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# THE EFFECT OF ORGANIZATIONAL CONTEXT ON INDIVIDUAL PERFORMANCE

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**ABSTRACT**

Several observers have suggested that highly skilled workers convey little in the way of competitive advantage for firms due to their mobility. Implicit in this view is the belief that organizations are not important in determining the performance of such individuals. In this study, we address this issue by examining skilled individuals who work within multiple organizations roughly simultaneously. Specifically, we consider the performance of cardiac surgeons, many of whom perform operations at multiple hospitals during the course of a given year. Using patient mortality as an outcome measure, we find that the quality of a surgeon's performance at a given hospital improves significantly with increases in his or her annual procedure volume at that hospital but does not significantly improve with increases in his or her volume at other hospitals. Our findings suggest that surgeon performance is not fully portable across hospitals (i.e., some portion of performance is firm specific). We consider the implications of our results for settings beyond health care.

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# I. INTRODUCTION

Managers are often quick to assert that human capital is one of the most important, if not the most important, asset of their firms. In some industries, such as pharmaceuticals, software, and electronics, companies will compete vigorously to recruit and retain "best athletes"—those individuals with top scientific and technical talent. Other firms will dedicate resources to train their employees in hopes of improving performance. Drucker (2002) observes, "It is one thing for a company to take advantage of long-term freelance talent or to outsource the more tedious aspects of its human resources management. It is quite another to forget that developing talent is business's most important task—the sine qua non of competition in a knowledge economy." As has often been discussed in the literature, however, neither the best-athlete nor the training approach is likely to be a source of sustained competitive advantage *unless human capital is firm specific*.[1] Only when workers have skills that make their marginal productivity higher at their current employer than at other firms do they have a strong incentive to stay put.

While highly skilled workers are commonly cited as a source of knowledge within firms (Starbuck, 1992; Argote and Ingram, 2000), it is often presumed that the human capital of these individuals, often referred to as knowledge workers, is not firm specific. With respect to inventive activity, Arrow (1962) notes the importance of the roles played by individuals relative to firms. Similarly, Coy (2002) makes the following observation concerning knowledge workers in high-technology firms, "They don't qualify as assets because (obviously) they aren't owned by shareholders. The corporate crown jewels are inside their craniums, and if they walk out the door, shareholders can do nothing about it." The above view suggests that organizational context should not significantly affect the performance of highly skilled workers. That is, a star will continue to perform like a star regardless of the organization by which he or she is employed.

[1] Variations of this argument are presented in several papers from the resource-based view of firm strategy (Barney, 1986; Dierickx and Cool, 1989; Peteraf, 1993; Wernerfelt, 1984).

A few recent studies have examined the mobility of highly skilled workers across firms or organizational contexts (Song, Almeida, and Wu, 2003; Baks, 2001; Groysberg, 2001; Rosenkopf and Almeida, 2001; Almeida and Kogut, 1999). These studies take advantage of the movement of workers from one firm (or setting) to another to examine the degree to which knowledge or performance is transferable across settings. Our approach serves as a complement to these studies by examining the performance of workers in multiple firms *at roughly the same point in time*. Specifically, we consider the performance of cardiac surgeons across multiple hospitals using data from every patient receiving coronary artery bypass graft (CABG) surgery in Pennsylvania during 1994 and 1995. For the most part, these surgeons are not employed by specific hospitals but rather have contractual relationships with multiple facilities. In this setting, we can examine a given worker across several firms at a single time, thereby avoiding the need to control for factors, such as increased experience, that may also affect a worker's performance as he or she moves sequentially from one firm to another.

The example of cardiac surgery is particularly rich because of the team setting in which service is provided. A typical cardiac surgical team includes a surgeon (i.e., the team leader), an anesthesiologist, nurses, and technicians. In contrast to surgeon, the other members of these teams are employed by a single hospital. By observing a surgeon's outcomes across several hospitals within a given year, we are able to disaggregate performance into three components: 1) surgeon performance independent of the hospital; 2) hospital performance (including its employed staff) independent of the surgeon; and 3) the hospital-specific performance of the surgeon.

We find evidence of some degree of hospital-specificity in surgeon performance. Our measure of performance is a surgeon's in-hospital mortality rate adjusted for the pre-procedure severity of his or her patients. After controlling for surgeon-specific and hospital-specific performance, we find a positive relationship between the surgeon's volume at a given hospital and his or her outcomes at that hospital. We do not find evidence, however, of any significant relationship between a surgeon's volume *at other hospitals* and his or her outcomes at the hospital of interest. In sum, these results suggest that surgeon performance is not fully portable across organizations. Finally, we investigate the degree to which the limited portability of performance is due to two factors—a surgeon's familiarity with the physical and human assets of an organization and his or her influence within that organization.

The remainder of this paper proceeds as follows. Section II addresses issues concerning the portability of worker performance across organizations. Section III describes the empirical setting and data. Section IV presents our empirical specifications, Section V discusses our results, and Section VI concludes.

## II. THE PORTABILITY OF PERFORMANCE ACROSS ORGANIZATIONS

There is a substantial literature on the degree to which knowledge can be transferred between organizations (see Argote and Epple (1990) for a discussion of this literature). To measure the extent of this transfer, most studies examine the relationship between performance in an individual firm or plant and the industry-wide base of knowledge, typically measured by some form of cumulative output (Zimmerman, 1982; Argote, Beckman, and Epple, 1990). An individual firm can benefit from the experience of other firms either by simply observing or hearing about that experience (e.g., informal discussion or interaction via professional organizations and groups) or by acquiring the key assets in which this experience resides (e.g., outright purchase of firms, licensing of key technologies, or employment of skilled individuals). Ingram and Simons (2002) consider the former form of experience transfer in their study of kibbutz federations in Israel. Our analysis focuses on a specific mechanism by which the latter form of knowledge transfer may occur—the movement of highly skilled workers between organizations.

