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Provider responses to market entry under competing health technologies*

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Abstract

We study how multi-technology hospitals respond to market entry of single-technology competitors using a rescindment of regulations for heart attack treatments that prompted a rapid expansion of catheterization laboratories (cath labs) in Sweden. We isolate supply-side effects by exploiting that patients cannot choose their hospital and compare outcomes of cardiac patients residing in areas affected and unaffected by provider market entry, respectively. We show that patients with indications for cardiac surgery were more likely to receive catheter-based treatment after a cath lab opened in their hospital, and document increases in adverse health outcomes for inframarginal patients. Incumbent hospitals responded to this demand reallocation by augmenting their own demand for surgery, but to a lesser extent and without patient health consequences.

Keywords: hospitals; market entry; technological substitution; supplier-induced demand; heart attacks

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1 Introduction

The healthcare industry is characterized by rapid technological innovation benefiting both individuals and societies in the form of improved longevity, productivity, and quality of life (see, e.g., Chandra and Skinner, 2012; Lichtenberg, 2014). Over time, new innovations replace or reduce the need for existing technologies.[1] This development encourages market entry by providers specializing in these new, competing technologies, which in turn may threaten market positions of incumbent providers invested in legacy technologies (Aghion et al., 2009; Gaynor and Town, 2011). The economic incentives that providers face under such circumstances have important implications for effective technological diffusion and substitution in healthcare markets.

In this paper, we study how market entry of specialized, single-technology hospital providers proliferates new medical technology, and whether incumbent, multi-technology hospitals respond to such competition by shifting activities towards older technologies. Standard economic theory predicts that firm entry into a market increases welfare by increasing competition between suppliers, resulting in more services being supplied at a lower price. However, technology-driven supplier-induced demand effects, where healthcare providers compete explicitly by adopting and promoting new medical technology to attract new patients (see, e.g., Dranove et al., 1992; Kessler and McClellan, 2000), may induce allocative inefficiencies (Chandra and Staiger, 2020). We investigate two such channels: excessive use of new medical technology from *direct* demand reallocation ("business stealing") effects (see, e.g., Mankiw and Whinston, 1986) by market entrants, and *indirect* demand augmenting effects by incumbent providers attempting to steer their demand back to legacy technologies (Barro et al., 2006; Li and Dor, 2015). Empirical investigation of these two effects provides knowledge about the underlying drivers of technological change in the healthcare sector, and inform suitable policy responses to offset inappropriate provider incentives to (dis)innovate.

[1] The global market for medical technology generated total revenue of USD 587 million in 2023 and is projected to reach 800 million by 2030 (see, e.g., Ernst & Young, 2024). In the same year, the US Food and Drug Administration received approximately 20,000 submissions for marketing approval and authorized nearly 6,000 medical devices for market access.

In our empirical analysis, we focus on the important setting of therapeutic treatment of Acute Coronary Syndrome (ACS). ACS is a medical condition that entails a reduction in blood flow to the heart caused by occlusion of one or more blood vessels where considerable controversy persists about best practice for patients with multi-vessel disease. The main treatment strategies to deal with such "complex" ACS are coronary artery bypass graft (CABG) surgery, a form of open heart surgery undertaken by cardiac surgeons in operating theaters, and the less invasive percutaneous coronary intervention (PCI), provided by interventional cardiologists in catheterization laboratories, or "cath labs". Although case complexity is an indicator that generally favors cardiac surgery, the novelty of PCI technology and mixed scientific evidence contributed to ambiguity in the recommended treatment modality for this patient group during the period we study.[2] We conjecture that this professional uncertainty may have tempted hospital providers to steer demand towards those specific technologies that they (extrinsically or intrinsically) prefer; a form of supplier-induced demand that arises as a strategic response to market entry (see, e.g., Evans, 1974; Johnson, 2014).

Our test bed, Sweden, offers an institutional context that allows us to establish causal inference under relatively weak conditions. Specifically, patients in the Swedish healthcare system are constrained in their choice of healthcare provider since individuals are assigned to hospitals based on where they reside according to mutually exclusive geographical boundaries. These local monopolies essentially rule out endogenous patient-provider sorting and provide hospitals with control over patient management decisions. Moreover, patient-physician sorting is unlikely since hospital physicians in Sweden are salaried employees and patients cannot freely choose their treating doctor. This institutional context enables us to rule out any demand-side effects obfuscating the provider responses we focus on in our analysis.

[2]The ambiguity around best practice for treating complex ACS is perhaps best illustrated by the former president of the Society for Cardiothoracic Surgery in the UK, David Taggart, in his 2006 Thomas B. Ferguson lecture: "So why is PCI replacing CABG against best evidence? There are three reasons: 1. the cardiologist is the gatekeeper, and this may produce a conflict of interest in terms of self-referral; 2. the disingenuous presentation and inappropriate application of results of randomized trials in highly select and atypical groups to the whole population; 3. the result of what happens when evidence-based medicine is challenged by a multibillion dollar industry" (Taggart, 2006).

Our empirical analysis is based on a policy change in the early 2000s that relaxed hospitals' restrictions to provide PCI services in Sweden which prompted a rapid expansion in the number of hospitals offering catheter-based treatments. Prior to decentralization, the ACS market was dominated by large, academic hospitals offering both PCI and CABG surgery. Due to perceived safety concerns, smaller hospitals were not permitted to offer PCI to patients unless they also had access to an operating theater to perform CABG, and therefore had to refer ACS patients in need of these services to the nearest academic hospital. Such patient transfers were undesirable by referring hospitals that, in contrast to *referral* hospitals, had strong incentives to minimize treatment costs due to being mainly funded by prospective global budgets. Hence, a swift deregulation of the market for catheter-based ACS treatments occurred when new clinical guidelines, emphasizing the importance of rapid access to reperfusion treatment after a heart attack (i.e., "the golden hour" , see, e.g., Hand et al., 1998), eroded existing arguments for care concentration. As a consequence, the number of hospitals in Sweden with capacity for providing PCI doubled within a 10 year period while the number of CABG-capable providers remained unchanged.

We exploit the expansion of the Swedish PCI market in a difference-in-differences (DID) framework to study the behaviors of *focal* hospitals that opened new cath labs, and *incumbent* hospitals that lost control over, often significant, patient market shares. Our analysis rests on the conjecture that whenever providers have financial incentives to treat patients in-house, as in our case, they may be tempted to use their market power to steer demand to allocate existing input factors effectively. We first test whether complex ACS patients residing in focal hospitals' catchment areas were more likely to be treated with PCI after a cath lab was opened in their hospital. All else equal, an increased likelihood for PCI treatments in this patient population after market entry provides evidence of a *demand reallocation* effect wherein the focal hospital "steals" patients that would otherwise have received CABG surgery in the incumbent hospital. Furthermore, we test whether incumbent hospitals, in turn, respond to such "theft" through a *demand augmentation* effect by adjusting the share of patients receiving PCI in their catchment areas to address potential underutilization of their operating theaters for CABG surgery. The latter effect is, a priori, ambiguous as it crucially depends on the size composition of ACS patients in the market that the incumbent hospital relinquished to the new entrant. Areas neither affected by market entry, nor served by academic hospitals that lost market share elsewhere, act as comparison group to control for parallel trends in the use of PCI technology.

Our estimation results reveal that complex ACS patients residing in catchment areas of focal hospitals were, on average, four percentage points (25 percent) more likely to undergo PCI treatment after their designated hospital began providing such services. We interpret this demand reallocation effect as reflecting a change in treatment modality among patients who would otherwise have received CABG surgery in the incumbent hospital. Estimating the corresponding effect for ACS patients in incumbent hospitals' catchment areas, we find that patients were two percentage points (10 percent) *less* likely to receive PCI after market entry. We interpret this demand augmentation result as a strategic response from incumbent providers to reallocate ACS patients to CABG surgery to account for reductions in patient referrals from focal hospitals. We provide empirical support that our findings are not driven by patient sorting, systematic downcoding of patient complexity, or selective market entry.

We corroborate mechanisms by exploring effect heterogeneity across PCI markets where new cath labs were opened. Specifically, we split our sample by market share losses of the incumbent provider, the capacity of new cath labs to accommodate ACS patients on a 24/7 basis, and the composition of hospitals' cardiologist workforce with respect to their preferences to assign patients to PCI after initial diagnostic assessment. While variation in the two latter factors is not associated with changes in propensity to use PCI, we do find that estimated effects are greater in magnitude where the incumbent provider lost a greater share of its ACS market to the focal provider. We interpret this finding as suggestive of that hospitals' induced demand responses intensified with the degree of competition for patients.

We find that market entry of new cath labs had adverse consequences for the quality of healthcare provided to patients in focal providers' catchment areas, including higher rates of patient death and subsequent interventions. We propose two different channels for this effect: inappropriate allocation of treatment to patients and variation in clinical quality between focal and incumbent providers. To test for treatment misallocation, we study cardiologists' treatment *recommendation* after diagnostic assessment (angiography) as an additional outcome. We find empirical support that recommendations also changed in favor of PCI after market entry. This finding is underpinned by further exploration of the relationship between the calculated SYNTAX II score (a clinician decision aid for choosing between PCI and CABG surgery) and recommendations for PCI among cardiologists in our sample, showing that focal providers are more likely to assign patients to PCI relative to incumbent hospitals conditional on relevant patient characteristics. In addition, we find that focal hospital providers have *higher* rates of adverse outcomes for inframarginal patients (i.e., patients who would have received CABG if their designated hospital did not have capability for PCI) but *lower* rates for patients with non-complex ACS compared to incumbent providers, despite having no observable differences in cardiologist proficiency. This finding suggests that hospitals used their market power to exacerbate treatment misallocation of complex ACS patients which in turn led to lower quality of care for some patients. We conclude that hospital providers appear to react to incentives to modify clinical management strategies when they have market power to do so, at least in settings where clinical guidelines are ambiguous and that this feature may have partially contributed to the respective rise and decline of PCI and CABG in Sweden over time.

Our paper contributes to the general literature on competition in healthcare markets (see, e.g., Abraham et al., 2007; Gaynor and Town, 2011), and more specifically to the scant body of work that explores consequences of market entry on the provider's behavior. In this domain, Cutler et al. (2010) study entry of cardiac surgery hospitals following a regulatory change in Pennsylvania and find evidence of "business-stealing" with shifts of market share from incumbents to entrants without an overall effect on market size. Similarly, Horn et al. (2022) show that hospital adoption of robotic surgery technology in the US settings both expands and reallocates the market to the entrants, whereas Ikegami et al. (2021) find that incumbent physicians exhibit strategic demand augmentation behavior following a technological acquisition in nearby hospitals in the context of Japan. Relatedly, modeling market entry by exploiting the scope of medical practice deregulation in the US, Currie et al. (2023) studies the effects of granting Nurse Practitioners (NPs) the ability to prescribe controlled substances on doctors' (GPs) opioid prescribing practice. Their study found that entry of NPs into the opioid prescribing market not only increases in areas with higher NPs but also spillover to the areas with larger concentrations of doctors, indicating both business-stealing and demand-augmentation behavior among different providers. Akin to the context we study, Li and Dor (2015) analyze hospital responses to entrants in PCI and CABG market following the rescindment of "certificate of need" (CON) regulation in the US, showing that market entry of cardiac surgery centers leads to risk reallocation of more severe patients to CABG surgery and less severe patients to less invasive PCI. Lastly, some papers explore consequences of market entry on productivity. For instance, Barro et al. (2006) and Kelly and Stoye (2020) study the entry of specialty hospitals providing cardiac and orthopedic surgery, respectively, on healthcare spending and patient health outcomes. Both these studies find that the entry of these providers results in lower healthcare spending without compromising patient outcomes.[3]

We extend this literature in several directions. First, we focus on entry in a regulated market setting with fixed prices and universal healthcare where providers are differentiated by healthcare technologies and have substantial discretion over treatment allocation. We leverage the unique richness of our clinical quality data to show that market responses lead to significant adverse demand reallocation effects in the form of increased treatment misallocation and lower quality of care. Furthermore, our

[3]Our work also relates to the more general literature on firms' responses to market entry of competitors. For example, Goolsbee and Syverson (2008) and Dafny (2005) study airline and hospital incumbents' responses to the threat of entry and find evidence of strategic entry-deterring investments by the incumbents. Ellison and Ellison (2011) find parallel results to Goolsbee and Syverson (2008) in the pharmaceutical incumbents following the loss of patent protection and Jackson (2012) analyzed responses of incumbent schools, specifically on teacher turnover and hiring of teachers following a nearby entry of charter schools.

context of local monopolies embodied by fixed hospital catchment areas enables us to rule out confounding demand-driven market mechanisms, such as patient choice of provider. Finally, we show that these findings are not only prevalent on the hospital level by exploring the behaviors of individual physicians in our data. Our results have welfare implications not just for public healthcare systems, but in more general contexts where place-based care is important and where competition may be impeded by other factors, including geographical and technological barriers.

