The Deadly Consequences of Skilled Labor Scarcity: Evidence from Hospitals*

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Abstract

Skilled labor scarcity is a major economic challenge in developed countries. Albeit present across industries, it is especially a pressing issue in the healthcare sector due to its size and importance. This paper studies how the shortage of nurses affects the provision of hospital services and patients' health. I leverage increased incentives to work in Switzerland, induced by a Swiss monetary policy, that led to a sudden and strong outflow of nurses in German hospitals. Based on administrative data covering the universe of hospitals and inpatient cases in Germany combined with a matched difference-in-differences design, I show that labor scarcity substantially alters the provision of healthcare services, increases mortality, and lowers life expectancy, especially for vulnerable subgroups.

Keywords: Skilled labor scarcity, Cross-border commuting, Wage differences, Nurses, Health effects, Hospital reaction

JEL classification: J22, J24, J31, J61, I10, I12, R23

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1 Introduction

The global trend of decelerating labor supply growth and the associated shortage of skilled workers pose enormous challenges for economies (ILO, 2023). This phenomenon is likely to amplify in industrialized countries in the coming years, where the strong aging of society leads to a reduction in the working population, especially of skilled and experienced workers. Already now, skilled labor scarcity increases production costs through higher wages and causes firms, regions, and even countries to compete over workers. Yet also workers themselves are potentially negatively affected, as the shortage of labor triggers the innovation and adaptation of labor-saving technologies such as robots (Acemoglu and Restrepo, 2022; Benmelech and Zator, 2022; Acemoglu, 2010). As argued by Jones (2022), the consequences of the shortage of labor due to demographic change even have the potential to put an end to economic growth

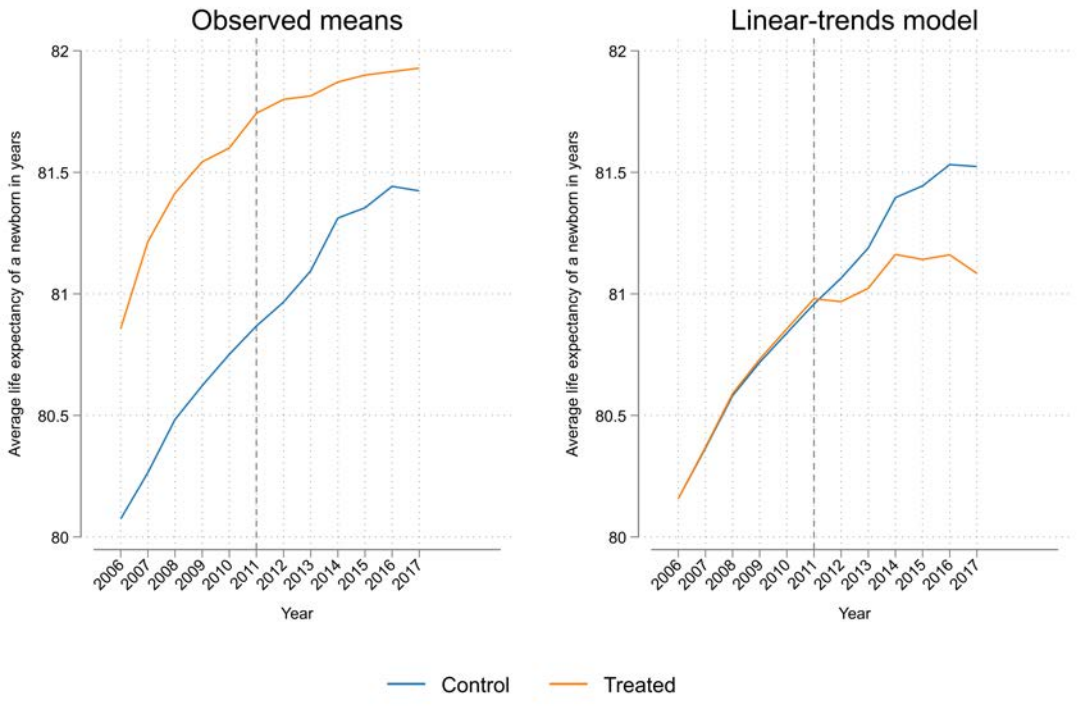
One sector where skilled labor scarcity is expected to be especially severe is healthcare. Not only is the healthcare sector of major importance, making up around 13% of GDP in Germany and almost 20% in the US in 2021; demographic change results both in fewer healthcare workers and in increasing demand due to a growing number of elderly people who are at the same time increasingly living longer and are, therefore, more dependent on care. Current projections thus anticipate a shortfall of almost 2.5 million full-time equivalents (FTEs) nurses across 23 OECD countries as early as 2030 (Scheffler and Arnold, 2019). This not only applies to the elderly but also to hospital care. In Germany alone, the demographic change increases the demand for nurses in hospitals by 63 thousand by 2030 (Blum et al., 2019). And these projections are unlikely to improve as, unlike in other professions, many tasks performed by healthcare workers in general, and nurses in particular, are socially interactive and thus hardly substitutable by capital or technology. The consequences for patients are potentially most severe in hospitals where nurses play a key role in ensuring timely and adequate treatment, especially for urgent cases (Zaranko et al., 2023). In hospitals, reduced care quality through nurse scarcity affects everyone, whether it's mothers and their newborns or family fathers having a heart attack in their forties. If the working-age population is not treated adequately and faces longer periods of sick leave or chronic issues impairing their productivity in the long run, this means that labor scarcity in hospitals has the potential to foster labor scarcity everywhere else. This paper aims to quantify the impact of labor scarcity in hospitals on patients' health outcomes. To overcome endogeneity issues, I utilize a strong and persistent appreciation of the Swiss franc in the aftermath of the EU debt crisis in late 2011, which increased the incentives for Germans to work in Switzerland. German hospitals, in turn, were affected by an outflow of workers only due to their proximity to the border. Compared to other (healthcare) occupations, registered ("high-skilled") nurses face low legal barriers of entry and were in high demand in Switzerland (Ruedin and Widmer, 2010). Thus, they

over-proportionally started to commute, and as these were previously mostly working in hospital care, German hospitals within commuting distance to Switzerland faced a sudden and strong decrease in staffing rates. I compare hospitals and patients in border counties that were affected by nurse shortages with similar unaffected counterparts further inland using a matched multi-period difference-in-differences approach. Rich indvidual-level administrative records covering the universe of all inpatient cases in Germany over a span of 12 years, along with hospital-level administrative and survey data, allow me to elaborate in detail on the mechanisms driving the effects. Due to collective wage bargaining and fixed prices for services, German hospitals had very little leeway to actively retain their workforce. Thus, the combination of a clean negative input factor shock without wage adjustment makes it an ideal case to study the consequences of labor scarcity in an important sector in a major country in Europe.

I find that due to the event and compared to the years before, the number of German healthcare workers newly commuting to Switzerland increased strongly and persistently by more than 45% from 2012 onwards. In turn German border hospitals lost, on average, 7% of their nursing staff relative to hospitals in similar counties further inland. This reduction is entirely driven by registered, i.e., high-skilled nurses, as they were not only in high demand in Switzerland but faced also only low barriers (Ruedin and Widmer, 2010). In contrast, other occupations, both within and outside healthcare, did not react, most likely because of low demand in Switzerland. Due to collective wage bargaining, German hospitals are not able to respond to higher outside options for their staff by increasing wages, which implies that border hospitals faced a clean input factor shock. While firms in the border region were able to react by increasing wages and maybe prices, even hospitals with private providers have little scope to adjust in both dimensions as they face a stringent case-based reimbursement scheme. In turn, patients saw a decrease in service provision. Even after controlling for demographic characteristics and the detailed main diagnosis, patients in hospitals affected by nurse scarcity receive (needed) surgeries around 3.7p.p., or 12%, less likely and have a 0.1p.p., or 5%, higher probability of dying during their stay in the hospital. While hospitals aim to reduce surgeries for non-urgent cases, especially older and urgent cases face increased mortality. Looking at the aggregate mortality and life expectancy at the regional level confirms these results. Already the raw means depicted in Figure 1 show that the life expectancy in treated and control counties starts to diverge. The matched multi-period difference-in-differences approach confirms: After 2011 and relative to control counties, the life expectancy in border counties decreases by, on average, 0.3 statistical life years. Extensive robustness checks and sensitivity analyses indicate that these effects cannot be explained by concurring events, or demand or supply effects, e.g., induced by accompanying demographic or socio-economic trends. Hence, given that hospitals were unable to counteract by increasing wages and were limited in their ability to substitute, the increasing mortality due to the decreasing staffing rates

presents conceptual proof that skilled labor scarcity in health care comes with deadly consequences.

