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The Deadly Consequences of Labor Scarcity: Evidence from Hospitals

Oliver Schlenker, University of Konstanz & ZEW Mannheim, oliver.schlenker@uni-konstanz.de

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About the author

Oliver Schlenker is a PhD candidate in economics at the Graduate School of the Social and Behavioral Sciences at the University of Konstanz. Additionally, he works as a Research Fellow at the Cluster of Excellence "The Politics of Inequality" and at the Leibniz-Centre for European Economic Research (ZEW) in Mannheim. Oliver Schlenker's main interests lie in the fields of labor and health economics, with a particular focus on the consequences of technological change and labor market frictions.

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The Deadly Consequences of Labor Scarcity: Evidence from Hospitals*

Oliver Schlenker†

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Abstract

This paper estimates the impact of nursing shortages in hospitals on healthcare provision and patient outcomes by exploiting a strong and stable appreciation of the Swiss franc in 2011. Due to collective bargaining hindering wage adjustments in the German healthcare sector, cross-border wage differentials increased and led to a significant outflow of German registered nurses to Switzerland, causing a 12.5% reduction in nurse staffing rates in German hospitals near the border. Using a matched difference-in-differences approach, I find that hospitals responded by decreasing care intensity, leading to a 12% decrease in surgeries. Although hospitals are increasingly performing triage, also patients with high medical needs – such as elderly and emergency cases – face a reduction in care and, consequently, a stark increase in mortality rates, resulting in a measurable decline in regional life expectancy.

Keywords: Labor scarcity, cross-border commuting, wage differentials, nurse shortages, healthcare provision, triage, patient outcomes

JEL classification: F22, I18, J22, J31, J61, I11, R23

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†University of Konstanz & ZEW Mannheim, Germany (e-mail: oliver.schlenker@uni-konstanz.de)

1 Introduction

Across advanced economies, labor markets have become increasingly tight, as evidenced by increasing vacancy rates (Domash and Summers, 2022; Duval et al., 2022).[1] Demographic trends are expected to further constrain labor supply and potentially hinder economic growth (Jones, 2022). In addition, labor market frictions – such as wage rigidities, search frictions, and institutional barriers – hinder timely wage adjustments which could attract labor, thereby impairing the resilience of economies to economic shocks (Blanchard and Galí, 2010; Shapiro and Stiglitz, 1984; Arrow and Capron, 1959). While research has examined the effects of labor scarcity on wages (e.g. Börschlein et al., 2024; Domash and Summers, 2022) and firm production (e.g. Le Barbanchon et al., 2023; Acemoglu and Restrepo, 2017; Acemoglu, 2010), less is known about its impact on the allocation and quality of goods and services.

One sector where labor scarcity is especially prominent is healthcare. There, aging not only decreases the supply of labor, like in other industries but also increases demand as the need for elderly and intensive care grows. Due to regulations such as licensing requirements, collective agreements, and fixed pricing, market conditions in healthcare are less flexible, exacerbating shortages. As a result, labor markets in healthcare may struggle to adjust sufficiently to attract workers – thus, the OECD (2017) projects a shortfall of 1.1 million nurses by 2030, translating to a 14% vacancy rate. In such a fixed-price setting, Michaillat and Saez (2015) demonstrate theoretically that increasing labor market tightness translates into product market tightness, i.e. excess demand. In the case of healthcare, such excess demand can have serious – even deadly – consequences for patients. This is particularly relevant in acute care hospitals as research consistently shows that hospital nurse staffing rates are positively correlated with patient outcomes (Griffiths et al., 2023; Zaranko et al., 2023).

Assessing the impact of labor scarcity poses conceptual challenges. In competitive labor markets, a decrease in labor supply leads to adjustments in market conditions, such as through changes in wages. Also in the healthcare sector, which is characterized by wage rigidity through market frictions, it is hard to establish a causal link between staffing rates due to unobservable factors influencing both staffing rates and hospital outcomes (Lin, 2014).

In this paper, I overcome endogeneity and identification issues and provide causal estimates of the effect of nursing scarcity in hospitals on the provision of healthcare services and patient health outcomes. I leverage a strong appreciation of the Swiss franc and its subsequent binding to the euro in 2011. Due to collective bargaining agreements

[1] One especially well-suited indicator as it reflects both the demand and supply side, is the rising vacancy-to-unemployment ratios (Mortensen and Pissarides, 1994). While this ratio is rising for most major OECD countries, the United States exhibits the most pronounced trends, already reaching approximately 1.5 job vacancies per unemployed person by the end of 2021 (Causa et al., 2022).

and fixed prices in the German hospital sector, cross-country wage differences increased and stabilized at a high level. As German registered nurses face low legal barriers and high demand in Switzerland, they were able to start working in Switzerland (Ruedin and Widmer, 2010). In turn, German hospitals experienced a significant outflow of registered nurses depending on their distance to the border. I use this exogenous decrease in nursing staff in German hospitals in proximity to Switzerland to link the shortage of nurses to the quantity and quality of healthcare services provided and to the health outcomes of patients.

Studying the response of German hospitals to labor scarcity offers a unique opportunity for several reasons. First, legal restrictions prevent hospitals from adjusting wages and reducing the number of patients treated, which allows me to interpret the reduction in staffing rates as a negative input factor shock and the corresponding findings as an effect of labor scarcity. Second, only registered nurses were able to react to the increasing wage differential due to occupation-specific differences in demand in Switzerland. This allows for an isolated estimation of the effect of a reduction in registered nurses, a critical occupational group, which is both essential for hospital care and expected to become increasingly scarce (Zaranko et al., 2023; Blum et al., 2019). Third, extensive robustness checks indicate that the event did not trigger demand-side adjustments, e.g. by influencing the composition of patients. In other words, the observed changes in hospital practices are responses to labor shortages rather than shifts in patient composition. This also means that it is possible to examine both the treatment heterogeneity, i.e., a targeted reduction of services ("triage"), and the effect heterogeneity of nurse scarcity across patient groups.

For the empirical analysis, I use administrative datasets spanning a 12-year period and covering various levels of aggregation as well as both Germany and Switzerland. This data enables me to characterize which types of workers responded to increasing outside options in Switzerland and identify the areas impacted ("treated"). The datasets also allow me to capture changes in hospital staffing rates and output at both the extensive margin (number of patients) and the intensive margin (treatment per patient), along with patient health outcomes at the individual, hospital, and county level. With approximately 18 million patient observations per year from all 2,000 hospitals in Germany, this rich dataset enables a detailed heterogeneity analysis at the finest level of granularity possible. Additionally, regional statistics provide insights into whether these health effects translate into broader aggregate health measures, such as mortality rates and life expectancy, while also enabling me to conduct extensive robustness checks to rule out potential confounding factors.

I analyse this rich administrative data in a multi-period difference-in-differences ("event study") approach to identify the effects of nursing shortages. As the treated border region is more rural than the German average, I first perform propensity score matching based on pre-event demographic and economic characteristics at the county level. This ensures that my estimates are not biased by confounding trends in rural areas, such as higher probabilities of hospital closures or demographic change. After identifying a suitable control group, I compare outcomes in the treated border region with those in control counties further inland that share similar characteristics but were unaffected by the increase in cross-country wage differentials. This approach allows for a rigorous assessment of the effect of increased outside options for German registered nurses near the border on staffing rates in and outside of hospitals – which can be seen as the first stage –, the provision of services, and health outcomes.

The first major finding is that cross-country wage differentials significantly influence commuting patterns and lead to labor shortages in the presence of wage rigidities. Specifically, a 52% increase in gross earnings for registered nurses (equivalent to 17,200 euros) leads to 46% more new cross-border healthcare commuters. This results in an approximately 12% reduction in nurse staffing rates in German hospitals near the Swiss border, with no notable changes observed for other occupational groups. Importantly, this reduction is accompanied by an increase in vacancies, indicating that the decrease is not a reaction of hospitals to changes in healthcare demand.

Secondly, hospitals react to nursing shortages by prioritizing patients based on medical urgency, a practice known as triage (Jenkins, 2024). Given the low substitutability across occupations and with capital, as well as the limited ability to adjust output at the extensive margin (i.e., reducing the number of patients), patients experience a 10% decline in the nurse-to-patient ratio and a 12% drop in the likelihood of surgery conditional on their medical needs. This reduction in surgeries is mainly driven by cases with low urgency, but also patients with emergency diagnoses receive less treatment – a pattern that is uniform across age groups. I rationalize this finding in a conceptual framework in which hospitals allocate resources between patient types. A negative labor supply shock leads them to allocate substantially less care to patients with elective (plannable) surgeries as those have a lower marginal return to nursing. However, as care mandates require hospitals to treat all incoming patients, urgent cases also see a decrease in treatment.

Lastly, the negative health effects of nursing shortages vary significantly across different patient groups. Although hospitals react with triage the mortality impacts are substantial. This is because even a small reduction in care leads to adverse health outcomes for vulnerable cases, i.e. patients with high age and urgent diagnoses, as the marginal returns to nursing increase with patient needs.[2] For instance, while the average patient saw a mortality increase of 0.1%-points (relative to a 2% baseline mortality rate), urgent cases aged 75 or older experienced a significantly higher increase of around 0.4%-points. The mortality rate for emergency cases, such as sepsis and heart attacks, increases even by 2.35 and 1.56%-points, respectively. These adverse health effects are also reflected in aggregate health statistics, where life expectancy decreases by 0.35 statistical life years,

[2]For instance, Hoe (2022) finds that under "hospitals crowding," i.e., in periods with high emergency admissions, unplanned readmission rates among patients with high medical needs especially increase.

with two-thirds of this reduction being driven by individuals over 60, who show the largest increases in mortality both inside and outside hospitals.

This paper contributes to three main strands of literature.

First, it expands the the emerging literature on the far-reaching effects of labor scarcity (e.g., Acemoglu and Restrepo, 2022; Benmelech and Zator, 2022; Sellars and Alix-Garcia, 2018; Acemoglu, 2010; Samuelson, 1965). While much of the literature has explored how labor shortages affect wages, thus increasing hiring costs and pressuring inflation (e.g., Le Barbanchon et al., 2023; Domash and Summers, 2022; Muehlemann and Strupler Leiser, 2018; Blanchard and Galí, 2010), as well as the production process and the adoption of technology (e.g., Lipowski, 2024; San, 2023; Acemoglu and Restrepo, 2022), this paper expands the focus by examining how labor scarcity influences product markets. Specifically, it empirically tests the theoretical predictions from Michaillat and Saez (2015), which are grounded in the general disequilibrium model of Barro and Grossman (1971) but matches labor market shortages to the product market. This paper demonstrates that in fixed-price settings like the German hospital sector, labor scarcity leads to a reduction of healthcare services, with severe consequences for patients. By linking nursing shortages to patient health outcomes, this study is the first, to the best of my knowledge, to empirically assess the impact of labor scarcity on consumers. Further, and related to Jäger and Heining (2022), who show that worker outflows increase demand for incumbent workers and alter production processes, this paper demonstrates that wage rigidities can prevent the remaining workforce from benefiting from labor scarcity in economic terms.

Second, this paper contributes to the literature examining the role of nurses in ensuring the quality of care and improving patient health outcomes (e.g., Friedrich and Hackmann, 2021; Aiken et al., 2021; Stevens et al., 2015; Propper and Van Reenen, 2010). Closely related to this paper is Propper and Van Reenen (2010), which uses region-specific differences in outside options for NHS nurses to causally link nurse staffing rates with heart attack death rates. This paper builds on their findings by showing that cross-country wage differentials, unlikely to be driven by unobservable regional demand shocks, increase mortality in hospitals – not only for heart attack patients but overall. I further complement their findings, which highlight that labor market regulations can have serious unintended consequences, by showing that not only collective wage setting but also case-based reimbursement schemes cause deaths, as patients in private hospitals (not subject to collective bargaining) also face an increase in mortality. Moreover, hospitals react to the lower availability of nurses by adjusting their medical practices and shifting resources toward patients with more urgent diagnoses, contributing to the observed significant regional variation in the intensity of care and clinical practice styles (Cutler et al., 2019; Finkelstein et al., 2016; Skinner, 2011). By accounting for patients' medical needs when estimating the impact of nursing shortages on treatment intensity, this paper extends the findings of Card et al. (2023) beyond childbirth outcomes to demonstrate the broader effects of labor shortages on healthcare provision.

Thirdly, it adds to the extensive literature on the causes and consequences of migration and especially emigration (e.g., Dustmann et al., 2017; Foged and Peri, 2016; Dustmann et al., 2015, 2013; Glitz, 2012; Card, 2009, 2001). While much of the existing research has focused on high-skilled emigration ("brain drain") (e.g., Docquier and Veljanoska, 2022; Docquier and Rapoport, 2012; Gibson and McKenzie, 2012) or the effects of cross-border commuting on receiving countries (e.g., Beerli et al., 2021; Dustmann et al., 2017), this paper broadens the scope by showing how cross-country wage differentials drive cross-border commuting patterns among middle-skilled occupations, with adverse effects on the sending country – in this case, harming its healthcare system. Given that nearly 1% (1.8 million) of the EU workforce consists of cross-border commuters (European Commission, 2024), this paper also underscores the potential unintended consequences of free movement, facilitated by the EU's single market, for local economies on both sides of national borders.

The remainder of the paper is organized as follows. Section 2 provides an overview of the institutional setting, with a focus on the key characteristics of the German hospital sector and the implications of the 2011 Swiss Franc Stabilization (SFS). Section 3 describes the data used in the analysis. Section 4 explains the empirical strategy, starting with the assignment of counties to the treatment group and to the control groups via propensity score matching, followed by the event study design and the identifying assumptions. Section 5 presents the results, beginning with the impact of the SFS on staffing rates and vacancies, followed by its effects on hospital output at both the extensive and intensive margin, and finally the health impacts on patients. This section also includes a detailed heterogeneity analysis, exploring both treatment heterogeneity and effect heterogeneity across patient groups. Extensive robustness checks, which are conducted throughout to ensure the validity of the findings, are also shown. Section 6 concludes with a discussion of the broader implications of the results and suggestions for future research.

2 Institutional Setting

This section gives an overview of the institutional setting in which the paper analyses the consequences of labor scarcity in hospitals for patients' health. First, it explains how the German hospital sector is organized, provides key facts, and contrasts it with other sectors and countries. It highlights that, compared to other industries, the hospital sector is especially vulnerable to region-specific shocks, such as labor scarcity, due to a high degree of friction. Secondly, it describes what led to increasing and stable cross-country wage differences between Germany and Switzerland at the beginning of the 2010s and why especially registered nurses were able to respond by commuting across borders.

2.1 The German Hospital Sector

The hospital sector forms an important cornerstone of the German healthcare system by ensuring access to comprehensive medical services, such as acute care, specialized treatments, and emergency services.[3] This importance is also reflected in the number of personnel (around 1.1 million) and the significant portion of healthcare expenditures being allocated to hospitals (29%) (Statistisches Bundesamt, 2012; OECD, 2017). Each year, German hospitals treat more than 18 million inpatient cases and provide around 6 beds per 1,000 inhabitants (Busse et al., 2017). Patients in Germany are free to choose their hospital, and the treatment costs are covered by universal health insurance.[4] Hospitals, on the other hand, have the statutory obligation to provide medical services as defined by federal states and anchored in the Hospital Financing Act (KHG) (Braun et al., 2011). This obligation, the so-called care mandates, ensures the availability of essential healthcare services to the population but limits the flexibility of providers to respond to hospital- or region-specific shocks (Busse et al., 2013b). For instance, hospitals cannot unilaterally reduce beds, close departments, or discontinue services if such actions would impair their established care mandate.

Hospitals are not only restricted in reducing output through care mandates but face both price and wage frictions. For each patient, hospitals receive a DRG (Diagnosis Related Groups) case-based payment intended to reflect the average costs for treating this case (Geissler et al., 2012). As the case-based payment is standardized at the state level, individual hospitals cannot negotiate higher rates or adjust prices based on their specific circumstances, such as region-specific cost differences.[5] In Germany, nursing staff and doctors are generally paid based on state-level collective agreements.[6] These collective agreements are binding for all public hospitals (48%) and most non-profit hospitals (34%), but also privately owned hospitals follow them closely (Busse et al., 2017). While hospitals, regardless of the type of ownership, theoretically have the autonomy to pay higher wages,

[3]The German healthcare system offers universal healthcare coverage and employs about 12% of Germany's workforce, corresponding to 5.2 million employees (Busse et al., 2017). This makes the German healthcare system, in relative terms, comparable to the US and Switzerland, whose share of the healthcare workforce amounts to around 13% (OECD, 2017).

[4]However, there are regional differences regarding the availability of medical specialties, which can limit freedom (Klauber et al., 2011). Additionally, patients usually require a referral from a general practitioner for planned inpatient treatments (Social Code Book V, §39).

[5]The DRG case-based payments are a classification system that groups medical cases according to diagnoses and treatments. A central goal of introducing the DRG case-based payments was to ensure uniformity, transparency, and efficiency by converging hospital-specific prices to a uniform price at the state level, the base rate ("Landesbasisfallwert") (Klein-Hitpaß and Scheller-Kreinsen, 2015). This base rate is negotiated annually at the level of each federal state (Bundesland) between the regional hospital associations and the health insurance funds and incentivizes hospitals, independent of their ownership, to reduce costs per case, e.g. by shortening patient stays, potentially leading to overprovision or unnecessary treatments (Busse et al., 2013a; Schreyögg and Stargardt, 2010).

[6]These collective agreements ("Tarifverhandlungen") are annually negotiated between employers' associations and trade unions at the state level and stipulate salaries, working hours, vacation entitlements, and working conditions.

in practice, they are limited in doing so due to the fixed prices imposed by the DRG case-based payment system.

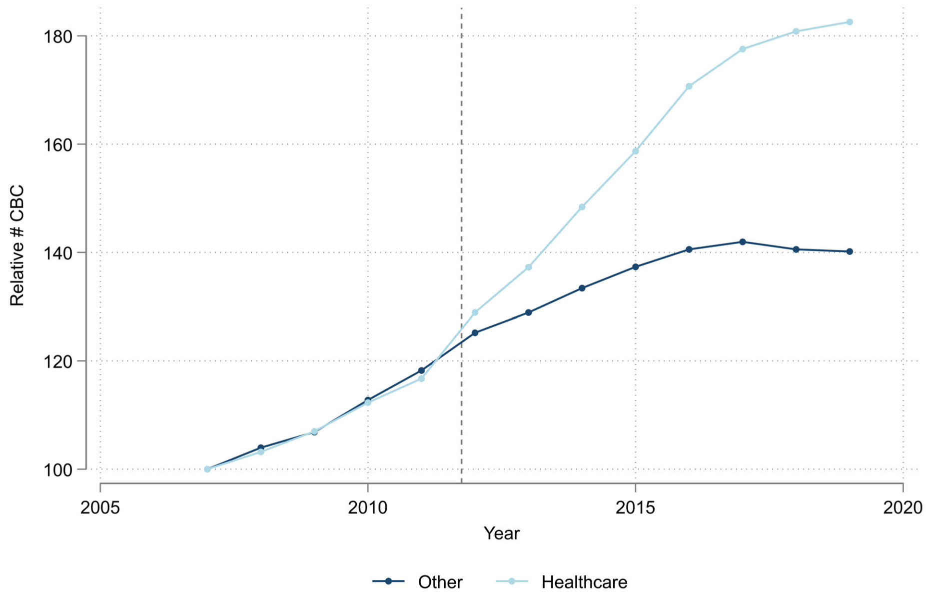
Registered nurses form the backbone of hospitals as they are fundamental to patient care and hard to substitute (Zaranko et al., 2023; Busse et al., 2017). In Germany in 2015, nursing staff forms around 40% of overall hospitals' staff of which around 80% are registered nurses (Blum et al., 2019). These registered nurses undergo a three-year vocational training program, culminating in a state examination, and perform most medical nursing tasks such as wound care, vital sign monitoring, and patient counseling with a high degree of responsibility. They also administrate medication prescriptions by doctors and assist surgeons and anesthetists during medical procedures and surgeries. This differentiates them substantially from nursing assistants, who undergo less training and perform mostly basic care tasks, which means that tasks are rarely substitutable across occupation groups.

