Online Appendix for "The Evolution of Physician Practice Styles: Evidence from Cardiologist Migration"

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Contents

1 Sample and variable construction

This section provides additional details on the data, sample selection, and variable measurement in the paper. The primary health care data consist of Medicare administrative and claims records from 1992-2012. These include demographic and enrollment characteristics for 100 percent of beneficiaries, hospital (MedPAR) records for a 100 percent sample of the fee-for-service population, and physician (carrier) claims for a 5 percent sample over years 1992-1997 and for a 20 percent sample of fee-for-service beneficiaries over the period 1998-2012. The analysis in the paper only relies on claims data from 1998-2012, the period over which physician claims are available for the 20 percent sample, but this appendix describes summary statistics for the full period 1992-2012 to provide additional historical context on heart attack (AMI) and cardiac catheterization rates in the Medicare population.

Table C.1 provides a variety of summary statistics related to the sample construction. Column (2) shows the number of unique Medicare beneficiaries eligible for Medicare in each year 1992-2012. The number of enrollees grew from 36.9 million in 1992 to 53.4 million by 2012. Over that same period, the share of beneficiaries enrolled in traditional fee-for-service Medicare dropped from 93.3 percent in 1992 to 72.4 percent in 2012 (see column 3). This is important because claims are generally not available for the non-fee-for-service beneficiaries who are enrolled in Medicare Advantage plans which are reimbursed by Medicare on a capitated basis. As a result, the characterization of physician behavior and practice environments in this paper is based on treatment patterns among the Medicare fee-for-service population only.

1.1 AMI cardiac catheterization

The central measure of regional intensity in this paper is the rate of 2-day cardiac catheterization ("cath") among heart attack (AMI) patients in that region. To create this measure, I use 100 percent MedPAR hospital admission data to identify a "master" sample of new heart attack episodes based on patients admitted to the hospital with a principal diagnosis of AMI (ICD-9-CM codes 410.x) and who had no other AMI hospital admission in the data within the previous year. I code each heart attack patient as NSTEMI if they were diagnosed with a subendocardial infarction (ICD-9-CM codes 410.7), labeling all other heart attacks as STEMI. Column (4) of Table C.1 shows the number of heart attack episodes identified each year, with 5.8 million episodes identified over the period 1992-2012.

For each heart attack patient, I measure whether the patient received a cardiac catheterization within two days of hospital admission. To identify cardiac catheterizations, I use ICD-9 procedure codes and dates submitted on the hospital claim, closely following the well-established methodology used by the Dartmouth Atlas.[1] Specifically, the procedure codes used to indicate cath include 3722-3 (left and combined right and left heart cardiac catheterization); 8855-7 (angiography); 3601-2, 3605, 3609, and 0066 (percutaneous coronary intervention); 3606-7 (coronary stent insertion); and 3610-3619 (coronary artery bypass graft). Column (12) of Table C.1 reports the raw 2-day cath rate each year from 1992-2012 over the 100 percent heart attack sample. Over the 6-year period 1992-1997, 2-day cath rates doubled from 16.3 percent to 32.7 percent. While they continued to rise in subsequent years, they did so at a much slower rate, increasing only 71 percent over the 15-year period 1998-2012.

Cardiac catheterizations are invasive procedures performed in a specialized examination room referred to as a cardiac catheterization (cath) lab. If a heart attack patient is first admitted to a hospital without a cath lab, the patient must be transferred to another hospital in order to receive the procedure. Thus, lack of cath facilities at the hospital of initial admission is likely to be a high barrier to early catheterization. Column (10) of Table C.1 reports the share of all heart attack patients first admitted to a hospital with a cath lab in operation that year. A hospital is defined to have a cath lab in a given year if at least two cardiac catheterization procedures are performed in that hospital that year (based on the 100 percent MedPAR sample of Medicare patients admitted for any condition, not just AMI). Even in early sample years 1992-1997 when cath rates were low, over 70 percent of patients were admitted to hospitals with cath facilities. By 2012, nearly 92 percent of all heart attack patients were admitted to hospitals with cath facilities. As shown in column (7) of Table 1, the fraction of patients admitted to a hospital with a cath lab is even higher

[1] See http://www.dartmouthatlas.org/downloads/methods/research_methods.pdf.

among patients seeing a cardiologist within two days of hospital admission. Especially over the period 1998-2012, these results suggest that whether a heart attack patient receives an early cath in most cases is not driven by lack of a cath lab at the hospital of initial admission.

1.1.1 Cardiologist catheterization rates

Beginning in 1992, Medicare required that physicians billing Medicare for services performed must provide their Unique Physician Identification Number (UPIN) on the claim form. Because UPINs uniquely identify individual physicians and remain with the physician throughout their career, it is possible to create histories of the patients a physician treats using the physician billing claims. Beginning in 2007, Medicare transitioned from UPINs to the National Provider Identifier (NPI) standard. I match NPIs to UPINs using a crosswalk developed by the NBER, and supplemented with Medicare physician claims that contain both UPIN and NPI fields.[2]

To identify histories of cardiologist treatment decisions, I first identify which UPINs correspond to cardiologists. I link the universe of Medicare UPINs to the American Medical Association (AMA) Physician Masterfile and identify cardiologists as those who have completed a 3-year fellowship in cardiovascular disease. The AMA Physician Masterfile includes current and historical data on virtually every Doctor of Medicine (MD) ever trained or licensed to practice in the United States, regardless of physician AMA membership. However, because the merge to the AMA Masterfile was based on UPINs, the set of cardiologists I identify in the sample period 1992-2012 does not include cardiologists first enrolling in Medicare after the transition to the NPI standard in 2007.

As described in Section I.B of the paper, I measure cardiologist practice styles by linking heart attack patients to the cardiologist(s) who treat them. Because physician claims identify the set of physicians providing services to each patient, I first limit the "master" set of AMI patient episodes to those patients for whom physician claims are available (5 percent of patients from 1992-1997, and 20 percent of patients from 1998-2012). I refer to this as the

[2] The NBER NPI to UPIN crosswalk is available at http://www.nber.org/data/npi-upin-crosswalk.html.

"physician" sample of AMI patients. The number of patients in this sample each year is shown in column (5) of Table C.1. Of the 792,970 AMI patients in the physician sample over the period 1998-2012, 669,397 (84.4 percent) see at least one cardiologist (defined to be any non-mover cardiologist, or a migrant cardiologist within 8 years of move) within two days of hospital admission. These patients are matched to the first cardiologist(s) who treat them to form the basis of the patient-cardiologist observations in the primary regression analysis in the paper (see Table 1). The number of unique cardiologists treating at least one heart attack patient as the first cardiologist in a given year is shown in column (15) of Table C.1, and the average number of AMI patients treated by each cardiologist that year is shown in column (16).

1.1.2 HRR catheterization rates

One of the primary measurement issues in the paper involves constructing 2-day cath rates at the Hospital Referral Region (HRR) level. Because the analysis aims to measure how changes in HRR cath rates across a move drive changes in a migrant's own behavior, it is important to purge the change in region-level cath rates of a mechanical relationship with the migrant's own treatment choices. To do this, I calculate for each cardiologist "leave-out" measures of risk-adjusted regional cath rates that omit the cardiologist's own patients.

Specifically, I first calculate the raw leave-out 2-day cath rate for physician j in HRR h and year t as

$$P(j,h,t) = \frac{1}{|i : i \in H, i \in T, i \notin J|} \sum_{i \in H, i \in T, i \notin J} \big(cath_i\big),$$

where $(cath_i)$ is an indicator for whether patient i received a cath within two days of hospital admisssion, and where H, T, and J reflect sets of AMI patients treated in HRR h, in year T, and by cardiologist j within two days of hospital admission, respectively.