Our findings have important implications for healthcare policy. In terms of the debate on healthcare centralization versus decentralization, much of the recent literature have focused on the former in terms of regionalization policies aiming to improve efficiency of healthcare production (see, e.g., Ramos et al., 2020, for an overview). For instance, Polsky et al. (2014) explore the effects of government regulation of entry in the home healthcare sector in the US and Avdic et al. (2024) examine the consequences of maternity ward closures on birth outcomes in Sweden. While it is well known that patients with non-complex ACS strongly benefit from PCI compared to medical therapy (see, e.g., Park et al., 2024), less is known about consequences for patients with more complex presentations. We show that decentralization in the form of geographical expansion of catheter-based treatment for heart attacks have negative consequences for inframarginal patients and relate to the general equilibrium effects in the form of productivity spillovers and externalities described in Chandra and Staiger (2007). Such unintended consequences are relevant when assessing welfare impacts with respect to treatment misallocation and overallocation from proliferation of new medical technology. Furthermore, we provide insights on the adverse impacts of the "medical arms race" (Hughes and Luft, 1991) with respect to technology-driven supplier-induced demand (see, e.g, Afendulis and Kessler, 2007; Iizuka, 2012; Clemens and Gottlieb, 2014), showing that it may also be present in healthcare systems with fixed prices, universal healthcare, and restricted consumer choice. Hence, strategic behavior of healthcare providers may exist even when providers are not directly competing over patients, highlighting the general importance of ensuring clear treatment protocols, consensus over clinical guidelines, and systematic quality control.

2 Institutional Setting

2.1 Healthcare in Sweden

Healthcare in Sweden is predominantly funded through direct income taxes raised by the three different levels of government: central, regional (21 county councils) and local (290 municipalities). The roles and responsibilities for providing healthcare are shared between the governments according to a scheme stipulated in the 1982 Swedish Health and Medical Service Act. Within each government tier, principals (elected politicians and bureaucrats) have substantial discretion in organizing the healthcare system in their administrative region, subject to a few general principles such as that all citizens are entitled to high-quality and accessible healthcare services based on their individual needs. Both county councils and municipality executive boards are political bodies that consist of representatives who are elected every four years.

The main responsibilities of the central government are to set general goals for national health policy, coordinate and provide advice to health and medical care providers, and to regulate prices and approval of new medical services, devices and drugs. Municipalities are mainly responsible for organizing long-term care for the elderly in their homes or in aged care facilities and to accommodate the needs of residents with chronic physical or mental disorders. Finally, the county councils are the main providers and financiers of healthcare in Sweden being responsible for primary and specialized healthcare on both the in- and outpatient basis in their region. Since the end of the 1990s, local and regional healthcare boards can contract out healthcare services to private providers in purchaser-provider split models. While outsourcing of healthcare services are common in the primary, outpatient and long-term care sectors, virtually all inpatient care is still operated by public providers.

The vast majority of healthcare spending in Sweden is paid for by county and municipal direct income taxes levied on local residents. Contributions from the central government are relatively small and mainly consist of providers pay-for-performance incentive schemes and interregional redistribution of resources. Each county council sets their own patient fees, although there is a national ceiling on the daily and annual amount a patient has to pay out of pocket to receive care at public and privately contracted healthcare providers.[4] Consequently, patient fees only account for around three percent of total spending on healthcare. All Swedish citizens are also covered by a statutory national sickness and disability insurance financed through employer social contributions. The insurance is relatively generous and replaces up to 80 percent of lost earnings and can often be topped up further for employees covered by collective agreements or through complementary private insurance plans. Hence, essentially all Swedish citizens have strong financial protection from both direct healthcare costs as well as indirect income losses from temporary or permanent work inability.

The decentralized structure and substantial autonomy of the county councils imply that Sweden has 21 concurrent healthcare systems in place. In addition, each county is made up by a set of mutually exclusive hospital catchment areas within which a *district* hospital is responsible for provision of inpatient healthcare services to residents in the area. Patients who require more advanced healthcare services that the district hospitals do not have capability to provide are referred to a larger *county* hospital of which there is one in each county. Finally, for tertiary care, such as advanced surgery (including CABG surgery), patients are assigned to one of six *regional* hospitals located across the country. Each of these hospitals are responsible for tertiary care across multiple counties (regions) based on its geographical location. Importantly, patients in this tiered system cannot freely choose their hospital but are normally assigned to the

[4]Primary care and specialist outpatient care attendances for patients 20-84 years of age pay between 100-400 Swedish kronor (SEK) (USD 10-40) and between SEK 250-450 (USD 25-45) per professional attendance, respectively, with a maximum of SEK 1,400 (USD 130) per annum. Individuals under 20 and over 84 are fully subsidized. For inpatient care, patients pay a maximum of SEK 130 (USD 13) per diem with no nationally regulated ceiling. A similar cost subsidy schedule exists for approved prescription medicines, where the maximum annual out of pocket cost is SEK 2,850 (USD 285). Dental care is fully subsidized for individuals under 23 years of age. Older age groups receive an annual support payment of SEK 300-600 (USD 30-60) earmarked for dental care and a variable subsidy for costs over SEK 3,000 (USD 300) from the social insurance agency. Some services and pharmaceuticals, such as breast and cervical cancer screening and contraceptive pills, are cost exempted. All figures refer to 2024 values. See also https://skr.se/skr/halsasjukvard/ekonomiavgifter/patientavgifter.

hospital whose catchment area they reside in and only referred to another hospital if their designated hospital is unable to provide the required services.

Financial responsibility for inpatient care is decentralized to the level of the individual hospital provider. Each hospital keeps its own budget, which is negotiated annually between the county council and the hospital board. Such agreements mainly consist of prospective global budgets for the time period we study in this paper.[5] A consequence of this system is that costs of interhospital patient transfers, both within and across counties, are charged by the treating hospital and billed to the hospital responsible for the patient. Hence, coupled with the global budgeting payment model which encourages cost-control, hospitals have strong incentives to treat patients in-house and to effectively utilize existing equipment whenever possible.

2.2 Treatment of acute coronary syndrome

Acute coronary syndrome (ACS), or heart attack, is one of the leading causes of death globally. ACS is caused by a sudden partial or complete blockage of one or more of the heart's blood vessels which could be fatal if not properly treated in the acute phase. There are also non-fatal consequences of ACS, including physical limitations, leading to reduced labor supply or unemployment, and reductions in the quality of life, such as onset of depression and other chronic health conditions (Luo et al., 2023; Hall et al., 2024). Recent advancement of medical technology and novel management strategies in the field of cardiology have led to major improvements in both survival and quality of life for individuals experiencing heart attacks (Cutler and McClellan, 2001).

The primary objective in treating patients with ACS is to restore blood flow to the heart as soon as possible. This result can be achieved through two different invasive medical procedures: Coronary Artery Bypass Graft (CABG) surgery and Percutaneous Coronary Intervention (PCI). CABG surgery, performed since the 1960s, is a highly-

[5] In the early 1990s, some county councils experimented with activity-based funding and purchaser-provider split models based on diagnosis related groups (DRG) that were augmented with stipulated cost controls such as volume thresholds. Most councils has since then reverted back to global capitation models due to the adverse incentives created by the DRG-based system, including upcoding and cream-skimming of patients (see, e.g., Anell, 1996; Janlöv et al., 2023).

invasive procedure in which cardio-thoracic surgeons install a surgically grafted artery to bypass a section of a blocked artery, thereby restoring blood flow to the distal part of the heart. More recently, PCI, a minimally invasive procedure using catheter-based methods, has emerged as a substitute technology for treatment of ACS. This procedure entails first dilating the obstructed blood vessel by means of inflating a balloon catheter that has been inserted through the skin, and subsequently reinforcing the damaged artery wall by placing a small metal mesh tube (stent) as a scaffold to maintain patency. PCI is performed by interventional cardiologists, a different clinical specialty than cardiac surgery, and provided in a catheterization laboratory (cath lab), whereas CABG surgery requires access to an operating theater.[6]

Clinical guidelines currently recommend PCI as the gold standard invasive treatment in most of ACS cases. This is especially true for acute episodes, such as ST-elevated myocardial infarction (STEMI), where rapid reperfusion therapy via (primary) PCI is critical for patient outcomes as most deaths occur within one hour from the onset of a heart attack (Sullivan et al., 2014). However, for cases with complex but stable lesions, including the left main coronary artery (LMCA) or blockages in three or more vessels, CABG is generally recommended as the primary treatment option (Mohr et al., 2013; Nagaraja et al., 2016; Mehta et al., 2019).[7] In contrast, PCI is considered the optimal treatment for non-complex lesions, a clinically mild form of ACS, where blockages are partial or only occur in one or two vessels. However, as described in the next subsection, consensus around the relative advantage of PCI versus CABG

[6] Non-complex ACS can also be managed with drugs via fibrinolytic therapy ("clot-busters"). In this paper, we focus on patients diagnosed with *complex* ACS to avoid conflation between different treatment effects. The reason is that we do not observe outcomes of patients who were prescribed fibrinolytic drugs in our data, which were likely to have changed with the expansion of cath labs in Sweden. Since PCI and CABG surgery are the only viable treatment options for patients with complex ACS presentations, focusing on this group therefore simplifies our empirical strategy described below.

[7] American Heart Association (AHA) guidelines in 1999 recommended CABG surgery for complex ACS cases although recent improvements in PCI technology reignited the debate on optimal treatment modality also for this patient group (see https://www.acc.org/latest-in-cardiology/articles/2019/12/17/08/40/pci-vs-cabg-in-patients-with-three-vessel-or-lm-cad). Numerous large scale, multi-center, trials were conducted to determine treatment recommendations, including the SYNTAX trial which provided evidence that CABG surgery is superior for complex lesions in the long run relative to PCI due to lower long-term mortality rates (Doenst et al., 2019). Both the American Heart Association (AHA) and the European Society of Cardiology currently recommend CABG for these cases (Amsterdam et al., 2014; Neumann et al., 2019).

during the time period we study (i.e., the 2000s) was highly contested and complex ACS patients were nevertheless often treated with PCI.

2.3 The proliferation of cath labs in Sweden

In the late 1990s, national guidelines on ACS treatment in Sweden stipulated that the provision of PCI should be exclusive to tertiary hospitals where capacity for cardiac surgery was also available. The stated reason for this policy was that in case of complications arising during PCI, timely access to a viable treatment alternative should be readily available to mitigate risks of serious complications or death. Moreover, there were also concerns among healthcare officials regarding the technical and professional capabilities of smaller district hospitals to provide safe PCI treatments.[8] At the time, patients in district hospitals were able to receive symptomatic treatment, fibrinolytic (drug) therapy and, if clinically indicated, coronary angiography, a diagnostic procedure to detect blockages in the coronary arteries. However, after being diagnosed, patients were generally referred to a tertiary hospital for therapeutic care. This context thus meant that both PCI and CABG surgery were essentially only provided in the few tertiary hospitals in Sweden at the end of the 1990s.

Figure 1 shows municipality-level maps of the CABG (left panel) and PCI (right panel) markets in Sweden in 2000. Diamond markers indicate the location of hospitals with capability for both PCI and CABG (PCI+CABG) while circles indicate hospitals with current or future capability for PCI (PCI-only). Different background colors indicate hospital catchment areas (markets) with respect to the specific treatment modality.[9] With a few notable exceptions, hospitals that offered CABG surgery in

[8]The regulations in our study are similar to the Certificate of Need (CON) regulation in the US. In the context of the US healthcare system, CON is intended as a regulatory instrument at the state level to maintain quality in the local healthcare market. Healthcare providers are required to obtain state approval before they can offer new or expanded services. The impact of CON regulation has been studied in several research papers, including Cutler et al. (2010) and Li and Dor (2015). CON laws currently apply in 35 states with local variations. See https://www.ncsl.org/research/health/con-certificate-of-need-state-laws.aspx for a review.

[9]Hospital catchment areas are not directly observed in our data. However, using geographical information on patient flows on the municipality level, we are able to assign patients to hospitals and trace out catchment areas for each hospital provider. This method has been used previously in several other papers, including Avdic (2016), Avdic et al. (2019), and Avdic et al. (2024). Compliance is generally very high (over 90 percent) and we corroborate the robustness of our main findings with

2000 were also the only hospitals that offered PCI, implying that the markets for both technologies almost completely overlapped.

[Figure 1 about here]

The number of PCI-equipped hospitals in Sweden expanded rapidly in the first half of the 2000s due to several factors. First, the clinical evidence and treatment recommendations which favored CABG over PCI were gradually weakened by the rapid advancements in PCI technology.[10] Furthermore, there was a growing concern among local healthcare planners that ACS patients in remote areas were unable to receive adequate medical treatment. Long travel times and the time-sensitive nature of the disease meant that many ACS patients were faced with inadequate treatment options. District hospital managers and healthcare officials therefore saw an opportunity to set up their own cath labs to provide better access to optimal ACS treatment.[11]

Finally, since tertiary hospitals were the only providers of both invasive ACS treatment modalities in their respective administrative areas, district hospitals had no choice other than to refer ACS patients to these existing providers. If costs of treatment for similar patients were on average higher in high-volume tertiary hospitals, for example, because of the availability and utilization of sophisticated equipment or specialized clinical staff (Jencks and Bobula, 1988), smaller district hospitals operating with lower budgets may have increasingly struggled to bear these referral costs. This is particularly pertinent in the present setting as improvements in PCI technology increased the patient population with indications for PCI and the practice of referring PCI patients likely became increasingly cost driving for district hospitals. Thus, the increased cost burden from ACS patient referrals was likely to have pushed district hospitals to invest in the establishment of on-site PCI capability.

respect to patient compliance in Section 6 below.

[10] In particular, the argument that timely access to an operating theater was necessary as a backup option in case a PCI procedure failed was not supported by available data (see, e.g., Dehmer et al., 2007). Inpatient records from tertiary hospitals suggested that very few PCI treatments were followed up by CABG surgery in hospitals with capacity for both treatment modalities.

[11] See for example current NICE ACS guidelines which state that primary PCI is optimal for patients with acute ST-segment-elevation myocardial infarction (STEMI) if treatment can be administered within 12 hours from symptom onset: https://www.nice.org.uk/guidance/qs68/chapter/Quality-statement-6-Primary-PCI-for-acute-STEMI.