2.2 The Swiss Franc Stabilization and Its Consequences

Cross-border commuting in Europe has high importance and cross-country wage differentials shape the decision of where to work. In 2022 European Union (EU) and European Free Trade Association (EFTA) member states reported around 1.8 million cross-border commuters (CBCs), amounting to nearly 1% of the EU workforce (European Commission, 2024). The EU's Single Market and several EU-EFTA treaties facilitate the recognition of qualifications across states, enabling workers to transfer their skills to jobs in neighboring countries more easily. Within the Eurozone, cross-country wage differentials substantially contribute to the decision to commute across borders as although cross-border commuters earn more in the high-wage country of employment, they can usually consume at the lower prices in the low-wage country of residence (European Commission, 2024). The same applies to those who work in Switzerland, a high-wage country, but live and spend in Germany. In addition, the two countries have different currencies, which means that the wage difference also depends on the exchange rate and is, therefore, subject to uncertainty.

In 2011, the Swiss franc experienced a significant exchange rate shock that had profound implications for cross-border commuters. In the course of the European financial and currency crisis, the Swiss franc appreciated sharply, putting pressure on the Swiss export industry in particular and leading to fears of a recession in the small open economy of Switzerland. After conventional monetary policy measures proved unsuccessful, the Swiss National Bank (SNB) intervened unexpectedly in September 2011, pegging the Swiss franc to the euro to stabilize the currency (Landmann et al., 2011). For Germans, commuting to Switzerland became more attractive depending on their proximity to the border, i.e. their commuting costs, as pay differences were on average high and lost volatility. However, whether someone is able to take advantage of this outside option also depends on the availability of open positions in Switzerland. Although the appreciation of the Swiss franc only had minor employment effects in Switzerland (Kaiser and Siegenthaler, 2016; Flückiger et al., 2016), new hires were reduced due to the economic pressure, which prevented most Germans from gaining access to the attractive Swiss labor market.[7]

Figure 1: Cross-border commuters by sector



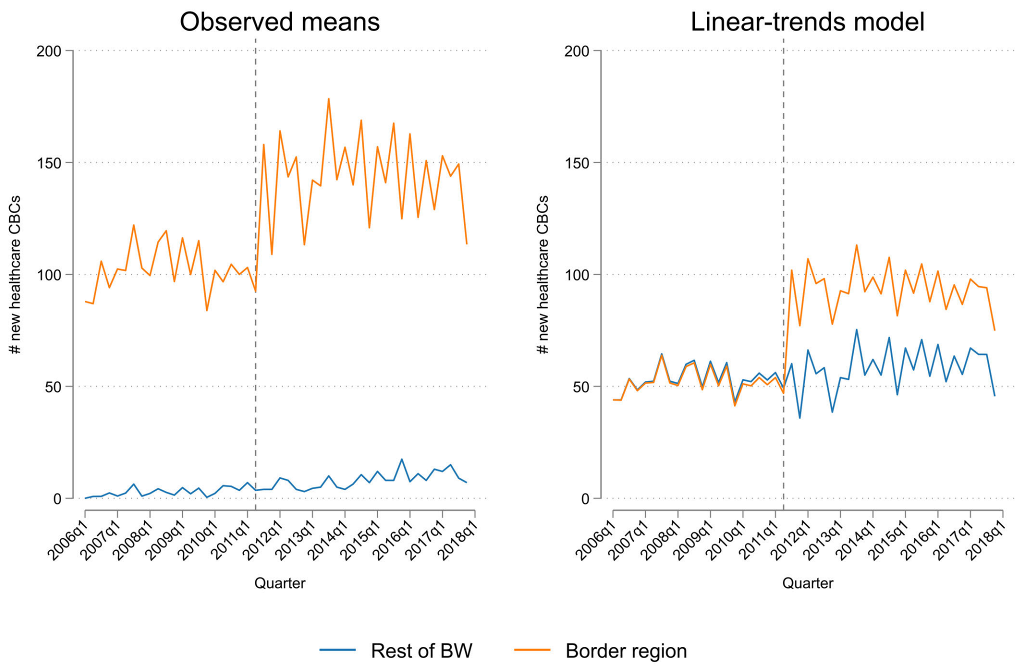
Notes: This figure shows the number of active German cross border commuters (CBCs) working in the Swiss healthcare sector (light blue) or in all other Swiss sectors (dark blue), relative to the year 2007. Assignment to sectors is based on the General Classification of Economic Activities (NOGA), the Swiss pendant to the Statistical Classification of Economic Activities in the European Community (NACE). The grey dotted line indicates the year 2012, the first year of the treatment. Data is obtained from the Swiss Cross-Border Commuter Statistic, described in detail in Section 3.

Figure 1 shows that the number of cross-border commuters in the healthcare sector is rising sharply – in contrast to all other sectors. This development is driven by the extensive margin, i.e. people who have never been cross-border commuters before (Figure 2). Their numbers rose sharply by 46% in the third quarter of 2011. Collective wage bargaining and fixed prices prevent wage adjustments in the healthcare sector, meaning that firms have limited means of retaining their staff when outside options increase. Within the healthcare sector, registered nurses were particularly able to leverage this increase in cross-country wage differences. As in Germany, registered nurses were in increasingly high demand in Switzerland in the early 2010s (Merçay et al., 2016), which is why those willing to

[7]There are two main reasons for this. Firstly, highly productive export companies were particularly affected by the high exchange rate but were able to adjust their markup (Berman et al., 2012). Secondly, the global economy recovered at the same time so demand for Swiss products remained high (Auer and Sauré, 2012).

commute are also highly likely to find a job. Between 2011 and 2013, 6% of positions were unfilled (Lobsiger and Kägi, 2016). In contrast, the share of vacancies for nursing assistants was only 0.7% and 2.5% for doctors in 2011 (SECO, 2014). Secondly, Also, in Swiss hospitals, registered nurses perform similar tasks and the German qualification is directly recognized, meaning that they can enter the Swiss labor market without legal barriers.[8]

Figure 2: 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 in raw means (left panel) and after accounting for linear trends (right panel). Assignment to sectors is based on the General Classification of Economic Activities (NOGA), the Swiss pendant to the Statistical Classification of Economic Activities in the European Community (NACE). "Border region" refers to German counties at the Swiss-German border, i.e., the treatment group as defined in Section 4, which are prone to cross-border commuting. "Rest of BW" refers to all other counties in the Federal State of Baden-Württemberg. Data is obtained from the Swiss Cross-Border Commuter Statistic, described in detail in Section 3.

While Swiss hospitals are now able to draw on a larger labor supply due to the stabilization of the Swiss franc, German hospitals are affected by an outflow of registered nurses. The magnitude of this negative labor supply shock for German hospitals depends on the distance to the border, i.e. the commuting costs of their staff. As already described,

[8]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 can take several months, but a so-called PreCheck reduces the waiting time usually to a few weeks.

the combination of rigid wages due to collective wage bargaining at the state level and fixed per-case prices due to the DRG reform prevents hospitals, regardless of ownership, from increasing wages in order to remain attractive to employees. Furthermore, the care mandates prevent hospitals from reducing output at the extensive margin, for example, by rejecting patients or reducing bed capacity at short notice. Lastly, there is little substitution potential between occupational groups and the use of automation technologies in the healthcare sector was of no significance in the early 2010s.

2.3 How Hospitals React to Labor Scarcity

To understand how hospitals react to labor scarcity and how, in turn, patients are affected, I develop a conceptual framework in Appendix C that compares the provision of healthcare services under labor scarcity to a baseline scenario without such constraints. In this framework, I assume that hospitals aim to maximally reduce total mortality among their patients by optimally allocating a limited number of nurses between two patient types: high-urgency patients who require immediate attention and low-urgency patients. The mortality reduction for each patient type depends on the nurse-to-patient ratio and exhibits diminishing marginal returns, with high-urgency patients being more sensitive to nursing care than low-urgency patients. Additionally, hospitals face the same constraints as described above: they have a limited number of nurses available, depending on outside options, have fixed prices and wages, and, importantly, due to care mandates, are obliged to treat all incoming patients and cannot reduce output at the extensive margin. The combination of these factors means that German hospitals have limited options for responding to a shortage of registered nurses other than by reducing care at the intensive margin – that is, by decreasing the intensity of treatment provided to patients.

From this framework, I derive two empirically testable predictions. First, labor scarcity leads to a relative shift of nursing resources towards high-urgency patients, i.e. triage (Jenkins, 2024). This is due to the higher marginal benefit from nursing for patients with more urgent medical needs. However, due to the care mandates, emergency cases do also receive less treatment compared to baseline. Second, despite receiving a relatively greater share of nursing resources, high-urgency patients likely experience a larger absolute increase in mortality compared to low-urgency patients. This is because even small reductions in treatment intensity can have significant adverse effects on high-urgency patients due to their higher sensitivity to nursing care.

Taken together, this empirical framework implies that under labor scarcity, hospitals' efforts to minimize overall mortality result in differential impacts on patient groups, with high-urgency patients being more adversely affected in absolute terms. The inability to reduce the number of patients treated forces hospitals to distribute fewer resources across all patients, disproportionately harming those who are most vulnerable to reductions in care intensity. In the following empirical analysis, I test these predictions by examining how hospitals respond to labor shortages and how different patient groups are affected.

3 Data Sources

This section describes the rich administrative dataset covering the years 2006 to 2017 that allows me to show in great detail the consequences of the Swiss Franc Stabilization in 2011, described in the previous section, on the staffing rates in hospitals, the provision of medical services for patients, as well as patients' and population' health.

Commuting patterns. In order to determine which German regions, and thus hospitals, actually see an outflow of healthcare workers to Switzerland, I use the **Swiss Cross-Border Commuter Statistic** (Schweizer Grenzgängerstatistik, henceforth: GGS). This data set is a quarterly panel covering individual-level data for all foreign individuals employed but not residing in Switzerland. It is provided by the Swiss Federal Statistical Office (SBFS) and calculated based on the cross-border commuter permits in the Central Migration Register (ZEMIS).[9] The data has been 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).[10] Assuming that cross-border commuters working in the Swiss healthcare sector (NOGA 86) formerly worked in the German healthcare sector, this data allows me to illustrate in detail their commuting patterns over time and space.[11]

Staffing rates. My main source of data to assess whether the increased outside options in Switzerland due to the Swiss Franc Stabilization had a "bite", i.e., actually negatively affected the staffing rates in German hospitals, is the **German Hospital Statistic** (Krankenhausstatistik, henceforth: KS). This dataset is a yearly panel of all accredited German hospitals since 1990, numbering around 2,000 in 2011.[12] The dataset contains general information on hospitals (e.g., number of beds, number of patients, ownership), as

[9] 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 accounted for by a weighting procedure based on data from the Pension and Survivors Insurance (AHV).

[10] The General Classification of Economic Activities (NOGA) is the Swiss pendant to the Statistical Classification of Economic Activities in the European Community (NACE).

[11] I solely rely on the sector information as, unfortunately, a further distinction based on the occupation is not reliable due to data limitations.

[12] Accredited German hospitals are "facilities in which medical and nursing care is used to diagnose, cure or alleviate illness, suffering or physical injuries are to be diagnosed, cured or alleviated or obstetrics is provided and in which the persons to care can be accommodated and fed" (Statistisches Bundesamt, 2014). This definition includes all hospitals, regardless of ownership (public, private) or type of accreditation (university hospital, hospital with or without care mandate).

well as detailed staffing rates by occupational groups such as doctors, registered nurses, and nursing assistants. Since the geographic location of hospitals is only specified at the NUTS2 level, I infer a more precise location based on the residences of admitted patients.[13] More specifically, hospitals are assigned to counties based on the place of residence of the majority of inpatient cases they treat. Furthermore, I use county-occupation level vacancy information from Bossler and Popp (2024) to investigate whether the decrease in staffing rates is a reaction by hospitals to changes in demand rather than to the availability of labor.[14] The data from Bossler and Popp (2024) originates from the Federal Employment Agency (FEA) and consists of the stock of registered vacancies as of June 15th for each year from 2007 onwards.

Employment structure. In order to determine whether the composition and compensation of nurses changed in treated hospitals, I use the **Integrated Employment Biographies** (Integrierte Erwerbsbiographien, henceforth: IEB), which contains administrative labor market records of all workers subject to social security contributions (Müller and Wolter, 2020).[15] The IEB includes daily records of employment spells subject to social security contributions, including start and end dates, occupation codes, industry classifications, employer identifiers, and earnings up to the social security contribution ceiling. In addition, it contains periods of registered unemployment, participation in labor market programs, and basic demographic data such as age, nationality, education, and gender. I use the yearly averages of workers' employment outcomes – wage, days employed (overall, in the same occupation, at the same establishment), and earnings – and socio-demographic characteristics – education, age, and gender – and aggregate them at the county-occupation level. In addition, I construct a binary indicator of whether an individual works in their county of residence, as well as indicators of whether a worker switched residence across counties and federal states. These indicators allow me to assess if nurses moved to the treated border region to fill open vacancies – and, by that, generate spillovers to the counties further inland.

Patient-level information. To capture how the decrease in healthcare personnel led hospitals to adjust the medical services provided and how this, in turn, affected patients, I leverage the **German Patient Statistic** (Patientenstatistik, henceforth: PS). These

[13]The NUTS2 level refers to the German regional administrative unit of "Regierungsbezirke", functioning between the federal state and the counties.

[14]The data is available at the 5-digit occupation level (according to Kldb 2010) and the NUTS07-3-digit region level, referring to the German counties ("Kreise"). However, I aggregate the vacancies to the 4-digit occupation level for clearer presentation of the findings, as this is sufficient to meaningfully distinguish healthcare occupations. Results at the 5-digit occupation level are available upon request.

[15]More specifically, I use the Integrated Employment Biographies (IEB v16.01.00) prepared by the Institute for Employment Research under access regulation according to Section 75 of the German Social Code (Book X). The dataset is available from 1975 onwards for West Germany and from 1992 onwards for East Germany.

individual-level administrative records cover all inpatient cases treated in all German hospitals, amounting to between 18 and 19 million observations each year. For each case, the dataset 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 ICD-10 main diagnosis (5-digit), as well as binary indicators of whether surgery was performed and whether death occurred. This richness of information allows me to compare individuals with similar characteristics who went to the hospital for the same reason, e.g., a heart attack, but likely differ in (i) how they are treated due to labor scarcity and (ii) how this then affects their probability of dying. Further, I can assess if and how hospitals target their adjustment mechanisms using age (as a proxy for innate health) and the urgency of the diagnosis reflected by the urgency score obtained from Krämer et al. (2019). Additionally, this urgency score allows me to restrict the analysis to emergency cases, i.e., patients that are not able to, a priori, willingly select into hospitals and for which hospitals need to react fast, meaning they unlikely are able to transfer patients to other hospitals.

Regional information. I complement the patient-level health information with data on life expectancy and mortality at the county level to validate and extend the results and to further investigate potential confounders. To this end, I combine administrative records on demographic, social, economic, and health characteristics from the **INKAR Database** of the Federal Institute for Research on Building, Urban Affairs and Spatial Development (BBSR) and the **Regional Statistics** of the German Federal Statistical Office to construct a balanced yearly panel covering all 401 German counties. To see if the patient-level health effects of labor scarcity in hospitals translate into aggregate health statistics, I use life expectancy as another main outcome. It is defined as the average number of years a person at a certain age is expected to live on further, assuming the mortality rates observed remain constant throughout the rest of the person's life. This number is a widely used indicator reflecting regional differences in mortality and the average health status of the population. As it is calculated from actual deaths, changes over time reflect changing morality rates without distortions due to changes in age or population structure, which gives me another well-suited measure to capture the effect of labor scarcity in hospitals on populations' health. The database contains the life expectancy for newborns and at age 60, using a rolling average over the most recent three years, which allows me to see, to what extent changes in life expectancy are driven by changes in mortality at higher or lower ages. Additionally, to see which detailed age group is most strongly affected by labor scarcity in hospitals, I use age group-specific mortality rates.[16]

[16]The mortality rate is calculated, both for each age group as well as overall, as the number of death cases per 100,000 inhabitants. Further, to make this self-calculated measure of mortality comparable to life expectancy, I use a three-year rolling average as well.

4 Empirical Strategy

In this Section, I first describe the basis for the assignment of counties into the treatment group and how these treated counties are then matched to suitable control counties using propensity score matching. Then, I describe the multi-period difference-in-differences ("event study") design with which I aim to answer whether the increase in outside options for German nurses due to the Swiss Franc Stabilization of 2011 has reduced hospital staffing rates, decreased access to medical services, and led to higher mortality for patients and the overall population in border counties.

Treatment group assignment. To examine the consequences of labor scarcity in hospitals, it is crucial to know in which regions it is feasible for individuals to start commuting to Switzerland, i.e., whether hospitals lying in these counties are likely exposed to labor scarcity due to exchange rate trends and the Swiss Franc Stabilization in 2011. Using the information from the GGS on where German cross-border commuters already working in the Swiss healthcare sector in 2011 live, Figure A.1 in Appendix A shows that German counties in close proximity to the Swiss border are, unsurprisingly, particularly prone to cross-border commuting. However, as the GGS does not allow me to distinguish further between occupations, assigning counties based on past patterns of Germans working in the Swiss healthcare sector assumes that those commuters have also previously worked in the German healthcare sector. For this reason, I additionally create a more general exposure measure based on travel times to the Swiss border using Open Street Maps (OSM).[17] As Appendix Figure A.2 shows, most new cross-border commuters drove 45 minutes or less to the nearest border crossing in 2012. Thus, to incorporate both general commuting patterns and specific patterns of healthcare workers, I assign counties (i) whose centroid either lies within a 45-minute drive to the border or (ii) are one of the five counties with the highest count of cross-border commuters working in the Swiss healthcare sector prior to the event to the treatment group.

Control group assignment. The comparison in Table 1 between all 401 German counties (column 1) and the 7 counties assigned to the treatment group in 2011 (column 2) shows that although border counties are economically similar to the German average, they have a lower population density. This difference in urbanity might expose them to potential confounding factors, such as time-varying differences in health-related behavior, health literacy, or diminishing access to medical services due to the over-proportional closure of smaller hospitals in rural areas in Germany (Klauber et al., 2015; Augurzky et al.,

[17] 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). To calculate the distance and, thus, the travel time, I use the geographic centroid of each municipality and county.

2012). To ensure that treated and control counties are comparable and similarly exposed to confounding trends, I match counties based on pre-event characteristics. Before matching, I omit those counties adjacent to the treated border region from the pool of possible control units to ensure that the control group is not affected by spillovers. Then, I use a 10-nearest neighbor propensity score matching with a caliper of one-quarter of the standard deviation of the propensity score as suggested by Stuart and Rubin (2008a,b).[18] I base the matching on the number of inhabitants, overall and per square kilometer, the GDP per inhabitant, and the average age of the population in 2011.[19] The resulting sample of treated (orange) and matched control counties (blue) is depicted in Figure 3. Overall, most control counties lie in the wealthy south of Germany and even in the same state, meaning that they are subject to the same or similar legal requirements and institutional regulations, e.g., hospitals have the same remuneration per inpatient case. Figure A.3 in Appendix A displays the distribution of the propensity score of the final sample (Figure A.3a) as well as the bias across the covariates used for matching (Figure A.3b). In all four dimensions, but especially regarding urbanity, the matched control counties are strongly more similar.

Final sample. The resulting final sample consists of 66 counties and 277 hospitals with around 2.45 million inpatient cases every year, corresponding to around 13-14% of all German hospitals and cases. Table 1 shows summary statistics of the treatment group compared to all German counties as well as the matched control counties. Not only along the dimensions used for matching but across a wide range of other characteristics, the 7 treated and 59 control counties are quite alike, meaning that the matching successfully eliminated observable differences and thus reduced the threat of results being driven by confounding factors. However, as I match at the county level and further assign patients based on the location of the hospital they are treated in and not their place of residence, lower aggregate levels do not necessarily need to be as similar.[20] Table A.1 and Table A.2 in Appendix A show the mean comparison between the treated and control groups for hospitals and inpatient cases. On average, hospitals in the border region are

[18]Using a larger positive number of neighbors ensures a sufficiently large sample as treated counties can have more than one matched control county. At the same time, the caliper ensures that the similarity between matches is sufficiently strong, i.e. propensity scores are close.

[19]I use 2011 as a reference year due to the German "census shock", i.e., many inferred or projected statistics were corrected due to the German full census in 2011, causing partially stark disparities between 2010 and 2011.

