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A matter of life and death?

Hospital distance and quality of care: evidence from emergency room closures and myocardial infarctions

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A matter of life and death? Hospital distance and quality of care: Evidence from emergency room closures and myocardial infarctions*

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Abstract

Recent health care centralization trends raise the important question of the extent to which the quality of emergency medical services may offset effects from decreased access to emergency health care. This article analyzes whether residential proximity from an emergency room affects the probability of surviving an acute myocardial infarction (AMI). The critical time aspect in AMI treatment provides an ideal application for evaluating this proximity-outcome hypothesis. Previous studies have encountered empirical difficulties relating to potential endogenous health-based spatial sorting of involved agents and data limitations on out-of-hospital mortality. Using policy-induced variation in hospital distance arising from emergency room closures in the highly regulated Swedish health care sector and data on all AMI deaths in Sweden over two decades, estimation results show a clear and gradually declining probability of surviving an AMI as residential distance from an emergency room increases. The results further show that spatial sorting is likely to significantly attenuate the distance effect unless accounted for.

JEL Classification: I14, I18.

Keywords: myocardial infarction, geographical access, hospital closures, health policy, spatial sorting, self-selection, causal effect

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1 Introduction

Over the past two decades more than half a million Swedish residents, a country with approximately nine million inhabitants, suffered an acute myocardial infarction (AMI). Moreover, a majority of these individuals are now deceased, with AMI as either the primary or as a contributing cause of death. Overall AMI incidence in Sweden over the same period exceeded 800,000 cases, making AMI one of the leading causes of hospitalization as well as the leading cause of death in Sweden at the time (Socialstyrelsen, 2009). Put differently, around twelve percent of the Swedish population is expected to experience an AMI at some point in their life (Nationellt register för hjärtstopp, 2011). Far from unique in this respect, Sweden shares these morbidity and mortality patterns with most of the Western world. For example, half a million deaths in the U.S. per year are the result of an AMI (American Heart Association, 2012).

The relatively high mortality rates for AMI arise primarily from two specific characteristics of the disease; the lack of indication signals, or the unexpectedness, of the disease (more than two-thirds of Swedish AMIs occur in the home) and the critical importance of time for a successful treatment. In the event of a cardiac arrest, a common manifestation of the infarction, the brain suffers irreversible damage after only five minutes due to the lack of oxygen. After fifteen minutes, death is essentially unavoidable regardless of any resuscitation attempts made (Pell *et al.*, 2001; GUSTO Investigators, 1993). Together, these two disease characteristics imply that professional medical assistance may often be unavailable and out of reach when the life-threatening condition occurs. Hence, many AMI patients expires before they reach an emergency care facility.[1]

Trends of health care consolidation have recently emerged in many countries. In countries with more deregulated health care markets, such as the U.S., these trends have primarily been driven by increased competition in the health care sector, in which hospitals have either merged into giant multi-hospital units or been ousted by competition from

[1] For example, more than sixty percent of all AMI deaths in the U.S. occur outside a hospital (American Heart Association, 2012).

more efficiently driven hospitals (Dranove *et al.*, 1996; Succi *et al.*, 1997; Evans-Cuellar and Gertler, 2003). In countries with mandatory and, mainly, public provision of health care such as Sweden, rapidly increasing costs of health care and public budget deficits have been, along with general technological progress and innovations in health care, a driving factor behind the structural changes. Examples of such changes are increased reliance on outpatient care, and on paramedic and emergency ambulance services (Landstingsförbundet, 2002; Sveriges Kommuner och Landsting, 2008). Hence, irrespective of the institutional context, the long-run trend in the organization of inpatient health care has been a considerable increase in centralization of resources. One noteworthy feature of these recent trends have been the tendency of an increase in the number of rural hospital closures and a corresponding growth in size of urban hospitals. While potentially leading to efficiency gains, these consolidation trends are likely to also entail adverse effects on health care quality; in particular a deterioration of geographical access to care.[2]

The focus of this paper is to empirically assess the impact of geographical access to health care on AMI survival for individuals who suffered an AMI in Sweden between 1990 and 2010. Previous research on this topic have typically found that ambulance response time increases the chance of surviving an out-of-hospital AMI (Bachmann *et al.*, 1986; Piette and Moos, 1996; Norris, 1998; Pell *et al.*, 2001). However, this conclusion mainly stems from evidence based on case studies, i.e. studies using data on single hospitals and/or data culled at one particular point in time, and results inferred from these studies may potentially suffer appreciably from limitations associated with both the external and internal validity of any estimated parameters. Furthermore, location data on both patients and hospitals is likely to be subject to dynamic spatial sorting where agents' choice of residence is based on factors related to AMI survival probabilities

[2]In this context it is interesting to note that Swedish health care authorities justified the health care consolidation policy with the argument that emergency hospitals, while traditionally important for health care equity policies, are less important today due to recent innovations in emergency medical treatment (Sveriges Kommuner och Landsting, 2004). For example, over the last few decades some therapeutic progress has been made, including the introduction of specific MI wards, mobile defibrillators, more effective treatment of cardiac arrest and the introduction of drugs such as beta blockers, thrombolytic agents, aspirin, ACE inhibitors and lipid-lowering drugs (Julian, 1961; Dellborg *et al.*, 1994; Herlitz, 2000).

such as individual health and the quality of nearby hospitals. In particular, individuals in poor health would, *ceteris paribus*, choose to reside closer to a hospital, compared to individuals in good health. A few economic studies has taken the analysis a step further and estimated the effect of hospital closures on health outcomes using large U.S. administrative data sets (Buchmueller *et al.*, 2006; Herr, 2009). However, one potential difficulty with this approach is that hospitals in more market-oriented health care systems are likely to be strategically located with regard to underlying patient characteristics and competition aspects. For example, profit-maximizing hospitals are unlikely to be located in impoverished areas where the patient population has poor general health (Dranove *et al.*, 1996; Succi *et al.*, 1997). Hence, there is a risk that observed hospital closures used to evaluate the consequences of health care access in such contexts may partly be the result of selective referrals.

A second problem hampering the assessment of the impact of distance to hospital on health in previous studies is the lack of out-of-hospital data. Using only inpatient data when attempting to quantify the effect of distance implies that patients who expire before reaching hospital are censored in the analysis. Clearly, if geographical access to health care has an impact on survival probability, omitting patients that die en route to hospital will underestimate any true distance effect, since patients admitted to hospital living farther away from, relative to admitted patients living closer to, a hospital will, on average, be in a better health state (Gillum, 1990; O'Neill, 2003).

The main contribution of this paper is to extend the relatively scarce literature on the effects of geographical access to health care on health outcomes by utilizing very detailed nationwide Swedish administrative data on all AMI occurrences over a twenty-year long period. The data makes it possible to account for both cross-sectional and time variation in AMI survival rates and to control for observed individual heterogeneity. Moreover, the out-of-hospital AMI mortality sample selection problem are accounted for by supplementing the Swedish national inpatient registry with the Swedish national causes of deaths registry, which consists of detailed information on all deaths that occurred in Sweden for all years of study.

A further contribution of this article is to obtain plausibly exogenous changes in hospital distance by making use of a number of Swedish emergency hospital closures over the studied time period. In the beginning of the 1990s, Sweden had a very large geographical spread of emergency hospitals across the country. However, the economic crisis of the 1990s resulted in large public deficits and, as a reaction to this, aggregate health care spending was cut by more than ten percent. A large portion of these cost savings were derived from centralization measures; in particular the closure of a number of emergency hospitals. These closures, plausibly unrelated to individual AMI survival probabilities due to the public nature of health care provision, entailed an implicit change in the distance to an emergency hospital for patients residing in the catchment areas of a closed emergency hospital. Utilizing variation in individual distances to hospitals generated from the policy-induced closures, endogeneity problems arising from self-selection is circumvented by estimating AMI survival probability as a function of the current geographical distance to an emergency hospital while conditioning on pre-closure distance.

Results from estimation show that an increase in distance significantly predicts a lower AMI survival probability for patients residing in the catchment area of a closed emergency hospital. Specifically, the estimates suggest that increasing geographical distance to an emergency hospital from within a ten-kilometer radius to more than fifty kilometers radius would result in a decrease in expected AMI survival probability of 11.5 percentage points, corresponding to a 15 percent reduction at sample mean survival rates. Furthermore, this effect is primarily driven by an increased risk of out-of-hospital mortality among affected patients. Much smaller effects are found when estimating the impact of distance based on actual distances to hospital, indicating that selective residential sorting is likely to greatly dilute the effect of distance. Moreover, the effect is concentrated to the first year after the closures, indicating that no long-run elevated AMI mortality from the closures seems to have occurred. A causal interpretation is also supported by results from relaxing the linear restriction of the distance effect and the finding that the effect is symmetric; i.e. that patients whom experienced a *decrease* hospital distance from the closures also *increased* the probability of surviving an AMI. Finally, there is no evidence that catchment area case-mix or quality of closed hospitals were any different from the characteristics of remaining hospitals prior to the closures.

The results from this study may to some extent be contrasted to the volume-outcome literature in which resource consolidation may increase health care quality, due to e.g. scale effects and learning-by-doing (Maerki *et al.*, 1986; Luft *et al.*, 1987; Hamilton and Ho, 1998). According to this literature, consolidation increases health care quality and is hence considered desirable. However, the disease context may be crucial as to which of these effects is likely to dominate. In particular, while Thiemann *et al.* (1999) finds a positive association between hospital volume and survival of AMI patients, it is likely that any positive quality effects from centralization in this context should be more counteracted by the negative effects on survival, arising from a decrease in geographical access to health care, than for planned surgery where the situation is less acute (e.g. organ transplants and cancer surgery).

The remainder of the article begins with a brief summary of the Swedish health care system in section two. Section three includes a presentation of the data and the sampling methodology. Section four offers a careful review of the empirical approach, in particular with respect to the various inferential problems encountered. Section five presents the results from estimation while section six contains a short summary along with some concluding remarks.

2 The Swedish health care system

In contrast to e.g. the U.S., health care in Sweden is highly regulated. The vast majority of Swedish hospitals are owned and run by the public sector. The Swedish health care system is organized and financed by 21 independent regions, Stockholm being the largest (with about 2 million inhabitants) and Gotland the smallest (with about 60,000 inhabitants). Health care is the single most important responsibility for the regional administration; for instance, in 2012 on average 82 percent of the county budgets were on health care spending. The regional administrations are governed by political councils elected in national elections every four years. Besides following a few general guidelines set by the national government (e.g., that health care should be provided to all Swedish citizens) the regional authorities have high levels of discretion in organizing health care. This institutional setting implies in practice that political representatives of the county councils and bureaucrats, rather than competition among providers, largely determine the number, size, location and coverage of hospitals in each region.