Figure 1: Raw Means of Life Expectancy in Border and Control Counties



Notes: This graph shows the average life expectancy in means (left panel) and after accounting for linear trends (right panel) for treated and matched control counties. Treated refers to counties at the Swiss-German border characterized by being prone to cross-border commuting. Control refers to the most similar counties based on pre-event characteristics in terms of population size, population density, population age, and GDP per capita. The allocation of counties into treated and control counties is explained in detail in Section 4.

This paper adds to several strands of the literature. Firstly, I add to the literature on the determinants of healthcare workforce labor supply (Eberth et al., 2016; Combes et al., 2015; Propper and Van Reenen, 2010). By showing that skilled nurses react strongly to relative wage differences, this paper tackles the notion that nurses' labor supply elasticity with respect to wages is low and rather dependent on non-wage factors. Secondly, despite their importance, there is still limited knowledge to which extent the shortage of nurses in hospitals affects the functioning of hospitals and, thus, patients' health. One main reason is endogeneity, i.e. the simultaneous relationship between the quality of care and staffing rates. As high-quality hospitals *per se* face less likely shortages, estimates relating nurse staffing rates to patients' outcomes likely suffer from bias (Lin, 2014). Thus, as the strong health effects are entirely driven by the sudden and persistent outflow of skilled nurses in border hospitals, this paper adds to the literature on the importance of nurses for the quality of care and patients' health (Friedrich and Hackmann, 2021; Aiken et al.,

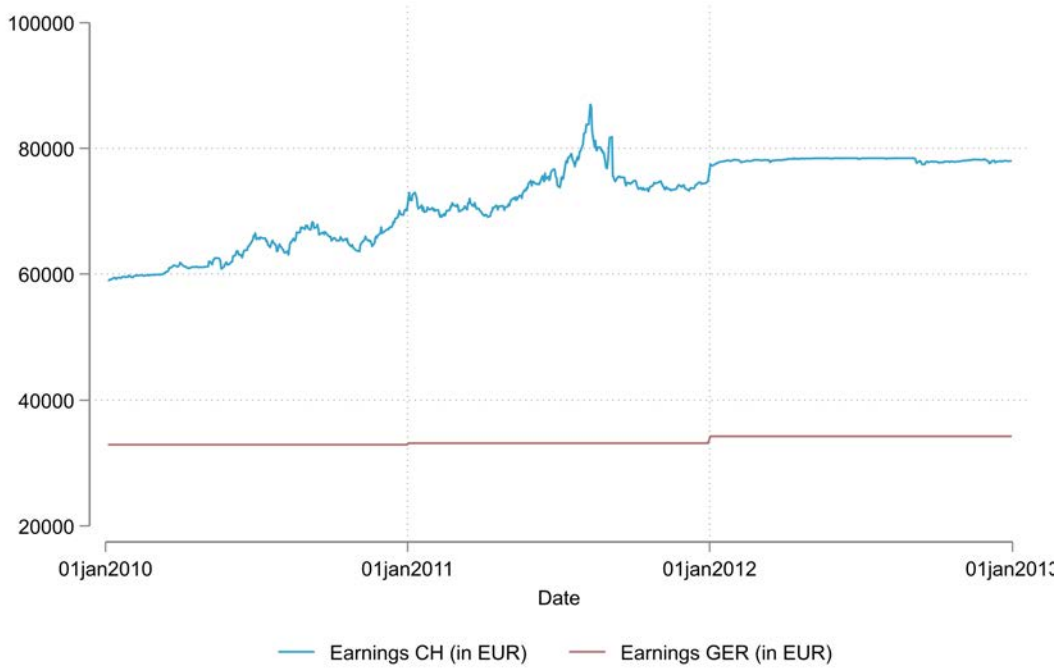
2021; Stevens et al., 2015; Propper and Van Reenen, 2010). But the rich individual-level administrative data covering the universe of all inpatient cases in Germany allows me not only to exactly pin down, who is most strongly affected. It also allows me to examine how hospitals react to a clean negative input factor shock and, by that, relate to a broad literature on the identification of hospital production functions (Kleiner, 2019; Romley and Sood, 2013). For the German border region, the increasing cross-border commuting of registered nurses as a reaction to higher wages in a neighboring country meant a serious "brain drain". Here, I add to the migration literature by looking at the implications of middle-skilled cross-border commuting for sending countries where much of the literature so far considered either high-skilled migration (Docquier and Veljanoska, 2022; Docquier and Rapoport, 2012; Gibson and McKenzie, 2012) or the impact of cross-border commuting on receiving countries (Beerli et al., 2021; Dustmann et al., 2017).
The structure of the paper is as follows. Section 2 provides the institutional background and gives an overview of the causes and consequences of the policy, which has led to the persistently high wage differences between Germany and Switzerland. In Section 3, I describe the main data sources that are used for the causal analysis. The empirical strategy, including the matching process and assignment into treatment and control group, is described in Section 4. Section 5 presents results showing how strongly nurses react to increasing cross-country wage differences, and how, in turn, hospital staffing rates and patients' health are affected. Section 6 concludes and presents a short outlook.

2 Institutional Setting

In the wake of the European financial and debt crisis, the Swiss franc (CHF) began to emerge as a popular alternative to the euro. This led to a strong appreciation of the CHF relative to the euro and to concerns that the Swiss economy, which is highly dependent on exports, was heading for a recession. Driven by political and economic pressure, the Swiss National Bank (SNB) soon began to lower interest rates and increase liquidity. Despite initial success, however, the exchange rate continued to rise rapidly, which is why the SNB went for the ultima ratio in September 2011: It announced to bind the CHF to the euro at the minimum level of CHF 1.20 per euro (Landmann et al., 2011).
For German employees living along the German-Swiss border, the strong appreciation meant a sharp increase in the attractiveness of commuting to Switzerland. While German nurses could earn around 20,000 Euros gross more when working in Switzerland instead of Germany in 2008, this difference almost doubled by 2011 (see Figure 2). However, this income difference was subject to uncertainty. Only the stabilization of the exchange rate ultimately led not only to a higher but also a *guaranteed and permanently higher* outside option. In addition, the surprising announcement of the monetary policy attracted widespread media attention, especially in the particularly affected regions close to the

border. This is also directly reflected in the number of cross-border commuters depicted in Figure 3: Before the third quarter of 2011, the number of Germans in the healthcare sector newly starting to commute to Switzerland remained at a consistently low level despite the rising exchange rate. Only when the stabilization policy took place did their number increase by 46% compared to prior years and remained at a consistently high level.

Figure 2: Comparison of Relative Gross Earnings between German and Swiss Healthcare Workers



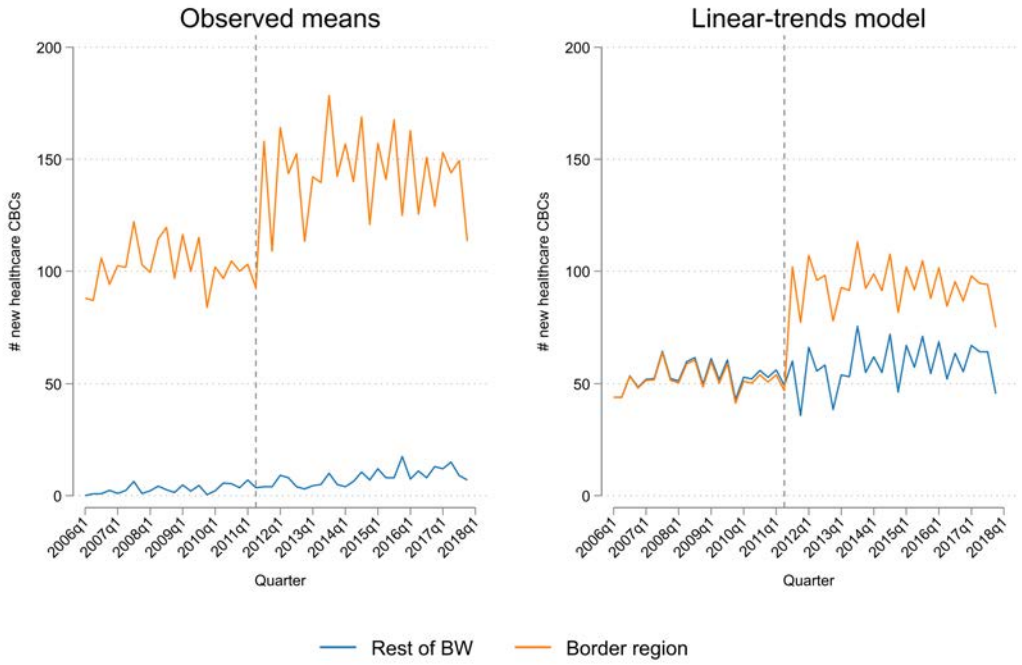
Notes: This graph compares the gross earnings of a full-time healthcare worker in Germany (DE) and Switzerland (CH). For Switzerland, this corresponds to the annual gross salary of a full-time position in the health and social care sector (overall average across requirement level 2 ("skilled")) obtained from the Swiss Earnings Structure Survey (LSE). As the LSE is conducted biannually, the years between are interpolated. For Germany, the line refers to the annual salary of a full-time position according to the German Collective Agreement of the Public Service of the Federal States (TVÖD-K E7a (level 4), corresponding to a nurse training after six years on the job. The conversion is based on the daily average EUR-CHF exchange rate provided by the European Central Bank.

