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List of Abbreviations

2SLS....Two-stage least squares
AGIL ....Adaptation, goal attainment, integration, and latency
COVID-19 ....Coronavirus disease 2019
C-section....Caesarean section
GI ....Goal attainment and integration
GMM.... Generalized method of moments
GP.... General practitioners
HCW .... Healthcare worker
IQTIG….Institut für Qualitätssicherung und Transparenz im Gesundheitswesen [Institute for Quality Assurance and Transparency in Healthcare]
IV....Instrument variable
OLS .... Ordinary least squares
PED.... Paediatricians
PP .... Pandemic preparedness
PPE ....Personal protective equipment
SARS-CoV-2....Severe acute respiratory syndrome coronavirus 2
SC ....Social capital
TL.... Transformational leadership

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Introduction

Physician behaviour is a key factor in the provision of high-quality care and for ensuring favourable health outcomes for patients (Chauhan et al., 2017; Godager & Scott, 2020; Md Rezal et al., 2015). Previous research has emphasised the psychological (George et al., 2023; Patey et al., 2023), economic (Dzampe & Takahashi, 2024; Godager & Scott, 2020; A. Scott et al., 2011), and educational factors (Chauhan et al., 2017) influencing physician behaviour, as physicians face a very wide set of tasks and responsibilities in daily practice (Sinsky et al., 2016). Indeed, beyond direct patient interaction, their professional duties include interprofessional communication and collaboration (Vatn & Dahl, 2022); administrative work and documentation (Rao et al., 2017), management of both medical and non-medical staff (Frich et al., 2015); and overseeing practices, hospital wards, and departments (Bode & Maerker, 2014). Reflecting this complexity, the recent literature on physician behaviour has broadened to incorporate these wider professional dimensions (Chauhan et al., 2017).

One key outcome of physician behaviour is healthcare quality for which Donabedian's (1988) influential model introduced outcome, process, and structural measures to evaluate quality of care. The Institute of Medicine (2006) has also outlined six domains of quality of care: patient safety, effectiveness, patient-centredness, timeliness, efficiency, and equity. In recent years, quality of care has been increasingly understood as a multifaceted concept that extends beyond traditional focuses on health outcomes and patient safety to include aspects such as communication, motivation, knowledge and institutional quality culture (Hannawa et al., 2022).

This dissertation aligns with the current trend by exploring quality of care beyond traditional factors such as effectiveness, safety (I. Scott, 2009), and health outcomes (A. Scott et al., 2011) to incorporate the broader dimensions mentioned above (Hannawa et al., 2022; Institute of Medicine, 2006; Lachman et al., 2020). Accordingly, various aspects of physician behaviour and quality of care were examined, as this work investigated the preliminary conditions of physician behaviour affecting quality of care, such as organisational factors and workplace management, as well as processes and outcomes of healthcare quality itself such as patient safety, effectiveness and efficiency.

This thesis comprises four independent studies from Germany: Chapter 1 and 2 focus on the outpatient sector, surveying physicians and their behaviour directly, while Chapters 3 and 4 concentrate on physician behaviour within hospitals, utilising and analysing secondary data. In the outpatient setting, individual physician behaviour was assessed, whereas in the inpatient setting, a systemic perspective was adopted, which involved examining physician behaviour collectively at the department or hospital level. The research questions focused on how physicians adapt and sustain their services under demanding conditions such as the COVID-19 pandemic (Study I), how they interact with patients who have differing attitudes to medical decisions (Study II), how social and organisational factors influence patient safety and quality of care within the hospital system (Study III), and how patient volume and medical staffing affect obstetric treatments (Study IV).

Chapter 1, *"Stockpiled personal protective equipment and knowledge of pandemic plans as predictors of perceived pandemic preparedness among German general practitioners"*,[1] examines the behaviour of primary care physicians at the onset of the COVID-19 pandemic in spring 2020. During this period, outpatient physicians faced numerous challenges, including managing patient relationships and treatments, adapting practice operations, and coping with the impact of the pandemic measures on their private lives and the lives of other medical staff. As such, this chapter analyses how physicians' stockpiling of different personal protective equipment and their knowledge of pandemic plans related to their perceived pandemic preparedness. This chapter also explores whether knowledge about a pandemic plan affected the stockpiling of personal protective equipment.

The existing literature on physicians' behaviour in relation to stockpiling and using personal protective equipment was somewhat general and rarely distinguished between

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This article is a collaborative work with Ibrahim Demirer (University of Cologne), Sophie Gunkel (University of Cologne), Jan Hoffmann (University of Cologne), Laura Mause (University of Cologne), Tim Ohnhäuser (University of Cologne), and Nadine Scholten (University of Cologne), conducted under the research project 'COVID-GAMS'. All data were collected as part of this project. Nadine Scholten and I conceptualised the study. I conducted the formal analysis and drafted the original manuscript. Ibrahim Demirer and Nadine Scholten assisted me in designing the methodology. Nadine Scholten, Sophie Gunkel, Jan Hoffmann, Laura Mause, and Tim Ohnhäuser, and I developed the questionnaire and conducted the survey. Sophie Gunkel managed the data curation. Ibrahim Demirer, Jan Hoffmann, Laura Mause, and Nadine Scholten provided a careful review of the manuscript.

different types of personal protective equipment (Fiorino et al., 2020; M. H. Temsah, Alhuzaimi, et al., 2020); studies on physicians' knowledge of pandemic plans are limited in number (Azziz-Baumgartner et al., 2009; Sotomayor-Castillo et al., 2021; Tomizuka et al., 2013). For the study in this chapter, the responses of 508 general practitioners participating in the COVID-GAMS study[2] during the summer of 2020 were evaluated. The survey assessed stocks of various types of personal protective equipment – including face masks, gloves, and face shields – held by physicians in their practices before the official declaration of the pandemic in Germany in March 2020.

The findings revealed that physicians with higher personal protective equipment stock levels reported significantly higher levels of perceived pandemic preparedness. Face masks (medical face masks and FFP-2/3 masks), face shields, and protective suits were identified as critically important. Additionally, prior knowledge of a pandemic plan was associated with a significantly increased sense of pandemic preparedness. No significant correlation was found between knowledge of a pandemic plan and higher levels of personal protective equipment stockpiling. According to the six dimension of quality-of-care outlined by the Institute of Medicine (2006), these results offer valuable insights into the factors influencing the behaviour and preparedness of outpatient physicians during pandemics, thus contributing to improving patient safety (protecting patients and healthcare workers from transmission), efficiency (ensuring adequate stock of personal protective equipment), and timeliness (maintaining and delivering health care services) in healthcare provision for future public health crises.

In **Chapter 2**, *"What impact does the attitude toward COVID-19 vaccination have on physicians as vaccine providers? A cross sectional study from the German outpatient sector"*,[3] various aspects of physician behaviour during COVID-19 immunisation

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[2] This research project '*COVID-GAMS: The COVID-19 Crisis and its impact on the German ambulatory sector – the physicians' view*' (https://www.covid-gams.de), funded by the German Federal Ministry of Education and Research (BMBF 01KI2099, https://www.bmbf.de/bmbf/en/) investigated the organisational, economic, and personal challenges posed by the COVID-19 pandemic and the impact of the pandemic on outpatient care from the perspective of physicians from various specialist disciplines in Germany. This work was conducted at the Institute of Medical Sociology, Health Services Research and Rehabilitation Science, University of Cologne, Cologne, Germany, between 1 May 2020 and 31 October 2021 under the supervision of Nadine Scholten. Tim Ohnhäuser and I supported Nadine Scholten in the funding acquisition for the research grant, and we administrated the project together.

[3] This article has been published and should be cited as follows: A. Stöcker, J. Hoffmann, L. Mause et al., What impact does the attitude toward COVID-19 vaccination have on physicians as vaccine providers? A cross sectional study from

campaigns were examined. Specifically, following an initial transition phase in which vaccinations were primarily administered in newly established vaccination centres at the start of the campaign, outpatient physicians took on the primary role of administering COVID-19 vaccines to the population in Germany. In addition to managing tasks such as vaccine procurement, distribution, storage, and administration, these physicians were responsible for patient communication in vaccine discussions and contributed to post-approval vaccine safety monitoring (phase IV). These responsibilities presented unique challenges during the pandemic and heightened societal tensions. The previous literature in this field has highlighted the significant influence of physicians' attitudes towards vaccines on both patient communication (Katzman & Katzman, 2021; Okoli et al., 2021) and patient vaccine decisions (Henrikson et al., 2015; Moss, 2016). This chapter provides insights from the outpatient sector, an under-explored research area (Peterson, 2022), on the impact of physician's attitudes towards COVID-19 vaccination on their performance as outpatient vaccine providers.

Using survey responses from 932 general practitioners, gynaecologists, and paediatricians (the main group of vaccinating physicians) in autumn 2021, the study explores the following: physician attitudes towards COVID-19 vaccines, vaccination behaviour, perceptions of vaccine safety, reporting of adverse effects, and behaviour in vaccination education discussions, including self-efficacy and communication strategies.

The findings revealed that physicians held significantly more negative attitudes towards COVID-19 vaccines compared to other vaccines (8% versus 1% reporting negative attitudes). Among general practitioners and paediatricians, those with negative

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the German outpatient sector, *Vaccine*, Volume 41, Issue 1, (2023), Pages 263-273, ISSN 0264-410X, https://doi.org/10.1016/j.vaccine.2022.11.054. The layout and citation style have been adjusted to the format chosen for this dissertation.

This article was a collaborative study conducted with Jan Hoffmann (University of Cologne), Laura Mause (University of Cologne), Julia Neufeind (Robert Koch Institute, Berlin), Tim Ohnhäuser (University of Cologne), and Nadine Scholten (University of Cologne) and is part of the research project 'COVID-GAMS'. All data were collected within the research project. The general questionnaire development and survey were conducted by Jan Hoffmann, Laura Mause, Tim Ohnhäuser, Nadine Scholten, and me, with the specific sections on vaccines and vaccination behaviour compiled and prepared by myself. Nadine Scholten provided support in conceptualising the study and refining its methodology. I conducted the formal analysis, prepared the visualisation, drafted the original manuscript, and curated the data. Julia Neufeind contributed significant insights on vaccination behaviour among medical staff and assisted in interpreting the results. Jan Hoffmann, Laura Mause, Julia Neufeind, Tim Ohnhäuser, and Nadine Scholten provided critical revisions to the manuscript.

vaccination attitudes reported significantly lower vaccination rates among their patients. On average, physicians with negative attitudes towards COVID-19 vaccination reported significantly higher confidence in patient education discussions and in providing information resources and answering questions from vaccine-hesitant patients or their legal representatives. These physicians also exhibited significantly greater empathy for objections during vaccination education discussions and were more inclined to accept patients' decisions not to be vaccinated. Conversely, physicians with positive attitudes towards COVID-19 vaccination were significantly more likely to engage in in-depth discussions to persuade patients who were refusing vaccines, to explain the impact of being unvaccinated on herd immunity, or in rare cases, to recommend a change of physician. Nearly all physicians with negative attitudes towards COVID-19 vaccination reported observing adverse effects, while 50% of those with positive attitudes reported this. The level of reporting of adverse effects did not differ significantly between the two groups, although neither group had 100% of physicians fully reporting adverse vaccine effects to the regulatory authorities. Overall, these findings provide insights into how to improve quality of care by demonstrating how attitudes towards vaccination changes physicians' behaviour in terms of patient safety and effectiveness (perceived vaccination safety, vaccination rates, and reporting of adverse effects), and patient-centredness (physicians' behaviour during vaccination education discussions).

In Chapters 3 and 4, the focus shifts from the outpatient sector to inpatient settings to provide a broader perspective regarding physician behaviour. Unlike the direct surveys used in the outpatient-focused studies, these chapters rely on secondary data analyses drawn from structured hospital quality reports.[4]

Chapter 3, "*Combining transformational leadership and social capital in hospital care quality: a longitudinal analysis from chief medical officers' perspective*",[5] combines

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[4] The structured hospital quality reports are compiled and disclosed in accordance with Sections 136 and 137 of the German Social Security Code (Sozialgesetzbuch) V as part of the quality reporting requirements. These reports are primarily designed to provide transparency for patients and physicians regarding the type, scope, and quality of hospital services rather than for scientific research purposes. The reports are published annually and present data aggregated at the departmental level, with no individual data on treatments, patients, or healthcare workers. To enable the analysis presented here, I performed extensive work to link the cross-sectional quality reports into a longitudinal dataset.

[5] The chapter presented here formed the basis for a manuscript currently under review at *BMC Health Services Research*, titled "Leveraging sociological systems theory: integrating transformational leadership and social capital to enhance quality of care – a longitudinal exploratory study of German hospitals" and is currently in the review process.

quality of care and patient safety data from structured hospital quality reports with data from a survey of medical directors. Efforts to improve quality of care often encounter setbacks related to inconclusive results from research studies and challenges in implementing interventions in real-world healthcare settings (Schiff & Shojania, 2022; Singer et al., 2015). This chapter employs an underutilised social system approach (Allen et al., 2016b) that shifts the focus from the individual perspective to the examination of organisations from a systems perspective. This approach aligns with the understanding that medical errors often originate at the system rather than at the individual level (Kohn et al., 2000). By contributing to ongoing research efforts (Allen et al., 2016a), it addresses these challenges from a new perspective.

As part of the ATräk study,[6] medical directors from 508 hospitals were surveyed using two validated scales to assess social cohesion (social capital) within the workforce and the leadership behaviours (i.e., transformational leadership) of senior management staff in their hospitals. Adapting Talcott Parson's adaptation, goal attainment, integration, latency (AGIL) framework, this study combined the dimensions of goal attainment and integration into a new concept (GI factor) based on the idea that effective organisations require both a cohesive workforce and a leadership system that can define and pursue clear goals. Hence, responses on each scale were dichotomised to form two groups: one representing high social capital and transformational leadership (high GI factor), and the other representing low social capital or low transformational leadership (low GI factor). These groups with 3,940 observations were then evaluated longitudinally for the period 2012–2019 to assess differences between them in terms of treatment quality and patient safety, as reflected by the indicators in the quality reports. External assessments of multiple quality indicators within the quality reports were divided into two categories:

This work was co-authored with Jeffrey Braithwaite (Macquarie University, Sydney), Ludwig Kuntz (University of Cologne), Verena Maschke (University of Cologne), and Holger Pfaff (University of Cologne). Holger Pfaff and I conceptualised the study. I developed and designed the study methodology, conducted the investigation and formal analysis, prepared the visualisation, and drafted the original manuscript. Verena Maschke and I curated the data. Holger Pfaff and Jefferey Braithwaite established the theoretical framework for the GI factor (Pfaff and Braithwaite (2020)). Verena Maschke completed preliminary work with a cross-sectional analysis in her master's thesis, which Holger Pfaff and I supervised. Jefferey Braithwaite, Ludwig Kuntz, Verena Maschke, and Holger Pfaff provided critical revisions to the manuscript.

[6] The ATräk survey, conducted in 2008 by Holger Pfaff and colleagues (Gloede et al. (2013)), examined the effects of hospital ownership structures on quality of healthcare. Although I was not involved in that study, I used its data for this work.

quality irregularities and quality deficiencies. Quality irregularities included, for example, inadequate documentation, software problems, and reporting delays, while quality deficiencies included direct shortcomings in quality of care.

The results showed that hospitals with high social capital and strong transformational leadership exhibited significantly fewer quality irregularities over the 9-year study period. While there was some indication of fewer quality deficiencies in these hospitals, the differences between the groups were not statistically significant. These insights suggest that strong social cohesion and transformational leadership have a greater impact on process-related quality than on outcome-related quality and, thus, may inform strategies for improving patient safety and equity (providing safe and high-quality health care) and efficiency (compliance with external reporting regularities).

In the final **Chapter 4**, "*Exploring the influence of medical staffing and birth volume on observed-to-expected cesarean deliveries: A panel data analysis of integrated obstetric and gynecological departments in Germany*",[7] physician behaviour is examined at the departmental level of integrated obstetric and gynaecological departments (n = 519 with 2,089 observations), focusing on the influence of organisational factors on decision-making in obstetrics, where the choice of birth mode is of critical importance. From an organisational research perspective, differences in obstetric care across organisation types have been well-documented (Mikolajczyk et al., 2013; Zipfel & Weidmann, 2022), while differences within obstetric departments have received less attention.

Using quality report data from 2015 to 2019, this study examined how the number of physicians and midwives, along with the total number of deliveries, influences risk-adjusted caesarean section rates. The metric compares expected to observed caesarean sections, accounting for various aspects of maternal and foetal health outcomes. Several instrumental analysis methods were applied to identify potential causal mechanisms

[7] This article has been published and should be cited as follows: Stöcker A, Pfaff H, Scholten N, Kuntz L. Exploring the influence of medical staffing and birth volume on observed-to-expected cesarean deliveries: a panel data analysis of integrated obstetric and gynecological departments in Germany. *Eur J Health Econ* (2025). https://doi: 10.1007/s10198-024-01749-0. The layout and citation style have been adjusted to the format chosen for this dissertation.
This work was co-authored with Holger Pfaff (University of Cologne), Nadine Scholten (University of Bonn), and Ludwig Kuntz (University of Cologne). Data for the studies were sourced from German structured hospital quality reports. Ludwig Kuntz, Nadine Scholten, and I developed and conceptualised the study. I developed and designed the methodology of the study, curated the data, conducted the investigation and formal analysis, and drafted the original manuscript. Holger Pfaff, Nadine Scholten, and Ludwig Kuntz critically revised the manuscript.

underpinning differences in caesarean section rates within integrated obstetric and gynaecological departments. The results indicated that departments with more full-time equivalent physicians per delivery have higher risk-adjusted caesarean section rates.

Furthermore, the instrumental analysis suggested a causal effect for this relationship. One possible interpretation is that within integrated obstetric and gynaecological departments, greater specialisation in obstetric care (indicated by higher number of deliveries per full-time equivalent physician) leads to lower risk-adjusted caesarean section rates. In contrast, no such significant correlations were observed in dedicated solo obstetric departments, which already had significantly lower risk-adjusted caesarean section rates. These findings contribute to advancing equity and patient-centredness (respecting maternal preference for the delivery method), and efficiency and effectiveness (performing caesarean sections based on maternal and medical indications) in obstetric care.

Chapter 1

Stockpiled personal protective equipment and knowledge of pandemic plans as predictors of perceived pandemic preparedness among German general practitioners

Abstract

Background: The COVID-19 pandemic significantly changed the work of general practitioners (GPs). At the onset of the pandemic in March 2020, German outpatient practices had to adapt quickly. Pandemic preparedness (PP) of GPs may play a vital role in their management of a pandemic. ***Objectives:*** The study aimed to examine the association in the stock of seven personal protective equipment (PPE) items and knowledge of pandemic plans on perceived PP among GPs. ***Methods:*** Three multivariable linear regression models were developed based on an online cross-sectional survey for the period March–April 2020 (the onset of the pandemic in Germany). Data were collected using self-developed items on self-assessed PP and knowledge of a pandemic plan and its utility. The stock of seven PPE items was queried. For PPE items, three different PPE scores were compared. Control variables for all models were gender and age. ***Results:*** In total, 508 GPs were included in the study; 65.16% believed that they were very poorly or poorly prepared. Furthermore, 13.83% of GPs were aware of a pandemic plan; 40% rated those plans as beneficial. The stock of FFP-2/3 masks, protective suits, face shields, safety glasses, and medical face masks were mostly considered completely insufficient or insufficient, whereas disposable gloves and disinfectants were considered sufficient or completely sufficient. The stock of PPE was significantly positively associated with PP and had the largest effect on PP; the association of the knowledge of a pandemic plan was significant but small. PPE scores did not vary considerably in their explanatory power. The assessment of a pandemic plan as beneficial did not significantly affect PP. ***Conclusion:*** The stock of PPE seems to be the determining factor for PP among German GPs; for COVID-19, sufficient masks are the determining factor. Knowledge of a pandemic plans play a secondary role in PP.

1.1 Introduction

The coronavirus disease 2019 (COVID-19) pandemic took Germany and many other countries by surprise in 2020. Within a few weeks, social and work life changed. The healthcare sector was one of the most affected areas (Ali et al., 2020; Provenzano et al., 2020; Zewudie et al., 2021). Pandemic plans were activated (Holthof & Luedi, 2021), and emergency measures were taken in hospitals and intensive care units to treat a large number of patients with COVID-19 (Tartari et al., 2020). However, general practitioners (GPs) are often the first to have contact with potential patients with COVID-19 (Huston et al., 2020; Zewudie et al., 2021) and the majority of patients with COVID-19 – mostly with mild and moderate symptoms (Fiorino et al., 2020; Sotomayor-Castillo et al., 2021) – are treated in GP practices. Apart from the additional workload of treating patients with COVID-19, GPs have to maintain regular primary health care (Ali et al., 2020; Lau et al., 2021; J. Q. Lee et al., 2020; Zewudie et al., 2021). General practitioners have been facing multiple challenges during the COVID-19 pandemic, such as a high risk of being infected by severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) themselves (Verhoeven et al., 2020), including the risk of mortality (Campbell, 2020) and psychological impacts with regard to work and personal life (Feingold et al., 2021). Overall, pandemic preparedness (PP) is an important factor in being better able to manage the challenges of a pandemic (Fineberg, 2014; Riegel et al., 2020).

At the beginning of the COVID-19 pandemic, many personal protective equipment (PPE) items were in short supply in Germany and worldwide (Cohen & van der Rodgers, 2020; Hoernke et al., 2021), both for private use (Gierthmuehlen et al., 2020) and in the healthcare sector (Boškoski et al., 2020; Widmer & Richner, 2020). Specifically, medical masks and FFP-2/3 masks were in high demand and short supply (Boškoski et al., 2020). As Germany has a federated and self-governing system in the healthcare sector with 17 self-regulatory regional organization for the outpatient sector, clear division of responsibilities was often absent (Buthe et al., 2020). Many physicians complained about a general, long-lasting shortage of PPE (Pult, 2020; Wernhart et al., 2020).

Prior to the outbreak of the COVID-19 pandemic, a variety of pandemic plans existed in Germany (Lange & Gusy, 2015). For example, the Robert Koch Institute, a German federal government agency responsible for disease control and prevention, established a national influenza pandemic plan (last update 2016/2017) (Robert-Koch-Institut, 2017). On March 4, 2020, a supplement to the national pandemic plan regarding

COVID-19 was published (Robert-Koch-Institut, 2020). On March 13, 2020, the national pandemic plan has been activated (König et al., 2021). In addition, the Kassenärztliche Bundesvereingung (German Association of Statutory Health Insurance Physicians) had published a document regarding influenza pandemic "Risk Management in Medical Practices" in 2008, which is specifically aimed at the outpatient sector (Frosch et al., 2008). Furthermore, each of the 16 German states has its own pandemic plan, and several cities have also established their own pandemic plans (Lange & Gusy, 2015; Piwernetz & Neugebauer, 2020). In the event of an influenza pandemic, German pandemic plans ensure priority of outpatient treatment (Lange & Gusy, 2015).