To risk-adjust the leave-out rates, I calculate the clinical cath appropriateness for each patient by estimating a logistic regression of patient cath within 2 days of a heart attack as a function of calendar year dummies, patient comorbidities (age, race, sex, and first heart attack), and comorbidities interacted with calendar year. Once estimated, the model is used to predict cath receipt for each patient in the sample and these patient-level predictions are averaged at the HRR-year-level to form a new variable $\hat{Pr}(h,t)$ which describes the predicted cath rate in HRR h in calendar year t. The risk-adjusted leave-out rate for physician j in HRR h and year t is then calculated as

$$\tilde{P}(j,h,t) = P(j,h,t) - \hat{Pr}(h,t).$$

$\tilde{P}(j,h,t)$ is a risk-adjusted physician-leave-out mean of the degree to which HRR h is more intensive than the national average in year t, omitting cardiologist j's patients. Using this measure, I define the physician-leave-out difference in risk-adjusted cath rates between any two HRRs h_1 and h_2 in a given year t as

$$\Delta_j(h_1,h_2,t) = \tilde{P}(j,h_2,t) - \tilde{P}(j,h_1,t). \tag{1.1}$$

A key simplification used throughout the paper is to use time-invariant physician-leave-out differences in cath rates between HRRs over the sample period 1998-2012. To calculate the time invariant differences, I first average $\tilde{P}(j,h,t)$ across years, using as weights the share $w(j,h,t)$ of patients treated each year in that HRR, not counting physician j's patients. This weighted average is a time-invariant physician-leave-out mean of the degree to which a given HRR's cath rate deviated from the national average over the sample period, omitting cardiologist j's patients. The time-invariant physician-leave-out difference between HRRs h_1 and h_2 is then defined as

$$\Delta_j(h_1,h_2) = \sum_t \tilde{P}(j,h_2,t)w(j,h_2,t) - \sum_t \tilde{P}(j,h_1,t)w(j,h_1,t). \tag{1.2}$$

In the paper, I use time-invariant physician-leave-out differences in cath rates $\Delta_j(h_1,h_2)$

over the period 1998-2012 to describe differences in HRR cath environments. Later in this appendix, I explore the relationship between the time-invariant and year-specific cath rates, and also evaluate robustness to using the year-specific differences in cath rates $\Delta_j(h_1, h_2, t)$ to measure physician behavior response to a change in the HRR environment.

1.1.3 Hospital catheterization rates

As an alternative to the HRR definition of a physician's practice environment, I also measure 2-day cath rates at the hospital level. As with the HRR cath rate measures, I calculate hospital cath rates for each physician using a leave-out average that excludes the physician's own patients. Because there are many more hospitals than HRRs, precisely measuring year-specific hospital cath rates using the 20 percent physician sample of AMI patients is difficult. For this reason, I only consider time-invariant measures of cath intensity at the hospital level, defined analogously to the time-invariant HRR-level cath intensities described above.

1.2 Cardiologist migration

I define movers to be cardiologists who are observed to move their practice location across Hospital Referral Regions (HRRs). I identify movers, along with their origin and destination HRRs, as follows.

First, I use the "physician" sample of heart attack patients (defined in Section 1.1.1) over the period 1998-2012 to identify the first and last dates a cardiologist practices in each HRR (as defined by the date and HRR of hospital admission for each of the cardiologist's patients). I also measure the total number of patients treated by the cardiologist in the HRR. Together, the first/last dates and total number of patients treated characterize the cardiologist's "practice episode" in that HRR. Note that by this definition, it is only possible for a physician to have at most one practice episode per HRR. If a physician moves away from an HRR early in the sample and returns later in the sample, all observations are part of a single practice episode.

Next, I identify in which HRR a physician treats the most patients in the sample, and call this the physician's "primary" practice episode. Similarly, I further define a cardiologist's "secondary" practice episode to be the largest episode (in terms of patients treated) that does not overlap the primary episode, if such an episode exists. Movers are those with both primary and secondary practice episodes, with at least two patients in each episode.

This definition of a move has two additional implications. First, I only identify one move per migrant. Second, the move must involve a clean split in time between the origin and destination HRR, with no overlap in time. If a cardiologist practices in HRR A from dates $d_1 - d_2$ and HRR B from dates $d_3 - d_4$, this would be considered a move as long as $d_2 \leq d_3$. However, if $d_2 > d_3$, which could happen if the cardiologist returns to practice in HRR A after first switching to HRR B, this would not be marked as a move.

Finally, for each mover and corresponding primary and secondary episodes, I mark the earlier practice episode (in terms of practice dates) to be the "origin" HRR and the later episode to be the "destination" HRR. Some of the specifications in the paper also include non-migrants, which are all cardiologists not identified as movers. For non-migrant cardiologists, I define the origin and destination HRRs to be the same, and equal to the HRR where the cardiologist is treating patients at that point in time. Column (17) of Table C.1 shows the number of cardiologists moving in each year from 1998-2012. Section I.B of the paper describes additional summary statistics for the migrant sample.

2 Robustness

2.1 Time-Varying Cath Rates

2.1.1 Rank-order preservation

In the paper, time-invariant regional cath rates were used to measure the change in intensity a physician experiences across a move. To the extent that the intensity of a region relative to the secular trend remains stable over time, differences in regional cath propensities averaged over a pooled period of time will be the same as the difference in propensity in any given year. However, if regional intensity with respect to the national secular trend changes over time, then measuring regions as having a time-invariant intensity may introduce measurement error into the key independent variable in the analysis $\Delta_j = (\textit{destination region cath intensity})_j - (\textit{origin region cath intensity})_j$, potentially biasing the estimated environment effects.

HRR cath trends by quartile of average intensity I begin by evaluating the stability of HRR cath intensities relative to the national average over time. As a first approach, I partition the 306 HRRs into quartiles based on each HRR's average risk-adjusted 2-day cath intensity over the period 1998-2012. For each quartile, Figure C.1 plots the average year-specific cath rate across HRRs in that quartile. In 1998, the most intensive quartile of HRRs had a cath rate of 46.4 percent, compared to 24.9 percent for the least intensive quartile. This difference of 21.5 percentage points in 1998 had shrunk to 13.1 percentage points in 2012, indicating that absolute differences in cath rates between these groups are not perfectly stable over time. Importantly, this figure implies that migrants moving, say, from a top-quartile HRR to a bottom-quartile HRR early in the sample period on average experienced somewhat larger changes in regional cath environments across a move than a migrant moving later in the sample.

Rank preservation among top/bottom HRRs Table C.2 sheds light more directly on the stability of rankings of individual HRRs over time. I first assign each HRR a rank order from 1 (most intensive) to 306 (least intensive) based on each HRR's average 2-day cath intensity over the period 1998-2012. I also rank each HRR based on 1998 cath rates and again on 2012 cath rates. Panels A and B of Table C.2 list the top and bottom 10 HRRs, respectively, based on the average cath rate ranking. While the rank-order of these HRRs was not perfectly preserved from 1998 through 2012, there does appear to be a substantial amount of rank persistence. All regions in Panel A were in the top-25 percent of regions in both 1998 and 2012, and all but one were in the top-15 percent both years. Similarly, and regions in Panel B were in the bottom-33 percent both years, and all but two were in the bottom-10 percent.

Panels C and D show the top and bottom 10 regions, respectively, based on ranking in 1998. While the most (least) intensive regions sill tended to be more (less) intensive than average in 2012, there is quite a bit of movement in the rank-order for some regions. Perhaps most prominently, McAllen, Texas was the second-most intensive region in 1998, with a 2-day cath rate of nearly 70 percent, but was the 12th least-intensive region by 2012 with a cath rate of 46.1 percent. McAllen is an exceptional case in many respects, and was profiled as one of the most expensive health care markets in an influential New Yorker article in 2009 that even highlighted the propensity in McAllen to perform cardiac catheterization (**?**). The cath rate in McAllen was already trending downward in McAllen prior to 2009, but this example highlights that it is possible for regions to change relative intensity over time.