Beyond the level of industry-wide (i.e., public) knowledge, three broad types of factors can impact the performance of a highly skilled worker within a firm. These are: 1) worker-specific effects that are independent of the firm; 2) firm-specific effects that are independent of the worker; and 3) effects that are specific to worker-firm combinations. The theoretical explanations for the first two effects are relatively straightforward. For example, worker-specific effects might be attributed to an individual's underlying ability or level of training, while firm-specific effects might be due to the quality of the managerial or technological resources held by a given organization or the firm's underlying ability or willingness to absorb the information required for innovation (Cohen and Levinthal, 1990). Our focus in this paper is to test for the presence of the third class of effects described above, worker-firm interactions. In particular, we aim to identify the extent to which the performance of a surgeon at one hospital is transferable to another hospital.

In theory, the three types of effects—worker, firm, and worker-firm—may be due to either static or dynamic factors. For example, an individual surgeon may have superior performance simply because she possesses extremely good hand-eye coordination (a static effect) or because she has an innate capacity to improve her performance more quickly than others with the same level of experience (a dynamic, or learning, effect).[2] Similarly, worker-firm effects may result from team members simply having compatible approaches to their work from day one or from their learning how to work together over time.[3] While our setting provides a unique

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[2] Nelson and Winter (1982) discuss the varied nature of "routines" used by firms and note that certain routines may apply to firm operations at a specific point in time while others guide the process of modifying a firm's operations over time. In a related manner, Adler and Clark (1991) highlight the fact the first- and second-order elements of learning.

[3] In their analysis of the introduction of new technologies in factory settings, Tyre and von Hippel (1997) identify the importance of the organizational context in which learning occurs. Specifically, they find that certain types of learning occur most effectively on the production floor while others are better suited to laboratory settings. Their findings raise the question of the magnitude of within-setting (e.g., across production floors or across laboratories) differences in learning performance. In related work, von

environment in which to test for the presence of worker-firm interactions, it does not enable us to address the more complex issue of distinguishing static from dynamic effects.

**Potential Explanations for Firm-Specific Performance**

The potential causes of worker-firm effects are subtle and merit further discussion. One category of explanations for firm-specific effects revolves around the importance of familiarity between members of a team or organization in settings where much of the knowledge required for effective performance is tacit (Polanyi, 1966) rather than explicit. For example, Edmondson, Bohmer, and Pisano (2001) note that well-developed surgical teams are often capable of performing procedures with minimal verbal communication between members. Weick and Roberts (1993) suggest that team familiarity is beneficial not because it leads to habit formation, but rather because it provides team members with a common base of experience that fosters future learning. Several studies (Katz, 1982; Berman, Down, and Hill, 2002) note that the relationship between familiarity and team performance may be non-linear, with the relationship between group longevity and performance being positive over lower values of longevity before becoming negative at higher levels.

A second group of explanations attributes firm-specific individual performance to differences in the influence that an individual wields within particular organizations (Milgrom and Roberts, 1988). With respect to our empirical setting, a surgeon who performs a large number of surgeries at a given hospital may achieve better outcomes at that hospital than at other facilities, not simply because of greater familiarity with the staff in the operating room, but also because her high procedural volume makes her someone who is highly valued by the hospital and, as a result, avails her of preferential access to a hospital's limited resources. For example, to

Hippel (1994) suggests that context-specific differences in learning reflect variations in the "stickiness", or cost of transferring, information across settings.

the extent that a given hospital has several anesthesiologists or nursing teams of varied quality, an influential surgeon (i.e., one with high volume at that facility) may be able to demand access to the top performers in staffing their surgical teams. In turn, this may enable the surgeon to achieve better surgical outcomes. In Section IV, we describe the empirical approach that we use first to determine the degree to which firm-worker effects exist and then to begin to distinguish between the familiarity and influence explanations for such effects.

**Measuring Firm-Specific Performance**

A common empirical approach for measuring the portability of skilled talent is to examine such individuals across multiple teams or organizations. This approach takes advantage of an individual's change of team or employer over time. Nevertheless, the fact that an individual is typically employed by a single firm—or involved with a single team—at any given point in time, creates difficulty in distinguishing the effect of switching teams or firms from the simple passage of calendar time, which may exert an independent influence on performance through factors such as learning by doing. Some studies control for learning by including a measure of a worker's overall experience. In settings where individuals learn at different rates, however, such measures may not be able to control fully for learning over time.[4]

The empirical setting for our study allows us to abstract from having to control for learning over time. Specifically, we observe highly skilled individuals (i.e., surgeons) who, as contractors, split their time across multiple organizations (i.e., hospitals) *roughly simultaneously*.[5]

[4] As an analogue to differences in rates of learning across individuals, several studies discuss differences in the rate of learning across organizations (Argote and Epple, 1990; Pisano, Bohmer, and Edmondson, 2001).

[5] By "roughly simultaneously", we mean within the course of a relatively short period of time, such as one week or one month. For the purpose of protecting patient confidentiality, the Pennsylvania data only allows one to identify the calendar quarter—not the month or day—in which individual procedures were performed. Nevertheless, most surgeons who split their time across hospitals appear to do

The movement of surgeons across hospitals during this period enables us to obtain separate estimates for each of the three effects—surgeon-specific, hospital-specific, and surgeon-hospital-specific—described above without having to worry about dramatic changes in a surgeon's level of general experience.

## III. EMPIRICAL SETTING AND DATA

### Description of CABG

Developed in the late 1960s, CABG is an invasive surgical procedure that involves taking a section of vein (from the leg) or artery (from the chest) and grafting it to create a bypass of blockage in the coronary artery. It requires opening the patient's chest and relies on a heart-lung bypass machine to perform the functions of the heart during the grafting process. Outcomes for the procedure have improved substantially over time. For example, the rate of in-hospital mortality for patients receiving CABG in Pennsylvania fell by 38% from 3.9% in 1990 (Pennsylvania Health Care Cost Containment Council, 1992) to 2.4% in 2000 (Pennsylvania Health Care Cost Containment Council, 2002). Similarly, in New York State, the in-hospital mortality rate for CABG fell from 3.1% in 1991 (New York State Department of Health, 1992) to 2.2% in 1999 (New York State Department of Health, 2002). This improvement is typically attributed to learning and technological change.

For several reasons, CABG represents an instructive setting in which to analyze the performance of highly skilled workers. First, cardiac surgeons are archetypal knowledge workers. They are highly trained, typically receiving up to seven years of residency and fellowship following their four years of medical school. The fact that many states publicly report

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so evenly across the four quarters of the year. We, therefore, assume that these surgeons likely split their time evenly within time periods shorter than calendar quarters (e.g., months or weeks).