Although the combination of a relatively strong CHF and a guaranteed exchange rate was certainly attractive to many Germans living close to the border, regardless of their occupation, German registered nurses were especially able to take up the opportunity of working in Switzerland as Figure 4 shows. Relative to all other industries, the number of healthcare cross-border commuters increases way more strongly. Looking more closely by occupation reveals that the increase is especially pronounced for registered nurses (see Figure **??** in the Appendix).

This is due to a combination of several factors. Firstly, their state certification is directly recognized by Switzerland, meaning that there are no legal barriers that would delay or complicate their access to work.[1] Secondly, the shortage of skilled workers was particularly high among nursing staff. Between 2011 and 2013, 6% of vacancies were unfilled (Lobsiger and Kägi, 2016), and estimates assumed a growing need for nursing staff due to the aging of society (Merçay et al., 2016). In comparison, the proportion of vacancies for nursing assistants was only 0.7% and for doctors 2.5% in 2011 (SECO, 2014). Thirdly, while the German private sector has the opportunity to respond to a changing value of outside options by increasing wages, the public (healthcare) sector, including most hospitals, has little room for maneuvering. In Germany, most employees in the public sector are paid according to collective agreements for which changes are negotiated annually at a high aggregate level. Single hospitals have de facto no influence on wage negotiations and are very limited in their ability to individually re-negotiate with their workforce by providing amenities. Even a larger group of hospitals affected by labor scarcity has little influence on wage negotiations, especially since negotiations for 2012 were already completed in the fall of 2011, i.e. at the time of stabilization. Also, hospitals operated by private providers have limited possibilities to adjust their wages because they get reimbursed at a fixed flat rate per case, i.e., for the most part, they cannot adjust the prices for their services themselves.

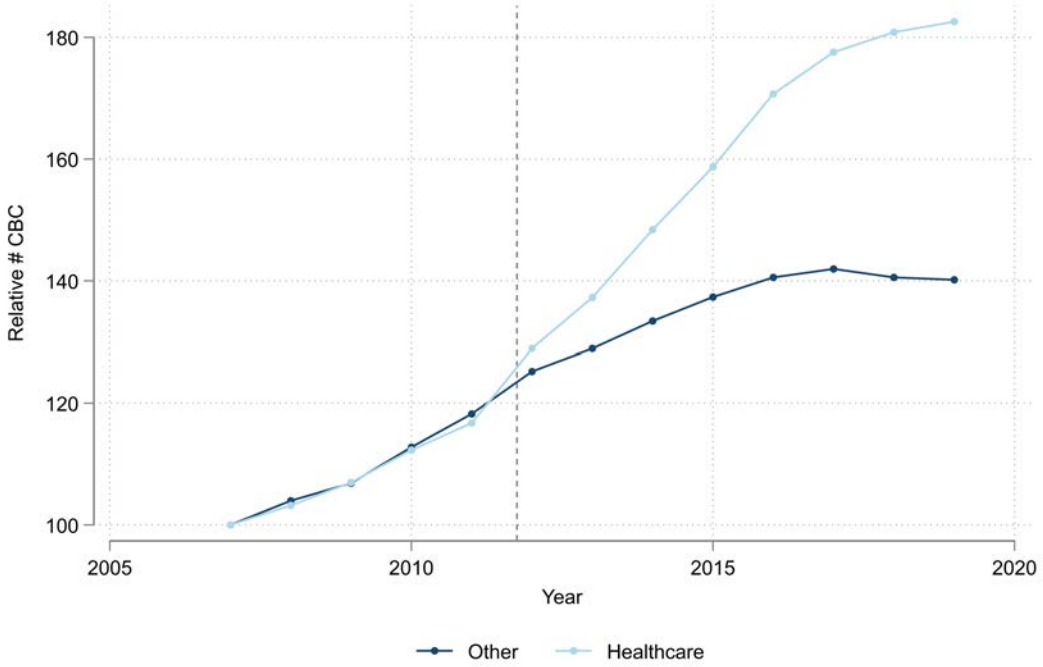
[1] Under the European-Swiss Agreement on the Free Movement of Persons and the EU Directive 2005/36 (applicable to Switzerland), European diplomas in all healthcare professions are recognized by Switzerland. For this, only an application for recognition must be submitted to the respective responsible authority. This process takes several months, but nurses only have to wait a few weeks due to a so-called PreCheck.

Figure 3: New Cross-Border Commuters in the Healthcare Sector



Notes: This graph shows the number of German cross-border commuters newly starting to work in the Swiss healthcare sector (according to NOGA) in raw means (left panel) and after accounting for linear trends (right panel) for treated and matched control counties. Treated refers to counties at the Swiss-German border characterized by being prone to cross-border commuting. Rest of BW refers to all other counties in the Federal State of Baden-Württemberg.

Figure 4: Cross-Border Commuters across Sectors



Notes: This graph shows the number of active German cross-border commuters relative to 2007, either working in the Swiss healthcare (light blue) or all other sectors (dark blue).

German hospitals in the border region not only have little leeway to prevent nurses from starting working in Switzerland but also face output quantity constraints. If a hospital is accredited, it has a contractually negotiated and fixed supply mandate. This means that it must provide a minimum number of beds and is obliged to treat patients if they seek (urgent) care. In addition, legal regulations in Germany prevent hospitals from freely substituting tasks typically performed by registered nurses trough lower skilled nursing assistants. The substitution with capital is theoretically possible, but practically often not feasible as nursing tasks consist of a high degree of socially interactive tasks. Therefore, the combination of minimum output constraints, upward wage rigidity, fixed prices, and a negative labor shock without the possibility of input factor substitution is a hard hit for border hospitals. Still, hospitals can react by reducing the provision of services. Given the high hospitalization rate in Germany, reducing non-needed surgeries might even decrease over-provision and improve patients' welfare. On the other hand, if hospitals cut needed surgeries and services, especially vulnerable patients likely suffer. How hospitals ultimately react to a negative skilled labor supply shock and how this affects the health of patients is the question I aim to answer in the following.

3 Data Sources

Swiss Cross-Border Commuter Statistic (GGS). In order to determine which regions, and thus hospitals, are actually affected by the increase in cross-border health care workers, I use the Swiss Cross-Border Commuter Statistic (Schweizer Grenzgängerstatistik, henceforth: GGS). This data set covers quarterly individual-level data for all foreign individuals being employed but not residing in Switzerland. It is provided by the Swiss Federal Statistical Office (SBFS) and calculated on the basis of the cross-border commuter permits in the Central Migration Register (ZEMIS).[2] The data is available since 1996 and contains information on the place of residence and workplace (both at the country-specific ZIP code level) as well as the sector (according to NOGA). Unfortunately, however, the data does not allow for a further distinction between occupations, which is why I additionally create a more general exposure measure of patients and hospitals based on travel times to the Swiss border using Open Street Maps (OSM). More specifically, for every municipality, I calculate the shortest travel time by car among the four metrically closest border crossings.Data on border crossings is obtained from the online appendix of Beerli et al. (2021). This travel time is then later used as an exposure measure to the Swiss Franc Shock and its induced labor scarcity, while I mainly use the GGS for plausibility checks and robustness.

German Hospital Statistic (KS). To assess whether the event had a "bite", I use the German Hospital Statistic (Krankenhausstatistik, henceforth: KS). The KS is an administrative yearly panel covering all accredited German hospitals since 1990 and contains data both for the past calendar year (e.g., beds, medical and non-medical staff) and as of December 31 of the calendar year (e.g., facilities and equipment). This information is available at different aggregate levels. The staffing situation for physicians is provided at the specialty level, while non-physician staff is listed at the occupational group level. Beds, services offered, patient attrition (to other hospitals, nursing homes, and due to death), and complications are available at the department level, except for department-specific services such as cesarean sections. Variables on the cost and input structure are included at the hospital level.