[20]This assignment based on the place of treatment increases the precision of the results as it is known whether a patient was exposed to skill shortages during treatment, but might induce selection bias if patients are aware of differences in staffing rates and the potentially resulting lower care quality, and adjust accordingly by selecting hospitals. Although almost 65% of individuals in Germany are treated in the same county, I later investigate this by looking at whether the share of individuals treated in their county of residence changes and restricting the sample to patients with emergency diagnoses and, as a case study, myocardial infarction, also known as "heart attacks". For the latter, it is unlikely that neither patients willingly choose their hospitals nor hospitals are able to refuse treatment or transfer them to other hospitals.

smaller, and thus, overall costs are lower. However, relative to the number of patients, border hospitals spend around 350 euros more per patient, and nurses treat on average 5 patients less – with patients being similar in their demographics but more likely to undergo surgery and less likely to die in treated border hospitals prior to the event. Additionally, I restrict hospitals to be continuously operating during the whole period of investigation, i.e., between 2006 and 2017, which ensures that results are not driven by the changing composition of hospitals as hospital closures over-proportionally affected smaller hospitals in rural areas.[21] This restriction on successful facilities with a higher economic resilience can lead to more conservative estimates as these hospitals are likely more able to also deal with the consequences of labor scarcity. Thus, in a robustness test in Section 5, I lift this restriction.

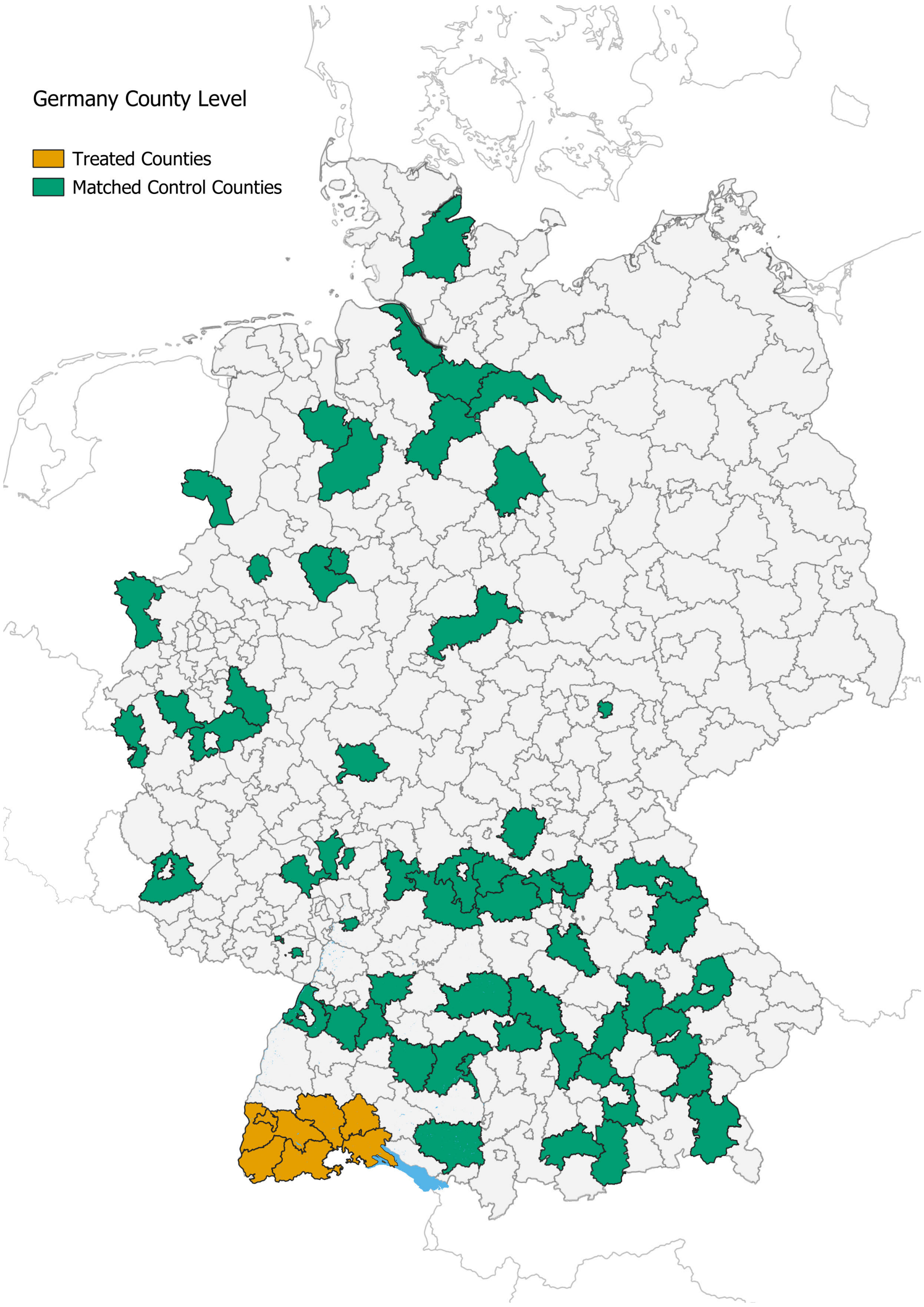
[21]Over the period of investigation, Germany saw a decline in the number of hospitals by 7.7% from initially around 2,100 (Statistisches Bundesamt, 2023). This decline was especially pronounced in rural areas as the implementation of the DRG (Diagnosis Related Groups) in 2005 increased the financial pressure, especially for small hospitals lacking economies of scale, as it replaced the per diem payment scheme with fixed payments (Messerle and Schreyögg, 2024; Herwartz and Strumann, 2014).

Table 1: Summary statistics of counties in 2011

	Germany	Treatment	Control
Gross monthly earnings (per employed)	2310.57	2397.51	2376.23
	(350.13)	(147.02)	(344.83)
Employment rate (in %)	54.12	51.00	54.47
	(4.02)	(6.55)	(4.15)
Women (in %)	51.10	51.43	50.83
	(0.67)	(0.80)	(0.63)
Fertility rate	1.42	1.41	1.43
	(0.10)	(0.12)	(0.10)
Hospital beds (per 1,000 inhabitants)	6.52	5.47	5.24
	(3.86)	(2.66)	(4.04)
Share in secondary sector	27.65	31.89	28.38
	(8.92)	(13.03)	(8.63)
Share in tertiary sector	70.08	66.57	68.63
	(9.60)	(13.10)	(9.42)
Covariates			
Population density (per sq km)	512.71	385.97	319.92
	(665.62)	(451.43)	(324.74)
Population (in 1,000)	200.32	206.82	214.42
	(225.87)	(46.63)	(166.49)
GDP per inhabitant (in 1,000 Euro)	31.39	32.46	32.17
	(13.92)	(7.18)	(13.48)
Average age (in years)	43.78	42.36	42.47
	(1.74)	(1.22)	(0.81)
Observations	401	7	59

Notes: This table shows the means and standard deviations across multiple variables in 2011, separately for all counties in Germany, treated counties, and control counties. The assignment to the treatment and control group is described in detail in Section 4. The secondary (tertiary) sector refers to the manufacturing (service) sector. Fertility rate is defined as the mean child per woman and the share of women refers to the whole population living in a given county. Data is obtained from the INKAR Database and the Regional Statistics, described in detail in Section 3.

Figure 3: Treatment and matched control counties in Germany



Notes: This map of Germany shows treated (orange) and matched control counties (blue). Treated counties are defined to be (i) lying within a 45-minute drive to the border or (ii) one of the five counties with the highest count of cross-border commuters working in the Swiss healthcare sector prior to the event. The assignment to the control group is based on a 10-nearest neighbor propensity score matching approach using regional characteristics (population size, population density, GDP per inhabitant, and average age of the population) in 2011. For details regarding the assignment to the treatment and control group, see Section 4.

Event study design. This empirical approach leverages the exogenous variation in the incentives for German healthcare workers to start working in Switzerland induced by the consistently strong Swiss Franc in 2011, which German hospitals were exposed to depending on their proximity to the German-Swiss border. Using a multi-period difference-in-differences ("event study") design, I compare hospitals, patients, and counties in the border region with their counterparts in matched control counties. First, I estimate the following regression for each outcome Y of hospital h in county c in year t:

$$Y_{ht} = \alpha + \sum_{t=2006;t\neq2011}^{2017} \delta_t \times I_t \times I_{g(h)} + \zeta_t + \theta_h + \epsilon_{ht} \qquad (1)$$

where $g \in \{Treatment, Control\}$ reflects the treatment status. I_g is a treatment group indicator, equal to 1 if an observation is located in the border region and 0 otherwise, whereas I_t is a year indicator. ζ_t are year fixed effects, and α_h are hospital fixed effects, capturing time-invariant differences between hospitals, e.g., regarding the size and organization of departments or the ownership structure. Further, the comparison of means in Appendix Table A.1 hints at pre-treatment differences regarding the size of hospitals in the border and control region. These imbalances do not pose a threat to identification and are accounted for in the hospital fixed effects; additionally, observations are weighted based on hospital size in 2011.[22] Robust standard errors are clustered at the county level, i.e. the treatment assignment, to account for county-specific interdependencies and shocks (Bertrand et al., 2004). In the same manner, I compare the evolution of outcomes Y between the treated and control groups at the case and county levels. For the county-level analysis, this follows the same pattern as for hospitals with the exception that I adjust the fixed effects to match the aggregate level of observation, i.e. use county fixed effects instead of hospital fixed effects, and do not weigh observations. At the case level, I cannot include patient fixed effects as cases are only observed once but remain with hospital fixed effects. However, I additionally include gender, age group fixed effects (8 groups), and 3-digit ICD-Code fixed effects as controls in order to compare the outcomes of similar patients with similar conditions, differing by being treated in hospitals in the affected border region or a similar county further inland.

Outcomes of interest. To first see if the event had a "bite", I look at the staffing situation for doctors, nurses (registered and assistant), and other healthcare personnel at the hospital level. For most occupations, this information is available both as the number of employees and full-time equivalents (FTEs), which is preferable to look at given the high share of part-time workers in healthcare (OECD, 2013). Then, I use the number

[22] As the main weight, I use the number of beds in 2011. In a sensitivity analysis in Section 5, I present results using the number of patients and number of care days as alternative weights, as well as unweighted results.

of patients and the patient-to-staff ratio across occupation groups to capture if labor scarcity triggers a reduction of output at the extensive (amount of patients) or intensive (amount of treatment per patient) margin. At the case level, I use the number of days in care, and indicators for whether surgery was performed and death occurred as main outcomes of interest. Additionally, I use the information on case characteristics regarding demographics and diagnosis to test for a changing case mix reflecting confounding changes in healthcare demand. Lastly, I complement the analysis using mortality and life expectancy at the county level as the main outcomes. Again, comparing also the evolution of the demographic composition, economic situation, and healthcare supply (e.g., staff in nursing homes, number of general practitioners and specialists) across treatment and control counties over time allows me to test for the presence of confounding effects of the reform.

Identifying assumptions. The vector of coefficients δ_t reflects the difference in outcomes between treated and control observations over time and relative to 2011. As the Swiss Franc Stabilization affected all border counties at the same time, estimates are free from recently highlighted biases arising in staggered treatment designs (Goodman-Bacon, 2021; de Chaisemartin and D'Haultfœuille, 2020). However, for a causal interpretation of this coefficient, several assumptions have to be met:

Firstly, the **parallel trends assumption** requires that, in the absence of treatment, the outcomes of treatment and control group would have followed the same time trend. Although this assumption is not directly testable, a common placebo test is to assess whether pre-trends exist, i.e., whether the coefficients of interest are close to zero prior to the event ($\delta_t = 0 \ \forall \ t \leq 2011$).

Secondly, a causal interpretation requires **no anticipation** of the event by hospitals and patients, leading them to alter their behavior accordingly. If hospitals in the border region were able to adjust their capacities in anticipation of future staffing shortages due to the Swiss Franc Stabilization, this could distort the estimated effects. The same is true for patients, e.g. by shifting their demand for hospital services to the period prior to the event to avoid a lower care quality. As highlighted in Section 2, the Swiss Franc appreciated fast, and the Swiss National Bank introduced the stabilization policy surprisingly. This is also reflected by the suddenly increasing number of cross-border commuting healthcare workers shown in Figure 2 in Section 2 – implying that neither hospitals nor patients were able to anticipate the event.

Thirdly, the **stable unit treatment value assumption (SUTVA)** states that the Swiss Franc Stabilization does not affect the control group. This assumption is violated, for instance, if treated and untreated hospitals interact, for instance, due to agreements that allow hospitals to frequently transfer patients in case hospitals are low on staff. To ensure that matched control counties are unlikely to be affected by spillovers due to the event, I excluded all counties neighboring the border region prior to matching. Butts (2023) highlights that this approach removes all bias in the treatment effect arising from spillovers if the "ring" of excluded units is sufficiently large. However, as hospital providers are often organized at the county level and the matched control counties lie further inland than practical for cross-border commuters, this assumption is likely met.

Fourthly, to be able to interpret the findings as a direct result of labor scarcity in hospitals induced by the event, there should be **no concurring events**. Around the event, there were no major changes influencing the probability of individuals commuting across borders.[23] However, in 2013, the Health Care Structure Act was implemented. This reform of the German needs-based planning system, which aimed at decreasing the discrepancies in access to primary care across regions, resulted in an over-proportional reduction in the general practitioner density in the border region relative to the control group. Thus, I perform a robustness check in Section 5 in which I additionally control for the number of general practitioners at the county level.

Lastly, the appreciation of the Swiss Franc and its stabilization could lead to **indirect effects** by influencing the health of individuals at the border through other channels than through lower staffing rates in hospitals. Although existing literature suggests that in the end, the Swiss Franc Stabilization had little aggregate economic effects in Switzerland, and Figure 1 in Section 2 indicates that mostly healthcare occupations and specifically registered nurses were able to start commuting, I additionally approach this threat to identification more directly To this end, I use confounding outcomes in the same regression framework in extensive robustness checks in Section 5. For instance, at the hospital level, I look at the case mix to rule out changes in the composition of patients, hinting at demographic shifts or an increasing endogenous selection from the side of hospitals or patients. I also restrict the analysis to cases with high urgency, such as heart attacks, where endogenous selection is unlikely. Similarly, I look at changes in demographics and the economic situation at the county level as, for instance, due to the relatively strong Franc, more Swiss could have resided and consumed in Germany and by this affected the age composition or increased the number of car accidents due to increased traffic.

Two-period design. To ease the representation of the findings, I additionally use the equivalent two-period difference-in-differences design. In this setting, I analogously estimate the following regression:

$$Y_{ht} = \alpha + \delta_{post} \times I_{post} \times I_{g(h)} + \zeta_t + \theta_h + \epsilon_{ht} \tag{2}$$

[23]Later, in 2015, the SNB suddenly and surprisingly lifted the binding of the Swiss Franc to the euro, known as the Swiss Franc Shock (Bernholz et al., 2015). Around the same time, in 2014, a referendum was passed in Switzerland which requested the government within 3 years to impose quotas on residence and work permits for foreigners, also from EU and EFTA member states.

Here, δ_{post} is the coefficient of interest and reflects the difference in the outcome Y between the treatment and control group averaged over the years 2012 to 2017 (post-event period) and relative to the years 2006 to 2011 (pre-event period). As before, I adjust the estimation equation to the case and county level and cluster standard errors at the county level to account for interdependencies between hospitals and county-specific shocks.

5 The Effect of the Swiss Franc Stabilization

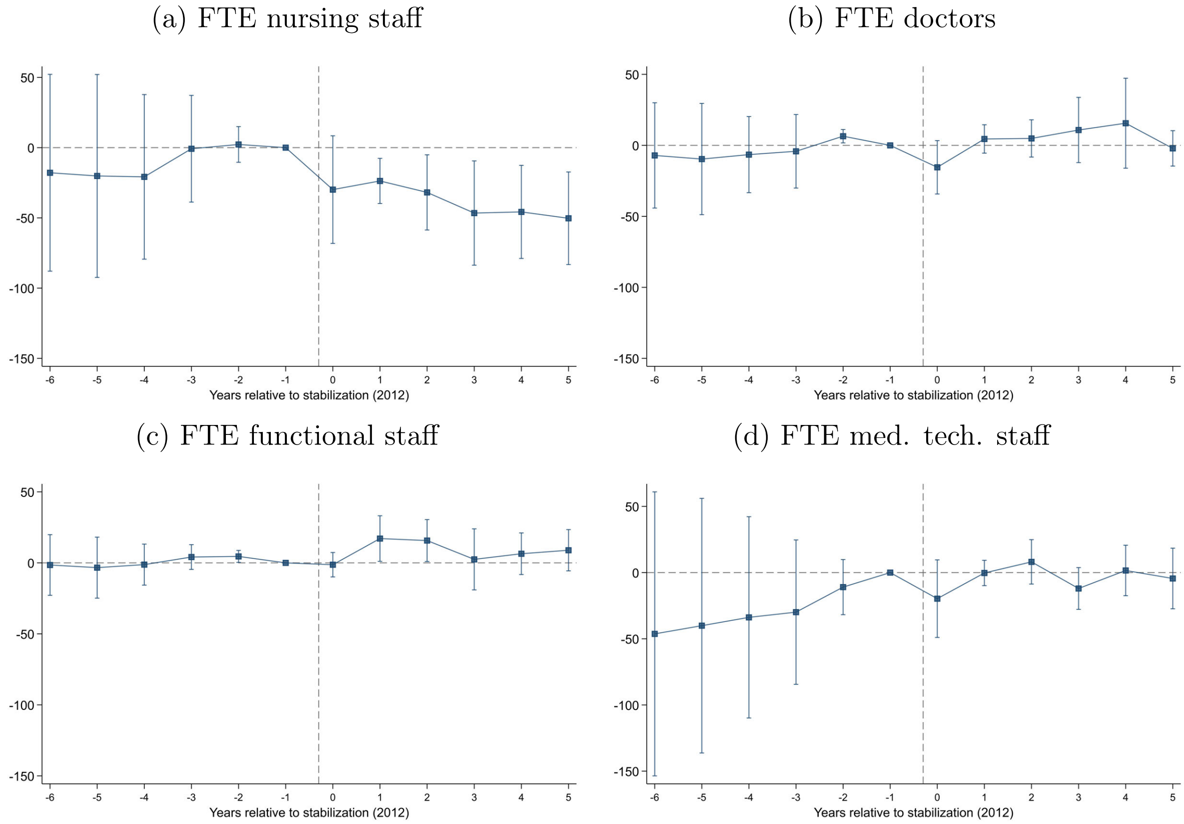
This section presents the results from the multi-period difference-in-differences ("event study") model outlined in Equation 1, incorporating all key specifications described in detail in Section 4. First, I examine the impact of the 2011 Swiss Franc Stabilization on German hospital staffing rates in the border region and relative to their counterparts in matched control counties further inland. Next, I analyze hospitals' responses by investigating both the extensive margin (number of patients treated) and the intensive margin (treatments provided per patient). Leveraging comprehensive patient-level data, I assess whether hospitals account for patient needs when reducing nursing care, thus exploring the potential use of triage mechanisms in resource allocation. Finally, I assess how these adjustments affect patient health outcomes, identify the patient groups most affected, and evaluate whether these effects are reflected in broader regional health statistics.

Personnel situation in hospitals. Figure 4 presents the event study coefficients illustrating the effect of the 2011 Swiss Franc Stabilization on staffing rates across key healthcare occupations in hospitals, including nursing, doctoral, functional, and medical technical staff.[24] While staffing levels for doctors, functional, and medical technical staff remain stable, a significant decline in the number of nurses is observed in hospitals near the border. Specifically, Figure 4a shows a sharp reduction of around 25 full-time equivalent (FTE) nurses in 2012 relative to 2011, with the decline continuing to reach approximately 50 FTEs over time. Relative to the weighted mean of hospitals in the sample, this reduction reflects not only a statistically but also economically significant drop in the availability of nurses of 12%. In contrast, the staffing rates for doctors (Figure 4b) and other non-doctoral personnel (Figure 4c and 4d) did not experience a similar decline, likely due to the lower legal barriers, stronger cross-country earnings differentials, and high demand for registered nurses in Switzerland, as discussed in Section 2. For instance, before the event, Switzerland faced a significant shortage of registered nurses, with un-

[24]Nursing staff are registered nurses, pediatric nurses, and geriatric nurses, as well as nursing assistants. Functional staff are employees who perform specific technical, diagnostic, or therapeutic tasks, e.g., ambulance drivers or ergotherapists, but also specialized nurses, e.g., in anesthesia. Thus functional staff and nursing staff have an overlap. Medical technical staff refers to healthcare workers operating advanced medical equipment and assisting in therapeutic interventions, e.g., medical technical assistants in laboratories, pharmacists, and psychologists.

filled positions nearly nine times higher than for nursing assistants and 2.5 times higher for doctors (Lobsiger and Kägi, 2016; SECO, 2014).