While the necessity of sufficient knowledge (M. H. Temsah, Alhuzaimi, et al., 2020) and adequate PPE in general (Fiorino et al., 2020; J. Q. Lee et al., 2020; Sotomayor-Castillo et al., 2021) have been recognized for protecting health care professionals and maintaining the operation of medical facilities during a pandemic, different PPE items have been considered and compared less often. Therefore, in this study, we aim to further investigate how stocked PPE items effect perceived PP. In addition to adequate PPE, pandemic plans are considered a firm cornerstone with regard to PP in the healthcare sector (Azziz-Baumgartner et al., 2009; Tomizuka et al., 2013). However, the effect of pandemic plans on GPs' personal PP has not been studied to our knowledge; other studies are limited to polling knowledge of pandemic plans and their utility (Sotomayor-Castillo et al., 2021). Hence, in this study we investigated how the stock of seven PPE items and knowledge of a pandemic plan are associated with PP among German GPs.

1.2 Method

1.2.1 Design

This analysis is part of the research project "The COVID-19 crisis and its impact on the German ambulatory sector–the physicians' view" (COVID-GAMS). The study is based on an anonymous, online cross-sectional survey that is conducted at three different points in time in 2020 and 2021. The first survey was conducted in June–September 2020 retrospectively for the period March–April 2020, which corresponded with the peak of the first COVID-19 wave in Germany. During questionnaire conception and development, preliminary interviews were conducted with different representatives of the listed group of specialists. The questionnaire was subsequently tested by several physicians from different specialty groups who were not involved in the design. The questions relevant to this study can be accessed in German and English in the appendix (Appendix Table A.1).

1.2.2 Participants and recruitment

A total of 18,000 outpatient physicians were invited to participate in the online survey: GPs (6,500), dentists (4,000), gynecologists (2,000), pediatricians (2,000), otolaryngologists (2,000), cardiologists (1,000), and gastroenterologists (500). The study population was selected to capture outpatient care during the Corona pandemic from the perspective of different medical disciplines. The address data for the random study sample was selected in collaboration with the National Association of Statutory Health Insurance Physicians. Invitations were sent by fax and e-mail, followed by three reminders at 2-week intervals. In addition, physicians were invited to participate in the survey via the project homepage (www.covid-gams.de) and various specialist associations. In this analysis, we examine only responses of GPs. The survey (including invitation letter, study and privacy information and questionnaire) was approved by the Ethics Committee of the University of Cologne (20–1169_1). The online survey was conducted anonymously, without directly collecting personal identifying information, so that only implicit consent had to be obtained in accordance with the ethics vote of the Ethics Committee of the University Hospital of Cologne. The terms and conditions of the study had to be agreed to in order to participate in the study. Participation in the survey could be terminated at any time. The possibility to pause the survey and continue it later was technically possible. Participation was voluntary for all participants. No expense allowance or payment was paid for participation.

1.2.3 Measures

The focus of the analysis, examined as the dependent variable, was the following research question: "How prepared did you feel at your practice for a pandemic in early March?" Answers were given on a 5-point Likert scale (1 = very bad, 2 = bad, 3 = moderate, 4 = good, 5 = very good) and processed as numerical outcomes (Carifio & Perla, 2007). The first predictor was stockpiled PPE (FFP-2/3 masks, medical face masks, disposable gloves, hand and surface disinfectants, safety glasses, protective suits, and face shields). The following answers could be given for the question "As of early March, what was your inventory of the following protective and hygienic materials?": not relevant, completely inadequate (1), inadequate (2), adequate (3), completely adequate (4). Responses with "not relevant" were excluded for further analysis. The second predictor of interest was knowledge of an epidemic or pandemic plan (yes/no). General practitioners who reported having knowledge of a pandemic plan were further asked whether those plans helped them manage during the COVID-19 pandemic (yes/no). On the basis of these responses, two binary-coded variables were developed (no = 0, yes = 1). Age (in 10-year increments) and gender of the participating GPs were included as control variables in each regression model. Gender has been found to affect PP in some studies in the past (Aoyagi et al., 2015; Dickinson et al., 2013). Early in the COVID-19 pandemic, there was strong evidence that advanced age has an effect on disease progression (Promislow, 2020) and, hence, older GPs may have felt generally less prepared for the pandemic. Therefore, it was reasonable to include both variables in the model to control for any confounding effects. Because the study population of GPs was otherwise rather homogeneous, we refrained from including additional control variables.

1.2.4 Statistical analysis

Three groups of multivariate regression models were used to examine the factors affecting perceived PP. In the first set of models, three different PPE scores were compared. We assumed that there is an underlying interplay between relevant PPE items, hence, different PPE scores were computed. If an essential PPE item is missing, the protection chain may be interrupted, so that even items that are actually sufficiently on hand cannot develop their full protective effect. Therefore, it seemed appropriate to combine PPE items into PPE scores. Three types of PPE scores were obtained: 1. a general PPE score with all PPE items combined, 2. an exploratively investigated optimized PPE score with those PPE items that showed a significant association with PP, and 3. a masks-only score with the two PPE mask types (FFP-2/-3 and medical masks) as masks provide the greatest protection against SARS-CoV-2 infection. For each type of score, the numeric responses given to each included PPE item were summed and divided by the number of PPE items. Thus, each PPE score ranges between 1 and 4. The optimized PPE score is an exploratory compiled value used to compare the goodness of the models with the general PPE and the masks score. In the second regression model, the association of knowledge of a pandemic plan on PP was examined. In addition, a potential interaction effect between knowledge of a pandemic plan and stocked PPE on perceived PP was explored. Knowledge of a pandemic plan may have an interaction effect with stocked PPE, as more PPE maybe stored if a pandemic plan is known or higher PP can be reported with the same level of stockpiled PPE if a pandemic plan is known. The third model investigated whether a pandemic plan rated as beneficial was associated with perceived PP. Again, a potential interaction effect between a pandemic plan viewed as beneficial and PPE in storage was included in the model to test interactions similar to those described in model 2. Data preparation (tidyverse package [1.3.0]) and analysis (lessR package [3.9.9] and psych package [2.0.12]) were performed in R (version 4.03) and RStudio (version 1.3.1093).

1.3 Results

1.3.1 Sample

In total, 1,703 physicians participated in the first survey, including 535 GPs. Of these, 508 GPs responded to the relevant item on PP. In total, 265 male, 242 female, and one non-binary GP participated (Table 1.1); of these, 11.05% were 31–40 years old, 25.44% were 41–50 years old, 40.83% were 51–60 years old, and 22.68% were older than 60 years.

Table 1.1 General practitioners' (n = 508) characteristics and pandemic preparedness, personal protective equipment, and knowledge on a pandemic plan and its utility.

Variables		n (%)
Pandemic preparedness (n = 508)		
	very poor	134 (26.38)
	poor	197 (38.78)
	partly	132 (26.98)
	good	34 (6.67)
	very good	11 (2.17)
	missings	-
FFP-2/3 Masks (n= 507)		
	not relevant	4 (0.79)
	completely insufficient	315 (62.13)
	insufficient	125 (24.65)
	sufficient	52 (10.26)
	completely sufficient	11 (2.17)
	missings	1
Mouth and nose protection (n= 508)		
	not relevant	1 (0.20)
	completely insufficient	118 (23.23)
	insufficient	214 (42.13)
	sufficient	141 (27.76)
	completely sufficient	34 (6.69)
	missings	-
Disposable gloves (n= 508)		
	not relevant	-
	completely insufficient	12 (2.36)
	insufficient	61 (12.01)
	sufficient	305 (60.04)
	completely sufficient	130 (25.59)

	missings	-
Hand and surface disinfectants (n= 508)		
	not relevant	-
	completely insufficient	22 (4.33)
	insufficient	105 (20.67)
	sufficient	276 (54.33)
	completely sufficient	105 (20.67)
	missings	-
Safety glasses (n= 508)		
	not relevant	9 (1.77)
	completely insufficient	253 (49.80)
	insufficient	128 (25.20)
	sufficient	95 (18.70)
	completely sufficient	23 (4.53)
	missings	
Protective suits (n= 508)		
	not relevant	9 (1.77)
	completely insufficient	305 (60.04)
	insufficient	130 (25.59)
	sufficient	52 (10.24)
	completely sufficient	12 (2.36)
	missings	
Face shields (n= 507)		
	not relevant	57 (11.24)
	completely insufficient	331 (65.29)
	insufficient	81 (15.98)
	sufficient	30 (5.92)
	completely sufficient	8 (1.58)
	missings	1
Prior knowledge of any pandemic plan (n= 506)		
	no	436 (86.17)
	yes	70 (13.83)
	missings	2
if yes: Helpfulness of pandemic plan (n = 70)		
	no	42 (60.00)
	yes	28 (40.00)
	missings	-
Age (n = 507)		
	30 years and younger	-
	31 to 40 years	56 (11.05)
	41 to 50 years	129 (25.44)
	51 to 60 years	207 (40.83)
	older than 60 years	115 (22.68)
	missings	1
Gender (n = 508)		
	male	265 (52.16)
	female	242 (47.64)
	none-binary	1 (0.00)
	missings	-

Nearly two-thirds of GPs believed that they and their practice were poorly or very poorly prepared for a pandemic; only 8.84% reported that they were well or very well prepared. In terms of PPE stock, GPs reported that FFP-2/3 masks (89.78%), protective suits (85.63%), face shields (81.27%), safety glasses (75.00%), and medical face masks (65.36%), respectively, were completely insufficient or insufficient, whereas GPs reported that disposable gloves (85.63%) and hand and surface disinfectants (75.00%) were sufficient or completely sufficient at the beginning of March 2020. Cronbach's alpha for the seven PPE items was .81 (CI: .78; .83). There was no collinearity between different PPE items as no individual variance inflation factors did exceed 2 (Table 1.2). A high number of GPs (86.17%) had no knowledge of a pandemic plan; of the 70 GPs who had knowledge of such a plan, a slight majority (60%) rated such plans as not beneficial for the SARS-CoV-2 pandemic.

Table 1.2 Collinearity: Variance inflation factor and tolerance for personal protective equipment items.

	VIF	Tolerance
FFP-2/3 masks	1.750	.571
medical masks	1.500	.667
surgical gloves	1.917	.522
hand and surface disinfectants	1.939	.516
safety glasses	1.739	.575
protective suits	1.990	.503
face shields	1.553	.644

1.3.2 Multivariable linear regression models

Individuals with no information on age or gender or categories with less than three individuals per group were excluded from further investigation for statistical reasons (n = 2). In total, three groups of multivariate linear regression models were examined. The first model group examined the association of PPE and different PPE scores with PP. The second examined knowledge of a pandemic plan, and the third explored estimates of the utility of known pandemic plans on PP.

In the first set of linear regressions (Table 1.3), we examined PPE more closely. In the first linear regression model, the association between a general PPE score and PP was measured with age and gender as control variables. The PPE score showed to be a significant coefficient with a positive, non-standardized effect of 1.011 on PP; the adjusted R^2 value was .348. In the second model, a masks-only score was calculated on the basis of only the two mask types (FFP-2/3 and medical masks). The masks-only score explained the variance in the data analogously to the general PPE score in the first model (adj. R^2 =

.349), with a significant association of .797 ($p < .001$). All PPE items were included individually in the third model (Table 1.3). Because 61 physicians did not provide information on all PPE items, only 445 responses from GPs were included into this model. The model with the individual materials showed an adjusted R^2 of .359. FFP-2/3 masks (coef. = .263), medical masks (coef. = .252), protective suits (coef. = .229), and face shields (coef. = .207) had a significant positive effect on PP. On the basis of these exploratory findings, an optimized PPE score was generated in model 4 (Table 1.3), with the four significant PPE items. This score was found to explain the observed variances slightly better (adj. R^2 = .379) than the general PPE score or the masks-only score, with a significant effect of .928 ($p < .001$). In the first two models (general PPE score and masks-only score), the control variable age >60 was significantly negatively associated with PP.

Table 1.3 Multivariable linear regression model on personal protective equipment and pandemic preparedness among general practitioners.

	Model I (General PPE score)			**Model II** (Masks score)			**Model III** (Individual PPE materials)			**Model IV** (Optimized PPE score)		
Parameter	Estimate [95% conf. interval]	Std. error	P-value	Estimate [95% conf. interval]	Std. error	P-value	Estimate [95% conf. interval]	Std. error	P-value	Estimate [95% conf. interval]	Std. error	P-value
Intercept	.227 [-.109; .563]	.171	.185	.913 [.636; 1.190]	.141	<.001	.472 [.057; .887]	.211	.026	.785 [.509; 1.060]	.140	<.001
Independent variables												
FFP-2/3 masks							**.263 [.136; .390]**	**.065**	**<.001**			
medical face masks							**.252 [.147; .354]**	**.053**	**<.001**			
disposable gloves							.058 [-.083; .200]	.072	.419			
hand and surface disinfectants							.077 [-.051; .204]	.065	.238			
safety glasses							-.048 [-.151; .055]	.052	.356			
protective suits							**.229 [.096; .363]**	**.068**	**.001**			
face shields							**.207 [.081; .333]**	**.064**	**.001**			
PPE score	**1.011 [.889; 1.133]**	**.062**	**<.001**									

PPE score optimized										**.928 [.822; 1.033]**	**.053**	**<.001**
Masks score				**.797 [.701; .894]**	**.049**	**<.001**						
Control variables												
Age												
41 to 50 years	-.140 [-.388; .108]	.126	.267	-.128 [-.374; .118]	.125	.308	-.161 [-.407; .084]	.125	.198	-.116 [-.356; .124]	.122	.343
51 to 60 years	-.141 [-.376; .094]	.120	.238	-.195 [-.428; .039]	.119	.102	-.207 [-.438; .023]	.117	.078	-.127 [-.355; .101]	.116	.273
older than 60 years	-.185 [-.438; .067]	.128	.150	**-.258 [-.509; -.007]**	**.128**	**.044**	**-.262 [-.514; -.010]**	**.128**	**.041**	-.192 [-.437; .054]	.125	.125
Gender												
female	-.010 [-.152; .132]	.072	.887	-.066 [-.206; .075]	.072	.360	-.046 [-.191; .099]	.074	.537	-.066 [-.203; .072]	.070	.348
Number of obs.	506			505			445			505		
R^2	.355			.355			.375			.385		
Adj. R^2	.348			.349			.359			.379		
F-stats	54.986			54.994			23.623			62.568		
df	500			499			433			499		
p-value	<.001			<.001			<.001			<.001		

The next set of models (Table 1.4) examined the effect of knowledge of a pandemic plan on perceived PP. The first linear regression model (Table 1.4) included the variable regarding knowledge of a pandemic plan (no = 0, yes = 1) and the two control variables age and gender. A significant positive association of .521 with PP was found; however, the model quality was low, with an adjusted R^2 of .037. Adding the general PPE score containing all PPE items to the model (model 2, Table 1.4) improved the explained variance, with an adjusted R^2 value of .359. Both PPE score (coef. = .987) and knowledge of a pandemic plan (coef. = .300) are significantly positively associated with perceived PP. Similar results were observed when using the masks-only score (model 3, Table 1.4) as well as the optimized PPE score (model 4, Table 1.4). In addition, the covariance factor for age >60 showed significant associations with PP in the model with the masks-only score. The final variable included in the model was an interaction term between the general PPE score and knowledge on a pandemic plan (model 5, Table 1.4). The interaction term showed no association with perceived PP. Likewise, there was no significant interaction effect observed in the other two models with the other two PPE scores. These two models are not presented here.

Table 1.4 Multivariable linear regression model on knowledge of a pandemic plan and pandemic preparedness among general practitioners.

	Model I (Knowledge on plan)			**Model II** (Knowledge on plan + PPE score)			**Model III** (Knowledge on plan + masks score)			**Modell IV** (Knowledge on plan + optimized PPE score)			**Model V** (Knowledge on plan:PPE score)		
Parameter	Estimate [95 % conf. interval]	Std. error	P-value	Estimate [95 % conf. interval]	Std. error	P-value	Estimate [95 % conf. interval]	Std. error	P-value	Estimate [95 % conf. interval]	Std. error	P-value	Estimate [95 % conf. interval]	Std. error	P-value
Intercept	2.309 [2.046; 2.571]	.134	<.001	.240 [-.094; .574]	.170	.158	.895 [.620; 1.170]	.140	<.001	.780 [.507; 1.054]	.139	<.001	.341 [.014; .696]	.180	.059
Independent variables															
Prior knowledge of pandemic plan	**.521 [.278; .764]**	**.124**	**<.001**	**.300 [.100; .500]**	**.102**	**.003**	**.333 [.135; .532]**	**.101**	**.001**	**.274 [.079; .469]**	**.099**	**.006**	-.265 [-.971; .442]	.360	.462
PPE score				**.987 [.865; 1.109]**	**.062**	**<.001**							**.936 [.800; 1.073]**	**.069**	**<.001**
PPE score optimized										**.909 [.804; 1.015]**	**.054**	**<.001**			
Mask score							**.783 [.687; .879]**	**.049**	**<.001**						
Knowledge:PPE score													.253 [-.050; .555]	.154	.102
Control variables															
Age															
41 to 50 years	-.050 [-.351; .252]	.153	.746	-.147 [-.393; .099]	.125	.242	-.136 [-.380; .108]	.124	.273	-.123 [-.361; .116]	.121	.313	-.139 [-.385; .107]	.125	.266
51 to 60 years	-.150 [-.436; .136]	.146	.304	-.141 [-.375; .093]	.119	.236	-.191 [-.423; .040]	.118	.105	-.128 [-.355; .099]	.115	.268	-.140 [-.373; .093]	.119	.239
older than 60 years	-.304 [-.611; .003]	.156	.052	-.200 [-.450; .051]	.128	.119	**-270 [-.518; -.021]**	**.127**	**.034**	-.203 [-.446; .041]	.124	.103	-.194 [-.445; .056]	.127	.129
Gender															

female	-.088 [-.260; .085]	.088	.319	-.010 [-.151; .131]	.072	.893	-.060 [-.200; .079]	.071	.397	-.063 [-.200; .073]	.070	.363	-.010 [-.151; .131]	.072	.891
Number of obs.	504			504			503			503			504		
R^2	.046			.367			.369			.395			.370		
Adj. R^2	.037			.359			.362			.388			.361		
F-stats	4.843			47.968			48.409			54.085			41.638		
df	498			497			496			496			496		
p-value	<.001			<.001			<.001			<.001			<.001		

In the final group of models (Table 1.5), we considered only those GPs who reported being aware of a pandemic plan prior to the outbreak of the COVID-19 pandemic. These 70 GPs were asked whether they considered the known pandemic plan beneficial in managing the COVID-19 pandemic. The first regression model (model 1, Table 1.5) showed that the assessment of the pandemic plan as beneficial controlled for the two variables age and gender was not significantly associated with perceived PP. In the next model (model 2, Table 1.5), the PPE score was added. With the addition of the PPE score, the explanation of variance increased to an adjusted R^2 of .546; again, the PPE score itself showed a significant positive association with PP (1.195), but an assessment of the utility of the pandemic plan did not. In the final regression model (model 3, Table 1.5), an interaction term was formed between the assessment of the pandemic plan as beneficial and the PPE score. Assessing the pandemic plan as beneficial did not significantly interact with the PPE score on perceived PP ($p = .052$). The model indicated a good fit, with an adjusted R^2 of .566. Models with the other two scores did not show such close significance values. These two models are not presented here.

Table 1.5 Multivariable linear regression model of assessment of pandemic plan as beneficial and pandemic preparedness among general practitioners.

	Model I (Plan helpful)			**Model II** (Plan helpful + PPE-Score)			**Model III** (Plan helpful + PPE-Score + Plan helpful:PPE-Score)		
Parameter	Estimate [95% conf. interval]	Std. error	P-value	Estimate [95% conf. interval]	Std. error	P-value	Estimate [95% conf. interval]	Std. error	P-value
Intercept	2.717 [1.830; 3.603]	.444	<.001	-.207 [-1.079; .665]	.436	.637	-.668 [-1.639; .304]	.486	.174
Independent variables									
Pandemic plan helpful	.348 [-.196; .892]	.272	.206	.300 [-.062; .661]	.181	. 102	**1.476 [.236; 2.715]**	**.620**	**.020**

PPE score				**1.195 [.932; .459]**	**.132**	**<.001**	**1.404 [1.071; 1.737]**	**.166**	**<.001**
Pandemic plan helpful:PPE score							-.515 [-1.035; .005]	.260	.052
Control variables									
Age									
41 to 50 years	-.090 [-1.067; .887]	.489	.854	.038 [-.611; .687]	.325	.907	.023 [-.611; .658]	.318	.941
51 to 60 years	-.032 [-.991; .927]	.480	.947	.030 [-.606; .666]	.319	.925	.026 [-.596; .649]	.311	.933
older than 60 years	-.262 [-1.245; .721]	.492	.597	.100 [-.557; .758]	.329	.761	.118 [-.525; .761]	.322	.716
Gender									
female	-.237 [-.792; .318]	.278	.396	-.100 [-.470; .269]	.185	.590	-.124 [-.486; .238]	.181	.495
Number of obs.	70			70			70		
R^2	.042			.585			.610		
Adj. R^2	-.032			.546			.566		
F-stats	.566			14.805			13.837		
df	64			63			62		
p-value	.725			<.001			<.001		

1.4 Discussion

The aim of this study was to determine the association of stockpiled PPE and knowledge of pandemic plans on the PP of German GPs. It has been shown that the stock of PPE is the most important factor for PP. Different PPE scores differed only to a small extent in the variance explained. Knowledge of a pandemic plan also showed to be significantly associated with PP, but the association was much smaller in comparison with PPE. Assessment of the utility of a known pandemic plan showed no significant association with PP.

