations for more complex tasks.

Managerial Summary: When firms diversify into new activities, the increased coordination may worsen performance in their original, prediversification activities. We show how this change in performance depends on the characteristics of the work itself. We examine kidney transplant centers that diversified into liver transplants. Young patients, who are typically less

complex to treat, had worse outcomes when centers diversified. However, for the oldest patients—generally the most complex to treat, with the greatest chance of complications—diversification was associated with slightly *improved* performance. This suggests that while coordination is difficult, organizations that diversify may be able to acquire coordination skills that can be applied to more complex tasks. Simpler tasks are unlikely to benefit from these skills, and thus we find worsened performance in these tasks after diversification.

KEYWORDS

diversification, factory focus, health care, task complexity, task uncertainty

1 | INTRODUCTION

How does a firm's entry into a new business affect the performance of its existing businesses? The research literature has demonstrated that firms that can put the advantages from their new business to work in their original businesses can reap ample benefits. But the new increase in scope is naturally accompanied by increases in coordination and bureaucratic costs. Thus, an increase in scope can have negative repercussions for a firm's existing businesses, potentially offsetting any gains from the new business and reducing overall firm performance.

Increasingly, scholars are turning their attention to organizational characteristics that can determine whether the benefits of diversification outweigh the costs. The existing scope (Clark & Huckman, 2011) or complexity (Zhou, 2011) of firm operations, as well as organizational rigidity (Rawley, 2010), have all been shown to affect whether a firm's performance in their original business will be helped or harmed by diversification, or will deter a firm from diversifying at all. We contribute to this literature by examining how characteristics of the work itself—specifically, task complexity—can affect the costs associated with diversification. We analyze the performance of organ-transplant centers that diversified from kidney transplants into the related area of liver transplants. The surgery setting is a useful one in which to test the effects of diversification at the task level. Data on patient outcomes (mortality rates) provide a strong measure of quality performance. In addition, there exists a bevy of well-tested clinical indicators to measure how complicated a surgery will be, which all transplant centers are required to record.

We find that, on average, diversification into liver transplants worsened quality performance in kidney transplants for younger patients, whose cases were likely to be comparatively routine. This negative effect of diversification for younger patients is almost entirely offset for older patients, who experienced no negative consequences from diversification on quality performance. We argue that in our hospital setting, diversification detracted from organizational focus but may have offered benefits in organizational responsiveness. Thus, we show that the calculus of diversification can depend on the nature of the work within the organization itself.

We begin by reviewing the prior literature on the costs associated with diversification and how these are affected by firm and task characteristics. We then give a detailed background on the transplant center setting and a brief explanation of our empirical strategy. After presenting the results, we discuss the implications for the nature of a firm's work, and diversification more generally. We conclude with implications for research on corporate strategy and organization, and for public policy.

1.1 | Effects of diversification on the performance of the firm's existing businesses

For decades, strategic management scholars have highlighted the superior gains from related diversification (Rumelt, 1982; Palepu, 1985). From the outset, diversification research has emphasized understanding the benefits of diversification: Ensuring continuity (Teece, 1980); enhancing organizational learning (Markides and Williamson, 1994); or making use of excess capabilities or resources that cannot be sold, but which could be put to use via diversification (Penrose, 1959).

Firms must balance any economies of scope with the concomitant diseconomies that arise from managing a larger, more varied firm (Chandler, 1969; Rumelt, 1982). The greater the degree of sharing of resources and activities between the units in a diversified firm, the greater the potential for coordination costs. As relatedness in diversification is typically measured by the degree of interdependencies between business units, it is logical to expect that coordination costs will be greater in related diversification (Jones & Hill, 1988; Hill et al., 1992; Nayyar, 1992; Zhou, 2011). As Levinthal and Wu (2010) point out, many intangible resources that firms hope to leverage by diversifying, such as managerial know-how, necessitate a degree of coordination that does not exist in a single-segment firm. As Rawley (2010) notes, when firms diversify, "resources that were optimized *ex ante*, with respect to maximizing business unit performance, may be underutilized [or over-utilized] *ex post*, as business unit decisions are sublimated to serve the greater good of the overall firm." Conversely, by focusing on a single business, the firm can avoid the coordination and organizational conflicts that arise from sharing resources across different activities with potentially incompatible goals (Simon, 1962; Cyert and March, 1963; Ethiraj and Levinthal, 2009; Bresnahan, Greenstein, and Henderson, 2011).

Despite coordination costs, most firms add new businesses over time (Christensen and Montgomery, 1981; Hill, Hitt, and Hoskisson, 1992), and much research in the strategic management literature has emphasized the potential benefits of expanding corporate scope. In contrast, researchers in finance and operations often argue that value is generated by restructuring organizations in the opposite direction. Diversified firms tend to be valued at a discount in financial markets (Rajan et al., 2000; Mazur and Zhang, 2015), and stock prices typically rise following the spinout or divestment of businesses (Miles and Rosenfeld, 1983; Jain, 1985).

In the operations management literature, pursuing focus—that is, *narrowing* the activities performed by a firm or productive unit—as a strategy for improving operational performance was first introduced by Skinner (1974). In settings as diverse as manufacturing (Berry et al., 1991), professional service firms (van Dierdonck & Brandt, 1988), and health care (Hyer et al., 2009), studies have shown that focused organizational units tend to exhibit superior cost and quality performance. Indeed, the "law of factory focus" is regarded as an important element of received wisdom in the field of operations management (Schmenner & Swink, 1998; Clark & Huckman, 2011).

Strategy scholars have increasingly been delving into operational details to better understand coordination costs and the implications of complexity. Rawley (2010) demonstrates that organizational rigidity combined with related diversification hurts financial performance in the original activity; that is, firms that lack the flexibility needed to incorporate new activities can worsen their performance in their original task. Similarly, Zhou (2011) examines how complexity can deter diversification entirely: For firms that are already managing complexity, the higher degree of coordination that related diversification would introduce discourages firms from diversifying. Chen et al. (2019) take these insights further, using simulations to demonstrate a curvilinear relationship between firm complexity and a diversification disadvantage. They note that while complexity does amplify the constraints imposed by coordination, this disadvantage arises even at middling levels of firm complexity, and additional complexity has a little additional effect.

All of these papers find that organizational characteristics—independent from or in addition to the relatedness of the diversification—substantially affect the firm's ability to benefit from diversification. Such recent studies in corporate strategy address the drivers of costs associated with diversification to better understand the conditions under which diversification or focus will result in superior performance.

1.2 | Tasks and diversification

The nature of an organization's tasks can affect the coordination that the sharing of resources from diversification entails. Following the definitions proposed by Wood (1986), tasks may be complex because they require many pieces of information and actions to complete (component complexity), because they require coordination (coordinative complexity), or because the nature of the task is changing (dynamic complexity).

Diversification increases coordinative complexity across the board. Prior research has shown that coordination is even more costly and difficult when work is both complex and dynamic, as interdependencies may shift, particularly when they are unpredictable (Wood, 1986; Faraj and Xiao, 2006). Thus, coordination costs from diversification increase with task complexity. The more complex (and particularly, the more dynamically complex) the task, the less firms can rely on routines, because the nature of the interdependency to be coordinated may change midtask (Brown and Duguid, 2001; Gittell, 2002). In these types of settings, the potential for scope economies can be considerable but easily outweighed by the substantial coordination costs.

Given the dynamics of organizational learning, coordinative complexity may temporarily increase immediately after diversification but become more manageable as the firm adapts. One of the key arguments for focus is repetition: Focus allows the development of routines that can be repeated, and through this repetition workers' efficacy will be improved. Hence, the negative effects of diversification could diminish over time, as new routines develop to manage an increase in coordinative complexity. Staats and Gino (2012) found that firms that diversify into new tasks suffer from temporary performance reductions as they learn to manage their new tasks. On the other hand, Chen et al. (2019) demonstrate theoretically that is highly related, complex businesses, diversification results in a long-term performance reduction, even in the presence of short-run synergies. Thus, it is important to assess whether any decline in performance after diversification might be of limited duration.

1.3 | Diversification in health care

While the benefits of focus have been shown in a variety of industries, many recent studies have examined the health care sector due to its economic and policy significance, and to the richness of the available data. In a study of clinical trials, Huckman and Zinner (2008) found that focused firms had higher output and productivity than unfocused firms. Within a hospital setting, Clark and Huckman (2011) found that focus had a positive effect on quality performance, which they attributed to reduced complexity, lower uncertainty, and the development of specialized expertise. Kc and Staats (2012) showed that experience on related tasks improved cardiac surgeons' performance on their focal tasks, but that "excessive variety" in task experience led to a worsened performance. In a study of cardiac care departments, Kc and Terwiesch (2009) found quality benefits of focus leading to reduced mortality and length of stay. They concluded that "general hospitals may be better equipped for treating the 'harder-to-treat' patients, whereas focused hospitals are more effective with 'easy-to-treat' patients," suggesting an optimal division of labor based on patient characteristics.

Task-level metrics for performance include the quality (Lapré et al., 2000; Huckman and Zinner, 2008; Clark & Huckman, 2011), timeliness (Argote and Darr, 2000), and customer satisfaction (Lapré and Tsikriktsis, 2006). The standard clinical indicator of performance for transplant centers in patient mortality within a year. This is not only the de facto measure of quality—each center's mortality rates are made public to enable patients to compare centers—and most would argue that patient survival is the first-order priority for any hospital. Even so, it is important to note that we do not observe the financial performance of the transplant centers.

1.4 | Contribution of this study

We contribute to the literature on the optimal scope by examining how characteristics of the work itself can affect the costs associated with diversification. Similar to Rawley (2010) and Clark and Huckman (2011), we consider how diversification into a new activity affects performance in the organization's original activity. Rather than looking at how organizational characteristics may influence the benefits or costs of diversification, we examine the characteristics of the organization's activity itself—namely, how complexity in the work undertaken affects whether diversification at the organization level will help or harm task-level performance. As discussed in Zhou (2011), the more related the diversification, the greater degree of coordination that will be necessary, increasing coordination costs even for those activities in which the firm was originally engaged.

2 | SETTING AND SAMPLE

In this article, we contrast transplant centers that perform kidney but not liver transplants with centers that perform both transplant types. While centers may perform as many as eight kinds of transplants, livers, and kidneys account for 80% of all transplants. We compare the addition of liver programs because it is the most highly related type of diversification within a transplant center. The technologies and skills needed to perform liver transplants are more similar to kidney transplants than to other types of transplants; for instance, laparoscopic techniques are common in kidney transplants, but they have recently been deployed in liver transplants as

well. Thus, this type of diversification is more likely to result in benefits from related diversification as well as coordination costs from sharing facilities, equipment, and staff.[1]

2.1 | Market characteristics

Each transplant center receives organs for transplant from a geographically designated organ procurement organization (OPO), which is overseen by the United Network for Organ Sharing (UNOS, 2009); each of these is independent of the hospitals they supply. OPOs allocate kidneys to the various transplant centers within an OPO's coverage area to minimize the incidence of mismatch between recipient and donor—OPOs evaluate human leukocyte antigens first, then blood type, and so on. Waitlisted patients are ranked by a computer algorithm that assigns points to relevant characteristics: Time on waitlist, quality of the match, child or not, availability of the patient, and so on. To be placed on the waitlist, patients must meet minimum acuity requirements, presumably to prevent them from "gaming the system," as happens in the liver-allocation market (Snyder, 2010). The allocation of kidneys (unlike livers) considers only fairness (e.g., time on waitlist) and match quality, and not the severity of the illness. Because organs are allocated primarily based on the match between donor and recipient, and because what organs will become available cannot be anticipated, it is virtually impossible for centers to "game" their waitlists by selectively enrolling patients.

2.2 | Firm characteristics

Our data cover 293 kidney centers, of which 244 were still performing transplants in 2007; of these, 150 also performed liver transplants. Among the transplant centers we observed, only one liver-transplant center did not also perform kidney transplants (due to a legal dispute); thus, generally speaking, the pool of transplant centers that perform kidney transplants can be viewed as the set of potential entrants to the liver-transplant market. To be eligible to receive Medicare reimbursement for kidney transplants, centers must perform at least 15 transplants per year. (All patients with end-stage renal disease are eligible for Medicare, regardless of age.)

When a center decides to expand into liver transplants, the start-up costs are nontrivial: Nursing coordinators must be retrained, and centers often hire a separate liver-transplant surgeon. Concerns about volume must also be addressed. While the largest centers may have sufficient volume to support separate facilities (separate operating rooms, clinicians, and support staff) for different transplant programs, smaller centers have to coordinate these resources across the different transplant programs within their centers. We spoke with clinicians at three diversified transplant programs; in discussing the motivating factors for diversifying into liver transplants, none of them mentioned patient well-being. None of them believed that adding a new transplant program would have an impact, either positive or negative, on patients in the original transplant program.

[1]In Appendix C: Other Measures of Diversification, we also look at transplant centers that diversify into the next-largest transplant program, heart transplants. The results here are replicated for centers that diversify into both liver and heart transplants; however, for the subset of centers that diversify only into heart transplants but not livers, the results are too noisy (due to the small sample size) for this subset of centers to draw any meaningful conclusions about generalizability.

2.3 | Demand characteristics

For kidneys, patients contact one or more transplant centers for evaluation (some transplant centers require referring physicians to contact the center, others allow patients to refer themselves). Patients deemed suitable for a transplant will be placed on that center's waitlist. When a kidney becomes available, it will be offered first to the most preferred patient within that OPO; if no suitable patient is on that waitlist, it will be offered to the preferred patient in that OPO's larger region. For all types of patients, the time between the organ becoming available (either the organ's removal from or the death of the donor) and the transplant is critical; as a result, immediate patient availability plays a role in the assignment of transplants and organizational speed will have an important impact on survival.

2.4 | Task characteristics

Liver transplants are more complex than kidney transplants. Kidney transplant surgeries typically take a single surgeon less than 2 hr, while liver transplants typically take about three and a half hours and allow for a second surgeon. Liver patients are typically sicker than kidney patients at the time of transplant because there is no substitute for a functioning liver (while a patient with kidney failure can live on dialysis for many years). This is reflected in the relevant patient mortality rates: Currently, the 1-year rate is 2.9% for kidney transplants and 8.8% for liver transplants.