Figure 4: Effect on staffing rates in hospitals



Notes: This figure shows the effect of the Swiss Franc Stabilization (SFS) in 2011 on staffing rates in hospitals. Staffing rates are measured in full-time equivalents (FTE) and the respective occupation group is displayed above each sub-figure. All sub-figures display the multi-period difference-in-differences estimates obtained from Equation 1. Vertical bars indicate 95% confidence intervals based on robust standard errors clustered at the county level. The sample of hospitals contains continuously operating hospitals in the border region (treatment group) and hospitals in matched counties further inland (control group). The matching procedure is explained in detail in Section 4. Observations are weighted using the number of beds in 2011 at the hospital level due to imbalances regarding hospital size between the treatment and control group.

To further investigate if really registered nurses drive the reduction in staffing rates in German hospitals, I differentiate between them and nursing assistants.[25] Figure 5 confirms that the negative labor supply shock is driven entirely by registered nurses, with border hospitals employing, on average, 49 fewer registered nurses (a 12.5% reduction) after 2011, while the number of nursing assistants remained relatively unchanged (-0.2). Appendix Tables A.3 and A.4 show that most other essential occupation groups did not experience a reduction, leading to the conclusion that the Swiss Franc Stabilization induced a sharp

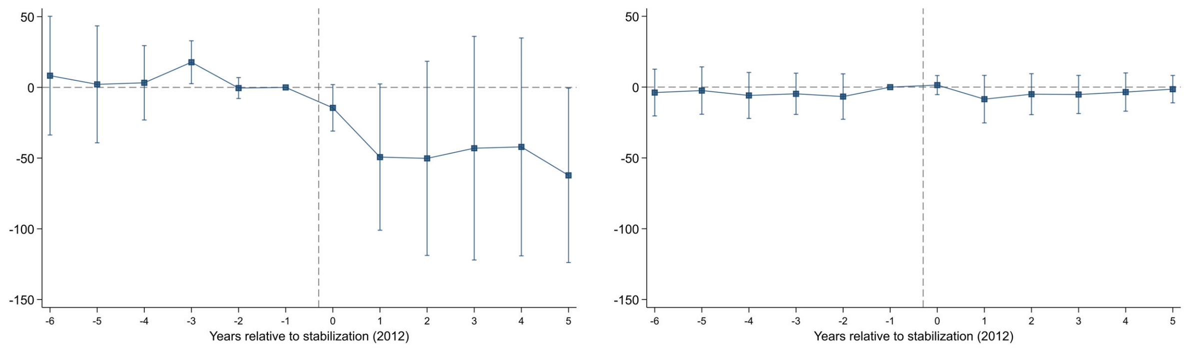
[25]Due to data limitations, I am only able to further differentiate between occupational sub-groups using the number of employees, not FTEs.

negative supply shock solely for registered nurses in German border hospitals of around 12%.

The reduction in nurse staffing is unlikely to be driven by changes in labor demand as the number of vacancies for nursing positions has increased simultaneously, as shown in Table A.5 in Appendix A. While there were approximately 15.4 open nursing positions at the county level on June 15, 2011, this number rose significantly more in the border region compared to similar counties further inland, by 9.54 positions or 62%. In contrast, other healthcare professions experienced little to no increase in vacancies. This trend is likely due to the fact that hospitals, as discussed in Section 2, face both wage and price rigidities due to state-wide uniform prices and collective bargaining. Thus, individual hospitals are unable to retain their staff through wage increases to counterbalance the enhanced outside options without putting their financial stability at risk.

Figure 5: Effect on number of nurses in hospitals

(a) Registered nurses (b) Assistant nurses



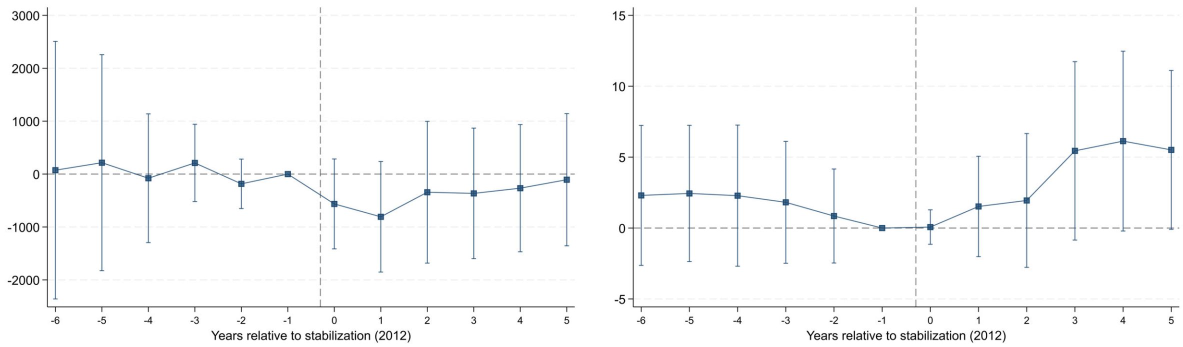
Notes: This figure shows the effect of the Swiss Franc Stabilization (SFS) in 2011 on the number of nurses employed in hospitals, separately for registered nurses and nursing assistants. All sub-figures display the multi-period difference-in-differences estimates obtained from Equation 1. Vertical bars indicate 95% confidence intervals based on robust standard errors clustered at the county level. The sample of hospitals contains continuously operating hospitals in the border region (treatment group) and hospitals in matched counties further inland (control group). The matching procedure is explained in detail in Section 4. Observations are weighted using the number of beds in 2011 at the hospital level due to imbalances regarding hospital size between the treatment and control group.

Indeed, as column 1 in Appendix A Table A.6 shows, there were no notable changes in nurse compensation in response to the Swiss Franc Stabilization in the border region, neither in terms of wages nor earnings. Also, the remaining nurses do not appear to be compensating for the staff shortages, as the number of annual workdays per nurse did not increase on average. Additionally, there is little evidence for compositional changes regarding tenure and skill, as the number of days employed in the occupation and at the same establishment, as well as the share of college graduates, remains similar. The same is true for age and gender (see columns 1 and 2 in Appendix A Table A.7). This also suggests that there is no change in the selectivity of cross-border commuters. It rather appears that the median nurses are reacting to the higher wages offered in Switzerland, resulting in a shortage of skilled workers in German border hospitals, which lack the means to retain staff through counteractive measures.

Output adjustments by hospitals. The persistent reduction in the availability of nurses prompted hospitals to adjust their service provision along both the extensive and intensive margin. Due to care mandates, hospitals are obliged to provide (minimal) treatment to patients and cannot unilaterally reduce beds, close departments, or discontinue services. This substantially restricts their ability to reduce output at the extensive margin, meaning hospitals must continue treating a similar number of patients despite a diminished workforce. As a result, with fewer nurses available, the intensity of care inevitably decreases. Figure 6a illustrates this phenomenon in the border region, where the number of patients per hospital has remained relatively stable at approximately 6,500, except for a temporary reduction of about 10% (or 650 cases) in 2012 and 2013. This stability, combined with the decrease in nursing staff, has led to a notable increase in the patient-to-nurse ratio, with each nurse handling up to five additional cases per FTE after 2011, corresponding to a rise of almost 10% (see Figure 6b).

Figure 6: Effect on hospital output

(a) Number of patients (b) Patients per nurse



Notes: This figure shows the effect of the Swiss Franc Stabilization (SFS) in 2011 on the number of patients treated and the number of patients per full-time equivalent nurse. All sub-figures display the multi-period difference-in-differences estimates obtained from Equation 1. Vertical bars indicate 95% confidence intervals based on robust standard errors clustered at the county level. The sample of hospitals contains continuously operating hospitals in the border region (treatment group) and hospitals in matched counties further inland (control group). The matching procedure is explained in detail in Section 4. Observations are weighted using the number of beds in 2011 at the hospital level due to imbalances regarding hospital size between the treatment and control group.

This observed change cannot be attributed to a shift in case mix, as the probability of hospitalization across specific main diagnoses groups remains stable over time between the border region and control counties (see Tables B.12 to B.15 in Appendix B for details).[26]

The decrease in care intensity translates into a lower likelihood of patients receiving surgery, illustrated in Figure 7a. As shown in column 2 of Appendix Table A.8, patients in border region hospitals are 3.85%-points less likely to undergo surgery – a substantial drop of 12% relative to the baseline probability of 31.4% in 2011. Given that I control for a detailed set of patient characteristics, such as gender, age, and diagnosis, these results indicate that patients are less likely to receive surgery due to the shortage of nursing staff although they have the same medical needs.

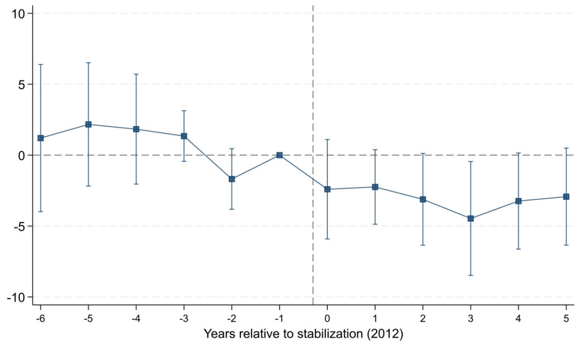
However, there is no significant change in the average length of hospital stays as column 3 of Table A.8 in Appendix A shows. Although this null finding may seem a little intuitive at first sight, it may reflect the counterbalancing influences of several factors: on the one hand, the shortage of nurses could reduce patient management efficiency, leading to longer stays and an increased risk of infections from multi-resistant germs; on the other hand, hospitals might discharge patients earlier to save on labor, which could shorten the length of stay but potentially increase the health risks associated with early discharge. Thus, it might map substantial heterogeneity across patient groups and does not necessarily imply that patients are not harmed by lower staffing rates – especially given that they receive (needed) surgery less likely.

In-hospital health effects. Next, I examine whether the decrease in output at the intensive margin – specifically, the lower care rate and reduced likelihood of receiving surgery — translates into adverse health outcomes for patients. Figure 7 shows that patients experience an increase in the probability of in-hospital death, on average, by 0.09%-points, or 4.35% (see also Appendix Table A.8). As before, I control for a rich set of patient characteristics such as the main diagnosis and age, which indicates that patients with similar medical needs and innate health experience a different probability of death due to a change in treatment. Columns 4 and 5 present the effects on the length of stay and mortality for patients who underwent surgery. Notably, these patients do not experience a reduction in length of stay, nor do they show a statistically significant increase in mortality. This suggests that the observed increase in mortality may result from patients not receiving necessary treatment or surgery, rather than from surgical complications. Table A.9 in Appendix A corroborates this, showing no significant rise in the occurrence of complications, both across all and for specific classes of surgeries.

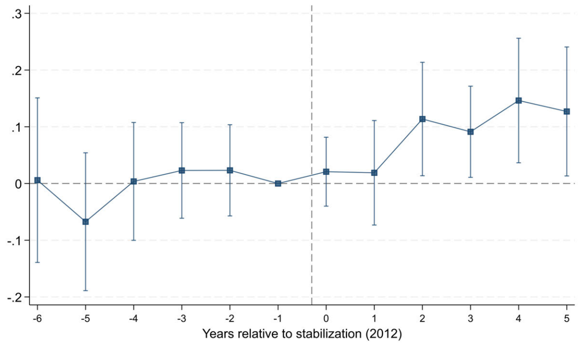
[26] On average, the absolute value of the coefficients relative to the mean (standard deviation) of the hospitalization probability at baseline is 0.06 (0.01). The only notable exception is for diagnoses in chapter IV (endocrine, nutritional, and metabolic diseases), where the coefficient indicates a 0.25%-point increase, equivalent to a quarter of the baseline mean.

Figure 7: Effect on patients' outcomes (event study)

(a) Surgery



(b) Mortality



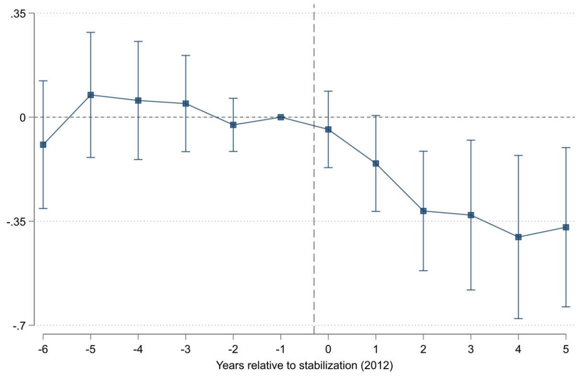
Notes: This figure shows the effect of the Swiss Franc Stabilization (SFS) in 2011 on the probability of surgery and the probability of in-hospital death (in percent). All sub-figures display the multi-period difference-in-differences estimates obtained from Equation 1. Case-level controls are female, age bin, and 3-digit ICD-10 diagnosis code fixed effects. Vertical bars indicate 95% confidence intervals based on robust standard errors clustered at the county level. The sample consists of all inpatient cases treated in continuously operating hospitals in the border region (treatment group) and in hospitals in matched counties further inland (control group). The matching procedure is explained in detail in Section 4.

The effect on aggregate life expectancy. If patients are less likely to receive surgery, it is important to consider also aggregate statistics, as patients discharged without adequate care may experience health consequences later, i.e. outside of hospitals. Therefore, focusing solely on in-hospital mortality presents a lower bound of the estimates as it does not capture the full impact of labor shortages on health outcomes. To assess the broader effect of reduced hospital staffing in the border region, I examine changes in life expectancy, a widely used measure that reflects mortality conditions for a cohort at a specific time (e.g., individuals aged 60 in Germany in 2011). Life expectancy is calculated from actual death rates for all ages at that moment, ensuring that changes over time reflect changing morality rates without distortions due to changes in age or population structure. Figure 8 illustrates the change in life expectancy for newborns (Figure 8a) and individuals at age 60 (Figure 8b) in the treated border region relative to matched control counties. From 2012 onwards, the border region experiences a gradually increasing decline in life expectancy, which stabilizes at a reduction of 0.35 statistical life years in the longer run.[27]

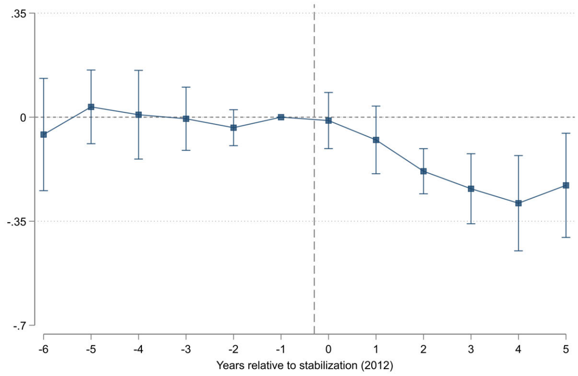
[27]This gradual decline is due to the calculation of life expectancy in Germany as a three-year rolling average, meaning that the life expectancy in 2011 is calculated using the average of 2009-2011. As a result, even a sharp increase in mortality in 2012 is smoothed over time, and the leveling effect observed exactly two years after the event supports the attribution of this decline to the Swiss Franc Stabilization and the subsequent outflow of nursing staff from German hospitals.

Figure 8: Effect on aggregate life expectancy

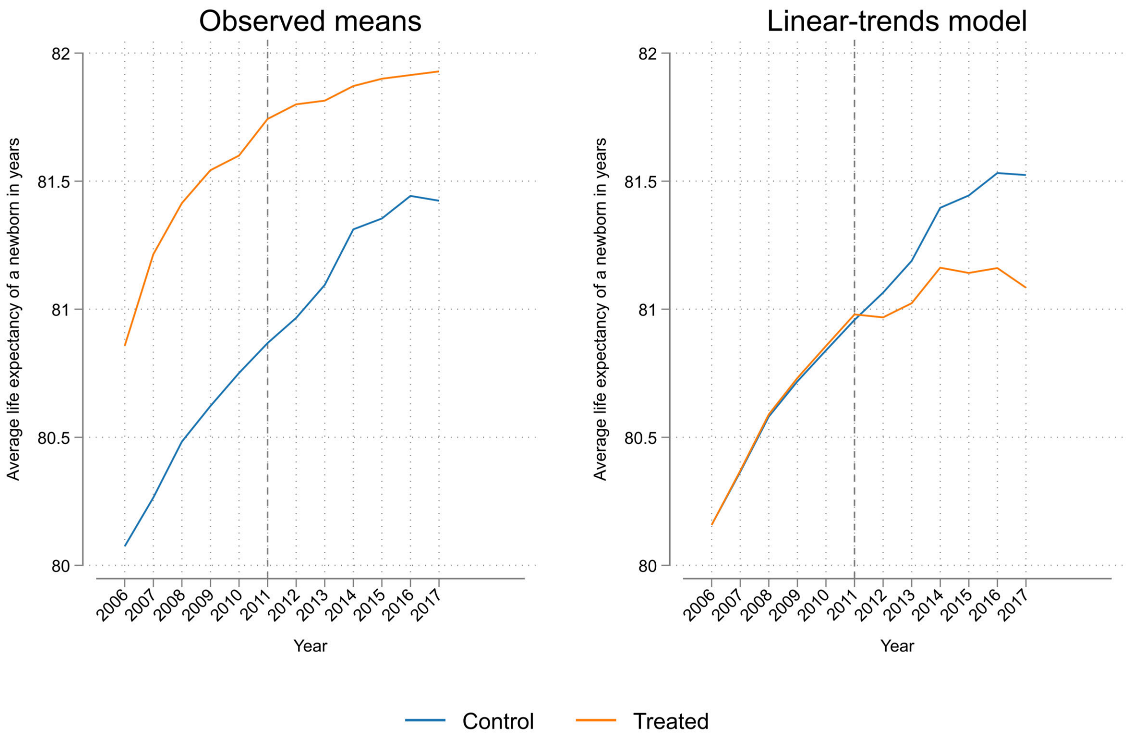
(a) Life expectancy



(b) Remaining life expectancy



(c) Life expectancy in means



Notes: This figure shows the effect of the Swiss Franc Stabilization (SFS) in 2011 on the aggregate life expectancy (for newborns) and the remaining life expectancy (for individuals age 60). Sub-figures 8a and 8b display the multi-period difference-in-differences estimates obtained from Equation 1. Vertical bars indicate 95% confidence intervals based on robust standard errors clustered at the county level. Sub-figure 8c shows the life expectancy (for newborns) in raw means (left panel) and after accounting for linear trends (right panel) for treated and matched control counties. The sample contains counties in the border region (treatment group) and matched counties further inland. The matching procedure is explained in detail in Section 4.

This reduction in life expectancy is quite sizeable, given a standard deviation of 0.94 years and an interquartile range (IQR) of 1.2 years. Looking at the raw means in Figure 8c, a clear divergence in life expectancy trends starting in 2012 becomes visible. While the matched control counties continue to experience an upward trend in life expectancy, consistent with global trends (OECD, 2017), the treated border counties see a stagnation in life expectancy from 2012 onwards. This means that the gap in life expectancy is widening over time which becomes particularly evident when accounting for linear trends in the right panel of Figure 8c. Additionally, Figure 8b highlights that especially older individuals contribute to the decreasing life expectancy. The reduction of around 0.22 statistical life years for individuals at age 60 constitutes nearly two-thirds of the total decline in life expectancy.

Table 2: Effect on aggregate mortality by age groups

	25 − 49	50 − 64	65 − 74	75+
Post × Treatment	3.23	13.80**	49.44**	171.26***
	(2.12)	(6.75)	(22.26)	(55.20)
Mean of Y	120.99	578.09	1789.80	7201.36
Std. Dev. of Y	26.87	103.66	266.35	848.48
Observations	1320	1340	1340	1340

Notes: This table shows the effect of the Swiss Franc Stabilization (SFS) in 2011 on aggregate mortality at the county level, separately across age groups. For each age group, mortality is defined as the number of death cases divided by the age group-specific population and normalized to per 100,000 inhabitants. Additionally, it is converted into a three-year rolling average to better match the concept of life expectancy. Displayed coefficients reflect difference-in-differences estimates obtained from Equation 2. The standard deviation of the estimates displayed in parenthesis is based on robust standard errors clustered at the county level. Stars refer to the 1% *, 5% **, and 10% *** significance level. The mean and standard deviation of the outcome variable Y refers to the year 2011. The sample contains counties in the border region (treatment group) and matched counties further inland. The matching procedure is explained in detail in Section 4.