Numerous studies on the effect of the COVID-19 pandemic on the outpatient sector report low levels of PP in Germany (Siebenhofer et al., 2021) and in several other countries (Al-Ashwal et al., 2020; Sotomayor-Castillo et al., 2021), with only a few exceptions (Lau et al., 2021). The significance of availability and access to PPE for pandemic management was frequently observed during the COVID-19 pandemic (Fiorino et al., 2020; Sotomayor-Castillo et al., 2021) and during other pandemics (Fogel et al., 2017). However, many studies do not specifically address the particular inventory of different PPE items (Siebenhofer et al., 2021). Our results suggest that for reasons of simplicity and data minimization, it seems appropriate to focus on the stock of FFP-2/3 and medical masks in regard to PP in the context of the COVID-19 pandemic. The insignificant changes in the explained variance of the different PPE scores point in this direction. Because SARS-COV-2 is transmitted via the respiratory tract, this focus seems theoretical plausible as well. However, comparability between the different PPE scores and the model with individual PPE items is somewhat limited by missing individual values for different items. In particular, face shields were not considered relevant by 57 GPs. This high number of assessments of face shields as irrelevant contradicts to some extent the results of our model, where a significant positive association between face shields and PP was identified. Also other studies have shown that eye and face protection are important factors (Jefferson et al., 2020). The significant positive association of protective suits cannot be classified in the category of protection of eyes and face. Because the survey referred to the beginning of the pandemic in Germany in March–April 2020, this may can be interpreted as the effect of a great uncertainty among the GPs, who demanded complete protection on the face of great uncertainty.

The calculation of the mean value of the PPE scores was chosen in order to consider possible interactions between different PPE items. However, the results between the models with PPE scores and the model with the individual PPE items did not show large differences for the different approaches. Thus, an actual interaction between different PPE items has not been confirmed beyond doubt. It can also be argued that a simple average of PPE items does not adequately represent the interaction. It may would be conceivable to weight lower inventories to a greater extent. Different PPE items are needed for optimal protection, so the lack of just one item may make sufficient stocks in all other items inadequate.

Physicians face unique challenges in times of pandemics; therefore, a well-structured and widely known pandemic plan is believed to help establish effective strategies in advance (Sotomayor-Castillo et al., 2021). However, we found that the majority of GPs considered a pandemic plan not beneficial regarding the COVID-19 pandemic and that the assessment of a plan as beneficial did not show a significant effect on PP, whereas pre-existing knowledge of such a plan had a small positive effect on PP, which indicates that the specific content of the pandemic plan is somewhat less relevant. If engagement with a pandemic plan helps to address general and cross-pandemic processes in advance, it may create an overall pandemic awareness that can be adapted to individual challenges of a particular pandemic. Knowledge on a pandemic plan could than serve as proxy for pandemic awareness. Nevertheless, the variance explained by this predictor was rather small. However, the knowledge of a pandemic plan may also have an opposite effect of decreasing the perceived PP because the knowledge of such plans makes GPs aware of what they have to consider and how great their deficits truly are. Furthermore, other influencing factors of PP not examined here, include profound knowledge about the disease and the manner in which that knowledge is disseminated (Uyaroğlu et al., 2020) and proper use of PPE (Fogel et al., 2017), fear of transmitting the infection to families and loved ones (Fogel et al., 2017), compliance of healthcare workers with proper infection prevention (M.-H. Temsah, Al-Sohime, et al., 2020), emotional support (Kurotschka et al., 2021), and years of experience, and training in infection control (Dalky et al., 2021).

The interaction term examining the relationship between the assessment of the pandemic plan as beneficial and the stockpile of PPE items in model 3 in Table 1.4 showed a non-significant association between the assessment of a pandemic plan as beneficial and the PPE score that was just slightly above the threshold for significance at .05 ($p = .052$). Because only 70 GPs were even aware of a pandemic plan, this association should be further investigated. Our findings give rise to the hypothesis that when a pandemic plan is considered beneficial, the quantity of PPE items is not quite as crucial as without this assessment. Knowledge of a beneficial pandemic plan would than enhance the effect on perceived PP when the PPE items is in low supply, but when sufficient PPE are available, the positive effect of PPE on PP is no longer quite as large.

1.4.1 Limitations

As the cross-sectional online survey was conducted in the early stages of the COVID-19 pandemic in Germany, the study may have certain limitations. First, the survey was conducted in June–September 2020 retrospectively for the period March–April 2020. Therefore, the possibility that evaluations and assessments were ex post distorted between the observation and survey period cannot be eliminated, especially in the case of a dynamic event such as a pandemic. The survey period was chosen in order to consider the different summer school holidays in the German federal states. Second, although the sample was chosen for representative purposes, selection bias may have occurred owing to the low response rate and the distribution of the survey via the project homepage and the different specialist societies, which makes it challenging to draw conclusions about all German GPs. The low response rate may be explained by GPs' increased workload and uncertainty during a pandemic. Because PP among German GPs was generally rated as poor and this is a cross-sectional study, it is not clear whether there is a true causal relationship between stockpiled PPE and perceived PP. Moreover, the results on individual PPE items may have limited applicability to other pandemic scenarios as each pandemic presents different challenges to physicians and the infection and transmission pathways differ between pandemics. With regard to the provision of disinfectants, the inventory of hand and surface disinfectants was queried together. Accordingly, this survey cannot provide more precise information on the distinction between the two PPE materials.

Because this is an anonymous survey, it cannot be ruled out that participants may have responded to the survey more than once or that non-physicians participated. Though, at the beginning of the survey, it was asked whether the participant works as a physician in the outpatient sector. If this answer was negative, participation in the survey was terminated. Nevertheless, it cannot be ruled out that deliberately false statements were made here. The selected recruitment method does not allow representative conclusions for GPs in Germany. However, if we consider key sociodemographic characteristics of the study participants (Appendix

Table A.2) and compare them with the basic population of German GPs, it becomes clear that there are indications that the study population represents German GPs reasonably accurately. First of all, participants from all 16 German federal states and city states took part in the study. In view of the statistical data from the German Federal Register of Physicians, it appears that our study population was, on average, somewhat younger than the average German GPs (approximately 53 years compared to 55.4 years) (German Federal Registry of Physicians [Kassenärztliche Bundesvereinigung]. With regard to the gender distribution of the sample, this corresponds to the national average for GPs (52% male, 48% female) provided by the Federal Register of Physicians (Kassenärztliche Bundesvereinigung). About 90% of the physicians surveyed reported that they are self-employed. This is about 10 percentage points higher than the national average according to data from the 2020 physician statistics of the German Medical Association (German Medical Association [Bundesärztekammer], 2021). The overrepresentation of self-employed physicians can possibly be explained by the fact that they were contacted via fax. Although the invitation letters were personalized, the faxes may nevertheless have been presented to the practice owner. Also, in the case of practice email addresses, the practice owner may have been the primary contact or may have had access first. It is also possible that self-employed physicians have a higher level of commitment and identification with their own profession, so that a slight selection bias cannot be ruled out. Furthermore, a possible selections bias may also have implications for the reported PP. More job committed individuals may also have higher general preparedness. As a result, this could lead to a slight overestimation of the pandemic preparedness of the analyses in the population.

1.5 Conclusion

In Germany, a large proportion of GPs believed that they were poorly or very poorly prepared for a pandemic at the beginning of the COVID-19 pandemic; however, high PP among GPs can play a vital role in ensuring that the healthcare sector as a whole is better prepared for future pandemics. Pandemic preparedness can be explained in large part by the possession of sufficient PPE. Possession of FFP-2/3 masks, medical masks, protective suits, and face shields are significantly positively associated with PP. The findings of the study justify focusing on the stock of medical and FFP 2/3 masks among PPE. Overall, only 14% of GPs had knowledge about a pandemic plan. A multivariate linear regression analysis showed that knowledge of a pandemic plan is significantly associated to a small positive extent with perceived PP among German GPs. However, the positive association of PPE significantly exceeded that of knowledge of a pandemic plan. Whether the known pandemic plan was rated as beneficial or not showed no effect on addressing the challenges associated with COVID-19. The PP of German GPs thus depends largely on the stockpile of PPE; pandemic plans play a rather subordinate role.

Chapter 2

What impact does the attitude toward COVID-19 vaccination have on physicians as vaccine providers? A cross sectional study from the German outpatient sector

Abstract

Background: COVID-19 vaccination is recognized as a key component in addressing the COVID-19 pandemic. Physicians' attitudes toward vaccination are known to play a defining role in the management and dissemination of medical advice to patients. In Germany, outpatient practitioners are predominantly responsible for the dissemination of vaccines. ***Method:*** Using a cross-sectional online survey, 932 outpatient general practitioners, gynecologists, and pediatricians in Germany were asked in fall, 2021, about their attitude toward COVID-19 vaccination and – among others – their communication in vaccine discussions, their assessment of vaccine safety, and reporting of suspected adverse events. Physicians were divided into two groups along their attitudes toward COVID-19 vaccination. In addition, multivariate linear regression models were constructed to assess differences in communication strategies. ***Results:*** 92 % of physicians had a positive or very positive attitude toward COVID-19 vaccination. Own vaccination status, practice-based vaccination delivery, and estimated vaccination coverage among patients were significantly associated with the attitude toward vaccination. Confidence in vaccine safety was significantly lower among physicians with negative attitudes. There were no differences between the two groups in self-assessment of the ability to detect suspected adverse events, but there were differences in the observing and reporting of adverse events. For the linear regression models, we found that a more negative attitude toward COVID-19 vaccination was significantly associated with increased acceptance of patient refusal of COVID-19 vaccination and empathic behavior for patient concerns. In contrast, willingness to engage in a detailed persuasion consultation was significantly lower. Pediatricians showed significantly higher empathy for patient-side concerns compared to general practitioners, whereas gynecologists showed less empathy than general practitioners. ***Discussion:*** The physician's attitude toward COVID-19 vaccination influences the physician's practices as a vaccine provider. However, when providing medical advice and healthcare, the physician should focus on the actual needs of the patient.

2.1 Background

The SARS-COV-2 pandemic has been marked by the most rapid development and approval of vaccines and the roll-out of the largest vaccination programs in the history of modern medicine. In this regard, vaccines have been widely credited with making a significant contribution to addressing the pandemic by preventing severe disease progression and COVID-19-related deaths.

COVID-19 vaccines have been met with a wide range of attitudes, from supportive to hesitant or openly dismissive (Katzman & Katzman, 2021). Hesitant attitudes toward vaccines have a long history and exist for many vaccines (Kaufman et al., 2019; Wheeler & Buttenheim, 2013). Additionally, these hesitant attitudes are not limited to patients and parents (Ellingson et al., 2019; Jarrett et al., 2015; Yılmaz & Sahin, 2021) but are found among medical personnel in general (Karlsson et al., 2019; Lin, 2021) and physicians in particular (Učakar, 2019; Verger et al., 2015).

In Germany, the outpatient sector has played an important role in the COVID-19 vaccination campaign. Indeed, outside of high-risk groups, the nationwide vaccination campaign was largely conducted by the outpatient sector. This sector was likewise an important pillar in the booster vaccination campaign.

Physicians play multiple roles in vaccination. They are the main vaccine providers in Germany – and they are vaccine recipients themselves, of course. In addition, their actions are indirectly perceived by many patients as role models for health behavior (G. A. Poland, 2010; Vorsters et al., 2019). From research on other vaccinations, it is well-known that hesitant vaccine attitudes among healthcare workers (HCW) negatively affect vaccination recommendations to patients (McRee et al., 2014; Paterson et al., 2016), and that the physician's attitude toward a vaccination can affect their professional behavior (Neufeind et al., 2021). This phenomenon is especially relevant for physicians, as medical and physician staff play a significant role in communicating the benefits and risks of vaccinations to patients (Katzman & Katzman, 2021; Leung, 2019; Okoli et al., 2021; Scherr et al., 2016). For example, studies have shown that physicians are the most important source of information for patients (Ebi et al., 2022) and that medical advice from this professional group is one of the most important contributors to patients' vaccination decisions (Henrikson et al., 2015; Moss, 2016).

While some empirical research has focused on HCWs' attitudes toward COVID-19 vaccination and willingness to be vaccinated (Dzieciolowska et al., 2021; Galanis et al., 2021; İkiışık, 2022; Oliver et al., 2022; Presotto, 2022), the outpatient sector has been less frequently examined (İkiışık, 2022; Peterson, 2022). Moreover, there has been little empirical research in Germany and worldwide on the impact of the attitudes toward COVID-19 vaccination on physicians' performance as vaccine providers in the outpatient sector (Peterson, 2022).

In principle, the patient's interests should be at the center of the provision of medical information regarding medical interventions. Indeed, in Germany, physicians have a legal duty to inform patients about a medical intervention in a neutral and evidence-based manner. A greater understanding of physicians' attitudes toward COVID-19 vaccination and the impact on physician behavior toward patients may contribute to successfully address the challenges of the COVID-19 pandemic. Therefore, this study aims to

i) assess attitudes toward COVID-19 vaccination among main vaccine providers in Germany, and
ii) examine how physicians with negative attitudes toward COVID-19 vaccines differed from those with positive attitudes concerning their vaccination status, performing of vaccination services in their practice, confidence in detecting adverse events and reporting such events, and handling of vaccine discussions – both their communication self-efficacy when talking with patients about vaccinations and communication strategies used in those discussions.

This study provides a better understanding of vaccination efforts in the outpatient sector and the contribution of physicians during the COVID-19 pandemic.

German vaccination campaign

In Germany, the first COVID-19 vaccine (Comirnaty) was deployed in high-risk groups and medical professionals in December 2020; over time, other vaccines were subsequently added. By the beginning of the survey period of the present study (September 2021), four vaccines with conditional approval from the European Medicines Agency and a recommendation by the German Standing Committee on Vaccination (Ständige Impfkommission) were available for use in Germany. The first vaccine (Comirnaty) for adolescents (12–17 years) was licensed at the end of May 2021, and the license was extended at the end of November 2021 to a low-dose (pediatric vaccine) for children between 6 and 11 years of age. In Germany, the COVID-19 vaccination program was initially not delivered via the outpatient sector as is usually the case (e.g. for flu vaccination), but a nationwide structure of vaccination centers was established to enable the fastest possible distribution of vaccines. It was not until April 2021 — four months into the vaccination campaign — that physicians in private practice were integrated into the vaccination campaign on a nationwide basis. Over the course of 2021, vaccination recommendations on individual vaccines, their use in different age groups, intervals between two vaccinations, and cross-vaccinations were continuously changed, meaning that, by the end of 2021, a heterogeneous vaccination schedule had emerged (Appendix Figure B.1).

2.2 Methods

2.2.1 Design

The data analyzed for this study were collected in the third and final wave of a series of cross-sectional online surveys from the COVID-GAMS study (The COVID-19 Crisis and its impact on the German ambulatory sector—the physicians' view; German Federal Ministry of Education and Research (BMBF 01KI2099, https://www.bmbf.de/bmbf/en/). The third wave was conducted from mid-September until the end of November 2021. In this study, we focused on general practitioners (GPs), gynecologists, and pediatricians (PEDs), since these physicians are the main vaccine providers in Germany. Indeed, these physician groups are an important research target in terms of informational discussions about vaccination with patients as well as the occurrence of unexpected reactions to medical treatment.

2.2.2 Participants and recruitment

A total of 18,000 outpatient physicians were invited to participate in the online survey: GPs (6,500), dentists (4,000), gynecologists (2,000), PEDs (2,000), otolaryngologists (2,000), cardiologists (1,000), and gastroenterologists (500). This broader survey population from which we derived our study population was selected to examine outpatient care during the COVID-19 pandemic from the perspective of different medical disciplines. The address data for the random study sample were selected in collaboration with the National Association of Statutory Health Insurance Physicians. Personalized invitations were sent by fax and e-mail, followed by three reminders at 2-week intervals. In addition, physicians were invited to participate in the survey via the project homepage (www.covid-gams.de) and various specialist and medical associations were contacted which in turn informed about the survey via newsletters and homepages. Therefore, the study sample comprises of two groups regarding access to the survey: a group with personalized invitation and group who participated via an open survey link. The survey (including invitation letter, study and privacy information) was approved by the Ethics Committee of the University of Cologne (20–1169_1). The online survey was conducted anonymously, so in accordance with the ethics vote, only implicit consent had to be obtained. Participation in the survey was voluntary and could be terminated at any time. No expense allowance or payment was given for participation.

2.3 Measures

2.3.1 Survey instrument

Two series of questions were adopted from other vaccination surveys, modified for examining COVID-19 vaccination, and supplemented with questions about COVID-19 vaccination developed by the COVID-GAMS team and informed by representatives of the target groups. The questionnaire was checked for comprehensibility by scientists and ambulatory physicians not involved in the study development. All relevant survey questions and an English translation can be found in the supplementary file (Table B.1).

2.3.2 Attitude toward COVID-19 vaccination

Attitudes toward vaccination in general and COVID-19 vaccination, in particular, was measured using a self-developed item "What is your attitude toward vaccinations in general/COVID-19 vaccination?". Respondents indicated their attitude on a 4-point Likert scale (1 = very positive – 4 = very negative).

2.3.3 Vaccination status and providing

Own vaccination status could be stated as a binary response of either "fully vaccinated" or "not fully vaccinated". Whether COVID-19 vaccination services were offered in the physicians' practice was assessed using three self-developed categories: "yes", "no vaccination in own practice but referral of patients to other practices or vaccination centers", or "no". Furthermore, physicians were asked to provide estimates of the vaccination rate among their patients as a percentage.

2.3.4 Confidence in detecting suspected adverse events

Physicians' confidence in vaccine safety was assessed using a self-developed item ("Based on your experience in your daily practice, how safe do you consider the COVID-19 vaccines currently licensed in Germany regarding adverse events?”). For each of the four COVID-19 vaccines, respondents stated their confidence in vaccine safety on a 4-point Likert scale (1 = very unsafe – 4 = very safe). In addition, the participants could indicate that they were unable to assess vaccine safety. These answers were handled as missing data points. Pediatricians were asked exclusively about Comirnaty (BioNTech/Pfizer), as this was the only vaccine licensed in Germany for adolescents aged 12 years and older at the time. Physicians were asked to indicate on a 5-point Likert scale how easy or difficult it is for them to recognize possible adverse events of vaccines among their patients (1 = very easy – 5 = very difficult). Physicians could answer that they could not judge the ease of detecting such adverse events. In addition, four self-developed categories of responses were provided to assess the extent to which physicians were reporting suspected adverse events to the German authorities: “yes, all reported”; “yes, some reported”; “no, none reported”; “no, none seen”.

2.3.5 Communication self-efficacy and communication strategies

A set of questions on physicians’ confidence in communicating with patients about vaccines (communication self-efficacy) was based on the self-efficacy questionnaire used by Henrikson et al. (2015) with slight COVID-19-specific adaptations. Three aspects were examined, including confidence in talking about the risks of vaccines, in providing vaccine information resources, and in answering difficult questions about vaccines, and supplemented by an extension question from Neufeind et al. (2021): confidence in talking to patients or their legal representatives about vaccines. Answers were given on a 5-point Likert scale (1 = not at all confident – 5 = very confident). In addition, physicians were asked on a 5-point Likert scale how vaccine discussions with patients about COVID-19 vaccination differ from discussions about other vaccines (1 = much easier – 5 = much more difficult). To examine how physicians communicate with vaccine-hesitant patients about the COVID-19 vaccination, six behavioral strategies were asked separately in the questionnaire (communication strategies): acceptance of the patient’s decision not to be vaccinated without further discussion; recommendation to switch physicians; conducting a detailed persuasion consultation; expressing empathy for concerns; education about the individual risks of vaccination omission; and educating about the impact of non-vaccination on community protection. Answers were provided on a 5-point Likert scale (1 = does not apply at all – 5 = fully applies). We based our questions on the questionnaire used by Neufeind et al. (2021) in their study examining physicians' attitudes toward the measles vaccine mandate in Germany with slight COVID-19-specific adaptations.

2.3.6 Socio-demographic characteristics

Finally, socio-demographic factors were surveyed, including age (10-year groups), years of work experience, specialist group, gender, and employment status (self-employed, employed).

2.3.7 Statistical analysis

To examine the differences between physicians with positive attitudes toward COVID-19 vaccination and those with negative attitudes toward COVID-19 vaccination, we formed two groups according to their stated attitudes (very positive/positive vs. negative/very negative). For the communication strategies used in vaccine discussions with vaccine-hesitant patients, we built linear regression models with robust estimators. Data preparation (tidyverse package [1.3.1]) and analysis (stats package [4.1.3], car package [3.0–12], gtsummary package [1.5.2]) were performed in R (version 4.13) and RStudio (version 2022.02.3 + 492).

2.4 Results

2.4.1 Sociodemographic characteristics

A total of 1,122 physicians participated in the survey, with 552 GPs, 205 gynecologists, 175 pediatricians (n = 932). In all three specialist groups, the majority of participants were self-employed (GPs and gynecologists: 92.4 %, PEDs: 87.4 %). In terms of gender distribution, among GPs and PEDs, both genders were approximately equally represented (GPs: 53.8 % male, PEDs: 48.3 % male); however, nearly three-quarters of the surveyed gynecologists were female (73.9 %). In all three groups, the largest age group was those between 51 and 60 years (GPs: 41.9 %, gynecologists: 53.2 %, PEDs: 44.8 %). On average, GPs had 19.3 years of work experience, and PEDs and gynecologists had 16.7 years each. Among the PEDs and gynecologists, about 16 % of each group came from the five eastern German states, while, among the general practitioners, this proportion was 12.8 %. Altogether, 42.8 % of GPs, 29.8 % of PEDs, and 52 % of gynecologists participated via the open survey (Table 2.1).

Table 2.1 Characteristics of the 932 study participants (September-November 2021).

Characteristic	N	Overall, N = 932[1]	Specialist		
			GPs, N = 552[1]	Gynecology, N = 205[1]	PEDs, N = 175[1]
Employment status	924				
self-employed		845 (91.45 %)	509 (92.38 %)	184 (92.46 %)	152 (87.36 %)
employed		79 (8.55 %)	42 (7.62 %)	15 (7.54 %)	22 (12.64 %)
missing		8	1	6	1
Gender	917				
female		494 (53.87 %)	255 (47.05 %)	150 (73.89 %)	89 (51.74 %)
male		420 (45.80 %)	286 (52.77 %)	51 (25.12 %)	83 (48.26 %)
diverse		3 (0.33 %)	1 (0.18 %)	2 (0.99 %)	0 (0.00 %)
missing		15	10	2	3
Age	923				
30 years and younger		1 (0.11 %)	1 (0.18 %)	0 (0.00 %)	0 (0.00 %)
31 to 40 years		33 (3.58 %)	20 (3.66 %)	8 (3.94 %)	5 (2.87 %)
41 to 50 years		208 (22.54 %)	113 (20.70 %)	48 (23.65 %)	47 (27.01 %)
51 to 60 years		415 (44.96 %)	229 (41.94 %)	108 (53.20 %)	78 (44.83 %)
older than 60 years		266 (28.82 %)	183 (33.52 %)	39 (19.21 %)	44 (25.29 %)
missing		9	6	2	1
Years of service	926	18.22 (9.45)	19.28 (9.86)	16.67 (8.93)	16.66 (8.21)
missing		6	1	3	2
Federal states	904				
East		130 (14.38 %)	68 (12.81 %)	33 (16.42 %)	29 (16.86 %)
West		774 (85.62 %)	463 (87.19 %)	168 (83.58 %)	143 (83.14 %)
missing		28	21	4	3
Access to survey	932				
via personalized invitation		388 (41.63 %)	236 (42.75 %)	61 (29.76 %)	91 (52.00 %)
via open survey link		544 (58.37 %)	316 (57.25 %)	144 (70.24 %)	84 (48.00 %)

[1]*n (%); Mean (SD)*

2.4.2 Attitudes toward COVID-19 vaccination

Overall, 883 physicians stated both their attitudes toward vaccination in general and toward COVID-19 vaccines in particular (GPs: 521, gynecologists: 198, PEDs: 164). A large majority of physicians had a positive or very positive view of vaccinations in general (98.6 %), as well as toward COVID-19 vaccines in particular (91.9 %). However, while only 1.3 % reported a negative or very negative attitude toward vaccines in general, 8.1 % expressed negative or very negative attitudes toward COVID-19 vaccines (Figure 2.1). Therefore, there was a shift toward a more negative attitude toward COVID-19 vaccines. Gynecologists stated more positive attitudes toward COVID-19 vaccination than GPs and PEDs, but the difference was not significant (Kruskal-Wallis rank sum test, p =.192).