German Patient Statistic (PS). The KS is supplemented by the German Patient Statistic (Patientenstatistik, henceforth: PS), which contains individual-level information on all inpatients treated in German hospitals and allows me to investigate if patients in treated hospitals face health consequences through reduced care intensity. For each case,

[2]In the case of an unlimited employment contract, such a permit is valid for 5 years. Since it does not have to be reported if a cross-border commuter stops working in Switzerland despite a valid permit, the number of active cross-border commuters tends to be overestimated by the number of cross-border commuter permits. This is corrected for by a weighting procedure based on data from the Pension and Survivors Insurance (AHV).

the data set contains information on age, sex, place of residence (at the municipality level), the exact date of admission, the length of stay, the department in which a patient remained the longest, the main diagnosis, as well as indicators of whether surgery was performed and whether death occurred.

To validate the results obtained from the hospital data and to investigate other potential drivers of the health effects, such as changing economic circumstances, I use administrative information from the **INKAR database** of the Federal Institute for Research on Building, Urban Affairs and Spatial Development (BBSR). This database contains rich information at the county level, including demographic, social, economic, and health characteristics. From the number of death cases (by age group), I create a measure of mortality by simply dividing the cases by the population in the respective age group. A more often used measure of regional variations in mortality and the average health status of the population is life expectancy. It is defined as the average number of years a newborn is expected to live, assuming the mortality rates observed during the reporting period remain constant throughout the child's life. Thus, it represents the mortality conditions of a fictitious generation at a certain point in time (e.g. newborns in Germany in 2011) and is calculated from the actual death cases. This means that a change over time reflects changing morality rates without distortions due to changes in age or population structure. Deaths at a young age have a greater effect on the life expectancy of newborns than deaths of older individuals. In the INKAR database, the life expectancy is calculated for newborns and at age 60, and as an average over the most recent three years.[3]

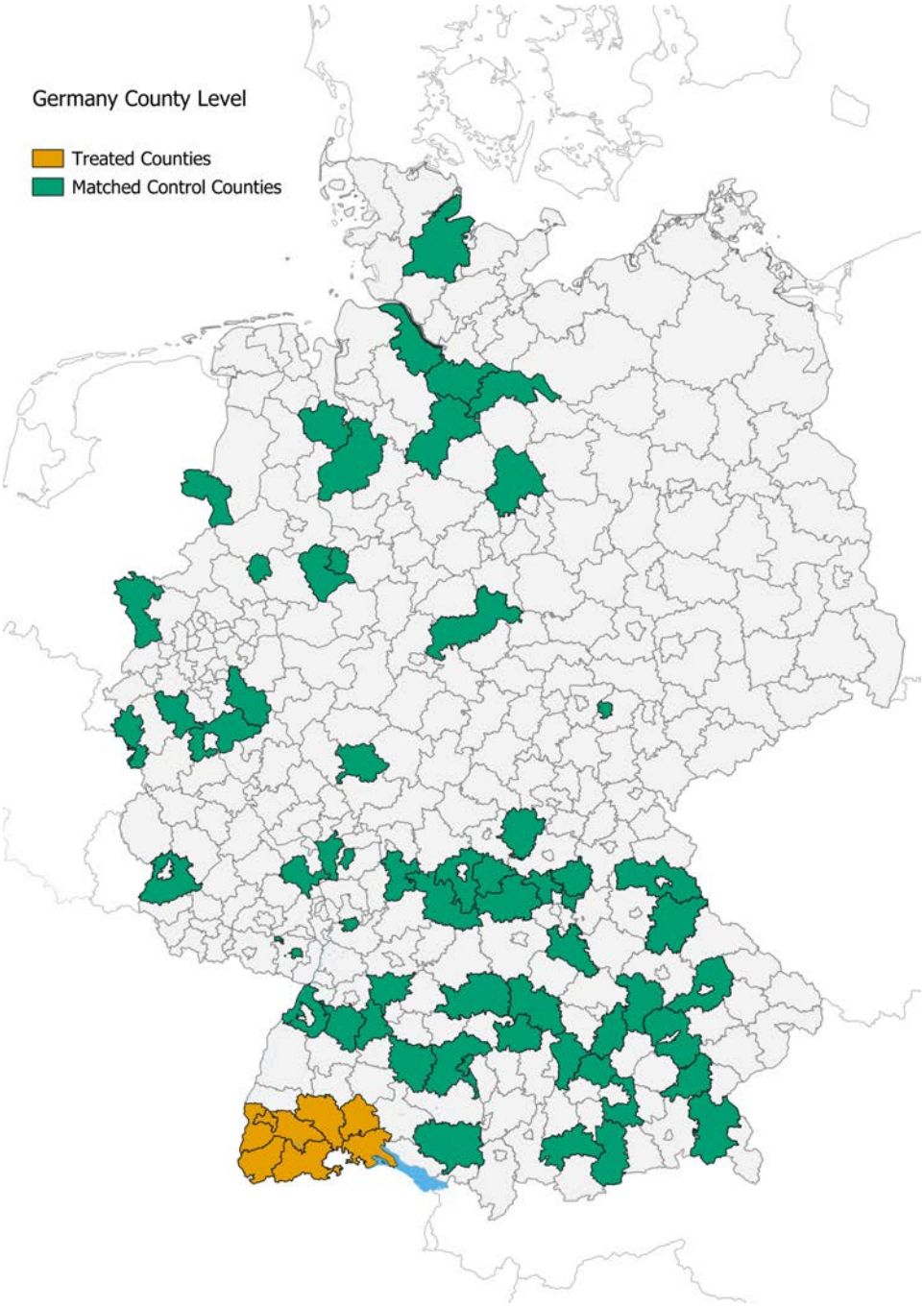
4 Empirical Strategy

In this chapter, I describe the basis for the assignment of regions into the treatment group and how treated counties are matched to suitable control counties using propensity score matching. Then, I describe the event-study design with which I answer, whether the Swiss Franc Stabilization of 2011 has reduced hospital staffing rates, decreased care intensity, and led to a higher mortality for patients and a lower life expectancy in border counties.

Treatment group assignment and matching. The assignment of counties to the border region, i.e., the treatment group, is based on the feasibility of commuting. Figure A.1 in the Appendix shows that German counties in close proximity to the Swiss border are, very unsurprisingly, particularly prone to cross-border commuting. I assign the seven counties close to the border with the highest number of cross-border commuters in the healthcare sector to the treatment group.

[3]To make my self-calculated measure of mortality comparable, I use a three-year rolling average as well.

Figure 5: Treatment and Control Counties in Germany



Notes: In this map of Germany, treated (control) counties are highlighted in orange (green). Treatment is based on the feasibility of commuting to Switzerland as described above. The assignment to the control group is based on a propensity score matching approach using regional characteristics (population size, population density, GDP per inhabitant, and average age of the population) in 2011, also described above. Counties adjacent to the treated counties are excluded from the pool of potential control counties due to spillovers.

Using propensity score matching, I identify statistically similar counties in Germany based on their size, urbanity, economic condition, and demographics in 2011.[4] Before matching,

[4]More specifically, I use a 10-nearest neighbor matching using population size, population density,

I omit those counties adjacent to the border region from the pool of possible control units as they are potentially prone to spillovers; thus, the stable unit treatment value assumption (SUTVA) might likely not hold for them. The map of Germany in Figure 5 highlights the border region (orange) and the suitable control counties (green). Those are, with only one exception, solely located in Western Germany and mostly in the south. Table A.1 shows a mean comparison between the treatment and control counties. Only small and insignificant differences indicate that border counties are very similar to the control areas further inland.[5] Also the comparison of hospitals (Table A.2) and cases (Table A.3) in the border region compared to those in control counties allows the same conclusion: The 47 hospitals with about 320 thousand cases per year in the border region are relatively similar to the 229 control hospitals with about 2,150 thousand cases per year.