The effect on mortality by age group. To better see if the negative health effects indeed concentrate among the elderly, I consider aggregate mortality separately by age group. As expected, given the significant contribution of older individuals to the declining life expectancy at the border, I see a substantial increase in mortality especially among the elderly (Table 2).[28] For individuals aged 75 and older, mortality increases by approximately 171 cases per 100,000 inhabitants. While this effect is substantially smaller for younger age groups in absolute terms (between 3.2 and 49.4 additional death cases per 100,000 inhabitants), the relative increase in mortality remains comparable. Across all

[28]For reasons of confidentiality, there are several missing observations for the two age groups under 50. As these missings are considerably more frequent among the age group of under 25-year-olds, I omit the results due to potential biases.

age groups, the rise in mortality ranges from 2.38% to 2.76%.

Effect heterogeneity across patient types. I now explore why older individuals are adversely affected by labor scarcity in hospitals and test whether the increase in aggregate mortality among the elderly is mirrored in hospitals. To do so, I revisit the changes in hospital service provision to see if hospitals begin to prioritize patients according to their needs when resources are scarce, i.e. engage in triage (Jenkins, 2024).[29] To assess whether German hospitals incorporate the needs of patients when facing labor scarcity, I classify diagnoses using an urgency score derived from (Krämer et al., 2019). Column 1 of Table 3 shows that hospitals do attempt to allocate limited resources towards urgent cases, as the reduction in the probability of receiving surgery is 1.56%-points for them, compared to 4.6%-points overall. However, hospitals are not able to triage to the extent that urgent cases, i.e., patients who benefit most from hospital care, see no change in care intensity. This pattern holds consistently across all age groups (columns 2 – 6 of Table 3). After controlling for patient characteristics, low-urgency cases see a fairly uniform reduction in the probability of receiving surgery, ranging from 3.6 to 5.2%-points across age groups. For urgent cases, this reduction is between 2.7 and 3.2%-points less. Thus, while hospitals consider the urgency of patients in resource allocation, they do not fully compensate for the shortage of nursing staff by prioritizing urgent cases to the extent potentially necessary. This may be due to the unpredictable nature of emergency case inflow or due to the care mandates, which prevent hospitals from reducing output at the extensive margin, i.e., treating fewer patients. When examining mortality across age groups and looking at heterogeneity regarding the urgency of patients' diagnoses, an interesting pattern emerges: while younger patients, even those with more urgent diagnoses, appear to compensate for the reduced care in the short run, older individuals with lower levels of innate health do not. Table 4 shows that patients aged 75 and older experience an increase in the probability of dying of 0.13%-points – and three-fold more so when requiring urgent treatment (+0.41%-points). However, this does not imply that younger individuals are unaffected by reduced care. Firstly, the long-term effects may manifest in the long run through an increased prevalence of chronic conditions, which I am not able to capture. Therefore, the small and statistically insignificant effect observed for younger patients may well represent a lower bound of the health effects of labor scarcity. Secondly, emergencies, i.e., where nurses are needed most, are less common for younger individuals; therefore, looking at all cases of an age group in aggregate might mask substantial heterogeneity. To get a more nuanced picture, I look at diagnoses that are also prevalent among and dangerous for younger patients, namely heart attacks and sepsis. Appendix Table A.10 shows that while the rate of hospital admissions due to heart attacks remains unchanged,

[29]The German General Equal Treatment Act (Allgemeines Gleichbehandlungsgesetz) prohibits hospitals from discriminating against patients based on individual characteristics, such as age, nationality, or gender, beyond the medical needs of patients, i.e., the urgency of the diagnosis.

patients admitted to border hospitals facing labor scarcity are 1.56%-points more likely to die from a heart attack.[30] This increase is both statistically and economically significant, given the average mortality rate of 8.8% in 2011. A similar pattern is observed for sepsis, an overreaction of the immune system to infections, which can lead to organ failure and is one of the leading causes of death worldwide (Rudd et al., 2020). Sepsis is also a costly condition, with estimated hospital-wide costs of around $32,000 per case, and it is common across all age groups, particularly among those with weakened immune systems, such as newborns, the elderly, and individuals with chronic illnesses (Arefian et al., 2017). As a frequent complication during hospitalization, sepsis has a prevalence of approximately 15 patients per 1,000 hospitalizations (WHO, 2024) and serves as a common indicator of care quality (Winter et al., 2023). As with heart attacks, in cases of sepsis, mortality increases significantly by 2.35%-points although the occurrence remains similar (Table A.11 in Appendix A). Additionally, patients with sepsis are less likely to receive surgery and see a reduction in the length of stay.

Table 3: Effect on patients' probability of surgery across age groups

	Overall	−24	25 − 49	50 − 64	65 − 74	75+
Post × Treatment	-4.60**	-3.57**	-5.13*	-4.60**	-5.20***	-4.46**
	(1.99)	(1.57)	(2.59)	(1.95)	(1.94)	(1.89)
Post × Treatment × Urgent	3.04***	2.69***	3.23**	2.91***	2.93***	2.67***
	(0.85)	(0.86)	(1.54)	(0.87)	(0.97)	(0.78)
Mean of Y	31.41	21.74	37.46	36.54	34.72	25.87
Std. Dev. of Y	46.41	41.25	48.40	48.16	47.61	43.79
Observations	25145786	3546715	4865729	5273569	4660874	6798807

Notes: This table shows the effect of the Swiss Franc Stabilization (SFS) in 2011 on patients' probability of surgery at the case level, overall (column 1) and separately across age groups (columns 2 - 6). Displayed coefficients reflect difference-in-differences estimates obtained from Equation 2 but additionally interacted with an indicator variable equaling one if a case has an urgency score above 0.5, i.e. is classified as an urgent case according to Krämer et al. (2019). Case-level controls are female, age bin, and 3-digit ICD-10 diagnosis code fixed effects. Also all lower-order interaction terms between $I(post)$, $I(treatment)$, and $I(urgent)$ are included. The standard deviation of the estimates displayed in parenthesis is based on robust standard errors clustered at the county level. Stars refer to the 1% *, 5% **, and 10% *** significance level. The mean and standard deviation of the outcome variable Y refers to the year 2011. The sample consists of all inpatient cases treated in continuously operating hospitals in the border region (treatment group) and in hospitals in matched counties further inland (control group). The matching procedure is explained in detail in Section 4.

[30] In the US in 2020, the prevalence of cardiovascular diseases is with 6.3% of adults very prevalent and ranges from 0.9% among adults aged 18–44 to 5.9% among those aged 45–64, and 18.2% among those aged 65 and older (National Center for Health Statistics, 2022).

Table 4: Effect on patients' mortality across age groups

	-24	$25-49$	$50-64$	$65-74$	75+
Post × Treatment	0.00	-0.00	0.08	0.06	0.13*
	(0.01)	(0.02)	(0.06)	(0.06)	(0.07)
Post × Treatment × Urgent	-0.02	0.01	-0.08	0.01	0.28**
	(0.02)	(0.04)	(0.10)	(0.10)	(0.13)
Mean of Y	0.16	0.34	1.43	2.48	5.28
Std. Dev. of Y	4.02	5.79	11.88	15.55	22.36
Observations	3546715	4865729	5273569	4660874	6798807

Notes: This table shows the effect of the Swiss Franc Stabilization (SFS) in 2011 on patients' probability of dying at the case level separately across age groups (columns 2 - 6). Displayed coefficients reflect difference-in-differences estimates obtained from Equation 2 but additionally interacted with an indicator variable equaling one if a case has an urgency score above 0.5, i.e. is classified as an urgent case according to Krämer et al. (2019). Case-level controls are female, age bin, and 3-digit ICD-10 diagnosis code fixed effects. Also all lower-order interaction terms between $I(post)$, $I(treatment)$, and $I(urgent)$ are included. The standard deviation of the estimates displayed in parenthesis is based on robust standard errors clustered at the county level. Stars refer to the 1% *, 5% **, and 10% *** significance level. The mean and standard deviation of the outcome variable Y refers to the year 2011. The sample consists of all inpatient cases treated in continuously operating hospitals in the border region (treatment group) and in hospitals in matched counties further inland (control group). The matching procedure is explained in detail in Section 4.

Robustness. To ensure that the observed health effects are truly driven by the shortage of nursing staff in hospitals, I present several robustness checks.

One alternative explanation for the increase in patient mortality could stem from changes in healthcare demand trough adjustments by both patients in hospitals. As discussed in Section 2, hospitals face strict care mandates that limit their ability to adjust output at the extensive margin, i.e., by rejecting patients. However, hospitals seem to experience stable healthcare demand reflected by the absence of significant changes in the number of patients treated (Figure 6a) as well as the composition of patients regarding their diagnosis (Tables B.12 to B.15 in Appendix B) and their demographics (Table B.16 in Appendix B).[31] Moreover, there is no evidence of differential changes in regional-level demographic characteristics between border and control counties, including population size, age distribution, dependency rates, and births (columns 1 – 4 in Appendix Table B.17). To investigate if patients responded to a perceived decline in care quality in border hos-

[31] The only statistically significant change in patient demographics is related to gender, but the effect is economically negligible. No significant changes are detected for the share of patients aged 75 or older, those with emergency diagnoses, or in the urgency of their diagnoses. Similarly, there are no notable shifts in the prevalence of diagnoses, except for a 0.25%-point increase in endocrine and metabolic diseases.

pitals by seeking treatment elsewhere, I look at the share of patients treated in a hospital in the county they reside in. Yet, this does not appear to be the case as Figure A.4d in Appendix A suggests. While cross-border commuting has increased, particularly among Germans in healthcare occupations (Figure 1), there is no economic incentive for a corresponding response from Swiss workers, as wages in Germany are overall substantially lower and further decreasing in relative terms. However, Swiss residents could make use of the increased purchasing power in Germany by consuming more in Germany. This could raise demand either directly through the substitution of Swiss hospital care with relatively cheaper German hospital care or indirectly by raising demand for hospital care through a rise in (car) accidents through increased "shopping tourism." Again, the stable share of inpatient cases being treated in the county of residence (see Figure A.4d in Appendix A) suggests that the former does not seem to be of relevance. Columns 5 – 6 in Appendix Table B.17 on the other hand show that while the number of road casualties remains unchanged, road fatalities increase by 0.95 cases per year, representing a 16% rise. This increase in road fatalities could be an outcome of nursing scarcity in hospitals as serious car accidents likely end up as emergency cases in hospitals. Finally, given that the largest health effects are observed for emergency diagnoses such as heart attacks and sepsis — conditions for which patients are unlikely to choose their hospital and for which hospitals cannot refuse care — an increase in selectivity by patients does not seem to explain the observed increase in mortality rates in hospitals near the border.

Although the Swiss Franc Stabilization primarily impacted the Swiss economy —- and even to a limited extent (see, for instance, Kaiser and Siegenthaler, 2016; Flückiger et al., 2016) —- the German border region may still be impacted by economic spillovers, either due to the reduced demand for German workers in the flagging Swiss export industry or the increased Swiss consumption in Germany. However, Table B.19 in Appendix B shows that, across a wide range of indicators, the economic conditions in the German border region did not diverge significantly from those in the control counties as key measures of economic performance, including GDP per capita and labor market outcomes such as unemployment and earnings, remained stable. At the same time, there was a statistically significant but economically small increase in public service employment, but no change in the public debt level, indicating limited economic effects of the Swiss Franc Stabilization on the border region.

Another potential confounding factor is the increase in hospital mortality due to differential changes in healthcare supply outside hospitals. As highlighted in Section 2, registered nurses are crucial for hospital care and are not easily substitutable by other nursing occupations, such as nursing assistants. However, other healthcare professionals outside hospitals are also essential for maintaining a functioning healthcare system. For the elderly – the group for which the largest effects are observed —- the negative health effects could stem from reduced staffing in nursing homes. Table B.18 in Appendix B indicates this is not the case, as staffing levels for both residential and ambulatory nursing care remained stable. As in many other developed countries, general practitioners (GPs) play a critical role in the German healthcare system, offering essential services such as consultations, screenings, treatment of chronic conditions, and hospital referrals (Blümel et al., 2020). In 2013, the Health Care Structure Act adversely affected the availability of GPs in the border region by restricting the opening of new practices. However, I can directly control for the policy's concurring effect by controlling for the number of GPs at the county level when examining the effect of the Swiss Franc Stabilization on aggregate health statistics. Figures B.5a-B.5f show that the results remain largely unchanged, both for life expectancy and mortality across age groups. Lastly, due to its rurality, the treated region might be more exposed to hospital closures compared to the German average. Additional to matching treated rural counties to similarly rural control counties and restricting the sample to continuously operating hospitals throughout the main analysis at the hospital and case level, I analyse the availability of hospital bed per capita in column 4 in Table B.18 in Appendix B and find no divergence between the treatment and control area.

Sensitivity. Alongside these robustness checks, I conduct several sensitivity analyses to further validate the results.

Throughout the hospital-level analysis, I weight observations based on the number of beds at baseline. This approach accounts for imbalances between the treatment and control group as hospitals in the border region are, on average, smaller than those in the control counties (see Appendix Table A.1). To ensure that the findings are not dependent on the specific weighting method, I re-run the main analysis using alternative weighting schemes, including the number of occupancy days, the number of inpatient cases, and an unweighted model. The results, presented in Table B.20 in Appendix B, indicate that while the coefficients differ in absolute terms between the unweighted and weighted settings, they remain fairly consistent when expressed relative to the (weighted) baseline mean, ranging from 9.1 to 12%. Moreover, the coefficients for the reduction in registered nurses due to the event are remarkably stable across different weighting methods, ranging between 47.2 and 49.3 nurses (equivalent to 11.3 to 12% relative to the baseline mean).

To verify that the results are not sensitive to the matching procedure or the assignment of counties to the treatment group based on commuting patterns, I reassign counties using regional administrative units. Specifically, I compare the outcomes of counties within the NUTS2 government district (Regierungsbezirk) of Freiburg to all other counties in the two southernmost federal states of Germany, Baden-Württemberg and Bavaria.[32] Appendix

[32]These two states have a combined population of around 25 million and are well-suited for comparison given their similar economic and organizational structures. "Regierungsbezirke" are regional administrative units functioning between the federal state and county levels, corresponding to the NUTS2 classification.

Figures B.6a-B.6f illustrate that the coefficients from this approach are remarkably similar to those derived from the matching procedure. If anything, the mortality effects are even slightly larger, further reinforcing the robustness of the main findings. This is not surprising as firstly, the government district of Freiburg entirely includes the border region – with three counties in addition – and over half of the matched control counties lie within the states of Baden-Württemberg and Bavaria, confirming that the states are comparable regarding their economic and demographic structure. Thus, the results remain robust across a wide range of sensitivity and robustness checks, confirming the validity of the finding that labor shortages in hospitals have severe consequences for both patient and population health.

6 Conclusion

This paper explores the effects of nursing scarcity on healthcare service provision and patient health outcomes in hospitals, using the persistent appreciation of the Swiss franc in 2011 as an exogenous shock. I investigate how cross-country wage differences prompted German registered nurses to commute to Switzerland, facilitated by low legal barriers and high demand in Switzerland. In turn, German hospitals near the border experienced nursing shortages as they were unable to retain staff by adjusting wages due to collective bargaining agreements and fixed case-based reimbursement rates. By using rich administrative data covering the full population of inpatient cases in all German hospitals over a time span of 12 years in a matched multi-period difference-in-differences design, I am able to examine how hospitals adapt to a negative labor shock and its impact on patient care and health outcomes.

From 2011 onwards, the number of new German healthcare cross-border commuters increased by 46% resulting in excess demand for nurses, indicated by a strong increase in open vacancies of 62%. German hospitals near the Swiss border experienced an average decline of 12% in nursing staff, and a 12.5% reduction in registered nurses, with no notable changes in other occupational groups. Hospitals, facing limited flexibility in output adjustments at the extensive margin due to care mandates, saw a corresponding 10% decrease in the nurse-to-patient ratio and a 12% decline in the likelihood of patients receiving surgery conditional on their medical needs. I find that hospitals increasingly begin to prioritize patients according to their medical needs and especially reduce surgeries for non-urgent cases, i.e. perform triage (Jenkins, 2024). Still, also vulnerable patients receive less care, leading to the most severe health impacts being concentrated among older patients and emergency cases. Individuals above 75 with urgent diagnoses see an increase in mortality of 0.41%-points, while patients with sepsis and heart attacks even an increase of 2.35%-point and 1.56%-points respectively. These individual-level health effects also translate into aggregate health statistics: regional mortality rates increase by

2.38% to 2.76% across different age groups, and life expectancy falls by 0.35 statistical life years, or one-third of the standard deviation. While life expectancy continued to rise throughout Germany, the border region experienced stagnation from 2012 onward. This suggests that labor scarcity may not only impede economic growth – as pointed out by Jones (2022) – but also the global rise in life expectancy.

This paper contributes to the literature on the economic effects of labor scarcity, particularly in healthcare, by quantifying the health impact of nurse shortages. The distinct setting allows me to present two highly policy-relevant figures: Firstly, the marginal return to one registered nurse in hospitals is equal to a reduction of 0.12 death cases per year and an increase of 0.01 statistical life years (SLYs) in aggregate. This reduction in SLYs refers to an average private willingness to pay per inhabitant in the border regions of 1,585 euros per year and highlights the decisive role registered nurses play in healthcare.[33] Secondly, the average cost per life saved in a hospital amounts to 192,000 euros but decreases substantially with treatment urgency, where the returns to nursing are higher.[34]

While this study centers on mortality, additional quality-of-care metrics, particularly for younger and healthier patients, are crucial to fully understanding the broader impact of labor scarcity in hospitals. Although no significant mortality effects are observable for these groups, it is plausible that they experience reduced care quality and adverse long-term health outcomes. Future research should, therefore, focus on examining a wider range of healthcare quality indicators to provide a more comprehensive assessment of the costs of nursing shortages in hospitals. Moreover, the working conditions of the remaining nurses demand further attention. On the one hand, they may have experienced an increase in bargaining power, particularly over non-pecuniary aspects such as working conditions and co-determination. On the other hand, labor scarcity likely increased their workload, unpaid overtime, and stress, potentially affecting their health and well-being. Understanding these dynamics is essential for designing policies to mitigate not only the negative effects of labor scarcity for patients but also for the remaining workforce. Thirdly, while this study highlights that exchange rate changes lead to a brain drain in German hospitals, the corresponding gain for Swiss healthcare opens new avenues for research. Exploring how Swiss hospitals adapt to the sudden inflow of foreign labor and identifying the factors determining their attractiveness offers valuable insights for current policies aiming to attract foreign nurses. Future studies could also examine whether the Swiss population benefits from increased access to foreign nurses in terms of improved health outcomes. Also, given the prevalence of cross-border labor markets in Europe and

[33]Schlander et al. (2018) present 158,500 euros as an estimate for the 2014 value of a statistical life in Europe.

[34]I base this number on the increase in the cross-border gross wage difference by 17,200 euros (51,85%), amounting to 23,100 euros when accounting for employer contributions and the reduction in death cases of 0.12 per nurse. This finding relates well to recent cross-country estimates on the cost-effectiveness of nurse staffing presented in Griffiths et al. (2023).

globally – such as between the US and Canada or Mexico – this case presents a unique opportunity to simultaneously investigate the implications of changes to wage differentials for both sending and receiving countries.