Another consequence of the highly regulated health care sector in Sweden is that patients have little choice as to which hospital they are admitted to in an emergency situation. As health care in Sweden is funded predominantly by direct taxes, there are no individual contracts between patients and hospitals.[3] Instead, depending on where a patient lives, he or she will be directed to a specified nearby hospital when in need of health care. This institutional setting ensures that each patient has a designated "home hospital" each year, which can be identified by using aggregated historical admission data for each municipality and linking this information to the patients' registered home.

The time period studied in this article, i.e. 1990-2010, was a period of strong consolidation of the Swedish health care sector. These measures were deemed necessary by regional authorities in order to increase efficiency and to cover public deficits caused by the economic turbulence in Sweden in the beginning of the 1990s.[4] In total, government

[3]When seeking health care in Sweden a small fee is normally paid up front by the patient. In Stockholm county this fee currently (2013) ranges from 100 SEK (≈10 EUR) when e.g. visiting a physiotherapist to 400 SEK (≈40 EUR) when visiting an emergency room. However, when a patient has paid a total of 1,100 SEK (≈110 EUR)in health care fees in one year, he or she receives a "free card" and health care is free for the remainder of the year. A similar payment system exists for pharmaceuticals in which the patient's share of the drug cost decreases with the total amount spent. In 2013, the maximum amount paid by the patient was 2,200 SEK (≈220 EUR). See e.g. http://www.vardguiden.se/Sa-funkar-det for more information.

[4]The Swedish 1990s economic crisis took place between 1990-1994 and was a combined banking, financial and housing market crisis which is said to have been primarily caused by an unfortunate deregulation of the Swedish credit markets in 1985 (Wohlin, 1998). The financial deregulation led to currency and housing speculation bubbles which deflated in 1991 and resulted in a severe credit crunch and widespread bank insolvency. The cause and development of the Swedish 1990s crisis had much in common with the U.S. subprime mortgage crisis of 2007-2008.

spending on health care decreased by 11 percent, from 8.8 to 7.7 percent of GDP, between 1990 and 2000. A significant share of these savings were derived from structural changes in health care organization within counties; in particular the closure of a number of emergency hospitals across the country (Landstingsförbundet, 2002).

Importantly, due to the institutional features of the Swedish health care sector, the hospital closures should be unrelated to the health characteristics of the underlying population in the hospitals' catchment areas. Moreover, as each individual patient's designated hospital is known at each point in time, the policy-induced closures can be used in order to compute the shift in geographical distance to the new home hospital among patients whose emergency hospitals were closed.

3 Data and sampling

The data used in this article is primarily based on administrative registers from the Swedish National Board of Health and Welfare, covering all Swedish citizens for all years of study. The registers include the Swedish National Patient Register (NPR), consisting of detailed information on all recorded hospitalizations in Sweden, and the National Causes of Death Register (NCDR), consisting of all recorded deaths that occurred in Sweden for individuals with a permanent residence in the country.[5,6] Specifically, the NPR includes individual-level data, for each hospital, on date of admission and discharge, whether the patient were admitted from home or from another clinic, a set of patient characteristics, medical data on diagnoses classified according to the ICD standard[7] and any surgical procedure(s) undertaken during the hospital visit. In addition, the NCDR includes the

[5]The population consists of all deaths that were reported to the Swedish Tax Agency, including all individuals registered as Swedish residents at the time of death. Hence, registered citizens who died outside Sweden (e.g. vacationers) are included while unregistered citizens who died in Sweden are not.

[6]The number of deaths recorded in the NCDR is in practice equivalent to all deaths that occurred in the relevant population. The number of unrecorded deaths in the NCDR in e.g. 2007 amounted to 0.84% (773) of all deaths.

[7]The diagnoses are made by physicians and classified according to the World Health Organization's International Statistical Classification of Diseases and Related Health Problems (ICD-10). ICD-10 is a seven digit coding of diseases and signs, symptoms, abnormal findings, complaints, and external causes of injury or diseases. See e.g. http://www.who.int/classifications/icd/en.

date, place and primary and contributing causes for each death in the data.

The population of interest consists of all Swedish residents who suffered an AMI between 1990 and 2010. Therefore, the analysis sample includes all hospitalization and deaths records caused by ischemic heart diseases with a primary ICD-10 diagnosis code of I.21 or I.22, corresponding to an acute myocardial infarction or re-infarction. Additional information from each hospitalization is also collected, such as patient age, gender, residence, specific hospital and clinic as well as hospitalization and AMI histories for each patient dating back to 1987. The date of death is added to this data from the NCDR (if the individual died at some point).[8] As the data contains individual identifiers it is possible to link the sample to other population registers from Statistics Sweden to include additional patient characteristics. One crucial such characteristic is detailed geographical coordinates for each individual's registered place of residence, measured according to the RT-90 standard.[9] These coordinates are subsequently used to compute the geographical distance from the registered place of residence of each AMI patient included to his or her designated home hospital for each analysis year.

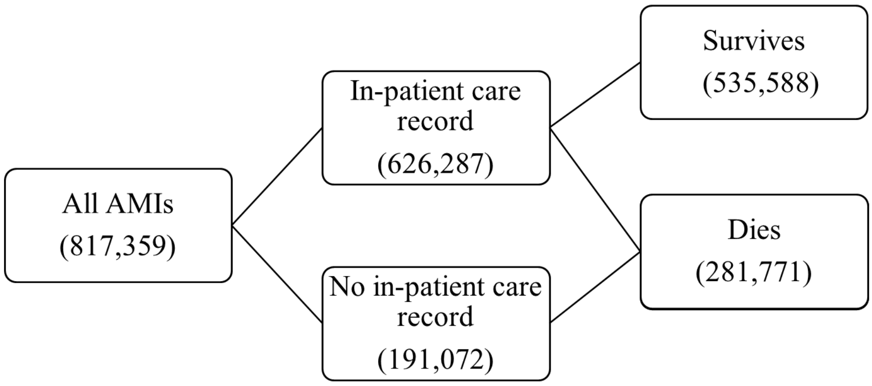
Figure 3.1 illustrates the total number of recorded AMIs between 1990-2010 broken down into relevant categories. As can be seen, out of approximately 817,000 AMIs, about 75 percent (626,000) show up in the NPR as inpatient care records while the remaining quarter (191,000) consists of individuals who died before arriving at a hospital, and hence only show up in the NCDR. In total, about 65 percent (535,000) of the AMI population

[8]As the main outcome of the empirical analysis is the probability of surviving an AMI, the following population breakdown is important; *i)* patients who survived until they were admitted to a hospital, survived the AMI and were discharged, *ii)* patients who survived until they were admitted to a hospital but died while in hospital and *iii)* individuals who died before reaching a hospital and hence were not admitted. It is assumed that all AMI patients need inpatient care and hence that there are no patients who survived the AMI but were not admitted. As the goal of the empirical analysis is to investigate the effects of the distance to hospital on AMI mortality, excluding out-of-hospital AMI deaths will entail an endogenous sample selection under the alternative hypothesis of the existence of an effect of distance. Therefore, the inclusion of all three categories, using data from both the NPR and the NCDR, is essential to establish inference to the population of interest.

[9]Coordinates in "Rikets koordinatsystem" (RT-90) are computed using the Gauss conformal projection or the *Transverse Mercator map projection*. In contrast to the Standard Mercator projection, the transverse projection takes into account that the world is shaped as an ellipsoid and uses complicated calculations and so-called geodetic datums in order to deliver improved accuracy positioning measurements. According to the Swedish Ordnance Survey, the RT-90 measurements cover approximately 3800 triangular points over the country with a relative distance accuracy of 1-2 ppm (mm/km).

survive the AMI while about 35 percent (281,000) die, either before (68 percent) or after (32 percent) being admitted. Clearly, ignoring out-of-hospital mortality will greatly underestimate total AMI mortality in Sweden during this period.

Figure 3.1: Acute Myocardial Infarctions in Sweden,1990-2010



Note.—Data source: Swedish National Board for Health and Welfare. An AMI is defined as an ICD-10 coding of either I.21 or I.22. The total number of AMIs are obtained by combining the inpatient registry (NPR) and the national causes for death registry (NCDR).

3.1 Home hospitals, emergency room closures and referral hospitals

In order to compute an individual's distance to a hospital a "home hospital" is defined for each individual and calendar year based on his or her place of residence. This hospital is selected using historical data on AMI hospitalizations and municipality of residence from the NPR for each municipality and year. In particular, the hospital to which most of the inhabitants of a given municipality are admitted (i.e. the modal hospital) is defined as the home hospital for all individuals residing in this municipal. For most municipalities this procedure is straightforward. However, a few municipalities do not have a clearly defined home hospital for all the years concerned and, for this reason, patients residing in these municipalities are removed from the analysis.[10] Rather than using the actual hospital a

[10]The dropped municipalities are: Salem, Håbo, Boxholm, Ödeshög, Vaggeryd, Hultsfred, Mönsterås, Aneby, Osby, Kungsbacka, Tanum, Färgelanda, Herrljunga, Örkelljunga, Svedala, Falkenberg, Lerum, Grästorp, Vansbro, Leksand and Jokkmokk. These municipalities constitute about seven percent of the total number of Swedish municipalities and much less of the total AMI population. Moreover, none of these municipalities are located in regions where an emergency hospital closure occurred.

patient visits to compute hospital distance, the distance to the designated home hospital is used. In most cases, but not always, these are the same.[11]

The home hospital definition is used to compute distance changes due to hospital closures in two steps: First, in order to identify individuals who were affected by an emergency hospital closure and, subsequently, to compute the new distance to hospital for these individuals by defining a new home hospital (the referral hospital) and the new geographical distance to this hospital.[12] The distance to the new home hospital after closure is subsequently used in the empirical application to estimate the parameters of interest. Emergency hospital closures are defined by the change in the number of AMI admissions they receive across two consecutive years.[13] I find a total of sixteen closures between 1990-2010.[14] The closures identified in the data are also validated from other sources such as official documents, local media coverage and previous research.[15]

Figure 3.2 (and Figures A.1–A.6 in the Appendix) present the monthly number of visits for each closed hospital and the corresponding referral hospital over the period of study. The panel on the left of each closure plot displays the unadjusted raw number of admissions while the panel on the right displays a six-month moving average of admission frequency. The figures show that the referral hospitals almost absorb the full reduction of admissions of the hospitals that were closed.[16]

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[11]This classification is used for several reasons: First, a counter-factual hospital needs to be assigned for AMI patients who expired before reaching a hospital. Second, patients observed to be treated at other hospitals than their designated home hospital are likely to be unrepresentative with regard to the distance they actually traveled (e.g. because they were in another region when the AMI occurred). Third, the Swedish institutional setting makes the home hospital definition very reliable; more than 80 percent of all admissions in the sample occurs at the home hospital.