CABG outcomes by surgeon suggests that these individuals are perceived as being integral to the quality of cardiac care.

Second, while a surgeon is clearly a critical worker, he or she is only one member of a much larger surgical team that includes anesthesiologists, nurses, perfusionists, and other technicians. Unlike most surgeons, the other members of a surgical team are typically employed by a hospital. In addition to employing key team members, hospitals also provide a wide range of other organizational assets (e.g., operating room, equipment, marketing and managerial expertise) that may have an impact on the quality of CABG outcomes regardless of the skill of an individual surgeon.

Third, there exists broad agreement concerning the appropriate measure of performance with respect to CABG—risk-adjusted mortality. Much of the clinical literature on CABG uses some measure of in-hospital or long-term (e.g., several months to several years) mortality following the procedure. This outcome is easily and accurately measured, and it is characterized by enough variation across doctors and hospitals to make it a meaningful dimension for performance evaluation. In addition, the public reporting of CABG outcomes by hospital and surgeon suggests that cardiac surgeons have an incentive to perform well in terms of their risk-adjusted mortality rates.

Finally, CABG patients account for a significant portion of hospital revenues. In 2000, over 27,000 CABG procedures were performed in Pennsylvania and the average hospital charge for each admission involving CABG was roughly $59,900 (Pennsylvania Health Care Cost Containment Council, 2002). While charges represent the "list prices" for hospitals, the total revenue that Pennsylvania hospitals derived from CABG admissions—assuming that hospitals collected anywhere from 50% to 70% of charges—would range from $800 million to $1.1 billion. Scaling these figures up to the roughly 355,000 CABG patients in the United States during 1999 (American Heart Association, 2001), suggests nationwide hospital revenues of between $10.5

billion and $14.5 billion for CABG patients alone. This range represents between 3% and 4% of total patient revenue ($342 billion in 2000[6]) for all hospitals in the United States.

In addition to the benefits mentioned above, studying CABG *within Pennsylvania* allows testing for the firm-specific performance of skilled workers (i.e., surgeons). There is a well-documented relationship between annual procedure volume—for both hospitals and surgeons—and mortality outcomes for CABG.[7] Nevertheless, prior studies have not considered the importance of *firm-specific* volume. Given the prevalence of surgeons who split their time across hospitals in Pennsylvania, we are able to separate the impact of a surgeon's hospital-specific volume from that of his or her volume at other hospitals.[8] When coupled with the high levels of training and status held by many cardiac surgeons, this tendency to split effort across organizations positions these physicians as potential "gatekeepers" or "boundary spanners" (Allen and Cohen, 1969; Tushman, 1977).

## Data

The data for this analysis are from the Pennsylvania Health Care Cost Containment Council (PHC4) and include patient-level records for every individual receiving CABG at a hospital in Pennsylvania in 1994 or 1995. These data cover more than 38,000 procedures performed by 203 surgeons operating at 43 hospitals. In addition to identifying the hospital and surgeon for each procedure, the PHC4 data also provide a broad range of demographic and clinical information for each patient. This information includes patient age, gender, illness

[6] Health Forum (2002).

[7] Luft, Bunker, Enthoven (1979), Showstack *et al*. (1987), and Pisano, Bohmer, and Edmondson (2001), find evidence of a positive relationship between volume and outcome for CABG at the hospital level. Hannan *et al*. (1989) and Hannan *et al*. (1991) find evidence of a similar relationship at the surgeon level.

severity upon hospital admission, and a series of variables indicating the presence of particular comorbidities such as kidney failure, heart failure, and acute myocardial infarction (i.e., heart attack). PHC4 uses this information to create risk-adjusted measures of in-hospital mortality by surgeon and hospital (Pennsylvania Health Care Cost Containment Council, 1998a).

**Splitters and Non-Splitters**

The potential explanations for why surgeons split their time across multiple hospitals are numerous. For example, surgeons with strong reputations may draw patients from a relatively broad geography and may offer multiple hospital options to ensure patient convenience. In a related vein, many surgeons are members of multi-physician group practices. To the extent that surgeons provide coverage for their colleagues—who tend to practice at different hospitals—one would expect to see some degree of splitting activity. Finally, splitting patterns may have emerged from the increase in mergers and other affiliations between hospitals in the 1990s. To the extent that these transactions linked multiple hospitals, each of which had its own CABG program, one might expect to see surgeons splitting their time across these facilities as part of a "systemwide" CABG program. The PHC4 data does not provide information as to which, if any, of the above factors explain splitting behavior. As such, this paper focuses on the *effects*, rather than the *causes*, of this activity.

To the extent that surgeons might decide to perform particular types of cases at specific hospitals, the causality between splitting behavior and operating outcomes is not clear. We address these causality issues with multivariate techniques later in the paper. At this point, however, we provide simple comparisons of volumes and performance for "splitters" and "non-splitters." For this initial analysis, we consider a surgeon to be a splitter during a particular

[8] In other states that track the performance of CABG surgeons, such as New York, there is a much smaller percentage of surgeons who split their time across multiple hospitals.

quarter of the calendar year if he or she performed at least one procedure at each of two or more hospitals during that quarter. Based on this criterion, roughly 30% of the cardiac surgeons in the sample were splitters during the average quarter during the sample period. Further, surgeons who were splitters in one quarter tended to be a splitter in the subsequent quarter; the correlation between being a splitter in the current quarter and the prior quarter is 0.82.

Table 1 provides a comparison of procedural volumes and risk-adjusted mortality rates for splitters versus non-splitters. Each observation represents a surgeon in a given three-month quarter during the 1994-1995 period. The average splitter performed 5.9 (22%) more procedures per quarter than the average non-splitter, and this difference is significant at the 1% level. We note that the lower CABG volume of non-splitters does not appear to be due to their substituting non-CABG surgeries, such as valve replacements, for CABG procedures. In fact, the average number of non-CABG surgeries is very small—roughly one per quarter—for both groups.