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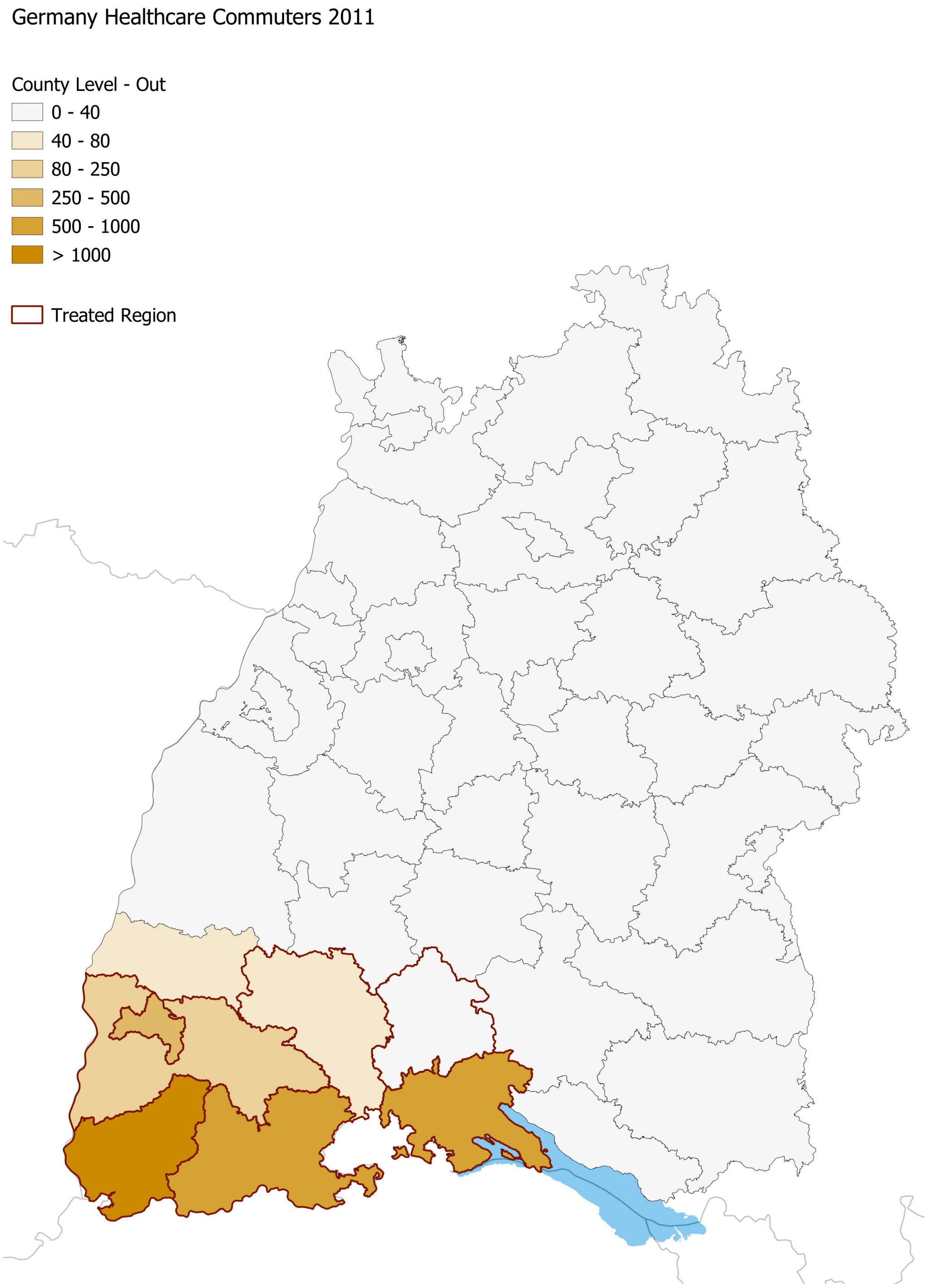
Appendix

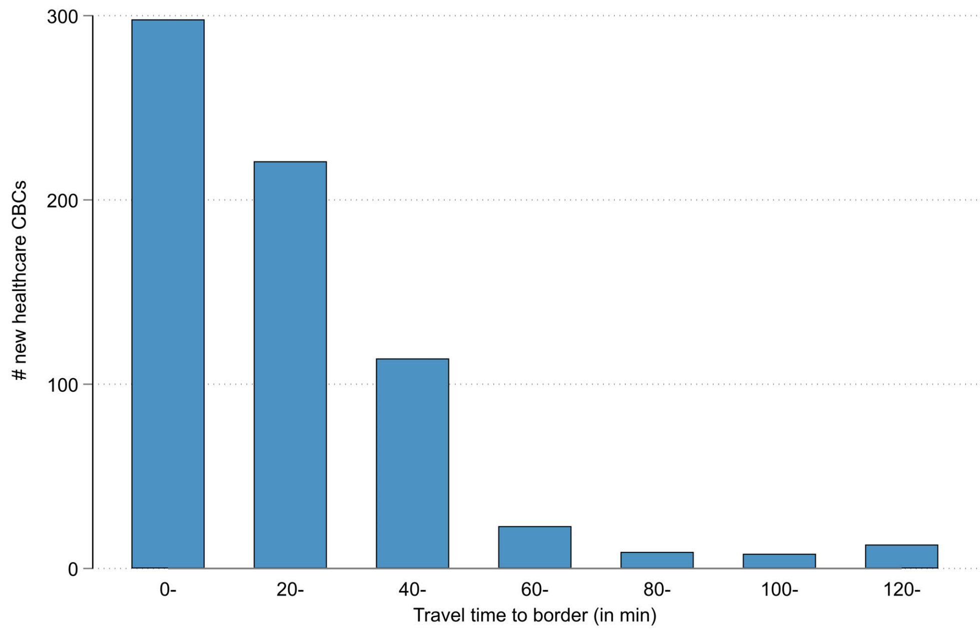
A Additional Tables and Figures

Figure A.1: County-level cross-border commuters in the healthcare sector



Notes: This map shows the number of active German cross-border commuters (CBCs) working in the Swiss healthcare sector at the county level for the entire state of Baden-Württemberg in 2011. "Treated Region" refers to counties in the border region that are assigned to the treatment group based on travel distance and commuting patterns prior to the event. The assignment process is described in detail in Section 4. Lake Constance, a natural obstacle to mobility between Germany and Switzerland, is indicated in light blue.

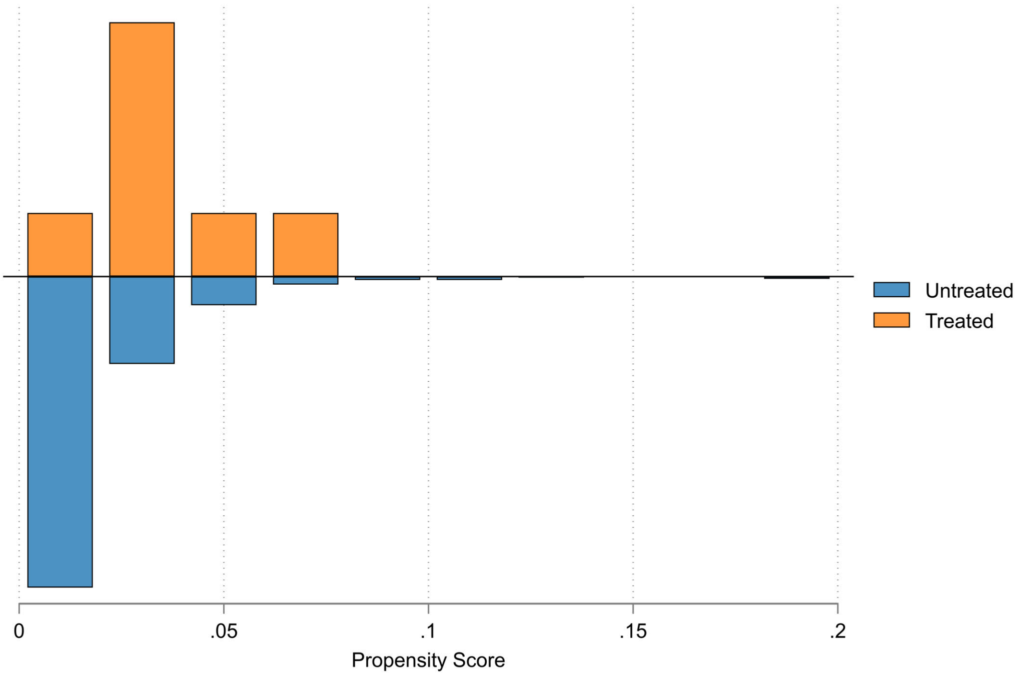
Figure A.2: Travel time to the border for new cross-border commuters in the healthcare sector



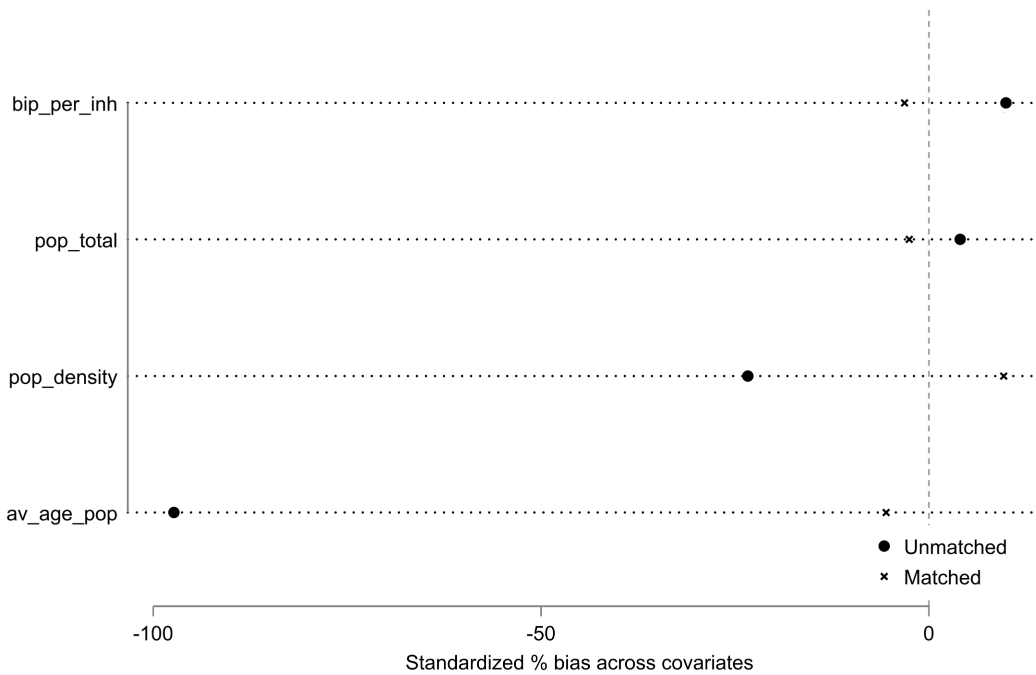
Notes: This figure shows the distribution of a how far inland German cross-border commuters (CBCs) newly starting to work in the Swiss healthcare sector in 2012 live. The x-axis displays the minutes that it takes by car to reach the border crossing with the shortest travel among the four metrically closest border crossings. Data on border crossings is obtained from the Online Appendix of Beerli et al. (2021); cross-border commuter data is obtained from the Swiss Cross-Border Commuter Statistic, described in detail in Section 3.

Figure A.3: Matching procedure

(a) Propensity score distribution



(b) Covariate bias



Notes: Figure A.3a shows the distribution of the propensity score between treated and untreated counties. The covariates used for the calculation of the propensity score are population size (*pop_ total*), population density (*pop_ density*), GDP per inhabitant (*bip_ per_ inh*), and the average age of the population (*av_ age_ pop*) in 2011. Figure A.3b shows the bias of these covariates of treated counties relative to the untreated counties, either with or without matching. Data is obtained from the INKAR Database and the Regional Statistics, described in detail in Section 3. For more details regarding the matching procedure see Section 4.

Table A.1: Summary statistics of hospitals in 2011

	Germany	Treatment	Control
Beds (annual average)	253.80	181.47	244.35
	(293.56)	(285.32)	(266.07)
Occupancy days	71626.07	50794.09	68678.78
	(87195.40)	(84094.23)	(77978.68)
Patients	9270.43	6568.72	9049.22
	(11824.31)	(11825.91)	(10529.31)
Outpatient operations	942.40	673.40	1012.36
	(1408.66)	(1462.10)	(1425.36)
Women delivered	324.67	254.32	347.53
	(578.24)	(494.58)	(488.98)
FTE doctors	70.88	59.75	72.18
	(134.44)	(167.98)	(136.50)
FTE nursing staff	158.19	123.28	154.04
	(217.79)	(257.81)	(205.69)
Doctors	78.61	65.87	80.04
	(145.06)	(178.09)	(144.69)
Nursing staff	209.73	170.79	213.84
	(280.93)	(335.13)	(264.92)
Total staff costs	25.22	21.52	26.42
	(44.18)	(55.50)	(46.99)
Total hospital costs	41.66	33.53	42.80
	(75.09)	(85.50)	(77.40)
Continuously existing	83.67	85.11	84.35
	(36.97)	(35.99)	(36.41)
Observations	1978	47	230

Notes: This table shows the means and standard deviations across multiple variables in 2011, separately for all hospitals in Germany, in treated counties, and in control counties. The assignment to the treatment and control group is described in detail in Section 4. FTE refers to full-time equivalent. Costs are in millions of euros. "Continuously existing" refers to the share of hospitals that continuously report between 2006 and 2017. Data is obtained from the German Hospital Statistic, described in detail in Section 3. Hospitals are assigned to counties based on the place of residence of the majority of inpatient cases treated (see Section 3 for details).

Table A.2: Summary statistics of patients in 2011

	Germany	Treatment	Control
Male	47.24	48.21	47.14
	(49.92)	(49.97)	(49.92)
Mortality	2.14	1.86	2.13
	(14.47)	(13.49)	(14.43)
Surgery	29.72	35.10	30.58
	(45.70)	(47.73)	(46.07)
Days in care	7.70	7.74	7.48
	(11.18)	(12.46)	(11.11)
Age	54.10	53.04	53.46
	(25.07)	(25.66)	(25.44)
Elderly	24.24	23.56	24.29
	(42.85)	(42.44)	(42.88)
Urgency	42.64	43.13	44.08
	(31.57)	(31.49)	(31.69)
Emergency case	41.26	42.06	43.30
	(49.23)	(49.37)	(49.55)
Same county	64.91	58.00	65.51
	(47.73)	(49.36)	(47.53)
Continuously existing	93.48	91.82	92.59
	(24.69)	(27.40)	(26.20)
Observations	18748504	318285	2134606

Notes: This table shows the means and standard deviations across multiple variables in 2011, separately for all patients treated in Germany, treated counties, and control counties. The assignment to the treatment and control group is described in detail in Section 4. "Mortality"/"Surgery" refers to the likelihood of death/surgery performance (in %). "Elderly", "Emergency case", and "Male" refer to the shares of individuals above 74, having an urgency score above 50, and being male. Data is obtained from the German Patient Statistic, described in detail in Section 3. The urgency score is obtained from Krämer et al. (2019). It is a numerical value between 0 and 100, reflecting the degree to which a patient needs immediate treatment based on the patient's diagnosis. "Continuously existing" refers to the share of patients treated in hospitals that continuously report between 2006 and 2017. The assignment of patients to counties is based on the location of the hospitals they are treated in (see Section 3 for details).

Table A.3: Staffing effect among nursing occupations

	Nursing staff	Registered	Assistant
Post × Treatment	-46.19	-48.70**	0.23
	(35.25)	(23.06)	(2.94)
Mean of Y	512.34	404.24	16.71
Std. Dev. of Y	481.66	372.83	22.31
Observations	2789	2789	2789

Notes: This table shows the effect of the Swiss Franc Stabilization (SFS) in 2011 on the number of staff across nursing occupations in hospitals. Nursing staff refers to all nursing occupations, while column 2 (3) refers to registered (assistant) nurses. Displayed coefficients reflect difference-in-differences estimates obtained from Equation 2. The standard deviation of the estimates displayed in parenthesis is based on robust standard errors clustered at the county level. Stars refer to the 1% *, 5% **, and 10% *** significance level. The mean and standard deviation of the outcome variable Y refers to the year 2011. The sample of hospitals contains continuously operating hospitals in the border region (treatment group) and hospitals in matched counties further inland (control group). The matching procedure is explained in detail in Section 4. Observations are weighted using the number of beds in 2011 at the hospital level due to imbalances regarding hospital size between the treatment and control group.

Table A.4: Staffing effect among other healthcare occupations

	Doctors	Med. techn.	Functional	Surgical	Midwives	Ambulance
Post × Treatment	6.52	29.17	24.49	3.34	-0.92	-3.85*
	(15.61)	(33.97)	(20.25)	(4.99)	(0.70)	(2.06)
Mean of Y	236.00	343.41	144.11	42.45	10.33	3.25
Std. Dev. of Y	295.09	561.28	141.09	45.67	10.56	8.49
Observations	2801	2789	2789	2789	2789	2789

Notes: This table shows the effect of the Swiss Franc Stabilization (SFS) in 2011 on the number of staff across occupation groups in hospitals. Displayed coefficients reflect difference-in-differences estimates obtained from Equation 2. The standard deviation of the estimates displayed in parenthesis is based on robust standard errors clustered at the county level. Stars refer to the 1% *, 5% **, and 10% *** significance level. The mean and standard deviation of the outcome variable Y refers to the year 2011. The sample of hospitals contains continuously operating hospitals in the border region (treatment group) and hospitals in matched counties further inland (control group). The matching procedure is explained in detail in Section 4. Observations are weighted using the number of beds in 2011 at the hospital level due to imbalances regarding hospital size between the treatment and control group.

Table A.5: Effect on the number of vacancies among healthcare occupations

	Nursing	Doctors	Dentist	Veterinarian	Laboratory	Pharmacists
Post × Treatment	9.54**	1.85*	0.15	-0.04	0.32	0.40
	(4.74)	(0.93)	(0.17)	(0.16)	(0.38)	(0.55)
Mean of Y	15.41	3.18	0.33	0.24	0.68	1.35
Std. Dev. of Y	12.92	3.59	0.73	0.47	2.35	1.74
Observations	726	726	725	726	726	726

Notes: This table shows the effect of the Swiss Franc Stabilization (SFS) in 2011 on the number of reported open vacancies at the county level as of June 15 every year across healthcare occupation groups. Occupations refer to the Kldb 2010 4-digit occupations 8130, 8140, 8147, 8150, 8121, and 8180. Displayed coefficients reflect difference-in-differences estimates obtained from Equation 2. The standard deviation of the estimates displayed in parenthesis is based on robust standard errors clustered at the county level. Stars refer to the 1% *, 5% **, and 10% *** significance level. The mean and standard deviation of the outcome variable Y refers to the year 2011. The sample contains counties in the border region (treatment group) and matched counties further inland. The matching procedure is explained in detail in Section 4.

Table A.6: Effect on the economic occupational composition of nurses

	Wage	Earnings	Days employed	Tenure (occ)	Tenure (est)	College share
Post × Treatment	0.55	89.01	-0.43	-130.66	-170.31	0.27
	(1.22)	(366.57)	(0.43)	(98.31)	(115.75)	(0.68)
Mean of Y	77.97	28145.39	350.80	2917.69	3426.04	16.91
Std. Dev. of Y	5.05	1793.86	2.01	537.50	714.11	7.39
Observations	924	924	924	924	924	924

Notes: This table shows the effect of the Swiss Franc Stabilization (SFS) in 2011 on the occupational composition of nurses (Kldb 1992-occupation group 853) across economic outcomes at the county level. "Wage" refers to daily, and "Earnings" and "Days employed" to yearly averages. Tenure is measured as the number of days employed in the same occupation (column 4) or same establishment (column 5). Displayed coefficients reflect difference-in-differences estimates obtained from Equation 2. The standard deviation of the estimates displayed in parenthesis is based on robust standard errors clustered at the county level. Stars refer to the 1% *, 5% **, and 10% *** significance level. The mean and standard deviation of the outcome variable Y refers to the year 2011. The sample contains counties in the border region (treatment group) and matched counties further inland. The matching procedure is explained in detail in Section 4.

Table A.7: Effect on the demographic occupational composition of nurses and commuting

	Age	Female	Within county	Mover (county)	Mover (state)
Post × Treatment	0.03	0.12	1.52*	-0.26	-0.06
	(0.28)	(0.27)	(0.79)	(0.23)	(0.10)
Mean of Y	37.23	86.73	69.57	3.26	1.06
Std. Dev. of Y	1.31	4.01	16.06	1.53	0.81
Observations	924	924	924	924	924

Notes: This table shows the effect of the Swiss Franc Stabilization (SFS) in 2011 on the occupational composition of nurses (Kldb 1992-occupation group 853) across demographic and commuting outcomes at the county level. "Age" refers to the average age, and "Female" refers to the share of female employees. "Within county" is the share of employees commuting within the same county. "Movers" reflects the number of individuals switching residence from another county or state. Displayed coefficients reflect difference-in-differences estimates obtained from Equation 2. The standard deviation of the estimates displayed in parenthesis is based on robust standard errors clustered at the county level. Stars refer to the 1% *, 5% **, and 10% *** significance level. The mean and standard deviation of the outcome variable Y refers to the year 2011. The sample contains counties in the border region (treatment group) and matched counties further inland. The matching procedure is explained in detail in Section 4.