[12]I use the same strategy to define the referral home hospitals as the other home hospitals, i.e. using historical admissions in the NPR, I infer which hospital patients living in closure-affected municipalities are referred to after a closure.

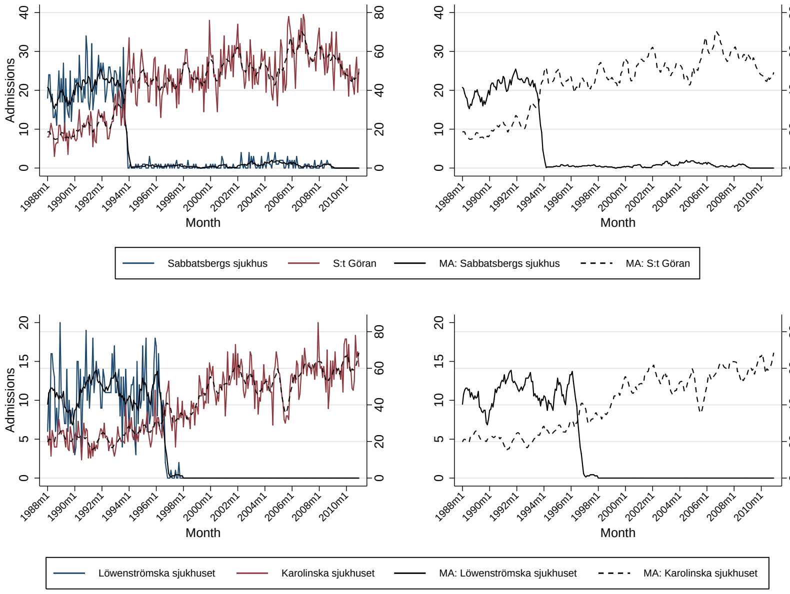
[13]Specifically, a hospital is classified as closed if the number of AMI admissions between two years decreases by more than 90 percent

[14]The closed emergency hospitals are Löwenströmska, Nacka, Finspång, Simrishamn, Landskrona, Strömstad, Falköping, Kristinehamn, Säffle, Sala, Fagersta, Sandviken, Söderhamn, Härnösand, Boden and Luleå hospitals

[15]Lindbom (2013) investigates protests movements in relation to the hospital closures over the same time period. Moreover, Landstingsförbundet (2002) discusses Swedish emergency hospital closures between 1992 and 2000.

[16]Note that the hospitals are plotted on different axes.

Figure 3.2: Number of visits at closing hospitals and their referral hospitals over time



NOTE.— Data source: Swedish National Board for Health and Welfare. The plots on the left show the monthly number of AMI visits at hospitals with closing emergency rooms (blue lines and left y-axis) and referral hospitals (red lines and right y-axis). The plots on the right show the corresponding six-month moving averages of the same plots (three leads and three lags).

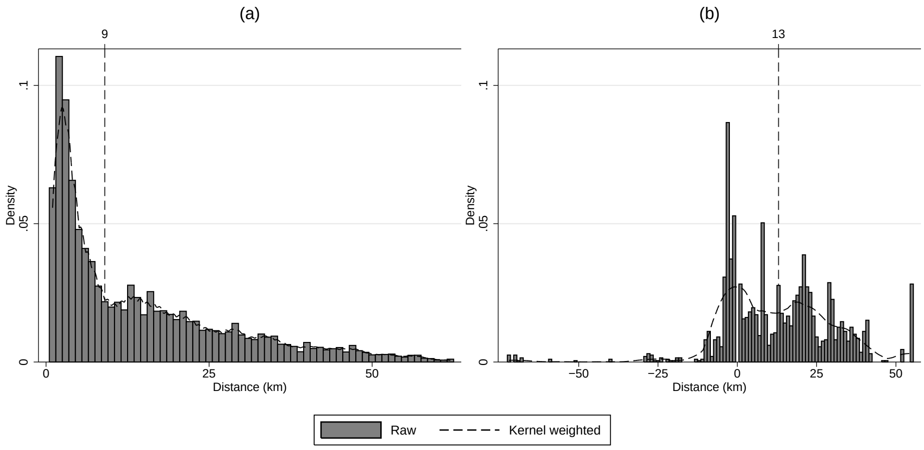
The left panel in Figure 3.3 shows the distribution of distance from a home hospital in the data aggregated over all years of study. Approximately 95 percent of the population lives within a sixty-kilometer radius of their home hospital with a median distance of nine kilometers.[17] As the distance distribution is highly right skewed, I trim the upper five percentiles of the distribution in order to have a more homogeneous sample and to avoid introducing estimation problems from extreme outliers. This restriction mainly affects individuals living in the rural parts of northern Sweden.[18] The panel on the right in Figure 3.3 shows the corresponding distribution of the changes in distance generated from the emergency hospital closures. These changes in distance have reasonably good coverage over the support of the baseline distance distribution in the panel on the left.[19]

[17] I adopt the metric system as length measurement in this article. One English mile is approximately 1.61 kilometers.

[18] Since the inhabitants of this region are typically older and have a lower level of education than the overall Swedish population, it is likely that these individuals also have lower underlying AMI survival probabilities. Hence omitting them would, if anything, give a lower bound on the estimates.

[19] See also Table A.1 in the Appendix for some descriptive sample statistics.

Figure 3.3: Distribution of distance and changes in distance to home hospital



NOTE.— Data source: Swedish National Board for Health and Welfare. Hospital distance is obtained by computing the distance from an individual patient's registered residence to his or her home hospital. The panel on the left shows the residential distance distribution to the home hospital for the analysis sample of AMI patients for the period 1990-2010. The panel on the right shows the distribution of the changes in distance generated by emergency room closures as defined in the data section. The dashed vertical lines indicate the median of the distribution. The dashed smoothed lines are kernel density estimates using a standard Epanechnikov kernel with a bandwidth of 3.9.

4 Empirical approach

Let D be the geographical distance from a patient's home to his or her designated (home) hospital and let y be a binary variable indicating whether an AMI patient survived the infarction or not. Specifically, y is coded as one if an individual survives a certain follow-up period and as zero if the individual died during this period. The empirical focus of this paper is to evaluate the impact of D on y.

There are several problems associated with empirically isolating the effect of hospital distance on AMI survival. The main difficulty is, most likely, that an individual's choice of where to live in relation to a hospital will depend on the health of the same. In particular, any effect of distance would be biased downwards if individuals with poorer health are more likely to take access to health care into consideration when choosing place of residence.[20] In addition to identification problems arising from the optimizing behavior of individuals there are also other problems related to the organization of health

[20] An upward bias could occur if individuals choosing to live further away from a hospital care in general less about their health relative to people living closer to a hospital due to e.g. heterogeneous health preferences. I do not rule out this possibility in the estimations but consider it less likely from a theoretical point of view.

care and the population case-mix in the catchment areas. Average AMI survival rates at a given hospital might vary both over time and with the location and quality of the hospital.[21]

It is possible to control for heterogeneity and common trends across hospitals by including fixed-effects for these factors in a regression model. Moreover, as the data contains a number of individual health and socioeconomic characteristics, these can also be added to the model in order to adjust for individual-level heterogeneity of the patient population within catchment areas. For an individual i experiencing an AMI at calendar time t with home hospital h the effect of distance on survival could hence be estimated using the following regression model:

$$y_{iht} = \alpha + D_{iht}\beta + X_{it}\gamma + \lambda_h + \lambda_t + \nu_{iht},$$

where λ_h and λ_t are hospital and time fixed effects. The effect of distance, β, would be identified in this model if the individual error ν_{iht} was uncorrelated with the distance measure. Given that the health of individual patients is partly unobservable, residential sorting within catchment areas is likely to exist also after including X_{it}, hence invalidating the independence assumption.[22]

To further address the problem of residential sorting, we use variation in individual

[21] Hospitals located in rural areas admit patients with on average both longer distances to the hospital and poorer health characteristics (e.g. older and with a lower level of education). In addition, the preparedness levels for emergency situations may vary between hospitals (e.g. the number of turnkey ambulances) as a consequence of the geographical size of the catchment area.

[22] A simple example may be illustrative. Assume that (y_{it} = AMI survival, κ_i = health status)

$$Pr(y_{it} = 1|D_{it}) = 0 \quad \text{if} \quad I(\kappa_i < \kappa_i'|D_{it}) \tag{i}$$

and that $\frac{\partial \kappa_i'}{\partial D_i} < 0$ so that patients in poor health have incentives to reside nearer to a hospital

Consider the following relation determining distance

$$D_{it} = \alpha + \gamma\kappa_i^* + \tau_{it}$$

where health is measured with error, i.e.

$$\kappa_i^* = \kappa_i + \pi_{it}$$

Then distance will be endogenously related to health if (i) applies, i.e. $Cov(\pi_{it}, D_{it}) < 0$.

distances to hospital generated from emergency hospital closures. By exploiting this variation across time, it is possible to estimate the impact of distance on AMI survival among patients who lived in a closed hospital's catchment area at the time of the closure.[23]

Specifically, first assume that the distance variation the closures generate can be implemented by estimating (OLS) the following model

$$y_{iht} = \alpha + D_{iht}\beta + D_{iht-j}\beta_2 + X_{it}\gamma + \lambda_h + \lambda_t + \eta_{iht}, \tag{1}$$

where D_{iht-j} is the distance for an AMI patient $t-j$ years before the AMI occurred.[24] Here, $\Delta_{D_{iht-j}} = D_{iht} - D_{iht-j}$ is the change in distance to the home hospital between the years t and $t-j$. For all patients living in the catchment area of a non-closing hospital, these distances are the same, i.e. $D_{iht} = D_{iht-j}$. The latter do not contribute to the identification of the effect of distance but are still included as they increase precision of the estimated control variable parameters.