Prior to comparing the performance of splitters and non-splitters with respect to their risk-adjusted mortality rates (RAMRs), we provide a brief discussion of how this dependent variable is calculated. Given heterogeneity in the severity of patients' pre-operative conditions, raw (i.e., observed) mortality rates represent potentially biased measures of the quality of surgeon performance. In particular, higher quality surgeons may attract patients with more severe forms of CAD, who are more likely to die in the hospital independent of provider quality. To mitigate this bias, PHC4 performs logistic regression using several clinical variables as controls to risk-adjust the mortality rates for surgeons and hospitals.[9] Each observation corresponds to an individual CABG procedure, and the dependent variable is an indicator equal to one if a patient

[9] The estimates for this regression using the 1994 and 1995 Pennsylvania data can be found in the report released by PHC4 in 1998 (Pennsylvania Health Care Cost Containment Council, 1998b). Similar techniques are used by other states including New York (New York State Department of Health, 2002), New Jersey (New Jersey Department of Health and Senior Services, 2001), and California (Damberg, Chung, and Steimle, 2001).

dies in the hospital and zero otherwise. For each patient, the PCH4 calculates a predicted probability of death based on the fitted values obtained from the logistic regression.

Using this information on observed and predicted mortality, we calculate the RAMR for surgeon *s* at hospital *h* as follows:

$$RAMR_{s,h}=(OMR_{s,h}/EMR_{s,h})*OMR_{state} \quad (1)$$

where $OMR_{s,h}$ and $EMR_{s,h}$ are the average observed and expected mortality rates, respectively, across all of surgeon *s*' patients at hospital *h* in a given time period. This ratio is then multiplied by $OMR_{state}$, the average observed mortality rate for the entire state over the same period, to normalize the RAMR.[10] As illustrated in the second row of Table 1, we find that the RAMR for splitters is slightly higher than that for non-splitters, though these rates are not significantly different at conventional levels.[11]

Table 2 offers illustrative data on the performance and case volumes for a few splitters in the sample. These surgeons were not selected at random, but rather were chosen because of the relatively stark differences in their performance across hospitals. For example, Surgeon D's observed mortality rate at Hospital 1—where he performed roughly two-thirds of his cases—was 0.7%. By comparison, the observed mortality for his cases at Hospital 2 was nearly 10 times as large at 6.8%. Analysis of Surgeon D's risk-adjusted mortality rates suggests that this difference was not simply due to his performing on sicker patients at Hospital 2 than at Hospital 1. Even after risk-adjustment, his mortality rate at Hospital 2 was still five times that at Hospital 1. Our

[10] Later in the paper, we also calculate similar risk-adjusted rates, $RAMR_p$ and $RAMR_h$, at the surgeon and hospital levels, respectively.

[11] An analysis cardiac surgeon performance in Pennsylvania in 2000 found that patients treated by surgeons affiliated with more than one hospital were significantly more likely to be readmitted to the hospital within both seven and 30 days. This finding suggests that splitting activity was correlated with lower quality in Pennsylvania in 2000 (Pennsylvania Health Care Cost Containment Council, 2000).

multivariate analysis described in the next section enables us to disentangle whether such performance differences are due to underlying differences in hospital quality or to specific interactions between surgeons and hospitals.

## IV. EMPIRICAL SPECIFICATION

The summary analysis of splitters and non-splitters does not account for unobserved heterogeneity between the two groups. This heterogeneity may be due to systematic differences in performance between splitting and non-splitting *surgeons* or differences in the quality of the *hospitals* at which the two types of doctors tend to practice. Further, the simple binary comparison of splitters and non-splitters does not account for the potential continuous effect that splitting may have on performance. For example, one might expect that a surgeon who spends 90 percent of his time at a given hospital—while technically a splitter—would not have performance that differs much from an otherwise identical non-splitter. To address both of these issues, we estimate multivariate regression models that incorporate controls for underlying surgeon and hospital quality as well as continuous measures for the level of splitting activity by individual surgeons. The unit of observation for this analysis is the individual CABG procedure. Table 3 provides summary statistics for the key variables used in these regressions.

### Total Surgeon Volume

Before examining the portability of skill across organizations, we need to establish the basic relationship between a surgeon's total (i.e., across all hospitals) volume of procedures and his or her outcomes at a particular hospital. Our basic logistic regression takes the following form:

$$ln\left(\frac{Pr(MORT_{i,s,h}=1|x_i)}{1-Pr(MORT_{i,s,h}=1|x_i)}\right) = \gamma_0 + \gamma_1 \cdot TOTCASE_{s,q-1} + \gamma_2 \cdot RAMR_{s,q-1} + \gamma_3 \cdot RAMR_{h,q-1} + \gamma_4 \cdot Z_i + \varepsilon_{i,s,h} \quad (2)$$

$MORT_{i,s,h}$ is an indicator equal to one if patient *i*—who received CABG from surgeon *s* at hospital *h*—at died in the hospital and zero otherwise. To reduce concerns regarding reverse causality, we lag all of the other independent variables by one quarter. Thus, $TOTCASE_{s,q-1}$ is the number of CABG cases performed by surgeon *s* at all Pennsylvania hospitals the prior quarter.

To control for the fact that surgeons and hospitals have different underlying levels of quality due to factors that are independent of procedure volume, we include two additional variables. The first, $RAMR_{s,q-1}$, is the risk-adjusted mortality rate for surgeon *s across all hospitals* in the prior quarter; this variable captures the effect of surgeon quality on performance. Similarly, the second variable, $RAMR_{h,q-1}$, is the same measure for hospital *h across all surgeons* in the prior quarter; it controls for the impact of hospital quality on outcomes. Finally, $Z_i$ is a vector that includes all of the patient-level clinical variables described in the previous section as well as fixed effects for each calendar quarter. To address any lack of independence in the error terms, we cluster the standard errors in (2) by surgeon.