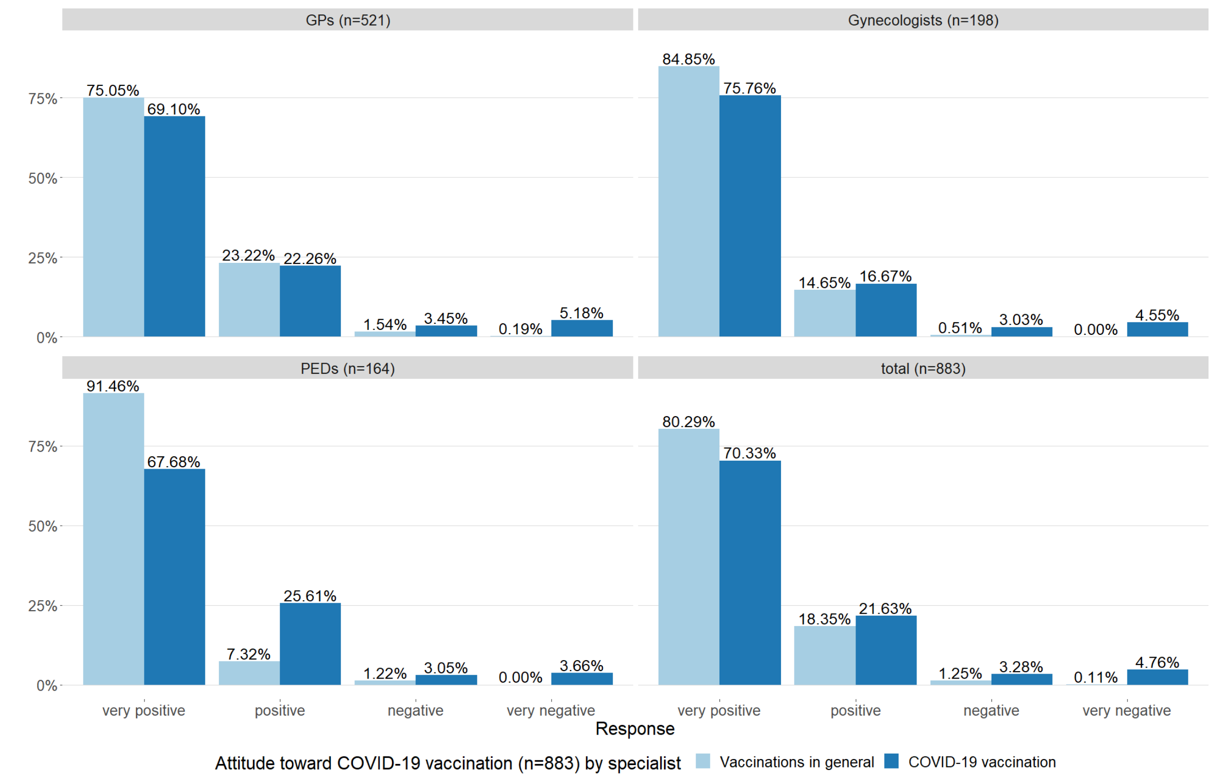


Figure 2.1 Attitudes toward vaccination in general and COVID-19 vaccination (Cross-specialty and specialty-specific) (n = 883).

2.4.3 Associations between attitude toward COVID-19 vaccination and own vaccination status

Overall, 93.7 % of physicians reported being fully vaccinated against COVID-19 in September-November 2021 (Table 2.2). Attitudes toward COVID-19 vaccination were significantly associated with the individual practitioner's vaccination status (Fisher's Exact Test, p <.001). Specifically, 99.1 % of the group with positive attitudes toward COVID-19 vaccination (n = 816) reported being fully vaccinated. 30 % of the group with negative attitudes toward COVID-19 vaccination (n = 70) reported being fully vaccinated.

Table 2.2 Cross table of vaccination status by attitude toward COVID-19 vaccination.

	Fully vaccinated	Not fully vaccinated	N
Positive/very positive	809 (99.14 %)	7 (0.86 %)	816
Negative/very negative	21 (30 %)	49 (70 %)	70
	830 (93.68 %)	56 (6.32 %)	886

2.4.4 Associations between attitude toward COVID-19 vaccination and vaccination services provided

Overall, 88 % of physicians reported providing COVID-19 vaccination services in their practice. Out of the 12 % who did not performed vaccination, 57.8 % referred patients to another practice or a vaccination center. There were significant differences (Fisher's

Exact Test, p <.001) between the two groups in terms of the extent to which physicians offered COVID-19 vaccines at their private practice (Table 2.3). While 97.1 % of the physicians with positive attitudes toward COVID-19 vaccination provided COVID-19 vaccines at their practice or referred patients to a colleague or a vaccination center, 68.3 % of the physicians with negative attitudes did so.

Table 2.3 Cross table of vaccination services provided by attitude toward COVID-19 vaccination.

	Yes	**No, but referred patients to a vaccination center or another practice**	**No**	**N**
Positive/very positive	716 (91.09 %)	47 (5.98 %)	23 (2.93 %)	786
Negative/very negative	31 (49.21 %)	12 (19.05 %)	20 (31.75 %)	63
	747	59	43	849

2.4.5 Associations between attitude toward COVID-19 vaccination and physician-estimated vaccination rate among patients

GPs (70.7 %) and gynecologists (72.4 %) both reported a similar mean for the estimated vaccination rate among their patients, while PEDs had a mean rate of 29 %. The estimated vaccination rate among adult patients differed significantly between the groups with positive and negative COVID-19 vaccination attitudes (Welch test, p <.001) for GPs (72 % vs. 55.1 % for the positive and negative attitude groups, respectively) but not for gynecologists (72.5 % vs. 70.8 % for the positive and negative attitude groups, respectively, *t*-test, p =.633). A significant difference was again found for PEDs (Mann-Whitney *U* test, p =.040), showing that those with negative attitudes estimated 15.3 % of adolescents 12–17 years of age to be vaccinated, whereas those with positive attitudes estimated 29.6 % to be vaccinated (Figure 2.2).

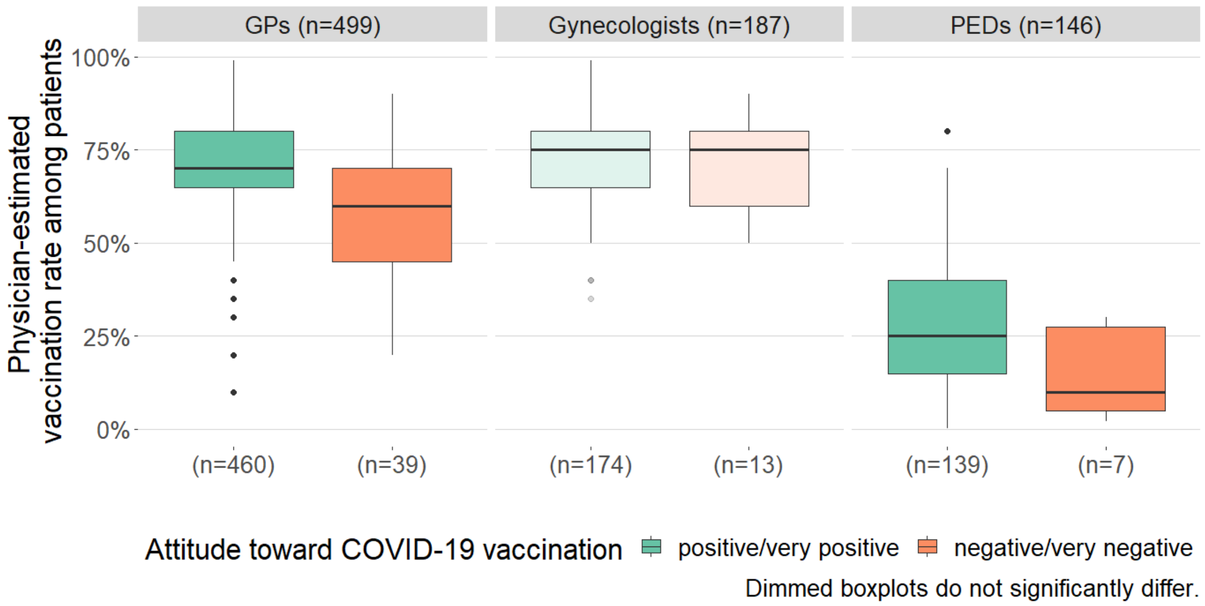


Figure 2.2 Estimated vaccination rate of patients by attitude toward COVID-19 vaccination and specialist group.

2.4.6 Associations between attitude toward COVID-19 vaccination and confidence in vaccine safety

There were significant differences in safety assessments for all four vaccines between the two groups (Mann-Whitney *U* test, p <.001), with those physicians with positive attitudes reporting more confidence in vaccine safety than those with negative attitudes (Figure 2. 3). Physicians with positive attitudes toward COVID-19 vaccination (n = 481) had significantly more confidence in the safety of mRNA vaccines (SD = 0.5) than the vector vaccines (SD = 0.7) (Mann-Whitney *U* test, p <.001). Physicians with negative attitudes (n = 35) showed no differences (Mann-Whitney *U* test, p =.975) in their safety assessment between the two vaccine groups (mRNA SD = 0.46; vector SD = 0.63). In this group, all vaccines were considered unsafe on average.

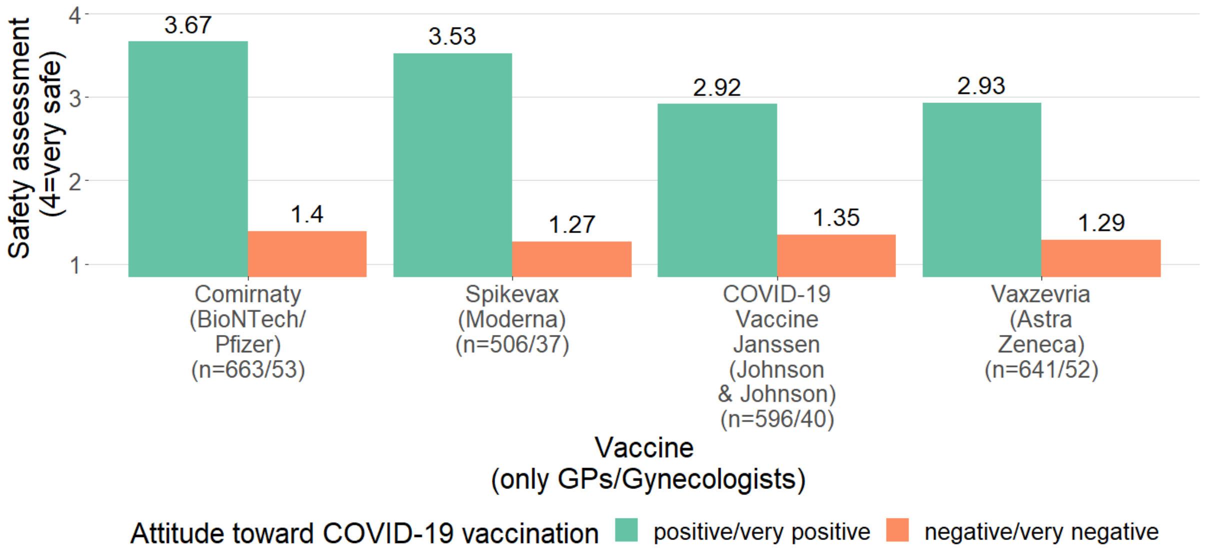


Figure 2. 3 Confidence in COVID-19 vaccine safety by attitude toward COVID-19 vaccination (binary) (n = 721).

PEDs (n = 165) were surveyed separately only for the then-approved vaccine for adolescents, Comirnaty (BioNTech/Pfizer). Nine PEDs were excluded as they indicated that they could not provide any information on safety. PEDs with a positive attitude (n = 147) had an average attitude score of 3.48 on the 4-point scale from very unsafe to very safe, whereas pediatricians with a negative attitude (n = 9) had an average attitude score of 1.44. This difference was significant (Mann-Whitney *U* test, p <.001).

2.4.7 Associations between attitude toward COVID-19 vaccination and reporting on suspected adverse events

Regarding the ease with which physicians indicated to identify possible adverse events (vaccination complications) of COVID-19 vaccination among their patients, no differences between both attitude groups could be established on a 5-point Likert scale (mean for positive attitude group = 3.06; mean for negative attitude group = 3.09; Mann-Whitney *U* test, p =.98). Overall, 51.4 % of physicians observed possible adverse events of COVID-19 vaccination (Table 2.4). The extent to which suspected adverse events were reported, differed significantly between the two groups (Pearson's Chi-squared test, p <.001). Overall, 95.2 % of all physicians with negative attitudes toward COVID-19 vaccination observed one or more adverse events in their patients. This was in contrast to 48 % of physicians with positive attitudes toward vaccination. Reporting of possible vaccine adverse events (all/some/none) differed between the two groups, but not significantly (Pearson's Chi-squared test, p =.159). While physicians with positive attitudes toward COVID-19 vaccination reported more frequently all adverse events observed (31.3 % vs. 20.3 % of physicians with negative attitudes), physicians with negative attitudes toward

COVID-19 vaccination more often reported some but not all adverse events (33.9 % vs. 24.9 % of physicians with positive attitudes). In both groups, nearly half of physicians stated not reporting observed adverse events (43.9 % vs. 45.8 % for the positive attitude group and negative attitude group, respectively).

Table 2.4 Cross table reporting of suspected side effects by attitude toward COVID-19 vaccination.

	Observed suspected adverse events			**N**	**None observed**	**N**
	All reported	**Some reported**	**None reported**			
Positive/very positive	117 (31.28 %)	93 (24.87 %)	164 (43.85 %)	374 (47.95 %)	406	780
Negative/very negative	12 (20.34 %)	20 (33.90 %)	27 (45.76 %)	59 (95.16 %)	3	62
	129	113	191	433 (51.43 %)	409 (48.56 %)	842

2.4.8 Associations between attitude toward COVID-19 vaccination and communication self-efficacy

Both groups felt mostly confident in their ability to speak with patients about COVID-19 vaccines (Figure 2.4). However, physicians with negative attitudes toward COVID-19 vaccination stated significantly higher confidence in their abilities to talk about vaccination (Mann-Whitney *U* test, $p = .027$), provide information (Mann-Whitney *U* test, $p = .016$), and answer difficult questions (Mann-Whitney *U* test, $p < .001$). Only the assessment of their ability to talk about the risks of vaccinations did not differ significantly between the two groups (Mann-Whitney *U* test, $p = .063$). Furthermore, on average, physicians indicated that vaccine discussions about COVID-19 were more difficult than those about other vaccines (3.59 on a 5-point Likert scale). There was no significant difference between the two groups in this regard (Mann-Whitney *U* test, $p = .255$).

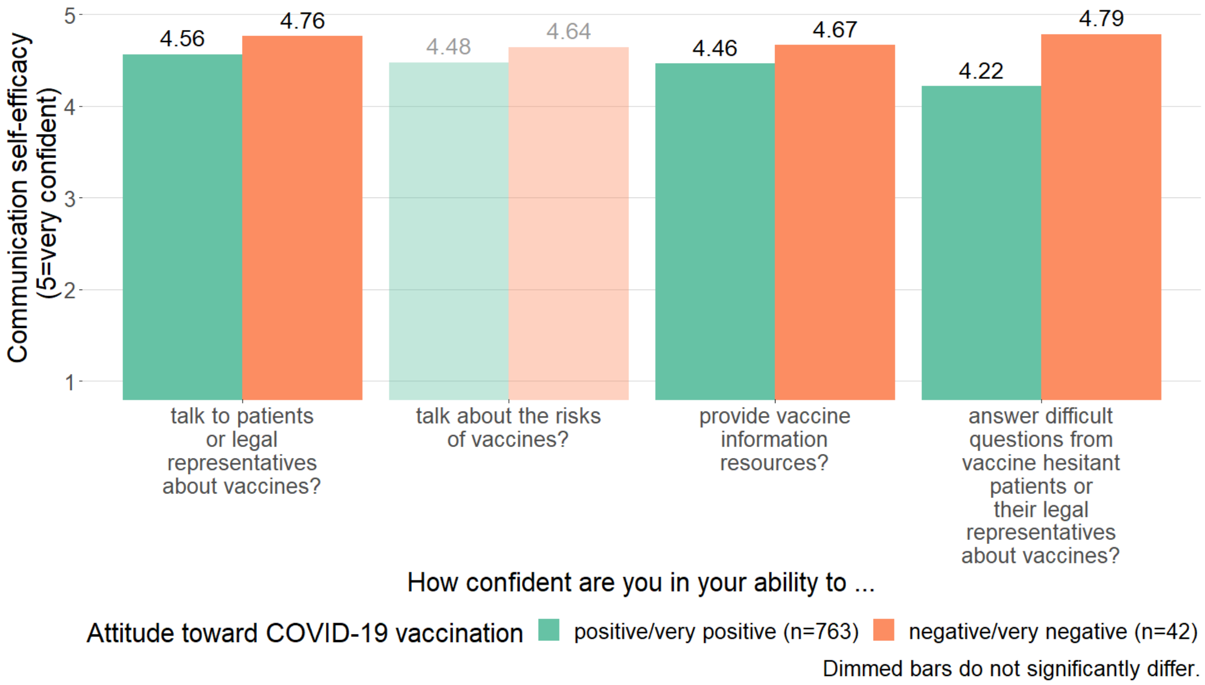


Figure 2.4 Communication self-efficacy by attitude toward COVID-19 vaccination (binary) (n = 805).

2.4.9 Associations between attitude toward COVID-19 vaccination and communication strategies utilized

We queried six physicians' communication strategies in COVID-19 vaccine discussions with declining patients (Figure 2.5). There were significant differences between the groups in five of the strategies. Physicians with positive attitudes reported more often conducting detailed, persuasive discussions with the patient (Mann-Whitney *U* test, p <.001) and informing patients about the consequences of non-vaccination for community protection (Mann-Whitney *U* test, p <.001). Physicians with negative attitudes reported more often accepting the patient's decision against vaccination without further discussions (Mann-Whitney *U* test, p <.001) and showing empathy for concerns (Mann-Whitney *U* test, p <.001). Both groups recommended a physician change only very rarely, and those with negative attitudes significantly less often (Mann-Whitney *U* test, p =.004). Finally, both groups, for the most part, stated to provide neutral explanations of the individual risks of omitting vaccination when confronted with a patient who declined the COVID-19 vaccine (Mann-Whitney *U* test, p =.186).

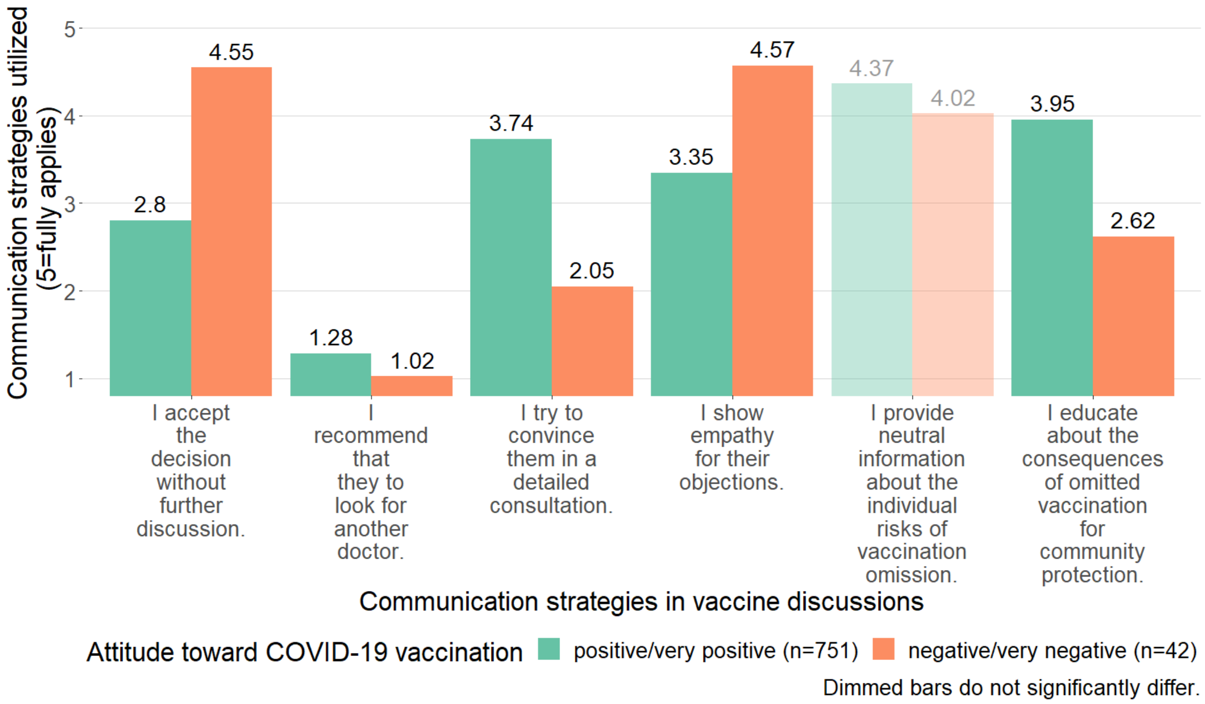


Figure 2.5 Communication strategies used by attitude toward COVID-19 vaccination (binary) (n = 793).