The primary justification for the identification strategy is that individuals cannot immediately adapt to the changing health care environment caused by the decisions of regional authorities to close certain hospitals. The total number of data observations experiencing a change in distance will vary depending on the length of the time window between the closure and the AMI. However, extending the time window to increase the number of patients that are affected also increases the risk of endogenous reactions to the closures, such as selective migration, and may bias the estimation results. Hence, the credibility of the assumption of no endogenous response decreases with the lag j.

[23]The closures would formally correspond to individual variation in hospital distance arising from random shocks to τ_{it} in the previous footnote.

[24]Variation in distance to home hospital may hypothetically emerge from two different sources; closures and migration. Specifically, consider the following distance-generating functions for time periods t and $t-j$, $d_t(coord_{it}, coord_{ht})$, $d_{t-j}(coord_{it-j}, coord_{ht-j})$, where the first argument in the functions is the patient's residential coordinates and the second argument is the coordinates of the patient's home hospital. Now, given that a patient in the year of the closure $(t-j)$ does not migrate between the two time periods (i.e. $coord_{it} = coord_{it-j}$) only a switch of home hospital may result in a distance change. Hence, under the assumption that individuals do not selectively migrate between the two time periods, the change in distance should be unrelated to individual AMI survival probabilities, conditional on the pre-closure distance.

In model (1) the distance and the lagged distance are both included linearly. This specification is highly restrictive since the outcome y is a binary variable. To increase the validity of the regression model, the linearity restriction is relaxed by instead including a set of indicator variables for each ten-kilometer distance. Specifically,

$$y_{iht} = \alpha + I^m_{iht}\beta^m + I^m_{iht-j}\beta^m_2 + X_{it}\gamma + \lambda_h + \lambda_t + \eta_{iht}, m = 1, ..., M, \quad (2)$$

where

$$I^m_{iht-j} = 1((m-1) \times 10) < D_{iht} \leq m \times 10), m = 1, ..., M \text{ and } j = 0, 1.$$

As the emergency room closures also generated distance *cuts* to their home hospital for some patients, it is possible to investigate the symmetry of the effect of distance. One way of investigating effect symmetry is to regress the effect of a positive change and a negative change separately and statistically test whether the coefficients differ. Specifically, the following model is estimated

$$y_{iht} = \alpha + \delta_1(\Delta_{D_{it}} \times I^-_\Delta) + \delta_2(\Delta_{D_{it}} \times I^+_\Delta) + X_{it}\gamma + \lambda_h + \lambda_t + \eta_{iht}, m = 1, ..., M \quad (3)$$

where $I^+_\Delta = 1(\Delta_{D_{it}} > 0)$ and $I^-_\Delta = 1(\Delta_{D_{it}} < 0)$. To test the symmetry of the estimated effect, a simple Wald test of equality of δ_1 and δ_2 is performed.[25]

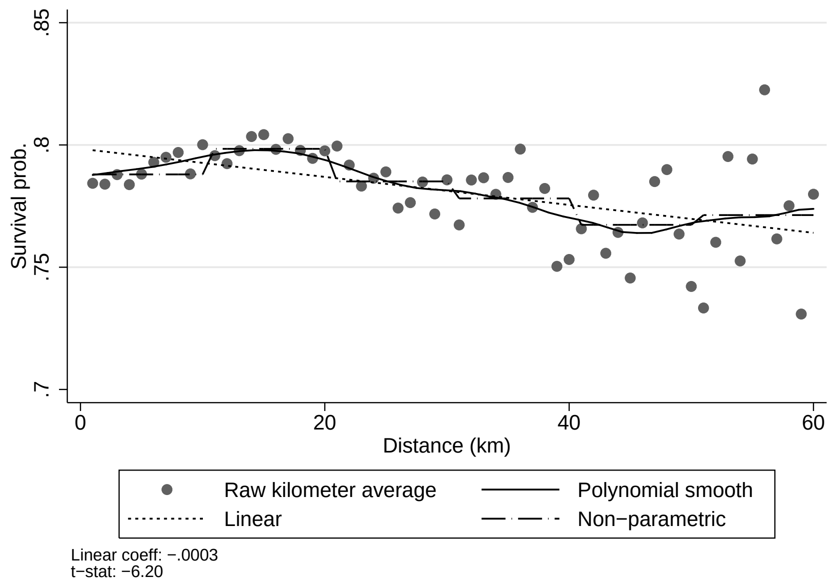
5 Results

We begin this section with a simple descriptive analysis of the observed distance-survival relationship in the data. Figure 5.1 plots correlations of distance to home hospital and

[25]Importantly, since the dependent variable in the models is dichotomous, the linear probability models are an approximation of an unknown data generating process. In an attempt to test the validity of the model approximation, all the results below were also estimated using non-linear (logit) regression models. The results remain qualitatively unchanged by this particular change in specification. The linear estimates are presented throughout the paper to facilitate coefficient interpretation.

AMI survival rates for different parameterizations. Specifically, the gray dots indicate the average survival rate for each kilometer to hospital while the dotted, dashed and solid lines illustrate the relationship under a linear regression model, a locally smoothed and a kernel weighted parameterization, respectively. The figure suggests a negative, albeit weak, correlation between distance and AMI survival with slightly higher survival rates for individuals living closer to their home hospital. The estimate from the linear model, reported below the plot, suggests a decreased survival probability of 0.03 percentage points for each additional kilometer a patient resides from his or her home hospital. With a mean survival rate in the analysis sample of about 78 percent, this is clearly a small difference. However, the upward sloping survival trend at the lower end of the distance distribution raises some doubt about whether the plotted relationship can be interpreted causally. For example, Figures A.7–A.8 in the Appendix show substantial heterogeneity in survival rates both across hospitals and over time. If these factors are correlated with the distance to the home hospital, any estimated effect of distance will be confounded unless they are accounted for.

Figure 5.1: Correlations of distance to home hospital and survival probability from an AMI under various parametric assumptions



NOTE.— Data source: Swedish National Board for Health and Welfare. The figures display the observed correlation between distance to home hospital and survival probability for the sample of AMI patients used in the empirical analysis under different parametric assumptions. The dots indicate the raw kilometer average while the lines show the relationship for different models; the dotted line shows the linear relationship, the dashed line the non-parametric relationship with a dummy indicator for each ten kilometers and the solid line shows a kernel density estimator using a standard Epanechnikov kernel with a bandwidth of 3.9.

5.1 Main results

Table 5.1 presents the main results from the estimation of the effect of distance for different models using the full analysis sample (scaled with a factor of ten for presentation reasons). The first through third columns include only the observed *current* distance to the home hospital, i.e. the observed distance in the year the AMI occurred. The first column reproduces the linear estimate of the distance-survival correlation from Figure 5.1, while the second and third columns include covariate adjustments for a number of health-related characteristics and hospital and calendar time fixed effects, respectively. The estimated distance coefficient remains approximately the same in all specifications, implying relatively small variations in average AMI survival rates over different distances to home hospital.

The fourth column of Table 5.1 additionally includes the *lagged* distance for patients in the year before they were the subject of an AMI, corresponding to equation (1) with

$j = 1$ from the empirical section. The coefficient on current distance now increases in magnitude by a factor of four while the lagged distance coefficient is estimated to be slightly lower and with opposite sign. Comparing over specifications, note that netting out the predicted effect for individuals with the same distance in both periods reproduces, as expected, the distance coefficient displayed in column (3). The estimated current distance coefficient is now interpreted as the marginal effect for an AMI patient of increasing the distance to his or her home hospital by ten kilometers. Hence, this estimate shows a difference in AMI survival probability of about 15 percent for individuals at the lower and upper support of the distance distribution, i.e. zero and sixty kilometers, at mean survival rates.

One theoretical prediction for the effects of geographical access to health care on AMI survival is that it should be monotonously decreasing with hospital distance. The last two columns of Table 5.1 evaluate this prediction by relaxing the assumption of linearity of the effect by replacing the continuous distance measure with a set of dummy variables for each ten-kilometer distance (with the closest distance group, 0-10 kilometers from the hospital, as reference category). The results from estimating model (2) without and with the full set of controls are reported in the right and left of these columns respectively. The estimation result, irrespective of the inclusion of controls, shows a remarkably clear monotonous pattern on AMI survival probability of experiencing a change in distance to home hospital.[26] The estimated coefficients are highly significant and the pattern corresponds quite well with a linear specification, except for distances between 11 and 20 and 21 and 30 kilometers where there seem to be a discontinuous shift in survival probability. In other words, this finding suggests a critical distance threshold where the risk of AMI mortality increases dramatically.[27] Thus, the conforming of the results to

[26]It is interesting to note that including health controls in the last column does not change the results qualitatively. This finding suggests that the endogeneity between the changes in distance and pre-closure distance may not be a severe problem in this application.

[27]This threshold is plausible since, according to Nationellt register för hjärtstopp (2011), if medical assistance is not received within 15 minutes after suffering from a cardiac arrest, death is almost certain. Doing a back-of-the envelope calculation assuming that an ambulance has an average speed of 100 km/h it will take emergency medical personnel about 15 minutes to travel a distance of 25 kilometers, which is exactly in the middle of the empirical threshold where the distance effect kicks in.

the theoretical prediction with respect to the pattern of the effect of distance provides some evidence for the empirical design.