**Facility-Specific Surgeon Volume**

To examine the portability of surgeon performance across hospitals, we also estimate a variant of (2) in which a surgeon’s total volume of procedures in the prior quarter is divided into his or her volume at hospital *h* and that at all other hospitals. This specification appears below:

$$ln\left(\frac{Pr(MORT_{i,s,h}=1|x_i)}{1-Pr(MORT_{i,s,h}=1|x_i)}\right) = \beta_0 + \beta_1 \cdot SPLIT_{s,q-1} + \beta_2 \cdot HOSPCASE_{s,h,q-1} +$$

$$\beta_3 \cdot (SPLIT_{s,q-1} \ x \ OTHCASE_{s,h,q-1}) + \beta_4 \cdot RAMR_{s,q-1} + \beta_5 \cdot RAMR_{h,q-1} + \beta_6 \cdot SHARE_{s,h,q-1} + \beta_7 \cdot Z_i + \mu_{i,s,h} \quad (3)$$

$SPLIT_{s,q-1}$ is an indicator variable equal to one if surgeon *s* split his or her time between multiple Pennsylvania hospitals in the prior quarter and zero otherwise. $HOSPCASE_{s,h,q-1}$ is the number of CABG cases performed by surgeon *s* at hospital *h* in the prior quarter, and $OTHCASE_{s,h,q-1}$ is the number of cases performed by that surgeon at all Pennsylvania hospitals other than *h* in the prior quarter. $\beta_1$ measures the degree to which the mortality rate for splitters differs, on average, from that for non-splitters. Interacting *SPLIT* with *OTHCASE* allows us to measure the impact of volume at other hospitals after controlling for the fact that the value of *OTHCASE* for non-splitters will be zero by definition. The difference between $\beta_2$ and $\beta_3$ thus captures the degree of hospital-specificity in the volume-outcome relationship.

As a proxy for a surgeon's level of influence at a particular hospital, we introduce the variable $SHARE_{s,h,q-1}$, which represents the CABG volume of surgeon *s* at hospital *h* as a share of hospital *h*'s total CABG volume in the prior quarter. Given the high level of hospital profit generated by CABG procedures (Huckman, 2002), we believe that *SHARE* represents a good proxy for a surgeon's ability to command resources from a particular organization. The financial resources that hospitals spend recruiting surgeons and advertising the quality of their cardiac surgery underscore the value of a high-volume cardiac surgeon to a particular organization. We include *SHARE* to begin to distinguish between the familiarity and influence explanations for firm-specific performance that are discussed in Section II. In regressions that include *SHARE*, we can thus view the coefficient on *HOSPCASE* as a measure of how performance depends on a surgeon's familiarity with a specific hospital *after controlling for his or her influence or ability to command superior resources from that institution*.

Table 4 summarizes our hypotheses concerning the direction of the coefficients on the independent variables in (3). Based on the substantial literature suggesting the presence of volume-outcome effects for cardiac surgeons, we would expect the coefficients on both *HOSPCASE* and *OTHCASE* to be negative. Our test for the importance of firm-specific experience focuses on the relative magnitudes and significance of these two coefficients. In the extreme case of no firm-specificity in experience, these coefficients would be identical. Under the hypothesis that some portion of experience is firm specific, one would expect the coefficient on *HOSPCASE* to be greater in absolute magnitude (i.e., more negative) than that on *OTHCASE*. With respect to the remaining variables, we would not expect the issue of firm-specificity to affect the direction of the coefficients. For both the lagged surgeon ($RAMR_{s,q-1}$) and hospital ($RAMR_{h,q-1}$) quality variables, we would expect the coefficients to be positive. That is, higher quality (i.e., lower mortality) in the prior year is indicative of a high level of surgeon- or hospital-specific quality that will affect mortality in the current period. Finally, we would expect the coefficient on *SHARE* to be negative in both cases, as greater influence within the hospital should help improve a surgeon's access to resources and, in turn, his or her performance.

## V. RESULTS AND DISCUSSION

Table 5 shows the results for regressions using total surgeon volume (i.e., across *all* hospitals). Column 1 illustrates that an increase in a surgeon's total volume in the prior year is correlated with a reduction in RAMR. This negative coefficient, which is significant at the 1% level, is consistent in direction with the hypothesized volume-outcome effect that has been observed at the physician level in prior studies (Hannan *et al*., 1989; Hannan *et al*., 1991). The rows toward the bottom of the table reveal that an increase of one standard deviation in total cases is correlated with a decrease of 0.26 percentage points in the probability of mortality. Relative to the predicted probability of mortality evaluated at the means of the independent variables (1.8%), this change represents a decline of 14.4%.[12]

[12] Relative to the unconditional probability of mortality in the sample (3.1%), this represents a decline of 8.4%.

The addition of controls for surgeon RAMR and hospital RAMR does not substantially affect the magnitude or significance of the coefficient on total surgeon cases (Column 2). It is not surprising that the coefficient on surgeon RAMR is positive and highly significant, as surgeons with worse results across all hospitals in the prior quarter would be expected to have worse results at hospital *h* in the current period. While the direction of the coefficient on the lagged hospital RAMR is negative—which runs counter to our expectation—it is not significant at conventional levels. One interpretation of the results for these two controls is that the underlying quality of the surgeon is more important than that of the hospital in determining the quality of future outcomes for the surgeon-hospital pair. Alternatively, the high insignificant and counterintuitive coefficient on hospital RAMR could simply be due to the correlation (0.35) between the surgeon RAMR and hospital RAMR variables. We are not concerned about our inability to distinguish between these two explanations empirically. Rather, we are more interested in making sure that we control for the effects of underlying quality at both the surgeon and hospital level, and this specification achieves that goal.

Column 1 of Table 6 decomposes a surgeon's total case volume into those performed at hospital *h* (*HOSPCASE*) and those occurring elsewhere (*SPLIT x OTHCASE*). Both coefficients are negative, but that on *HOSPCASE* is significant at 1%, while that on *SPLIT x OTHCASE* is much smaller in magnitude and insignificant at conventional levels. An increase of one standard deviation in *HOSPCASE* is associated with a decline of 0.34 percentage points (18.9%) relative to the average predicted probability. For *SPLIT x OTHCASE*, a similar increase of one standard deviation results in a decline of only 0.01 percentage points which, again, is insignificant at conventional levels.