Both liver and kidney transplants are subject to a variety of complications. Some are common to both transplant types, such as blood clots, hemorrhage, infection, and acute rejection of the transplanted organ (Akbar et al., 2005; Moreno and Berenguer, 2006); others are transplant-specific. While complications are on average more likely to occur for the liver than kidney transplants, complication rates for both types of surgery have been falling over time. Individual patient characteristics also exert a strong effect on the risk of complications developing (see Empirical Strategy).

Appendix D contains more details about the transplant setting, including market, firm, demand, and task characteristics.

2.5 | Sample selection

Our analysis deals with liver and kidney transplants performed by U.S. transplant centers from 1988 to 2007. The data set provided by UNOS is not a sample, but rather the universe of patients in the United States who were ever registered on a waitlist or received a transplant, and contains the clinical details of every patient and transplanted organ, in our study period. To isolate the impact of diversification, we simplify the setting as much as possible: Waitlisted patients who did not receive transplants are omitted, as are observations for which the center performed fewer than 15 kidney transplants (the minimum volume to be eligible for Medicare).[2] Liver data

[2]A center need only meet the minimum volume threshold in accreditation years, and accreditation does not (usually) happen annually. This exclusion omits centers that would not have been accredited in a given year, if they are evaluated. While the mortality at these centers is higher, we cannot say that they are statistically significantly different from Medicare-qualified centers—the estimates from these centers are very noisy due to small sample size. The results we present here are robust to the inclusion of these centers.

were aggregated to the center level and were merged into the kidney-transplant data, using UNOS's unique center-identification codes. The resultant data comprises the universe of kidney transplants at centers that are or would be federally accredited between 1988 and 2007. Nationwide, 89 centers diversified during this period.

2.6 | Performance

Performance by organ-transplant centers is measured on clinical indicators, primarily mortality rates with risk-adjustment indicators within 1 year of transplant; this is the only metric that UNOS makes publicly available to all physicians and patients. We discuss our approach to risk adjustment in the description of our empirical strategy, as well as in Appendix B. Quality performance is a common and conceptually tidy measure for task-based performance. It is particularly relevant in this setting, as transplant centers are typically not-for-profit organizations. Even at a for-profit hospital, however, quality in the form of patient survival is of first-order importance.

Though quality performance is of first-order importance in hospital-level decision-making, our research does not address whether the effect of diversification on financial performance will play out in the same way. For instance, transplant centers are popularly viewed as a source of prestige for hospitals (Levine, 2006), particularly centers with multiple transplant types (DHHS Report, 2003). Centers do not make available any financial data (separate from that of the hospital as a whole) that would allow us to test the impact on financial performance; we leave that for future research.

3 | EMPIRICAL STRATEGY

To test the impact of diversification on performance, we use a linear probability model with post-kidney-transplant mortality within 1 year as the dependent variable.[3] Over our sample period, this mortality rate steadily declined, 0.17% per year on average, reflecting advances in surgical techniques and technologies. To account for this trend, all specifications include transplant-year fixed effects.

We use a binary indicator for diversification, equal to one beginning on the day that a center does its first liver transplant; UNOS does not report the physician who performed the surgery, so all measures of diversification are at the level of the transplant center. A simple indicator of diversification's effect on quality is the average change in kidney patient mortality following diversification. Without any risk adjustment, the average mortality rate for centers was 4.9% before diversifying, and 5.4% after diversifying (among centers that diversified between 1988 and 2008). Although an increase of 0.5% may seem small, we infer that absent diversification of the unadjusted mortality rate of these centers would have *declined* by about 0.5% due to the time trend. Combining these figures gives an increase in mortality of 1% on a base level of 4.9%.

[3]Although the binary dependent variable suggests a probit estimator, the large number of fixed effects would lead to highly biased estimates, due to the incidental-parameter problem (Lancaster, 2000). The main issues with using OLS with a binary dependent variable are heteroskedastic errors and an unconstrained dependent variable. We deal with heteroskedasticity by using robust standard errors. About 2.7% of our observations yield probability estimates below zero in the fully specified model; our results are robust to a specification using a trimmed OLS estimator that omits these, as suggested in Horrace and Oaxaca (2006), and are available on request.

Thus, the raw data imply that the mortality rate for centers that diversified increased by roughly 20% (1% divided by 4.9%).

Above, we discussed the importance of controlling for a variety of firm-specific effects. To control for unobservable center quality, we include time-invariant center-level fixed effects in every specification. We also control for center-level characteristics that may vary over time: Volume, supply volatility, competition, and clinical risk adjustments for the patients seen by the center. Table 1 describes each of these characteristics in detail.

Our primary interest is in the complexity of the tasks a center performs, and how this complexity interacts with diversification. In this setting, the degree of complexity is dictated by patients and their attendant medical needs. Naturally, a patient who requires both a kidney and a liver transplant will receive additional value from a diversified center. We are also interested in how patient-level complexity affects the likelihood that diversification will improve or worsen quality performance.

The lead transplant surgeon at a large academic medical center stated that the four main factors that influence the difficulty of a surgery are (a) the patient's age; (b) the patient's use of

TABLE 1 Variables used in empirical estimations

Phenomenon	Measure	Details
Firm learning	Log of the lagged cumulative kidney transplants performed by a center	Learning by doing is a critical determinant of performance (Luft, Bunker, Enthoven, 1979; Ramanarayanan, 2008). This control is included in addition to a firm fixed effect, so this control measures the effect of changes in volume, rather than the absolute effect of volume.
Supply volatility	Standard deviation in the quarter-to-quarter transplants in the year in which a given transplant takes place	Some hospital executives have noted that when the supply of transplantable organs is volatile, centers may accept transplants of lower quality. Volatility in the kidney supply may also allow diversified centers to make use of otherwise slack resources by providing liver transplants.
Competition	Herfindahl index for kidney transplants for centers within a given OPO	Competition in the organ-allocation market will affect a center's organ supply; competition has also been alleged to increase the need to accept lower-quality organs.
Clinical controls/ patient riskiness	B-antigen mismatch level, DR-antigen mismatch level, known comorbidities, hypertension, BMI, time on the waitlist, peak panel-reactive antibodies, whether the kidney came from a live donor, and the time that the transplanted organ spent in cold storage (cold ischemic time)	To ensure a meaningful comparison across patients, it is necessary to include clinical controls for risk adjustment. We omit multiorgan transplants, which are higher-risk surgeries performed only by diversified centers (although all results are robust to their inclusion as a control).
Task complexity	Patient age (additional measures in Appendix G)	See text.

life-support equipment, such as a ventilator or dialysis; (c) prior surgery on the same site; and (d) severity of the disease. For each of these factors, "you're less likely to tolerate complications but you're more likely to have them."

We rely on age as our proxy for complexity. Unfortunately, we are not able to operationalize the other sources of unanticipated complications, due to limitations of the data.[4] Clinicians are certainly aware of the increased risk when operating on an older patient, but they cannot anticipate which complications (e.g., blood clots, hemorrhage, electrolyte imbalance, infection, and undiagnosed comorbidities) are most likely to occur; age increases the risk of all of these (Aakhus et al., 1999; Grundy et al., 1999; Meier-Kriesche et al., 2000; Pinto et al., 2017). Age is highly correlated with subclinical comorbidities; that is, another disease or condition that is "asymptomatic, presymptomatic, atypically symptomatic, or simply undiagnosed" (Newman et al., 2008). There is a large degree of heterogeneity, particularly among older adults, where risk from subclinical disease burden can range from very low to very high (Newman et al., 2008). Advanced age is also correlated with disabilities such as frailty that are not captured in standard preoperative assessments (Makary et al., 2010). Geriatric-specific risk predictors may be more difficult to detect using standard protocols (Kim et al., 2014). This results in a higher degree of complexity for older patients—from previously unknown comorbidities that may complicate the transplant (Guralnik, LaCroix, Everett, & Kovar, 1989), and from the physiologic reserves necessary to recuperate from the surgery. Both are difficult to identify using standard evaluation protocols, resulting in a higher rate of complications (both mid- and postprocedure) for older patients (e.g., Meier-Kriesche et al., 2000; Polanczyk et al., 2001). In kidney transplants specifically, renal failure in older patients is more likely to result from "lifestyle diseases" such as diabetes, which are highly correlated with multiple comorbidities that may not have been diagnosed; the subclinical comorbidities include major mortality risks such as heart disease (Grundy et al., 1999). Any given complication increases the component complexity of the operation; the broad range of potential complications and the difficulty in identifying them ahead of time using standard evaluation protocols also increase dynamic complexity.

Table 1 summarizes the controls and proxies for complexity used in our specifications. The baseline specification for patient i at center c in year t in OPO market m is

$$\begin{aligned}\text{Outcome}_{ictm} = {} & \beta_0 + \beta_1 \text{Diversified}_{ct} + \text{Complexity}_i + \text{SupplyVolatility}_{ct} \\ & + \text{Volume}_{ct} + \text{Concentration}_{mt} + \text{ClinicalRiskAdjustment}_i + \text{Year}_t + \text{Center}_c + \varepsilon_{ictm}.\end{aligned}$$

To understand the role of task-level complexity on the impact of diversification, we will add the interaction between task complexity (measured by patient age) and firm-level diversification.

[4]For life-support equipment, over 90% of our sample is on dialysis at the time of transplant; this is the only type of life-support equipment used in our data. UNOS tracks prior kidney transplants (7% of our sample) but not other types of abdominal surgeries that would also affect difficulty. And while UNOS began collecting data on measures of disease severity (such as serum creatinine) as of 1994, these data are not recorded for most transplants until the mid-2000s. For each of these measures of difficulty, the results are much the same as our analysis for age (diversification associated with a significant increase in mortality on average, but diversification interacted with the measure of complexity decreases mortality) with the exception of the significance of the interaction with the diversification term ($p < .14$ for dialysis, $p < .38$ for prior kidney transplants, $p < .20$ for serum creatinine at time of transplant). While the prevalence of dialysis in this context will likely make it difficult to identify the effect of diversification for the foreseeable future, this may be a fruitful avenue of future research, once more data are collected on measures of severity.

3.1 | Selection

Finally, we take steps to ensure that our estimation will be robust to empirical issues that commonly plague the estimation of diversification. The primary issue that needs to be addressed in such a setting is selection. As demonstrated in the diversification discount literature, notably Villalonga (2004), selection into diversification may in fact lead to the overestimation of a negative effect of diversification on firm-level performance. Our hospital setting faces the same selection problem, in that diversification is not randomly assigned among firms but rather is selected as a firm strategy. To the extent that diversified and undiversified firms differ systematically in characteristics that would affect mortality, this will create a selection bias in results and will necessitate an empirical model that addresses this bias.

Empirically addressing the impact of diversification on mortality is a thorny issue, because mortality may be endogenous to the diversification decision. One might expect that firms that perform kidney transplants well would be more likely to diversify into liver transplants. In this setting, we might also expect that the prestige associated with a multiorgan transplant center would enhance performance of the hospital overall, in the form of increased access to resources, which could create an incentive for centers to stay in the transplant market when their performance is relatively poor. Thus, there could be a direct incentive to enter this market for centers with either low or high kidney-transplant mortality rates. Although we are agnostic on the direction of selection, clearly the initial choice of diversification may not be exogenous to kidney-transplant performance, so we must control for selection.

The inclusion of firm-specific fixed effects will control for any time-invariant unobservable differences that could drive selection. There will continue to be a problem, however, if some firm characteristics that vary over time—such as competition within an OPO—influence both the diversification decision as well as patient outcomes. Accordingly, we will employ an inverse-probability weight treatment, which is similar to propensity score matching but allows for time variation.

Inverse-probability weighting, also called propensity-score weighting, is a common method in other disciplines for dealing with problems caused by selection on observable characteristics (e.g., Robins et al., 2000; Wooldridge, 2007). In short, we use a probit model to estimate the probability that a given center will be diversified in a given year, based on characteristics of both the firm and its market: Competition, slack resources, and experience. Appendix B provides details on the measures used to predict diversification and the results of this probit model. Each observation is assigned a weight equal to the inverse of the probability that the center will be diversified in that year, so that observations from centers we would expect to be diversified will be weighted less than observations from centers we would not expect to be diversified. Variables that may affect both the probability of entry and the kidney-transplant mortality rate will be included in both the main specifications as well as the calculation of the probability weights. Our results include these weights as a selection correction.[5]

The inverse-probability weights address selection on observables, while the firm fixed effects help to control for time-invariant unobservables (Villalonga, 2004; Appendix A provides additional detail on the observable characteristics of centers that diversify). These specifications do not address time-varying unobservable characteristics that may affect both the decision to diversify as well as quality performance for different types of patients. The primary concern for

[5]All findings are robust to the omission of these weights; the unweighted results are available from the first author on request.

selection on unobservables in health care is patient selection: Patients who are treated at diversified centers may be unobservably sicker than those who are treated at focused centers, perhaps due to the prestige associated with being a diversified medical provider. We address patient selection in Appendix B by examining all available measures of patient severity, and we do not find systematic differences; however, this phenomenon will bias our results only if sorting occurs differently for young and old patients (which again, we do not find evidence for). That is, if diversification results in (or occurs at the same time as) unobservably healthier young patients and/or sicker older patients choosing focused transplant centers, our results may be biased. If sicker patients prefer diversified centers[6] in a way that does not systematically differ by age, the negative effect of diversification will be overstated on average but will have no impact on our analysis of task complexity. To test for transient effects of diversification such as those found by Staats and Gino (2012), we add a measure of time since diversification for those centers that did diversify into liver transplants (Table 4).

4 | RESULTS

4.1 | Summary statistics

Table 2 summarizes the key variables used to measure patient outcomes. On a non-risk-adjusted basis, patient mortality does not differ much between diversified centers and the population overall.

Diversified centers are larger than undiversified centers in terms of transplant volumes, with an average of 230 transplants over 3 years at diversified centers, compared with only 112 at undiversified centers. Nearly all transplant centers perform kidney transplants, and may later add additional transplant programs. Liver transplants were still deemed an experimental treatment until 1983, while kidney transplants had become common as early as the 1960s, with the advent of immunosuppression (Manzarbeitia et al., 2002). Thus, while it is natural for larger, more established kidney programs to be more diversified than relatively smaller centers, this difference in size highlights the importance of controlling for the center characteristics that may affect performance.