2.4.10 Multivariable linear regression models on communication strategies

We developed four regression models to control for the effect of possible confounders on the results regarding physician communication strategies in vaccine discussions. We omitted two behaviors in these models. First, we refrained from further investigating the item on providing neutral information since we found no significant differences. Second, we refrained from constructing a model for the recommendation to switch physician as the distribution of the values was skewed, and the assumption of normal distribution of the residual term was violated. The models assessed attitudes toward COVID-19 vaccination was on a 4-point Likert scale. Individuals with missing information on either of the variables and groups with three or fewer individuals (n = 4) were excluded from further investigation for statistical reasons. Ultimately, 744 individuals were included in the four multivariable linear regression models.

When examining attitudes toward COVID-19 vaccination alone (Table 2.5) and its association with the strategies in the information consultation, vaccination attitude was found to be significantly associated with all four strategies. Specifically, vaccination refusal was significantly more likely to be accepted without further discussion when the physician had more negative attitudes toward COVID-19 vaccination (0.714, p <.001). The same applies to expressing empathy toward concerns which is positively associated with negative vaccination attitudes (0.506, p <.001). In contrast, willingness to engage in extensive persuasion (−0.579, p <.001) and educating about community protection (−0.526, p <.001) decreased when physicians had more negative attitudes toward COVID-19 vaccination. The goodness of fit of the four models varied, showing relevant explanatory power, especially for acceptance of the patient's decision without discussion (R2 = 0.126) and willingness to engage in extensive persuasion (R2 = 0.105), whereas the predictive power values for willingness to engage in discussions about community protection (R2 = 0.080) and empathy for concerns (R2 = 0.076) were smaller.

Table 2.5 Physician communication strategies in vaccine discussions (uni- and multivariate).

	I accept the decision without further discussion		**I try to convince them in a detailed consultation**		**I show empathy for their objections**		**I educate about the consequences of omitted vaccination for community protection**	
	uni-variate model	**multi-ple model**	**uni-variate model**	**multi-ple model**	**uni-variate model**	**multi-ple model**	**uni-variate model**	**multi-ple model**
Attitude toward COVID-19 vaccination	**0.714*****	**0.708*****	**−0.579*****	**−0.520*****	**0.506*****	**0.346*****	**−0.526*****	**−0.494*****
CI	**[0.606, 0.823]**	**[0.530, 0.887]**	**[−0.735, −0.422]**	**[−0.728, −0.312]**	**[0.413, 0.599]**	**[0.191, 0.501]**	**[−0.695, −0.357]**	**[−0.701, −0.286]**
SE	**(0.055)**	**(0.091)**	**(0.080)**	**(0.106)**	**(0.047)**	**(0.079)**	**(0.086)**	**(0.106)**
Attitude toward vaccination in general		−0.006		−0.069		0.015		0.144
CI		[−0.227, 0.216]		[−0.276, 0.138]		[−0.203, 0.232]		[−0.123, 0.412]
SE		(0.113)		(0.106)		(0.111)		(0.136)
Fully vaccinated (0 = yes/1 = no)		0.068		−0.244		**0.833*****		−0.534
CI		[−0.520, 0.655]		[−0.901, 0.413]		**[0.485, 1.181]**		[−1.263, 0.196]
SE		(0.299)		(0.334)		**(0.177)**		(0.372)
Specialty (0 = GP/ 1 = pediatrician)		0.189		−0.033		**0.350*****		−0.020
CI		[−0.070, 0.448]		[−0.245, 0.180]		**[0.149, 0.552]**		[−0.244, 0.203]
SE		(0.132)		(0.108)		**(0.103)**		(0.114)
Specialty (0 = GP/ 1 = gynecologist)		0.205+		**−0.289****		−0.198+		**−0.234***
CI		[−0.015, 0.426]		**[−0.493, −0.085]**		[−0.410, 0.015]		**[−0.447, −0.022]**
SE		(0.112)		**(0.104)**		(0.108)		**(0.108)**
Gender (0 = male/1 = female)		−0.176+		0.137		−0.023		0.127
CI		[−0.359, 0.008]		[−0.029, 0.302]		[−0.192, 0.146]		[−0.042, 0.296]
SE		(0.093)		(0.084)		(0.086)		(0.086)

Age (0 = 31–40 years/ 1 = 41–50 years)		−0.170		0.053		−0.199		−0.166
CI		[−0.670, 0.330]		[−0.342, 0.449]		[−0.737, 0.340]		[−0.543, 0.211]
SE		(0.254)		(0.201)		(0.274)		(0.192)
Age (0 = 31–40 years/1 = 51–60 years)		−0.195		0.008		−0.329		−0.242
CI		[−0.682, 0.292]		[−0.370, 0.386]		[−0.857, 0.199]		[−0.605, 0.120]
SE		(0.248)		(0.192)		(0.269)		(0.185)
Age (0 = 31–40 years/ 1= +60 years)		−0.162		−0.083		**−0.758****		−0.101
CI		[−0.661, 0.337]		[−0.477, 0.310]		**[−1.297, −0.220]**		[−0.469, 0.268]
SE		(0.254)		(0.200)		**(0.274)**		(0.188)
Num.Obs.	744	744	744	744	744	744	744	744
R2	0.126	0.136	0.105	0.123	0.076	0.142	0.080	0.100
R2 Adj.	0.125	0.125	0.104	0.111	0.074	0.130	0.079	0.088
AIC	2358.7	2368.3	2203.4	2206.1	2270.9	2233.3	2278.3	2280.4
BIC	2372.6	2423.6	2217.2	2261.5	2284.7	2288.7	2292.1	2335.7
Log.Lik.	−1176.366	−1172.145	−1098.681	−1091.064	−1132.434	−1104.654	−1136.128	−1128.201
F	166.801	18.546	52.526	7.571	113.584	32.867	37.272	4.845
RMSE	1.18	1.17	1.06	1.05	1.11	1.07	1.11	1.10
Std.Errors	HC3	HC3	HC3	HC3	HC3	HC3	HC3	HC3

*+ p < 0.1, * p < 0.05, ** p < 0.01, *** p < 0.001*

Response options: 1= 'does not apply at all'; 2= 'rather does not apply'; 3= 'partly/partially'; 4= 'rather applies'; 5= 'fully applies'

When adding variables on the attitude toward vaccines in general, own vaccination status, and specialty, as well as control variables (age group, gender), the associations between attitudes toward COVID-19 vaccination and communication strategies remained significant for all models (Table 2.5). However, in all models the estimates decreased slightly.

In terms of the specific associations between certain confounding variables and communication strategies, not being fully vaccinated (n = 25) showed a significant positive association with empathy (0.833, p <.001). Additionally, PEDs showed significantly higher understanding and empathy for patient-side concerns than family physicians (0.350, p <.001). In contrast, gynecologists showed less willingness to engage in detailed, persuasive discussions (−0.289, p <.01) and were less willing to educate about the implication of non-vaccination on community protection (−0.234, p <.05). Explained variance improved slightly in all multivariate models compared to the univariate models, most notably for empathy for concerns (from R^2 of 0.076 to 0.142). All multivariate models and included variables were tested for multicollinearity with GVIF values below 2.

2.5 Discussion

This study examined how physicians in the outpatient sector thought about the COVID-19 vaccine and how their attitudes were associated with their performance as vaccine providers. Our results show that while physicians predominantly endorsed COVID-19 vaccines, there was a relevant fraction of hesitant physicians. This hesitancy translates to both vaccination status and communication strategies. Overall, physicians' attitudes toward COVID-19 vaccination were markedly more negative than their attitudes toward other vaccines.

2.5.1 Vaccination status

The vaccination rate (93.7 % fully vaccinated) among surveyed physicians is comparable with the results from the German COVID-19 vaccination rate monitoring (COVIMO), where the vaccination rate (at least one vaccination) for HCWs was reported to be 90.2 % (Robert Koch-Institut, 2021), and the hospital-based online survey on COVID-19 vaccination (KROCO), where 95 % of physicians working in hospitals reported being fully vaccinated (Robert Koch-Institut, 2022) for the observation period. Compared to other healthcare professionals, physicians tend to show a higher willingness to opt for COVID-19 vaccination, although outpatient physicians may show lower willingness than hospital-based physicians (Puertas et al., 2022; Robert Koch-Institut, 2021, 2022). The survey period included the first booster phase in Germany. It is possible that physicians with an infection had not yet received a third vaccination at this time and, thus, did not consider themselves fully vaccinated. Furthermore, a rare medical contraindication may not have permitted vaccination.

2.5.2 Vaccination attitude

While the majority of physicians viewed COVID-19 vaccination as positive or very positive, still, 8 % expressed negative or very negative attitudes in the fall of 2021. This is in line with other findings, where a comparable percentage of COVID-19 vaccination hesitancy among physicians was internationally reported (Leigh et al., 2022; Peterson, 2022). Multiple factors exit that influence the attitude on vaccination recommendations (Peterson, 2022; Robert Koch-Institut, 2022). Reasons for a negative attitude toward COVID-19 vaccination may be the rapid development and approval, the number of issued safety warnings, increased observation of vaccine breakthroughs and adverse events, or general dissatisfaction with the COVID-19 protective measures taken (Peterson, 2022). Among the 70 % of not fully vaccinated physicians with negative attitudes toward COVID-19 vaccination, it can be assumed that a fundamental distrust of COVID-19 vaccination has prevailed from the onset of the vaccination campaign. Since physicians were part of the prioritized first-line vaccination group, the decision not to get vaccinated could not stem from experiential knowledge with the newly development vaccines. In contrast, among the 30 % fully vaccinated physicians with negative attitudes toward COVID-19 vaccination, personal experiences and/or their patients' experiences with vaccination could serve as an explanation for their attitudes. These experiences with vaccinations could have led them to develop experience-driven negative attitudes. The link between physicians' vaccination status and their vaccination recommendations to patients (Neufeind et al., 2020), as well as the negative association between physician attitudes toward vaccination and recommendations to patients, are established from studies on other vaccinations (Verger et al., 2015). Accordingly, physician's recommendations to vaccinate are strongly influenced by their beliefs regarding the efficacy and safety of a vaccine (Karafillakis et al., 2016; Karlsson et al., 2019).

2.5.3 Vaccination safety

Physicians with negative attitudes appeared to have general safety concerns about all COVID-19 vaccines, whereas physicians with positive attitudes toward COVID-19 vaccine had high confidence in vaccine safety, but still differentiated between platforms: vector vaccines were rated lower in safety than mRNA vaccines. This is consistent with the greater number of safety warnings issued for this class of vaccines (8 out of 10) by the German authorities at that time (Paul-Ehrlich-Institut).

The association between negative attitudes and a lack of confidence in safety of COVID-19 vaccination is in line with the results from multiplied countries (Leigh et al., 2022) and other studies conducted among the German general population (Robert Koch-Institut, 2021) and hospital personnel (Robert Koch-Institut, 2022). It seems that it is one of the major determinant of vaccination behavior in general (Betsch et al., 2018; Larson et al., 2014). Consequently, physicians with negative attitudes toward COVID-19 vaccines had significantly more safety concerns about all COVID-19 vaccines and had more frequently observed adverse events in their patients that they attributed to the COVID-19 vaccines. Causality cannot be provided in our study. It is unclear whether experiencing adverse events triggered a lack of confidence and in turn a negative attitude toward the vaccine or whether a negative attitude shaped the perception and experience of the vaccine.

Regarding incomplete or non-reporting suspected adverse events, attitudes had no significant effect on reporting. Physicians with negative and positive attitudes toward the COVID-19 vaccine both indicated incomplete reporting. Nearly 50 % of respondents, who have observed adverse events, indicated to not have reported them according to §6 para. 1, no. 3 Infektionsschutzgesetz [Infection Protection Act], where a "suspicion of health damage exceeding the usual extent of a vaccination reaction" must be reported to German medical regulatory bodies. Importantly, these are suspected adverse events. The study cannot provide information on the type of suspected cases nor the further course of the reports. We did not include any further questions on the severity and/or number of suspected adverse events. Studies on reporting of adverse events indicate that more serious events are more likely to be reported (McNeil et al., 2013).

In a multinational qualitative study in several European countries, suspected adverse effects of vaccination were identified as the most important reason for a reluctance to vaccinate (Karafillakis et al., 2016). Fear of adverse events is also associated with vaccine hesitancy (Verger et al., 2015). Similarly, the development of new vaccines may contribute to concerns that the vaccines have not been tested sufficiently or for long enough and, thus, that unknown adverse events may occur (Karafillakis et al., 2016). Finally, dealing with suspected adverse events of COVID-19 vaccination is partly seen as a taboo subject by physicians in Germany who are concerned that this may encourage hesitancy to vaccinate (Rydlink, 2022).

2.5.4 Vaccination communication

In our data, we found that physicians with positive versus negative attitudes toward the COVID-19 vaccine used different communication strategies when discussing the vaccine with declining patients. Those with negative attitudes expressed more empathy with concerns and tended to accept the decision without further discussion. This is in line with previous works which reported that HCWs with a negative attitude toward vaccines are less likely to try to convince vaccine-hesitant patients to vaccinate (Collange et al., 2019; Karlsson et al., 2019; Napolitano et al., 2018; Paterson et al., 2016). Therefore, compared to HCWs with a positive attitude toward vaccines, HCWs with a negative attitude may be engaged in supporting patient autonomy more regarding their health decisions (Marcu et al., 2015). Importantly, empathy toward patients is considered a foundational component for having a successful discussion on vaccines (Dudley et al., 2018; C. M. Poland & Ratishvili, 2022). In addition, physicians with positive attitudes were more likely to try convincing declining patients in a detailed discussion and to educate them about the consequences of non-vaccination for community protection. This might imply that these physicians tend to use a directive style of communication – meaning to impose a vaccination on a patient rather than encouraging the patient to make an informed vaccination decision. This communication style is common in physicians but can spark reactance and alienate patients (Gagneur, 2020). Patients with different attitudes toward vaccination have different needs (Glenton et al., 2021; Leask et al., 2012; Opel et al., 2013). Therefore, it is useful for physicians who interact with patients with a deviating opinion during a vaccine discussion to pay special attention to the way they address patients. Communication should be conducted in a way to avoid further reinforcing rejectionist attitudes. For those who decline vaccination, showing empathy, letting patients express their concerns, and building a trusting relationship might be the first steps to evoke behavioral change (Gagneur, 2020).

2.5.5 Limitations

As this is a cross-sectional survey, causal relationships cannot be inferred. As a result, we cannot determine, e.g., whether negative attitudes toward COVID-19 vaccination arose from negative experiences (adverse events, vaccine breakthroughs) or whether negative attitudes influenced physicians' views on vaccine safety. In addition, a unidimensional question on general attitudes toward COVID-19 vaccination may not be specific enough. For example, it is conceivable that attitudes toward COVID-19 vaccination would differ for heterogeneous patient populations (such as by age, preexisting conditions, and infection status).

As participation in the survey was possible via an open online survey, there may have been a selection bias. However, the central outcome – attitude toward COVID-19 vaccination – does not significantly differ between the participants with the personalized invitation and those from the open survey (mean personalized: 1.41, mean open: 1.43; Mann-Whitney *U* test, p =.36).

The study population was not selected as representative of the German outpatient sector. However, key socio-demographic characteristics are, for the most part, in line with national averages for 2021 regarding age (54.2 years on average) (Kassenärztliche

Bundesvereinigung), and gender distribution (average female GPs: 48.8 %, female gynecologists: 70.9 %, and female PEDs: 57.9 %) (Kassenärztliche Bundesvereinigung). In regard to employment status, we see an overrepresentation of about ten percentage points for self-employed physicians in our study compared to the nationwide data for 2021 (Bundesärztekammer, 2022). Overall, a slight selection bias cannot be ruled out.

2.6 Conclusion

Physicians with negative attitudes toward the COVID-19 vaccine were less likely to be vaccinated themselves, less likely to provide COVID-19 vaccination services in their practice, and their estimate of their patients' vaccination coverage was lower. This highlights that physicians' attitudes toward the COVID-19 vaccine translate into various behaviors that impact their role as vaccine providers.

Chapter 3

Combining transformational leadership and social capital in hospital care quality: a longitudinal analysis from chief medical officers' perspective

Abstract

Background: Numerous studies have led to fruitful discussions on the possibility of improving the quality of care and patient safety. From a sociological perspective, prevailing shortcomings in this effort may stem from an underutilization of sociological concepts in studying the collective endeavour in healthcare. Recognizing the significance of social system factors influencing quality of care, we adopted parts of Parsons' AGIL scheme to identify two social prerequisites for collective organizational and quality action: Goal attainment and Integration. The hypothesis was that healthcare organizations which fulfil both prerequisites combined deliver better care quality in the long run. ***Methods:*** Based on a 2008 survey of medical directors of German hospitals, we administered a transformational leadership scale (proxy for goal attainment) and a social capital scale (proxy for integration). Using median splits, we created two groups of hospitals with high and low values on both functions. Survey data were matched in a longitudinal study (2012-2019) with quality data from nation-wide mandatory quality reports of German hospitals. We developed panel data models for two outcome variables: share of quality irregularities and share of quality deficiencies. ***Results:*** For 508 hospitals with 3,940 observations (representing one-third of all German hospitals), the combination of strong transformational leadership and high social capital was associated with a significantly lower proportion of quality irregularities, though not with quality deficiencies. ***Conclusion:*** The combination of perceived strong transformational leadership and social capital appears to significantly enhance the ability within the social system hospital to prevent hospital-wide quality irregularities. This synergy likely promotes goal-oriented collective action, particularly the collaborative efforts necessary to safeguard and improve quality of care and patient safety. It seems beneficial for hospital leadership to strategically strengthen both factors to amplify the organization's capacity for collective quality improvement. Moreover, we suggest that applying sociological theory can provide valuable insights into the social conditions essential for maintaining quality and safety in healthcare settings.

3.1 Introduction

Ensuring the quality of care and promoting patient safety stand as pivotal objectives within healthcare (Dixon-Woods et al., 2014). Although some interventions have proven effective (Groene et al., 2014; Leape, 2021), an overarching disillusionment prevails regarding the overall endeavours of improving quality of care (Schiff & Shojania, 2022; Singer et al., 2015).

A possible explanation is the ongoing challenge in deeply comprehending the intricate dynamics of quality and patient safety, coupled with the requisite contextual conditions (Bate et al., 2008), essential for the effective implementation of corresponding measures. Additionally, an emerging perspective emphasizes the need to complement this empirical approach with a theory-based approach in quality and safety (S. E. Lee et al., 2019). As a consequence, for instance, more initiatives have focused on developing new theories or frameworks through qualitative research (Johannessen et al., 2020)

Amidst these endeavours to theoretically underpin research on quality and safety, sociological theories, perhaps surprisingly, have been underutilized (Allen et al., 2016b). This raises concerns, considering that healthcare organizations operate as social systems, where quality initiatives emerge from collective learning and action, transcending individual efforts (Schiff & Shojania, 2022; Singer et al., 2015). Recognizing this gap, commendable efforts have emerged to integrate sociological theoretical approaches into research on quality and safety (Allen et al., 2016a). We endorse the ongoing exploration of this promising stance and seek to contribute to its advancement.

3.1.1 Sociological perspective on quality of care and patient safety

Despite safety researchers emphasizing the significance of system factors in quality and safety (Leape, 2021; Schiff & Shojania, 2022), it is surprising that social systems theory has not been systematically utilized more extensively. We firmly believe that among the wide array of sociological theories, sociological system theories hold particular promise in providing fresh insights into the systemic factors influencing quality and safety. Moreover, we contend that Talcott Parsons' structural-functional theory could be especially valuable in analysing the fundamental prerequisites for quality and safety (Bate et al., 2008; Johannessen et al., 2020; Singer et al., 2015). We argue that this form of systems theory, particularly the AGIL scheme (Parsons, 1978), could illuminate foundational prerequisites of quality and safety.

3.1.2 Goal attainment and integration as prerequisites for successful collective action

The quality of healthcare is significantly influenced by effective cooperation and coordination among hospital departments, health professionals, and individuals (Dixon-Woods et al., 2014). This enterprise hinges on the healthcare organization's overarching ability to consistently establish and pursue goals, and on its general ability to foster cohesive collective action. Two conditions of Parsons' AGIL scheme become instrumental here: Goal attainment and Integration. These prerequisites for collective quality actions are met when there is a prevailing pattern of goal attainment behaviour within the healthcare organization (G function) and when the network of employees is socially integrated (I function). The inherent characteristics of healthcare organizations as professional bureaucracies (Lega & Pietro, 2005) make it challenging to set common goals (Pronovost et al., 2003) and to be a socially integrated entity with high cohesion (Ansmann et al., 2020; Strömgren et al., 2016) and sufficient levels of collaboration (Reeves et al., 2017). Goal-oriented collective action, in general, and collective safety action, in particular, are facilitated by the general ability to set and pursue goals (G), to integrate the group of professionals (I), and to align the group towards these goals.

3.1.3 Combining goal attainment and integration: guiding the collective energy of an integrated group with a purpose

In the pursuit of ensuring and elevating quality and safety, the synergy of goal attainment and integration becomes paramount, forming what we term the GI factor. The full potential of the GI factor is realized, for instance, when leaders align organizational goals with the objectives of the cohesive collectively they lead (Sy & Choi, 2013), or when a unified collective strives for shared, self-determined, or co-created goals (Shamir, 2007). In both scenarios, a dynamic interplay between goal-orientation and social integration unfolds, guiding the collective energy of the cohesive group. And in both cases the collective energy of a cohesive group is given a direction by leaders.

Hence, our hypothesis posits that the presence of both goal attainment behaviour in leaders (G), measured through transformational leadership, and the social integration of health care professionals (I), measured by social capital, serves as a social foundation and predictor of quality and safety outcomes in hospitals.

3.2 Methods

We deployed a longitudinal study design. As the outcome variable is time constant, we deployed a panel regression model with between estimators. We used data from two sources. First, data on transformational leadership (TL, proxy for goal attainment) and social capital (SC, proxy for integration) came from a 2008 survey of medical directors of German hospitals. Second, information on the quality of care, patient safety, and general organizational data of hospitals was derived from the national-wide mandatory quality reports of German hospitals across the years 2012–2019.

3.2.1 Data source 1: Quality reports of German hospitals

German hospitals are obliged to publish a quality report. Data are collected and publicly accessible, published in accordance with Sections 136 and 137 of the German Social Security Code V. The reports provide a comprehensive insight into the structures, services, and quality of the respective hospitals and their specialist departments. Hospitals document various quality indicators and scores. If previously defined reference values are exceeded, a structured dialogue is initiated with the respective hospital. A structured dialogue aims to assess whether arithmetically conspicuous results are really qualitatively conspicuous and clarifies why they have occurred.

