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The nature of surgeon human capital depreciation☆

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ABSTRACT

To test how practice interruptions affect worker productivity, we estimate how temporal breaks affect surgeons' performance of coronary artery bypass grafting (CABG). Examining 188 surgeons who performed 56,315 CABG surgeries in Pennsylvania between 2006 and 2010, we find that a surgeon's additional day away from the operating room raised patients' inpatient mortality by up to 0.067 percentage points (2.4% relative effect) but reduced total hospitalization costs by up to 0.59 percentage points. Among emergent patients treated by high-volume providers, where temporal distance is most plausibly exogenous, an additional day away raised mortality risk by 0.398 percentage points (11.4% relative effect) but reduced cost by up to 1.4 percentage points. This is consistent with the hypothesis that as temporal distance increases, surgeons are less likely to recognize and address life-threatening complications. Our estimates imply additional intraprocedural treatment intensity has a cost per life-year preserved of $7871–18,500, well within conventional cost-effectiveness cutoffs.

1. Introduction

Fluctuations of human capital and worker productivity have been the subject of a long literature stretching back to Ben-Porath (1967). This early work on human capital and productivity spurred multiple lines of inquiry. One of these has focused on organizational forgetting, in that a firm's productivity may erode because its workers' human capital decays or because of turnover or breaks in production (Argote, 1999; Darr et al., 1995; Benkard, 2000; Thompson, 2007; David and Brachet, 2009, 2011).

Previous research has measured the reduction in individual worker productivity when the temporal distance between tasks increases. These reductions have been documented for jobs with routine tasks ranging from data entry (Globerson et al., 1989) to mechanical assembly (Bailey, 1989) and car radio production (Shafer et al., 2001). Recent work has focused on more complex tasks arising in the provision of health care. These studies suggest temporal distance effects may substantially impact patient outcomes in surgery (Hockenberry et al., 2008) and in the delivery of emergency medical services (David and Brachet, 2011).

In this paper we make three contributions. First, we develop a framework for distinguishing between two mechanisms that explain how a decline in surgeon human capital, measured here as increased temporal distance, might impair surgeon productivity, measured here as patient outcomes. Previous literature has documented that organizational and individual skill depreciation between performing temporally distant tasks adversely affects health care outcomes, but the underlying mechanism has not been established (Hockenberry et al., 2008; David and Brachet, 2011).

Increasing temporal distance could lead to either inefficient care or inattentive care. After temporal breaks, surgeons may fail to identify and treat life-threatening complications (inattentive care). For instance, surgeons may be less likely to notice small but potentially life-threatening anomalies during surgery that require additional tests or procedures to ensure the patient's survival. This form of human capital depreciation will reduce the patient's survival probability and at the same time reduce resource use.

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Alternatively, temporal breaks may erode surgeons' proficiency and thus prompt them to apply more treatment (inefficient care). For instance, surgeons may take longer to complete a given procedure or compensate for lower proficiency with additional testing and procedures. This form of human capital depreciation will raise the surgeon's resource use without raising the patient's survival probability.

We observe the resource use and survival probabilities of patients undergoing coronary artery bypass grafting (CABG) and thus can distinguish between these two forms of surgeon human capital depreciation empirically. We find that the time since the surgeon last performed the procedure raises peri-procedural mortality in a clinically meaningful and statistically significant way. The temporal distance effects are lasting in that they also predict in-hospital mortality. We also find that temporal distance is associated with reduced resource use. This pattern is consistent with the hypothesis that temporal breaks lead to inattentive care in that surgeons tend to miss altogether and therefore fail to address life-threatening complications, rather than notice but address them less efficiently. Policies that affect surgeons' procedure schedules may reduce operative mortality for patients undergoing coronary revascularization but they may also raise cost.

Second, we test and compare how two measures of temporal distance affect surgeon performance. We examine both the impact of the number of days since the surgeon last performed CABG surgery, which captures the effect of depreciation in procedure-specific human capital, and the impact of the number of days since the surgeon performed any procedure, which proxies for depreciation in general surgical human capital.[1] Our empirical results suggest that general surgical human capital affects patient outcomes substantially more than procedure-specific human capital.