Multi-period difference-in-differences design. To address the effect of the Swiss Franc Stabilization on outcomes related to staffing and patients' health, I regress the following estimating equation for each outcome Y of either hospital h or case i in county c and year t:

$$Y_{ht} = \alpha + \sum_{t=2006; t \neq 2011}^{2017} \delta_t \times I_t \times I_{g(h)} + \zeta_t + \theta_h + \epsilon_{ht} \tag{1}$$

where $g \in \{Treatment, Control\}$ reflects the treatment status. I_t and I_g refer to year and treatment group dummies, and ζ_t and α_h are year and hospital fixed effects. Robust standard errors are clustered at the hospital level.[6]

The main outcomes of interest are (i) the staffing situation, (ii) hospital services provided, and (iii) patients' and populations' health. Regarding staffing, I consider the number, or full-time equivalents (FTE) if available, of employees separately across all healthcare occupation groups. Then, to see if hospitals adapt the provision of services, I use the number of days in care and the likelihood of receiving surgery as outcomes. For this analysis, I control for the background characteristics of the patients, meaning that the coefficient reflects a reduction in services for similar patients. The same is true for the analysis of mortality in the hospital. An increase in mortality found thus accounts for differences in the cases mix over time, although there is little evidence that the conditions of patients and health care demand, in general, evolved differently between the treated

GDP per inhabitant, and average age of the population, restricting matches to be within a caliper of one-quarter of the standard deviation of the propensity score as suggested by Stuart and Rubin (2008). I use 2011 as a reference year due to the German "census shock", i.e., many inferred or projected statistics were corrected, causing partially stark disparities between 2010 and 2011.

[5] The only significant difference lies is the share of foreigners, likely due to the proximity to the border.

[6] For simplicity, I only display the regression at the hospital level. At the case level, I add gender, age group fixed effects (8 groups), and 3-digit ICD-Code fixed effects as controls. When regressing at the county level, I use county fixed effects instead of hospital fixed effects and cluster at the county level.

and control group (see Section 5).

To rule out concurring demand and supply effects, I use additional outcomes in the same regression framework. At the hospital level, I am able to test whether the number of patients and beds remained similar, i.e. if hospitals were truly not able to adjust in the output quantity dimension. By looking at the demographics of cases over time, I can rule out a change in the composition hinting at endogenous selection from the side of hospitals or patients. I do the exact same at the county level to ensure that individuals, e.g. with chronic conditions, did not move away in response to the worse situation in hospitals. As the Swiss Franc Stabilization increased outside options not only for nurses but also across other occupations[7], the regional composition might have changed in terms as it attracted workers from further inland. Additionally, for the same reason, I look at economic outcomes as the local economy and especially exporting firms were affected. More obviously related to local health is the staffing situation in nursing homes, the availability of general practitioners, and car accidents due to increased traffic.

For δ_t to identify a causal effect, the assumption of (i) parallel trends and (ii) no anticipation must be met. While assumption (i) is indirectly testable through close-to-zero treatment coefficients before the event (i.e., $\delta_t = 0 \; \forall \; t \leq 2011$), one has to argue that there is likely no anticipation possible. In this specific case, assumption (ii) likely holds as the Swiss National Bank introduced the stabilization policy very surprisingly. Further, the exclusion of hospitals and regions that are potentially indirectly affected by spillovers should ease concerns regarding a violation of the stable unit treatment value assumption (SUTVA). Also, I could not find an alternative explanation or concurring event that either affected staffing rates and hospital outcomes at the same time or affected population health.[8]

5 Results

Staffing. Figure 6a shows that the observed increased number of German cross-border commuters displayed in Figure 3 directly translates into a reduction in the number of nurses in hospitals. After 2011 and relative to the control group, border hospitals lost on average around 7% of their nursing staff, or 12 FTEs.[9] Looking more closely among nurses shows that this reduction is almost entirely driven by registered ("high-skilled") nurses (see Table A.6). For other occupations, like doctors but also other types of nurses, like nursing assistants, there is neither an increase nor a reduction in the staffing rates

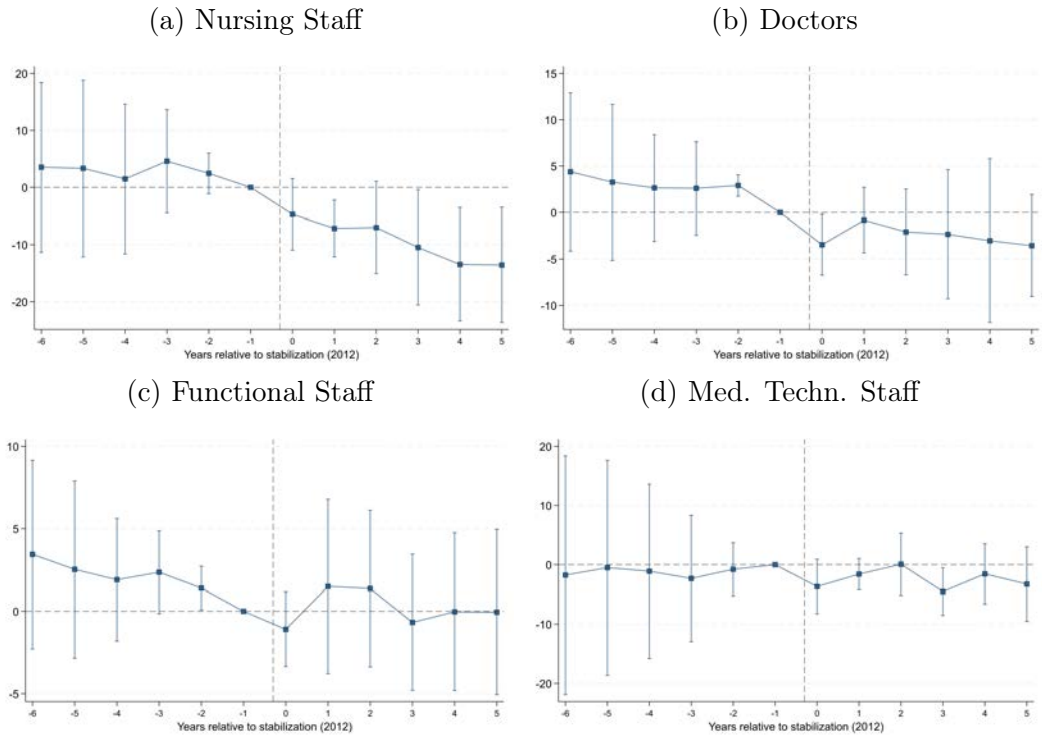
[7] Although the by far strongest response in relative terms is for them

[8] In 2012, a reform of the primary care provision was implemented which resulted in a stronger decrease in general practitioner density in the border region than in the control counties. In a robustness check, I directly control for the number of GPs, but the results remain largely unaffected both quantitatively and qualitatively.

[9] See Table A.4 for DiD estimates.

observable - potentially due to lower feasibility of commuting as explained in detail in Section 2.

Figure 6: Staffing



Notes: These graphs show event-study coefficients based on Equation 1. Outcome variables are displayed above each graph and measured in full-time equivalents (FTE). Blue dots reflect the estimated effect of being in the treatment relative to the control group, whereby whiskers refer to uniform 95% confidence bands based on robust standard errors clustered at the hospital level.

Care and Health of Patients. The reduction in registered nurses in border hospitals directly and strongly affected patients. Table 2 shows that similar patients in terms of age, gender, and diagnosis receive surgery with a 3.7p.p. lower probability in border hospitals although they remain similarly long in care. This reduction in surgery is not only statistically but also economically significant, given the mean probability of 31%.[10] This seems to ultimately translate into increasing mortality in hospitals: After 2011 and relative to the control group, patients at the border decease around 0.1p.p. or 5.2% more likely. Looking at the effect separately across age groups shows that the increase is mostly driven by the elderly (see Table A.7) and not by lower-quality surgeries. Conditional on surgery performed, neither the days in care nor the morality increased. This hints at omitted patient care and forgone needed surgery, rather than more fatal operations as a potential mechanism behind the increasing death rates. However, given that hospitals seem to react to nurse shortages by cutting the provision of surgeries, patients might

[10]Event-study estimates can be found in Figure A.2a-A.2d.

not face the consequences right away in the hospital, but at a later stage. Thus, only considering mortality in hospitals might structurally underestimate the consequences of nurse scarcity.

Table 1: Staffing Rates among Nurses

	Nurses	High-skill	Low-skill	Paediatric	Special training
Post × Treatment	-15.25*	-14.98**	-0.03	-1.41	2.17
	(8.92)	(6.76)	(1.17)	(1.15)	(5.14)
Mean of Y	229.45	182.73	9.58	24.12	32.72
Std. Dev. of Y	293.01	230.24	16.76	57.08	51.39
N	2789	2789	2789	2789	2789

Notes: This table shows the regression output of Equation 1 at the hospital level. Outcome variables reflect the yearly average number of personnel across nursing groups. High (low) skill refers to skilled (assistant) nurses. Special training refers to qualifications obtained beyond state examination. The mean and standard deviation of the outcome variable Y refers to the year 2011. Robust standard errors are clustered at the county level. Stars refer to the 1% *, 5% **, and 10% *** significance level.