Table 5.1: Estimated effects of distance on AMI survival probability from emergency room closures: Different estimators

	Estimator					
	$\hat{\beta}_{OLS}$	$\hat{\beta}_{OLS}$	$\hat{\beta}_{FE}$	$\hat{\beta}_{D}$	$\hat{\beta}_{NPD}$	$\hat{\beta}_{NPD}$
Current distance	-0.004***	-0.003***	-0.005***	-0.021***		
	(0.001)	(0.001)	(0.001)	(0.005)		
Lagged distance				0.016***		
				(0.005)		
Current Distance Dummies						
11-20 km					0.015	0.002
					(0.020)	(0.020)
21-30 km					-0.036*	-0.041**
					(0.020)	(0.020)
31-40 km					-0.064***	-0.051**
					(0.024)	(0.023)
41-50 km					-0.073**	-0.086***
					(0.032)	(0.031)
51-60 km					-0.109**	-0.115**
					(0.047)	(0.046)
Lagged Distance Dummies						
11-20 km					-0.002	0.001
					(0.020)	(0.020)
21-30 km					0.033*	0.031
					(0.020)	(0.020)
31-40 km					0.055*	0.036
					(0.024)	(0.023)
41-50 km					0.053	0.065**
					(0.032)	(0.031)
51-60 km					0.087*	0.095**
					(0.048)	(0.047)
Covariates		✓	✓	✓		✓
Fixed effects			✓	✓		✓
Observations	331,515	331,515	331,515	331,515	331,515	331,515

NOTE.— The table reports point estimates (standard error) of the effect of distance on survival probability from an acute myocardial infarction for different estimators as explained in the empirical section and using the full sample of all AMIs over the time period 1990-2010. Geographical coordinates are obtained by linking the patient/death data to the population register. Distance is obtained by computing the distance from an individual patient's registered residence to his or her home hospital. For more information see the data section. The current distance variable is defined as the residential distance in kilometers from an individual's home hospital in the current year while lagged distance corresponds to the same distance in the previous year. The last three columns, $\hat{\beta}_D$ and $\hat{\beta}_{NPD}$, estimate the effect of distance using variation in the distance to an individual's home hospital arising from closures of emergency rooms as explained in the data section. The last two columns include a number of distance dummies for each ten kilometers instead of the linear specification. Included covariates are gender, age, the number of previous hospitalizations (AMIs) and the number of years since the last hospitalization (AMI). Fixed effects include hospital and calendar year dummies. Standard errors are estimated using a robust covariance matrix. *, ** and *** denote significance at the 10, 5 and 1 percent levels.

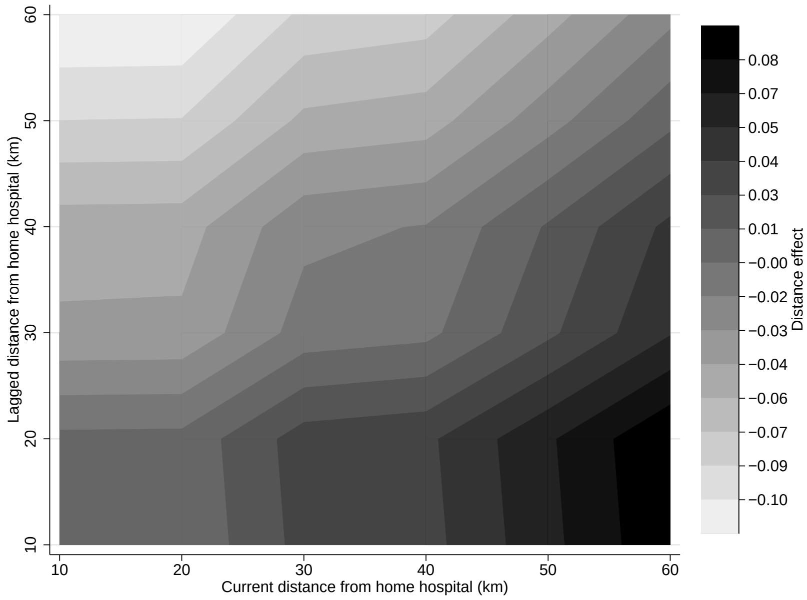
Under the more restrictive assumption of additive separability between hospital distance and health, the difference of the coefficients of Table 5.1 can be given a causal interpretation. Table 5.2 tabulates all possible combinations of these differences for given lagged and current distances under the additional assumption of homogeneity of the effect of distance across lagged distance. These effects are also graphically presented using a contour plot in Figure 5.2. Specifically, the brighter (darker) areas of the plot show for which combinations of lagged and current distance AMI survival probabilities decrease (increase). Going from the upper-left corner (illustrating the effect of an *increase* in geographical distance of 50 kilometers) to the lower-right corner (illustrating the effect of a *decrease* in geographical distance of 50 kilometers) the figure shows a clear monotonous and symmetric pattern of the distance effect.

Table 5.2: Estimated effects of distance on AMI survival probability for different pre-closure hospital distances

	Lagged Distance (km)					
Current distance (km)	0-10	11-20	21-30	31-40	41-50	51-60
0-10	0.000	0.001	0.031	0.036	0.065	0.095
11-20	0.002	0.003	0.033	0.038	0.067	0.097
21-30	-0.041	-0.041	-0.010	-0.005	0.024	0.054
31-40	-0.051	-0.050	-0.019	-0.015	0.014	0.044
41-50	-0.086	-0.086	-0.055	-0.050	-0.021	0.009
51-60	-0.115	-0.114	-0.083	-0.079	-0.050	-0.020

NOTE.— The table shows the estimated effect derived from the last column in Table 5.1 of experiencing a change in home hospital distance from a distance indicated in a given column to a distance indicated in a given row. Geographical coordinates are obtained by linking the patient/death data to the population register. Distance is obtained by computing the distance from an individual patient's registered residence to his or her home hospital. For more information see the data section. See Table 5.1 for estimation details. See also Figure A.8 for a graphical illustration of the effect.

Figure 5.2: Contour plot of the estimated effects of distance



NOTE.— Data source: Swedish National Board for Health and Welfare. The figure shows a three-dimensional contour plot of the estimated effect from Table 5.1 and Table 5.2. The darker areas in the plot correspond to a lower probability of survival while a brighter area corresponds to a higher probability of survival. The figure can be interpreted as showing the estimated effect of going from a given distance to home hospital in time period $t-1$ indicated on the y-axis to a given distance to home hospital in time period t indicated on the x-axis. See the data section for a definition of a home hospital, the computation of distance to home hospital and an explanation of the sample used in the analysis and the empirical section for an explanation of the estimated effects.

Finally, the model from equation (3) was estimated to statistically test the symmetry of the distance effect. The result from this exercise is shown in Table 5.3. The first column of the table reports the estimated coefficients for the change in distance and an indicator variable for a negative change interacted with the change in distance. Similarly, the second column reports results from regressing AMI survival on the *absolute* change in distance interacted with a dummy variable for a positive and a negative change respectively. Since the hypothesis that the coefficients are the same cannot be rejected for any conventional statistical significance levels ($p = 0.7990$), this suggests that the magnitude of the effect of distance is the same, regardless of whether an individual experienced an increase or a decrease in the distance to hospital.

Table 5.3: Estimated effects of distance on AMI survival probability: Symmetry of the effect

	(1)	(2)
Δ_D	-0.014***	
	(0.004)	
$I[\Delta_D < 0] \times \Delta_D$	0.004	
	(0.015)	
$I[\Delta_D > 0] \times Abs[\Delta_D] = b_1$		-0.014***
		(0.004)
$I[\Delta_D < 0] \times Abs[\Delta_D] = b_2$		0.010
		(0.014)
Test $b_1 = -b_2$		
χ^2-statistic (1 *df*)		0.06
p-value		0.7990
Observations	331,515	331,515

NOTE.— The table reports point estimates (standard error) from a linear regression model including the full sample of AMI patients as explained in the empirical section over the time period 1990-2010. Geographical coordinates are obtained by linking the patient/death data to the population register. Distance is obtained by computing the distance from an individual patient's registered residence to his or her home hospital. For more information see the data section. The $I[\cdot]$ functions are indicator functions that evaluate to one if the arguments within the brackets are true and zero otherwise. The lower part of the table displays the statistics from a Wald test on parameter equality between the effects of distance from a positive and a negative change in distance, (b_1 and b_2) respectively. Included covariates are gender, age, the number of previous hospitalizations (AMIs) and the number of years since the last hospitalization (AMI). Fixed effects include hospital and calendar year dummies. Standard errors are estimated using a robust covariance matrix. *, ** and *** denote significance at the 10, 5 and 1 percent levels.

5.2 Extensions and robustness checks

The specific outcome studied so far has been the probability of surviving until discharged from a hospital after suffering an AMI. Table 5.4 presents the results for a number of alternative survival definitions using the same analysis sample and the specification from the last column of Table 5.1. The first column of the table reproduces the main results while the second column reports the results for the probability of surviving the initial phase before being admitted to a hospital, i.e. the out-of-hospital phase. The four right-most columns reports results when the outcome is defined as a binary indicator for whether the patient was alive after one day, one month, one hundred days and one year from the AMI, respectively.[28]

The table reveals interesting effect mechanisms; first, comparing the first two columns of the table, it is clear that most of the effect on survival seem to arise from an increased probability of out-of-hospital mortality.[29] This finding is not unexpected since a longer

[28] As a complement to this analysis, Figure A.9 in the Appendix plots the distribution of deaths in the sample for the first hundred days after the AMI occurred. Day one is excluded in the figure for scaling reasons as the majority of all deaths occur within the first day of the AMI.

[29] The estimated coefficients are much smaller in magnitude and barely statistically significant when us-

geographical distance to hospital will increase both the time it takes to reach the patient and the time it takes to transport him or her to the hospital. Furthermore, the last four columns of Table 5.4 investigate whether the estimated effect is primarily driven by patients in very poor health, in which the additional distance is simply "the straw that broke the camel's back", i.e. a harvesting effect, by comparing results from different survival time horizons after the AMI. Interestingly, the pattern in the last four columns of Table 5.4 indicate that distance to hospital slightly *decreases* the probability of surviving more than one month, compared with surviving only the first day. This result suggests that the estimated effect is not due to harvesting, in which case we would rather see a substantial effect just after the AMI and thereafter a diminishing and even reversed sign of the effect for the more long-term outcomes.