As a consequence of these developments, a number of district hospitals established their own cath labs in the early 2000s, thereby retaining control over ACS patient populations in their respective catchment areas. To illustrate the magnitude of this expansion, Figure 2 shows the CABG and PCI markets in Sweden in 2010. In comparison with Figure 1, the number of hospitals in Sweden with PCI capacity doubled from 14 to 30 cath labs between 2000 and 2010. Hence, while the number of hospital providers with CABG surgery capability remained unchanged throughout the decade, the market for PCI became significantly less concentrated due to the rapid proliferation of new cath labs.

[Figure 2 about here]

Figure 3 shows trends in the total number, shares and growth rates of PCI and CABG procedures (complex and non-complex) in Sweden, and the number of hospital providers for each treatment modality between 2000 and 2010. Initially, the number of PCI and CABG procedures were comparable. Over time, however, PCI gradually began to dominate the ACS market, eventually reaching a share of more than 80 percent at the end of the period. Furthermore, as suggested by the bottom right panel, PCI began rising in popularity at around the same time as the expansion of cath labs. Although part of the increase in PCI was attributable to an increase in the overall number of patients who received invasive treatment, the negative growth rate for CABG surgery suggests that some of this increase was related to substitution of PCI for CABG.

[Figure 3 about here]

3 Empirical strategy

3.1 Defining hospital catchment areas

Our empirical approach exploits the decentralized setting of the Swedish healthcare system in which patients are restricted in their choice of hospital and where hospitals have significant autonomy to organize care in their respective catchment areas. We are primarily interested in the treatment modality provided to patients diagnosed with complex ACS based on their place of residence at the time of symptom onset. To formally describe the approach, we first introduce some notation and definitions. At each point in time $t \in T$, complex ACS patient $i \in N_{jt}$ residing in municipality $j \in J_{hr}$ is served by a hospital $h \in H_r$ belonging to regional PCI market $r \in R$, where $\sum_j N_{jt} = N_t$, $\sum_r H_r = H$, and $\sum_r \sum_h J_{hr} = J$ are the total number of complex ACS patients, hospitals and municipalities in Sweden at time t, respectively.[12] Each hospital serves multiple municipalities which together constitute the hospital's administrative catchment area. No municipality is served by more than one hospital. Catchment areas and PCI markets are fixed over time, but patients may be referred to another hospital in the same region if their designated hospital does not have capability to provide the required treatment. Importantly, this capability varies over time as new cath labs enter the market. For each regional PCI market entry, we define the time of cath lab opening to be equal to t^*.

Hospitals are categorized as either *PCI-only*, meaning that they can only provide PCI but not CABG, or *PCI+CABG*, meaning that they can provide both PCI and CABG.[13] While the latter type does not change over time, the former type consists of *focal* hospitals that open a cath lab during the study period. When a focal PCI-only hospital opens a cath lab, they retain their market share of ACS patients that were previously referred to an *incumbent* PCI+CABG hospital for treatment. Based on this classification, we assign all municipalities to one of three time-invariant and mutually exclusive catchment area groups within a regional PCI market, $g_r = \{inflow_r, outflow_r, control_r\}$. These are defined (for a given PCI market) as:

[12] In our analysis, we are only able to analyze effects in regional PCI markets where an opening of a cath lab actually occurred during our analysis period. This means that $R_{sample} \subsetneq R_{population}$ and empirical results are therefore only internally valid for this subset of regions in Sweden. However, as indicated in Figure 2, the expansion of cath labs was geographically spread out, meaning that our estimation results are likely to be nationally representative.

[13] There are no hospitals with capacity for CABG but not for PCI. Moreover, hospitals that did not have capacity for either procedure throughout the study period are not relevant for our approach since our sample frame includes only patients with clinical indications for PCI or CABG. Municipals served by these hospitals are therefore assigned to a hospital in the same region that offered PCI based on observed patient flows. See Section 4 for details.

(i) *Inflow area:* ACS patients in this municipality are referred to a PCI+CABG hospital for periods $t < t^*$ and served by a PCI-only hospital when $t \geq t^*$. The PCI-only hospital experiences an increase in its capability to treat ACS patients when it opens a cath lab at time t^*.

(ii) *Outflow area:* Patients in this municipality are served by a PCI+CABG hospital for all $t \in T$. The municipality is not directly affected by the opening of a cath lab. However, the hospital provider serving the outflow area experiences a reduction in ACS patients from an inflow area when a cath lab opens at time t^*.

(iii) *Control area:* Patients in this municipality are served by either a PCI-only or a PCI+CABG hospital for all $t \in T$. The hospital's capability to treat patients remains the same and it does not experience a reduction in ACS patients from an inflow area when a cath lab opens at time t^*.

Figure 4 provides a conceptual illustration of provider pathways to PCI treatment for ACS patients in each of the three types of catchment areas before and after the opening of a cath lab in a regional PCI market.

[Figure 4 about here]

3.2 Modeling regional PCI markets

To study how changes in hospital capability to treat ACS affected patients' treatment assignment, we first identify focal hospitals that opened a new cath lab, and when each opening took place. To this end, we combine information on patient flows from our data source, described in Section 4, with evidence of openings from public sources, such as newspapers, periodicals, and policy documents. In total, we identify and verify 14 new cath labs in hospitals between 2000 and 2010.[14] However, our empirical approach requires a minimum pre-treatment period to allow for estimation of causal effects. We

[14]The openings occur in S:t Göran (in 2000), Borås (2000), Trollhättan (2000), Västerås (2000), Jönköping (2001), Kristianstad (2001), Gävle (2001), Helsingborg (2001), Danderyd (2003), Kalmar (2003), Halmstad (2004), Sunderbyn (2004), Karlstad (2005) and Sundsvall (2008) hospitals.

must therefore exclude six hospitals and associated catchment areas that opened cath labs in the first year of our sampling period: S:t Göran, Borås, Trollhättan, Västerås, Jönköping, and Kristianstad hospitals.

Another technical issue relevant for our econometric approach is that it is necessary to link each focal hospital to specific incumbent and control hospitals in order to define counterfactual scenarios. In other words, we need to specify regional PCI markets so that we can identify which hospitals were affected and unaffected by a cath lab opening, respectively. To this end, we utilize the catchment area level data to split each market entry into mutually exclusive PCI markets, such that each market comprises catchment areas of one focal hospital, one incumbent hospital, and at least one nearby unaffected control hospital. This setup enables us to analyze both the separate effects of market entry for each regional PCI market, including only catchment areas that constitute the specific market, as well as the combined average effect, using the full sample.

Figure 5 plots compliance shares of ACS patients receiving PCI treatment in their designated hospital by catchment area type and over time. Each panel represents a separate regional PCI market in which a cath lab opened and where time has been re-centered around the quarter of market entry. As expected, shares in outflow and control areas are close to one and largely constant over time. In contrast, patients residing in inflow areas do not receive PCI treatment in their designated focal hospital prior to market entry. However, once a cath lab is opened in the focal hospital we observe a discontinuous increase in the share of patients being treated locally. The magnitude of these trends varies across markets, with some exhibiting a relatively modest initial increase and only gradually reach full compliance over time (Danderyd, Halmstad, and Gävle) while others reach full compliance immediately after market entry (Kalmar, Karlstad and Sundsvall). This heterogeneity is a consequence of that not all cath labs opened with 24/7 access; something we explore in further detail below.

[Figure 5 about here]

3.3 Econometric model

Using the catchment area classification and the regional PCI market definition outlined above, we set up and estimate a two-way fixed effects regression model for the share of complex ACS patients treated with PCI residing in municipality j belonging to PCI market region r in time period t as a function of catchment area type and timing of market entry of a regional cath lab. Our baseline model specification is

$$PCI_{jrt} = \alpha + d_j \times I_r(t \geq t_j^* : j \in r)\beta + (\lambda_r \times t)\gamma_r + \lambda_t + \epsilon_{jrt}, \tag{1}$$

where PCI_{jrt} is the risk-adjusted[15] share of PCIs in municipality j, market region r, and year-quarter t. The binary indicator d_j is equal to one if the patient's municipality of residence j is affected by the market entry (i.e., belongs to an inflow or outflow area) and zero otherwise (i.e., belongs to a control area). Similarly, $I_r(\cdot)$ is equal to one for patients presenting at a hospital in PCI market r after market entry and zero otherwise. In the context of the DID framework, d_j is the "treatment" group indicator and $I_r(\cdot)$ is the "post" indicator for treatment onset, defined at the regional PCI market level. Consequently, β is the DID estimator capturing the combined average effect of cath lab market entry on the propensity to receive PCI among patients in inflow and outflow areas across all regional PCI markets. Finally, time and market fixed effects interacted with linear time trends are included in the model to adjust for global and region-specific trends in the use of PCI over time.

Estimation of Equation (1) is informative about the *net* effect of a cath lab market entry on the change in the propensity to treat patients with PCI in inflow and outflow areas, relative to control areas. To study responses by area type, we extend our baseline model to allow for the estimation of separate effects in inflow (i.e., the *demand reallocation* effect) and outflow areas (i.e., the *demand augmentation* effect),

[15] We employ an Empirical Bayes Shrinkage (EBS) estimator to account for case-mix variation and variation in case numbers across municipalities and over time. To this end, we estimate a two-level mixed effects model for municipality PCI shares as a function of fixed region (r) and random municipality (j) intercepts and a set of fixed regressors reported in Table 1. We have also estimated corresponding individual-level linear probability models for the event that a complex patient i is treated with PCI with similar results.

respectively. Specifically, we estimate

$$PCI_{jrt} = \alpha + d_j^{In} \times I_r(t \geq t_j^*)\beta_{In} + d_j^{Out} \times I_r(t \geq t_j^*)\beta_{Out} + (\lambda_r \times t)\gamma_r + \lambda_t + \epsilon_{jrt}, \quad (2)$$

where d_j^{In} and d_j^{Out} are indicator variables and β_{In} and β_{Out} are corresponding DID estimators for patients residing in- and outflow areas, respectively.[16]

The demand reallocation hypothesis posits that patients residing in inflow areas should be more likely to be treated with PCI ($\beta_{In} > 0$) after a cath lab opens in their designated hospital, since focal hospitals have incentives to treat patients in-house. In contrast, the sign of the demand augmentation effect for patients in outflow areas is theoretically ambiguous, as it will depend on the relative strength of two counteracting mechanisms. On the one hand, if the demand reallocation effect is large, incumbent hospitals may attempt to augment demand in their catchment areas to increase rates of CABG surgery (i.e., decrease the PCI rate; $\beta_{Out} < 0$) to ensure efficient use of their operating theaters. On the other hand, incumbents may also attempt to induce a higher local demand for PCI due to the loss of a portion of their previous PCI market to a focal hospital (i.e., increase the PCI rate; $\beta_{Out} > 0$). An implication of this ambiguity is that the net effect from Equation (1) should be weakly positive ($\beta \geq 0$), implying that the share of CABG procedures should either remain the same or drop, but never increase, after a cath lab market entry.[17]

4 Data

We use patient-level data for years 2000–2010 from the Swedish Coronary Angiography and Angioplasty Registry (SCAAR) in our empirical analysis. SCAAR is a national clinical quality registry covering all diagnostic and interventional cardiac catheterization procedures conducted in Swedish hospitals.[18] The registry is collected prospec-

[16] Conditioning on r for $I_r(\cdot)$ in Equation (2) is implicit for brevity.

[17] This conclusion stems from that the demand augmentation effect is a response to the demand reallocation effect, and should hence never exceed the latter.

[18] The database was first established in 1990 but did not include all PCI-equipped hospitals in the country until 2000. We focus on the years between 2000 and 2010 as the expansion of cath labs

tively and includes a rich set of patient clinical and demographic characteristics, such as age, gender, ACS type (unstable angina, NSTEMI, STEMI), location and severity of arterial blockages (single- or multi-vessel, complex or non-complex), lifestyle factors (BMI, smoking status), relevant comorbidities (hypertension, renal function, diabetes, COPD), and medical history (previous infarctions and interventions). For each case, SCAAR also records the treatment recommendation by the attending clinician based on diagnostic information from a coronary angiogram (PCI, CABG surgery, or no coronary intervention), whether the patient received PCI treatment, and a set of clinical endpoints (patient death, re-infarction, and subsequent interventions). Information on medical treatments provided to patients other than angioplasty or angiography are not recorded in the registry.

We restrict our analysis to patients with complex coronary artery lesions[19] for three important reasons. First, given the severity of the condition, the only feasible treatment options for these patients are PCI or CABG surgery.[20] Restricting our sample to complex patients therefore allows us to reduce the decision problem to a binary choice. This sampling frame considerably simplifies interpretation of estimated coefficients from our models, in particular as we do not observe whether a patient received CABG in our data. Second, our data does not include ACS patients that neither received angiography (a diagnostic procedure) nor angioplasty (an intervention). This is unproblematic for complex patients who always receive angiography to identify and assess blocked arteries. However, patients with non-complex lesions are not always diagnosed using angiography and may thus not be included in the register. Focusing on patients diagnosed with complex ACS allows us to compare and estimate treatment decisions without incurring selection bias from censored (missing outcome) and truncated (missing data) patient data. Finally, we focus on complex ACS presentations

mainly occurred over this time period.

[19]A complex lesion is generally defined as the presence of blockage in the left main coronary artery or multiple blockages in three or more vessels (Riley et al., 2020). Blockages are defined and classified in the data by the physician responsible for performing the coronary angiography (angiographer) and based on visual inspection of an angiogram; a series of X-ray scans of the coronary arteries.