4.2 | Results

Table 3 presents the basic results. For the sake of length, we do not report coefficients on the control variables described above; the full results are reported in Appendix Table B3. Model 1 demonstrates the main effect of diversification on performance. In the simple binary breakdown of diversified vs. undiversified firms, diversification is associated with a 0.68-percentage-point increase in patient mortality, but is not significant ($p = .121$). As such, the main effect of diversification is unclear in a simple comparison. The subsequent estimations, in which we decompose the effect of diversification by the complexity of patients, suggest that this noisiness comes from the averaging of divergent trends within diversified centers. In the

[6]NB: although strategic patient selection by centers is a concern in other settings, the logistics of transplant allocation and survival make it essentially useless in this setting (see Appendix B). Thus, we are only concerned with the unobserved preferences of patients.

TABLE 2 Patient descriptive statistics

Variable	Observations	Mean	Standard deviation	Minimum	Maximum
Patient mortality	271,179	0.046	0.210	0	1
Diversified centers patient mortality	169,908	0.045	0.206	0	1
Focused centers patient mortality	101,271	0.049	0.216	0	1
White	271,179	0.620	0.485	0	1
Black	271,179	0.216	0.411	0	1
Asian	271,179	0.036	0.185	0	1
Hispanic	271,179	0.116	0.320	0	1
Age	271,179	43.713	15.092	0	90
Days on waiting list	271,179	425.118	538.546	0	7,915
B-antigen mismatch level	269,081	1.217	0.737	0	2
DR-antigen mismatch level	267,979	0.981	0.722	0	2
Number of previous kidney transplants	271,178	0.095	0.315	0	5
Live donors	271,179	0.320	0.466	0	1
Cold ischemic time	225,414	15.154	11.759	0	187
Hypertension	271,179	0.529	0.499	0	1
Comorbidity	271,179	0.030	0.172	0	1
Peak panel-reactive antibodies	196,934	13.040	24.953	0	100
Body mass index (BMI)	209,373	25.873	5.812	0	100

subsequent estimations in Table 3, we interact diversification with different measures of task complexity.

When we interact the effect of diversified centers with complexity (where advanced age is a proxy for a high risk of a broad range of complications), the results are striking. Age on its own is a highly significant predictor of mortality (point estimates range from a 0.18% to 0.20% increase in mortality per year of age, $p < .0001$ in all specifications). The diversification coefficient in the second regression in Table 3 implies that diversifying into liver transplants raised kidney patient mortality by 2.1% ($p = .003$). This is offset by the effect that for each additional year of age, diversification into livers reduced kidney patient mortality by 0.03% ($p = .028$). Thus, for younger patients, the estimates show a strong increase in mortality linked to diversification. However, for older patients, who are more likely to have complications, there are benefits to being treated at a center that does more diverse, complicated procedures. For instance, these estimates imply that a 75-year-old patient would have a marginally higher expected mortality rate at an undiversified center (10.7%) than at a diversified center (10.4%).[7] By comparison, a 25-year-old patient receiving a transplant at a diversified

[7]These comparisons are done using the margins command in Stata, which holds all other variables at their average level.

TABLE 3 Effect of diversification on mortality, dependent variable: Mortality within 1 year of transplant, *p* values are in italics

	Baseline	Age	Age and comorbidity	Age and hypertension	Age cohorts
Diversification (indicator)	0.0068	0.0206	0.0199	0.0276	0.0143
	.1211	*.0034*	*.0049*	*.0021*	.0085
Age	0.0018	0.0020	0.0020	0.0023	
	.0000	*.0000*	*.0000*	*.0000*	
Comorbidity	0.0171	0.0171	−0.0671	0.0177	0.0168
	.0107	*.0106*	*.1067*	*.0086*	*.0114*
Hypertension	−0.0071	−0.0070	−0.0070	0.0139	−0.0060
	.0005	*.0005*	*.0005*	*.1237*	*.0025*
Diversification × age		−0.0003	−0.0003	−0.0005	
		.0278	*.0400*	*.0090*	
Diversification × comorbidity			0.0547		
			.2644		
Comorbidity × age			0.0016		
			.0746		
Diversification comorbidity × age			−0.0010		
			.3355		
Diversification × hypertension				−0.0134	
				.2171	
Hypertension × age				−0.0005	
				.0122	
Diversification hypertension × age				0.0004	
				.1040	
Patient age 25–40					0.0098
					.0068
Patient age 40–55					0.0328
					.0000
Patient age 55–65					0.0649
					.0000
Patient age 65+					0.0991
					.0000
Diversified × patient age 25–40					−0.0046
					.2807
Diversified × patient age 40–55					−0.0088
					.0657
Diversified × patient age 55–65					−0.0112
					.0825

TABLE 3 (Continued)

	Baseline	Age	Age and comorbidity	Age and hypertension	Age cohorts
Diversified × patient age 65+					−0.0177
					.0484
Constant	−0.0825	−0.0901	−0.0890	−0.1017	−0.0437
	.0004	*.0002*	*.0002*	*.0000*	*.0573*
R^2	.0301	.0302	.0303	.0304	.0310
N	102,679	102,679	102,679	102,679	102,679

Notes: Patient characteristics included in the specification but not reported here: DR- and B-antigen mismatch, live donor, peak panel-reactive antibodies, days on waitlist, race, gender, BMI, cold ischemic time, multiorgan transplant, primary kidney diagnosis. Firm characteristics included in the specification but not reported here: annual volume quartile, quarterly volatility. Market (OPO) characteristics included in the specification but not reported here: kidney concentration, number of liver transplant centers in the previous period. All specifications include year and center fixed effects. Standard errors are robust and clustered at the center level, and are reported in parentheses. All specifications include inverse-probability weights to control for probability of selection. Diversification is an indicator variable equal to 1 beginning on the date that the center performed its first liver transplant.

center would have nearly triple the expected mortality rate (2.0%) compared to receiving a transplant at an undiversified center (0.7%). The magnitude of this increase is higher than the mortality risk from a primary antigen mismatch (1.13%; this is the leading cause of organ rejection, and the first factor UNOS considers when allocating organs). This suggests that for a 25-year-old patient, the increased mortality from being treated at a diversified center is approximately equivalent to an additional 3.4 years on the waitlist for a transplant.

These effects of age are robust to the inclusion of additional controls, as shown in the subsequent columns of Table 3. We add three-way interactions with comorbidities and drug-treated hypertension, both of which are correlated with age; these additional interactions have either no effect (comorbidities) or increase the magnitude and significance of the age-diversification interaction (for drug-treated hypertension). When we break age into cohorts, we find that the effect of diversification is approximately linear in age—the beneficial effect of diversification increases with age. The age results are also robust to an alternative specification of the diversification measure. Using the continuous measure of focus (Appendix Table C1), the results are similar in magnitude to those in Table 3, but the age-diversification interaction is even more statistically significant.

Table 4 repeats the specifications of Table 3, supplementing the diversification dummy with a measure of the years since a center first diversified. These specifications show that the increased mortality effect of related diversification does not decline over time. On the contrary, the mortality-increasing effect of diversification *increases* over time when we control for the effect of age interacted with diversification. Beyond the effect of time since diversification, Table 4 largely replicates the results of Table 3. Similar results were obtained when the time since diversification is broken down into 5-year periods to allow for the possibility of nonlinear trends (see Appendix E). These findings contrast with those of Staats and Gino (2012) for the banking industry, where task-level performance reductions due to diversification were found to be transitory.

TABLE 4 Effect of time since diversification on mortality, dependent variable: Mortality within 1 year of transplant, *p* values are in italics

	Baseline	Age	Age and comorbidity	Age and hypertension
Diversification (indicator)	0.0063	0.0060	0.0061	0.0061
	.1476	*.1687*	*.1620*	*.1637*
Years since diversification	0.0008	0.0025	0.0025	0.0037
	.1295	*.0003*	*.0004*	*.0002*
Years since diversification × age		0.0000	0.0000	−0.0001
		.0043	*.0033*	*.0003*
Years since diversification × comorbidity			0.0033	
			.4543	
Comorbidity × age			0.0013	
			.1113	
Years since diversification comorbidity × age			0.0000	
			.7085	
Years since diversification × hypertension				−0.0026
				.0141
Hypertension × age				−0.0005
				.0038
Years since diversification × hypertension × age				0.0001
				.0067
Age	0.0018	0.0020	0.0020	0.0022
	.0000	*.0000*	*.0000*	*.0000*
Comorbidity	0.0172	0.0173	−0.0539	0.0178
	.0105	*.0100*	*.1341*	*.0082*
Hypertension	−0.0070	−0.0068	−0.0068	0.0156
	.0005	*.0007*	*.0007*	*.0567*
Constant	−0.0808	−0.0870	−0.0867	−0.1002
	.0006	*.0003*	*.0003*	*.0000*
R^2	.0301	.0302	.0303	.0304
N	102,679	102,679	102,679	102,679

Notes: Patient characteristics included in the specification but not reported here: DR- and B-antigen mismatch, live donor, peak panel-reactive antibodies, days on waitlist, race, gender, BMI, cold ischemic time, multiorgan transplant, primary kidney diagnosis. Firm characteristics included in the specification but not reported here: annual volume quartile, quarterly volatility. Market (OPO) characteristics included in the specification but not reported here: kidney concentration, number of liver transplant centers in the previous period. All specifications include year and center fixed effects. Standard errors are robust and clustered at the center level, and are reported in parentheses. All specifications include inverse-probability weights to control for probability of selection. Diversification is an indicator variable equal to 1 beginning on the date that the center performed its first liver transplant.

Although the coefficients reported here are small, they are sizeable relative to the base rate. The effects are particularly salient given that the base rate is mortality—it is important to be mindful that the performance we are discussing is human life. Holding all other effects and

clinical determinants of mortality constant, had younger[8] patients gone to undiversified centers and older patients gone to diversified ones, our model predicts that the mortality rate would have dropped 0.6% (which is 13.0% of the observed mortality rate of 4.6%), or one additional life saved per 167 surgeries. Applied to the 271,179 transplants during our study period, this would amount to 1,267 fewer deaths. In reality, of course, a center cannot hold everything constant and change only their patients, so this is a hypothetical conclusion in order to illustrate the magnitude of these findings.

5 | DISCUSSION

Our data are limited to assessing the performance of an existing business (a kidney-transplant center) that diversifies into a related business (liver transplants). Therefore, we limit our discussion to the potential impact of diversification on the original business. Overall, we find that diversification had a negative effect on quality performance, consistent with other work demonstrating that when firms diversify, performance in the original activity may suffer (Huckman & Zinner, 2008; Rawley, 2010).

Our findings with respect to task complexity, the key element of our study, are more nuanced. Our empirical results contradict the general idea that in an organization, greater task complexity leads to worsened performance from diversification. Indeed, our findings within a hospital setting show that postdiversification performance declined for younger patients, for whom unexpected complications were the least likely. That is, after hospitals diversified, their performance worsened in treating cases where complexity was relatively *low*. In contrast, we find offsetting effects for older patients, for whom a diversified setting may have offered benefits in terms of organizational responsiveness to a broad range of problems that increase in likelihood with age.

These findings are perhaps best interpretable in the context of the operations management literature on the benefits of "factory focus," based on Skinner (1974) and subsequent work. The increase in mortality that we observe following diversification is concentrated among younger patients, whose cases tend to be less complex. These are precisely the patients most likely to benefit from a facility where workers develop routines through the repeated performance of specific tasks—in this case, focused on kidney (but not liver) transplantation. The movement of kidney-transplant centers away from this narrow focus on a single type of operation was harmful to at least some of these patients. On the other hand, diversification appears to have been beneficial (or less harmful) to older patients, whose transplant operations had more complexity, particularly complexity that may have been difficult to anticipate. While we cannot directly test the mechanism that leads this increase in center-level complexity to impact task-level performance, these results are suggestive of a link with routines. We present here a possible explanation for them as an avenue for future research: That routines for managing coordination in a diversified center may also be useful for managing coordination of complexity in patient care. Prior work has shown that the routines that develop for maximizing the output of multiple units, tasks, and so on, will necessarily be different than those designed to maximize performance for only a single task (Natividad and Rawley, 2015; Rawley, 2010). These new routines that develop to maximize the use of resources across multiple tasks will likely lead to performance declines in the original task, since employees are able to perform these routines more effectively when they have fewer

[8]Our model implies that the age at which diversification switches from a negative to a positive effect is 66; this calculation assumes all patients under 66 go to undiversified centers while those over 66 go to diversified centers.

routines to learn (Edmondson et al., 2001). Where transplant centers had developed routines for optimizing performance for kidney transplants, after diversifying they must develop new routines that accommodate liver transplants, and the attendant needs of a new set of patients, as well. When transplant centers diversify into liver transplants, they are adding a more complex, riskier surgery into their practice. Introducing a riskier surgery requires transplant centers to deal with: (a) increased coordination over shared resources, such as staff and equipment; (b) patients with more diverse diagnoses and needs (including simultaneous transplant patients); and (c) a new and more diverse set of known comorbidities among the patients they treat.

But not all tasks may be negatively affected by changes in the organization's routines. Staats and Gino (2012) find that while specialization improves productivity in the short run, intra-firm variety actually improves long-run productivity as workers became better at managing changeovers between activities—this skill may be especially valuable for managing rapid changeovers within a single activity, that is, operating on a patient who is likely to experience complications. Straightforward cases will have limited ability to take advantage of these benefits, however, and will likely experience only the increase in coordination costs.

To be sure, the increased mortality that we find following diversification may not have been a universal phenomenon. Some facilities in our sample may have avoided problems associated with loss of focus after they diversified into liver transplantation. Indeed, Skinner (1974) introduced the idea of a "plant within a plant," where two or more focused facilities can coexist within a single unit. Such organization may have been feasible for the larger transplant facilities in our sample. For example, the Ronald Reagan Hospital at UCLA maintains kidney- and liver-transplant centers on separate floors, thereby allowing each center to pursue greater operational focus than would be possible if they operated jointly within a single, multifunction unit.

Finally, our focus on quality performance in the firm's original business, and our lack of financial data on the combined set of businesses, mean that we have only a partial picture of the benefits and costs of diversification. The simple fact that virtually all the entrants into liver transplantation in the United States had prior experience in kidney transplantation signifies economies of scope. Such economies justify diversification by at least some kidney-transplant organizations, given the (private and social) value of performing liver transplants. However, these scope economies do not mean that all kidney-transplant centers should diversify. Rather, as we have argued, understanding the costs of diversification for existing units is essential to making good diversification decisions from both private and public policy perspectives.