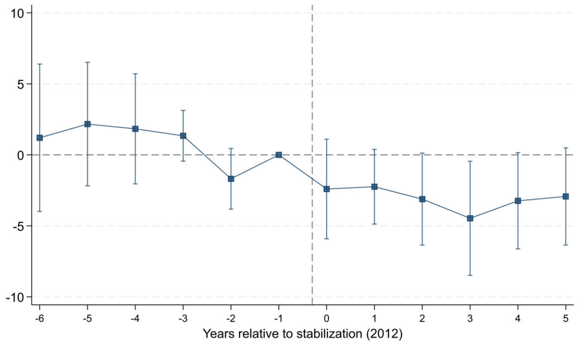
Table A.8: Effect on patients' outcomes

	Unconditional			Conditional on surgery	
	Mortality	Surgery	Length of stay	Mortality	Length of stay
Post × Treatment	0.09*	-3.85*	0.03	0.07	-0.00
	(0.04)	(1.99)	(0.10)	(0.04)	(0.15)
Mean of Y	2.07	31.41	7.58	1.19	7.51
Std. Dev. of Y	14.25	46.41	11.26	10.83	9.51
Observations	27516405	27516405	27516405	8440754	8440754

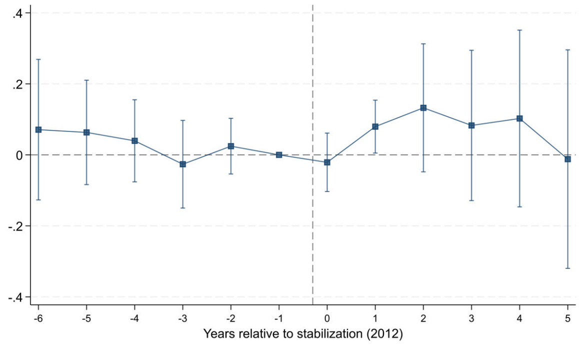
Notes: This table shows the effect of the Swiss Franc Stabilization (SFS) in 2011 on patients' outcomes at the case level, separately for all patients (columns 1 - 3) and for patients conditional on undergoing surgery (columns 4 - 5). Outcome variables are the probability of dying and of receiving surgery as well as the days in stationary hospital care. Displayed coefficients reflect difference-in-differences estimates obtained from Equation 2. Case-level controls are female, age bin, and 3-digit ICD-10 diagnosis code fixed effects. The standard deviation of the estimates displayed in parenthesis is based on robust standard errors clustered at the county level. Stars refer to the 1% *, 5% **, and 10% *** significance level. The mean and standard deviation of the outcome variable Y refers to the year 2011. The sample consists of all inpatient cases treated in continuously operating hospitals in the border region (treatment group) and in hospitals in matched counties further inland (control group). The matching procedure is explained in detail in Section 4.

Figure A.4: Effect on patients' outcomes (event study)

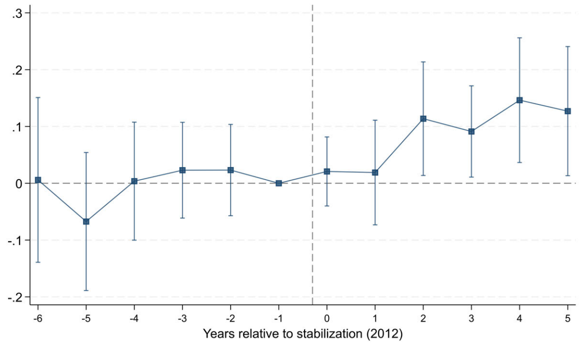
(a) Surgery



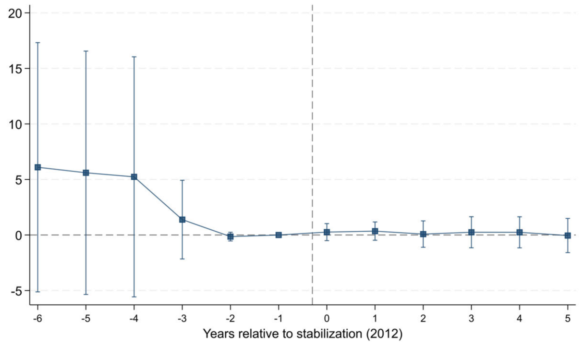
(b) Length of stay



(c) Mortality



(d) Same county



Notes: This figure shows the effect of the Swiss Franc Stabilization (SFS) in 2011 on the probability of surgery (in percent), the length of stay (in days), probability of in-hospital death (in percent), and the share of patients being treated in the county of residence. All sub-figures display the multi-period difference-in-differences estimates obtained from Equation 1. Case-level controls are female, age bin, and 3-digit ICD-10 diagnosis code fixed effects. Vertical bars indicate 95% confidence intervals based on robust standard errors clustered at the county level. The sample consists of all inpatient cases treated in continuously operating hospitals in the border region (treatment group) and in hospitals in matched counties further inland (control group). The matching procedure is explained in detail in Section 4.

Table A.9: Occurence of complications during surgical procedures

	Chirurgical (all)	Infusion	Intervention	Cardiovascular	Urogenital	Orthopedics	Internal	Other chirurgical
Post × Treatment	-0.07	-0.01	-0.02	-0.06***	0.01	-0.03	0.03	0.01
	(0.09)	(0.01)	(0.02)	(0.02)	(0.01)	(0.06)	(0.03)	(0.01)
Mean of Y	1.50	0.01	0.43	0.27	0.06	0.51	0.13	0.09
Std. Dev. of Y	12.17	1.13	6.55	5.17	2.45	7.13	3.57	3.06
Observations	27516415	27516415	27516415	27516415	27516415	27516415	27516415	27516415

Notes: This table shows the effect of the Swiss Franc Stabilization (SFS) in 2011 on the occurrence of complications experienced by patients that are related to surgical procedures. Outcome variables are patients' probability of having main diagnosis reflecting a complication related to an infusion/injection (T80), not classified interventions (T81), cardiovascular intervention (T82), urogenital intervention (T83), orthopedic intervention (T84), internal prostheses, implants or transplants (T85), other surgery-related complications (T87-88), and all mentioned complications together. Displayed coefficients reflect difference-in-differences estimates obtained from Equation 2. Case-level controls are female, age bin, and 3-digit ICD-10 diagnosis code fixed effects. The standard deviation of the estimates displayed in parenthesis is based on robust standard errors clustered at the county level. Stars refer to the 1% *, 5% **, and 10% *** significance level. The mean and standard deviation of the outcome variable Y refers to the year 2011. The sample consists of all inpatient cases treated in continuously operating hospitals in the border region (treatment group) and in hospitals in matched counties further inland (control group). The matching procedure is explained in detail in Section 4.

Table A.10: Health effects for patients with heart attack

	Heart attack	Mortality	Surgery	Length of stay
Post × Treatment	-0.02	1.56**	-5.72	0.45
	(0.18)	(0.65)	(3.73)	(0.44)
Mean of Y	1.17	8.82	16.41	8.26
Std. Dev. of Y	10.77	28.36	37.04	8.99
Observations	27516415	325447	325447	325447

Notes: This table shows the effect of the Swiss Franc Stabilization (SFS) in 2011 on patients' outcomes at the case level for patient with myocardial infarction (also known as "heart attack"). Outcome variables are the probability of being admitted to a hospital with a heart attack, of dying, and of receiving surgery as well as the days in stationary hospital care. Displayed coefficients reflect difference-in-differences estimates obtained from Equation 2. Case-level controls are female, age bin, and 3-digit ICD-10 diagnosis code fixed effects. The standard deviation of the estimates displayed in parenthesis is based on robust standard errors clustered at the county level. Stars refer to the 1% *, 5% **, and 10% *** significance level. The mean and standard deviation of the outcome variable Y refers to the year 2011. The sample consists of all inpatient cases treated in continuously operating hospitals in the border region (treatment group) and in hospitals in matched counties further inland (control group). The matching procedure is explained in detail in Section 4.

Table A.11: Health effects for patients with sepsis

	Sepsis	Mortality	Surgery	Length of stay
Post × Treatment	0.01	2.35**	-3.78**	0.78**
	(0.07)	(1.10)	(1.54)	(0.38)
Mean of Y	0.42	20.30	9.71	13.71
Std. Dev. of Y	6.45	40.22	29.61	13.26
Observations	27516415	128890	128890	128890

Notes: This table shows the effect of the Swiss Franc Stabilization (SFS) in 2011 on patients' outcomes at the case level for patient with sepsis. Outcome variables are the probability of being admitted to a hospital with sepsis, of dying, and of receiving surgery as well as the days in stationary hospital care. Displayed coefficients reflect difference-in-differences estimates obtained from Equation 2. Case-level controls are female, age bin, and 3-digit ICD-10 diagnosis code fixed effects. The standard deviation of the estimates displayed in parenthesis is based on robust standard errors clustered at the county level. Stars refer to the 1% *, 5% **, and 10% *** significance level. The mean and standard deviation of the outcome variable Y refers to the year 2011. The sample consists of all inpatient cases treated in continuously operating hospitals in the border region (treatment group) and in hospitals in matched counties further inland (control group). The matching procedure is explained in detail in Section 4.

B Additional Tables and Figures: Robustness

Table B.12: Change in case composition I (based on ICD-10-GM main chapters)

	Blood/Immune	Circulatory	Congenital	Digestive	Ear
Post × Treatment	0.01	-0.86	0.00	0.01	-0.23
	(0.02)	(0.94)	(0.00)	(0.13)	(0.20)
Mean of Y	0.67	14.33	0.00	0.67	9.84
Std. Dev. of Y	8.14	35.03	0.07	8.13	29.78
Observations	27516415	27516415	27516415	27516415	27516415

Notes: This table shows the effect of the Swiss Franc Stabilization (SFS) in 2011 on the probability of hospitalization due to patients' main diagnosis. Patients are assigned to the ICD-10-GM main chapter based on their main diagnosis. Displayed coefficients reflect difference-in-differences estimates obtained from Equation 2. Case-level controls are female and age bin fixed effects. The standard deviation of the estimates displayed in parenthesis is based on robust standard errors clustered at the county level. Stars refer to the 1% *, 5% **, and 10% *** significance level. The mean and standard deviation of the outcome variable Y refers to the year 2011. The sample consists of all inpatient cases treated in continuously operating hospitals in the border region (treatment group) and in hospitals in matched counties further inland (control group). The matching procedure is explained in detail in Section 4.

Table B.13: Change in case composition II (based on ICD-10-GM main chapters)

	Endocrine/Metabolic	Eye	Status Factors	NEC	Genitourinary
Post × Treatment	0.25**	0.13*	0.15	-0.15*	-0.25
	(0.11)	(0.06)	(0.12)	(0.09)	(0.17)
Mean of Y	0.90	2.66	1.75	3.41	4.73
Std. Dev. of Y	9.42	16.08	13.13	18.14	21.24
Observations	27516415	27516415	27516415	27516415	27516415

Notes: This table shows the effect of the Swiss Franc Stabilization (SFS) in 2011 on the probability of hospitalization due to patients' main diagnosis. Patients are assigned to the ICD-10-GM main chapter based on their main diagnosis. Displayed coefficients reflect difference-in-differences estimates obtained from Equation 2. Case-level controls are female and age bin fixed effects. The standard deviation of the estimates displayed in parenthesis is based on robust standard errors clustered at the county level. Stars refer to the 1% *, 5% **, and 10% *** significance level. The mean and standard deviation of the outcome variable Y refers to the year 2011. The sample consists of all inpatient cases treated in continuously operating hospitals in the border region (treatment group) and in hospitals in matched counties further inland (control group). The matching procedure is explained in detail in Section 4.

Table B.14: Change in case composition III (based on ICD-10-GM main chapters)

	Infectious	Injuries/Poisoning	Mental	Musculoskeletal	Neoplasms
Post × Treatment	0.07	-0.18	0.16	-0.23	-0.21
	(0.17)	(0.14)	(0.23)	(0.16)	(0.49)
Mean of Y	5.47	3.09	10.98	6.24	8.61
Std. Dev. of Y	22.74	17.30	31.27	24.18	28.04
Observations	27516415	27516415	27516415	27516415	27516415

Notes: This table shows the effect of the Swiss Franc Stabilization (SFS) in 2011 on the probability of hospitalization due to patients' main diagnosis. Patients are assigned to the ICD-10-GM main chapter based on their main diagnosis. Displayed coefficients reflect difference-in-differences estimates obtained from Equation 2. Case-level controls are female and age bin fixed effects. The standard deviation of the estimates displayed in parenthesis is based on robust standard errors clustered at the county level. Stars refer to the 1% *, 5% **, and 10% *** significance level. The mean and standard deviation of the outcome variable Y refers to the year 2011. The sample consists of all inpatient cases treated in continuously operating hospitals in the border region (treatment group) and in hospitals in matched counties further inland (control group). The matching procedure is explained in detail in Section 4.

Table B.15: Change in case composition IV (based on ICD-10-GM main chapters)

	Nervous System	Perinatal	Pregnancy/Childbirth	Respiratory	Skin
Post × Treatment	0.72**	0.32*	0.17*	0.24	-0.03
	(0.30)	(0.18)	(0.10)	(0.20)	(0.22)
Mean of Y	9.18	3.85	1.02	5.30	5.93
Std. Dev. of Y	28.87	19.24	10.05	22.40	23.62
Observations	27516415	27516415	27516415	27516415	27516415

Notes: This table shows the effect of the Swiss Franc Stabilization (SFS) in 2011 on the probability of hospitalization due to patients' main diagnosis. Patients are assigned to the ICD-10-GM main chapter based on their main diagnosis. Displayed coefficients reflect difference-in-differences estimates obtained from Equation 2. Case-level controls are female and age bin fixed effects. The standard deviation of the estimates displayed in parenthesis is based on robust standard errors clustered at the county level. Stars refer to the 1% *, 5% **, and 10% *** significance level. The mean and standard deviation of the outcome variable Y refers to the year 2011. The sample consists of all inpatient cases treated in continuously operating hospitals in the border region (treatment group) and in hospitals in matched counties further inland (control group). The matching procedure is explained in detail in Section 4.

Table B.16: Change in patient characteristics

	Male	Elderly	Urgency	Emergency case
Post × Treatment	-0.80**	-0.71	-0.33	-0.15
	(0.34)	(0.67)	(0.65)	(0.65)
Mean of Y	47.41	23.83	43.83	42.92
Std. Dev. of Y	49.93	42.60	31.64	49.50
Observations	27516415	27516415	25145786	25145786

Notes: This table shows the effect of the Swiss Franc Stabilization (SFS) in 2011 on patient characteristics. The outcome variables refer to patients' gender, whether a patient is 75 and older (elderly), the urgency score of main diagnosis, and whether a patient is classified as emergency case based on the urgency score obtained from Krämer et al. (2019). Displayed coefficients reflect difference-in-differences estimates obtained from Equation 2. There are no case level controls included. The standard deviation of the estimates displayed in parenthesis is based on robust standard errors clustered at the county level. Stars refer to the 1% *, 5% **, and 10% *** significance level. The mean and standard deviation of the outcome variable Y refers to the year 2011. The sample consists of all inpatient cases treated in continuously operating hospitals in the border region (treatment group) and in hospitals in matched counties further inland (control group). The matching procedure is explained in detail in Section 4.

Table B.17: Effect on aggregate demographic characteristics

	Population	Age	Dependency rate	Births	Road casualties	Road fatalities
Post × Treatment	0.20	-0.23	-0.26	0.03	-14.07	0.95**
	(1.29)	(0.22)	(0.31)	(0.10)	(9.05)	(0.42)
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	1876	1876	1876	1876	1867	1858

Notes: This table shows the effect of the Swiss Franc Stabilization (SFS) in 2011 on aggregate demographic characteristics 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. Displayed coefficients reflect difference-in-differences estimates obtained from Equation 2. The standard deviation of the estimates displayed in parenthesis is based on robust standard errors clustered at the county level. Stars refer to the 1% *, 5% **, and 10% *** significance level. The mean and standard deviation of the outcome variable Y refers to the year 2011. The sample contains counties in the border region (treatment group) and matched counties further inland. The matching procedure is explained in detail in Section 4.

Table B.18: Effect on healthcare supply outside hospitals

	Staff NH	Staff NS	GPs	Hospitals
Post × Treatment	-0.45	-3.05*	-6.95***	-0.18
	(0.77)	(1.55)	(1.65)	(0.35)
Mean of Y	90.00	48.80	130.63	4.67
Std. Dev. of Y	11.88	12.96	158.73	4.13
Observations	1474	1474	1474	1206

Notes: This table shows the effect of the Swiss Franc Stabilization (SFS) in 2011 on healthcare supply outside hospitals 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 healthcare supply is only available from 2009 onwards. Displayed coefficients reflect difference-in-differences estimates obtained from Equation 2. The standard deviation of the estimates displayed in parenthesis is based on robust standard errors clustered at the county level. Stars refer to the 1% *, 5% **, and 10% *** significance level. The mean and standard deviation of the outcome variable Y refers to the year 2011. The sample contains counties in the border region (treatment group) and matched counties further inland. The matching procedure is explained in detail in Section 4.

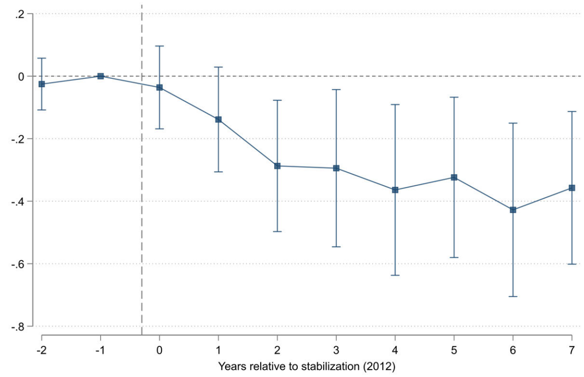
Table B.19: Effect on aggregate economic characteristics

	GDP per person	UE rate	Earnings	Public service	Public debt
Post × Treatment	-1.14	0.14	-28.58	8.46**	-29.41
	(0.88)	(0.09)	(19.66)	(3.81)	(44.29)
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	1876	1876	1876	1876	1340

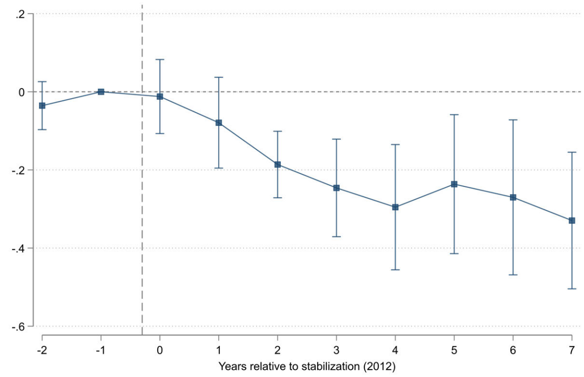
Notes: This table shows the effect of the Swiss Franc Stabilization (SFS) in 2011 on aggregate economic characteristics at the county level. Outcome variables are the GDP per inhabitant (in thousands), the unemployment rate (in percent), gross monthly earnings, the number of individuals working in municipal public service (per 10,000 inhabitants), and the municipal public debt per inhabitant. Information on municipal public debt is only available from 2010 onwards. Displayed coefficients reflect difference-in-differences estimates obtained from Equation 2. The standard deviation of the estimates displayed in parenthesis is based on robust standard errors clustered at the county level. Stars refer to the 1% *, 5% **, and 10% *** significance level. The mean and standard deviation of the outcome variable Y refers to the year 2011. The sample contains counties in the border region (treatment group) and matched counties further inland. The matching procedure is explained in detail in Section 4.