[20]Medical management using fibrinolytic drugs, or so-called "clot-busters", to open clogged arteries are not indicated in complex patients (Montalescot et al., 2013).

since the optimal treatment regime for this patient group was subject to considerable controversy during the time period we study (see, e.g., Taggart, 2006). This ambiguity is particularly relevant for our analysis as we are interested in supplied-induced demand market entry responses from hospital providers.

We furthermore exclude patients diagnosed with STEMI, who require rapid reperfusion therapy for which PCI is the preferred option. Finally, we also drop patients over 80 years of age from the analysis since these patients often have multiple comorbidities, frailty or other geriatric conditions that limit therapeutic options and increase complications rates. Our final sample consists of roughly 65,000 cases across all years. Table 1 provides sample summary statistics of the included variables by catchment area type. Average patient characteristics and outcomes are balanced across area types.

[Table 1 about here]

5 Results

5.1 Main results

Figure 6 shows descriptive evidence of the impact of a cath lab opening in a focal hospital on the propensity for patients to receive PCI treatment before and after market entry. Each panel refers to a different PCI market, except for the bottom right panel which displays pooled results across all markets. Separate propensity estimates are plotted for inflow and outflow areas with 95 percent confidence indicated by shaded areas. For ease of comparison across panels, estimates are indexed relative to the respective control area in the quarter prior to market entry, which is set to one.

The figure suggests that, although sometimes volatile, the trends for in- and outflow areas do not portray systematic deviations from the control group in the period leading up to market entry. With respect to the period after market entry, we observe varying responses across both PCI markets and catchment area types. Inflow areas in Kalmar, Karlstad, and Sundsvall markets exhibit discontinuous, large, and permanent increases in relative PCI shares of more than 20 percent after market entry. Responses are more muted in Danderyd and Helsingborg, or follow a more complex pattern as in Halmstad and Sunderbyn. The magnitude of responses to market entry is strongly correlated with the degree of focal hospital compliance from Figure 5, suggesting that market power is an important contributing factor in determining the strength of response. Corresponding results for outflow areas generally indicate weaker and more transient responses to market entry. Finally, the pooled estimate indicates a relative increase in the PCI share of around 10 percent in inflow catchment areas, while the effect for outflow areas is somewhat smaller in magnitude.

[Figure 6 about here]

Table 2 presents formal regression results from estimation of our DID model. Specifically, the first two columns report coefficient estimates for the combined net effect from Equation (1). The estimate for the interaction term in column (1) is interpreted as that opening a cath lab in a focal hospital increases the relative share of complex ACS patients that receive PCI treatment in in- and outflow areas by, on average, one percentage point, or five percent, compared to control areas. The estimate is not statistically significant but remains qualitatively similar after adjusting for the set of patient case-mix control from Table 1 and linear trends in PCI use over time.

The last two columns in the same table report separate effects for inflow and outflow areas from Equation (2). The former, demand reallocation, effect is positive and statistically significant, implying that complex ACS patients in inflow areas were, on average, around four percentage points more likely to be undergo PCI after a cath lab was opened in their designated hospital. This estimate corresponds to an increase of 25 percent or around 110 additional PCIs provided to patients each year across inflow areas in our sample. Assuming that these patients would otherwise have received CABG, this substitution effect is substantial. In contrast, the corresponding demand augmentation effect estimate for outflow areas is two percentage points, or around half of the inflow effect, corresponding to a reduction of only 40 PCIs per year. Since incumbent hospitals are multi-technology providers with capability for both PCI and CABG, this result may reflect ambiguity in responding to shrinking market shares for both treatment modalities.

[Table 2 about here]

Table 3 presents heterogeneous effects by PCI market where each column refers to results for a separate cath lab market entry, except for the first column which reproduces the main DID effect estimate from Table 2 for comparison. Most estimates for inflow areas are positive with magnitudes ranging between 2–10 percentage points. Estimates for the two exceptions, Helsingborg and Sunderbyn, are likely derived from poorly fitted pre-trends rather than arising from genuine treatment effects as indicated in Figure 6. In contrast, estimates for outflow areas are generally smaller in magnitude and exhibit varying signs, suggesting that responses were either muted or reflect conflicting incentives for providing both PCI and CABG surgery. We investigate potential mechanisms that could explain these differential responses below.

[Table 3 about here]

5.2 Effect mechanisms

Market reallocation

One possible reason for why hospitals varied in their responses to assign patients to PCI after a cath lab opened may be that the intensity of competition for patients within a regional PCI market may depend on the share of the market that was reallocated. The ACS market shares that incumbent hospitals lost after market entry varied substantially. For example, when Karlstad hospital opened a cath lab in 2003, the incumbent, Örebro hospital, lost more than half of its ACS market, while Lund hospital, the incumbent for Helsingborg hospital, only lost around 20 percent. Such variation in market contexts may have incited different provider responses if larger market share reallocations were associated with higher stakes.

To test the market share reallocation hypothesis, the top set of panels in Figure 7 shows a scatterplot relating the DID effect sizes from Table 3 to the incumbent's market share loss in each PCI market. Market share loss is defined as the share of complex ACS patients residing in the inflow area compared to the total complex ACS market in both in- and outflow areas in the year before market entry.[21] The fitted linear relationship suggests a positive relationship between the two factors, implying that the demand reallocation effect was stronger in areas with greater incumbent market share losses. In other words, the magnitude of provider response to market entry increased with the extent of ACS patient reallocation in the local PCI market.

Emergency capability

Patient compliance may also have been an explicit factor in affecting hospitals' responses to provide PCI in inflow areas. In particular, newly opened cath labs varied in their capability to provide 24/7 patient access. This means that ACS patients in inflow areas where non-24/7 access cath labs opened had to either wait for treatment until the next available appointment or be referred to the incumbent hospital. If focal hospitals with non-24/7 cath lab access had limited control over where their patients ended up receiving treatment, this would also likely erode their capacity to reallocate demand for PCI treatments. The middle set of panels in Figure 7 displays effect sizes as functions of the share of PCIs provided to emergency ACS patients in focal hospitals, respectively. We find no evidence that the demand reallocation effect was more pronounced in areas with greater emergency access capabilities. This result suggests that, unlike market shares, emergency access to a cath lab was not an important enabler for reallocating demand for PCI among hospital providers.

Cardiologist practice styles

The results are so far silent about the decision-making processes from which they are derived. On the one hand, they could be based on formal or informal directives

[21] To account for imperfect compliance across newly opened cath labs, we adjust the incumbent's market share loss by a factor equal to one minus the share of patients that still received PCI in the incumbent hospital in the year after market entry. For example, while Danderyd hospital's market share amounted to almost 80 percent of the total market for both inflow and outflow hospitals, it only treated around 40 percent of PCI in the first year after a cath lab was opened. Hence, the incumbent's market share loss in this case is equal to $0.80 \times 0.40 = 0.32$.

determined by hospital management. In contrast, effects could also be driven by individual physicians' treatment preferences, or practice styles. Provider practice styles have been shown to be important in explaining variations in healthcare use (see, e.g., Molitor, 2018; Currie and MacLeod, 2020; Avdic et al., 2023). In the current context, an increase in PCI treatment propensity in inflow areas could occur if cardiologists employed in focal hospitals are more likely to favor the application of PCI over CABG surgery relative to cardiologists in incumbent hospitals.

We characterize cardiologists' preferences for PCI using a mixed-effects model for the decision to recommend PCI after diagnostic assessment. We restrict our estimation sample to observations prior to market entry and adjust outcomes for patient characteristics, hospital-level effects and average use of PCI in the specific market. The estimated physician random effects are then used to test whether relatively more PCI-favoring cardiologists are more likely to be employed in focal hospitals using a median-split cutoff.

The bottom set of panels in Figure 7 compares the proportion of PCI-favoring cardiologists by PCI market. We find no clear or systematic association between our DID effects and the proportion of cardiologists with preference for PCI. Hence, this suggests that the demand reallocation and augmentation effects are unlikely to be channeled through individual cardiologists' preferences for specific treatment modalities.

[Figure 7 about here]

5.3 Quality of care

We next study whether the openings of new cath labs were associated with changes in health outcomes among complex ACS patients in affected areas. We first estimate market entry effects for a set of clinical quality indicators relevant for coronary interventions. Next, we investigate if these effects reflect inappropriate diagnostic patient assessments or variation in the quality of care across hospital providers.

Table 4 presents results from re-estimating our DID model for three patient health outcomes: reinfarction (i.e., repeat heart attack), revascularization (i.e., repeat intervention), and patient death within one year from the initial intervention. Point estimates for the net effect for both in- and outflow areas (odd-numbered columns) suggest positive and statistically significant, albeit small in magnitude, impacts of cath lab opening for two out of the three outcomes. Studying the effect estimates decomposed by area type (even-numbered columns) highlight important heterogeneity between focal and incumbent hospital providers. Specifically, ACS patients in inflow areas experienced an estimated 1.2 percentage point (20 percent) increase in mortality and a 0.6 percentage point (17 percent) increase in the likelihood of a new intervention after a cath lab opened in their hospital. In contrast, estimates for outflow areas are near-zero and statistically insignificant for all three outcomes.

[**Table 4 about here**]

The increased risk of a negative health outcome together with the results for the propensity to receive PCI for complex ACS patients in inflow areas suggest that these outcomes may be related. In the following, we explore two possible mechanisms that could explain this relationship. First, a higher likelihood for patients to receive PCI after market entry may have constituted inappropriate treatment and resulted in negative health consequences for this patient population. We test this conjecture by evaluating whether the angiographer's assessment (i.e., treatment *recommendation*) changed in accordance with treatment *propensity* after market entry. Columns (3) and (4) in Table 5 presents the results from this analysis with corresponding estimates for the propensity to receive PCI treatment reproduced in columns (1) and (2) for comparison. Point estimates for PCI treatment recommendation in both area types are comparable and not statistically distinguishable from PCI treatment propensity. This suggests that the market entry effect on PCI propensity arose from changes in the diagnostic assessment of the patient prior to treatment and strengthens the conclusion that these (inframarginal) patients would otherwise have received CABG surgery.

[**Table 5 about here**]

To characterize inframarginal patients in our sample, we apply the SYNTAX II score, which is an online decision aid to help physicians choose between PCI and CABG for patients with complex lesions (see, e.g., Escaned et al., 2017).[22] Patients' demographic and clinical information, including age, sex, creatinine clearance levels, and location and severity of lesions, are converted into points mapped from four-year mortality predictions for patients undergoing PCI or CABG surgery. The combination of SYNTAX II scores for each patient and treatment modality and the observed treatment assignment is informative about the extent to which patients were incorrectly assigned to undergo PCI.

Unfortunately, the critical information required to calculate the SYNTAX II score is only available from 2005 onward in our data. Due to this limitation, we use data between 2005–2010 to study the relationship between SYNTAX II scores for CABG surgery and PCI and treatment recommendations after diagnostic assessment separately for in- and outflow areas. Figure 8 displays a binned scatterplot of this relationship where patient-level SYNTAX II scores for PCI have been subtracted from the corresponding scores for CABG so that a positive value indicates a higher mortality risk for CABG surgery relative to PCI. In general, a higher net score is associated with a higher likelihood to be assigned to PCI as expected. However, the overlaid slope (fitted using a local linear estimator) is steeper for inflow areas than for outflow areas, starting to diverge around a net score of around -5. Cardiologists working in focal hospitals hence appear to, on average, assign more PCI to patients conditional on the latter's clinical profile relative to cardiologists in incumbent hospitals. This divergence may be expected given that the on-site presence of cardio-thoracic surgeons in incumbent hospital encourages more deliberation, for example through so-called "heart teams" in the form of multidisciplinary team meetings.[23]

[22]The SYNTAX II score was developed to quantify the severity of ACS patients with complex lesion and reflects the difference in short-term mortality risk following PCI and CABG surgery. See Head et al. (2014) for more information. See https://www.ecri-trials.com/studies/syntax-ii/syntax-score-ii for a summary of how the score is calculated from individual patient characteristics.

[23]Emergence of the Heart Team approach in treating cardiovascular disease was prompted by the need to "optimize the management of complex patient care issues" due to the abundance of new therapeutic methods and burgeoning amount of scientific information which risk that individual physician biases take overhand in clinical decisions (Holmes et al., 2013). The requirement of a case-based Heart

[Figure 8 about here]

Another reason for the increase in adverse health outcomes among ACS patients in inflow areas is related to that cath labs opened in focal hospitals may have been of lower quality than existing cath labs in incumbent hospitals. Indeed, some of the regulator's hesitation around permitting non-tertiary hospitals to provide PCI treatment was based on quality considerations, including provider technical capabilities and individual physician experience. The trade-off between access and quality have been previously documented in the literature (see, e.g., Afendulis and Kessler, 2007).

To study this explanation, we compare composite rates of patient deaths, reinfarctions, and revascularizations for three different groups: non-complex patients, inframarginal patients, and attending cardiologists, respectively. Comparing outcomes of patients with non-complex lesions across focal and incumbent hospitals is informative about differences in general quality of care between provider groups. Following the pattern we observed in Figure 8, we characterize inframarginal patients as those with net SYNTAX II scores between -5 and 15 (i.e., where the relative propensity to be assigned PCI diverges for focal and incumbent providers). We argue that inappropriate choice of treatment is likely to be the main driver of the results if it is mainly these patients who experience worse outcomes in the post-entry period, while overall provider quality is more likely to explain our findings if adverse outcomes are more prevalent among non-complex patients in focal hospitals. Finally, we classify cardiologists according to their risk-adjusted rates of patient deaths and reinfarctions and compare whether lower quality cardiologists are more likely to be employed in focal hospitals after cath lab market entry. Following Chandra et al. (2016), we extract the physician-specific effect on composite clinical outcomes prior to market entry, adjusting for patient characteristics and comorbidities as well as hospital-specific factors. We then characterize "proficient" cardiologists by a median split of the estimated physician-specific effect.