Since 2005, these reports were compiled and published every two years. Since 2012, this reporting has been conducted annually. Furthermore, from 2012 onward, a new system for evaluating the results of quality indicators and conspicuousness criteria was established. Thus, we have chosen the period from 2012 to 2019, the last year before the COVID-19 pandemic, since the measures taken in the course of the pandemic have significantly influenced everyday hospital practice (Ignatowicz et al., 2023).

Outcome variable: Classification of quality indicators

Within the quality reports, quality indicators are grouped into seven assessment categories (Table 3.1). For our analysis, we omitted all quality indicators where a valuation was not intended (category *N*). In addition, we assigned the remaining six categories into three groups:

- no quality issues: quality indicators with results within the reference range (category *R*) and quality indicators that have undergone the process of a structured dialogue due to conspicuous results but for which the evaluation established qualitative inconspicuous results (category *U*);

- quality irregularities: quality indicators that have undergone the process of a structured dialogue and where some sort of quality irregularities was detected (categories *H*, *D*, *S*);
- quality deficiencies: quality indicators for which a quality deficiency was identified during the structured dialogue (category *A*).

From our assignment, we formed two separate outcome variables for each hospital: 1) share of quality indicators with quality irregularities and 2) share of quality indicators with quality deficiencies. The denominator for both groups was the total number of all quality indicators for which a valuation was intended.

Table 3.1 Categorization of quality indicators. Depiction according to IQTIG (based on IQTIG – Institut für Qualitätssicherung und Transparenz im Gesundheitswesen, 2022a; own translation).

Category	Classification	Number	Explanatory note	Authors' classification for analysis
N	Valuation not intended	01	Quality indicator without result, as no corresponding cases have occurred.	*Omitted from analysis*
		02	Reference range is not defined for this indicator.	
		99	Other (explained in the comments)	
R	Result within reference range	10	Result is computationally inconspicuous; no structured dialogue is necessary.	No quality issues detected
U	Evaluation according to structured dialogue as qualitative inconspicuous	30	Correct documentation is confirmed (data validation)	
		31	Special clinical situation.	
		32	The deviating result is explained by individual cases.	
		33	No evidence of deficiencies in medical quality (isolated documentation problems).	
		99	Other (explained in the comments)	
H	Institution notified of arithmetically conspicuous result	20	Request for internal quality management to analyse the computational abnormality.	Quality irregularities detected
		99	Other (explained in the comments)	
D	Evaluation not possible because of faulty documentation	50	Incomplete or incorrect documentation.	
		51	Software problems have caused incorrect documentation.	
		99	Other (explained in the comments)	
S	Other	90	Waiver of measures in structured dialogue.	
		91	Structured dialogue not yet completed.	
		99	Other (explained in the comments)	
A	Evaluation according to structured dialogue as qualitative conspicuous	40	Incorrect documentation is confirmed (data validation)	Quality deficiencies detected

3.2.2 Data source 2: ATräk survey

Data on SC and TL were obtained from a study on effects of hospital ownership structures on quality of healthcare in 2008 (Gloede et al., 2013). Medical directors were chosen as suitable survey subjects due to their strategic and unique perspectives on organizational and clinical expertise as key informants (Pfaff & Braithwaite, 2020). Furthermore, they influence and assess processes, structures, and organizational culture (Nilsen et al., 2020; Pfaff & Braithwaite, 2020).

In the survey, SC was measured by a validated scale (Social Capital of Organisations (Ansmann et al., 2020)) with six aspects of the overall construct: mutual understanding, trust, warm circle, mutual help, we-feeling, and common values. A Likert scale was used for the responses, ranging from "strongly disagree" (1) to "strongly agree" (4). TL was surveyed by a six-item scale based on six key behaviours of transformational leaders identified by Podsakoff et al. (1990). Medical directors were asked to assess how often the executives of their hospital, such as top management, head physicians, and nursing management, exhibited transformational behaviour. A Likert scale was used ranging from "never" (1) to "always" (5).

Explanatory variable: GI factor

For our analysis, we dichotomized both scales using a median split technique; thus, two levels of the GI factor were generated (Table 3.2): High GI level (high SC and high TL) and low GI level (low SC and/or low TL).

Table 3.2 The goal-integration factor: goal-oriented integrated collective (based on Pfaff & Braithwaite, 2020.

	Integration=Low (SC<median [SC])	**Integration=High (SC>=median [SC])**
Goal attainment=High (TL<median [TL])	Goal-oriented individuals	Goal-oriented cohesive collective (GI factor)
Goal attainment=Low (TL>=median [TL])	Non-goal-oriented individuals	Non-goal-oriented cohesive collective

3.2.3 Statistical analysis

To analyse whether there is a difference between the two GI levels regarding quality of care and patient safety, we developed a panel data model with a between estimator as the main explanatory variable (GI factor) remained invariant over time. The organizational variables ownership (public, non-profit, private), number of beds (per 100), and teaching status (no teaching assignment, academic teaching hospital, university hospital) were included as control variables. Data preparation and analysis were performed with the R software (version 4.3.2).

3.3 Results

3.3.1 Description of the study population

From the 551 hospitals of the ATräk study, 22 were excluded as they did not publish any quality reports between 2012–2019, and 21 were excluded because they submitted quality reports for multiple sites of one hospital. Overall, data on 508 hospitals with 3,940 observations were included in the study population (Table 3.3), representing roughly one-third of all German hospitals. 205 hospitals had a high GI factor, while 303 hospitals had a low GI factor. The mean score on the TL was 3.57, while for the SC it was 2.9.

A sharp decrease in the average number of quality indicators per hospital can be noted, from 161.4 in 2012 to 81.8 in 2019. Especially from 2015 on, a sharp decline can be seen. On average, 77.9 quality indicators were classified as evaluable by the performing authorities. Over time, the share of evaluated quality indicators increased from 68.6 % in 2012 to 84.9% in 2019. On average, 8.1 quality indicators (10.4%) resulted in a structured dialogue per hospital annually. The absolute number of structured dialogues decreased over time (2012: 10.9 to 2019: 6.9), while the relative number or share of structured dialogues remained constant. Furthermore, the absolute number of detected quality irregularities decreased over time (2012: 6.0 to 2019: 3.3), while the relative number or share of quality irregularities slightly decreased (2012: 5.4% to 2019: 4.8%). Finally, the absolute number of detected quality deficiencies remained constant over time (2012: 1.2 to 2019: 1.1); accordingly, the relative number or share increased (2012: 1.1% to 2019: 1.5%).

Table 3.3 Descriptive table of study population (N = 3,940, n = 508).

Characteristic	Overall, N = 3,940 (n = 508)[1]	2012, N = 489[1]	2013, N = 497[1]	2014, N = 503[1]	2015, N = 494[1]	2016, N = 494[1]	2017, N = 490[1]	2018, N = 490[1]	2019, N = 483[1]
GI-factor									
low	2,350 (59.64%)	291 (59.51%)	294 (59.15%)	301 (59.84%)	295 (59.72%)	295 (59.72%)	292 (59.59%)	294 (60.00%)	288 (59.63%)
high	1,590 (40.36%)	198 (40.49%)	203 (40.85%)	202 (40.16%)	199 (40.28%)	199 (40.28%)	198 (40.41%)	196 (40.00%)	195 (40.37%)
Transformational leadership	3.57 / 3.67 (0.55)	3.58 / 3.67 (0.55)	3.58 / 3.67 (0.55)	3.57 / 3.67 (0.55)	3.57 / 3.67 (0.55)	3.57 / 3.67 (0.55)	3.57 / 3.67 (0.55)	3.57 / 3.67 (0.55)	3.57 / 3.67 (0.55)
Social capital	2.90 / 3.00 (0.48)	2.90 / 3.00 (0.48)	2.90 / 3.00 (0.47)	2.90 / 3.00 (0.48)	2.90 / 3.00 (0.48)	2.90 / 3.00 (0.48)	2.90 / 3.00 (0.48)	2.90 / 3.00 (0.48)	2.91 / 3.00 (0.47)

Characteristic	Overall, N = 3,940 (n = 508)[1]	2012, N = 489[1]	2013, N = 497[1]	2014, N = 503[1]	2015, N = 494[1]	2016, N = 494[1]	2017, N = 490[1]	2018, N = 490[1]	2019, N = 483[1]
Number of beds	335.74 / 258.00 (281.68)	332.91 / 253.00 (277.50)	331.41 / 253.00 (272.18)	331.85 / 261.00 (274.14)	336.40 / 258.00 (280.42)	334.12 / 255.00 (285.89)	340.66 / 261.50 (285.00)	341.03 / 260.50 (292.39)	337.77 / 260.00 (287.57)
Ownership									
non-profit	1,757 (44.59%)	217 (44.38%)	225 (45.27%)	227 (45.13%)	223 (45.14%)	220 (44.53%)	217 (44.29%)	217 (44.29%)	211 (43.69%)
private	545 (13.83%)	67 (13.70%)	65 (13.08%)	68 (13.52%)	66 (13.36%)	69 (13.97%)	70 (14.29%)	70 (14.29%)	70 (14.49%)
public	1,638 (41.57%)	205 (41.92%)	207 (41.65%)	208 (41.35%)	205 (41.50%)	205 (41.50%)	203 (41.43%)	203 (41.43%)	202 (41.82%)
Teaching status									
no teaching assignment	1,628 (41.32%)	227 (46.42%)	218 (43.86%)	213 (42.35%)	199 (40.28%)	203 (41.09%)	194 (39.59%)	189 (38.57%)	185 (38.30%)
academic teaching hospital	2,150 (54.57%)	245 (50.10%)	262 (52.72%)	273 (54.27%)	277 (56.07%)	268 (54.25%)	273 (55.71%)	278 (56.73%)	274 (56.73%)
university hospital	162 (4.11%)	17 (3.48%)	17 (3.42%)	17 (3.38%)	18 (3.64%)	23 (4.66%)	23 (4.69%)	23 (4.69%)	24 (4.97%)
Number of quality indicators	107.68 / 99.00 (50.09)	161.41 / 165.00 (49.24)	148.73 / 152.00 (46.48)	129.74 / 132.00 (41.72)	84.91 / 85.50 (39.40)	88.05 / 86.50 (36.91)	84.51 / 83.00 (34.48)	81.21 / 84.00 (28.31)	81.78 / 81.00 (31.41)
Number of quality indicators (without quality indicators no evaluation intended)	77.88 / 75.00 (34.64)	110.77 / 111.00 (38.19)	102.27 / 102.00 (33.58)	80.05 / 80.00 (26.23)	53.34 / 53.00 (24.90)	73.56 / 72.00 (29.94)	66.92 / 67.00 (26.41)	66.45 / 66.00 (26.51)	69.46 / 68.00 (28.31)
Structured dialogues	8.11 / 7.00 (5.44)	10.88 / 10.00 (6.71)	9.77 / 9.00 (5.80)	8.79 / 8.00 (5.25)	6.15 / 6.00 (4.35)	8.26 / 7.00 (5.20)	7.04 / 6.00 (4.62)	7.12 / 6.00 (4.66)	6.87 / 6.00 (4.87)
Detected quality irregularities	3.96 / 3.00 (3.53)	6.03 / 5.00 (4.76)	4.90 / 4.00 (3.62)	4.23 / 4.00 (3.43)	3.02 / 2.00 (2.66)	3.90 / 3.00 (3.30)	3.24 / 3.00 (2.90)	3.04 / 2.00 (2.66)	3.30 / 2.00 (3.30)
Detected quality deficiencies e	1.09 / 1.00 (1.52)	1.16 / 1.00 (1.61)	1.13 / 1.00 (1.70)	1.04 / 1.00 (1.44)	0.95 / 0.00 (1.43)	1.14 / 1.00 (1.45)	1.02 / 1.00 (1.51)	1.19 / 1.00 (1.55)	1.07 / 1.00 (1.47)

[1]Mean / Median (SD); n (%)

3.3.2 Visualization of the trend over time

We first visualized our two outcome variables (share of quality irregularities and share of quality deficiencies) with respect to the GI factor (Figure 3.1). Overall, the share of quality irregularities decreased, although the trend fluctuated over time. Hospitals with a low GI level showed a higher share of quality irregularities than hospitals with a high GI factor. The confidence intervals overlapped only in 2017 and 2019.

For the second examination of the quality indicators rated as deficiencies, the graphical visualization was similar to that of the previous examination. Overall, the trend that hospitals with a high GI factor had a lower share of quality deficiencies persisted for all years except 2014, though the difference between the GI levels was less distinct and more profound in the latter years. The confidence intervals did not overlap only in 2012, 2016 and 2017.

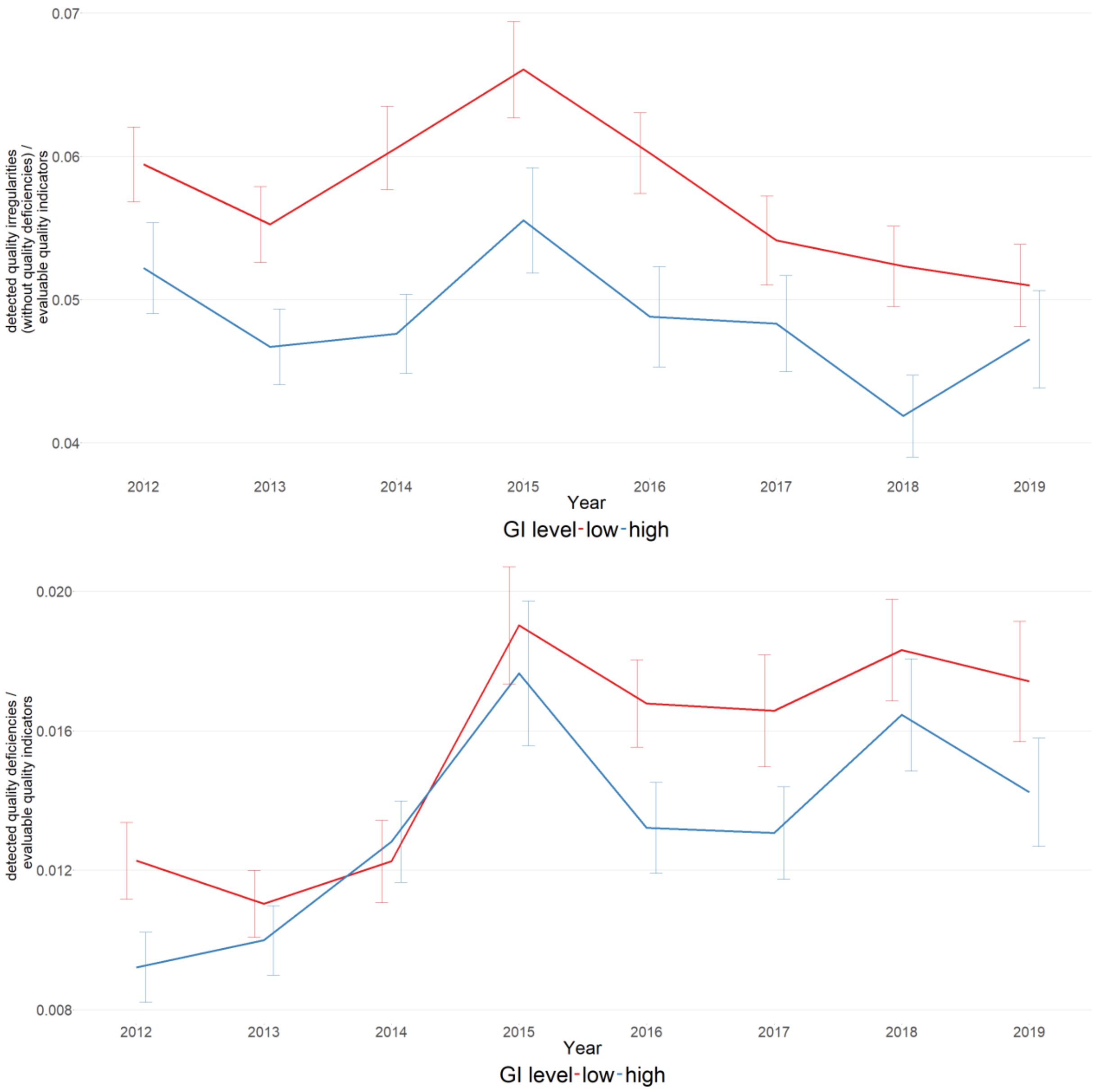


Figure 3.1 Year-by-year (2012–2019) share of detected quality irregularities (quality indicator classifications H, D, and S) with CI (upper chart) and share of quality deficiencies (quality indicator classification A) with CI (lower chart) by all evaluable quality indicators.

3.3.3 Panel model with a between-effects estimator

We constructed six panel models to analyse the effect of the GI factor variable on the share of quality irregularities and deficiencies (Table 3.4). First, a base model for quality irregularities was constructed (Model 1) with the controlling variables ownership, number of beds (per 100), teaching status, TL, and SC. Both TL and SC showed no significant associations. The R^2 for the model was .085. From this base model, we added the GI factor variable to model 2. Hospitals with a high GI level had a significantly lower share of quality indicators with reported quality irregularities (-.009, p = .001). Compared to the base model, the R^2 rose by .097. In the third model we controlled for SC and TL. The negative association (-.011) for the GI factor remained significant (p = .009).

For the next three models, we changed the outcome variable to the share of quality deficiencies. In model 4, the base model for quality deficiencies, both TL and SC showed no significant associations. The R^2 was .047. Again, in model 5, with the GI factor incorporated, it was apparent that a high GI level was associated with a significant lower share of quality deficiencies (.002; $p < .046$). The R^2 was .044. When controlled for SC and TL (Model 6) the association no longer remained significant.

Table 3.4 Linear regression models (between-effects estimator) for the GI variable effect on the share of structured dialogues and quality deficiencies (n = 508).

	Quality irregularities			**Quality deficiencies**		
	Model I: (base model)	**Model II:** (GI model)	**Model III:** (GI model controlled)	**Model IV:** (base model)	**Model V:** (GI model)	**Model VI:** (GI model controlled)
Intercept	0.085***	0.068***	0.063***	0.023***	0.015***	0.021***
95%-CI	[0.064, 0.105]	[0.062, 0.074]	[0.036, 0.089]	[0.015, 0.030]	[0.013, 0.017]	[0.012, 0.031]
SE	(0.011)	(0.003)	(0.013)	(0.004)	(0.001)	(0.005)
p-value	(<0.001)	(<0.001)	(<0.001)	(<0.001)	(<0.001)	(<0.001)
GI-factor high (RC: GI-factor low)		**-0.009****	**-0.011****		**-0.002***	-0.001
95%-CI		**[-0.015, -0.004]**	**[-0.019, -0.003]**		**[-0.004, 0.000]**	[-0.004, 0.002]
SE		**(0.003)**	**(0.004)**		**(0.001)**	(0.001)
p-value		**(0.001)**	**(0.009)**		**(0.046)**	(0.637)
Ownership: public (RC: non-profit)	**0.007***	**0.007***	**0.007***	0.002	0.002	0.002
95%-CI	**[0.001, 0.014]**	**[0.001, 0.014]**	**[0.001, 0.014]**	[-0.001, 0.004]	[-0.001, 0.004]	[-0.001, 0.004]
SE	**(0.003)**	**(0.003)**	**(0.003)**	(0.001)	(0.001)	(0.001)
p-value	**(0.020)**	**(0.020)**	**(0.020)**	(0.189)	(0.178)	(0.190)
Ownership: private (RC: non-profit)	-0.001	-0.001	-0.001	0.002	0.002	0.002

	Quality irregularities			Quality deficiencies		
	Model I: (base model)	**Model II:** (GI model)	**Model III:** (GI model controlled)	**Model IV:** (base model)	**Model V:** (GI model)	**Model VI:** (GI model controlled)
95%-CI	[-0.010, 0.008]	[-0.010, 0.007]	[-0.010, 0.007]	[-0.002, 0.005]	[-0.001, 0.005]	[-0.002, 0.005]
SE	(0.004)	(0.004)	(0.004)	(0.002)	(0.002)	(0.002)
p-value	(0.820)	(0.773)	(0.754)	(0.309)	(0.296)	(0.317)
Number of beds (by 100)	**-0.003*** **	**-0.003*** **	**-0.003*** **	0.000	0.000	0.000
95%-CI	**[-0.004, -0.002]**	**[-0.004, -0.002]**	**[-0.004, -0.002]**	[-0.001, 0.000]	[-0.001, 0.000]	[-0.001, 0.000]
SE	**(0.001)**	**(0.001)**	**(0.001)**	(0.000)	(0.000)	(0.000)
p-value	**(<0.001)**	**(<0.001)**	**(<0.001)**	(0.750)	(0.800)	(0.744)
Teaching status: academic teaching hospital (RC: no teaching assignment)	**-0.007***	**-0.007***	**-0.007***	-0.001	-0.001	-0.001
95%-CI	**[-0.014, 0.000]**	**[-0.014, 0.000]**	**[-0.014, 0.000]**	[-0.004, 0.001]	[-0.004, 0.001]	[-0.004, 0.001]
SE	**(0.004)**	**(0.004)**	**(0.004)**	(0.001)	(0.001)	(0.001)
p-value	**(0.037)**	**(0.040)**	**(0.040)**	(0.263)	(0.261)	(0.266)
Teaching status: university hospital (RC: no teaching assignment)	0.018+	0.019+	0.020+	**0.010****	**0.010****	**0.010****
95%-CI	[-0.001, 0.038]	[0.000, 0.039]	[0.000, 0.039]	**[0.002, 0.017]**	**[0.003, 0.017]**	**[0.002, 0.017]**
SE	(0.010)	(0.010)	(0.010)	**(0.004)**	**(0.004)**	**(0.004)**
p-value	(0.068)	(0.052)	(0.050)	**(0.009)**	**(0.008)**	**(0.009)**
Transformational leadership	-0.002		0.002	-0.001		-0.001
95%-CI	[-0.009, 0.004]		[-0.005, 0.009]	[-0.003, 0.001]		[-0.003, 0.002]
SE	(0.003)		(0.004)	(0.001)		(0.001)
p-value	(0.446)		(0.617)	(0.410)		(0.602)
Social capital	-0.004		0.000	-0.002		-0.002
95%-CI	[-0.011, 0.003]		[-0.008, 0.008]	[-0.004, 0.001]		[-0.004, 0.001]
SE	(0.004)		(0.004)	(0.001)		(0.001)
p-value	(0.283)		(0.984)	(0.194)		(0.304)
Num.Obs.	508	508	508	508	508	508
R2	0.085	0.097	0.098	0.047	0.044	0.048
R2 Adj.	0.072	0.086	0.083	0.034	0.033	0.033
AIC	-2056.9	-2065.6	-2061.8	-3076.6	-3076.9	-3074.8
BIC	-2018.8	-2031.7	-2019.5	-3038.5	-3043.0	-3032.5

*+ p < 0.1, * p < 0.05, ** p < 0.01, *** p < 0.001*

3.4 Discussion

3.4.1 Statement of principal findings

The analysis revealed significant differences in the quality of care and patient safety across German hospitals, with those possessing a low GI factor displaying significantly higher over-time shares of quality irregularities. When assessing the implications and impact of the results, it is essential to consider the absolute decrease of 0.9 percentage points in relation to the relatively low occurrence of quality irregularities (approximately 4% of quality indicators fell into this category).