Non-parametric rank correlation While Table C.2 is useful for summarizing the degree of rank preservation for the most and least intensive regions in the sample, it is less useful for providing a summary measure of rank preservation across all regions. To provide such a summary, I use the year-specific cath rates for each HRR and investigate whether the annual rank-order given by each of these annual intensity measures is preserved over time. If rank-order is preserved, then the intensity measures for any two years should be positively monotonically related.

Table C.3 reports non-parametric Kendall τ_a and Spearman correlation measures for pair-wise comparisons of the annual HRR cath rate measures. When two rankings have a monotonic and positive relationship, both the Kendall and Spearman coefficients are equal to 1, whereas they are both zero when the rankings are independent. The Kendall τ_a also has a convenient interpretation for any value not equal to zero or 1: for any two rank-order measures, the corresponding τ_a coefficient describes how much more likely (in percentage points) the two orderings will agree than disagree for any two randomly selected observations.

The estimated correlation coefficients show that rank-order in cath intensity is not fully preserved across years; the fact that the non-parametric correlations drop over time suggests that regions really do change their intensity relative to the secular trend over time, rather than being driven entirely by sampling error (which would result in correlations less than one, but stable over time).

Contemporaneous cath environment trends across move Finally, I investigate how the contemporaneous difference in cath intensity between a migrant's origin and destination HRRs (as defined in Equation 1.1) evolves relative to the average difference in cath intensity between the two HRRs (as defined in Equation 1.2). In other words, how well does the time-invariant difference in cath environment capture the year-specific difference in cath environment in the year of the move, as well as the years before and after the move?

I investigate this relationship by estimating a difference-in-differences event study similar to Equation 1, except where the outcome variable is $\Delta_j^t \equiv \Delta_j(\textit{origin HRR}, \textit{destination HRR}, t)$, the contemporaneous difference in cath intensity between migrant j's origin and destination HRRs t years since the cardiologist moves, omitting physician j's own patients (see Equation 1.1). Because the year-specific HRR cath rates are calculated over the patients of non-migrants only, trends in Δ_j^t describe how the migrant's origin and destination environments are differentially evolving across the move, exclusive of the migrant's own choices.

The results of estimating this regression are shown in Figure C.2. In the year of a migrant's move, each unit difference in the time-invariant measure of Δ_j corresponds to just slightly less than 1 unit different in the contemporaneous difference Δ_j^t. This suggests that at least on average, using the time-invariant difference in cath intensity is appropriate for evaluating the change in cath intensity experienced at the time of a physician's move.

Figure C.2 highlights another important consideration. Changes in Δ_j^t around the time of a physician's move are useful for either reinforcing or casting doubt on the validity of the parallel trends assumption underlying the difference-in-differences estimates of physician behavior response which are central to this paper. Specifically, abrupt changes in Δ_j^t at the time of a migrant's move that are driven by abrupt changes in cath rates in the origin environment would suggest that it may not be plausible to assume that the migrant's own behavior absent the move would have continued to follow the abruptly changing trend of cardiologists remaining in the origin region. On the other hand, it would reinforce the plausibility of the parallel trends assumption if Δ_j^t evolved smoothly across migrant moves, which in fact appears to be the case.

2.1.2 Difference-in-differences with time-varying cath environments

In this section, I explore whether the main estimates in the paper that rely on time-invariant differences in HRR cath intensity are sensitive to performing the analysis using year-specific differences in HRR cath intensity.

I begin by re-estimating the event study from Equation 1 in the paper, but replacing the time-invariant difference Δ_j (Equation 1.2) in cath intensity between the destination and origin HRRs with the year-specific difference Δ_j^t (Equation 1.1). To reduce annual fluctuations in Δ_j^t driven by sampling error, I first smooth the values of Δ_j^t using separate linear trends for each physician-HRR pair. Smoothing this way requires that changes in Δ_j^t across a physician's move are in fact smooth and approximately linear, an assumption that Figure C.2 supports.

The results of this regression, plotted in solid black in Figure C.3, are very similar to the results obtained using the time-invariant HRR cath rates reported in Figure 3 (also plotted in dashed gray in Figure C.3 for comparison). The main parameters of interest are the β_t coefficients. For a given value of t, β_t describes the difference between treatment styles of physicians t years since move per unit difference in Δ_j^t. The lack of any apparent pre-trend or level difference in physician behavior prior to the move indicates that physicians starting in the same region but moving to different regions practiced similarly before the move, quickly changed their behavior to partially conform to the new practice environment within one year of moving, and experience little to no additional convergence over the next 7 years.

The "step" pattern of physician behavior across a move revealed by the event study suggests that a traditional difference-in-difference (DD) estimate is appropriate for summarizing the change in physician behavior in response to a change in practice environment. The DD estimate comes from replacing the event time dummies in Equation 1 with a single "after" dummy $\mathbf{1}(t \geq 0)$. The DD results are shown in Table C.4, columns (4-8). For comparison, columns (1-3) show DD estimates based on the time-invariant measure of Δ_j. Note that columns (1-2) are the baseline DD estimates from Table 4 based on origin HRR and physician fixed effects, respectively, and repeated here for continuity.

I consider a number of different DD specifications using the year-specific difference Δ_t^j in cath rates between the destination and origin HRRs. First, column (5) repeats the same regression as column (1), except replacing the time-invariant Δ_j with the year-specific Δ_j^t. The resulting estimate changes little across these two specifications.

Columns (5-8) of Table C.4 explore whether the DD estimate appears to meaningfully differ between the first and second half of years in the sample. Since 1998-2012 are the 15 years used to estimate the DD regressions, I partition migrants into those moving prior to 2005 (the "early sample") and migrants moving in or after 2005 (the "late sample"). I estimate the DD regression over the early sample movers, first using only patients admitted to the hospital prior to 2005 (column 5) and second using only patients admitted to the hospital within 3 years of the cardiologists move year (column 6). Columns (7-8) estimate the DD regression over analogous samples for the late sample movers. The DD estimate remains fairly stable across both the early and late samples, suggesting that environment effects on cardiologist behavior over the period 1998-2012 remained relatively stable.

2.2 Other robustness

2.2.1 Balanced migrant panel

One issue that arises in the difference-in-differences approach estimated using the treatment choices of migrants for up to 8 years before and after a move is that not all migrants are observed for all years in this window. For example, physicians who move in 2000 have at most 2 years of pre-move behavior in the 1998-2012 sample. The trends in pre-move behavior in years 3-8 before the move are therefore only estimated over physicians who move later in the sample. An issue with this imbalance is that trends in measured behavior across a move may partly reflect changes in the composition of which migrants remain in the sample.

I therefore estimate a "balanced panel" DD specification where I estimate the same specification as in column (1) of Table C.4, but with two sample restrictions. First, I limit to the set of 1,358 migrants who are observed treating patients in the sample at least 3 years before and after a move. Second, I further limit the regression sample to patients treated within the same window 3-years before and after the move. The DD estimate from this balanced panel specification, reported in column (3), is again very similar to the other DD estimates in columns (1-2).

2.2.2 Physician volume across moves

As a final robustness check, I explore how the patient volume of migrant physicians changes around the time of the move. If volume changes abruptly across a move, this could raise concerns that something other than a change in a physician's environment is occurring contemporaneously with the move. While the difference-in-differences framework can account for time-of-move shocks that are common to all physicians who move (as captured by the event time fixed effects), it would be problematic if the size of these shocks were correlated with the change in intensity experienced at the time of the move. In that case, the difference-in-differences estimates would falsely attribute the differential time-of-move shock to the change in regional intensity experienced across the move, even if regional intensity played no role on physician behavior.