Further, the coefficient on *HOSPCASE* is not only significantly different from zero, but it is also significantly different from the *SPLIT x OTHCASE* at the 3% level. This latter result provides additional evidence of the firm-specificity in surgeon performance. More precisely, a surgeon's volume at a given hospital affects his or her outcomes at that hospital significantly more than does his or her volume at other hospitals.  The relative magnitude and significance of these key coefficients does not change meaningfully as we add controls for surgeon RAMR (Column 2) and hospital RAMR (Column 3).  In addition, the coefficients on *HOSPCASE* and *SPLIT x OTHCASE* remain significantly different from each other at the 3% level.

As one check on the robustness of this result, we replace lagged hospital quality ($RAMR_{h,q-1}$) with hospital fixed effects (Column 4).  This specification accounts for the possibility that mortality outcomes may be affected by fixed, hospital-level variables that are not fully captured by lagged quality.  We find that the results from the first three columns are robust to this alternate specification.  The coefficient on *HOSPCASE* remains similar terms of both magnitude and significance, and, though the coefficient on *SPLIT x OTHCASE* shifts from being slightly negative to slightly positive, its magnitude remains small and it is insignificant at conventional levels.[13]  Finally, the coefficients on *HOSPCASE* and *SPLIT x OTHCASE* are significantly different from each other at the 3% level.

The results in Columns 1 through 4 provide evidence of firm-specificity in surgeon performance, but they do not explain the degree to which that hospital specificity is driven by familiarity or surgeon influence.  To begin to understand these mechanisms, we add *SHARE* to the basic regression (Column 5).  The estimated coefficient on *SHARE* has the predicted negative sign, though it is only significant at the 13% level.  This result, in combination with the slight decline in the absolute magnitude of the *HOSPCASE* coefficient, suggests that surgeon influence plays some role in explaining the firm-specificity of performance.  Nevertheless, the relationship between the *HOSPCASE* and *SPLIT x OTHCASE* coefficients remains similar to that in the previous columns.  We note that these two coefficients are now different from each other at only

[13] To account for the potential lack of independence among observations, the standard errors in this regression are clustered by surgeon.  In terms of the significance of the key coefficients—*HOSPCASE* and *SPLIT* x *OTHCASE*—the results from Column 4 of Table 6 are robust to clustering observations by hospital.

the 13% level of significance. It is possible that this result is due to the relatively high correlation between *HOSPCASE* and *SHARE*.[14] Overall, this regression suggests that, even after controlling for a surgeon's influence within a particular hospital, his or her volume *at that facility* still plays a significant role in determining performance. This finding points to the importance of familiarity, as well as influence, in explaining the hospital-specific performance of surgeons.

**The Magnitude of Splitting Effects**

Using the results from Column 5 of Table 6, we conduct a thought experiment to estimate the magnitude of the impact that splitting has on the performance of the average splitter and on overall mortality in Pennsylvania. First, we consider the impact of moving all of the volume for a typical splitter to a single hospital. To facilitate this calculation, we assume that all splitters begin with risk-adjusted mortality rates that are equal to the median rate across all surgeons (3.00%) for the 1994-1995 period. To keep our estimates conservative, we assume that the conversion of splitters to non-splitters would occur by moving the smallest number of patients. For each splitter, we thus move all patients to their predominant hospital (i.e., the facility at which that surgeon performs the plurality of his or her procedures). Table 7 illustrates the impact of moving various percentages of a splitter's volume to his or her predominant hospital. We consider movements that vary within roughly one standard deviation (25% of volume) of the mean shift required to convert splitters into non-splitters. These figures assume an average volume of 33 cases per splitter per calendar quarter. As suggested by the table, moving all volume to the predominant hospital would decrease the RAMR for a splitter by between 0.08 (for a 90/10 splitter) and 0.32 (for a 60/40 splitter) percentage points. Relative to the median RAMR of 3.00

[14] The correlation between *SHARE* and *HOSPCASE* is 0.52. Given that *HOSPCASE* represents the numerator of *SHARE*, a surgeon with a large volume of cases at hospital *h* would be likely to represent a substantial share of hospital *h*'s total volume.

percent across all surgeons, these changes represent declines of between 2.7% and 10.7%, respectively. Alternatively, these declines would improve a surgeon who is at the 50$^{th}$ percentile in terms of RAMR to between the 43$^{rd}$ and 48$^{th}$ percentile of RAMR.

We also consider the impact of moving all splitters' cases to their predominant hospital on *statewide* mortality (i.e., across all surgeons). We again assume that all surgeons and hospitals have underlying mortality rates that are equal to the statewide average. Based on the actual values of *HOSPCASE* and *OTHCASE*, we determined that slightly more than 1,400 patients per year would move between hospitals to convert all splitters into non-splitters. Shifting these patients would decrease the statewide mortality rate by 0.06 percentage points, or roughly two percent of its average value for the 1994-1995 period. This improvement translates into a reduction of roughly 12 deaths per year throughout Pennsylvania (relative to the statewide average of 598 per year during 1994-1995).

Both of the above calculations must be qualified by the fact that they are based on the simplifying assumption of no underlying quality differences between surgeons and between hospitals. Nevertheless, they represent a reasonable first pass at estimating the magnitude of the performance benefit—in terms of reduced mortality— that would result from converting all splitters to non-splitters.

## VI. CONCLUSION

The empirical setting considered in this paper is particularly well suited for examining firm-specificity in the performance of skilled workers; it enables us to observe many individuals, each of whom is working within multiple organizations. Further, the well-established relationship between surgeon volume and clinical outcomes serves as a convenient means of correlating an individual's degree of contact with a given firm to his or her performance at that organization. We find a substantial degree of firm-specificity in surgeon performance. More precisely, higher annual volume for a given surgeon at a particular hospital is correlated with significantly lower risk-adjusted mortality for that surgeon-hospital pair. That volume, however, does not significantly improve the surgeon's performance at *other* hospitals (i.e., surgeon performance is not fully portable across organizations).

Based on our preliminary analysis—which uses a surgeon's share of a hospital's total CABG volume as a measure of his or her influence within that organization—we find that firm-specificity in surgeon performance is not simply an artifact of a surgeon's influence or power within a particular hospital. That is, this effect is not solely explained by the fact that a surgeon with high volume at a given hospital may be able to command superior resources from that hospital's administrators. Rather this relationship also reflects the productive benefits associated with a surgeon's familiarity with critical assets of the hospital organization. The specific nature of these key organizational assets—which may be specific employees, team structures, or operating routines—represents an area for future research.