Table 6 shows the results both for each market separately and pooled across all

Team has been codified in guideline documents of the 2010 European Society of Cardiology and the European Association for Cardio-Thoracic Surgery Guidelines for Coronary Revascularization and the 2012 ACC/AHA Guidelines for Coronary Artery Bypass Grafting surgery. Unfortunately, we do not have access to information whether a case was discussed in a Heart Team in our data.

markets. In terms of non-complex complication rates, focal hospital providers seem to outperform incumbent providers in all cases but one, which is also reflected in the pooled estimate. This result is reversed for inframarginal patients, who, on average, experience higher rates of adverse health outcomes in focal hospitals. Finally, incumbent hospitals tend to have a slightly higher share of proficient cardiologists, on average, although the differences in proficiency rates are statistically indistinguishable from zero. While we are unable to pin down exact mechanisms, these findings are in line with the hypothesis that the higher rates of adverse patient outcomes in focal hospitals after market entry of a cath lab was driven by an increase in inappropriate treatment allocations for inframarginal patients.

[**Table 6 about here**]

6 Robustness checks

In this section we summarize a set of robustness checks to study the sensitivity of our main results to various threats to identification. Our main identification assumption is that patients comply with their hospital assignment as determined by their area of residence. If patients systematically present at hospitals that are more likely to provide them with their preferred treatment, our estimates would not be exclusively driven by supply-side factors. There are at least two reasons for why patient selection could occur in practice. First, patients residing in inflow areas but near the catchment area border to an outflow hospital may be faced with a shorter distance to the latter hospital. Second, patients with more severe health conditions may feel inclined to visit tertiary hospitals located in outflow areas because of their perceived better ability to accommodate difficult cases.

To investigate whether patient compliance with their designated hospital provider is related to travel distance, we first calculate differences in euclidean distances between municipality midpoints and each of the inflow and the outflow hospitals in inflow catchment areas. We next relate this relative distance to the propensity to attend the inflow hospital. The top panel of Figure A.1 in Appendix A shows a scatter plot of the raw relationship between average compliance with the designated hospital and differential distance to the inflow hospital aggregated over all post-opening time periods. The fitted regression line shows a gradual decrease in compliance as municipalities are situated relatively further away from the inflow hospital. The bottom panel of the same figure displays the gradual change in compliance over time by ventiles of the relative distance distribution. Markers indicate different follow-up periods and the vertical dashed line shows cumulative average compliance shares starting from the bottom of the plot. Compliance increases sharply in the first quarters from around 0.4 in the opening quarter to around 0.8 two years later. We include relative distance as an additional control variable in a robustness check described below.

Next, we consider patient severity as a potential cause for non-compliance to hospital assignment. To provide a measure of patient severity, we again make use of the SYNTAX II score introduced in the previous section. Figure A.2 presents different representations of the distributions of mortality-augmented SYNTAX II scores for compliers and non-compliers in this restricted sample. First, the top left panel shows that the probability density distributions of augmented SYNTAX II scores for both groups are nearly identical. The Q-Q plot in the top right panel generally echoes this interpretation. The bottom left panel plots compliance shares against the ventiles of the SYNTAX II score distribution, while the bottom right panel shows the results from a pooled OLS model where we regress compliance on the augmented SYNTAX II scores conditional of a set of patient characteristics. If patient compliance with hospital assignment was based on case severity, we would expect to see a systematic relationship between compliance and mortality differences. However, the plots indicate no such relationship.

Hospitals may seek to change the number of patients eligible for either treatment, PCI or CABG, by manipulating or misrepresenting diagnostic information determining patient complexity. In particular, inflow hospitals may attempt to "downcode" (i.e., increasing the share of non-complex cases) patients who are eligible for PCI but not

CABG surgery. Outflow hospitals, on the other hand, have incentives to "upcode" (i.e., increasing the share of complex cases) patients in order to increase dwindling CABG numbers from lost market shares. To study whether up- or downcoding occurs as a result of cath lab market entry, we study whether the share of complex cases changed discontinuously at the time of the opening. Panels (a) and (b) in Figure A.3 plot the total caseload of complex ACS patients and the PCI shares of complex and non-complex cases in inflow and outflow areas, respectively. The drop line plot at the bottom of the left graph shows the year-to-year percentage changes in the share of complex patients by catchment area type relative to the controls and the top and bottom of each bar in the right figure indicate the share of PCIs in non-complex and complex ACS cases, respectively. The pattern displayed in both panels give no indication of systematic changes in the share of complex ACS patients or PCI shares around the time of opening of the cath lab, expect for the previously established increase in the average PCI share of complex cases in inflow areas.

Lastly, Table A.1 reports results from a set of robustness checks concerning the sensitivity of our main findings for alternative specifications of our empirical model. The first two columns of the table reproduces our main estimates on the propensity to treatment complex ACS patients with PCI from Table 2 for comparison. To study whether potential queues may have affected treatment choice, we construct a proxy variable for wait lists by including a lagged patient list for each catchment area as an additional control variable. The results are displayed in Columns (3)-(4) of the table. The next two sets of regression output assesses the sensitivity of our results with respect to provider compliance by excluding weekend admissions and controlling for relative distance from the inflow hospital (as highlighted above). Finally, the last two sets of columns in the table restricts our sample to only include patients' first recorded hospital admission and to patients under 70 years of age. Our main results are robust to each of these modifications.

7 Conclusion

Understanding healthcare providers decisions to innovate are important to model processes of technological substitution and the proliferation of new medical technology, including factors that lead to over- or underadoption. In this paper, we study how single- and multi-technology hospital providers in Sweden responded to the rapid expansion of catheterization laboratories ("cath labs") to treat heart attacks in a context with local monopolies, competing health technologies, and professional uncertainty about optimal treatment strategies. Results from our analysis suggest that opening a new cath lab triggered supplier-induced demand responses that increased local hospitals' propensity to treat patients with non-surgical catheter-based methods (PCI) at the expense of surgical methods (CABG). This substitution effect is linked to higher rates of adverse health events for impacted patients, likely triggered by an increase in inappropriate treatment assignment. We conclude that market structures that enable providers to exert considerable control over patient management may cause inefficiencies in the adoption and application of new medical technology.

Our findings have important policy implications for healthcare system efficiency. First, our paper nuances the debate around the trade-offs surrounding healthcare regionalization policies. The decentralization of cath labs was overall welfare-improving since more patients experiencing acute coronary syndrome (ACS) were able to access additional treatment options (see, e.g., Cutler and McClellan, 2001; Pursnani et al., 2012; Hagen et al., 2015). Our results are based on the group with complex ACS for whom a subset of patients would have received surgical treatment if a cath lab had not opened in their local hospital. Therefore, whether effects from regionalizing healthcare are beneficial or not critically depends on a range of clinical factors, such as time-sensitivity and severity of the medical condition (see, e.g., Avdic, 2016; Avdic et al., 2019, 2024).

Our results also speak to the question of the optimal diffusion rate of new medical technology by linking market entry to adverse impacts of the "medical arms race" (Hughes and Luft, 1991) with respect to technology-driven supplier-induced demand.

Similar to the case of robotic surgery studied in Horn et al. (2022), we show that hospital technology adoption reallocates the market for care. In addition, we also provide evidence on the patient group subjected to market reallocation and that overadoption of new technology is not only costly, but may also impact quality of care provided.

Finally, our paper shows that technology-driven inefficiencies exist even in publicly organized, managed, and financed healthcare system without formal competition or clear economic incentives for care providers. It is often argued that public healthcare systems are less prone to adverse competition effects (Barros et al., 2016). Whether the supplier-induced demand effects we report in this paper are more pronounced in market-based systems should depend on the degree of market power each provider has to shift demand. Future research on this topic could explore the underlying mechanisms between technology adoption and market power in such contexts.

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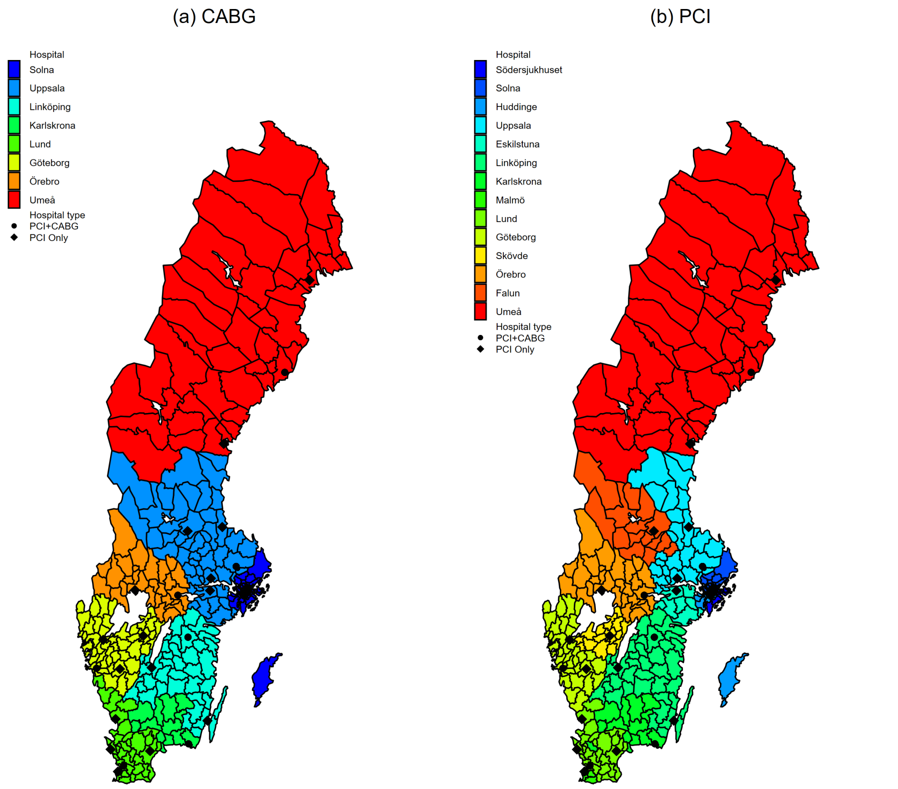
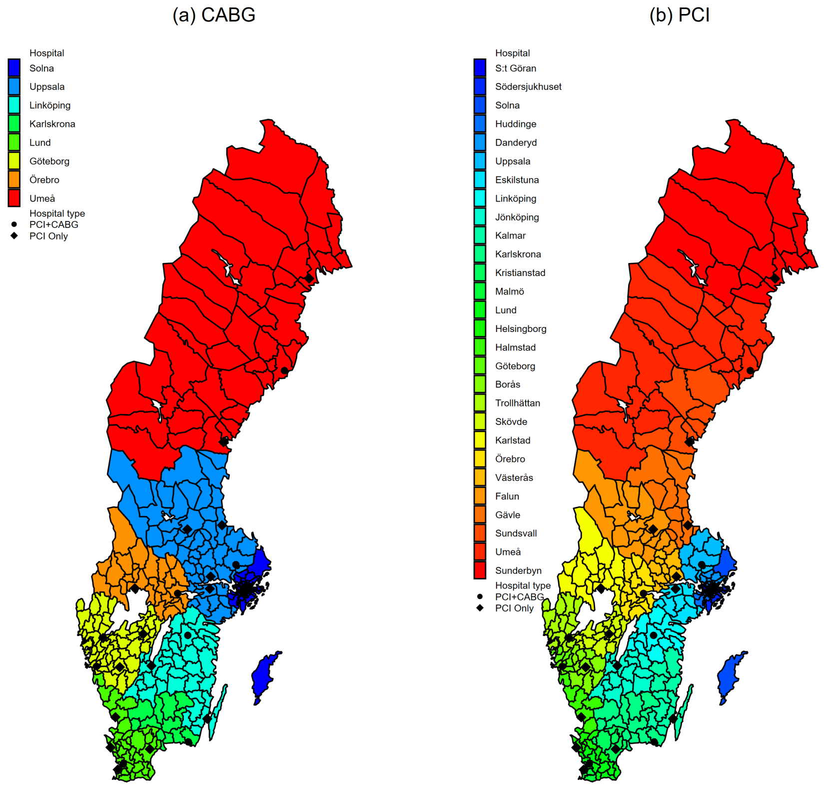
Tables and Figures

Figure 1.
CABG and PCI hospital catchment areas in Sweden in 2000



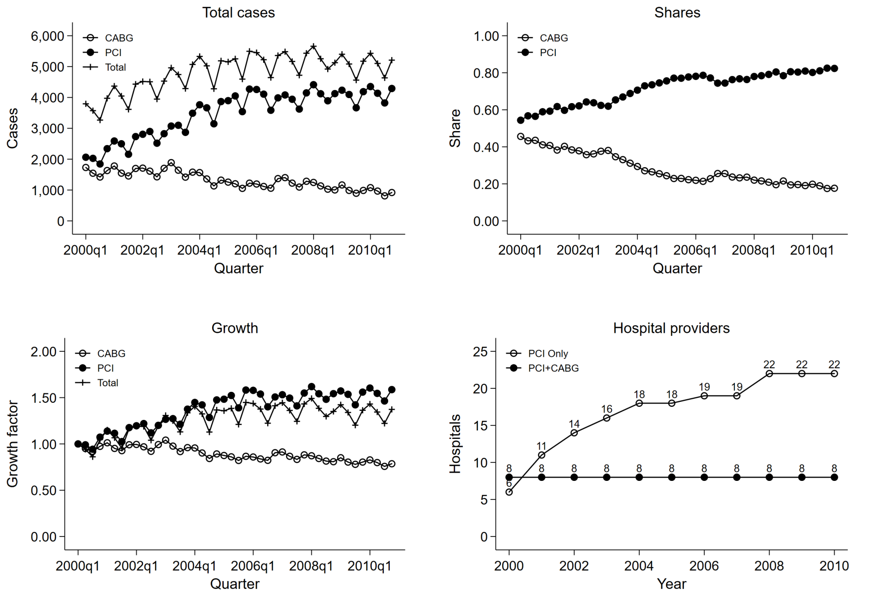
Note.— Own calculations based on data from the SCAAR registry. Each colored region represents a distinct catchment area for (a) CABG surgery and (b) PCI at a particular point in time. PCI-only hospitals are defined as single-technology providers with a cath lab but without a operating theater, while PCI+CABG hospitals have capability to offer both PCI and CABG surgery. Hospital catchment areas are fixed over time but individual providers may serve multiple catchment area, subject to the capability of other nearby providers.