6 | CONCLUSIONS

We find that when kidney-transplant centers diversify into liver transplants, quality performance in kidney transplants declines on average. Specifically, diversification has a negative effect on younger patients, whereas for older patients the negative effect is offset by gains from organizational responsiveness. We infer that relatively simpler surgeries may suffer a performance reduction from related diversification while more complex surgeries do not. Moreover, we find that this phenomenon cannot be attributed to a period of adjustment immediately following diversification—the effect becomes only more pronounced over time.

In service businesses such as health care, where one of the primary inputs is the customer, the interplay between complexity and predictability can strongly affect performance. The fact that quality performance varies in response to diversification highlights the need for research that examines not only the portfolio of the firm overall but also the nature of the work itself.

This returns to the tension between the benefits of focus, emphasized in the operations literature, and those of diversification, traditionally examined in the strategy literature. Focus is predicated on the idea that "simplicity, repetition, experience and homogeneity of tasks breed competence," that is, a narrow scope of activities enhances performance (Skinner, 1974). The strategic diversification literature has emphasized firms' ability to enhance their competence by applying their skills to, and learning from, related businesses. Our study posits that both phenomena may hold, even within the same organization, depending on the complexity of the task. Our results imply that focus offers the greatest benefit when complexity is relatively low.

This finding has important policy implications within the health care industry. The idea of improving health care providers' organizational performance by narrowing their scope has become a subject of much debate in recent years. Related diversification is essentially the status quo in the hospital industry, where specialty hospitals are still relatively rare, and most hospitals provide most types of health services. Increasingly research has supported the idea that hospitals may improve health outcomes by specializing. Our study supports the gains from specialization on average; however, the fact that an identifiable patient population may benefit from diversification is an important qualification. Our findings indicate a substantial opportunity for saving lives by sorting patients into the appropriate facility; based on our estimates, sorting patients by age into diversified or focused facilities could save a life for every 167 surgeries performed. Organizing services around the *characteristics* of patients, such as age, is rarely done outside children's hospitals; our results suggest that substantial gains could be had by considering the characteristics of patients in decisions of organizational scope.

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SUPPORTING INFORMATION

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The Impact of Diversification on Task Performance: Evidence from Kidney Transplant Centers

APPENDICES

Appendix A: The Centers that Diversify

In the specifications included here, we include time-invariant center level fixed effects; while this is empirically appropriate for isolating the effect of diversification, it does gloss over much of the variation that may drive centers to make the diversification decision to begin with. This appendix explores the characteristics of the centers that choose to diversify.

In Appendix Table A1, resents a summary of all transplant centers, with additional breakdowns for diversified and undiversified centers on all center-level control variables. As noted in the main text, diversified centers are larger than undiversified centers. In terms of competition, however, diversified and undiversified centers are more similar. Diversified centers tend to face slightly more competitive markets in terms of other centers in the OPO and the market concentration (0.37 compared with 0.33, measured using a Herfindahl index for kidney transplants).

Insert Appendix Table A1 about here

In Appendix Table A2, we remove the center fixed effects to explore how the characteristics of centers may influence mortality rates. Models 1 examines the effect of size—measured in number of transplants performed annually—affects mortality. Unsurprisingly, centers above the median had lower mortality rates. However, this effect is reduced when year fixed effects are included (Model 2), and becomes wholly insignificant when a center's diversification is taken into consideration (Model 3). Model 3 introduces an indicator variable for centers that never diversify (the omitted category), centers that diversify between 1988-2008 (i.e., the source of variation in the analyses presented in Tables 3 through 5), and centers that diversify prior to 1988. For centers that diversify in our sample, there is no significant effect; without controlling for unobserved center quality (as we do in

our prior analyses), the effect of diversification on its own is insignificant. Those centers that diversify prior to 1988, however, are consistently associated with lower mortality rates, regardless of any other controls included (Models 3 through 7).

Insert Appendix Table A2 about here

The insignificance of transplant volume on mortality when "always diversified" centers are controlled for suggests that the size of the kidney program is correlated with both the decision to diversify early (before 1988) as well as quality in the form of patient mortality rates. This raises the concern that the size of the center is correlated with diversification, introducing a multicollinearity problem. We explore the potential for multicollinearity below, and conclude that it has not biased the results presented here.

Appendix Table A3 provides simple cross tabulations of the count of observations by diversification status and the quartile of the number of transplants the center performs.[1] A cursory examination shows that there is a relationship between diversification and the size of the center—if we look at the share of observations in each quartile that come from centers that diversified, 97% of the top quartile by volume come from centers that diversified (81% between 1988-2008, 16% before 1988). In contrast, only 44% of observations in the bottom quartile come from centers that eventually diversified. Looking at observations from centers that diversified during the period observed in this sample (i.e., the source of variation on which we identify the effect of diversification), 59% come from centers with above-median volumes. The overall correlation between annual transplant volume and diversification is 0.4431.

Insert Appendix Table A3 about here
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[1] Note that the quartiles are defined annually to avoid correlation with transplant year.

This correlation is not an immediate cause for concern for our other analyses, because if anything it should bias our results away from the result we in fact find—because size is associated with lower mortality rates, the relationship between center size and diversification should result in lower mortality rates at diversified centers. However, when we control for center-level fixed effects, we find the opposite. Nonetheless, this relationship could bias our standard errors. In Appendix Table A4, we check the variance inflation factors of each of the covariates in Table 6; none are above 3.

Insert Appendix Table A4 about here

Thus, while there is a relationship between the size of centers and their diversification status, we conclude that it is unlikely to have biased the results we have presented here.

Appendix B: Selection

It is clear that some centers are more likely to have diversified than others; as such, all specifications in Tables 3 through 5 include probability weights to control for selection. These probability weights are constructed using a probit model of center characteristics that predict whether a center will diversify or not, which in turn generates a probability of treatment for each observation. The inverse of these is used as a probability weight (i.e., observations that come from centers that are less likely to have diversified are weighted more heavily than observations from centers that are very likely to have diversified). For reference, we include the mean results in Appendix Table B1.

Insert Appendix Table B1 about here

To assess the probability of diversification, we used observable[2] center-level characteristics that individuals involved in transplant centers hypothesized would be relevant to the decision to diversify: competition, slack resources, and experience.

Competition is perhaps the most straightforward: the more liver centers that are already operating within an OPO, the less likely a kidney center is to open a new liver transplant program. This may be due to the market, regulations, or both— all centers must justify the addition of any new transplant programs to the OPTN as part of requesting authorization for the new program (without this authorization, their patients will not be allocated any organs from outside the hospital). Most states also have Certificate of Need programs in which centers must establish there is clinical need in their market which existing hospitals are unable to address. Beyond these regulations, it will be difficult to get sufficient volume if there are numerous other centers already operating liver transplant programs in the area. We also include competition in kidney transplants (measured using the HHI of kidney transplant shares within a given OPO). While this is a measure of competition, it can also contribute to slack resources (see below).

The next category is experience; we include both the years of experience in kidney transplants (older centers are significantly more likely to diversify) and the size of the center in terms of kidney transplants (we base the weights on 3-year transplant volume as this measure was the most closely correlated with diversification; however, the results presented in the paper are all robust to alternative specification of the weights including alternative measures of volume. Detailed results available from the authors upon request).

The final category is slack resources. In order to be approved for a transplant program by the OPTN, centers must demonstrate significant, dedicated resources, including personnel.[3]

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[2] While the desire to increase the status or reputation of the center was mentioned by all individuals we spoke with, we omitted it due to lack of ability to operationalize it in this context.

[3] https://www.unos.org/wp-content/uploads/unos/B_New_Transplant_Program_Existing_Center.pdf

Furthermore, while most physicians are not employed by their hospitals but rather are paid by insurance companies directly, if the center does not perform enough transplants for the surgeon(s) to support themselves, they will need to "make it up" by performing other types of surgeries. Because we cannot directly observe whether the center had slack resources, we use a number of measures as a proxy for this: quarterly transplant volatility at the center itself (larger variations in the number of transplants performed over the course of a year increase the likelihood that there are unused resources during "slow" periods); volatility interacted with transplant volume (larger centers may be better able to weather volatility, and thus be less reliant on diversification to make up volume); the total kidney transplants in the region, which measures the total supply of transplants (some regions will have a lower supply of transplantable organs [Evans, Orians, and Ascher 1992]. When the supply of transplantable kidneys is lower, kidney centers in that region will be more likely to have slack resources; note that demand does not play a role, as demand for organ transplants is significantly greater than supply in all regions and all years).

Another potential source of selection comes from cherry-picking patients. Prior work on factory focus in the health care setting has shown that some focused organizations achieve superior quality performance by simply selecting less-risky patients (e.g., Casalino, Devers and Brewster, 2003). This will be less of a concern in the transplant setting than in other medical contexts, because the riskiness of a given transplant depends in large part on the quality of the match between the donor and the recipient. Hospitals have no control over the organs that become available, whether the donors are living or deceased. While it was possible to "game" transplants for livers for many years by manipulating ICU status (Snyder, 2010), the allocation of kidneys has always been based on clinical indicators outside of the control of transplant centers. Thus the best way to lower the risk is not through "cherry picking" patients, but rather through maximizing the diversity of the waitlist.

To further explore the effect of potential patient cherry-picking, we look at how patient profiles differ across diversified and undiversified centers, as well as how controlling for these clinical characteristics impact our findings. Appendix Table B2 presents simple means across the different clinical characteristics that affect mortality rates; note that we include all clinical characteristics with demonstrated impact on mortality rates, not just those that the center could potentially "game." The differences between the means are quite small. For controls associated with lower mortality, all but one (patient ethnicity is Hispanic) is slightly higher at diversified centers, suggesting that diversified centers should have lower (not higher) mortality rates. For controls associated with higher mortality, four are lower at undiversified centers (DR mismatch, B mismatch, comorbidity, and days on the waitlist) and four are lower at diversified centers (age, peak PRA, BMI, cold ischemic time). These differences are slight, however, and do not suggest a marked difference in case mix across the type of centers, but these are only simple means that do not account for within-center changes in patient mix that may occur after diversification.

Insert Appendix Table B2 about here

To further address this issue, we next examine the effect of adding each additional clinical control on our results in Appendix Table B3, while including center fixed effects in all specifications. Note that Model 20, the fully specified model, corresponds to the "Age" model in Table 3. The main effect of diversification is noisy ($p< 0.11$ to 0.15) until the differential impact of diversification on patient age is taken into account. We should note that the distribution of patient age does not significantly differ across diversified versus undiversified centers; see Appendix Figure B1 for a comparison of the distribution of patient ages.

Insert Appendix Table B3 about here

In subsequent specifications in Table B3, the addition of clinical controls does increase the overall fit of the model, but does not have much of an impact on the effect of diversification, age, or diversification interacted with age. The only significant movement in the main effect of diversification occurs when BMI is added to the model. We don't see any differences in the distribution of BMI by center diversification status (see Figure B2); however, because BMI is not always recorded (as is the case for other clinical variables not required by UNOS for risk adjustment), the addition of this control results in a significant decrease in the sample that may affect the results. The prior models (Models 3 through 13) demonstrate, however, that our result is robust to either the omission or inclusion of these clinical characteristics.

Insert Appendix Figures B1 and B2 about here

The coefficients on each of the clinical controls are significant and consistent with expectations, with the exception of BMI again, which is not significant. BMI in general has a positive and significant association with mortality, so we repeated this analysis beginning with BMI as the only predictor of mortality, then added each additional control one at a time (full results available from the authors upon request) to verify this result. BMI is a positive and significant predictor of mortality until primary kidney diagnosis fixed effects are added to the specification. We did not include the individual diagnoses in the correlations shown in Appendix Table D1 because they are categorical variables, but there is clearly a strong association between certain diagnoses and BMI. The mean BMI across all patients is 25.66; the mean within a given kidney diagnosis ranges from 19.60 (IgA nephropathy) up to 29.26 (diabetes mellitus, type II). Separately identifying the effect of BMI and diagnoses is thus difficult; however, this does not influence our effects of interest.

Appendix C: Alternate Measures of Diversification

The results reported in the main text all use a binary indicator for diversification. It is also possible to look at a continuous measure of focus, namely the share of kidneys out of all kidney and liver transplants. Appendix Table C1 replicates Table 3, but using a continuous measure of focus (the log of the share of kidney transplants out of total transplants for the center in the prior 3 years). The continuous measure of focus is not significant in the baseline specification, implying that it is the presence of diversification, rather than the degree, that is associated with higher mortality. However, when the continuous focus variable is interacted with patient age, the results are similar in magnitude to the binary diversification specification in Table 3, but even more precise (3.04%, significant at the 99% level); it is important to note that the sign of the coefficients is opposite in this table because we are looking at focus (i.e., a measure that increases as the degree of diversification decreases).

Insert Appendix Table C1 about here

As another alternative measure of diversification, one might also look at the effect of diversifying into other organ transplantation programs; after kidneys and livers, the next most common type of organ transplant is heart transplantation. We have replicated Table 3 using another alternative to diversification: centers that have diversified into liver transplants, centers that have diversified into heart transplants, and centers that have diversified into both.

The identification strategy in this paper relies on observing centers before and after diversification. Because all centers (but one, for legal reasons noted previously) perform kidney transplants before liver transplants, this creates a tidy set of potential diversifiers. Unfortunately, diversification into heart transplants is not as well-defined.

While heart transplants are the third largest organ transplant type, it is still significantly smaller (in 2008, there were 6,319 livers transplanted vs. 2,163 hearts). The order of transplant programs is also not as clear cut: there are 109 centers that perform both kidney and heart

transplants in our sample, but of these, only 48 added a heart program after their kidney program. 15 of the 109 become more focused/less diversified (i.e., the last year that they perform a given type of transplant occurs prior to the end of our sample in 2008).[4]

That said, heart transplantation is quite different from higher volume transplants like kidney and liver, in that centers may go several years without performing a heart transplant. Of the 48 centers that begin performing heart transplants during our sample period, the median number of hearts transplanted per year is 11; the 35th percentile performs none at all. While there is also a minimum transplant volume to be eligible for Medicare reimbursement for heart transplants (12, versus 15 for kidneys), this is less likely to be binding because only patients over 65 will be eligible for Medicare (whereas all patients with end-stage renal disease are eligible for Medicare, regardless of age). However the centers that do not meet this minimum threshold are also much more likely to perform heart transplants in some years but not others.

In the results presented below, we have specified three categories of diversification: those centers that have diversified into livers only, hearts only, or both livers and hearts. We consider a center diversified into hearts in the period in which it is performing the Medicare-minimum number of heart transplants. We have also replicated this table using centers that did not meet the Medicare-minimum threshold, but the results were not meaningfully different (available from the authors upon request).