Below we discuss some potential limitations and extensions of our analysis. First, our results are based on only one type of highly skilled worker (i.e., cardiac surgeons). It is, therefore, possible that the pattern of organization-specific performance that we identify may not be as strong in other settings. For example, in cases where firms are exploring knowledge that is "technologically distant" (Song, Almeida, and Wu, 2003) from their current areas of expertise, there may be more benefits associated with splitting as a means of knowledge transfer. Offsetting this possible limitation of our analysis, however, is the benefit of the rich detail that our data provide about the degree of splitting activity for individual workers and the quality of their performance within different organizations.

Second, our analysis might benefit from a deeper panel with additional years of data for each surgeon and hospital. While Pennsylvania has made data for 2000 available for purchase by researchers, information for the years from 1996 to 1999 is not available, thus creating gaps in efforts to create a continuous panel from 1994 to 2000. Finally, the share-based proxy for surgeon influence enables us to make suggestive, but not definitive, statements concerning the roles of familiarity and influence in explaining firm-specific performance. More detailed observational or anecdotal data might provide additional insight concerning this distinction.

Despite these potential limitations, this study has implications for managers both within and beyond the health care industry. First, it sheds light on strategies for allocating skilled workers across divisions or projects within a firm. For example, firms that manage a portfolio of simultaneous R&D initiatives (e.g., software or electronics companies) must determine how to staff engineers to various projects. Similarly, diversified firms must decide how to allocate finite managerial resources and attention across individual business units. Consistent with Wheelwright and Clark (1992), our findings imply that these skilled workers may achieve superior outcomes, all else equal, to the extent that they limit the splitting of their time across multiple organizational settings or units. In addition, our results should encourage managers to take a more critical eye to the practice of building firm capabilities through the "best-athlete" strategy of hiring. Particularly when a highly skilled worker must interact with a complex array of other assets—human and physical—within a given firm, the performance of that worker may not be easily transferred across organizational settings.

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**Table 1: Comparison of Splitters and Non-Splitters**

| | ***Splitters (n=357)*** | | ***Non-Splitters (n=996)*** | | |
|---|---|---|---|---|---|
| | Mean | Standard Deviation | Mean | Standard Deviation | |
| CABG Cases/Surgeon Per Calendar Quarter (1994 and 1995 Combined) | 32.9 | 17.7 | 27.0 | 17.0 | *** |
| Risk-Adjusted Mortality Rate (1994 and 1995 Combined) | 3.35% | 3.42% | 3.01% | 4.24% | |

*Note: *,**,*** denote that the mean value for splitters and non-splitters are significantly different at the 10%, 5%, and 1% levels, respectively. The level of observation is a surgeon for a given calendar quarter. A surgeon is a "splitter" for a given quarter if he or she performed at least one CABG procedure at each of two or more hospitals in Pennsylvania during that quarter.*

**Table 2: Examples of Splitter Performance by Hospital, 1995**

| | **CABG Cases** | **Observed Mortality Rate** | **Risk-Adjusted Mortality Rate** |
|---|---|---|---|
| Doctor A | | | |
| Hospital 1 | 220 | 2.7% | 2.9% |
| Hospital 2 | 54 | 5.6% | 4.8% |
| Doctor B | | | |
| Hospital 1 | 140 | 0.6% | 0.7% |
| Hospital 2 | 98 | 2.0% | 2.0% |
| Doctor C | | | |
| Hospital 1 | 186 | 2.7% | 2.8% |
| Hospital 2 | 38 | 7.9% | 11.0% |
| Doctor D | | | |
| Hospital 1 | 143 | 0.7% | 0.7% |
| Hospital 2 | 74 | 6.8% | 3.6% |

## Table 3: Summary Statistics for Key Variables in Logistic Regressions

| | Observations | Mean | Standard Deviation |
|---|---|---|---|
| $MORT_{i,s,h}$: Did CABG Patient Die in Hospital? | 34,173 | 3.1% | 17.3% |
| $TOTCASE_{s,q-1}$: Total Surgeon Cases (Lagged) | 34,173 | 36.8 | 17.4 |
| $HOSPCASE_{s,h,q-1}$: Surgeon Cases at Hospital (Lagged) | 34,173 | 32.3 | 17.7 |
| $OTHCASE_{s,h,q-1}$: Surgeon Cases at Other Hospitals (Lagged) | 34,173 | 4.5 | 10.0 |
| $RAMR_{s,q-1}$: Surgeon RAMR (Lagged) | 33,610 | 3.1% | 4.5% |
| $RAMR_{h,q-1}$: Hospital RAMR (Lagged) | 34,171 | 3.1% | 1.9% |
| $SHARE_{s,h,q-1}$: Surgeon Share of Total Hospital Cases (Lagged) | 34,171 | 27.0% | 20.0% |

*Note: Data covers all CABG procedures at hospitals in Pennsylvania for the last three quarters of 1994 and all of 1995.*

## Table 4: Hypothesized Direction of Coefficients in Base Regression

| Variable | Description | Hypothesized Effect on Likelihood of Mortality | |
|---|---|---|---|
| | | *If Perfomance Is Firm-Specific (i.e., Limited Portability)* | *If Perfomance Is Not Firm-Specific (i.e., Full Portability)* |
| $HOSPCASE_{s,h,q-1}$ | Total CABG cases performed by surgeon *s* at hospital *h* in prior quarter | Negative | Negative |
| $SPLIT_{s,q-1}$ x $OTHCASE_{s,h,q-1}$ | For splitters only, the total CABG cases performed by surgeon *s* at facilities other than hospital *h* in prior quarter | Negative but not as large or significant as *HOSPCASE* coefficient | Negative and of roughly the same magnitude and significance as the *HOSPCASE* coefficient |
| $RAMR_{s,q-1}$ | Risk-adjusted mortality rate for surgeon *s* across all hospitals in prior quarter | Positive | Positive |
| $RAMR_{h,q-1}$ | Risk-adjusted mortality rate for hospital *h* across all surgeons in prior quarter | Positive | Positive |
| $SHARE_{s,h,q-1}$ | CABG cases performed by surgeon *s* at hospital *h* as a percentage of hospital *h*'s total CABG cases in prior quarter | Negative | Negative |