Table 5.4: Estimated effects of distance on AMI survival probability from emergency room closures: Different survival outcomes

	Survival Outcome					
	Hospitalization		Survival time			
	Baseline (AMI=1)	OOH Survival (AMI≠ 2)	Survives > 1 day	Survives > 30 days	Survives > 100 days	Survives > 365 days
Current Distance Dummies						
11-20 km	0.002	0.001	-0.003	0.001	0.003	-0.003
	(0.020)	(0.018)	(0.019)	(0.020)	(0.020)	(0.021)
21-30 km	-0.041**	-0.031*	-0.030	-0.041**	-0.053***	-0.070***
	(0.020)	(0.018)	(0.019)	(0.020)	(0.020)	(0.020)
31-40 km	-0.051**	-0.057***	-0.054**	-0.055**	-0.064***	-0.075***
	(0.023)	(0.021)	(0.022)	(0.023)	(0.024)	(0.024)
41-50 km	-0.086***	-0.052*	-0.061**	-0.089***	-0.085***	-0.098***
	(0.031)	(0.029)	(0.030)	(0.032)	(0.032)	(0.033)
51-60 km	-0.115**	-0.090**	-0.104**	-0.166***	-0.158***	-0.159***
	(0.046)	(0.044)	(0.044)	(0.047)	(0.047)	(0.048)
Observations	331,515	331,515	331,515	331,515	331,515	331,515

NOTE.— The table reports point estimates (standard error) of the effect of distance on survival probability from an acute myocardial infarction as explained in the empirical section and using the full sample of all AMIs over the time period 1990-2010. Geographical coordinates are obtained by linking the patient/death data to the population register. Distance is obtained by computing the distance from an individual patient's registered residence to his or her home hospital. For more information see the data section. The current distance variable is defined as the residential distance in kilometers from an individual's home hospital in the current year while lagged distance corresponds to the same distance in the previous year. Outcomes are defined as indicator functions for being alive when discharged from the hospital following the infarction or surviving until admitted (in the first two columns) and as being alive after a certain time after the AMI occurred (in columns 3-5). Reported coefficients in each column are a number of distance dummies for each ten kilometers. Included covariates are gender, age, the number of previous hospitalizations (AMIs) and years since the last hospitalization (AMI). Fixed effects include hospital and calendar year dummies. Standard errors are estimated using a robust covariance matrix. *, ** and *** denote significance at the 10, 5 and 1 percent levels.

ing the probability of in-hospital mortality as the outcome. The monotonous pattern remains unchanged, however.

Another interesting extension is to investigate whether the estimated effects of distance vary over the time span between an emergency hospital closure and the AMI. Over time, potential coping strategies from both individuals and the health care administrations may arise in order to accommodate any perceived or real distance effects subsequent to the closures. For instance, patients with relatively poor health who experienced reduced access to emergency health care may decide to move closer to the new home hospital. Another possibility is that health care authorities may *ex post* invest more in emergency health care. Both these potential coping behaviors would then serve to diminish the distance effect on survival over time from the closure.

Table 5.5 presents estimation results for AMI patients living in a region in year t where an emergency hospital closure occurred $t - j$ years earlier, with $j = 1, ..., 5$ and where $j = 1$ has been the baseline case studied so far. The sample size is different as the five first years of the sampling period, i.e. 1987-1992, are dropped from the analysis. These five years are excluded in all the specifications in the table in order to facilitate comparison of the results. The header of each column indicates the number of years from closure evaluated and the reported results are based solely on variation in distance for AMI patients who experienced a shift in distance to their home hospital for this particular number of years since hospital closure.

The results from the estimation are striking; there is only a clear effect of distance for the first year after a hospital closure. At each subsequent leading year, the effect is smaller in magnitude and statistically insignificant while measured with similar precision. This pattern indicates that long-run effects of distance from the closures on AMI survival are unlikely to prevail, perhaps as a consequence of various coping strategies among the involved agents. This result is somewhat reassuring for policy-makers since, besides from the initial shock, the hospital closures does not seem to have entailed long-lasting elevated AMI mortality rates.[30]

[30] A back-of-the-envelope analysis might bring some further insights regarding the cost-benefit tradeoff of the closures. In particular, a regression model was estimated of the survival measure including a dummy variable for being affected by a hospital closure on the right hand side (along with the other covariates), which subsequently was related to the average survival rates and AMI incidence in the

Table 5.5: Estimated effects of distance on AMI survival probability from emergency room closures: Short and long-term effects

	Time Horizon (years from closure)				
	One	Two	Three	Four	Five
Current Distance Dummies					
11-20 km	-0.002	-0.013	-0.037**	-0.040**	0.031
	(0.019)	(0.019)	(0.018)	(0.018)	(0.019)
21-30 km	-0.036*	-0.024	-0.017	-0.000	-0.030
	(0.019)	(0.019)	(0.018)	(0.019)	(0.020)
31-40 km	-0.038*	-0.001	-0.016	-0.004	-0.010
	(0.022)	(0.022)	(0.022)	(0.021)	(0.021)
41-50 km	-0.082***	-0.052	-0.034	-0.021	-0.027
	(0.031)	(0.032)	(0.030)	(0.029)	(0.029)
51-60 km	-0.116**	0.013	-0.061	0.087**	0.080
	(0.046)	(0.044)	(0.049)	(0.044)	(0.050)
Observations	285,883	286,030	286,020	286,120	285,988

NOTE.— The table reports point estimates (standard error) of the effect of distance on survival probability from an acute myocardial infarction as explained in the empirical section and using the full sample of all AMIs over the time period 1990-2010. Geographical coordinates are obtained by linking the patient/death data to the population register. Distance is obtained by computing the distance from an individual patient's registered residence to his or her home hospital. For more information see the data section. The current distance variable is defined as the residential distance in kilometers from an individual's home hospital in the current year while lagged distance corresponds to the same distance in the previous year. Outcome is defined as an indicator function for being alive when discharged from a hospital following the infarction. Each specification pertains to a specific time horizon from an emergency room closure (the number of lagged years). Reported coefficients in each column are a number of distance dummies for each ten kilometers. Included covariates are gender, age, the number of previous hospitalizations (AMIs) and the number of years since the last hospitalization (AMI). Fixed effects include hospital and calendar year dummies. Standard errors are estimated using a robust covariance matrix. *, ** and *** denote significance at the 10, 5 and 1 percent levels.

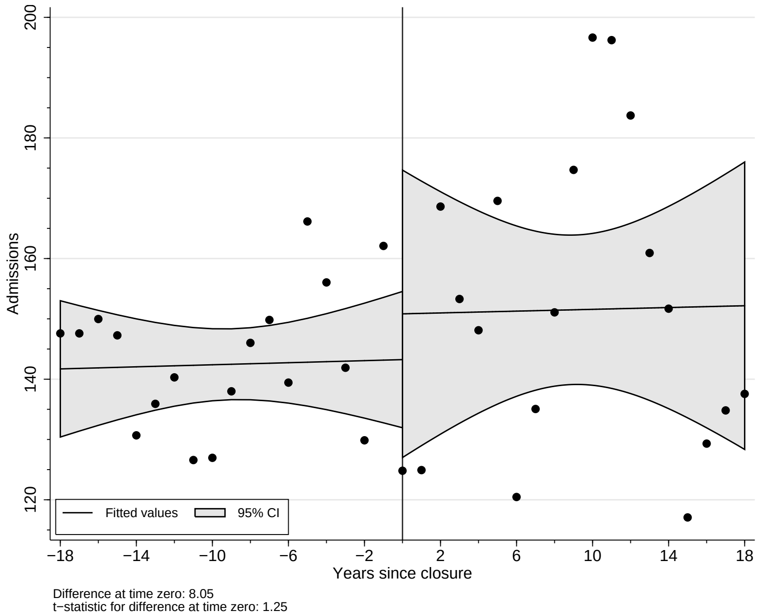
A potential problem caused by restricting the sample to only include individuals who suffered an AMI is that the closures may have endogenously changed the population at risk of having an AMI. This could occur, for example, if admissions for other reasons than AMI may change a patient's general perception of his or her health risks and induce a more proactive behavior. In this respect, the closures may have affected the population at risk for an AMI through the reduced access to health care which, in turn, might have induced a downward bias on the estimated distance effect.

To evaluate whether the closures affected the population at risk for an AMI we can study AMI incidence rates in closing hospitals' catchment areas over time. Figure 5.3

relevant population. The effect of being affected by a hospital closure reduced the average survival probability with an estimated two percentage points, i.e. from 0.79 to 0.77 at mean survival rates. As the annual average number of AMIs is about 20,000, this estimate suggests that about 320 extra deaths would have occurred had the closures affected the full AMI patient population. However, as the underlying population of the relevant catchment areas is only about ten percent of the total AMI population in a given year, the closures caused only an estimated 32 additional deaths. Hence, the total of 16 closures in the data meant an additional two deaths per closure. Assuming that the value of a statistical life is about €2 million, the closures could thus be deemed "cost-effective" if the cost savings were more than €4 million per closed hospital.

shows the empirical relationship between AMI admission frequency in municipalities where a closure occurred in years from the time of the closures after adjusting for calendar year trends in AMI incidence. The dots in the figure indicate yearly averages and the solid line plots the piece-wise linear relationship allowing for a discontinuity in the year of the closure (indicated by the vertical line). The figure reveals a small increase in AMI incidence after, as compared to before, the hospital closures. However, the change is not significantly different from zero at any conventional levels of statistical significance.

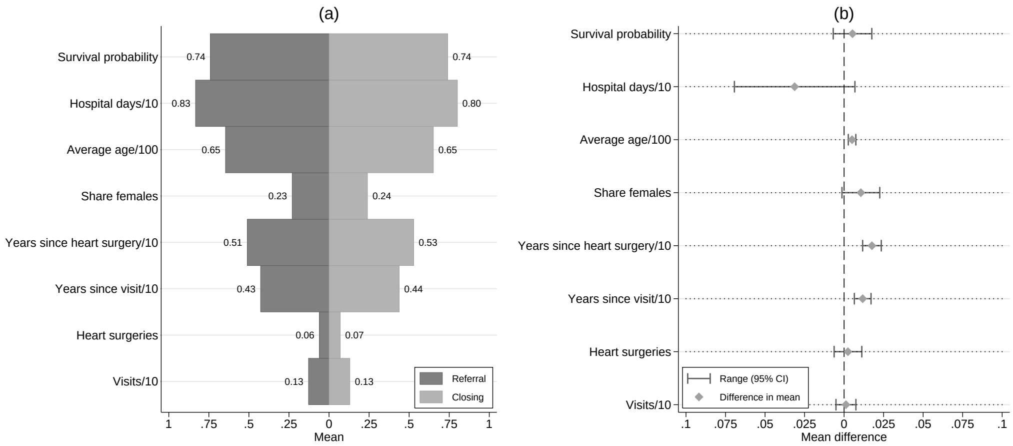
Figure 5.3: Effect of the closures on AMI incidence



NOTE.—Data source: Swedish National Board of Health and Welfare. The figure shows the relationship between the average number of admissions in a closing hospital's catchment area over time since the closure occurred, adjusting for calendar time trends in AMI incidence. The dots show the average values for each particular time period and the solid line pertains to a piece-wise linear relationship allowing for discontinuity at the time of closure, indicated by the vertical line. The shaded area marks the 95% confidence interval of the linear estimate.