Unfortunately, of the centers that either begin or end doing heart transplants during our sample period, only 15 centers added heart programs before their liver transplant programs, with a total of 2,299 observations. Given that the fully risk-adjusted model includes 20 year fixed effects, 72 diagnosis fixed effects, 240 center fixed effects, and numerous patient-level controls, it is unlikely

[4] Note that we use the public use data, which identifies transplants performed up until June 2018, to determine the final year of transplants. For example, if a center has not performed any heart transplants from 2008-2018, we specify the final year of heart transplants as 2007.

that we will have enough variation to identify the effect of adding a heart transplant center specifically.

Appendix Table C2 again replicates Table 3; the results for centers that are diversified into livers only or both livers and hearts are largely replicated as well. The effect of diversification becomes much more significant when controlling for the differential effect of age and diversification; in this case, the main effect of diversification for centers that have diversified only into livers (0.0212, $p<0.0099$) versus those that have diversified into both livers and hearts (0.0206, $p<0.0097$) are not statistically significantly different. This is consistent with the results in Table C1, in which the degree of diversification did not matter as much as the fact of diversification at all.

The effect of diversification is never significant for those centers that have only diversified into heart transplants but not livers. It is impossible to tell, however, whether this is because of a lack of effect from diversification or because there is not enough identifying variation in the much-smaller sample of heart-transplant diversifiers. For instance, among heart-transplant diversifiers, the following clinical factors also do not have a statistically significant impact on mortality: having a comorbidity ($p<0.496$ in centers that only added heart transplants, vs. $p<0.023$ in centers that did only livers or both livers and hearts); days on the waitlist ($p<0.332$ vs $p<0.000$); or cold ischemic time ($p<0.632$ vs. $p<0.000$). In other words, there are a number of very well-established clinical determinants of mortality that do not have a statistically significant effect when we narrow the sample so substantially. Given that these clinical determinants of mortality have been robustly demonstrated, we do not believe that the fact that they are not statistically significant in a fully-specified model with a small sample calls their generalizability into question. Similarly, we do not believe that these results are indicative of generalizability of the effect of diversification (either that the results do generalize or they do not). There is simply not enough information to say.

Looking at the effect of age and diversification, the magnitude of the coefficients is somewhat noisier when we separate liver-only diversifiers ($p<0.0983$) from centers that diversify into both liver and heart transplants ($p<0.0132$), but otherwise replicate the results in Table 3 and are not statistically distinguishable from one another.

Appendix D: Additional Institutional Details on Transplant Setting

The nationwide Organ Procurement and Transplantation Network (OPTN) was created in 1986 and oversees the allocation of transplants. The service is provided by the United Network for Organ Sharing (UNOS), which is a nonprofit organization; participation in UNOS by transplant centers is not mandatory, although all US transplant programs have complied with UNOS policies voluntarily.

Each transplant center receives organs for transplant from a geographically designated Organ Procurement Organization (OPO), which is independent from the hospitals it supplies. Although OPOs are defined geographically, they do not conform to any particular geographic boundary—in less populous areas there may be multiple states served by a single OPO, whereas more populous states may have multiple OPOs. Beginning January 1, 1996, the Health Care Financing Administration required that an OPO include an entire state or territory, or that it recover organs from at least 50 potential or 24 actual donors per calendar year. While a small portion of organs may be transferred from one OPO to another, each transplant center receives all its organs from its designated OPO. Although in theory organs may be shared nationwide in order to maximize social welfare, inter-OPO transplant supply sharing beyond the 12 geographic regions (designated by groups of states) is uncommon.

Transplant centers can operate between one and eight transplant programs. Almost all transplant centers (243 of 255 in 2010) perform kidney transplants, while fewer centers have other programs. Kidney transplant surgeons may work in general surgery to make up income (e.g., urology), while liver transplant surgeons will typically do other types of liver surgeries. As noted in

the text, kidney transplant mortality rates have been declining over time due to advances in surgical techniques and technologies.

Insert Appendix Figure D1 About Here

A patient may apply before he or she begins dialysis, but are not considered officially "on the waitlist" until certain clinical thresholds are met.[5] Currently, time on the waiting list receives the most weight in allocation decisions.[6] Some OPOs have exceptions for patients with demonstrated "urgent need," but the majority do not. In the case of both livers and kidneys, patients may also obtain an organ (for kidneys) or a part of an organ (for livers) from a live donor. While less than 5 percent of liver donations come from living donors, 32 percent of kidney donations are from living donors. The supply and demand for organs varies significantly by region, so wealthy patients who are able to travel will often enter waitlists in OPOs with lower wait times. The median wait time for kidneys in 2001 (most recent available for all states) nationwide was 3.23 years (1180 days); in California, the median wait was 6.41 years (2,342 days), while in Oregon it was only 9 months (275 days) (UNOS 2009 Annual Report). However, given the importance of minimizing the time between donation and transplant (cold ischemic time is one of the strongest correlates of mortality in transplants), the vast majority of patients register at the transplant center that is geographically closest. Even waiting for a commercial flight would significantly affect the probability of a patient's mortality.

One surgeon stated that "any surgeon that does both [kidney and liver transplants] will tell you that livers are orders of magnitude harder. A kidney transplant is probably not going to die on the table. A liver transplant might." This is due to both the mechanics of the surgery itself, and also liver transplant patients' relative severity (discussed in the text).

[5] Glomerular filtration rate drops to 0.20 mL per minute or lower
[6] https://optn.transplant.hrsa.gov/learn/professional-education/kidney-allocation-system/

All patients with end-stage renal disease (ESRD) are eligible for Medicare, a government-administered health insurance plan. In order for a center to be eligible to be reimbursed by Medicare for a kidney transplant, they must perform at least 15 kidney transplant surgeries per year. However, a center need only meet the minimum volume threshold in accreditation years, and accreditation does not (usually) happen annually. In this paper, we exclude centers that would not have been accredited in a given year, if they are evaluated. While the mortality at these centers is higher, we cannot say that they are statistically significantly different from Medicare-qualified centers—the estimates from these centers are very noisy due to small sample size. The results we present in the paper are robust to the inclusion of these centers.

Appendix E: Time Since Diversification

Table 4 demonstrates that the effect of diversification on mortality is not a transient effect by looking at the years since a center has diversified. Appendix Table E1 breaks the time since diversification down into five year periods[7] to allow for the possibility of non-linear time trends. Again, the mortality-increasing effect of diversification increases over time. Looking at the effect of patient age interacted with diversification, once again the mortality increasing effect of diversification is offset for older patients. This effect increases in the number of years a center has been diversified, with the exception of centers that have been diversified for 10-15 years. However, this appears to be an artifact of the increasing prevalence of drug-treated hypertension in the later years of the data.[8] When we introduce a separate interaction for hypertension to separate out the impact of patient age, we can see that the joint effect of age and diversification is also increasing in magnitude over time, from -0.04% per year of age (only significant at the 87% level) when a center

[7] Five years was chosen simply because it was a round number that evenly divided the sample period; the results are robust to a variety of alternate specifications of years since diversification (2 year blocks, 3 year blocks, more or less than 5 years, or including a squared years since diversification measure) and are available from the authors on request.

[8] As noted previously, the use of statins to treat hypertension increased dramatically over the course of the observation period, so later years have a much higher use of hypertension medication. Similarly, by necessity centers that have been diversified for more than 10 years come from 1998 and later. By 1998, drug-treated hypertension had reached 71.2% of patients (versus 23.4% of patients from 1988-1997). Thus it is important to control separately for the interaction between hypertension and diversification in specifications that examine the number of years since diversification, particularly where categorical variables are used.

first diversifies, up to -0.14% per year of age (significant at the 99% level) for centers that have been diversified for at least 15 years.

Insert Appendix Table E1 about here

Figure E1 illustrates this for our 25 year old and 75 year old hypothetical patients. For a 75 year old, their expected mortality rate at a diversified center is largely unaffected by how long the center has been diversified. In contrast, a 25 year old patient's expected mortality is significantly higher at a diversified center, and this increases the longer that center has been diversified.[9]

Insert Appendix Figure E1 about here

Appendix F: Correlations

Appendix Table E1 shows the correlation between all of the continuous covariates used in the fully-specified models.

Insert Appendix Table F1 about here

Appendix G: Alternative Measures of Task Complexity

Throughout this paper, we examine patient age as the primary measure of task complexity. Patient age, which is highly correlated with a host of potential complications, is one of the primary determinants of surgical difficulty. However, a large source of this difficulty comes from the

[9] These results are based on the variation observed in centers that diversified at some point during the period of our sample. Comparing centers that did not diversify in-sample—i.e., those that diversified before 1988, or had not diversified by 2008—confirms these trends. For a 75 year old in a center that diversified prior to 1988, the risk adjusted mortality rate was 9.37% vs. 10.49% at a center that had not diversified by 2008. A 25 year old would have faced the opposite (1.77% mortality at a diversified center versus 1.17% at an undiversified center). While this confirms the overall trend, it is important to note that these simple means do not account for time-invariant center quality. In particular, the centers that added liver transplants prior to 1988 (when livers had been deemed an experimental treatment up until 1983) are some of the largest and most prestigious in the country; thus we simply present these averages for illustrative purposes.

uncertainty associated with not just *whether* a complication will arise, but also *which* complication is most likely. In other words, uncertainty in the form of patient complications has a twofold impact on complexity: the likelihood of a complication, but also the scope of potential complications. Returning to the complexity taxonomy of Wood (1986), within dynamic complexity, there can be additional difficulty as a result of uncertainty—if the components of the task are changing in ways that are difficult to anticipate beforehand, they will require a greater breadth of knowledge and faster decision-processing in order to identify and correctly update in response to multiple potential changes that may occur. Thus age increases both dynamic complexity in the form of a high likelihood of complications, but it compounds this with unpredictability as well. While any case with a high risk of complications is likely to necessitate more coordination than a routine case, when the set of potential complications is broad, the demands for coordination are even higher.

There are alternative measures of task complexity for which this level of uncertainty is not present, such as antigen mismatch (which significantly increases the risk of organ rejection) or previously diagnosed comorbidities (which each have attendant complications that are known to the clinical team ahead of time). These risk factors increase the probability of dynamic complexity (in that patients are more likely to experience complications while being treated), but in much more predictable ways. E.g., in the case of antigen mismatch, this risk is identified prior to the surgery through tissue typing, and is known to the surgeons and all clinical staff before the surgery. Thus while antigen mismatch significantly increases the riskiness of the surgery, the scope of potential complications (namely, organ rejection) is very narrow. While this is a serious complication that will demand a good deal of dynamic updating and coordination from the clinical team, because of its relative predictability, they will be better able to prepare for it.

In addition to age, we estimated the effect of diversification interacted with these more predictable sources of task complexity: DR-antigen mismatch, B-antigen mismatch, and the presence

of a known comorbidity[10]. However, none of the results of these measures of task complexity interacted with diversification are significant. While one of the estimates (DR antigen 1 mismatch) appears to be significant when diversification is specified as an indicator, because it is not robust to any alternative specifications, this result is neither consistent nor informative.

Unfortunately this field setting does not permit us to more precisely identify and separate these types of predictable vs. unpredictable task complexity; i.e., we cannot identify the degree to which the unpredictability vs. other sources of dynamic complexity vs. coordinative complexity from age-related complications drives our results. However, these results—that more unpredictable task complexity does appear to benefit from a diversified organization, while more predictable sources of task complexity do not—are both interesting and suggestive for future work.

Insert Appendix Table F1 about here

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[10] The primary comorbidities tracked by UNOS are angina, cerebral vascular disease, drug-treated COPD, drug-treated hypertension, malignant tumor of the kidney, peptic ulcers, and pulmonary embolism. We combine these into a single indicator, equal to one if at least one comorbidity is present, with the exception of drug-treated hypertension, which has a separate indicator. This is to reflect the fact that the popularization of statins to treat hypertension occurred early in our sample. In 1993, 1.1% of transplant recipients had drug-treated hypertension; in 1994, it was 21.5%. This rate continued to grow, reaching a maximum of 78% of transplant recipients in 2006. While other comorbidities are relatively rare and associated with higher mortality rates in our sample, hypertension is not. Thus they are treated separately in our regressions.

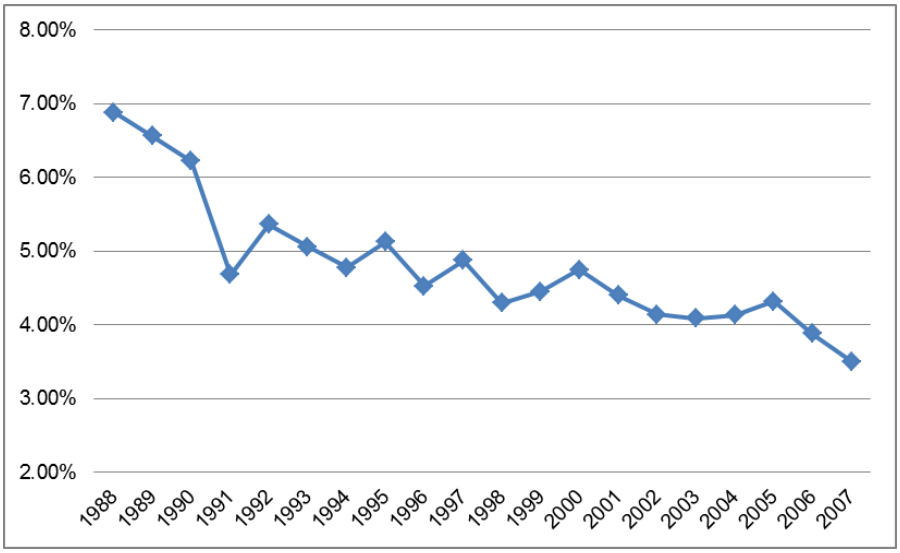


Figure 1: One year post-kidney transplant mortality rate

* We omitted transplant centers that did not meet Medicare's minimum threshold of 15 annual transplants.