We interpret quality irregularities (such as documentation and software problems) as not as severe for the quality of care and patient safety as detected quality deficiencies. Nevertheless, we contend that they signify non-optimal organizational features related to quality and safety management. Quality irregularities can be understood as early warning indicators, reflecting the collective attitude toward quality and safety management. Undoubtedly, they highlight imperfections in the organization's procedures and processes. In contrast, quality deficiencies are indicative of problems related to health outcomes.

Internationally, hospitals have been characterized as high-reliability organizations (Bagnara et al., 2010), a trait that can be extended to the healthcare system in Germany. Consequently, it is not surprising that quality issues are relatively infrequent. While outcome quality in Germany is ensured by a high level of formal training among medical staff, high levels of resources, and a large number of guidelines and standards, process quality is more likely to be determined by organizational influences. This could be a contributing factor to the result indicating that the GI factor is a better instrument for quality processes than for quality and safety outcomes.

3.4.2 Interpretation within the context of the wider literature

Goal setting, particularly when coupled with feedback for goal attainment, consistently leads to enhanced overall performance (Leape, 2021). It correlates with improved quality and safety behaviour (Pronovost et al., 2003) and yields superior safety outcomes (Groene et al., 2014). Furthermore, TL behaviour patterns, in particular, are conducive to collaboratively setting and achieving goals with followers (Steinmann, 2020). Significantly, TL has been demonstrated to improve patient safety outcomes and quality of care (Singh et al., 2023).

An integrated collective of professionals is characterized by high SC, and can be regarded as a collaborative community (Adler et al., 2008). Studies have established a positive relationship between SC and quality of care (Strömgren et al., 2016). Additionally studies have shown that good collaboration between professionals, one of the results of SC, enhances quality and safety outcomes, though on a limited evidence base (Reeves et al., 2017).

3.4.3 Strengths and limitations

We derived our data from two independent sources and, thus, avoided a common method bias for this analysis. Nonetheless, the survey itself on SC and TL was based on one-person's judgment and opinion, the medical chief director of the hospital. Thus, we cannot provide an objective assessment of both concepts but must rely on subjects' judgements, which is a potential bias and may or may not align with the perspectives of other senior management staff in the hospital. Nonetheless, from an action theory perspective, the medical leader's perception of leadership style and social capital is crucial for guiding leadership decisions, in line with the Thomas Theorem. Furthermore, as the survey participation in the ATräk-study was voluntary, we cannot rule out a selection bias. The measurements of the concepts of SC and TL, though validated, are open to possible forms of bias, but both provide satisfactory reliability (Pfaff & Braithwaite, 2020). While the assessment of SC and TL was subjective, our outcome variables were objective in nature, as they derived from an intensive internal and external quality process within the German inpatient sector. This enhances the robustness of our results, highlighting the significance of the GI concept in the realm of healthcare quality.

As we argued that both parts of the GI factor must be present, we refrained from solely multiplying both scales. Through multiplication, a high value in one scale would compensate for a large deficiency in the other, contradicting our theoretical derivation of the GI factor. Nonetheless, dichotomizing both measures resulted in an information loss, and the selection of the median split is not theoretically chosen with a relative rather than an absolute cut-off limit.

Finally, the survey on SC and TL occurred in 2008, four years before the study period. It is not apparent how both constructs have developed since then. Therefore, our study is based on the explicit assumption of organizational inertia, in which organizational cultures change only slowly, and possible changes are random across hospitals. We are confident of the validity of this assumption; as success rates for culture change are low (Johnson et al., 2016) and changes are challenging for organizations and their staff (Nilsen et al., 2020), hence, organizational culture can be regarded in some respects as rather time constant. However, some studies described a shift in organizational cultures in hospitals over time (Konteh et al., 2023). Thus, we cannot rule out changes in both concepts in the observed hospitals. The survey focused on medical directors' assessments of the overall hospital climate and leadership behaviour of executives, indicating that these organizational aspects can be considered to be more stable over time. While the personal leadership style of a medical director may change with personnel shifts, the broader organizational culture and behaviour of medical and nursing executives are perceived as less susceptible to change. As before, this is an assumption that we cannot support with empirical data.

3.4.4 Implications for policy, practice and research

Hospitals, their staff, and patients can benefit from the synergistic combination and alignment of goals and collective cohesion. Recognizing healthcare as a complex environment, our research indicates that the influence of the GI factor is no standalone construct for achieving better quality and patient safety. Other aspects influencing quality of care and patient safety include patient engagement, human resources management quality, innovation technology, skills certification, education in patient safety, teamwork, and effective communication (Buja et al., 2022).

3.5 Conclusions

Hospital that are characterized by the combined presence of transformational leadership and social capital exhibited significantly fewer quality irregularities over an eight-year period. The possible mechanism behind this is that this combination enables goal-oriented collective action.

Chapter 4

Exploring the Influence of Medical Staffing and Birth Volume on Observed-to-Expected Cesarean Deliveries: A Panel Data Analysis of Integrated Obstetric and Gynecological Departments in Germany

Abstract

Introduction: Cesarean deliveries account for approximately one-third of all births in Germany, prompting ongoing discussions on cesarean section rates and their connection to medical staffing and birth volume. In Germany, the majority of departments integrate obstetric and gynecological care within a single department. ***Methods:*** The analysis utilized quality reports from German hospitals spanning 2015 to 2019. The outcome variable was the annual risk-adjusted cesarean section ratio—a metric comparing expected to observed cesarean sections. Explanatory variables included annual counts of physicians, midwives, and births. To account for case number-related staffing variations, full-time equivalent midwife and physician staff positions were normalized by the number of deliveries. Uni- and multivariate panel models were applied, complemented by multiple instrument variable analyses, including two-stage least square and generalized method of moments models. ***Results:*** Incorporating data from 509 integrated obstetric departments and 2,089 observations, representing 2,335,839 deliveries with 720,795 cesarean sections (over 60% of all inpatient births in Germany), multivariate model with fixed effects revealed a statistically significant positive association between the number of physicians per birth and the risk-adjusted cesarean section ratio (.004, p=.004). Two-stage least square instrument variable analysis (.020, p<.001) and a system GMM estimator models (.004, p<.001) validated these results, providing compelling evidence for a causal relationship. ***Conclusion:*** The study established a robust connection between the number of physicians per birth and the risk-adjusted cesarean section ratio in integrated obstetric and gynecological departments in Germany. While the cause of the effect remains unclear, one possible explanation is a lack of specialization within these departments due to the combined provision of both obstetric and gynecological care.

4.1 Introduction

Over the past few decades, the global prevalence of cesarean section (C-section) births has steadily increased (Boerma et al., 2018). Some experts and researchers go so far as to characterize this trend as an endemic or pandemic of C-sections (Fait et al., 2022; Owens, 2019). This is noteworthy given that vaginal delivery is generally regarded as the preferred method compared to cesarean birth (Sandall et al., 2018). In Germany, the C-section rate has doubled since 1991 and has stabilized at approximately 30% since the mid-2000s (Statistisches Bundesamt, 2022). Thereby, indications for a cesarean section can be divided into absolute and relative indications. This increase is predominantly attributed to relative indications, such as breech presentation, birth arrest, impending fetal hypoxia, and post-section conditions (Schneider, 2013), with 90% of C-sections lacking absolute medical indications in Germany (Deutsche Gesellschaft für Gynäkologie und Geburtshilfe, 2020). Thus, understanding non-medical factors, including organizational influences, is imperative for a comprehensive study of delivery methods.

Given the imperative for health care providers to align their actions with medical necessities and patient preferences, comprehending the factors influencing medical practice decisions is crucial. In the case of C-sections, obviously maternal desire is a key factor (Betrán et al., 2018; Kirchengast & Hartmann, 2018; Loke et al., 2015; Schneider, 2013). From the provider's perspective, numerous factors influence the choice of birth method. These encompass individual factors of the physician (Betrán et al., 2018; Facchini, 2022; Mulchandani et al., 2020; Owens, 2019; Panda et al., 2018; Wolf, 2018) or midwife (Josefsson et al., 2011; Monari et al., 2008), as well as organizational factors at the hospital or obstetric department level (Biro et al., 2014; Gross et al., 2015; Hemminki et al., 2011; Joaquim et al., 2022; Panda et al., 2018; Science Media Center Germany, 2020; Zipfel & Weidmann, 2022). Additionally, context-related factors, such as the complexities of caseload (Perrotta et al., 2022), contribute to the decision-making process. Studies on C-section rates and the quality of obstetric care reveal organization-specific differences linked to factors such as hospital ownership, number of beds, and teaching activity, both in Germany (Gross et al., 2015; Kolip et al., 2012; Mikolajczyk et al., 2013; Science Media Center Germany, 2020; Zipfel & Weidmann, 2022) and internationally (Epstein & Nicholson, 2009; Guglielminotti et al., 2016; Hanley et al., 2010; Kyser et al., 2012; Walther et al., 2021).

While variations between departments with different organizational factors have been extensively studied, understanding relationships and interactions within obstetric departments is equally vital. These inter-organizational influences can potentially impact all departments uniformly, independent of specific organizational factors such as culture, region, socio-demographics, and patient population effects. From an organizational standpoint, comprehending these influences is crucial for making informed decisions about medical practices. Organizations can enhance their understanding of the factors shaping medical practice within their purview and implement adjustments accordingly (Plough et al., 2018).

This analysis focuses on two organizational factors, namely, medical staffing and caseload volume, and explores their interplay. Both factors have been acknowledged for their influence on the quality and quantity of obstetric care in general (Guglielminotti et al., 2016; Leonard et al., 2020) and specifically on C-sections (e.g., volume of births (Bozzuto et al., 2019; K.-S. Lee & Kwak, 2014) or the number of physicians/deliveries per physician per year (Mark A. Clapp et al., 2014; Gombolay et al., 2019; Zbiri et al., 2018)). Overall, medical staffing levels have been less frequently investigated than birth volume as an explanatory variable. Our study enhances current understanding through a longitudinal investigation that encompasses a significant portion of German obstetric departments and deliveries. Importantly, by employing an externally evaluated risk-adjusted C-section ratio, our analysis addresses methodological limitations by accounting for medical indications on the part of both mother and child. Consequently, the ratio and the analysis remain robust, mitigating biases induced by underlying medical reasons that may prompt a C-section (Ramani et al., 2022).

Our research question delved into how the number of full-time equivalent physicians and midwives per birth, coupled with the volume of births, impact the risk-adjusted C-section ratio in German combined obstetric and gynecological departments. In doing so, we address methodological shortcomings by focusing on differences within hospital departments, contributing to the understanding of factors independent of variances between hospital departments. Utilizing a panel model data set with individual and time effects, we control for department- and patient-specific characteristics, ensuring a comprehensive analysis (Curry et al., 2018).

4.2 Methods

4.2.1 Data source

This analysis was based on the structured quality reports of German hospitals, which serve as a cornerstone of transparency in the inpatient sector in Germany (W. de Cruppé & Geraedts, 2016; Werner de Cruppé & Geraedts, 2018; Messer & Reilley, 2015; Scholten et al., 2015; Vorbeck et al., 2022). These reports are compiled and disclosed in accordance with Sections 136 and 137 of the German Social Security Code (Sozialgesetzbuch) V. They offer a comprehensive overview of the structures, services, and quality of the respective hospital and its specialist departments. Annual reports include documentation of performance, organizational metrics, and various quality indicators and scores. Details are delineated to the department level. Although this data set has been utilized for cross-sectional analyses of various indicators (W. de Cruppé & Geraedts, 2016; Werner de Cruppé & Geraedts, 2018; Scholten et al., 2015; Volkert et al., 2020; Volkert et al., 2023; Zipfel & Weidmann, 2022), its application in the context of longitudinal analyses with a specific focus on obstetrics is novel. During the study period, approximately 30 quality indicators related to obstetric care were published (Appendix Table D.1). Our analysis centers on the quality indicator for risk-adjusted C-section rates per hospital.

In preparation for this analysis, a panel data set was compiled using annually published quality reports. In these reports each hospital is assigned a unique identification code, and each site within a hospital is designated a site number. As outlined by Kraska et al. (Kraska et al., 2017), identification codes and site numbers may undergo changes over the years. Therefore, automated linking without content verification could yield a success rate ranging from 80% to 90%. Recognizing potential changes in identification codes and site numbers over the years, a manual matching process was employed to ensure accuracy, supplementing a machine linkage via identification codes and site numbers. The linkage incorporated hospital and site addresses, bed numbers, and the names of responsible department and general hospital managers. Two independent researchers performed the manual linkage, resolving disputed assignments through consensus. Each hospital and site received a master identification number, forming the foundation for the panel study.

As this analysis employs secondary data, and the data are publicly available, no ethical committee vote was deemed necessary.

4.2.2 Study population

In Germany, the vast majority of deliveries occur in hospitals, with less than two percent taking place at home or in birthing centers. Obstetric care is predominantly administered in departments specializing in both obstetrics and gynecology simultaneously. Consequently, two closely related but increasingly distinct medical services are offered within the same departments. Given the inherent organizational disparities between those integrated obstetrics departments and departments primarily dedicated on obstetric care, we excluded obstetric departments with a primary focus on obstetric care from our analysis. Importantly, there are no systematic differences between these two types of departments in terms of patient population or medical standards. The cut-off value was determined through a data-driven approach, as information on organizational focus was not consistently or continuously included in the quality reports. Additionally, departments with attending physicians were excluded due to their typically higher C-section rates in Germany (Kolip et al., 2012; Science Media Center Germany, 2020; Zipfel & Weidmann, 2022).

Ensuring data integrity, we identified potential outliers through Cook's distance and subsequently verified them manually. Closed departments were confirmed through cross-referencing with press reports. The exclusion was deemed necessary to avoid inaccuracies resulting from scenarios where a department, operational for only six months, reported staffing numbers analogously for the entire year. Consequently, staffing figures were not proportionately reported in the quality report, and the number of deliveries was only accounted for during the specified six-month period. This meticulous approach was adopted to maintain the accuracy and reliability of the dataset.

4.2.3 Study period

The observation period spans from 2015 to 2019, as the relevant quality indicator on the cesarean section ratio was introduced in 2015, and 2019 marks the last year before the onset of the COVID-19 pandemic. Recognizing the potential impact of measures associated with the pandemic on daily hospital practices (Schmiedhofer et al., 2022; Woeber et al., 2022), data from 2020 onwards was excluded to minimize bias. Moreover, the introduction of the Robson indicator to the quality indicator in 2020 (IQTIG – Institut für Qualitätssicherung und Transparenz im Gesundheitswesen, 2021) further complicates longitudinal comparisons.

4.2.4 Measures

Outcome variable

The dependent variable in the study was the risk-adjusted cesarean section ratio at the department level (quality indicator no. 52249). This ratio is calculated as the observed number of C-sections divided by the expected number of C-sections. The declared quality objective is the minimization of cesarean births (IQTIG – Institut für Qualitätssicherung und Transparenz im Gesundheitswesen, 2021). The numerator includes all observed cesarean deliveries within a department, while the denominator comprises risk-adjusted expected cesarean deliveries. In 2015 and 2016, all mothers with at least one child born after 24 weeks were included, while from 2017 onwards, only mothers delivering between weeks 24 and 42 were considered. Risk adjustment is performed by the Institute for Quality Assurance and Transparency in Healthcare (Institut für Qualitätssicherung und Transparenz im Gesundheitswesen [IQTIG]). While individual patient data are considered in this process, only aggregated, annual department-level data were accessible for this analysis open access.

Notably, the researchers involved in this study were not directly engaged in the risk adjustment process. The selection of risk factors was guided by Becker and Eissler (Becker & Eissler, 2013) in collaboration with the Federal Perinatal Medicine Group. Risk factors considered encompassed variables such as maternal age, comprehensive data on infant and maternal health status, and information on previous deliveries (Appendix Table D.16). Each year, these risk factors were adjusted based on their respective regression coefficients. Consequently, the risk adjustment undertaken compensates for the divergent patient structures across different facilities, offering a more equitable basis for facility comparisons. This adjustment proves pivotal in ensuring a fair assessment, as patients bring individual risk factors, including concomitant diseases, that could systematically influence the quality outcome. Through risk adjustment, institutions with a higher prevalence of high-risk cases can be statistically juxtaposed more equitably with those handling a larger proportion of low-risk cases, thereby facilitating an unbiased analysis (Chen & Pan, 2022). In the context of the risk-adjusted C-section ratio, values below 1 indicate that a department is performing fewer cesarean sections than expected. Conversely, a ratio above 1 signifies that more risk-adjusted cesarean sections are being performed than anticipated. For instance, a C-section ratio of 1.1 would imply that 10% more cesarean sections were performed than expected. Furthermore, a reference category is defined for each year, designating departments above the 90th percentile as conspicuous. The corresponding value for the review period ranged from 1.23 to 1.27.

Explanatory variables

Three independent variables were utilized: 1. the number of deliveries per department (mothers giving birth) per 1,000, 2. the number of full-time equivalent physicians in the department per 1,000 deliveries, 3. and the number of full-time equivalent midwives in the department per 1,000 deliveries. Staffing levels have been divided by 1,000 to account for volume related differences in the departments. The data on deliveries were extracted from the denominator of the quality indicator for each department. The data on both staffing levels were presented separately for each department within a hospital. Staffing data for physicians were aggregated for residents and specialists, collectively referred to as physicians in subsequent discussions. Physician assistants were excluded. As these departments integrate obstetrics and gynecology, physicians represent both specialties. In Germany, the 'Facharztstandard' (specialist standard) ensures high-quality medical treatments and procedures, typically carried out or supervised by a specialist. However, sufficiently trained residents or assistant physicians may also perform treatments and procedures independently, including cesarean sections. Since there is no strict threshold for determining when a physician has gained sufficient experience and knowledge, we opted to include the total number of physicians in our variable. In addition, a midwife has to be present during labor in Germany ('Hinzuziehungspflicht'; midwife's obligation to consult).

Control variables

Three organizational variables served as control variables in the analyses: 1. hospital ownership (non-profit, private, public), 2. teaching status (no teaching assignment, academic teaching hospital, university hospital), and 3. perinatal care level (regular obstetric departments [care level 4], perinatal focus [care level 3], perinatal center level II [care level 2], perinatal center level I [care level 1]). Regular obstetric departments provide standard perinatal care from 36+0 weeks of gestation without anticipated complications. Departments with a perinatal focus cater to pregnant women expecting premature infants with an estimated birth weight of at least 1,500 grams or with a gestational age from 32+0 to less than or equal to 35+6 weeks. Level II perinatal centers serve pregnant women with anticipated premature infants weighing between 1,250 and 1,499 grams or with a gestational age from 32+0 to less than or equal to 35+6 weeks. Level

I perinatal centers offer the highest level of obstetric care for pregnant women expecting premature infants with an estimated birth weight under 1,250 grams or with a gestational age from 29+0 to less than weeks. All three organizational variables were frequently cited as influential factors in C-section rates (Brazier et al., 2022; Hoxha et al., 2021).

4.2.5 Model description

We developed various static and dynamic panel models featuring time- and individual-specific effects (two-way effects), employing cluster-robust estimators for each department:

a) Fixed effects estimator models

$$y_{it} = \beta_0 + \beta_1 x_{it} + \gamma_t + \alpha_i + e_{it}$$

b) Correlated random effects estimator models

$$y_{it} = \beta_0 + \beta_1 x_{it} + \beta_2 \bar{x}_i + \beta_3 z_{it} + \gamma_t + \alpha_i + e_{it}$$

c) Two stage least square estimator models

$$y_{it} = \beta_0 + \beta_1 \hat{x}_{it} + \beta_2 z_{it} + \gamma_t + \alpha_i + e_{it}$$

$$\hat{x}_{it} = \delta_0 + \delta_1 i_{it} + \delta_2 z_{it} + \psi_t + \phi_i + v_{it}$$

d) System generalized method of moments estimator (Blundell/Bond (Blundell & Bond, 1998) and Arellano/Bover (Arellano & Bover, 1995)) models

$$\text{Model: } y_{it} = \beta_0 + \beta_1 x_{it-1} + \beta_2 y_{it-1} + \beta_3 z_{it} + \gamma_t + \alpha_i + e_{it}$$

$$\text{Difference: } y_{it} - y_{it-1} = \beta_1 (x_{it-1} - x_{it-2}) + \beta_2 (y_{it-1} - y_{it-2}) + \beta_3 (z_{it} - z_{it-1}) + (e_{it} - e_{it-1})$$

$$\text{Level: } y_{it} = \beta_0 + \beta_1 x_{it-1} + \beta_2 y_{it-1} + \beta_3 z_{it-1} + \gamma_t + \alpha_i + e_{it}$$

Where:

y_{it} = vector of dependent variable,
x_{it} = vector of independent variables,
$\bar{x}_i$ = vector of cluster means independent variables,
$\hat{x}_{it}$ = vector of estimated independent variables from the first stage least square regression,
z_{it} = vector of (time constant) independent control variables,
β = vector of model coefficients,
γ_t = unobserved time-specific effect,
α_i= unobserved department-specific effect,
e_{it} = individual error term,
δ = vector of parameters to be estimated in the first stage least square regression,
i_{it} = instrument for independent variable,
ψ_t = unobserved time-specific effects in the first stage,
ϕ_i = unobserved department -specific effects in the first stage,
v_{it} = error term in the first stage.

Where entities (departments) are denoted as $i = 1, \dots, n$ and observation periods (years) $t = 2015, \dots, 2019$. The term γ_t incorporated the time effect on the dependent variable, independent of observable or unobservable differences between individual observation units. This temporal effect captured the influence of changes over time on the dependent variable and served as a global temporal component. α_i was the fixed unobserved heterogeneity of each hospital department, and e_{it} signified the error term for each hospital department over time. Standard errors robust for group-wise heteroscedasticity and serial correlation were used. To choose between fixed effects or random effects models, we utilized a robust Hausman-like test.

Organizational characteristics in the German hospital sector exhibit minimal variation and remain relatively time-persistent. Including them in a fixed effect model would render the results valid only in the rare event of a shift in one of the categories, making it unsuitable for a true comparison between different organizational factors. Consequently, alongside a model with fixed effect estimators, we adopted a correlated random effects (CRE) modeling approach (Antonakis et al., 2021) to incorporate and control for other organizational variables, enhancing model sensitivity and specificity. Acknowledging potential unmeasured confounders and endogeneity with the explanatory variables in our panel regression models, two models with instrument variables (IV) were constructed and analyzed to address possible endogeneity.