Finally, we exploit the variation in resource use induced by variation in temporal distance to measure the productivity of additional medical spending on the margin. Our back-of-the-envelope calculation suggests that the cost per life-year saved resulting from more attentive, and thus intensive treatment within a chosen procedure, ranges from \$7400 to \$17,500, in line with other recent estimates (Doyle, 2005, 2011; Chandra and Staiger, 2007; Almond et al., 2010) and well below the conventional \$100,000 per life-year threshold (Cutler, 2004).

2. Background

2.1. Background on human capital depreciation

There is an extensive literature in industrial engineering that seeks to establish the degree of human capital depreciation, also referred to as forgetting, in productive tasks. Several studies have examined the speed of human capital depreciation by randomizing individuals engaged in a repetitive task, ranging from breaks of one day to a few weeks to even a few months (Globerson et al., 1989; Bailey, 1989; Shafer et al., 2001). Worker productivity declined a few percentage points after an interruption lasting a single day (Globerson et al., 1989) and increased at an increasing rate with each additional day of interruption (Jaber, 2011).

While studies of human capital depreciation in manufacturing settings have focused on the performance of repetitive tasks, they have ignored more complex cognitive tasks like those often found in health care delivery. For instance, highly variable "inputs" in health care delivery, such as each patient's individual anatomy and disease progression profile, differ from the largely homogeneous inputs found in manufacturing. Thus healthcare delivery, and in our case surgery, places significant demands on workers' cognitive skills. Earlier work examined how breaks in the performance of cardiac surgery affect patient outcomes, arguing that these outcomes reflect productivity differences (Hockenberry et al., 2008). For CABG surgery in Taiwan, the authors estimated that relative to a 0–2 days break, a break from performing CABG of 3–14 days raised mortality by 11–14%, and a break of more than 15 days raised mortality by 22%.

That study only measured temporal distance between performing CABG procedures. Yet, studies on forgetting suggest that other activities in which workers engage during breaks from the productive task of interest may play an equally important role in human capital depreciation (Jaber, 2011). In our context, many surgeons will perform other procedures, such as isolated heart valve procedures and other vascular procedures that require the same cognitive skill set as CABG and that therefore may slow the rate of skill depreciation between CABG procedures. Thus, to the extent that Hockenberry et al. did not account for the performance of skill-preserving tasks between the CABG surgeries they observed, their results would underestimate the true effect of skill depreciation on surgeon productivity. In this paper, we contrast the performance effects of the number of days since the surgeon last performed CABG with the performance effects of the number of days since the surgeon performed any procedure to assess the role of CABG-specific skill components in explaining the productivity loss after temporal breaks.

2.2. The performance and organization of CABG

Coronary artery bypass graft (CABG) is a major surgical procedure intended to improve the heart's supply with oxygen. A surgeon harvests part of a vessel from a different area of the body (typically the groin or chest wall), opens the chest cavity, and implants the harvested vessel segment to bypass the diseased section of the artery. CABG surgery takes approximately 4 h and patients generally spend at least one week recovering in the hospital. In some cases the patient will also need a concomitant valve replacement or repair procedure, which lengthens surgery time further (Hockenberry et al., 2011).

3. Methods

3.1. Empirical model

We assume that a surgeon's human capital Q_0 decays exponentially over time at rate δ (Rubin and Wenzel, 1996; Kahana and Adler, 2012):

$$Q(t) = Q_0 e^{-\delta t}$$

or

$$\ln Q(t) = \ln Q_0 - \delta t \quad (1)$$

If we further assume that patient outcomes improve with human capital, (1) predicts that a surgeon's longer temporal break will reduce patient survival.

Our proxy for the current stock of human capital $Q(t)$ is based on the literature on organizational learning and forgetting.[2] This

[1] We examined the frequency distributions of the other procedures and found those that are typically performed by the surgeons who perform CABG include heart valve procedures, procedures on thoracic vessels (other than bypass), and device implants.

[2] The lifetime stock of accumulated capital and its depreciation will be captured empirically by individual fixed effects and surgeons' years of experience, measured