APPENDIX TABLES

Table A1: Center descriptive statistics

Variable	Observations	Mean	Standard Deviation	Minimum
Diversified	4,761	0.458	0.495	-
3 year kidney volume	3,887	172.214	170.556	-
Diversified	*1,987*	*229.63*	*208.02*	*0*
Undiversified	*1,900*	*112.17*	*84.93*	*5*
OPO* Kidney Concentration	4,761	0.351	0.223	0.092
Diversified	*2,225*	*0.37*	*0.25*	*0.092*
Undiversified	*2,536*	*0.33*	*0.19*	*0.092*
Count of liver centers in OPO in prior year*	4,550	2.853	2.052	-
Diversified	*2,168*	*3.28*	*2.02*	*0*
Undiversified	*2,382*	*2.47*	*2.01*	*0*
Quarterly kidney volatility (annual average)	4,761	21.197	10.468	0.82
Diversified	*2,225*	*21.53*	*10.57*	*0.823*
Undiversified	*2,536*	*20.90*	*10.37*	*0.823*

* OPO: Organ Procurement Organization; in organ transplants, this roughly defines the boundaries of the market

Appendix Table A2: Effect of Center Characteristics on Mortality

Dependent variable: mortality within one year of transplant

Standard errors reported in parentheses, p-values in italics

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7

Transplant Volume - 2nd Quartile	-0.0026	-0.00192	-0.0006	-0.0003	-0.0005	-0.0006	-0.0006
	0.3402	*0.4710*	*0.7983*	*0.8902*	*0.8544*	*0.8057*	*0.8131*
	(0.0027)	(0.0027)	(0.0025)	(0.0025)	(0.0025)	(0.0025)	(0.0025)
Transplant Volume - 3rd Quartile	-0.0092	-0.0076	-0.005	-0.0044	-0.0044	-0.0049	-0.0049
	0.0041	*0.0190*	*0.1179*	*0.1828*	*0.1767*	*0.1414*	*0.1591*
	(0.0032)	(0.0032)	(0.0032)	(0.0033)	(0.0033)	(0.0033)	(0.0034)
Transplant Volume - Top Quartile	-0.0078	-0.00586	-0.0016	-0.0002	-0.0002	-0.0012	-0.0011
	0.0566	*0.1440*	*0.6750*	*0.9711*	*0.9638*	*0.7922*	*0.8090*
	(0.0041)	(0.0040)	(0.0038)	(0.0044)	(0.0044)	(0.0044)	(0.0045)
Diversified Between 1988-2008			-0.0039	-0.0037	-0.0041	-0.0044	-0.0043
			0.1776	*0.1934*	*0.1488*	*0.1220*	*0.2050*
			(0.0029)	(0.0028)	(0.0028)	(0.0029)	(0.0034)
Diversified Prior to 1988			-0.0145	-0.0141	-0.0147	-0.0152	-0.0150
			0.0001	*0.0002*	*0.0001*	*0.0001*	*0.0017*
			(0.0037)	(0.0037)	(0.0037)	(0.0037)	(0.0047)
Quarterly Volatility in Kidney Transplant Volume				-0.0003	-0.0003	-0.0004	-0.0004
				0.4875	*0.5113*	*0.3911*	*0.3902*
				(0.0004)	(0.0004)	(0.0004)	(0.0004)
Liver Centers in OPO in Prior Year					0.0006	0.001	0.001
					0.4582	*0.2389*	*0.2434*
					(0.0007)	(0.0009)	(0.0009)
OPO Concentration in Kidney Transplants						0.0062	0.0062
						0.3677	*0.3682*
						(0.0068)	(0.0069)
Years Since Diversification							0
							0.9423
							(0.0004)
Patient-level Clinical Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Transplant Year FE	No	Yes	Yes	Yes	Yes	Yes	Yes
Constant	-0.0322	-0.0325	-0.0298	-0.0292	-0.0298	-0.0320	-0.0321
	0.0000	*0.0000*	*0.0005*	*0.0007*	*0.0005*	*0.0005*	*0.0007*
	(0.0067)	(0.0082)	(0.0084)	(0.0085)	(0.0085)	(0.0090)	(0.0093)
R^2	0.0239	0.0246	0.0248	0.0248	0.0248	0.0248	0.0248
N	103,558	103,558	103,558	103,558	103,558	103,558	103,558

Patient characteristics included in the specification but not reported here: drug-treated hypertension, live donor, peak PRA, days on waitlist, race, gender, BMI, cold ischemic time, multi-organ transplant, primary kidney diagnosis. Firm characteristics included in the specification but not reported here: annual volume quartile, quarterly volatility

Market (OPO) characteristics included in the specification but not reported here: kidney concentration, number of liver transplant centers in the previous period

All specifications include year and center fixed effects. Standard errors are robust and clustered at the center level, and are reported in parentheses

All specifications include inverse probability weights to control for probability of selection

Diversification is an indicator variable equal to 1 beginning on the date that the center performed its first liver transplant

Appendix Table A3: Observations by Number of Transplants and Diversifiers

	Bottom Quartile	2nd Quartile	3rd Quartile	Top Quartile
Never Diversified	35,611	17,253	7,275	2,194
Diversified in Sample	25,073	44,550	48,866	50,861
Always Diversified	3,205	1,721	5,564	9,779

Share of Diversifiers

	Bottom Quartile	2nd Quartile	3rd Quartile	Top Quartile
Never Diversified	57%	28%	12%	4%
Diversified in Sample	15%	26%	29%	30%
Always Diversified	16%	8%	27%	48%

Share of Quartiles

	Bottom Quartile	2nd Quartile	3rd Quartile	Top Quartile
Never Diversified	56%	27%	12%	3%
Diversified in Sample	39%	70%	79%	81%
Always Diversified	5%	3%	9%	16%
	100%	100%	100%	100%

Correlation between annual transplant volume and diversification: 0.4431

Appendix Table A4: VIF for Explanatory Variables in Appendix Table 1

Variable	VIF	1/VIF
Annual Transplant Quartile		
2nd quartile	1.33	0.75
3rd quartile	1.62	0.62
4th quartile	2.21	0.45
Diversifier		
Diversified in sample	2.21	0.45
Diversified before 1988	1.66	0.60
Volatility	1.88	0.53
Lag OPO Liver Centers	1.86	0.54
OPO Kidney Concentraion (HHI)	1.94	0.52
Years of liver experience	2.74	0.37

Appendix Table B1: Probit Model of Diversification Used to Generate Inverse Probability Weights

Dependent Variable: Transplant Center Diversification
p-values in italics

							IPW Weighting Model
Liver centers in previous period	-0.0253 0.0136	0.0147 0.2605	-0.0257 0.0599	-0.0327 0.0362	-0.0359 0.022	-0.0354 0.0239	-0.0305 0.0568
Kidney transplant concentration		0.5791 0.0000	0.4363 0.0003	-0.2174 0.1509	-0.2613 0.0864	-0.2549 0.0947	-0.2166 0.1621
Years experience (kidney)			0.0517 0.0000	0.021 0.0001	0.0209 0.0001	0.0207 0.0001	0.0231 0.0000
Log of lagged kidney transplant volume				0.0049 0.0000	0.0043 0.0000	0.0046 0.0000	0.0045 0.0000
Kidney transplant volatility					0.0644 0.0000	0.0782 0.0024	0.0759 0.0034
Kidney transplant volume * volatility						-0.0001 0.4983	-0.0001 0.5631
Kidney transplants in region							-0.0001 0.1024
Constant	0.0413 0.1971	-0.256 0.0002	-0.6043 0.0000	-0.908 0.0000	-0.9943 0.0000	-1.0409 0.0000	-0.996 0.0000
Pseudo R^2	0.0012	0.006	0.0398	0.1623	0.1666	0.1667	0.1673
N	3,655	3,655	3,655	3,185	3,183	3,183	3,183

Appendix Table B2: Clinical Controls by Diversification Status

Controls associated with lower mortality	**Undiversified**	**Diversified**
Living donor	0.1569	0.1573
Female	0.3952	0.3986
Patient race - Hispanic	0.1197	0.1074
Patient race - Asian	0.0316	0.0394
Drug-treated hypertension	0.5289	0.5853
Controls associated with higher mortality		
Age	44.9590	44.4596
DR-antigen mismatch	0.9243	0.9920
B-antigen mismatch	1.1702	1.2363
Peak PRA	14.1742	13.0444
BMI	25.7771	25.5962
Comorbidity	0.0213	0.0232
Days on waitlist	491.0344	506.9090
Cold ischemic time	17.4476	17.0549

Appendix Table B3: Effect of Adding Individual Controls

Dependent Variable: Transplant Center Diversification

p-values in italics

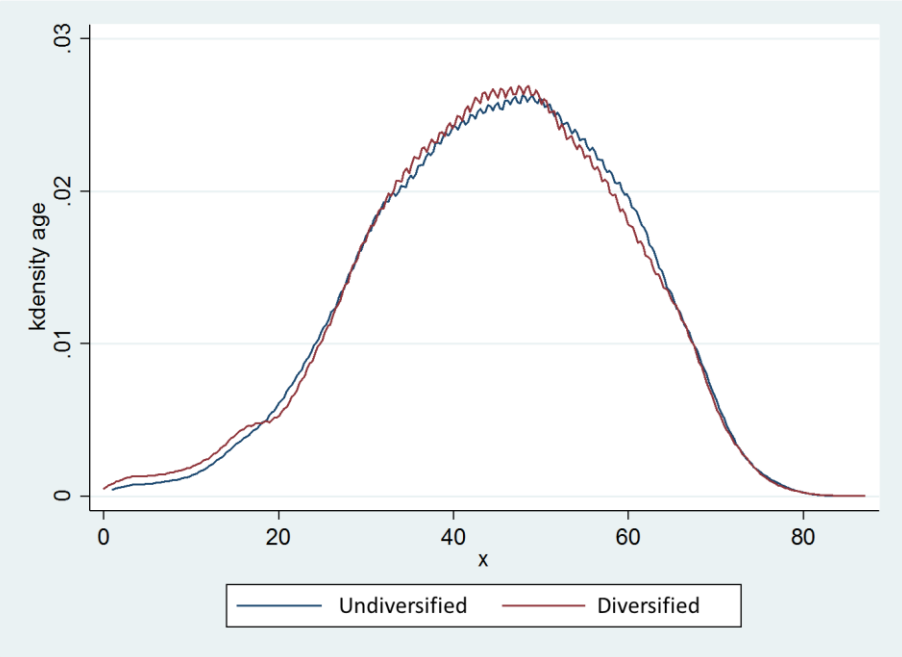
	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8	Model 9	Model 10
Diversified	-0.0037	0.0045	0.0039	0.0190	0.0195	0.0193	0.0193	0.0193	0.0193	0.0195
	0.1492	*0.1135*	*0.1457*	*0.0001*	*0.0001*	*0.0001*	*0.0001*	*0.0001*	*0.0001*	*0.0001*
Age			0.0016	0.0018	0.0018	0.0018	0.0018	0.0018	0.0018	0.0018
			0.0000	*0.0000*	*0.0000*	*0.0000*	*0.0000*	*0.0000*	*0.0000*	*0.0000*
Diversified * Age				-0.0003	-0.0003	-0.0003	-0.0003	-0.0003	-0.0003	-0.0003
				0.0006	*0.0009*	*0.0010*	*0.0011*	*0.0011*	*0.0011*	*0.0010*
Hypertension						-0.0068	-0.0067	-0.0066	-0.0068	-0.0069
						0.0000	*0.0000*	*0.0000*	*0.0000*	*0.0000*
DR Mismatch 1							0.0049	0.0026	0.0026	0.0026
							0.0001	*0.0659*	*0.0637*	*0.0679*
DR Mismatch 2							0.0106	0.0057	0.0057	0.0057
							0.0000	*0.0022*	*0.0021*	*0.0021*
B Mismatch 1								0.0026	0.0026	0.0025
								0.1008	*0.0994*	*0.1044*
B Mismatch 2								0.0104	0.0104	0.0103
								0.0000	*0.0000*	*0.0000*
Other comorbidity									0.0116	0.0116
									0.0044	*0.0048*
Patient race - Black										0.0023
										0.1345
Patient race - Asian										-0.0088
										0.0044
Patient race - Hispanic										-0.0072
										0.0000
Center FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Diagnosis FE	No	No	No	No	Yes	Yes	Yes	Yes	Yes	Yes
Constant	0.0453	0.0465	-0.0178	-0.0261	-0.0264	-0.0271	-0.0306	-0.0326	-0.0324	-0.0315
	0.0000	*0.0000*	*0.0000*	*0.0000*	*0.0000*	*0.0000*	*0.0000*	*0.0000*	*0.0000*	*0.0000*
r2	0.0062	0.0068	0.0188	0.0189	0.0232	0.0234	0.0238	0.0242	0.0242	0.0244
N	228,569	228,569	228,569	228,569	218,748	218,748	217,196	217,138	217,138	217,138