I begin by showing summary statistics of the number of sample patients each migrant treats in each of the 8 years before and after a move. I aim to capture how volume may change asymmetrically for physicians who move to more- versus less-intensive regions, and also how volume may change differentially for physicians experiencing a "large" versus "small" change in environment across a move. For ease of analysis, I first normalize the time-invariant cath difference Δ_j between a physician j's origin and destination HRRs into a z-score Δ_z, standardized to have mean zero and variance of 1 across all migrants. This normalization is useful, because $\Delta_z > 0$ essentially captures physicians moving to more-intensive regions (since mean(Δ_j)=0.007 is very close to zero), and $|\Delta_z| > 1$ captures physician's facing a change in cath environment greater than 1 standard deviation.

Figure C.4a plots raw summary statistics of the average number of sample patients each physician treats in the 8 years before and after moving. In the left figure, the statistics are reported separately for physicians moving to more-intensive regions ($\Delta_z > 0$, in orange) and those moving to less-intensive regions ($\Delta_z <= 0$, in blue). There appears to be a slight increase in patient volume following the move, but there does not appear to be any meaningful asymmetry in either levels or trends between the two physician groups. The right column plots the same volume statistics, but separately for physicians experiencing a "large" change in environment ($|\Delta_z| > 1|$) versus those facing a small change. Here, patient volume prior to the move appears to be about 15 percent higher among physicians facing a large change in environment, with the gap closing and possibly reversing slightly contemporaneous with the move. This differential change in patient volume between the two physician groups may reflect shocks that differentially affect physicians experiencing larger moves, or may simply reflect differential patient volumes common to all cardiologists in the origin and destination HRRs.

Because a cardiologist's patient volume depends not only on shocks to the specific physician, but also depend on characteristics of the HRR, I aim to isolate the physician-specific shocks over time by measuring cardiologist volume relative to the average patient volume across all cardiologists practicing in the same HRR. This is also useful for evaluating whether migrant cardiologists look systematically different in terms of patient volume than non-migrants in the same region.

Figure C.4b plots the same summary statistics as in Figure C.4a, except for relative physician volume. Both the left and right columns tell a similar story: prior to moving, migrants treat a similar number of patients each year compared to non-migrants in the origin HRR. After the move, migrants treat roughly 10 percent more patients each year than non-migrants in the destination HRR. However, there do not appear to be differential levels or trends in relative patient volume for cardiologists moving to more- versus less-intensive regions, or for cardiologists facing larger versus smaller absolute changes in intensity.

To evaluate more rigorously whether volume changes differentially across a move based on the size of the move, I estimate an event study of the form

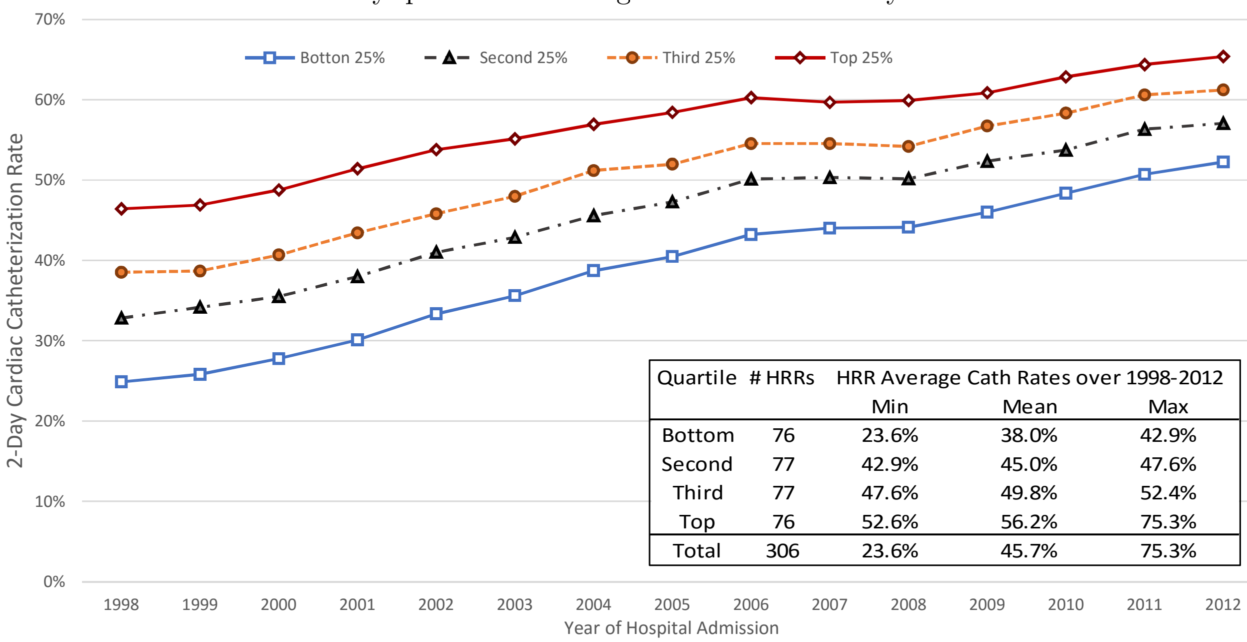
$$(relative\ volume)_{jt} = \{origin\ HRR\ FEs\}_j + \sum_{s=-8}^{7} \left[\alpha_t \mathbf{1}(s=t) + \beta_t size(\Delta_z) \mathbf{1}(s=t) \right] + \{calendar\ year\ FEs\}_i + \epsilon_{jt}, \tag{2.1}$$

where an observation is a cardiologist-year over the 8 years before and after a move. The outcome variable *relative volume*$)_{jt}$ is cardiologist j's volume relative to the current HRR average, and is defined each year where the cardiologist treats at least one patient. The key independent variable of interest is $size(\Delta_z)$, which either takes on the value Δ_z to evaluate the asymmetric effect changes in cath environment on relative volume, or $|\Delta_z|$ to evaluate the volume effect of larger versus smaller absolute changes in the environment.

The results of the volume event study are reported in Figure C.4c. Consistent with the relative volume summary trends shown in Figure C.4b, the event study does not reveal any volume shocks specific to the time of the move that are also correlated with differences in the size of the change in environment. This result further supports the plausibility that changes in physician practice styles across a move are driven by changes in the HRR environment, rather than by idiosyncratic shocks at the time of the move that correlate with the change in environment.