## Table 5: Logistic Regression with Total Surgeon Volume

| | Dependent Variable: Did CABG Patient Die in Hospital? | |
|---|---|---|
| | (1) | (2) |
| *$TOTCASE_{s,q-1}$*: | -0.0087 *** | -0.0090 *** |
| Total Surgeon Cases (Lagged) | (0.0023) | (0.0024) |
| *$RAMR_{s,q-1}$*: | | 0.9293 ** |
| Surgeon RAMR (Lagged) | | (0.4826) |
| *$RAMR_{h,q-1}$*: | | -0.3233 |
| Hospital RAMR (Lagged) | | (1.7905) |
| Constant | -3.4194 *** | -3.7491 *** |
| | (1.2815) | (1.2841) |
| *Average Predicted Probability of Mortality (Evaluated at Means of Independent Variables)* | 1.80% | 1.80% |
| *Impact of One Standard Deviation Increase in:* | | |
| Total Surgeon Cases | -0.26% | -0.27% |
| Observations | 34,173 | 33,610 |
| Pseudo $R^2$ | 0.1745 | 0.1753 |
| Wald Chi-Squared | 1941.8 *** | 1933.3 *** |

*Note: *,**,*** denote statistical significance at the 10%, 5%, and 1% levels, respectively. The following variables are included in the regressions, but are not shown in the table: age, $age^2$/100, fixed effects for quarter of calendar year, and indicators for cardiogenic shock, concurrent angioplasty, complicated hypertension, dialysis, female gender, heart failure, and prior CABG or heart valve surgery. Observations are weighted by the number of procedures for each surgeon-hospital pairing. Standard errors are heteroskedasticity robust and clustered by surgeon.*

**Table 6: Logistic Regression with Hospital-Specific Volume and Volume at Other Facilities**

| | Dependent Variable: Did CABG Patient Die in Hospital? | | | | |
|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) |
| *$SPLIT_{s,q-1}$:* | 0.0243 | 0.0178 | 0.0202 | 0.0426 | -0.0073 |
| Did Surgeon Split Across Hospitals? (Lagged) | (0.1001) | (0.0989) | (0.0994) | (0.1228) | (0.0993) |
| *$HOSPCASE_{s,h,q-1}$:* | -0.0111 *** | -0.0106 *** | -0.0106 *** | -0.0101 *** | -0.0084 *** |
| Surgeon Cases at Hospital (Lagged) | (0.0023) | (0.0023) | (0.0023) | (0.0024) | (0.0026) |
| *$SPLIT_{s,q-1}$ x $OTHCASE_{s,h,q-1}$:* | -0.0007 | -0.0002 | -0.0003 | 0.0018 | -0.0005 |
| $SPLIT_{s,q-1}$ x Surgeon Cases at Other Hospitals (Lagged) | (0.0049) | (0.0049) | (0.0049) | (0.0055) | (0.0050) |
| *$RAMR_{s,q-1}$:* | | 1.1102 * | 1.2110 * | -0.0075 | 1.1602 * |
| Surgeon RAMR (Lagged) | | (0.6631) | (0.6830) | (0.7714) | (0.6806) |
| *$RAMR_{h,q-1}$:* | | | -0.7730 | | -0.7673 |
| Hospital RAMR (Lagged) | | | (1.8216) | | (1.8303) |
| *$SHARE_{s,h,q-1}$:* | | | | | -0.0043 |
| Surgeon Share of Total Hospital Cases (Lagged) | | | | | (0.0028) |
| Constant | -3.7927 *** | -3.8508 *** | -3.8246 *** | -4.9982 *** | -3.7580 *** |
| | (1.2712) | (1.2808) | (1.2849) | (1.3074) | (1.2845) |
| Hospital Fixed Effects? | No | No | No | Yes | No |
| *Average Predicted Probability of Mortality (Evaluated at Means of Independent Variables)* | 1.80% | 1.80% | 1.80% | 1.70% | 1.80% |
| *Impact of One Standard Deviation Increase in:* | | | | | |
| Surgeon Cases at Hospital | -0.34% | -0.32% | -0.33% | -0.28% | -0.26% |
| Surgeon Cases at Other Hospitals | -0.01% | -0.003% | -0.01% | 0.04% | -0.01% |
| *Level at which* HOSPCASE *is significantly different from* SPLIT x OTHCASE | 3% | 3% | 3% | 3% | 13% |
| Observations | 33,584 | 33,584 | 33,584 | 33,584 | 33,584 |
| Pseudo $R^2$ | 0.1762 | 0.1764 | 0.1764 | 0.1843 | 0.1768 |
| Wald Chi-Squared | 2035.9 *** | 2043.4 *** | 2067.2 *** | 4740.3 *** | 2225.8 *** |

*Note: *,**,*** denote statistical significance at the 10%, 5%, and 1% levels, respectively. The following variables are included in the regressions, but are not shown in the table: age, age2/100, fixed effects for quarter of calendar year, and indicators for cardiogenic shock, concurrent angioplasty, complicated hypertension, dialysis, female gender, heart failure, and prior CABG or heart valve surgery. Observations are weighted by the number of procedures for each surgeon-hospital pairing. Standard errors are heteroskedasticity robust and clustered by surgeon.*

## Table 7:  Performance Impact of Converting Splitters to Non-Splitters

| Split Ratio (Predominant/Other) | Cases Moved to Predominant Hospital* | Impact on RAMR (Relative to Median = 3.00%) | |
|---|---|---|---|
| | | *Percentage Point Change* | *Change in Percentile Rank*** |
| 60/40 | 13 | -0.32 | From 50 to 43 |
| 70/30 | 10 | -0.24 | From 50 to 44 |
| 80/20 | 7 | -0.16 | From 50 to 46 |
| 90/10 | 3 | -0.08 | From 50 to 48 |

* *Assumes an annual average of 33 CABG cases per splitter per calendar quarter.*

** *Given that a lower RAMR is associated with higher quality, shifting all of a surgeon's volume to the predominant hospital will reduce that surgeon's RAMR percentile rank.  The baseline RAMR of 3.00% is the median across all surgeons in Pennsylvania for the 1994-1995 period.*