Continued, next page

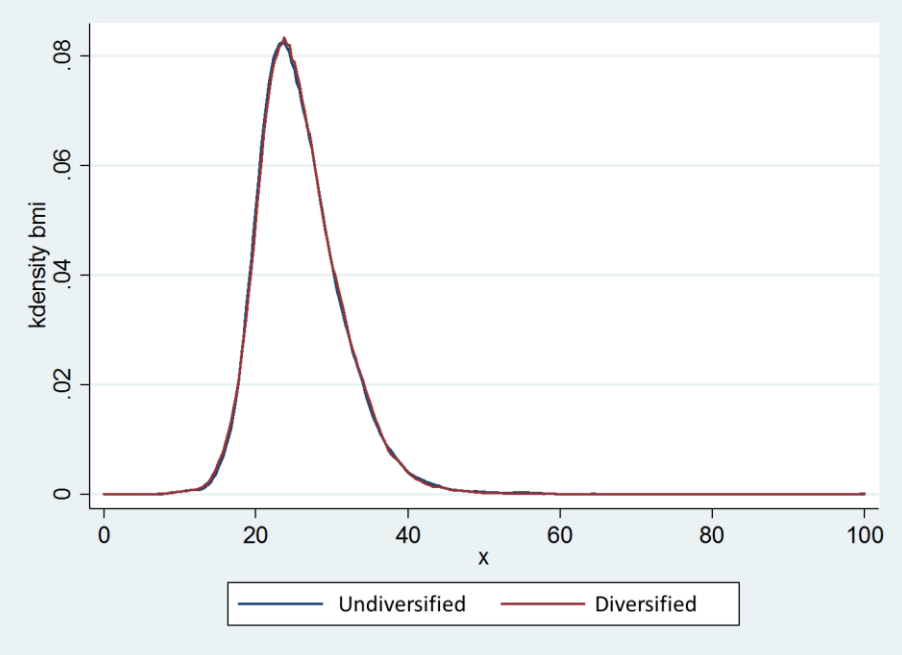
	Model 11	Model 12	Model 13	Model 14	Model 15	Model 16	Model 17	Model 18	Model 19	Model 20
Diversified	0.0195	0.0189	0.0194	0.0183	0.0172	0.0222	0.0210	0.0210	0.0207	0.0206
	0.0001	0.0002	0.0001	0.0006	0.0041	0.0020	0.0029	0.0028	0.0035	0.0034
Age	0.0018	0.0017	0.0017	0.0017	0.0017	0.0020	0.0020	0.0020	0.0020	0.0020
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Diversified * Age	-0.0003	-0.0003	-0.0003	-0.0003	-0.0003	-0.0003	-0.0003	-0.0003	-0.0003	-0.0003
	0.0010	0.0017	0.0011	0.0087	0.0380	0.0281	0.0272	0.0278	0.0275	0.0278
Hypertension	-0.0070	-0.0060	-0.0050	-0.0057	-0.0061	-0.0070	-0.0070	-0.0070	-0.0070	-0.0070
	0.0000	0.0000	0.0001	0.0001	0.0003	0.0005	0.0006	0.0005	0.0005	0.0005
DR Mismatch 1	0.0026	0.0042	0.0038	0.0034	0.0036	0.0042	0.0042	0.0042	0.0042	0.0042
	0.0688	0.0035	0.0078	0.0310	0.0432	0.0434	0.0445	0.0439	0.0439	0.0439
DR Mismatch 2	0.0057	0.0058	0.0052	0.0055	0.0048	0.0048	0.0047	0.0047	0.0047	0.0047
	0.0022	0.0017	0.0047	0.0072	0.0464	0.0797	0.0818	0.0815	0.0818	0.0813
B Mismatch 1	0.0025	0.0038	0.0033	0.0036	0.0033	0.0044	0.0044	0.0044	0.0044	0.0044
	0.1128	0.0148	0.0373	0.0466	0.1175	0.0804	0.0827	0.0807	0.0808	0.0812
B Mismatch 2	0.0102	0.0071	0.0061	0.0066	0.0081	0.0099	0.0099	0.0099	0.0099	0.0099
	0.0000	0.0002	0.0012	0.0017	0.0011	0.0006	0.0006	0.0006	0.0006	0.0006
Other comorbidity	0.0115	0.0119	0.0127	0.0145	0.0170	0.0172	0.0171	0.0171	0.0171	0.0171
	0.0049	0.0035	0.0019	0.0020	0.0065	0.0104	0.0106	0.0107	0.0106	0.0106
Patient race - Black	0.0024	-0.0007	-0.0021	-0.0017	-0.0017	-0.0025	-0.0025	-0.0025	-0.0025	-0.0025
	0.1168	0.6423	0.1743	0.3259	0.4215	0.3376	0.3376	0.3374	0.3377	0.3383
Patient race - Asian	-0.0085	-0.0105	-0.0113	-0.0110	-0.0099	-0.0108	-0.0107	-0.0107	-0.0107	-0.0107
	0.0057	0.0006	0.0003	0.0013	0.0158	0.0195	0.0198	0.0199	0.0200	0.0200
Patient race - Hispanic	-0.0072	-0.0080	-0.0086	-0.0085	-0.0099	-0.0110	-0.0110	-0.0110	-0.0110	-0.0110
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Female	-0.0032	-0.0030	-0.0031	-0.0036	-0.0032	-0.0033	-0.0034	-0.0034	-0.0034	-0.0034
	0.0035	0.0055	0.0043	0.0027	0.0348	0.0486	0.0459	0.0459	0.0459	0.0459
Live donor		-0.0218	-0.0177	-0.0102	-0.0080	-0.0091	-0.0093	-0.0092	-0.0092	-0.0092
		0.0000	0.0000	0.0000	0.0020	0.0026	0.0021	0.0021	0.0021	0.0021
Days on waitlist			0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
			0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Cold ischemic time				0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004
				0.0000	0.0004	0.0005	0.0006	0.0006	0.0006	0.0006
Peak PRA					0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
					0.0757	0.0260	0.0280	0.0282	0.0282	0.0282
BMI						0.0000	0.0000	0.0000	0.0000	0.0000
						0.9081	0.9014	0.9041	0.9032	0.9041
Log lag cumul. kidney volume							0.0093	0.0097	0.0098	0.0096
							0.0433	0.0373	0.0369	0.0450
Transplant volatility								-0.0005	-0.0005	-0.0005
								0.2469	0.2412	0.2326

Lag OPO liver centers									0.0003	0.0003
									0.8395	0.8267
Kidney concentration										0.0057
										0.7835
Center FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Diagnosis FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Constant	-0.0300	-0.0192	-0.0207	-0.0292	-0.0322	-0.0446	-0.0880	-0.0885	-0.0890	-0.0901
	0.0000	0.0004	0.0001	0.0000	0.0000	0.0000	0.0001	0.0001	0.0001	0.0002
R^2	0.0245	0.0265	0.0270	0.0274	0.0280	0.0301	0.0302	0.0302	0.0302	0.0302
N	217,138	217,138	217,138	181,128	129,410	102,679	102,679	102,679	102,679	102,679

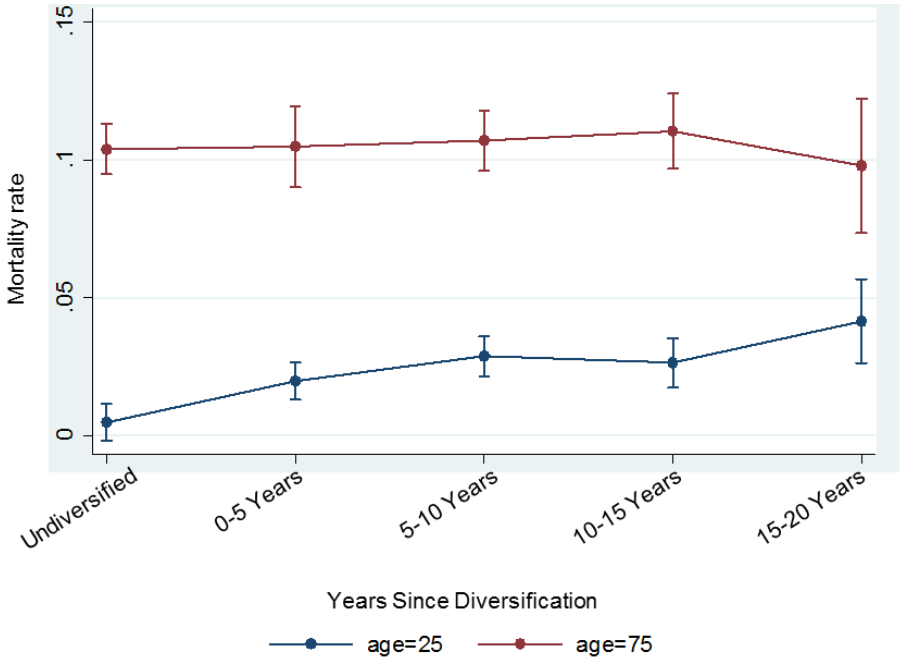
Appendix Figure B1: Distribution of Patient Age by Center Diversification Status



Appendix Figure B2: Distribution of Patient BMI by Center Diversification Status



Appendix Figure E1: Expected mortality rates for a 25 year old patient vs. a 75 year old patient, by the number of years a center has been diversified



Appendix Table C1: Effect of Focus (Continuous) on Mortality

Dependent variable: mortality within one year of transplant
p-values in italics
NB: This replicates Table 3, but with a continuous measure of diversification

	Baseline	DR-Mismatch	B-Mismatch	Age	Comorbidity	Age and Comorbidity	Age and Hyper-tension
Diversification (Continuous)	0.0015	0.0021	0.0058	-0.0290	0.0012	-0.0283	-0.0387
	0.8302	*0.7715*	*0.4598*	*0.0029*	*0.8661*	*0.0045*	*0.0117*
Age	0.0018	0.0018	0.0018	0.0020	0.0018	0.0019	0.0022
	0.0000	*0.0000*	*0.0000*	*0.0000*	*0.0000*	*0.0000*	*0.0000*
Comorbidity	0.0172	0.0172	0.0172	0.0172	0.0197	-0.0440	0.0178
	0.0104	*0.0104*	*0.0104*	*0.0100*	*0.0168*	*0.1310*	*0.0080*
Hypertension	-0.0070	-0.0070	-0.0070	-0.0069	-0.0070	-0.0069	0.0114
	0.0006	*0.0006*	*0.0005*	*0.0006*	*0.0006*	*0.0006*	*0.1006*
DR Mismatch 1	0.0042	0.0044	0.0042	0.0042	0.0042	0.0042	0.0042
	0.0442	*0.0895*	*0.0452*	*0.0448*	*0.0441*	*0.0448*	*0.0460*
DR Mismatch 2	0.0048	0.0039	0.0048	0.0047	0.0048	0.0048	0.0047
	0.0775	*0.2493*	*0.0786*	*0.0821*	*0.0774*	*0.0807*	*0.0853*
B Mismatch 1	0.0044	0.0044	0.0032	0.0044	0.0044	0.0044	0.0044
	0.0796	*0.0803*	*0.2951*	*0.0811*	*0.0802*	*0.0797*	*0.0814*
B Mismatch 2	0.0099	0.0099	0.0093	0.0099	0.0099	0.0100	0.0099
	0.0005	*0.0006*	*0.0086*	*0.0005*	*0.0006*	*0.0005*	*0.0006*
Diversification * DR Mismatch 1		0.0011					
		0.8418					
Diversification *		-0.0050					

DR Mismatch 2		0.4101					
Diversification * B Mismatch 1			-0.0067 0.3468				
Diversification * B Mismatch 2			-0.0038 0.5659				
Diversification * Age				0.0007 *0.0005*		0.0007 *0.0010*	0.0009 *0.0089*
Diversification * Comorbidity					0.0128 *0.4539*	-0.0278 *0.5779*	
Comorbidity * Age						0.0012 *0.0539*	
Diversification * Comorbidity * Age						*0.0007* 0.5317	
Hypertension * Age							*0.0195* *0.2356*
Diversification * Hypertension							-0.0004 *0.0130*
Diversification * Hypertension * Age							-0.0005 *0.2755*
Constant	-0.0850 *0.0004*	-0.0851 *0.0004*	-0.0843 *0.0004*	-0.0890 *0.0002*	-0.0850 *0.0004*	-0.0880 *0.0002*	-0.0983 *0.0001*
R^2	0.0301	0.0301	0.0301	0.0302	0.0301	0.0303	0.0303
N	102,679	102,679	102,679	102,679	102,679	102,679	102,679

Appendix Table C2: Heart Transplant Diversification

Dependent variable: mortality within one year of transplant

p-values in italics

NB: This replicates Table 3, but includes heart transplant centers in the measure of diversification

	Baseline	DR-Mismatch	B-Mismatch	Age	Co-morbidity	Age and Comorbidity	Age and Hypertension
Diversification: Livers	0.0085 *0.0740*	0.0107 *0.0512*	0.0074 *0.2507*	0.0212 *0.0099*	0.0088 *0.0636*	0.0198 *0.0174*	0.026 *0.0212*
Diversification: Hearts	-0.0012 *0.8660*	0.0076 *0.3867*	-0.0068 *0.5184*	0.0159 *0.1965*	-0.0012 *0.8734*	0.0160 *0.1863*	0.0127 *0.4768*
Diversification: Livers and Hearts	0.0022 *0.6588*	0.0073 *0.2031*	0.0013 *0.8398*	0.0206 *0.0097*	0.0021 *0.6848*	0.0204 *0.0107*	0.0298 *0.0044*
Age	0.0018 *0.0000*	0.0018 *0.0000*	0.0018 *0.0000*	0.002 *0.0000*	0.0018 *0.0000*	0.002 *0.0000*	0.0023 *0.0000*
Comorbidity	0.0171 *0.0108*	0.017 *0.0111*	0.0171 *0.0109*	0.017 *0.0113*	0.018 *0.1304*	-0.0683 *0.1462*	0.0176 *0.0089*
Hypertension	-0.0071	-0.0071	-0.0071	-0.007	-0.0071	-0.007	0.0141

	0.0005	*0.0005*	*0.0005*	*0.0006*	*0.0005*	*0.0005*	*0.1438*
DR Mismatch 1	0.0043	0.0098	0.0043	0.0043	0.0043	0.0043	0.0042
	0.0429	*0.0043*	*0.0417*	*0.0424*	*0.0426*	*0.0428*	*0.0446*
DR Mismatch 2	0.0048	0.0037	0.0048	0.0048	0.0048	0.0048	0.0047
	0.0769	*0.4034*	*0.0742*	*0.0799*	*0.0755*	*0.0779*	*0.0855*
B Mismatch 1	0.0044	0.0043	0.0025	0.0043	0.0044	0.0044	0.0043
	0.0805	*0.0839*	*0.5624*	*0.0837*	*0.0805*	*0.0812*	*0.0860*
B Mismatch 2	0.0099	0.0099	0.0098	0.0099	0.0099	0.0099	0.0098
	0.0005	*0.0006*	*0.0487*	*0.0006*	*0.0006*	*0.0005*	*0.0006*
Diversification (Livers) * DR Mismatch 1		-0.0098					
		0.0324					
Diversification (Livers) * DR Mismatch 2		0.0091					
		0.1089					
Diversification (Hearts) * DR Mismatch 1		-0.0155					
		0.0189					
Diversification (Hearts) * DR Mismatch 2		-0.0055					
		0.5603					
Diversification (Livers & Hearts)* DR Mismatch 1		-0.0092					
		0.0239					
Diversification (Livers & Hearts)* DR Mismatch 2		-0.0022					
		0.6542					
Diversification (Livers) * B Mismatch 1			0.0017				
			0.7722				
Diversification (Livers) * B Mismatch 2			0.0007				
			0.9112				
Diversification (Hearts) * B Mismatch 1			0.0098				
			0.2582				
Diversification (Hearts) * B Mismatch 2			0.0036				
			0.6770				
Diversification (Livers & Hearts)* B Mismatch 1			0.0033				
			0.5108				
Diversification (Livers & Hearts)* B Mismatch 2			-0.001				
			0.8546				
Diversification (Livers) * Age				-0.0003		-0.0003	-0.0004
				0.0983		*0.1589*	*0.0913*
Diversification (Hearts) * Age				-0.0004		-0.0004	-0.0002
				0.1400		*0.1287*	*0.6351*
Diversification (Livers & Hearts) * Age				-0.0004		-0.0004	-0.0007
				0.0132		*0.0145*	*0.0075*
Diversification (Livers)* Comorbidity					-0.0139	0.0723	
					0.3956	*0.2093*	