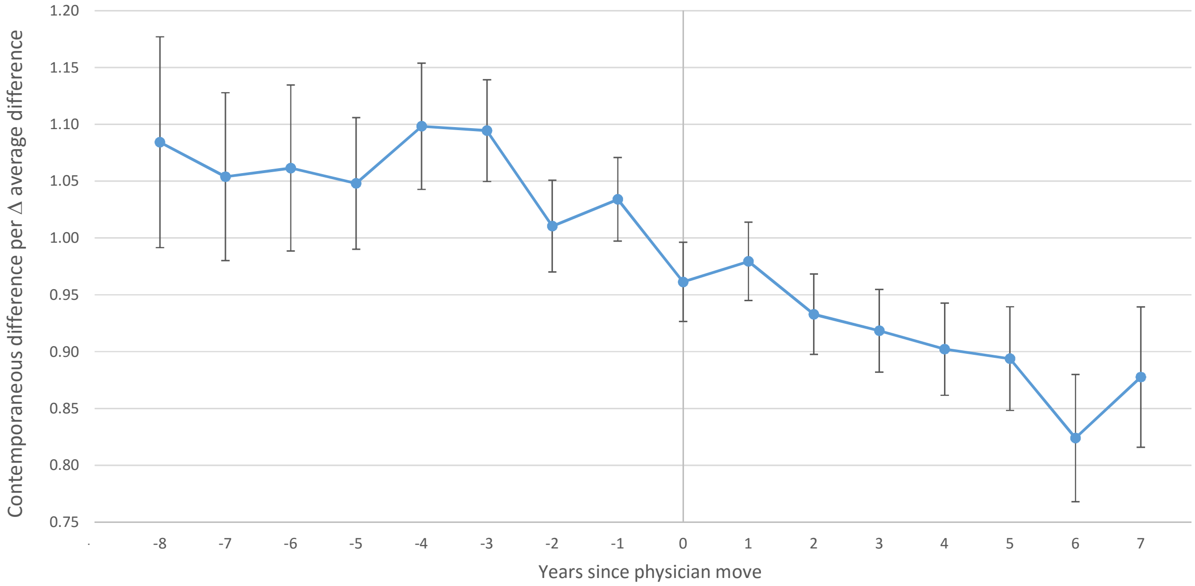
3 Additional Tables and Figures

Figure C.1: Annual 2-day cath rates among heart attack (AMI) patients
by quartiles of average HRR cath intensity



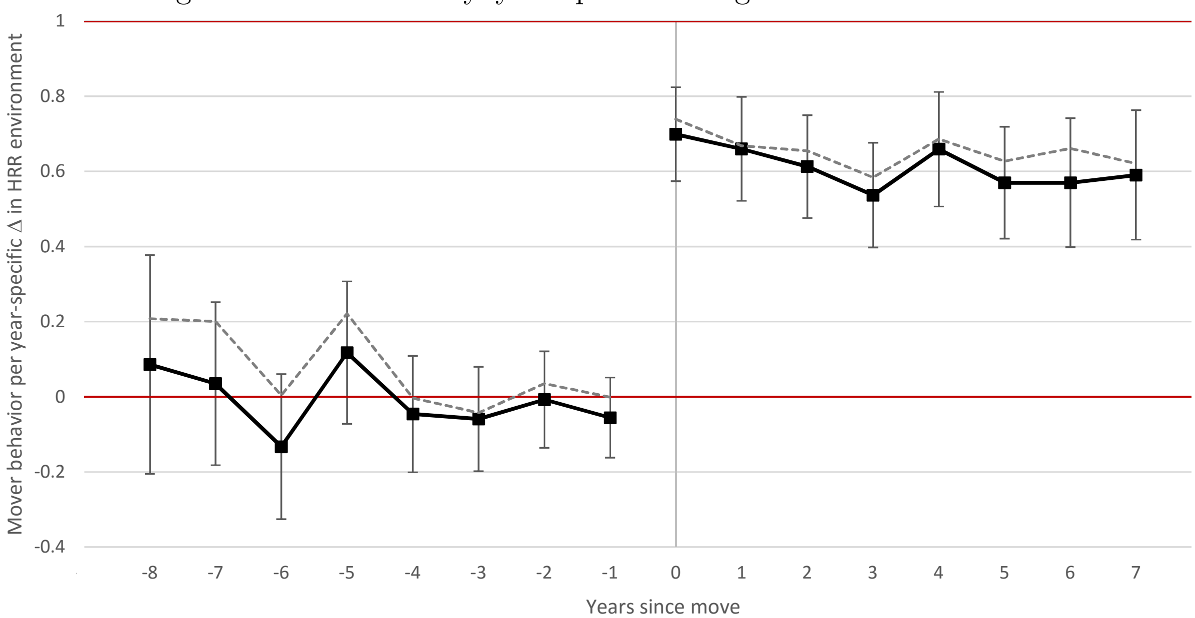
Notes: Figure plots representative cath rates for high and low cath regions by quartile of regional intensity. HRRs are partitioned into quartiles based on average cath rates over all years, such that the composition of HRRs in each quartile remains constant across years. The table shows the distribution of average HRR cath rates over all years, which define the quartiles.

Figure C.2: Contemporaneous vs. average difference between migrant HRR environments



Notes: Graph shows how the year-specific cath difference Δ_j^t between a migrant physician's origin and destination HRRs evolves over time as a function of the time-invariant average cath difference Δ_j between the HRRs. These estimates come from a regression where an observation is a migrant-year and controls include fixed effects for origin HRR, calendar year, and years since physician move. Both Δ_j^t and Δ_j are based on leave-out means that exclude physician j's own patients. Bands indicate 95 percent confidence intervals constructed from two-way clustered standard errors at the physician and HRR levels.

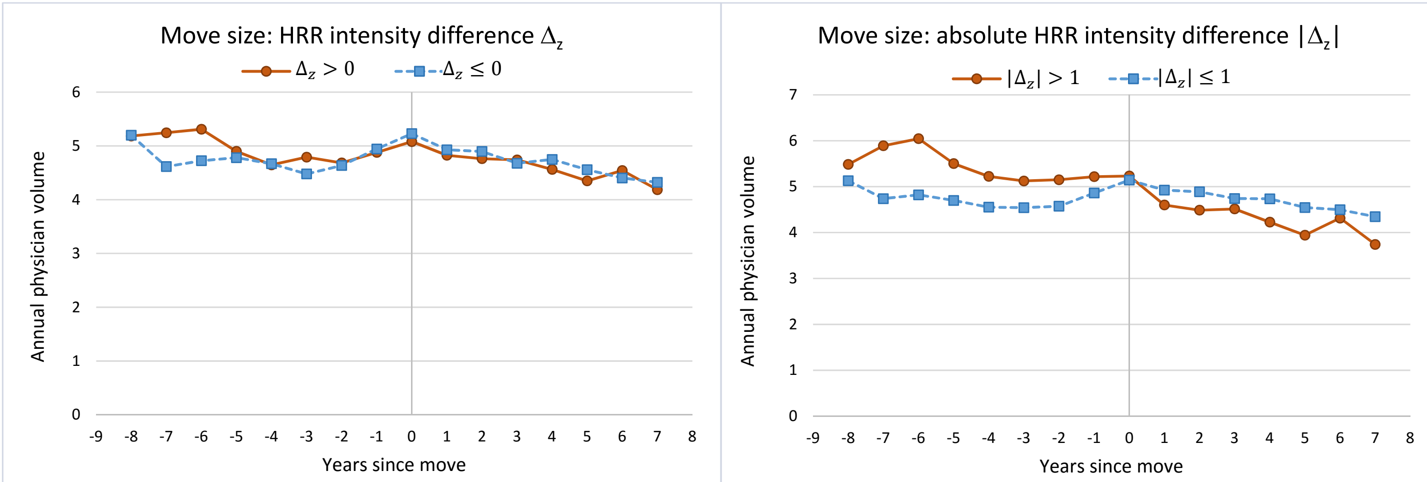
Figure C.3: Event study–year-specific change in HRR environment