Figure B.5: Aggregate health effects when controlling for GP density

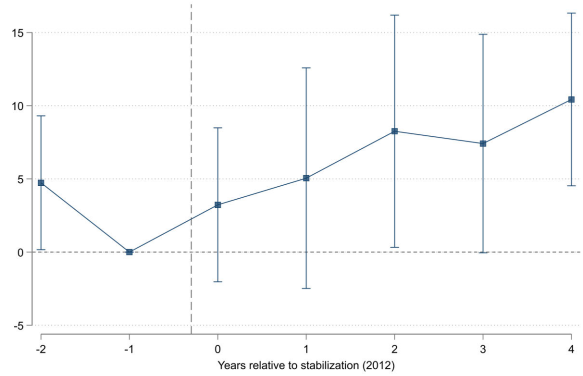
(a) Life expectancy



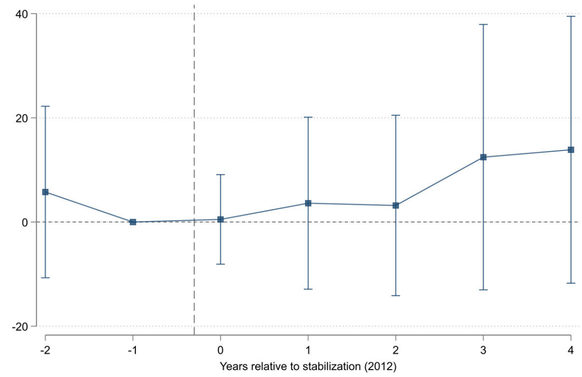
(b) Remaining life expectancy



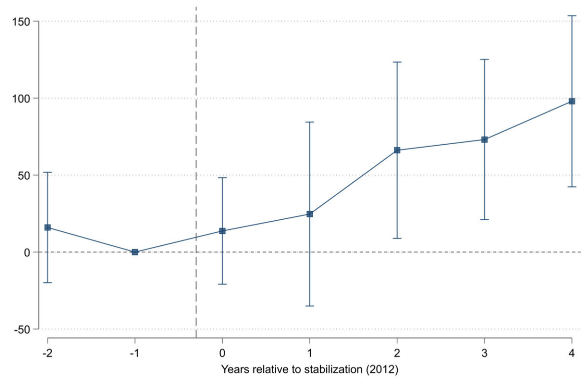
(c) Mortality (25-49)



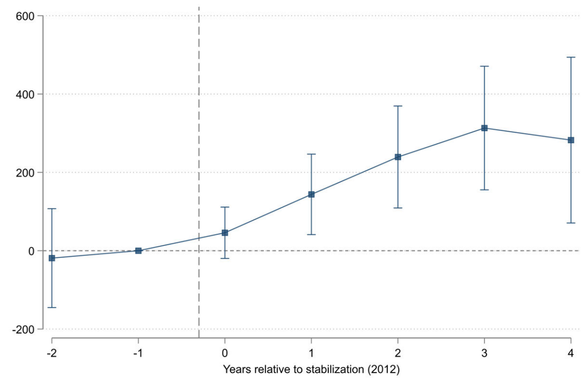
(d) Mortality (50-64)



(e) Mortality (65-74)



(f) Mortality (75+)



Notes: This figure shows the effect of the Swiss Franc Stabilization (SFS) in 2011 on the aggregate life expectancy (for newborns) and the remaining life expectancy (for individuals age 60), as well as mortality across age groups. All sub-figures display the multi-period difference-in-differences estimates obtained from Equation 1, but additionally controlling for the number of general practitioners (GPs) per capita at the county level. Information on GPs at the county level is only available from 2010 onwards and mortality only until 2016, thus restricting the period of observation. Vertical bars indicate 95% confidence intervals based on robust standard errors clustered at the county level. The sample contains counties in the border region (treatment group) and matched counties further inland. The matching procedure is explained in detail in Section 4.

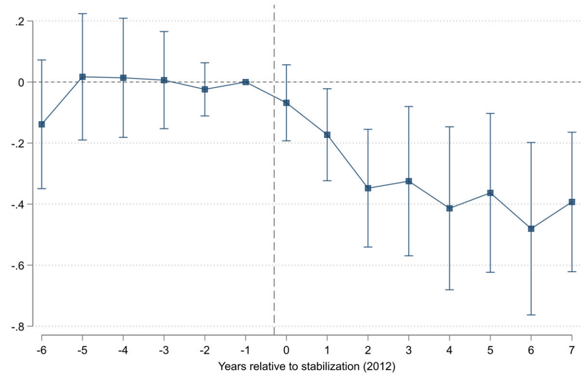
Table B.20: Effect comparison across weighting procedures

	No weight	Beds (2011)	Occ. days (2011)	Patients (2011)
Post × Treatment	-14.9762**	-48.6965**	-49.3288**	-47.1574*
	(6.980)	(21.883)	(21.749)	(25.099)
Mean of Y	164.73	404.24	416.15	417.26
Std. Dev. of Y	218.32	372.83	378.85	376.34
Observations	2789	2789	2789	2789

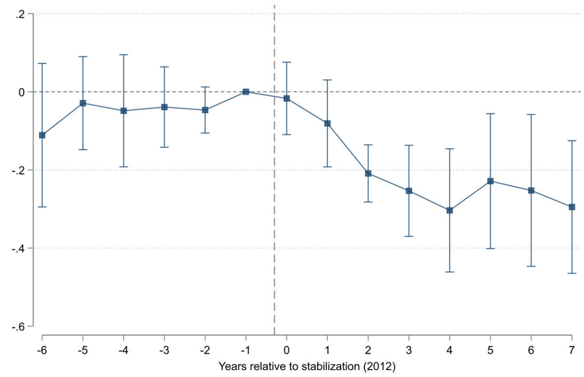
Notes: This table shows the effect of the Swiss Franc Stabilization (SFS) in 2011 on the number of registered nurses in hospitals using different weighting procedures. Displayed coefficients reflect difference-in-differences estimates obtained from Equation 2. Weights are the average number of beds (column 2), total number of occupancy days (column 3), and total number of inpatient cases (column 4). Column 1 displays coefficients without weighting. The standard deviation of the estimates displayed in parenthesis is based on robust standard errors clustered at the county level. Stars refer to the 1% *, 5% **, and 10% *** significance level. The mean and standard deviation of the outcome variable Y refers to the year 2011. The sample of hospitals contains continuously operating hospitals in the border region (treatment group) and hospitals in matched counties further inland (control group). The matching procedure is explained in detail in Section 4.

Figure B.6: Aggregate health effects without matching

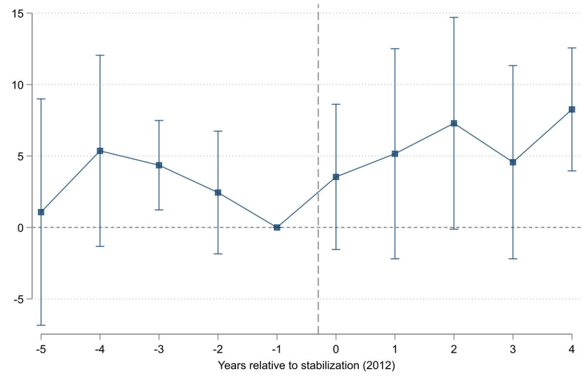
(a) Life expectancy



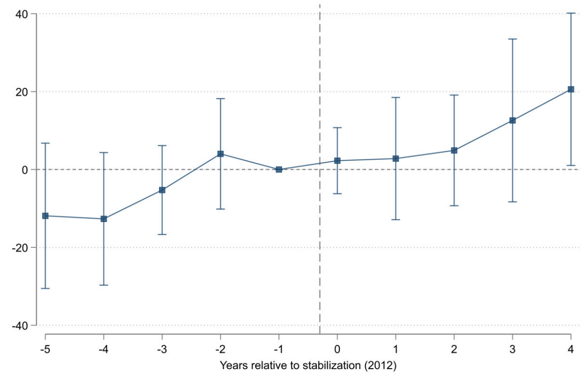
(b) Remaining life expectancy



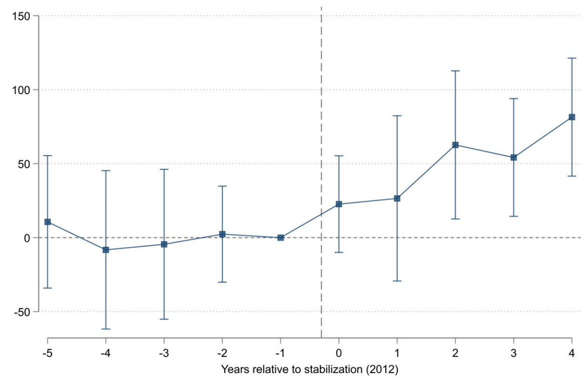
(c) Mortality (25-49)



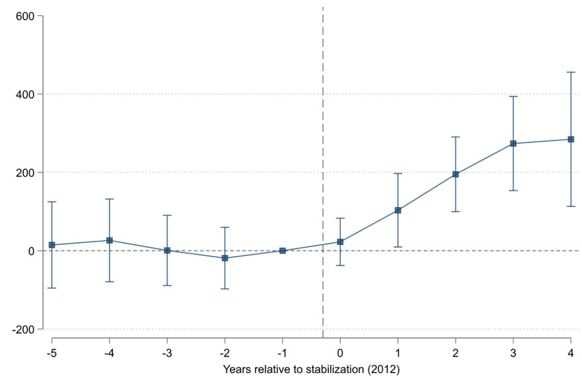
(d) Mortality (50-64)



(e) Mortality (65-74)



(f) Mortality (75+)



Notes: This figure shows the effect of the Swiss Franc Stabilization (SFS) in 2011 on the aggregate life expectancy (for newborns) and the remaining life expectancy (for individuals age 60), as well as mortality across age groups. All sub-figures display the multi-period difference-in-differences estimates obtained from Equation 1, but instead of comparing the treated border region with matched control counties, this regression compares the government district of Freiburg to the rest of the federal states of Baden-Württemberg and Bayern. Vertical bars indicate 95% confidence intervals based on robust standard errors clustered at the county level.

C Conceptual Thoughts

This appendix section presents conceptual thoughts on how hospitals respond to a negative labor shock due to an increase in nurses' outside options. The model focuses on the allocation of nursing resources between patients with high-urgency and low-urgency diagnoses and the subsequent impact on patient mortality. The aim is to derive testable hypotheses about the hospital's resource allocation decisions and the resulting changes in mortality across patient groups.

Model Setup. A representative hospital seeks to maximize the total mortality reduction among its patients by optimally allocating a limited number of nurses between two patient types: high-urgency patients (H) who require immediate attention and low-urgency patients (L). The hospital aims to maximize the total reduction in mortality, thus its objective function is given by:

$$\max_{N_L, N_H} \quad R = P_L f(r_L) + P_H g(r_H) \tag{3}$$

where $r_L = \dfrac{N_L}{P_L}$ and $r_H = \dfrac{N_H}{P_H}$ denote the ratio between nurses (N_L and N_H) and patients (P_L and P_H) for each patient type. This nurse-to-patient ratio reflects the intensity of care but also reflects the probability of receiving a specific treatment, e.g., surgery or screening. $f(r_L)$ and $g(r_H)$ represent the mortality reduction due to hospital care and are specified as:

$$f(r_L) = \alpha_L r_L^{\beta_L} \tag{4}$$
$$g(r_H) = \alpha_H r_H^{\beta_H} \tag{5}$$

where $\alpha_L, \alpha_H > 0$ are parameters reflecting the effectiveness of nursing care in reducing mortality, and $0 < \beta_H < \beta_L < 1$ are elasticity parameters. Both functions are characterized by diminishing marginal returns to nursing and are increasing in r, which means that more nurses per patient lead to greater mortality reduction, whereby $\beta_H < \beta_L$ indicates that high-urgency patients are more sensitive to nursing care. Additionally, the hospital faces the following constraints: Firstly, the number of nurses allocated across both patient types cannot exceed the total available nurses (N), i.e.

$$N_L + N_H \leq N \tag{6}$$

Secondly, the budget constraint stipulates that the total wage expenditure on nurses cannot exceed the hospital's budget:

$$wN \leq B \tag{7}$$

where w is the wage rate for nurses and B is the hospital's budget for nursing staff. Thirdly, the supply of nurses depends on the wage w paid by hospitals and the value of the best alternative available to nurses, i.e. the outside options O:

$$N = N_s(w - O) \tag{8}$$

This equation states that an increase in O reduces the supply of nurses available to the hospital, i.e., induces labor scarcity. From the care mandates (explained in detail in Section 2), which state that hospitals are obliged to treat all incoming patients, I form the following constraint which ensures that both patient groups have to be treated, irrespective of the scarcity of input factors:

$$N_L > 0, \quad N_H > 0 \tag{9}$$

Thus, the hospital's optimization problem, the aim to reduce mortality (eq. (3)) under the constraints (eq. (6) - (9)), is given by:

$$\max_{N_L, N_H} \quad R = P_L f(r_L) + P_H g(r_H) \quad \text{subject to}$$

$$N_L + N_H \leq N, \quad wN \leq B, \quad N = N_s(w - O), \quad N_L > 0, \quad N_H > 0$$

Optimality conditions. From this maximization problem, I form the Lagrangian $\mathcal{L}$ and take the derivatives with respect to N_L and N_H to obtain the first-order conditions:[35]

$$\frac{\partial \mathcal{L}}{\partial N_L} = f'(r_L) - \lambda = 0, \tag{10}$$

$$\frac{\partial \mathcal{L}}{\partial N_H} = g'(r_H) - \lambda = 0. \tag{11}$$

where λ is the Lagrange multiplier associated with the constraint on the availability of nurses (eq. (6)). Taking the first derivative of the mortality reduction functions[36] and substituting them into (10) and (11), I obtain:

$$\alpha_L \beta_L r_L^{\beta_L - 1} = \lambda, \tag{12}$$

$$\alpha_H \beta_H r_H^{\beta_H - 1} = \lambda. \tag{13}$$

which results in the condition for the optimal allocation of nurses among patient types:

$$\alpha_L \beta_L r_L^{\beta_L - 1} = \alpha_H \beta_H r_H^{\beta_H - 1} \tag{14}$$

and in the following functional form for r_L in terms of r_H:

$$r_L = \left(\frac{\alpha_H \beta_H}{\alpha_L \beta_L} \right)^{\frac{1}{\beta_L - 1}} r_H^{\frac{\beta_H - 1}{\beta_L - 1}} \tag{15}$$

with $0 < \beta_H < \beta_L < 1$ and the exponent $\gamma = \frac{\beta_H - 1}{\beta_L - 1}$ being grater than 1.

[35] The Lagrangian $\mathcal{L} = P_L f(r_L) + P_H g(r_H) + \lambda(N - N_L - N_H)$ only incorporates the constraint on the availability of nurses, i.e. equation (6), due to the non-bindingness of the strict inequalities $N_L > 0$ and $N_H > 0$.

[36] Those are $f'(r_L) = \alpha_L \beta_L r_L^{\beta_L - 1}$ and $g'(r_H) = \alpha_H \beta_H r_H^{\beta_H - 1}$, respectively.

Treatment allocation under labor scarcity. Now, consider a scenario in which an increase in nurses' outside options (O) reduces the number of nurses available to the hospital to $N^{LS} < N^*$, as $\frac{dN}{dO} = -N_s'(w - O) < 0$. Assuming that the number of patients remains constant, this results in proportional changes in the nurse-to-patient ratios $\delta_g = \frac{r_g^{LS}}{r_g^*} = \frac{N_g^{LS}}{N_g^*}$ where $g \in \{L, H\}$. Relating the optimality conditions under both scenarios to each other leads to:

$$\left(\frac{r_L^{LS}}{r_L^*}\right)^{\beta_L - 1} \delta_L^{\beta_L - 1} = \delta_H^{\beta_H - 1} = \left(\frac{r_H^{LS}}{r_H^*}\right)^{\beta_H - 1} \tag{16}$$

Since $0 < \beta_H < \beta_L < 1$, it holds that $\beta_H - 1 < \beta_L - 1 < 0$ and $\gamma = \dfrac{\beta_H - 1}{\beta_L - 1} > 1$.

Taking natural logarithms of both sides of equation (16) and accounting for the fact that $\delta_g < 0$ (reflecting that nurse-to-patient ratios decrease under labor scarcity) and that $\gamma > 1$ (meaning that r_L decreases faster than r_H when N decreases), I arrive at:

$$\begin{aligned}(\beta_L - 1)\ln \delta_L &= (\beta_H - 1)\ln \delta_H, \\ \ln \delta_L &= \gamma \ln \delta_H < \ln \delta_H\end{aligned}$$

As the natural logarithm is a monotonically increasing function it implies that the proportional decrease in the nurse-to-patient ratio for low-urgency patients is greater than that for high-urgency patients, i.e. $\frac{r_L^{LS}}{r_L^*} = \delta_L < \delta_H = \frac{r_H^{LS}}{r_H^*} < 1$. Thus, under labor scarcity, hospitals allocate relatively more resources toward patients with high-urgency diagnoses compared to the baseline scenario without labor scarcity (**Hypothesis 1**).

Mortality under labor scarcity. The stronger allocation of nurses towards high-urgency patients under labor scarcity reflects the hospital's objective to maximize total mortality reduction. Still, due to the inability to allocate nurses exclusively to high-urgency patients (imposed by care mandates present in the German hospital sector), and the higher sensitivity of high-urgency patients to nurse staffing levels ($\beta_H < \beta_L$), any reduction in N_H leads to a significant increase in mortality for this type of patients. Consider the mortality reduction due to hospital services for each patient type $g \in \{L, H\}$ under labor scarcity is given by:

$$R_g^{LS} = \alpha_g P_g \left(r_g^{LS}\right)^{\beta_g} = \alpha_g P_g \left(\delta_g r_g^*\right)^{\beta_g} = R_g^* \delta_g^{\beta_g} \tag{17}$$

and hence the difference in mortality reduction between both scenarios is denoted by:

$$\Delta R_g = R_g^{LS} - R_g^* = \alpha_g P_g^{1-\beta_g} \left((N_g^{LS})^{\beta_g} - (N_g^*)^{\beta_g}\right) = R_g^* \left(\delta_g^{\beta_g} - 1\right) \tag{18}$$

where $R_g^* = \alpha_g P_g \left(r_g^*\right)^{\beta_g}$ is the baseline mortality reduction for each patient type g. As $\delta_L < \delta_H < 1$, i.e., the nurse-to-patient ratios decrease under labor scarcity, ΔR_L and ΔR_H are negative, meaning that also the mortality reduction due to hospital care decreases for both patient types. I am interested in which of the two groups experiences as stronger increase in mortality due to labor scarcity. Thus, I compare the ratio of the absolute changes between both types:

$$\frac{|\Delta R_H|}{|\Delta R_L|} = \frac{R_H^* \left(1 - \delta_H^{\beta_H}\right)}{R_L^* \left(1 - \delta_L^{\beta_L}\right)} \tag{19}$$

Given that $\delta_L^{\beta_L} = \delta_H^{\gamma\beta_L}$ and $\gamma > 1$, i.e. low-urgency patients see a stronger reduction of treatment intensity, it follows that $\delta_L^{\beta_L} < \delta_H^{\beta_L}$ and from $\delta_H < 1$ and $\beta_H < \beta_L$ it follows that $1 - \delta_H^{\beta_H} > 1 - \delta_H^{\beta_L}$, it follows that

$$\frac{1 - \delta_H^{\beta_H}}{1 - \delta_L^{\beta_L}} > 1 \tag{20}$$

Under the additional assumption that $R_L^* \lesssim R_H^*$, i.e. hospitals are equally reducing mortality between the two patient types or more strongly among high-urgency patients at baseline, $\frac{|\Delta R_H|}{|\Delta R_L|} > 1$. Thus, under labor scarcity, high-urgency patients see a stronger increase in mortality compared to low-urgency patients and compared to the baseline scenario without labor scarcity (**Hypothesis 2**).

Implications. This conceptual framework shows that hospitals strategically reallocate labor under labor scarcity. As patients with highly urgent diagnoses have higher marginal returns to nursing due to their critical conditions, hospitals allocate nurses to patients more strongly based on their medical needs under labor scarcity. This needs-based adjustment ("triage") results in a smaller proportional decrease in high-urgency patients' care intensity and probability of receiving treatment (**Hypothesis 1**). Despite this relative shift of resources towards urgent patients, they see a higher absolute increase in mortality compared to low-urgency patients (**Hypothesis 2**). This is because even small reductions in treatment intensity lead to significant increases in mortality for urgent cases and care mandates prevent hospitals from allocating all resources toward urgent cases.