Table 2: Patients' Outcomes

	Unconditional			Conditional on surgery	
	Mortality	Days in care	Surgery	Mortality	Days in care
Post × Treatment	0.11*	0.03	-3.70**	0.06	-0.06
	(0.06)	(0.11)	(1.74)	(0.05)	(0.13)
Mean of Y	2.09	7.51	31.15	2.09	7.51
Std. Dev. of Y	14.30	11.07	46.31	14.30	11.07
Observations	27516414	27516414	27516414	8440807	8440807

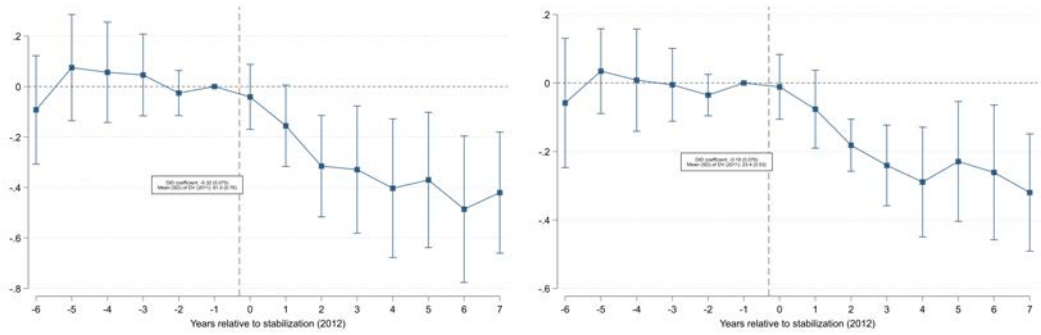
Notes: This table shows the regression output of Equation 1 at the case level, thus controlling for background characteristics and diagnoses fixed effects. Outcome variables reflect the probability of dying (mortality) or receiving surgery (surgery) and the number of days in stationary care. The mean and standard deviation of the outcome variable Y refers to the year 2011. Robust standard errors are clustered at the county level. Stars refer to the 1% *, 5% **, and 10% *** significance level.

Thus, to capture the whole effect of nurse shortages in hospitals, I examine if a reduction in life expectancy at the county level maps the increased mortality. 7a and 7b show that while the life expectancy developed similarly across treatment and control groups

prior to 2012, border counties thereafter faced a strong and significant relative decrease. Remarkably, only around 60% of the size of the coefficients is driven by higher mortality above age 60. This indicates that although the elderly seem to be especially vulnerable to skilled nurse scarcity in hospitals, the working-age population is strongly affected, too. As life expectancy is calculated as an average over the most recent three years, e.g. for 2011 being 2009 to 2011, results from a difference-in-differences model using all years of observation, as presented in Panel A of Table 3, are downward biased.[11] For this reason, Panel B shows results omitting the years 2012 and 2013 which paint, indeed, an even more drastic picture: A reduction in hospital nursing staff by 7% diminishes life expectancy by around 0.4 years. This effect seems economically small given a mean life expectancy of around 80 years, but put into perspective it reveals the importance of nurses. In 2011, there were around 1,075 newborns in the border region. For these, the shortage of skilled workers reduced life expectancy by a total of 4430 statistical life years. The fact that higher mortality in the over-60s only accounts for around 60% of the overall effect illustrates the significance of the problem for society as a whole: the shortage of skilled workers in hospitals affects not only the elderly but also young, productive workers.

Figure 7: Life Expectancy

(a) Newborn (b) Age 60



Notes: These graphs show event-study coefficients based on Equation 1 (all at the county level). Outcome variables are displayed above each graph. Blue dots reflect the estimated effect of being in the treatment relative to the control group, whereby whiskers refer to uniform 95% confidence bands based on robust standard errors clustered at the hospital level. Additional information regarding the mean and standard deviation of the outcome variable is displayed below each graph.

[11] The insignificance and low effect size at the beginning of the treatment period shown in Figure 7a and 7b is also a robustness check itself, because it would be peculiar to find an immediate jump given that the life expectancy is mainly based on the values of the past two years.

Table 3: Life Expectancy Effects

	Panel A: All years		Panel B: Excluding 2012 and 2013	
	Life expectancy (born)	Life expectancy (60)	Life expectancy (born)	Life expectancy (60)
Treated × Post 2012	-0.32***	-0.19**	-0.40***	-0.24***
	(0.07)	(0.08)	(0.09)	(0.09)
Mean of Y	80.27	23.00	80.27	23.00
Std. Dev. of Y	0.93	0.60	0.93	0.60
Observations	924	924	792	792

Notes: This table shows the regression output of Equation 1 at the county level. Outcome variables are life expectancy calculated at age zero (born) and age 60. In Panel A, coefficients are based on all observations available in the years between 2006 and 2019 whereas in Panel B, the years 2012 and 2013 are excluded. This takes into account that life expectancy is calculated as a rolling mean average over the last three years; thus, omitting 2012 and 2013 better reflects the actual effect of nursing shortages on life expectancy. The mean and standard deviation of the outcome variable Y refers to the year 2011. Robust standard errors are clustered at the county level. Stars refer to the 1% *, 5% **, and 10% *** significance level.

Robustness. Although the Swiss franc appreciation most heavily affected the Swiss economy, the German border region might have been influenced in several ways. Thus, to ensure that results are not driven by accompanying effects, I perform various robustness checks. Even if the data from the hospital clearly indicate that mainly registered nurses have (and could) respond to the increased outside options, there are other professions that are particularly essential for the health of the older population that could have experienced a change. However, Table A.5 shows that the care rates in outpatient and inpatient care have not changed. The number of beds per inhabitant has also remained the same, which in turn reflects the limited possibilities for hospitals to adjust the number of beds. Only the number of GPs in the border region has fallen, but this is due to a reform in 2012. In a further robustness analysis, I, therefore, control directly for the number of GPs when calculating the effects on life expectancy. However, coefficients remain both economically and statistically significant.[12] Not only the supply but also the demand for medical services may have changed as a result, as the border region is economically strongly interlinked across countries. However, Table A.8 shows that demographic factors that could lead to higher demand have remained unaltered. Even the number of road casualties and fatalities, driven by a higher volume of commuters as a response to changing wage and price differences, has remained the same.[13] Also economic factors influencing demand (Table A.9) show no change over time between the border and control regions.

[12]Results available upon request.

[13]Bello (2020), for instance, shows that Italian commuter traffic increased in 2015 due to a Swiss franc appreciation. This might have caused more road accidents and, thus, a higher demand for acute hospital care. Further, lower relative prices of products and services in Germany compared to Switzerland might have increased the number of Swiss cross-border consumers.

6 Conclusion

In this paper, I investigate how nurse shortages affect the provision of services in hospitals and, ultimately, patients' health. Regional wage differences between countries influence the decision of employees to commute across borders instead of working in their country of residence. I leverage a sudden and persistent appreciation of the Swiss franc in late 2011, which incentivized Germans to start working in Switzerland. Due to low legal barriers, a high earnings difference, and excess demand in Switzerland, especially registered ("high-skilled") nurses formerly working in German hospitals started commuting. Consequently, German hospitals close to the border faced a decrease in staffing rates only due to their distance to the border, while being subject to collective bargaining and fixed prices, limiting their ability to adjust in terms of wages. By combining rich administrative data for the population of inpatient cases in all German hospitals with a matched difference-in-differences design, I am able to investigate how hospitals react to this shortage of nursing staff and how patients are affected in terms of care and health. I find that from 2011 onwards, the number of new German healthcare cross-border commuters increased by 46%. Relative to hospitals in similar counties further inland, border hospitals lost on average around 12 full-time equivalents (FTE) or 7% of their nursing staff, entirely driven by high-skilled nurses as suggested. Hospitals seem to react to the shortage of skilled nurses by reducing the number of operations, as patients in border hospitals undergo surgery around 3.7p.p. or 12% less likely, even after controlling for demographics and rich diagnosis fixed effects. Consequently, mortality in hospitals increases by 5%. This is even reflected in the aggregate life expectancy which decreases in border counties by around 0.40 (0.24) years for newborns (60-year-olds) relative to control counties. Various robustness checks suggest that these effects are not driven by a change in healthcare demand or supply, or changing economic circumstances. These results highlight the decisive role registered nurses play in hospitals and that the projected growing labor scarcity has not only the potential to put a halt on economic growth, as suggested by Jones (2022), but also to the increasing life expectancy observed around the globe. In a next step, I use detailed information on the type of diagnosis and patients' characteristics, to see who is most strongly affected by the reduction in surgeries and in terms of health. In order to better understand how exactly hospitals address staff shortages, I use detailed survey data as well as administrative hospital data on cost structures, patient flows, and the use of time-contracted external nursing staff. Furthermore, the full sample of employment biographies from the IAB enables me to see if the skill composition of healthcare workers in border counties changed and, by that, sheds light on the question of who reacts most strongly to wage differences. Lastly, I collected Swiss administrative data on hospital staff and regional health outcomes, which allows me to investigate whether and how patients in Swiss hospitals benefited from the inflow of skilled nurses.