FIGURE 2.
CABG and PCI hospital catchment areas in Sweden in 2010



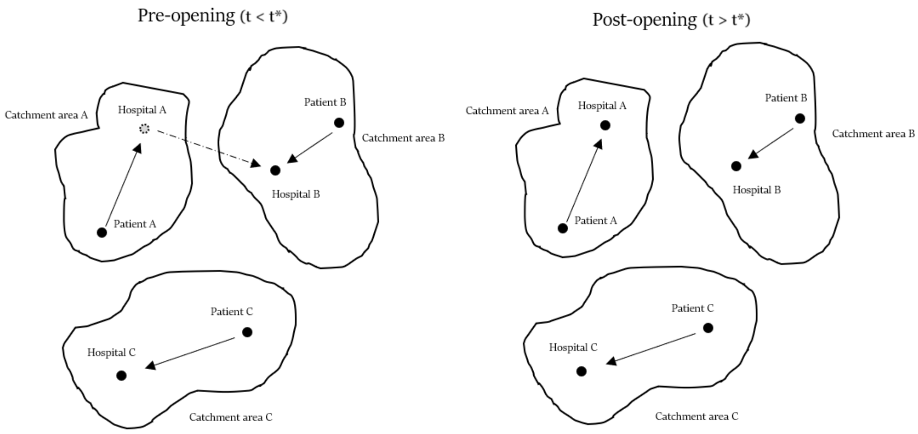
NOTE.— Own calculations based on data from the SCAAR registry. Each colored region represents a distinct catchment area for (a) CABG surgery and (b) PCI at a particular point in time. PCI-only hospitals are defined as single-technology providers with a cath lab but without a operating theater, while PCI+CABG hospitals have capability to offer both PCI and CABG surgery. Hospital catchment areas are fixed over time but individual providers may serve multiple catchment area, subject to the capability of other nearby providers.

Figure 3.
Trends in the use of PCI and CABG in Sweden, 2000-2010



Note.— Own calculations based on data from the SCAAR registry. Total cases, shares and growth rates of PCI and CABG procedures refer to both complex and non-complex ACS patients admitted to Swedish hospitals. Hospital providers refers to the number of hospitals with therapeutic capability to service ACS patients. PCI-only hospitals are defined as single-technology providers with a cath lab but without a operating theater, while PCI+CABG hospitals have capability to offer both PCI and CABG surgery.

Figure 4.
Conceptual depiction of patient flows and catchment area types



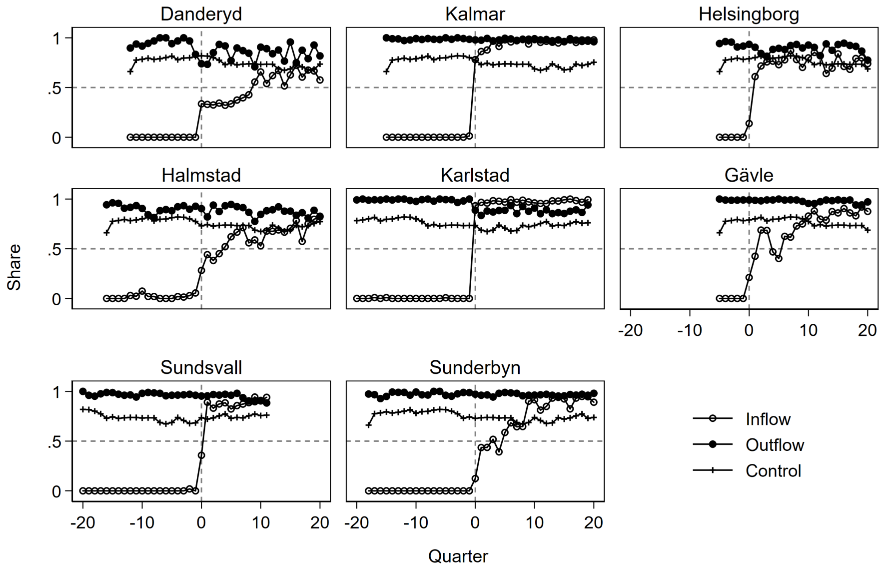
Note.— Catchment area A, B, and C correspond to *inflow*, *outflow*, and *control* areas in the text, respectively. Prior to the opening of a cath lab, ACS patients in catchment area A received diagnostic treatment in their designated hospital A (solid arrow) and were subsequently referred to hospital B for therapeutic treatment (dash arrow). After the opening of a cath lab, patients in catchment area A received diagnostic treatment and PCI in hospital A, but would still be referred if CABG surgery was recommended as treatment. ACS patients in catchment area C would receive diagnostic and therapeutic treatment in hospital C in both the pre- and post-opening periods.

Table 1.
Sample summary statistics by catchment area group

	Sample			
	(1) Inflow	(2) Outflow	(3) Control	(4) All
Age	67.378	67.206	66.940	67.205
	(8.718)	(8.717)	(9.009)	(8.805)
Female	0.217	0.211	0.211	0.214
	(0.412)	(0.408)	(0.408)	(0.410)
Creatinine Clearance	83.308	84.035	83.563	83.575
	(32.148)	(32.031)	(31.870)	(32.037)
Left Ventricular Ejection Fraction				
Normal (>50%)	0.168	0.169	0.141	0.160
	(0.374)	(0.375)	(0.348)	(0.367)
Mildly reduced (40–49%)	0.068	0.067	0.063	0.066
	(0.252)	(0.250)	(0.242)	(0.249)
Moderately reduced (30–39%)	0.042	0.045	0.035	0.041
	(0.201)	(0.208)	(0.184)	(0.198)
Severely reduced (<30%)	0.022	0.026	0.022	0.023
	(0.146)	(0.160)	(0.148)	(0.150)
Unknown	0.700	0.693	0.739	0.709
	(0.458)	(0.461)	(0.439)	(0.454)
Chronic Obstructive Pulmonary Disease	0.028	0.035	0.035	0.032
	(0.165)	(0.183)	(0.183)	(0.176)
Peripheral Vascular Disease	0.020	0.025	0.020	0.021
	(0.141)	(0.155)	(0.141)	(0.145)
Main diagnosis (ICD-10)				
I20	0.359	0.380	0.364	0.366
	(0.480)	(0.485)	(0.481)	(0.482)
I21	0.299	0.297	0.328	0.307
	(0.458)	(0.457)	(0.470)	(0.461)
I25	0.061	0.064	0.064	0.062
	(0.239)	(0.244)	(0.244)	(0.242)
Other	0.020	0.022	0.019	0.020
	(0.142)	(0.147)	(0.136)	(0.142)
Unknown	0.261	0.237	0.225	0.244
	(0.439)	(0.425)	(0.418)	(0.430)
Primary diagnosis				
Stable CAD	0.420	0.370	0.396	0.400
	(0.494)	(0.483)	(0.489)	(0.490)
Unstable angina	0.378	0.405	0.403	0.393
	(0.485)	(0.491)	(0.491)	(0.488)
NSTEMI	0.128	0.127	0.130	0.128
	(0.334)	(0.333)	(0.336)	(0.334)
Other	0.074	0.097	0.071	0.080
	(0.263)	(0.296)	(0.257)	(0.271)
Admission type				
Planned/office hours	0.398	0.346	0.399	0.384
	(0.489)	(0.476)	(0.490)	(0.486)
Emergency/office hours	0.088	0.095	0.068	0.084
	(0.284)	(0.293)	(0.252)	(0.278)
Emergency/on-call	0.031	0.063	0.022	0.037
	(0.173)	(0.242)	(0.148)	(0.188)
Sub-acute/office hours	0.146	0.161	0.191	0.163
	(0.353)	(0.367)	(0.393)	(0.369)
Sub-acute/on-call	0.006	0.016	0.004	0.008
	(0.079)	(0.125)	(0.060)	(0.089)
Unknown	0.331	0.320	0.315	0.324
	(0.471)	(0.467)	(0.464)	(0.468)
Day of admission				
Sunday	0.010	0.020	0.008	0.012
	(0.099)	(0.139)	(0.089)	(0.109)
Monday	0.200	0.194	0.203	0.199
	(0.400)	(0.396)	(0.402)	(0.399)
Tuesday	0.232	0.214	0.218	0.223
	(0.422)	(0.410)	(0.413)	(0.416)
Wednesday	0.213	0.204	0.223	0.214
	(0.409)	(0.403)	(0.416)	(0.410)
Thursday	0.220	0.198	0.208	0.211
	(0.414)	(0.398)	(0.406)	(0.408)
Friday	0.112	0.146	0.132	0.127
	(0.316)	(0.353)	(0.339)	(0.333)
Saturday	0.013	0.024	0.008	0.015
	(0.114)	(0.154)	(0.090)	(0.120)
Patients	28,216	16,882	18,425	63,523

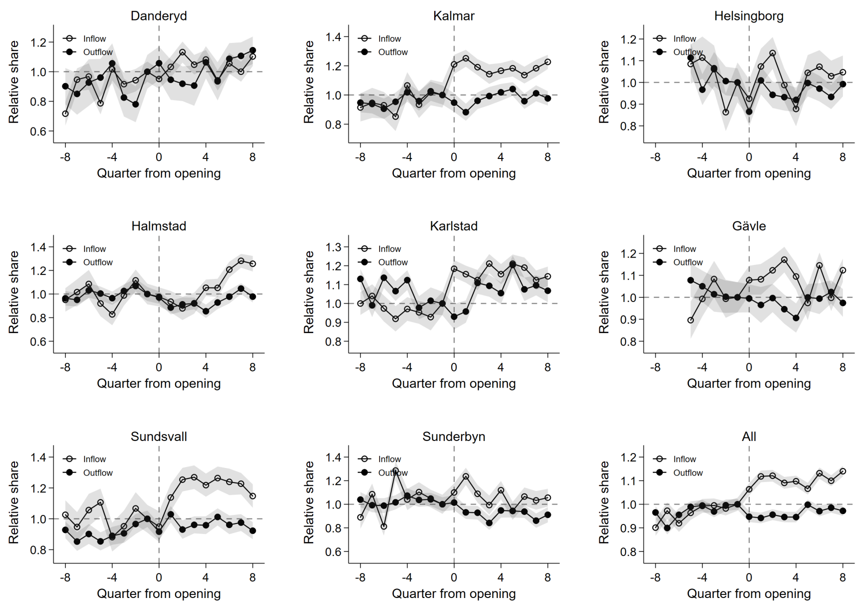
Note.— Own calculations based on data from the SCAAR registry. Means and standard deviations (in parentheses) refer to ACS cases for years 2000–2010, excluding patients diagnosed with non-complex lesions, STEMI presentations, and over 80 years of age. Inflow, outflow and control areas are defined as catchment areas of hospitals that opened a cath lab during the analysis period, catchment areas of incumbent hospitals who served the inflow areas prior to the cath lab's opening, and catchment areas of hospitals that were unaffected by the opening of a cath lab, respectively.

Figure 5.
Patient hospital compliance by time from cath lab opening



Note.— Own calculations based on data from the SCAAR registry for years 2000–2010. Panels refer to PCI markets in which a new cath lab opened during the analysis period. Shares refer to proportions of PCIs received by ACS patients in their designated hospital by time from cath lab opening. Inflow, outflow and control areas are defined as catchment areas of hospitals that opened a cath lab during the analysis period, catchment areas of incumbent hospitals who served the inflow areas prior to the cath lab's opening, and catchment areas of hospitals that were unaffected by the opening of a cath lab, respectively.

Figure 6.
Propensity for PCI treatment by time from cath lab opening



Note.— Own calculations based on data from the SCAAR registry for years 2000–2010. Panels refer to PCI markets in which a new cath lab opened during the analysis period. Shares refer to relative changes in the proportion of PCI treatment provided to ACS patients by time from cath lab opening indexed relative to control areas in the quarter prior to market entry. Inflow, outflow and control areas are defined as catchment areas of hospitals that opened a cath lab during the analysis period, catchment areas of incumbent hospitals who served the inflow areas prior to the cath lab's opening, and catchment areas of hospitals that were unaffected by the opening of a cath lab, respectively.