Finally, one potential concern of the empirical design is that the closing hospitals used to generate variation in hospital distance were selectively shut down with respect to the underlying survival probability of population case-mix in the respective catchment area. As mentioned earlier, this is unlikely due to the public nature of the health care provision in Sweden. Moreover, average hospital quality is also controlled for in the analysis. Nevertheless, the concern is further investigated by analyzing aggregate health characteristics in closing and referral hospital's catchments areas. Figure 5.4 shows the average values of a number of aggregate health characteristics for closing and referral hospital catchment areas (left panel) and their difference along with a 95-percent confidence band (right panel) for years prior to the hospital closures. The results are reassuring; both types of regions have, on average, similar health characteristics, indicating that regions where closures occurred are observationally unrelated to underlying patient population health characteristics.

Figure 5.4: Aggregate health indicators in closing and referral hospital catchment areas



Note.— Data source: Swedish National Board of Health and Welfare. See the data section for a definition of a home hospital, closing hospital and referral hospital. The left panel of the figure shows the average values for a number of health indicators for each type of region and the right panel shows the cross-regional mean difference for each of these indicators (point estimate and 95 percent confidence band). Some variables have been scaled to make the plot readable.

6 Summary and concluding remarks

Ischemic heart disease, with acute myocardial infarction (AMI) as one of its more serious manifestations, is the most common cause of death in Sweden as well as in most of the Western world. Since infarctions often occur relatively unexpectedly and rapid medical assistance is fundamental for recovery, the probability of surviving an AMI is highly dependent on a well-functioning health care system which can provide quick access to health care in emergency situations. This is particularly important in relatively sparsely populated countries like Sweden, where distances to medical care facilities with emergency room capacity vary greatly between individual residents.

This paper evaluates the existence and magnitude of the impact of geographical access to health care on health using AMI patients as the empirical application. Both the problem of missing mortality data and the likely residential sorting of individuals are circumvented by; *i)* adding nationwide information on AMI deaths from the Swedish national causes of death registry to supplement the national inpatient registry; and *ii)* utilizing geographical variation in distance to hospital arising from a number of emergency hospital closures during a period of strong centralization of the publicly administered Swedish health care sector. In Sweden, virtually all inpatient health care is publicly provided and financed, implying that competition effects on the number and placing of hospitals in the country should be negligible. Moreover, as individuals are directed to a specific hospital based on their place of residence, variation over time with respect to which hospital patients are directed to can be used to obtain plausibly exogenous shifts in individual distances to hospital. As the full AMI population over a twenty-year period is included in the analysis, i.e. both admitted patients and patients who die before reaching a hospital, the empirical design accounts for both of the presumably most serious identification problems in evaluating the health effects of geographical access to health care.

Using data on more than 300,000 AMI cases and sixteen emergency hospital closures over the period 1990-2010, we find a substantial, statistically significant and monotonously decreasing effect of emergency hospital proximity on AMI survival probability. In particular, patients who experienced an increase in the distance to their home hospital of between 51 and 60 kilometers ran an estimated 15 percent lower risk of surviving the AMI than patients who lived within ten kilometers of their home hospital during both periods. This effect is, as expected, primarily driven by an increased risk of out-of-hospital mortality. Moreover, much smaller effects are found when estimating the effects of distance based on actual distances to hospital, indicating that selective residential sorting is likely to dilute the distance effect. When varying the time window between the closures and AMI occurrence, the effect is shown to be only statistically significant in the first year after the closures. Perhaps reassuring for policy makers, the closures thus only seem to have had a short-run effect, which might later have been counteracted with various types of coping behavior among the involved agents. Finally, as a number of patients experienced a cut in hospital distance due to the closures, the symmetry of the distance effect is evaluated. The estimated effect is indeed reversed for patients who experienced a decrease in distance and symmetry cannot be rejected.

To conclude, in times when health care expenditure increased in most Western countries, Sweden went in the opposite direction and reduced its health care spending by approximately 11 percent between 1990 and 2000. Most of the cost savings were derived from structural changes in the health care sector; from inpatient to outpatient care and from increased resource consolidation of many care services. These tendencies were perhaps necessary given the public sector budget deficits, a consequence of the economic depression in Sweden at the time, but the question remains whether the reduction in health care expenditure came at the cost of a decrease in access to health care among individuals living in more remote parts of the country. The results in this paper provide some evidence for the notion that geographical access to health care does have an impact, albeit only temporarily, on the survival rates of AMI patients, and hence that health care centralization may have important side effects that should be taken into account. Perhaps more importantly, this effect of distance may be more persistent in other countries with more unregulated health care sectors due to the strategical positioning of profit-maximizing hospitals. Specifically, hospitals in these markets may abandon geographical areas in which aggregate incidence rates of costly emergency health care is higher, thus creating a "health care desert" similar to the phenomenon of food deserts recognized in many countries.

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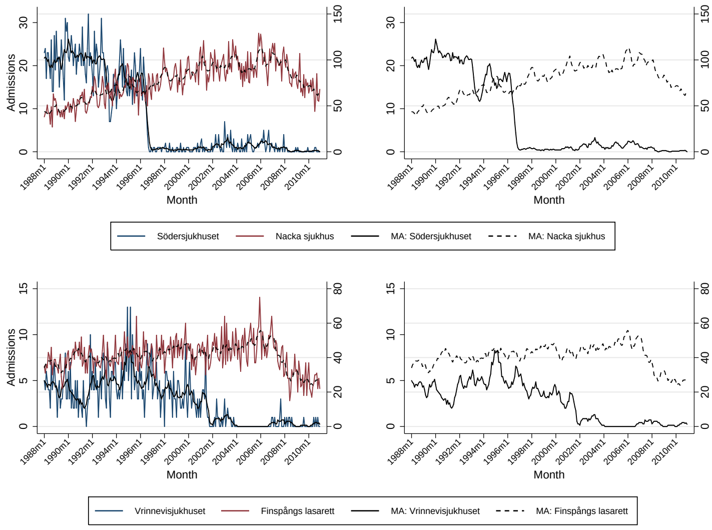
Appendix A Tables and figures

Table A.1: Descriptive sample statistics

Variable	Group averages: No distance change	Group averages: Distance change	Group difference: Mean difference	Group difference: $P(\|Z\| \leq z)$
Heart surgeries	0.137	0.141	0.004	0.780
	(0.537)	(0.525)	(0.012)	
Years since hospital visit	5.841	6.231	0.390	<0.001
	(3.001)	(3.104)	(0.072)	
Years since heart surgery	8.549	9.360	0.811	<0.001
	(2.450)	(1.615)	(0.058)	
Female	0.313	0.298	-0.015	0.188
Age	71.12	70.75	-0.37	0.165
	(1.113)	(1.123)	(0.027)	
Days in hospital	6.728	6.408	-0.320	0.067
	(6.607)	(5.198)	(0.176)	
Hospital distance in j	14.175	14.076	-0.100	0.757
	(13.516)	(11.163)	(0.323)	
Hospital distance in $j+1$	14.175	26.085	11.909	<0.001
	(13.516)	(12.659)	(0.323)	
Survived AMI	0.773	0.760	-0.013	0.194
OOH AMI death	0.174	0.194	0.020	0.027
IH AMI death	0.054	0.047	-0.007	0.191
Observations	329,756	1,759	331,515	-

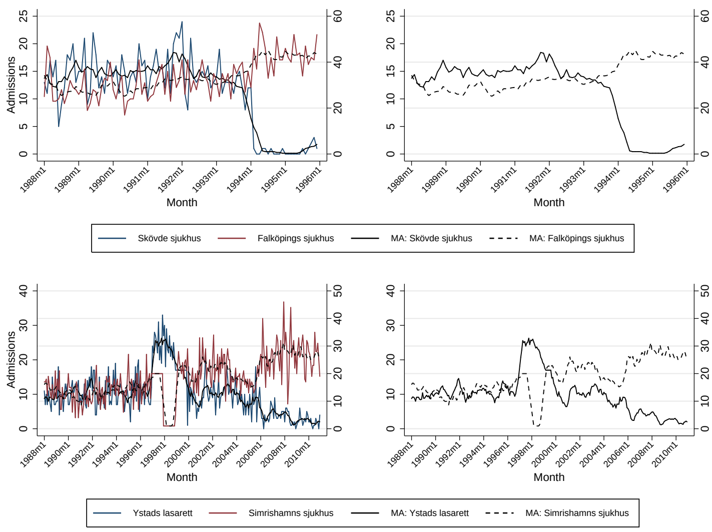
NOTE.—The table reports estimated means, mean differences and (standard deviations) of included covariates for sampled AMI patients who did or did not experience a change in distance from an emergency hospital closure respectively. The variables are; the historical number of heart surgeries, number of years since the last hospital visit, years since the last reported heart surgery, the individual's gender and age, the historical number of days in hospital since 1987, the observed distance from an individual's registered residence to his or her designated home hospital in time period j and $j+1$ where j indicates the year of the hospital closure respectively, and finally the proportion of patients who survived, died outside and inside a hospital respectively. The last two columns report the difference in group means and the result from a standard t-test of equality of means across the groups.

Figure A.1: Visits at closing hospitals and their referral hospitals over time



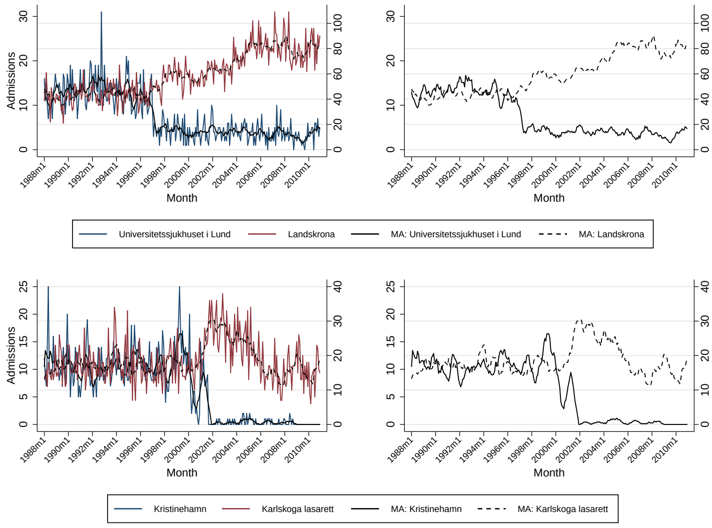
NOTE.— Data source: Swedish National Board for Health and Welfare. The plots on the left show the monthly number of AMI visits at hospitals with closing emergency rooms (blue lines and left y-axis) and referral hospitals (red lines and right y-axis). The plots on the right show the corresponding six-month moving averages of the same plots (three leads and three lags).