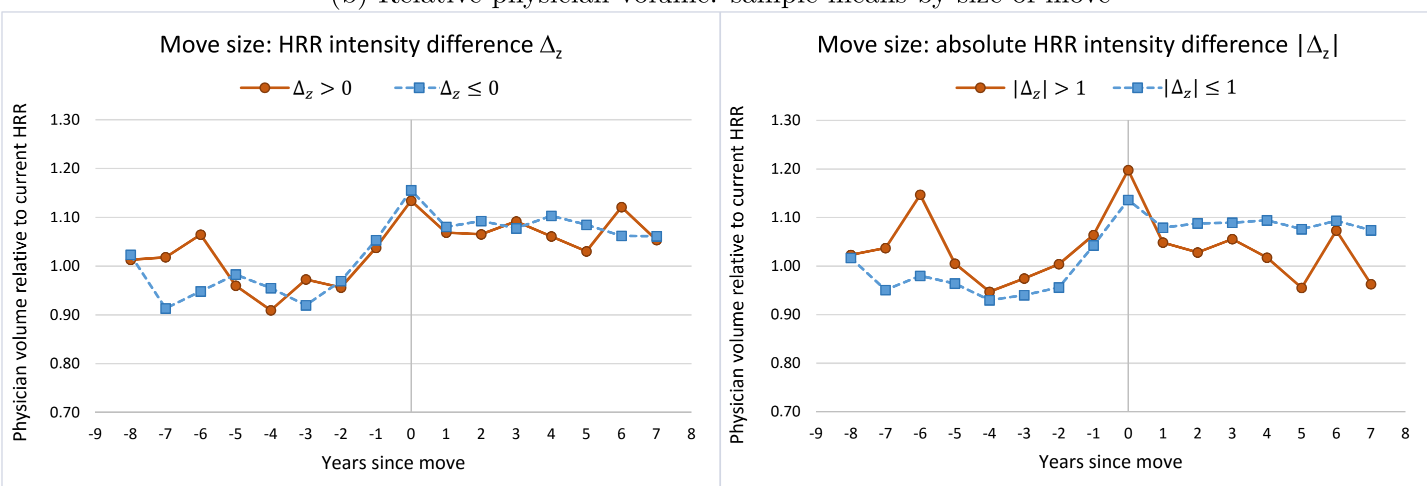
Notes: Graph plots estimates of physician practice style t years since move as a function of the year-specific difference in cath environments Δ_j^t between a migrant physician's destination and origin HRRs. These estimates come from a regression that includes fixed effects for origin HRR, calendar year of patient admission, years since physician move, and patient age, race, sex, and first heart attack. For comparison, the dashed gray line repeats the baseline results based on time-invariant differences in HRR cath rates (Figure 3). Bands indicate 95 percent confidence intervals constructed from two-way clustered standard errors at the physician and HRR levels.

Figure C.4: Physician volume across a move, by size of move

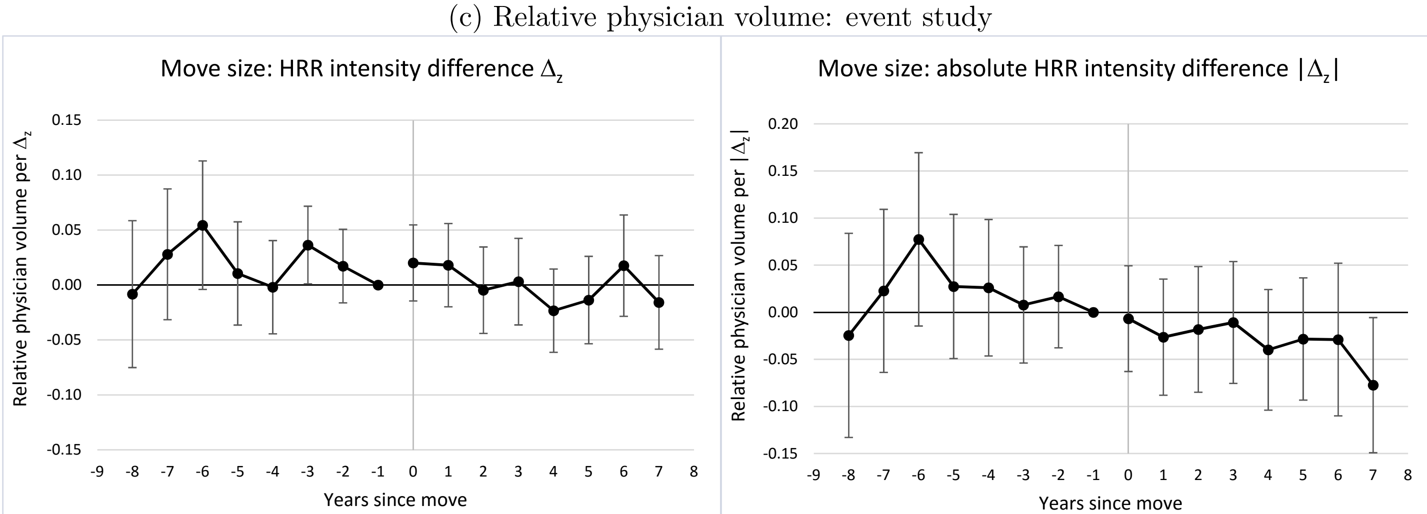
(a) Physician volume: sample means by size of move



(b) Relative physician volume: sample means by size of move



(c) Relative physician volume: event study



Notes: This figure describes how physician volume, in terms of the number or relative number of AMI sample patients treated each year, varies by time across a move and also by the size of the move. Δ_z is equal to the time-invariant difference in cath between the origin and destination HRRs for each migrant, standardized to have mean zero and a standard deviation of 1 across all migrants. Thus, $\Delta_z > 0$ means an above-average move, while $|\Delta_z| > 1$ indicates a move where the experienced change in cath environment is greater than one standard deviation.

Table C.1: Sample summary statistics

	Medicare Beneficiaries		AMI Patient Episodes		AMI Patient Characteristics									Cardiologist Characteristics		
year	Total (Millions)	Fraction in FFS	Total in FFS	Physician Sample	STEMI	Age	White	Male	Admitted to Cath Hospital	Cardiologist within 2 days	2-Day Cath Rate			Total	AMI patients as first card	HRR Moves
											Any AMI	NSTEMI	STEMI			
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)
Panel A: Years in which physician claims available for 5% of Medicare beneficiaries																
1992	36.9	93.3%	288,663	14,505	69.8%	75.3	89.3%	53.5%	69.6%	53.1%	16.3%	15.1%	16.8%	4,955	1.8	-
1993	37.7	92.6%	282,437	14,173	68.0%	75.3	89.1%	53.6%	71.1%	57.3%	19.3%	17.9%	20.0%	5,293	1.7	-
1994	38.7	91.6%	289,514	14,332	66.6%	75.3	90.5%	52.9%	73.3%	68.4%	23.0%	21.2%	24.0%	6,360	2.0	-
1995	39.3	89.7%	290,493	14,233	64.7%	75.4	90.2%	52.7%	74.4%	72.2%	27.0%	24.2%	28.6%	6,751	2.0	-
1996	39.8	87.3%	291,093	14,432	62.1%	75.6	89.9%	52.4%	75.6%	74.7%	30.6%	27.0%	32.7%	7,170	2.0	-
1997	40.2	84.5%	285,060	14,205	59.4%	75.8	89.5%	52.2%	77.1%	76.4%	32.7%	28.8%	35.3%	7,417	2.0	-
Panel B: Years in which physician claims available for 20% of Medicare beneficiaries																
1998	40.6	82.3%	285,601	56,174	55.7%	76.1	89.2%	51.7%	77.9%	78.2%	34.2%	29.9%	37.6%	11,790	5.0	55
1999	40.9	81.6%	291,399	58,102	52.1%	76.4	88.7%	51.3%	78.3%	79.9%	35.0%	30.6%	39.1%	12,397	5.1	154
2000	41.4	82.1%	300,255	59,131	48.3%	76.5	89.0%	51.0%	79.3%	82.4%	36.8%	31.8%	42.2%	12,842	5.2	221
2001	41.9	83.9%	306,328	60,139	45.8%	76.6	88.7%	51.1%	80.4%	83.6%	39.3%	34.1%	45.6%	13,160	5.3	239
2002	42.4	85.7%	313,879	61,670	44.0%	76.5	88.2%	51.2%	82.4%	83.8%	42.2%	36.6%	49.3%	13,735	5.4	261
2003	43.0	86.6%	308,448	61,016	42.4%	76.6	87.9%	51.3%	83.5%	86.4%	44.1%	38.1%	52.3%	14,047	5.4	262
2004	43.6	86.4%	294,555	58,287	40.6%	76.5	87.6%	51.4%	85.4%	87.3%	47.0%	40.8%	56.1%	14,339	5.2	290
2005	44.5	84.9%	277,937	54,691	38.9%	76.6	87.5%	51.7%	86.4%	88.2%	48.6%	42.2%	58.6%	14,456	4.9	264
2006	45.3	81.4%	257,325	50,593	37.1%	76.4	87.4%	52.0%	88.0%	88.4%	51.2%	44.2%	63.0%	14,598	4.6	323
2007	46.3	79.1%	246,053	48,551	34.4%	76.5	87.2%	52.1%	88.9%	88.4%	51.4%	44.4%	64.8%	14,472	4.4	287
2008	47.5	76.8%	242,494	47,396	31.4%	76.5	86.9%	52.0%	88.9%	87.4%	51.3%	44.2%	66.7%	13,973	4.3	201
2009	48.7	75.3%	229,787	44,881	29.9%	76.2	86.3%	52.7%	90.1%	86.4%	53.4%	46.3%	69.8%	13,443	4.2	164
2010	49.9	74.6%	229,947	45,317	28.7%	76.1	86.1%	53.0%	90.7%	84.3%	55.2%	47.9%	73.3%	13,030	4.2	164
2011	51.5	74.0%	227,058	44,438	27.4%	75.9	85.6%	53.6%	91.4%	82.1%	57.4%	50.3%	76.0%	12,488	4.2	128
2012	53.4	72.4%	217,829	42,584	26.3%	76.0	85.6%	53.6%	91.8%	80.0%	58.4%	51.3%	78.2%	11,903	4.1	76
1998-2012	45.4	80.1%	4,028,895	792,970	39.8%	76.4	87.6%	51.9%	85.0%	84.4%	46.2%	41.1%	54.0%	19,945	4.8	3,089