TABLE 2.
Effects of a cath lab opening on PCI propensity I: Pooled

	(1)	(2)	(3)	(4)
Post	0.002**	-0.001	0.002*	-0.002
	(0.001)	(0.002)	(0.001)	(0.002)
Treatment	-0.331***	-0.263***		
	(0.013)	(0.005)		
Inflow			-0.350***	-0.282***
			(0.015)	(0.008)
Outflow			-0.296***	-0.272***
			(0.009)	(0.003)
Treatment×Post	0.011	0.005		
	(0.012)	(0.007)		
Inflow×Post			0.043**	0.039***
			(0.017)	(0.013)
Outflow×Post			-0.013	-0.019***
			(0.013)	(0.005)
Covariates		✓		✓
Mean Inflow	0.15	0.15	0.15	0.15
Mean Outflow	0.22	0.22	0.22	0.22
Municipalities	225	225	225	225
Observations	9,226	9,226	9,226	9,226

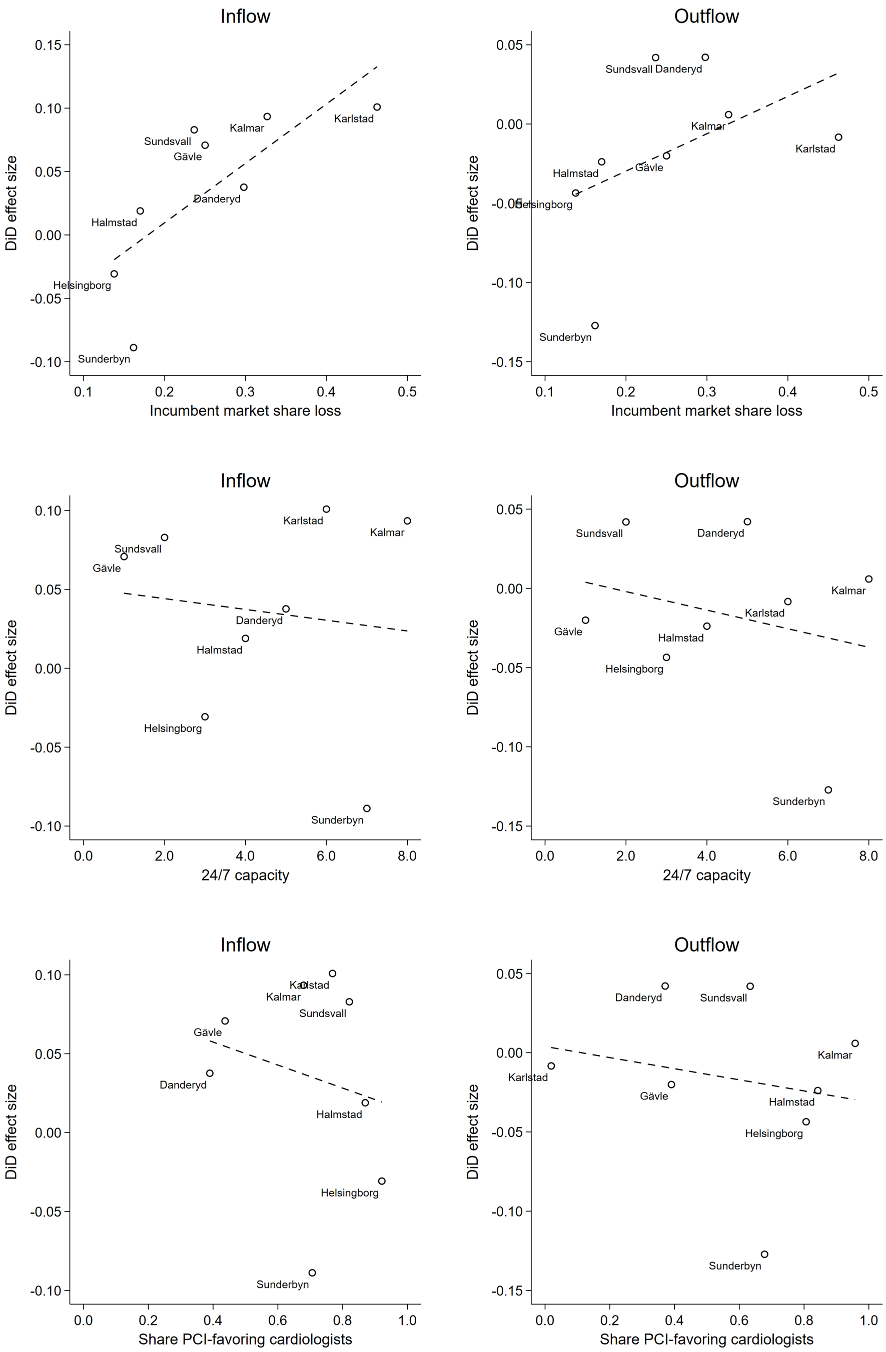
NOTE.— Own calculations based on data from the SCAAR registry for years 2000–2010. Columns (1)-(2) and (3)-(4) report OLS coefficient estimates from estimation of Equations (1) and (2), respectively. Inflow, outflow and control areas are defined as catchment areas of hospitals that opened a cath lab during the analysis period, catchment areas of incumbent hospitals who served the inflow areas prior to the cath lab's opening, and catchment areas of hospitals that were unaffected by the opening of a cath lab, respectively. Covariates include all variables listed in Table 1. Standard errors (in parentheses) clustered at the municipality level; * p<0.10, ** p<0.05, *** p<0.01.

TABLE 3.
Effects of a cath lab opening on PCI propensity II: By market

	(1) Danderyd	(2) Kalmar	(3) H-borg	(4) Halmstad	(5) Karlstad	(6) Gävle	(7) Sundsvall	(8) Sunderbyn	(9) All
Post	0.104***	0.081***	0.048***	0.076***	-0.003	0.064***	0.012	0.018	-0.003
	(0.018)	(0.026)	(0.016)	(0.024)	(0.015)	(0.017)	(0.012)	(0.024)	(0.003)
Inflow	-0.079***	-0.067***	-0.022	-0.042*	-0.031*	0.084**	-0.099**	0.022	-0.046***
	(0.022)	(0.025)	(0.032)	(0.025)	(0.017)	(0.032)	(0.041)	(0.029)	(0.013)
Outflow	-0.080***	-0.009	-0.012	-0.025	0.019	0.111***	-0.098***	0.049**	-0.018
	(0.021)	(0.018)	(0.028)	(0.020)	(0.016)	(0.016)	(0.031)	(0.019)	(0.011)
Inflow×Post	0.038	0.093***	-0.031	0.019	0.101***	0.071**	0.083**	-0.089***	0.039***
	(0.024)	(0.023)	(0.022)	(0.028)	(0.014)	(0.035)	(0.036)	(0.031)	(0.013)
Outflow×Post	0.042*	0.006	-0.044**	-0.024	-0.008	-0.020	0.042***	-0.127***	-0.019**
	(0.023)	(0.020)	(0.020)	(0.019)	(0.022)	(0.020)	(0.012)	(0.020)	(0.005)
Mean Inflow	0.07	0.11	0.06	0.15	0.28	0.04	0.21	0.18	0.15
Mean Outflow	0.07	0.17	0.12	0.20	0.35	0.09	0.23	0.27	0.22
Municipalities	83	93	91	88	96	85	98	106	225
Observations	1,047	1,124	828	1,237	1,430	584	1,491	1,485	9,226

NOTE.— Own calculations based on data from the SCAAR registry for years 2000–2010. Columns (1)–(8) report OLS coefficient estimates from estimation of Equation (2) separately by regional PCI market. Column (9) reports pooled results across all PCI markets. Inflow, outflow and control areas are defined as catchment areas of hospitals that opened a cath lab during the analysis period, catchment areas of incumbent hospitals who served the inflow areas prior to the cath lab's opening, and catchment areas of hospitals that were unaffected by the opening of a cath lab, respectively. All models control for the variables listed in Table 1. Standard errors (in parentheses) clustered at municipality level; * p<0.10, ** p<0.05, *** p<0.01.

FIGURE 7.
Effect mechanisms I: Incumbent market share loss, 24/7 capacity, and cardiologist treatment preferences



NOTE.— Own calculations based on data from the SCAAR registry for years 2000–2010. Panels from top to bottom refer to DID estimates from Table 3 plotted against the calculated market share loss of the incumbent hospitals; the calculated share of patients in each market's catchment areas treated outside office/normal hours; and the proportion of PCI-favoring cardiologists within and across markets eight (8) quarters prior to cath lab opening for inflow (left) and outflow (right) catchment area types, respectively. PCI-favoring cardiologists are characterized based on a median-split of physician-specific random effects for the likelihood to recommend PCI after diagnostic assessment estimated from a mixed-effects model using data prior to cath lab opening.

TABLE 4.
Effects of a cath lab opening on care quality I: Clinical endpoints

	Reinfarction		Revascularization		Death	
	(1)	(2)	(3)	(4)	(5)	(6)
Post	-0.001**	-0.001**	0.002**	0.001**	0.000	-0.000
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Treatment	-0.025***		-0.023***		-0.028***	
	(0.001)		(0.001)		(0.002)	
Inflow		-0.025***		-0.026***		-0.031***
		(0.001)		(0.002)		(0.002)
Outflow		-0.020***		-0.036***		-0.019***
		(0.001)		(0.001)		(0.002)
Treatment×Post	0.002*		0.001		0.005**	
	(0.001)		(0.002)		(0.002)	
Inflow×Post		0.003		0.006**		0.012***
		(0.002)		(0.003)		(0.003)
Outflow×Post		0.002		-0.003		0.000
		(0.002)		(0.003)		(0.003)
Mean Inflow	0.04	0.04	0.02	0.02	0.05	0.05
Mean Outflow	0.05	0.05	0.02	0.02	0.06	0.06
Municipalities	225	225	225	225	225	225
Observations	9,226	9,226	9,226	9,226	9,226	9,226

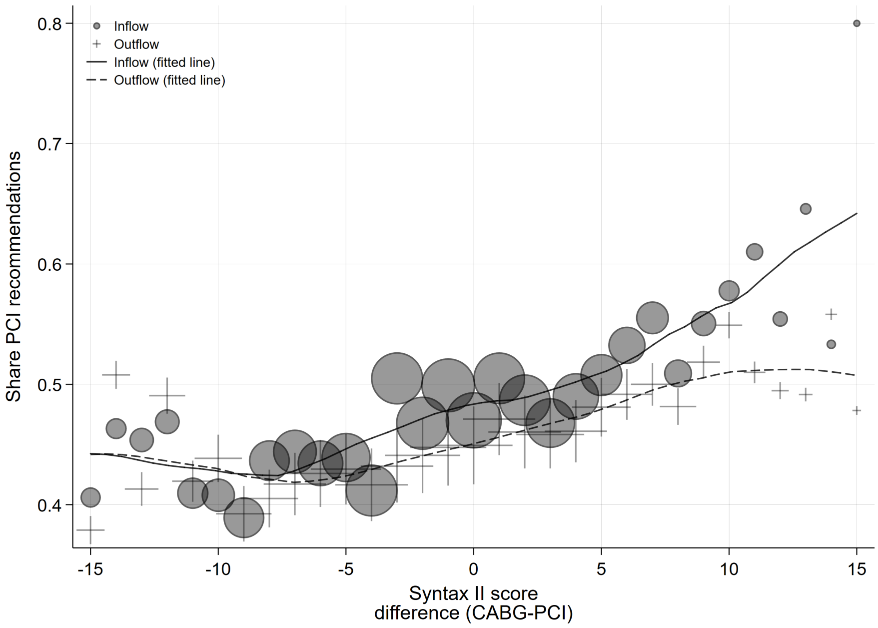
NOTE.— Own calculations based on data from the SCAAR registry for years 2000–2010. Odd and evenly numbered columns report OLS coefficient estimates from estimation of Equations (1) and (2) for patient clinical endpoints indicated in the column header, respectively. Inflow, outflow and control areas are defined as catchment areas of hospitals that opened a cath lab during the analysis period, catchment areas of incumbent hospitals who served the inflow areas prior to the cath lab's opening, and catchment areas of hospitals that were unaffected by the opening of a cath lab, respectively. All models control for the variables listed in Table 1. Standard errors (in parentheses) clustered at municipality level; * p<0.10, ** p<0.05, *** p<0.01.

TABLE 5.
Effects of a cath lab opening on care quality II: Diagnostic recommendation

	Baseline		Recommendation	
	(1)	(2)	(3)	(4)
Post	-0.001	-0.002	-0.001	-0.002
	(0.002)	(0.002)	(0.002)	(0.002)
Treatment	-0.263***		-0.250***	
	(0.005)		(0.005)	
Inflow		-0.282***		-0.266***
		(0.008)		(0.007)
Outflow		-0.272***		-0.261***
		(0.003)		(0.003)
Treatment×Post	0.005		0.001	
	(0.007)		(0.006)	
Inflow×Post		0.039***		0.028**
		(0.013)		(0.011)
Outflow×Post		-0.019***		-0.019***
		(0.005)		(0.005)
Mean Inflow	0.15	0.15	0.18	0.18
Mean Outflow	0.22	0.22	0.22	0.22
Municipalities	225	225	225	225
Observations	9,226	9,226	9,226	9,226

NOTE.— Own calculations based on data from the SCAAR registry for years 2000–2010. Odd and evenly numbered columns report OLS coefficient estimates from estimation of Equations (1) and (2) for PCI treatment propensity and treatment recommendation after diagnostic (angiographic) assessment, respectively. Inflow, outflow and control areas are defined as catchment areas of hospitals that opened a cath lab during the analysis period, catchment areas of incumbent hospitals who served the inflow areas prior to the cath lab's opening, and catchment areas of hospitals that were unaffected by the opening of a cath lab, respectively. All models control for the variables listed in Table 1. Standard errors (in parentheses) clustered at municipality level; * p<0.10, ** p<0.05, *** p<0.01.