Figure A.2: Visits at closing hospitals and their referral hospitals over time



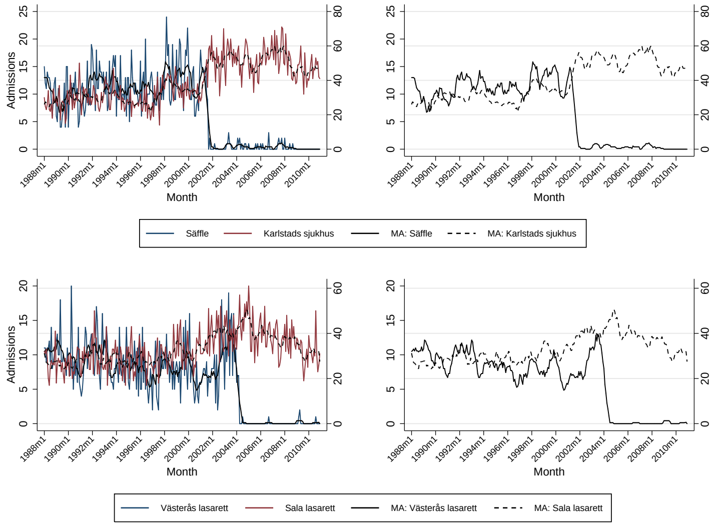
NOTE.— Data source: Swedish National Board for Health and Welfare. The plots on the left show the monthly number of AMI visits at hospitals with closing emergency rooms (blue lines and left y-axis) and referral hospitals (red lines and right y-axis). The plots on the right show the corresponding six-month moving averages of the same plots (three leads and three lags).

Figure A.3: Visits at closing hospitals and their referral hospitals over time



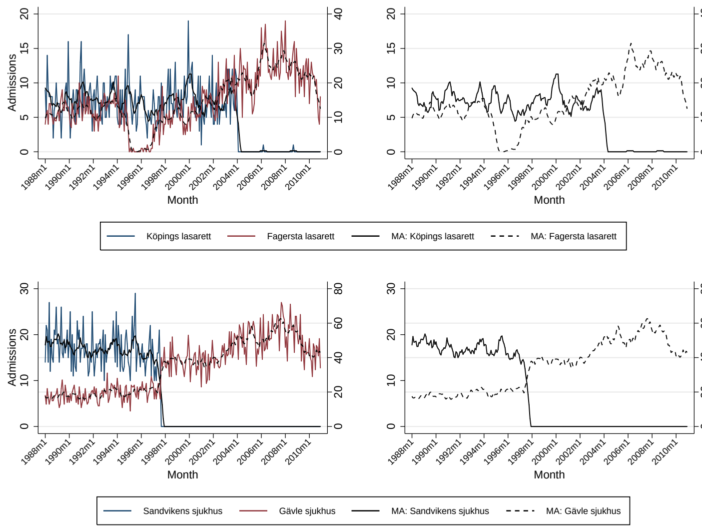
Note.— Data source: Swedish National Board for Health and Welfare. The plots on the left show the monthly number of AMI visits at hospitals with closing emergency rooms (blue lines and left y-axis) and referral hospitals (red lines and right y-axis). The plots on the right show the corresponding six-month moving averages of the same plots (three leads and three lags).

Figure A.4: Visits at closing hospitals and their referral hospitals over time



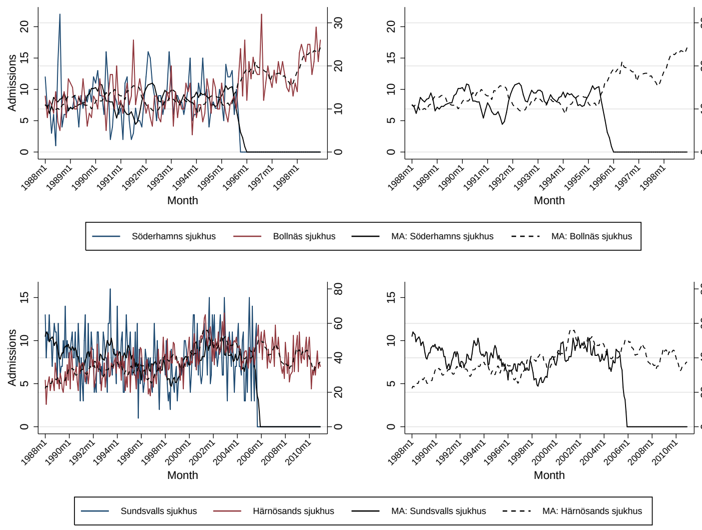
Note.— Data source: Swedish National Board for Health and Welfare. The plots on the left show the monthly number of AMI visits at hospitals with closing emergency rooms (blue lines and left y-axis) and referral hospitals (red lines and right y-axis). The plots on the right show the corresponding six-month moving averages of the same plots (three leads and three lags).

Figure A.5: Visits at closing hospitals and their referral hospitals over time



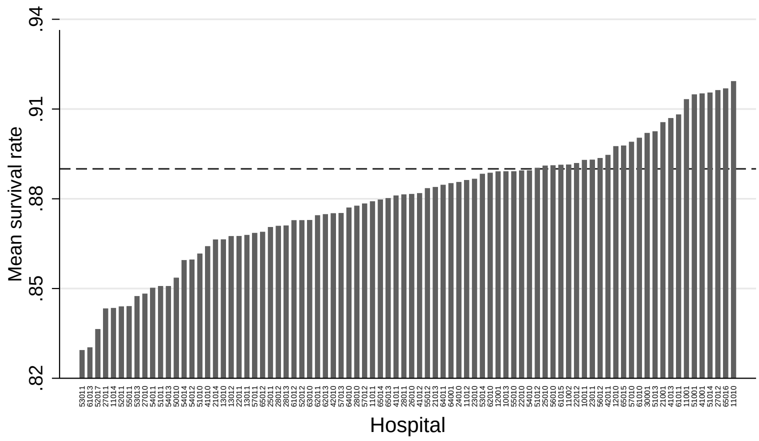
Note.— Data source: Swedish National Board for Health and Welfare. The plots on the left show the monthly number of AMI visits at hospitals with closing emergency rooms (blue lines and left y-axis) and referral hospitals (red lines and right y-axis). The plots on the right show the corresponding six-month moving averages of the same plots (three leads and three lags).

Figure A.6: Visits at closing hospitals and their referral hospitals over time



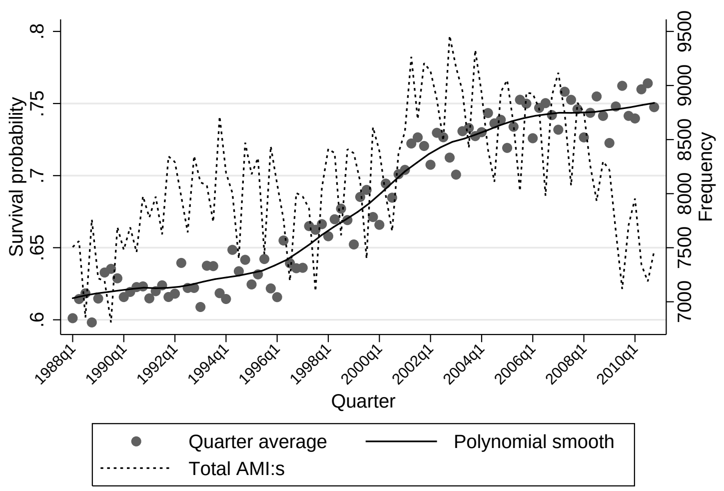
Note.— Data source: Swedish National Board for Health and Welfare. The plots on the left show the monthly number of AMI visits at hospitals with closing emergency rooms (blue lines and left y-axis) and referral hospitals (red lines and right y-axis). The plots on the right show the corresponding six-month moving averages of the same plots (three leads and three lags).

Figure A.7: Survival probability by home hospital



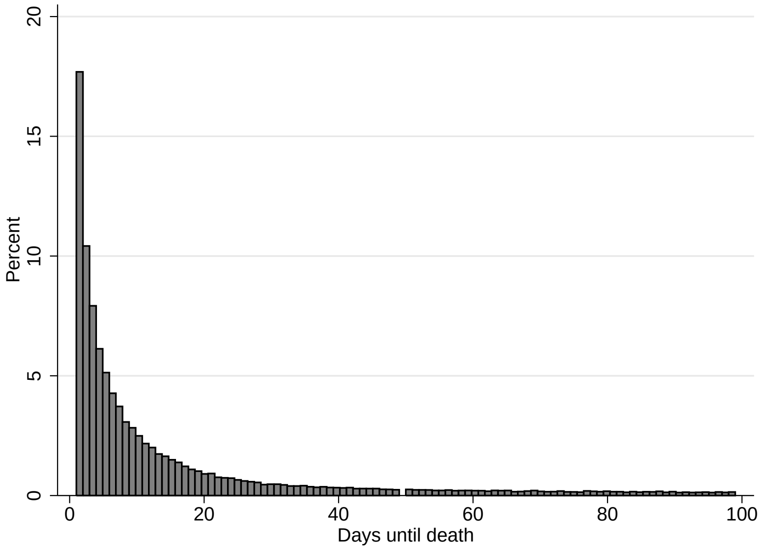
Note.— Data source: Swedish National Board for Health and Welfare. AMI survival probability for each hospital is measured as the share of individuals who were the subject of an AMI living in the hospitals catchment area and were discharged from the hospital alive. Individual hospitals are shown on the x-axis in ascending order with respect to survival probability aggregated over the period 1990-2010. The horizontal dashed line indicates hospital average survival probability in the sample of hospitals.

Figure A.8: AMI frequency and average survival rates, 1990-2010



Note.— Data source: Swedish National Board for Health and Welfare. The figure plots (on the left y-axis) average survival rates as a raw quarterly average and as a smoothed kernel density estimate using an Epanechnikov kernel with a bandwidth of 3.8. The quarterly number of AMIs over the period is plotted on the right y-axis.

Figure A.9: Distribution of deaths by days after an AMI



Note.— Data source: Swedish National Board of Health and Welfare. The figure shows the distribution of the observed number of deaths in the analysis sample of AMI patients excluding individuals that die on the same day as the AMI occurred (due to scaling issues). The number of AMI cases ending in death on the same day as the AMI occurred is approximately 191,000 or 58 percent of the total number of deaths.