Notes: Table shows summary statistics related to the sample and variable construction, as discussed in appendix Section 1.

Table C.2: HRR cath rank

HRR Number (1)	HRR City (2)	HRR State (3)	HRR Intensity Rank 1998 (4)	HRR Intensity Rank 2012 (5)	HRR Intensity Rank Average (6)	HRR Cath Rate 1998 (7)	HRR Cath Rate 2012 (8)	HRR Cath Rate Average (9)	Annual AMI Patients (10)
Panel A: Top 10 HRRs, by 1998-2012 Average Cath Rate									
101	Boulder	CO	4	4	1	62.4%	74.6%	75.3%	100.0
422	Provo	UT	9	1	2	57.4%	82.8%	74.8%	229.7
421	Ogden	UT	6	3	3	59.1%	76.3%	70.1%	211.6
104	Fort Collins	CO	3	75	4	67.1%	63.8%	66.0%	228.3
324	Minot	ND	47	8	5	46.8%	73.2%	65.1%	184.1
69	Palm Springs/Rancho Mira	CA	17	22	6	55.2%	69.8%	64.8%	305.7
142	Albany	GA	22	9	7	52.5%	72.6%	64.1%	239.5
190	Cedar Rapids	IA	14	35	8	56.4%	68.4%	63.6%	305.1
370	Rapid City	SD	27	7	9	51.8%	73.3%	62.8%	234.3
14	Sun City	AZ	1	15	10	71.5%	70.9%	62.7%	333.7
Panel B: Bottom 10 HRRs, by 1998-2012 Average Cath Rate									
289	Newark	NJ	291	297	297	18.6%	45.9%	32.9%	1314.4
367	Florence	SC	205	306	298	31.5%	32.3%	32.0%	670.6
350	Danville	PA	305	286	299	11.7%	49.6%	31.7%	751.2
221	Bangor	ME	302	304	300	14.9%	38.4%	31.4%	925.7
230	Springfield	MA	299	298	301	16.9%	45.2%	31.3%	853.8
443	Charleston	WV	294	293	302	17.8%	48.5%	30.9%	1491.9
347	Altoona	PA	301	252	303	15.0%	53.3%	30.9%	364.9
296	Binghamton	NY	303	305	304	14.1%	34.5%	27.9%	533.0
297	Bronx	NY	297	301	305	17.1%	41.1%	27.2%	716.8
299	Buffalo	NY	304	303	306	12.1%	40.2%	23.6%	1405.6
Panel C: Top 10 HRRs, by 1998 Cath Rate									
14	Sun City	AZ	1	15	10	71.5%	70.9%	62.7%	333.7
402	McAllen	TX	2	295	68	69.7%	46.1%	53.0%	518.3
104	Fort Collins	CO	3	75	4	67.1%	63.8%	66.0%	228.3
101	Boulder	CO	4	4	1	62.4%	74.6%	75.3%	100.0
154	Aurora	IL	5	90	21	59.7%	62.8%	59.5%	157.2
421	Ogden	UT	6	3	3	59.1%	76.3%	70.1%	211.6
456	Wausau	WI	7	14	13	58.7%	70.9%	61.5%	280.0
400	Lubbock	TX	8	64	30	58.0%	64.7%	57.5%	750.7
422	Provo	UT	9	1	2	57.4%	82.8%	74.8%	229.7
152	Idaho Falls	ID	10	5	11	57.0%	74.6%	62.4%	141.1
Panel D: Bottom 10 HRRs, by 1998 Cath Rate									
297	Bronx	NY	297	301	305	17.1%	41.1%	27.2%	716.8
420	Wichita Falls	TX	298	239	200	17.0%	54.5%	44.8%	289.5
230	Springfield	MA	299	298	301	16.9%	45.2%	31.3%	853.8
360	Scranton	PA	300	251	290	16.1%	53.5%	34.9%	517.5
347	Altoona	PA	301	252	303	15.0%	53.3%	30.9%	364.9
221	Bangor	ME	302	304	300	14.9%	38.4%	31.4%	925.7
296	Binghamton	NY	303	305	304	14.1%	34.5%	27.9%	533.0
299	Buffalo	NY	304	303	306	12.1%	40.2%	23.6%	1405.6
350	Danville	PA	305	286	299	11.7%	49.6%	31.7%	751.2
242	Muskegon	MI	306	125	283	11.3%	60.4%	37.1%	308.4

Notes: Table describes the top 10 and bottom 10 HRRs by average cath ranking over the period 1998-2012 (Panels A and B) and by 1998 ranking (Panels C and D). Columns (4-6) list the intensity ranks based on 1998, 2012, and average cath rates, respectively, where a rank of 1 indicates the highest-cath HRR and a rank of 306 indicates the lowest-cath HRR. Columns (7-9) show the cath rates from which the respective ranks in columns (4-6) derive.