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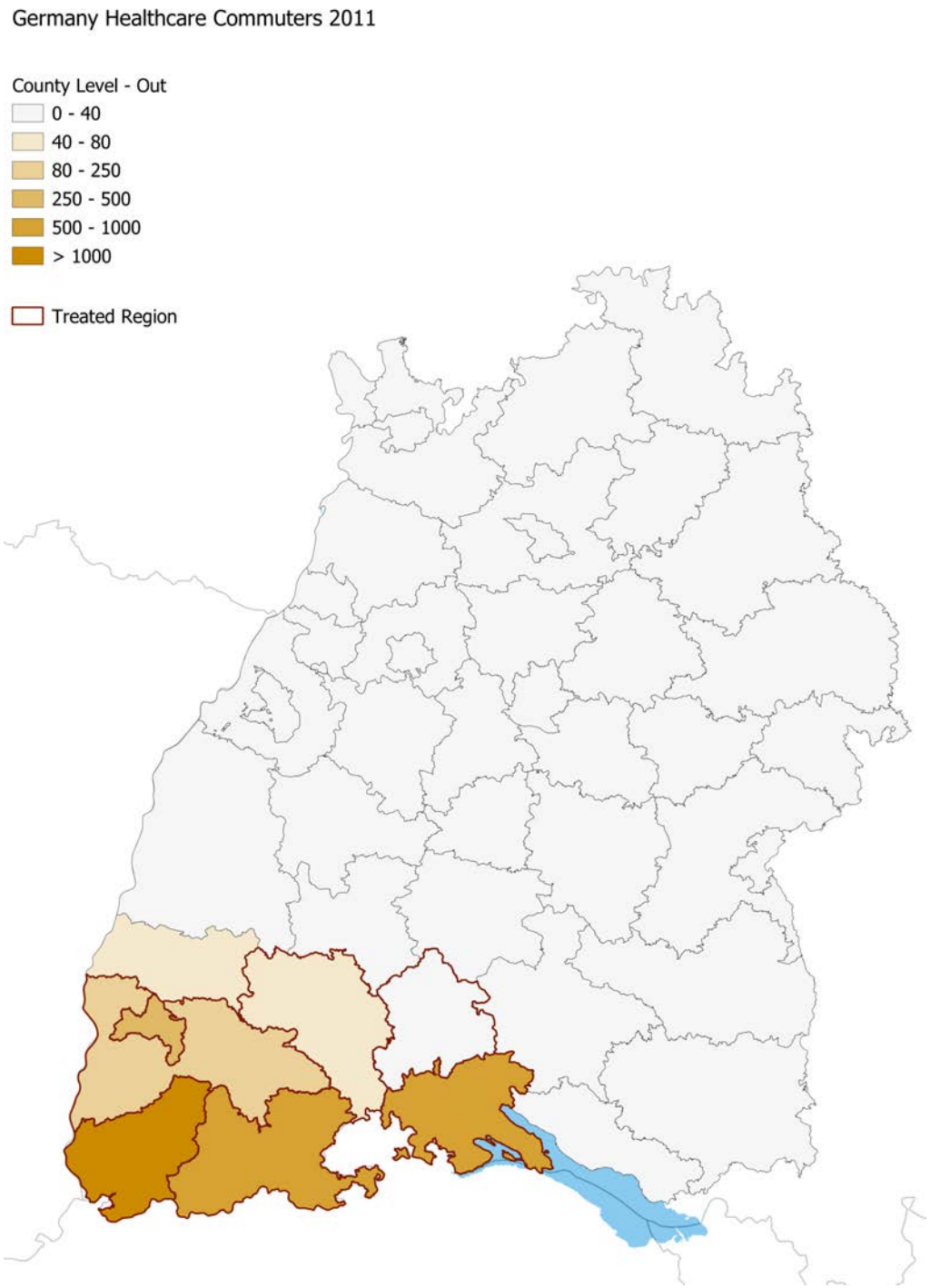
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Appendix

A Additional Tables and Figures

Figure A.1: Treatment Intensity at County Level in the State of Baden-Württemberg



Notes: This map shows the number of German cross-border commuters working in the Swiss healthcare sector at the county level. Counties surrounded by red lines indicate the border region, i.e. counties close to the border with the highest number of cross-border commuters in the healthcare sector in 2010.

Table A.1: Summary Statistics of Treatment and Control Counties in 2011

	Treatment		Control		T-test	
	mean	sd	mean	sd	b	se
Employment rate in %	51.00	6.55	54.54	4.16	3.54	2.53
Gross monthly earnings	2397.51	147.02	2374.71	343.98	-22.81	71.37
Share of foreigners	10.29	1.98	7.05	3.70	-3.23***	0.89
Share of women	51.43	0.80	50.82	0.62	-0.61*	0.31
Working population	206.82	46.63	200.31	117.75	-6.51	23.36
Population density	385.97	451.43	315.98	324.14	-69.99	175.77
GDP per inhabitant	32.46	7.18	32.06	13.44	-0.39	3.23
Average age	42.36	1.22	42.46	0.81	0.10	0.47
Observations	7		59		66	

Notes: This table shows the means and standard deviations across multiple variables for both the treatment (border counties) and control group (matched counties) in 2011. It further displays the mean difference and standard error resulting from a t-test for equality of the means. Stars refer to the 1% *, 5% **, and 10% *** significance levels, indicating whether the difference in means is statistically significant.

Table A.2: Summary Statistics of Treatment and Control Hospitals in 2011

	Treatment mean/sd	Control mean/sd	T-test b/t
Beds	181.47	245.40	63.93
	(285.32)	(266.18)	(1.42)
Occupancy days	50794.09	68977.99	18183.90
	(84094.23)	(78017.07)	(1.37)
Patients	6568.72	9088.66	2519.94
	(11825.91)	(10535.33)	(1.35)
FTE doctors	1.94	1.95	0.01
	(0.25)	(0.22)	(0.29)
FTE nursing staff	123.28	154.71	31.43
	(257.81)	(205.89)	(0.79)
Total staff costs	21519.35	26532.38	5013.03
	(55501.47)	(47062.48)	(0.58)
Total costs	34142.42	43964.60	9822.18
	(86776.30)	(78789.28)	(0.72)
Private hospital	0.49	0.24	-0.25
	(0.51)	(0.43)	(-3.16)
Plan hospital	0.62	0.85	0.23
	(0.49)	(0.36)	(3.11)
Continuously existing	0.85	0.85	-0.00
	(0.36)	(0.36)	(-0.07)
Observations	47	229	276

Notes: This table shows the means and standard deviations across multiple variables for both the treated hospitals (located in border counties) and control hospitals (located in matched control counties) in 2011. FTE refers to full-time equivalent. Costs are in thousands of euros. Plan hospitals are hospitals subject to contracted supply mandates (see § 109 SGB V). Continuously existing refers to hospitals that continuously report between 2006 and 2017. Assignment of hospitals to counties is based on the place of residence of treated patients using simple majority. It further displays the mean difference and t-statistic resulting from a t-test for equality of the means.