Diversification (Hearts) * Comorbidity				-0.0011	0.0031		
				0.9698	*0.9595*		
Diversification (Livers & Hearts) * Comorbidity				0.0092	0.0419		
				0.5416	*0.4837*		
Comorbidity * Age					0.0016		
					0.1066		
Diversification (Livers)* Comorbidity * Age					-0.0016		
					0.1950		
Diversification (Hearts) * Comorbidity * Age					0.0001		
					0.9475		
Diversification (Livers & Hearts) * Comorbidity * Age					-0.0005		
					0.6789		
Diversification (Livers) * Hypertension						-0.0095	
						0.4751	
Diversification (Hearts) * Hypertension						0.0066	
						0.8161	
Diversification (Livers & Hearts) * Hypertension						-0.0161	
						0.1949	
Hypertension * Age						-0.0005	
						0.0251	
Diversification (Livers) * Hypertension * Age						0.0003	
						0.3492	
Diversification (Hearts) * Hypertension * Age						-0.0005	
						0.5420	
Diversification (Livers & Hearts) * Hypertension * Age						0.0005	
						0.1388	
Constant	-0.0814	-0.0844	-0.0806	-0.091	-0.0813	-0.0896	-0.1008
	0.0005	*0.0004*	*0.0006*	*0.0002*	*0.0005*	*0.0002*	*0.0001*
R^2	0.0301	0.0303	0.0301	0.0302	0.0301	0.0304	0.0305
N	102,679	102,679	102,679	102,679	102,679	102,679	102,679

Patient characteristics included in the specification but not reported here: drug-treated hypertension, live donor, peak PRA, days on waitlist, race, gender, BMI, cold ischemic time, multi-organ transplant, primary kidney diagnosis. Firm characteristics included in the specification but not reported here: annual volume quartile, quarterly volatility

Market (OPO) characteristics included in the specification but not reported here: kidney concentration, number of liver transplant centers in the previous period

All specifications include year and center fixed effects. Standard errors are robust and clustered at the center level, and are reported in parentheses

All specifications include inverse probability weights to control for probability of selection

Appendix Table E1: Effect of time since diversification on mortality

Dependent variable: mortality within one year of transplant

p-values in italics

	Baseline	Age	Age and Comorbidity	Age and Hypertension
Diversification, Less than 5 Years	0.0076 *0.0913*	0.0166 *0.0588*	0.0153 *0.0850*	0.0221 *0.0459*
Diversification, 5-10 years	0.0135 *0.0203*	0.0345 *0.0001*	0.0338 *0.0001*	0.0389 *0.0005*
Diversification, 10-15 years	0.0164 *0.0212*	0.0292 *0.0017*	0.0289 *0.0020*	0.0412 *0.0012*
Diversification, 15-20 years	0.0199 *0.0254*	0.0510 *0.0004*	0.0539 *0.0002*	0.0733 *0.0001*
Diversification, Less than 5 Years * Age		-0.0002 *0.3167*	-0.0002 *0.4310*	-0.0004 *0.1317*
Diversification, 5-10 years * Age		-0.0005 *0.0074*	-0.0004 *0.0127*	-0.0006 *0.0186*
Diversification, 10-15 years * Age		-0.0003 *0.1058*	-0.0003 *0.1033*	-0.0007 *0.0113*
Diversification, 15-20 years * Age		-0.0006 *0.0275*	-0.0007 *0.0146*	-0.0014 *0.0019*
Diversification, Less than 5 Years * Comorbidity			0.0673 *0.1971*	
Diversification, 5-10 years * Comorbidity			0.0526 *0.3942*	
Diversification, 10-15 years * Comorbidity			0.0674 *0.2752*	
Diversification, 15-20 years * Comorbidity			-0.1065 *0.3575*	
Comorbidity * Age			0.0016 *0.0761*	
Diversification, Less than 5 Years * Comorbidity * Age			-0.0018 *0.1128*	
Diversification, 5-10 years * Comorbidity *Age			-0.0012 *0.3782*	
Diversification, 10-15 years * Comorbidity* Age			-0.0010 *0.4574*	
Diversification, 15-20 years * Comorbidity * Age			0.0024 *0.3063*	
Diversification, Less than 5 Years * Hypertension				-0.0080 *0.6416*
Diversification, 5-10 years * Hypertension				-0.0138 *0.3309*
Diversification, 10-15 years * Hypertension				*-0.0269* 0.0552
Diversification, 15-20 years * Hypertension				*-0.0428* *0.0345*
Age * Hypertension				-0.0005 *0.0124*
Diversification, Less than 5 Years Hypertension * Age				0.0003 *0.5013*
Diversification, 5-10 years * Hypertension * Age				0.0003 *0.3907*
Diversification, 10-15 years *				0.0008

Hypertension * Age				*0.0267*
Diversification, 15-20 years * Hypertension * Age				0.0012 *0.0174*
Age	0.0018 *0.0000*	0.0020 *0.0000*	0.0020 *0.0000*	0.0023 *0.0000*
Comorbidity	0.0171 *0.0105*	0.0172 *0.0102*	-0.0660 *0.1129*	0.0177 *0.0083*
Hypertension	-0.0070 *0.0006*	-0.0068 *0.0007*	-0.0068 *0.0007*	0.0154 *0.0951*
Constant	-0.0790 *0.0009*	-0.0878 *0.0004*	-0.0871 *0.0004*	-0.1016 *0.0001*
R^2	0.0301	0.0303	0.0305	0.0305
N	102,679	102,679	102,679	102,679

Standard errors robust and clustered at the physician-hospital level (not reported; available upon request).
Patient characteristics included in the specification but not reported here: DR- and B-antigen mismatch, live donor, peak PRA, days on waitlist, race, gender, BMI, cold ischemic time, multi-organ transplant, primary kidney diagnosis. Firm characteristics included in the specification but not reported here: annual volume quartile, quarterly volatility.
Market (OPO) characteristics included in the specification but not reported here: kidney concentration, number of liver transplant centers in the previous period.
All specifications include year and center fixed effects. Standard errors are robust and clustered at the center level, and are reported in parentheses.
All specifications include inverse probability weights to control for probability of selection
Diversification is an indicator variable equal to 1 beginning on the date that the center performed its first liver transplant

Appendix Table F1: Correlation Between Independent Variables

Appendix Table F1: Correlation Between Independent Variables	Diversified	Years liver transplant exp.	Age	Hyper-tension (i)	Multi-organ transplant (i)	Living Donor (i)	Peak PRA	Days on Waitlist	Cold Ischemic Time	Black (i)	Asian (i)	Hispanic (i)	Female (i)	BMI	Annual transplant volume	Quarterly Transplant Volatility	Liver centers in prior year	Kidney Transplant Conc.	Transplant Year
Diversified	1.00																		
Years of liver transplant experience	0.76	1.00																	
Age	(0.01)	0.05	1.00																
Hypertension (i)	0.07	0.25	0.14	1.00															
Multi-organ transplant (i)	0.06	0.07	0.02	(0.02)	1.00														
Living Donor (i)	0.01	0.06	(0.06)	0.12	(0.04)	1.00													
Peak PRA	(0.02)	(0.03)	(0.05)	(0.08)	0.00	(0.08)	1.00												
Days on Waitlist	0.03	0.12	0.07	0.02	(0.06)	(0.16)	0.24	1.00											
Cold Ischemic Time	(0.02)	(0.12)	0.06	(0.17)	(0.04)	(0.59)	0.08	0.08	1.00										
Black (i)	0.01	0.01	(0.03)	0.02	(0.02)	(0.07)	0.04	0.16	0.05	1.00									
Asian (i)	0.02	0.02	0.00	0.01	0.00	(0.00)	(0.01)	0.06	0.01	(0.11)	1.00								
Hispanic (i)	(0.02)	(0.02)	(0.06)	0.02	0.01	0.02	0.02	0.05	0.00	(0.20)	(0.07)	1.00							
Female (i)	0.00	0.01	(0.04)	(0.03)	(0.01)	0.02	0.18	0.02	(0.01)	0.00	0.02	(0.00)	1.00						
BMI	(0.01)	0.03	0.20	0.09	0.00	0.02	(0.04)	0.03	(0.01)	0.08	(0.09)	(0.02)	(0.04)	1.00					
Annual transplant volume	0.45	0.49	0.04	0.11	0.03	0.03	(0.03)	0.05	0.03	(0.02)	0.05	0.02	0.00	0.00	1.00				
Quarterly Transplant Volatility	0.34	0.38	0.02	0.08	0.02	0.00	(0.03)	0.01	0.03	(0.01)	0.02	(0.01)	(0.00)	0.00	0.64	1.00			
Liver centers in the same OPO in the prior year	0.19	0.20	0.04	0.14	0.02	0.09	(0.01)	0.14	(0.07)	(0.00)	0.05	0.09	0.00	0.02	0.03	0.00	1.00		
Kidney Transplant Concentration	0.18	0.17	(0.00)	0.03	0.00	(0.10)	(0.03)	(0.12)	0.05	(0.00)	(0.03)	(0.07)	(0.00)	(0.00)	0.34	0.32	(0.59)	1.00	
Transplant Year	0.14	0.48	0.16	0.58	0.03	0.16	(0.04)	0.24	(0.23)	0.02	0.03	0.05	0.00	0.12	0.20	0.13	0.29	(0.04)	1.00

Appendix Table G1: Alternative Measures of Task Complexity

Dependent variable: mortality within one year of transplant

p-values in italics

	Diversification Indicator				Years Since Diversification				Continuous Diversification			
	Baseline	DR-Mismatch	B-Mismatch	Comorbidity	Baseline	DR-Mismatch	B-Mismatch	Comorbidity	Baseline	DR-Mismatch	B-Mismatch	Comorbidity
Diversification (Indicator)	0.0068	0.0095	0.0065	0.0068	0.0063	0.0064	0.0063	0.0064	0.0015	0.0021	0.0058	0.0012
	0.1211	*0.0505*	*0.2593*	*0.1212*	*0.1476*	*0.1373*	*0.1496*	*0.1431*	*0.8302*	*0.7715*	*0.4598*	*0.8661*
Years since diversification					0.0008	0.0008	0.0008	0.0008				
					0.1295	*0.1612*	*0.1868*	*0.1521*				
Comorbidity	0.0171	0.0171	0.0171	0.0178	0.0172	0.0171	0.0172	0.0117	0.0172	0.0172	0.0172	0.0197
	0.0107	*0.0108*	*0.0108*	*0.1179*	*0.0105*	*0.0105*	*0.0105*	*0.2441*	*0.0104*	*0.0104*	*0.0104*	*0.0168*
DR Mismatch 1	0.0042	0.0078	0.0043	0.0042	0.0042	0.0055	0.0042	0.0042	0.0042	0.0044	0.0042	0.0042
	0.0432	*0.0150*	*0.0431*	*0.0432*	*0.0440*	*0.0540*	*0.0445*	*0.0438*	*0.0442*	*0.0895*	*0.0452*	*0.0441*
DR Mismatch 2	0.0048	0.0029	0.0048	0.0048	0.0048	0.0028	0.0048	0.0048	0.0048	0.0039	0.0048	0.0048
	0.0773	*0.4887*	*0.0756*	*0.0773*	*0.0779*	*0.4374*	*0.0766*	*0.0779*	*0.0775*	*0.2493*	*0.0786*	*0.0774*
B Mismatch 1	0.0044	0.0044	0.0037	0.0044	0.0044	0.0044	0.0040	0.0044	0.0044	0.0044	0.0032	0.0044
	0.0802	*0.0794*	*0.3416*	*0.0804*	*0.0803*	*0.0797*	*0.2422*	*0.0801*	*0.0796*	*0.0803*	*0.2951*	*0.0802*
B Mismatch 2	0.0099	0.0099	0.0103	0.0099	0.0099	0.0099	0.0099	0.0099	0.0099	0.0099	0.0093	0.0099
	0.0006	0.0005	0.0234	0.0006	*0.0006*	*0.0006*	*0.0105*	*0.0006*	*0.0005*	*0.0006*	*0.0086*	*0.0006*
Diversification * DR Mismatch 1		-0.0075				-0.0004				0.0011		
		0.0355				*0.3189*				0.8418		
Diversification * DR Mismatch 2		0.0035				0.0005				-0.0050		
		0.4394				*0.2523*				0.4101		
Diversification * B Mismatch 1			0.0014				0.0001				-0.0067	
			0.7543				*0.7935*				0.3468	
Diversification * B Mismatch 2			-0.0007				0.0000				-0.0038	
			0.8870				*0.9889*				0.5659	
Diversification * Comorbidity				-0.0013								0.0128
				0.9212								*0.4539*
Constant	-0.0825	-0.0841	-0.0824	-0.0825	-0.0808	-0.0815	-0.0806	-0.0810	-0.0850	-0.0851	-0.0843	-0.0850
	0.0004	*0.0003*	*0.0005*	*0.0004*	*0.0006*	*0.0006*	*0.0007*	*0.0006*	*0.0004*	*0.0004*	*0.0004*	*0.0004*
R^2	0.0301	0.0302	0.0301	0.0301	0.0301	0.0302	0.0301	0.0301	0.0301	0.0301	0.0301	0.0301
N	102,679	102,679	102,679	102,679	102,679	102,679	102,679	102,679	102,679	102,679	102,679	102,679

Standard errors robust and clustered at the physician-hospital level (not reported; available upon request).
Patient characteristics included in the specification but not reported here: patient age, drug-treated hypertension, live donor, peak PRA, days on waitlist, race, gender, BMI, cold ischemic time, multi-organ transplant, primary kidney diagnosis. Firm characteristics included in the specification but not reported here: annual volume quartile, quarterly volatility.
Market (OPO) characteristics included in the specification but not reported here: kidney concentration, number of liver transplant centers in the previous period.
All specifications include year and center fixed effects. All specifications include inverse probability weights to control for probability of selection
[1] Diversification is an indicator variable equal to 1 beginning on the date that the center performed its first liver transplant
[2] Diversification is an indicator variable equal to 1 beginning on the date that the center performed its first liver transplant
[3] Diversification is the log of the share of kidney transplants out of total transplants for the center in the prior 3 years. Higher values indicate less-diversified centers