Table C.3: HRR cath rank

Panel A: Kendall τ Rank-Order Coefficient

year	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
1998	1.00 ()													
1999	0.78 (0.02)	1.00 ()												
2000	0.72 (0.02)	0.77 (0.02)	1.00 ()											
2001	0.68 (0.02)	0.71 (0.02)	0.78 (0.02)	1.00 ()										
2002	0.62 (0.03)	0.65 (0.03)	0.72 (0.02)	0.77 (0.02)	1.00 ()									
2003	0.55 (0.03)	0.58 (0.03)	0.65 (0.02)	0.70 (0.02)	0.77 (0.02)	1.00 ()								
2004	0.50 (0.03)	0.52 (0.03)	0.59 (0.03)	0.63 (0.02)	0.68 (0.02)	0.74 (0.02)	1.00 ()							
2005	0.47 (0.03)	0.49 (0.03)	0.56 (0.03)	0.61 (0.02)	0.66 (0.02)	0.73 (0.02)	0.76 (0.02)	1.00 ()						
2006	0.46 (0.03)	0.48 (0.03)	0.52 (0.03)	0.57 (0.03)	0.62 (0.02)	0.68 (0.02)	0.70 (0.02)	0.76 (0.02)	1.00 ()					
2007	0.42 (0.03)	0.43 (0.03)	0.48 (0.03)	0.53 (0.03)	0.58 (0.03)	0.63 (0.02)	0.63 (0.02)	0.71 (0.02)	0.73 (0.02)	1.00 ()				
2008	0.40 (0.03)	0.40 (0.03)	0.45 (0.03)	0.49 (0.03)	0.54 (0.03)	0.58 (0.02)	0.61 (0.02)	0.66 (0.02)	0.70 (0.02)	0.71 (0.02)	1.00 ()			
2009	0.41 (0.03)	0.43 (0.03)	0.47 (0.03)	0.51 (0.03)	0.55 (0.03)	0.60 (0.02)	0.60 (0.02)	0.66 (0.02)	0.70 (0.02)	0.72 (0.02)	0.72 (0.02)	1.00 ()		
2010	0.39 (0.04)	0.40 (0.03)	0.44 (0.03)	0.48 (0.03)	0.53 (0.03)	0.56 (0.03)	0.54 (0.03)	0.63 (0.02)	0.63 (0.02)	0.69 (0.02)	0.68 (0.02)	0.71 (0.02)	1.00 ()	
2011	0.40 (0.03)	0.40 (0.03)	0.44 (0.03)	0.47 (0.03)	0.52 (0.03)	0.56 (0.03)	0.55 (0.03)	0.60 (0.02)	0.62 (0.02)	0.64 (0.02)	0.64 (0.02)	0.69 (0.02)	0.70 (0.02)	1.00 ()
2012	0.41 (0.03)	0.40 (0.04)	0.43 (0.03)	0.46 (0.03)	0.53 (0.03)	0.55 (0.03)	0.54 (0.03)	0.59 (0.03)	0.61 (0.03)	0.63 (0.02)	0.62 (0.03)	0.65 (0.02)	0.68 (0.02)	0.71 (0.02)

Panel B: Spearman Rank-Order Coefficient

year	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
1998	1.00 ()													
1999	0.93 (0.02)	1.00 ()												
2000	0.89 (0.03)	0.92 (0.02)	1.00 ()											
2001	0.85 (0.03)	0.88 (0.03)	0.93 (0.02)	1.00 ()										
2002	0.80 (0.03)	0.83 (0.03)	0.89 (0.03)	0.92 (0.02)	1.00 ()									
2003	0.73 (0.04)	0.75 (0.04)	0.83 (0.03)	0.87 (0.03)	0.92 (0.02)	1.00 ()								
2004	0.68 (0.04)	0.69 (0.04)	0.77 (0.04)	0.82 (0.03)	0.86 (0.03)	0.91 (0.02)	1.00 ()							
2005	0.65 (0.04)	0.67 (0.04)	0.74 (0.04)	0.80 (0.03)	0.84 (0.03)	0.91 (0.02)	0.92 (0.02)	1.00 ()						
2006	0.63 (0.04)	0.65 (0.04)	0.70 (0.04)	0.76 (0.04)	0.81 (0.03)	0.86 (0.03)	0.88 (0.03)	0.92 (0.02)	1.00 ()					
2007	0.59 (0.05)	0.59 (0.05)	0.66 (0.04)	0.71 (0.04)	0.77 (0.04)	0.82 (0.03)	0.82 (0.03)	0.88 (0.03)	0.90 (0.03)	1.00 ()				
2008	0.56 (0.05)	0.56 (0.05)	0.62 (0.04)	0.67 (0.04)	0.73 (0.04)	0.78 (0.04)	0.80 (0.03)	0.84 (0.03)	0.87 (0.03)	0.88 (0.03)	1.00 ()			
2009	0.58 (0.05)	0.59 (0.05)	0.65 (0.04)	0.70 (0.04)	0.73 (0.04)	0.79 (0.04)	0.79 (0.03)	0.84 (0.03)	0.88 (0.03)	0.89 (0.03)	0.89 (0.03)	1.00 ()		
2010	0.55 (0.05)	0.56 (0.05)	0.61 (0.05)	0.66 (0.04)	0.71 (0.04)	0.76 (0.04)	0.73 (0.04)	0.81 (0.03)	0.81 (0.03)	0.87 (0.03)	0.85 (0.03)	0.88 (0.03)	1.00 ()	
2011	0.56 (0.05)	0.56 (0.05)	0.62 (0.05)	0.65 (0.04)	0.70 (0.04)	0.75 (0.04)	0.73 (0.04)	0.79 (0.04)	0.81 (0.03)	0.82 (0.03)	0.82 (0.03)	0.87 (0.03)	0.88 (0.03)	1.00 ()
2012	0.57 (0.05)	0.56 (0.05)	0.60 (0.05)	0.63 (0.04)	0.70 (0.04)	0.73 (0.04)	0.72 (0.04)	0.78 (0.04)	0.79 (0.04)	0.81 (0.03)	0.80 (0.03)	0.84 (0.03)	0.85 (0.03)	0.88 (0.03)

Notes: Table gives the Kendall τ_a (Panel A) and Spearman (Panel B) coefficients corresponding to each pair of annual HRR 2-day cath intensity measures (standard errors in parentheses). When two rankings have a monotonic and positive relationship, both the Kendall and Spearman coefficients are equal to 1, whereas they are both zero when the rankings are independent. The Kendall τ_a also has a convenient interpretation for any value not equal to zero or 1: for any two rank-order measures, the corresponding τ_a coefficient describes how much more likely (in percentage points) the two orderings will agree than disagree for any two randomly selected observations.

Table C.4: Difference-in-differences robustness

Dependent variable: $(cath)_i \in \{0,1\}$, indicating cath within 2 days

	Time-invariant Δ in HRR environment			Year-specific Δ in HRR environment				
					early sample: move yr ≤ 2004		late sample: move yr ≥ 2005	
	all movers	all movers	bal panel: 3 years before/ after move	all movers	admit yr ≤ 2004	admits within 3 years of move	admit yr ≥ 2005	admits within 3 years of move
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Δ	0.037	--	--	-0.026	0.097	0.035	0.089	-.005
	(0.057)			(0.047)	(0.064)	(0.058)	(0.103)	(0.097)
Δ*(after)	0.628***	0.652***	0.622***	0.652***	0.696***	0.681***	0.569***	0.680***
	(0.055)	(0.059)	(0.080)	(0.053)	(0.073)	(0.066)	(0.105)	(0.098)
Fixed Effects								
HRR1	X			X	X	X	X	X
Physician		X	X					
Observations	124,650	161,944	38,852	161,944	44,492	50,389	31,588	29,233

Notes: Table presents additional difference-in-differences estimates of the change in a physician's practice style across a move as a function of the change Δ in cath environment. Each column presents results from a separate regression. Columns (1-3) use the time-invariant change in cath rates between the origin and destination HRRs, as defined by Equation 1.2. Columns (4-8) use the year-specific difference in cath rates between HRRs, as defined by Equation 1.1. The balanced panel specification in column (34) restricts to physicians who treat patients at least 3 years before and after the move, and also restricts to patients treated during that time window. All regressions include fixed effects for years since physician move, as well as for patient age, race, sex, and first heart attack. Two-way clustered standard errors at the physician and HRR levels shown in parentheses. *: $p < 0.10$; **: $p < 0.05$; ***: $p < 0.01$.