Table A.3: Summary Statistics of Treatment and Control Patients in 2011

	Treatment mean/sd	Control mean/sd	T-test b/t
Male	0.48	0.47	-0.01
	(0.50)	(0.50)	(-11.43)
Mortality	1.83	2.13	0.29
	(13.42)	(14.43)	(11.42)
Surgery	35.09	30.56	-4.52
	(47.73)	(46.07)	(-50.10)
Days in care	7.70	7.48	-0.23
	(12.35)	(10.87)	(-9.74)
Age	53.03	53.47	0.44
	(25.66)	(25.44)	(9.06)
Observations	317923	2135211	2453134

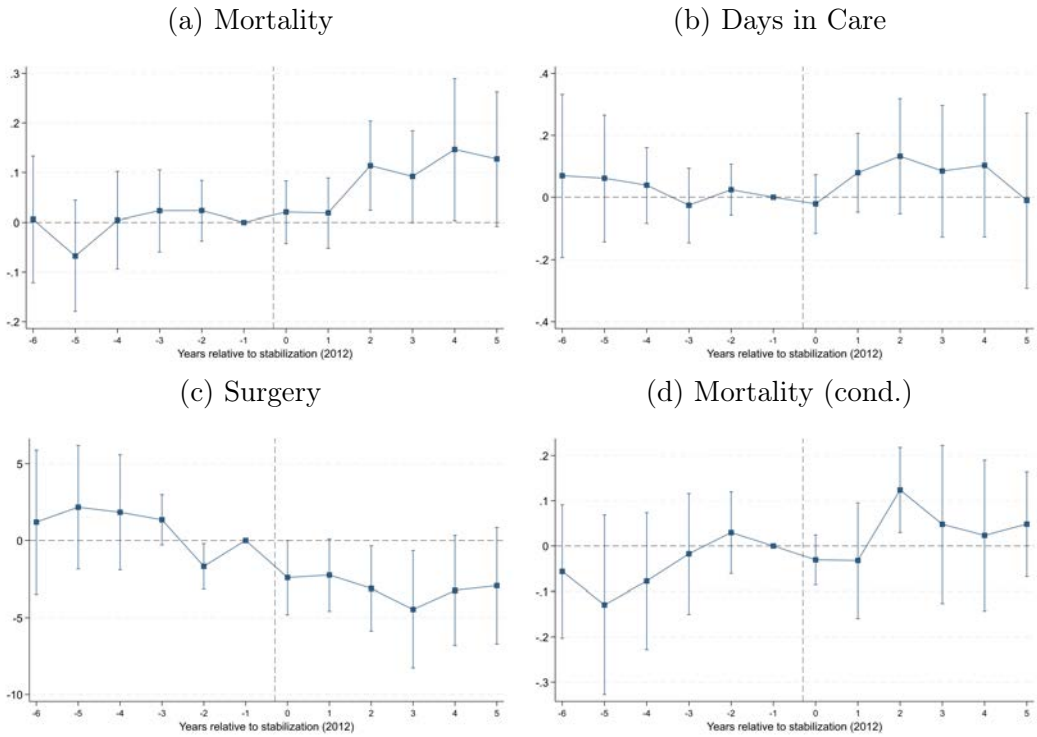
Notes: This table shows the means and standard deviations across multiple variables for both the treated patients (located in border counties) and control patients (located in matched control counties) in 2011. Mortality/surgery refer to the likelihood of death/surgery performance (in %). Male is the share of male individuals. The assignment of patients to counties is based on the location of the hospitals they are treated in. It further displays the mean difference and t-statistic resulting from a t-test for equality of the means.

Table A.4: Staffing Rates across Occupation Groups (in FTE)

	Doctors	Nursing staff	Med. techn. staff	Funct. staff	Trainees	Non-doc. staff
Post × Treatment	-5.18	-11.96**	-1.35	-1.77	-1.69	-11.84
	(4.22)	(5.41)	(6.04)	(3.14)	(1.58)	(25.21)
Mean of Y	78.48	165.79	84.32	48.44	9.44	402.06
Std. Dev. of Y	152.09	227.89	226.59	70.64	29.81	709.58
N	2801	2801	2801	2801	2801	2801
R-squared (within)	0.24	0.12	0.09	0.17	0.01	0.12

Notes: This table shows the regression output of Equation 1 at the hospital level. Outcome variables reflect the yearly average number of personnel across occupation groups in full-time equivalents (FTE). The mean and standard deviation of the outcome variable Y refers to the year 2011. Robust standard errors are clustered at the county level. Stars refer to the 1% *, 5% **, and 10% *** significance level.

Figure A.2: Patients' Outcomes



Notes: These graphs show event-study coefficients based on Equation 1. Outcome variables are displayed above each graph. Surgery (mortality) refers to the likelihood of receiving surgery (dying) and is used in a regression at the case level, thus controlling for case-level characteristics. Blue dots reflect the estimated effect of being in the treatment relative to the control group, whereby whiskers refer to uniform 95% confidence bands based on robust standard errors clustered at the hospital level.

Table A.5: Health Supply Effects

	Staff nursing homes	Staff nursing service	GPs	Hospital beds
Treated × Post 2012	0.12	-2.38	-8.85***	-0.03
	(0.99)	(1.75)	(1.76)	(0.36)
Mean of Y	90.00	48.80	130.63	4.67
Std. Dev. of Y	11.88	12.96	158.73	4.13
Observations	726	726	726	594

Notes: This table shows the regression output of Equation 1 at the county level. Outcome variables are the staff in nursing homes (per 100 inpatient cases), the staff in outpatient nursing services (per 100 outpatient cases), the number of general practitioners (GPs), and the hospital beds (1,000 inhabitants). Information on staff and GPs is only available from 2009 onwards. The mean and standard deviation of the outcome variable Y refers to the year 2011. Coefficients are based on observations available in the years between 2006 and 2019. Robust standard errors are clustered at the county level. Stars refer to the 1% *, 5% **, and 10% *** significance level.

Table A.6: Staffing Rates among Nurses

	Nurses	High-skill	Low-skill	Paediatric	Special training
Post × Treatment	-15.25*	-14.98**	-0.03	-1.41	2.17
	(8.92)	(6.76)	(1.17)	(1.15)	(5.14)
Mean of Y	229.45	182.73	9.58	24.12	32.72
Std. Dev. of Y	293.01	230.24	16.76	57.08	51.39
Observations	2789	2789	2789	2789	2789
R-squared (within)	0.11	0.10	0.01	0.00	0.05

Notes: This table shows the regression output of Equation 1 at the hospital level. Outcome variables reflect the yearly average number of personnel across nursing groups. High (low) skill refers to skilled (assistant) nurses. Special training refers to qualifications obtained beyond state examination. The mean and standard deviation of the outcome variable Y refers to the year 2011. Robust standard errors are clustered at the county level. Stars refer to the 1% *, 5% **, and 10% *** significance level.

Table A.7: Mortality Effects by Age Groups

	0-5	6-24	25-49	50-64	65-74	75+
Post × Treatment	-0.06***	0.00	0.00	0.08	0.10	0.33**
	(0.02)	(0.01)	(0.03)	(0.07)	(0.09)	(0.13)
Observations	2031842	2570146	6157731	5284844	4666506	6805325

Notes: This table shows the regression output of Equation 1 at the case level, thus controlling for background characteristics and diagnoses fixed effects. The outcome variables is the probability of dying (mortality) across age groups, indicated by the head of each column. Robust standard errors are clustered at the hospital level. Stars refer to the 1% *, 5% **, and 10% *** significance level.

Table A.8: Health Demand Effects

	Population	Age	Dependency rate	Births	Road casualties	Road fatalities
Treated × Post 2012	0.44	-0.34	-0.59*	0.16	-15.59	1.13**
	(1.23)	(0.23)	(0.32)	(0.10)	(9.63)	(0.45)
Mean of Y	200.27	43.80	32.25	7.90	508.17	5.92
Std. Dev. of Y	227.28	1.75	4.31	0.95	100.50	3.79
Observations	924	924	924	924	922	921

Notes: This table shows the regression output of Equation 1 at the county level. Outcome variables are the population (in thousands), the average age of the population (in years), the ratio of people above 65 to the working population (in percent), the number of births (in thousands), as well as the number of road casualties and fatalities. The mean and standard deviation of the outcome variable Y refers to the year 2011. Coefficients are based on observations available in the years between 2006 and 2019. Robust standard errors are clustered at the county level. Stars refer to the 1% *, 5% **, and 10% *** significance level.

Table A.9: Economic Effects

	GDP per person	UE rate	Earnings	Public service	Public debt
Treated × Post 2012	0.21	0.09	-11.64	7.57*	-83.93
	(0.83)	(0.10)	(21.38)	(4.16)	(51.76)
Mean of Y	31.37	6.64	2308.00	139.27	1676.72
Std. Dev. of Y	14.01	3.23	351.23	51.56	1317.70
Observations	924	924	924	924	660

Notes: This table shows the regression output of Equation 1 at the county level. Outcome variables are the GDP per inhabitant (in thousands), the unemployment rate (in percent), gross monthly earnings, the number of individuals working in municipal public service (per 10,000 inhabitants), and the municipal public debt per inhabitant. Information on municipal public debt is only available from 2010 onwards. The mean and standard deviation of the outcome variable Y refers to the year 2011. Coefficients are based on observations available in the years between 2006 and 2019. Robust standard errors are clustered at the county level. Stars refer to the 1% *, 5% **, and 10% *** significance level.