FIGURE 8.
Share of diagnostic PCI recommendations by SYNTAX II score difference



NOTE.— Own calculations based on data from the SCAAR registry for years 2005–2010. The plot relates the share of PCI treatment recommendation after diagnostic (angiographic) assessment to the net difference in SYNTAX II scores for CABG surgery and PCI. The SYNTAX II score is a decision aid to choose between PCI and CABG for patients with complex lesions (see, e.g., Escaned et al., 2017). Lines refer to local linear regression slope estimates with weights based on bin sample size reflected by the size of markers. Inflow, outflow and control areas are defined as catchment areas of hospitals that opened a cath lab during the analysis period, catchment areas of incumbent hospitals who served the inflow areas prior to the cath lab's opening, and catchment areas of hospitals that were unaffected by the opening of a cath lab, respectively.

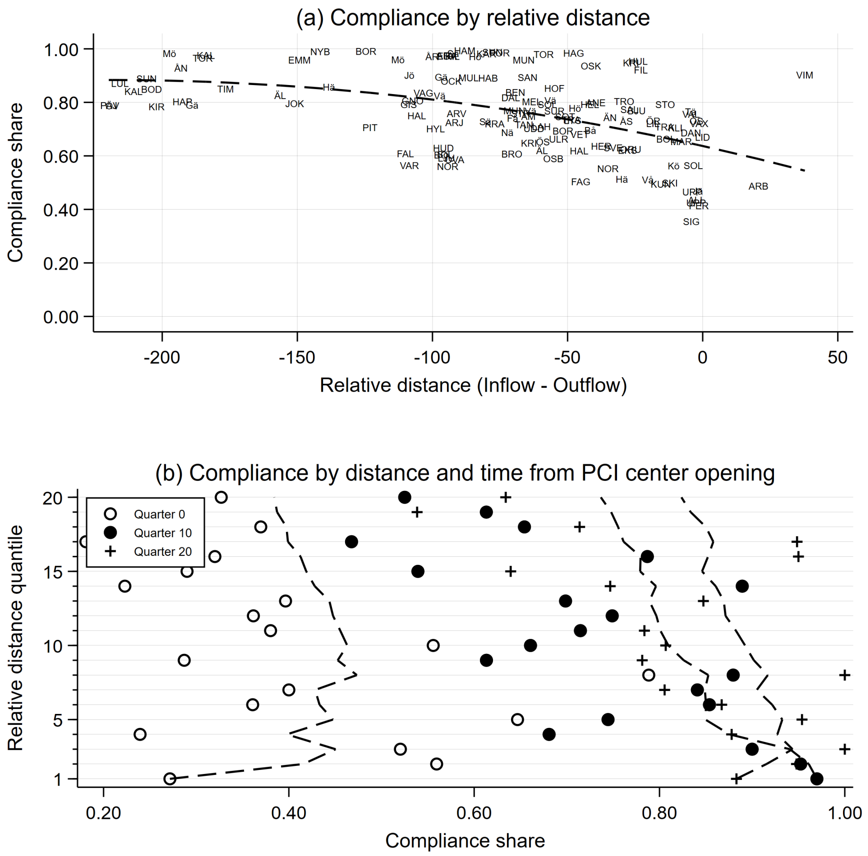
Table 6.
Effect mechanisms II: Hospital quality differences

	Non-complex adverse event rate			Inframarginal adverse event rate			Share of proficient cardiologists		
Group	**Inflow**	**Outflow**	**Difference**	**Inflow**	**Outflow**	**Difference**	**Inflow**	**Outflow**	**Difference**
Danderyd	0.109	0.113	−0.004	0.102	0.100	0.002	0.564	0.696	−0.132
Kalmar	0.122	0.125	−0.004	0.153	0.127	0.026**	0.656	0.087	0.569***
Helsingborg	0.093	0.102	−0.010***	0.109	0.116	−0.006	0.548	0.667	−0.120
Halmstad	0.110	0.124	−0.015***	0.108	0.116	−0.008	0.273	0.556	−0.283***
Karlstad	0.117	0.124	−0.006	0.106	0.112	−0.006	0.479	0.834	−0.354***
Gävle	0.091	0.107	−0.016***	0.124	0.108	0.017**	0.697	0.768	−0.071
Sundsvall	0.117	0.109	0.009*	0.088	0.082	0.006	0.435	0.376	0.060
Sunderbyn	0.095	0.108	−0.014***	0.111	0.082	0.029***	0.462	0.336	0.126
Pooled	0.105	0.112	−0.007***	0.114	0.101	0.013***	0.494	0.541	−0.046

Note.— Own calculations based on data from the SCAAR registry for years 2000–2010. The first set of columns reports risk-adjusted composite one-year adverse patient event (deaths, reinfarction, and revascularization) rates for non-complex (blockages in less than three vessels other than the left main branch) cases in hospitals over eight quarters after a cath lab opening. The second set of columns reports risk-adjusted composite one-year adverse patient event rates for inframarginal patients (patients with SYNTAX II net scores ranging from -5 to 15 in Figure 8) in hospitals over years 2005–2010. The last set of columns reports estimated shares of proficient cardiologists in hospitals over eight quarters after a cath lab opening. Groups refer to regional PCI markets and the pooled estimate pertains to the average estimate across all markets. Cardiologist proficiency is characterized based on a median-split of physician-specific random effects for the likelihood of composite one-year adverse patient events estimated from a mixed-effects model using data prior to cath lab opening and adjusting for patient risk factors and hospital fixed-effects. Inflow, outflow and control areas are defined as catchment areas of hospitals that opened a cath lab during the analysis period, catchment areas of incumbent hospitals who served the inflow areas prior to the cath lab's opening, and catchment areas of hospitals that were unaffected by the opening of a cath lab, respectively. * p <0.1 ; ** p<0.05; *** p<0.01.

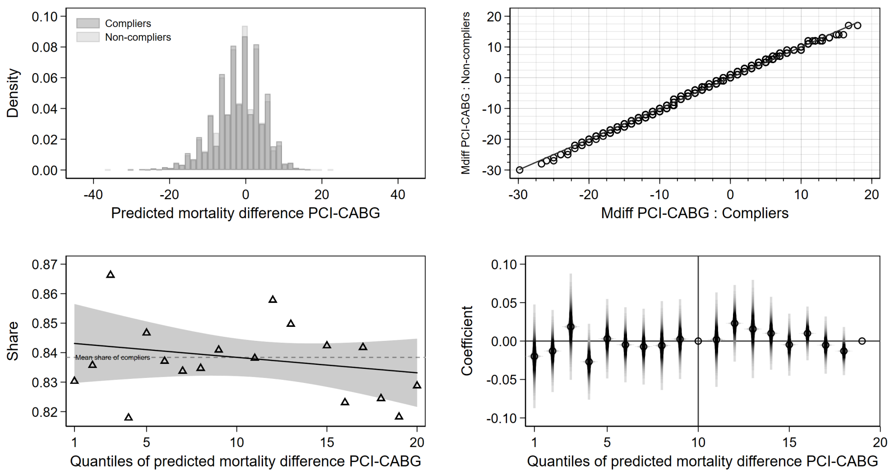
Appendix A Additional tables and figures

Figure A.1.
Patient hospital compliance by relative hospital distance



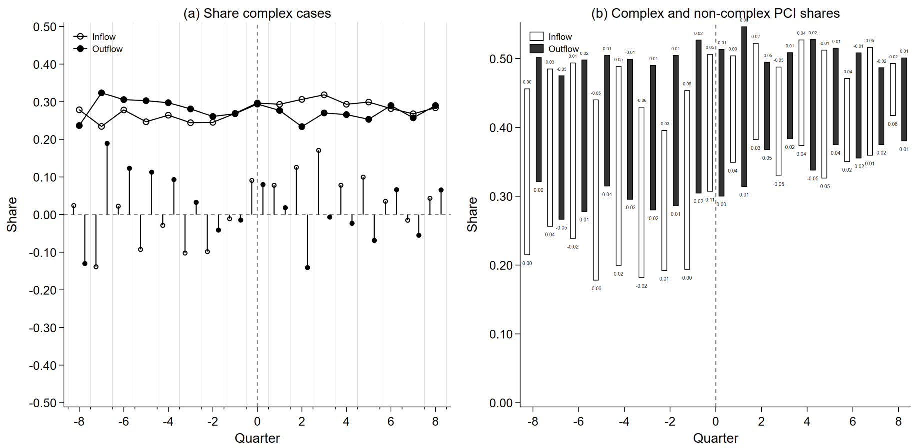
Note.— Own calculations based on data from the SCAAR registry for years 2000–2010. Markers in panel (a) refer to unweighted municipality-level averages pooled across all years by relative distance from municipality geographical midpoints to inflow and outflow hospitals, respectively. Compliance share is defined as the overall share of all patients residing in a given municipality that undergo PCI in their designated inflow hospital. Dashed line refers to predictions from an ordinary least-squares regression of compliance shares on a quadratic polynomial of relative distance. Markers in panel (b) refer to PCI compliance shares for municipalities in inflow areas grouped by ventiles of the relative distance distribution by time since a cath lab opened. Dashed lines refer to the group-specific cumulative average share from the lowest (closest to inflow) to the highest (furthest from inflow) distance ventile. Inflow, outflow and control areas are defined as catchment areas of hospitals that opened a cath lab during the analysis period, catchment areas of incumbent hospitals who served the inflow areas prior to the cath lab's opening, and catchment areas of hospitals that were unaffected by the opening of a cath lab, respectively.

Figure A.2.
Patient hospital compliance by SYNTAX II score



Note.— Own calculations based on data from the SCAAR registry for years 2005–2010. The top left and right panels display kernel density and quantiles-quantiles plot of the net difference in SYNTAX II scores for CABG surgery and PCI for compliers and non-compliers residing in inflow catchment areas, respectively. The bottom left and right panels display estimated shares of compliers across ventiles of the net SYNTAX II score difference distribution, and estimated coefficients from a pooled OLS model of the relative compliance share by quantiles of the SYNTAX II difference score using the median quantile as base, respectively. Compliance share is defined as the overall share of all patients residing in a given municipality that undergo PCI in their designated inflow hospital. The SYNTAX II score is a decision aid to choose between PCI and CABG for patients with complex lesions (see, e.g., Escaned et al., 2017).

Figure A.3.
PCI shares by ACS patient complexity



Note.— Own calculations based on data from the SCAAR registry for years 2005–2010. The line and dot plots in panel (a) display shares of complex (relative to non-complex) ACS patients and percentage point differences in shares of complex patients relative to control areas by area type and time from cath lab opening, respectively. Panel (b) displays shares of complex (bottom of bar) and non-complex (top of bar) patient PCI shares by area type and time from cath lab opening, respectively. Inflow, outflow and control areas are defined as catchment areas of hospitals that opened a cath lab during the analysis period, catchment areas of incumbent hospitals who served the inflow areas prior to the cath lab's opening, and catchment areas of hospitals that were unaffected by the opening of a cath lab, respectively.

Table A.1.

Heterogeneity analyses

	Baseline		Wait list		Weekend		Relative distance		First visit		Excluding 70	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Post	-0.001	-0.002	-0.000	-0.001	-0.001	-0.002	-0.001	-0.002	0.002	0.001	-0.003	-0.004
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.003)	(0.003)	(0.003)	(0.003)
Treatment	-0.263***		-0.259***		-0.264***		-0.261***		-0.220***		-0.300***	
	(0.005)		(0.006)		(0.005)		(0.005)		(0.005)		(0.006)	
Inflow		-0.282***		-0.281***		-0.284***		-0.280***		-0.242***		-0.327***
		(0.008)		(0.009)		(0.008)		(0.008)		(0.008)		(0.010)
Outflow		-0.272***		-0.269***		-0.283***		-0.272***		-0.214***		-0.292***
		(0.003)		(0.006)		(0.003)		(0.003)		(0.004)		(0.004)
Treatment×Post	0.005		0.001		0.005		0.005		0.008		0.008	
	(0.007)		(0.008)		(0.007)		(0.007)		(0.008)		(0.008)	
Inflow×Post		0.039***		0.037***		0.040***		0.039***		0.047***		0.054***
		(0.013)		(0.014)		(0.013)		(0.013)		(0.014)		(0.015)
Outflow×Post		-0.019***		-0.027***		-0.021***		-0.019***		-0.020***		-0.025***
		(0.005)		(0.006)		(0.005)		(0.005)		(0.007)		(0.006)
Mean Inflow	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.12	0.12	0.15	0.15
Mean Outflow	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.19	0.19	0.22	0.22
Municipalities	225	225	225	225	225	225	225	225	225	225	225	225
Observations	9,226	9,226	8,752	8,752	9,226	9,226	9,226	9,226	9,226	9,226	9,226	9,226

Note.— Own calculations based on data from the SCAAR registry for years 2005–2010. Odd and evenly numbered columns report OLS coefficient estimates from estimation of Equations (1) and (2) for different sample specifications, respectively. Columns (1)-(2) refer to baseline estimates reported in Table 2. Columns (3)-(4) includes a lagged patient list for each catchment area as an additional control variable. Columns (5)-(6) excludes weekend admissions from the sample. Columns (7)-(8) includes relative hospital distance between designated inflow and outflow hospitals as an additional control variable. Columns (9)-(10) excludes any subsequent hospitalizations of patients after the first visit. Finally, columns (11)-(12) restricts the sample to patients below the age of 70 at admission. Inflow, outflow and control areas are defined as catchment areas of hospitals that opened a cath lab during the analysis period, catchment areas of incumbent hospitals who served the inflow areas prior to the cath lab's opening, and catchment areas of hospitals that were unaffected by the opening of a cath lab, respectively. All models control for the variables listed in Table 1. Standard errors (in parentheses) clustered at municipality level; * p<0.10, ** p<0.05, *** p<0.01.