While the panel structure of the data already accounted for some aspects of endogeneity (Papies et al., 2017), models with instrumental variable estimation were employed to establish potential causal effects. Recommended best practices advocate for the inclusion of additional data to address endogeneity before resorting to IV estimation (Germann et al., 2015; Papies et al., 2017; Rossi, 2014), our data source had limitations in providing meaningful potential additional variables. The first model employed a static IV approach with a two-stage least squares (2SLS) estimator, using the number of nursing staff per 1,000 deliveries as an external IV. The second model employed a dynamic approach with generalized method of moments (GMM) estimators, incorporating the lagged ratios of observed to expected rates of cesarean births as an internal IV (Arellano & Bond, 1991; Arellano & Bover, 1995; Blundell & Bond, 1998). Additionally, to minimize data loss due to the unbalanced dataset and use more instruments for more efficient estimators, we referred to the system GMM estimator instead a difference GMM estimator

(Blundell & Bond, 1998). Two-step GMM estimators were chosen for their robustness to autocorrelation and heteroscedasticity (Roodman, 2009).

4.2.6 Statistical analysis

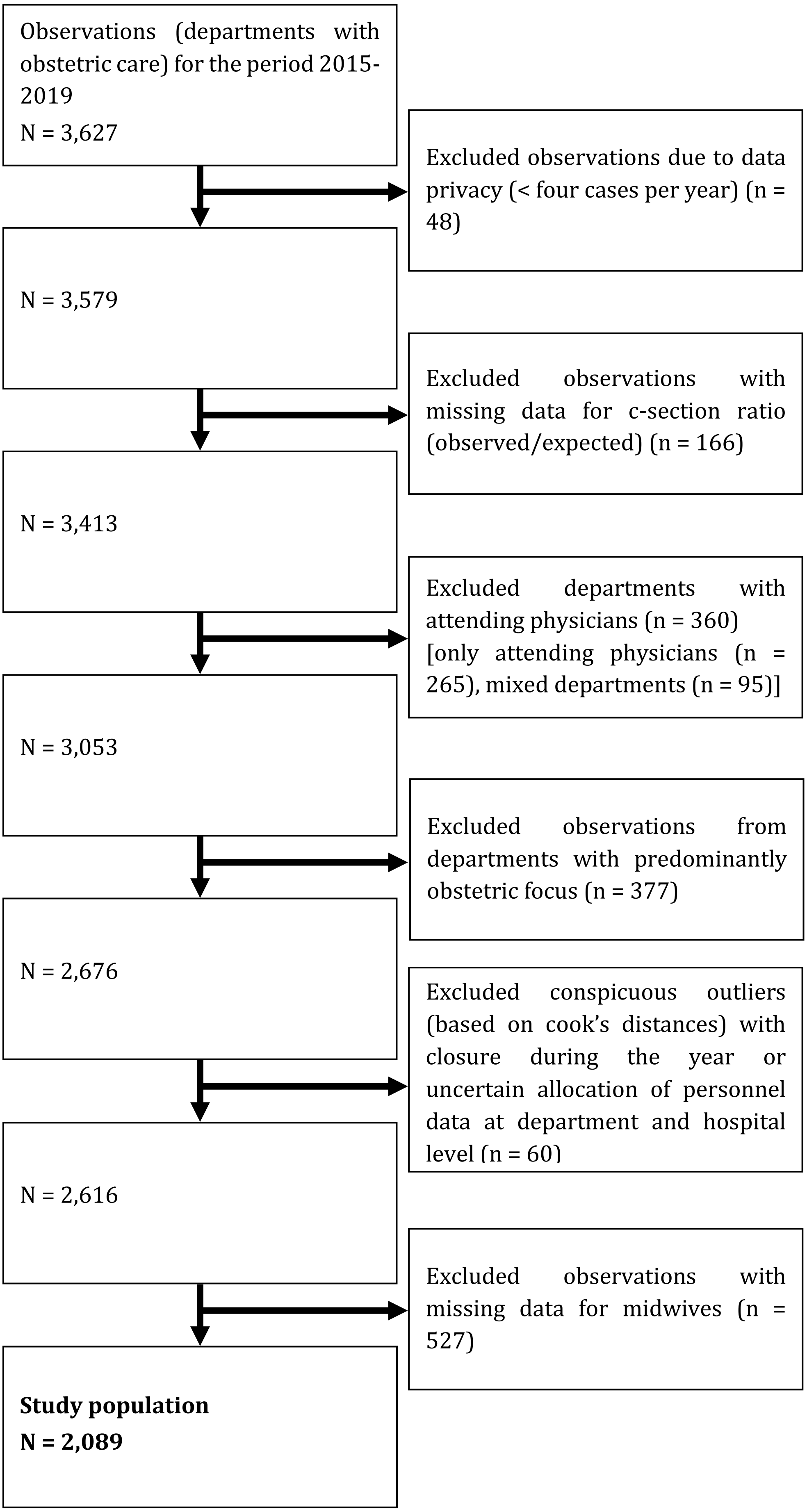
Data preparation (tidyverse package [2.0.0]) and analysis (plm package [2.6-3], lmtest package [0.9-40], gtsummary package [1.7.2], modelsummary package [1.4.3]) were performed in R (version 4.2.2) and RStudio (version 2023.06.1 +524).

4.3 Results

4.3.1 Data inclusion

Following the exclusion of duplicate entries, we identified data from 912 departments performing obstetric care, providing 3,627 observations from the quality reports (Figure 4.1). Regulatory authorities censored 48 observations due to data privacy concerns (less than four deliveries in the reporting year), these were excluded from further analysis. Additionally, 166 observations lacked data on the C-section ratio quality indicator for the respective year, leading to their exclusion. Of the remaining data, 360 reported having attending physicians in the respective year, and these departments were excluded. Similarly, departments primarily offering obstetric services were excluded, with a data-driven cut-off value set at 1.4 times the number of full inpatient cases compared to births (Appendix Figure D.1). 377 observations fell below the threshold and were categorized as solo obstetric departments, subsequently excluded. A manual check using Cook's distance method revealed 60 entries with conspicuous data, confirmed through cross-checking with media reports indicating closures within the reporting year. These departments were consequently excluded. Lastly, 527 observations lacked data on the variable for the number of midwives, resulting in their exclusion. The final analysis included 2,089 observations from 519 obstetric departments.

Figure 4.1 Flow chart of study population.



In total, the study population with 2,089 observations represented 2,335,839 mothers giving birth and 720,795 C-section deliveries (Table 4.1). The panel is unbalanced. As the study population no longer corresponded to a full survey of German obstetric departments, we validated the study population against data from IQTIG for the overall numbers on births and cesarean deliveries in obstetric departments in Germany. Over the period 2015 to 2019, the total number of mothers giving births increased from 713,563 to 745,941, with a slight decrease in the C-section rate from 31.42% to 30.85%. These trends were mirrored in the smaller study population (444,555 to 479,176 births). The study population covered 62.8% of all delivering mothers and 62.4% of all cesarean deliveries in Germany. While the year-by-year C-section rate in the study population was slightly lower than the national rate for all years except 2015, the differences were not significant (t-test, p = .408). Notably, the deviation in 2016 was attributed to missing data in the quality reports, discussed in more detail in the limitations section. Additionally, solo obstetric departments reported on average cesarean rates (30.3 %) similar to those of integrated departments (Appendix Table D.2).

Table 4.1 Comparison of births and cesarean sections between total German hospital population and study population (based on IQTIG – Institut für Qualitätssicherung und Transparenz im Gesundheitswesen, 2016a, 2017, 2018, 2019b, 2020a).

	Institute for Quality Assurance and Transparency in Healthcare (IQTIG)			**Study Population**		
	Deliveries (All mothers who have had at least one birth of a child)	Cesarean deliveries	C-section rate	Deliveries (All mothers who have had at least one birth of a child)	Cesarean deliveries	C-section rate
2015	713,563	224,197	31.42	444,555	139,940	31.48
2016	753,289	235,096	31.21	420,158	130,253	31.00
2017	756,146	235,765	31.18	492,692	151,074	30.66
2018	749,024	229,676	30.66	499,258	152,461	30.54
2019	745,941	230,105	30.85	479,176	147,067	30.69
Σ / Ø	3,717,963	1,154,839	31.06	2,335,839	720,795	30.87

4.3.2 Characteristics of study population

The observed risk-adjusted C-sections, on average, were marginally below the expected number, indicating a ratio of 0.98 (median 1.00) (Table 4.2). The number of deliveries per department averaged 1,118.2 births. Notably, from 2015 to 2019, the mean number of deliveries exhibited an increase of 123.1, rising from 1,031.5 to 1,154.6 births, with an intermediate spike observed from 2015 to 2016. However, the median, standing at 913, consistently trailed the mean. Regarding cesarean births, the annual average per department was 345, showing a modest increase of 21.7 from 2015 to 2016. Yet again, the median, at 240.3 cesarean births, lagged behind the mean.

The average number of physicians per department over the observation period was 12.5, with a median of 10.9. This experienced an increase of more than one full-time equivalent from 2015 to 2019. As outlined earlier, the total number of full-time equivalent physicians was divided by the department's number of births to ensure comparability across departments. The average number of full-time equivalent physicians per 1,000 deliveries per department remained constant around 12.5, with a median of 11.8, showing no significant change from 2015 to 2019. In terms of midwives, the average number per department hovered around 11 during the observation period, with a median of 9.2. The average number of full-time equivalent midwives per 1,000 deliveries per department was 10.7 (median 10.3). However, from 2015 to 2019, average number of full-time equivalent midwives per 1,000 deliveries decreased by nearly one. The average number of full-time equivalent nursing staff (excluding midwives) per department was 24, with a median of 19.6. Per 1,000 deliveries, there were 23.3 full-time equivalent nursing staff, with a median of 21.1. Notably, there was a decrease in the average number of full-time equivalent nursing staff per 1,000 births from 24.7 in 2015 to 22.3 in 2019.

Private hospitals constituted the minority in the study population at 16.6%, while non-profit hospitals (36.3%) and public hospitals (47.1%) comprised the majority. Regarding academic teaching, 70.5% of hospitals were listed as academic teaching hospitals, 7.6% were university hospitals, and 22% were not engaged in academic teaching. Beyond regular obstetric departments, the landscape encompasses facilities specializing in perinatal care, including level 1 and 2 perinatal centers. Additionally, 45% categorized as departments with the regular level of perinatal care. 19.4% reported a perinatal focus, 8.9% were a level II perinatal center, and 26.8% were a level I perinatal center – the highest form of obstetric health services for high intense care.

Compared to integrated obstetric departments, solo departments, on average, have a significantly lower risk-adjusted cesarean section ratio (0.95; t-test, $p = 0.001$), more deliveries (1,563.5; t-test, $p < 0.001$), and more cesarean sections (473.7; t-test, $p < 0.001$), but fewer full-time equivalent physicians (9.7; 6.8 per 1,000 deliveries; t-test, $p < 0.001$) and more midwives (13.4; 9.1 per 1,000 deliveries; t-test, $p < 0.001$). The crude cesarean section rate did not differ significantly from each other (mean solo department:

30.04 %, mean integrated department: 30.41 %; t-test: p-value = 0.371). Solo departments were more likely to be involved in academic teaching (80.1 %) and to have a higher perinatal care level (care level 4 = 33.1 %; care level 1 = 41.2 %) (Appendix Table D.3 for more details).

Table 4.2 Descriptive description study population.

Characteristic	Overall, N = 2,089[1]	2015, N = 431[1]	2016, N = 376[1]	2017, N = 430[1]	2018, N = 437[1]	2019, N = 415[1]
Risk-adjusted cesarean ratio	0.98 / 1.00 (0.18)	0.97 / 0.97 (0.19)	0.98 / 0.99 (0.18)	0.98 / 1.00 (0.19)	0.99 / 1.00 (0.18)	0.99 / 1.01 (0.18)
Number of deliveries	1,118.16 / 913.00 (695.53)	1,031.45 / 828.00 (641.20)	1,117.44 / 905.50 (701.29)	1,145.80 / 934.00 (708.85)	1,142.47 / 936.00 (702.03)	1,154.64 / 950.00 (719.08)
Number of C-sections	345.04 / 263.00 (240.27)	324.69 / 250.00 (229.90)	346.42 / 267.50 (240.73)	351.33 / 266.00 (241.12)	348.88 / 265.00 (242.04)	354.38 / 265.00 (247.48)
Number of full-time equivalent physicians	12.48 / 10.86 (7.10)	11.75 / 10.33 (6.57)	12.35 / 10.73 (7.30)	12.56 / 11.09 (7.12)	12.74 / 11.00 (7.17)	13.01 / 11.14 (7.32)
Number of full-time equivalent physicians per 1,000 deliveries	12.46 / 11.75 (4.45)	12.85 / 11.84 (4.90)	12.32 / 11.64 (4.54)	12.22 / 11.50 (4.36)	12.40 / 11.84 (4.21)	12.51 / 11.81 (4.17)
Number of full-time equivalent midwives	11.03 / 9.17 (7.56)	10.80 / 9.00 (6.80)	11.11 / 9.40 (7.56)	11.15 / 9.16 (7.59)	10.95 / 9.04 (7.71)	11.16 / 9.48 (8.13)
Number of full-time equivalent midwives per 1,000 deliveries	10.64 / 10.30 (4.53)	11.38 / 10.67 (4.35)	10.60 / 10.14 (4.09)	10.53 / 10.22 (4.86)	10.25 / 10.16 (4.31)	10.45 / 10.37 (4.88)
Number of full-time equivalent nursing staff	23.97 / 19.60 (17.03)	23.33 / 19.80 (15.86)	24.60 / 19.70 (18.54)	24.30 / 19.65 (16.97)	24.00 / 19.68 (17.12)	23.64 / 19.30 (16.68)
missing	49	40	2	2	3	2
Number of full-time equivalent nursing staff per 1,000 deliveries	23.34 / 21.06 (11.04)	24.69 / 22.25 (12.18)	23.99 / 21.90 (11.63)	23.19 / 21.17 (10.75)	22.76 / 20.54 (10.20)	22.27 / 20.12 (10.38)
missing	49	40	1	2	3	2
Ownership						
non-profit	759 (36.33%)	166 (38.52%)	123 (32.71%)	165 (38.37%)	159 (36.38%)	146 (35.18%)
private	346 (16.56%)	72 (16.71%)	67 (17.82%)	67 (15.58%)	72 (16.48%)	68 (16.39%)
public	984 (47.10%)	193 (44.78%)	186 (49.47%)	198 (46.05%)	206 (47.14%)	201 (48.43%)
Teaching status						
no teaching assignment	459 (21.97%)	97 (22.51%)	90 (23.94%)	98 (22.79%)	89 (20.37%)	85 (20.48%)
academic teaching hospital	1,472 (70.46%)	309 (71.69%)	256 (68.09%)	298 (69.30%)	313 (71.62%)	296 (71.33%)
university hospital	158 (7.56%)	25 (5.80%)	30 (7.98%)	34 (7.91%)	35 (8.01%)	34 (8.19%)
Perinatal care level						
regular obstetric department (care level 4)	939 (44.95%)	201 (46.64%)	164 (43.62%)	193 (44.88%)	195 (44.62%)	186 (44.82%)
perinatal focus (care level 3)	405 (19.39%)	73 (16.94%)	73 (19.41%)	87 (20.23%)	90 (20.59%)	82 (19.76%)
perinatal centers level II (care level 2)	185 (8.86%)	44 (10.21%)	36 (9.57%)	36 (8.37%)	36 (8.24%)	33 (7.95%)
perinatal centers level I (care level 1)	560 (26.81%)	113 (26.22%)	103 (27.39%)	114 (26.51%)	116 (26.54%)	114 (27.47%)

[1] n (%); Mean / Median (SD)

4.3.3 Uni- and multivariable panel models analyses

Initially, we constructed three univariable models to investigate the impact of physicians per 1,000 deliveries, midwives per 1,000 deliveries, and total number of 1,000 deliveries on the observed-to-expected rates of cesarean delivery (Table 4.3). All models considered the panel structure of the data, employing fixed-effects estimators that considered both time and individual effects. In the first model, the estimator for the number of physicians per 1,000 deliveries demonstrated a significant positive correlation with the observed-to-expected cesarean delivery ratio (0.005; $p < 0.001$). The second model, focusing on the number of midwives per 1,000 deliveries, revealed no significant effect on the ratio of observed-to-expected cesarean births. However, in the third model, the estimator for the number of deliveries per 1,000 was significantly negatively correlated with the observed-to-expected cesarean delivery ratio (-0.057; $p = 0.007$).

In the pooled multivariate model, no signs of multicollinearity were detected (VIF < 2 for each variable). Subsequently, we developed a multivariate model incorporating all three variables of interest. In this model, only the estimator for the number of physicians per 1,000 deliveries exhibited a statistically significant association with the observed-to-expected cesarean delivery ratio (0.004, $p = 0.004$). A robust Durbin-Wu-Hausman-like test, conducted for heteroscedastic robust standard errors, suggested using models with fixed effects instead of random effects (see Appendix Table D.4 for models with random effects estimators) for the univariate model for physicians (p=.048) and the multivariate model (p=.024), but not for univariate models for midwifes (p=.473) and deliveries (p=.669).

Overall, this initial analysis revealed a significant effect for the estimator on physicians per birth regarding the observed-to-expected cesarean delivery ratio, although the explanatory power on the C-section ratio was modest. The multivariate model demonstrated a higher within-R^2 (0.013) compared to the univariate model with only the physicians per birth estimator ($R^2 = 0.011$). Additionally, the multivariate model fit the data slightly better (AIC univariate model -5355.2 to AIC multivariate model -5354.3).

Table 4.3 Uni- and multivariate panel models with two-way fixed effects.

Ratio of observed to expected (O/E) cesarean births (2015-2019) (two-way fixed effects model)				
	Univariate models	**Univariate models**	**Univariate models**	**Multivariate models**
Number of physicians per 1,000 deliveries	**0.005*** **			**0.004** **

Ratio of observed to expected (O/E) cesarean births (2015-2019) (two-way fixed effects model)				
	Univariate models	**Univariate models**	**Univariate models**	**Multivariate models**
p-value	**(<0.001)**			**(0.004)**
95%-CI	**[0.002, 0.008]**			**[0.001, 0.007]**
SE	**(0.001)**			**(0.001)**
Number of midwives per 1,000 deliveries		0.002+		0.001
p-value		(0.079)		(0.375)
95%-CI		[0.000, 0.004]		[-0.001, 0.003]
SE		(0.001)		(0.001)
Number of deliveries per 1,000			**-0.057****	-0.016
p-value			**(0.007)**	(0.483)
95%-CI			**[-0.098, -0.016]**	[-0.062, 0.029]
SE			**(0.021)**	(0.023)
Num.Obs.	2089	2089	2089	2089
R2	0.011	0.003	0.004	0.013
R2 Adj.	-0.319	-0.330	-0.328	-0.319
AIC	-5355.2	-5338.4	-5340.5	-5354.3
BIC	-5343.9	-5327.1	-5329.2	-5331.7
Std.Errors	HC1	HC1	HC1	HC1

*+ p < 0.1, * p < 0.05, ** p < 0.01, *** p < 0.001*

4.3.4 Correlated random effects panel model analyses

To incorporate organizational characteristics, we conducted a correlated random effects (CRE) model (Table 4.4). The three variables from the fixed-effects model exhibited similar effects in the CRE model. The impact of the number of physicians per 1,000 deliveries remained consistent (0.005, p = 0.002). According to the robust Hausman tests above, a Wald test again indicated that the random effects assumption was not valid for both models ($\chi2$ = 3.21, p = 0.025; $\chi2$ = 3.15, p = 0.027). Notably, the department-mean number of physicians per 1,000 deliveries, capturing the contextual effect of the variable, showed a significant positive relationship (0.006, p = 0.020). This indicated that if the mean number of physicians per 1,000 deliveries increased across integrated obstetric departments, the ratio of observed to expected C-sections also increased. Among the control variables, perinatal centers of the first level, compared to regular obstetric wards, exhibited significantly higher C-section ratios (0.069, p = 0.006). The explained variance increased from 0.074 to 0.104 for the model with organizational controls.

Table 4.4 Multivariate panel models with two-way correlated random estimators.

Ratio of observed to expected (O/E) cesarean births (2015-2019) (two-way fixed effects model)		
	CRE/mixed effects model	**CRE/mixed effects model with control variables**
Intercept	**0.886*****	**0.934*****

Ratio of observed to expected (O/E) cesarean births (2015-2019) (two-way fixed effects model)		
	CRE/mixed effects model	**CRE/mixed effects model with control variables**
p-value	**(<0.001)**	**(<0.001)**
95%-CI	**[0.812, 0.959]**	**[0.842, 1.025]**
SE	**(0.038)**	**(0.047)**
Number of physicians per 1,000 deliveries	**0.005****	**0.005****
p-value	**(0.002)**	**(0.002)**
95%-CI	**[0.002, 0.008]**	**[0.002, 0.007]**
SE	**(0.001)**	**(0.001)**
Mean number of physicians per 1,000 deliveries	**0.007****	**0.006***
p-value	**(0.004)**	**(0.020)**
95%-CI	**[0.002, 0.012]**	**[0.001, 0.011]**
SE	**(0.002)**	**(0.003)**
Number of midwives per 1,000 deliveries	0.001	0.001
p-value	(0.352)	(0.310)
95%-CI	[-0.001, 0.004]	[-0.001, 0.004]
SE	(0.001)	(0.001)
Mean number of midwives per 1,000 deliveries	-0.004+	-0.004+
p-value	(0.094)	(0.087)
95%-CI	[-0.009, 0.001]	[-0.009, 0.001]
SE	(0.003)	(0.003)
Number of deliveries per 1,000	-0.003	-0.009
p-value	(0.882)	(0.698)
95%-CI	[-0.046, 0.040]	[-0.052, 0.035]
SE	(0.022)	(0.022)
Mean number of deliveries per 1,000	-0.008	-0.037
p-value	(0.752)	(0.159)
95%-CI	[-0.057, 0.041]	[-0.088, 0.014]
SE	(0.025)	(0.026)
Ownership: public (Ref. category: Ownership private)		-0.033
p-value		(0.164)
95%-CI		[-0.079, 0.013]
SE		(0.024)
Ownership: non-profit (Ref. category: Ownership private)		-0.035
p-value		(0.151)
95%-CI		[-0.082, 0.013]
SE		(0.024)
Perinatal centers level I (care level 1) (Ref. category: regular obstetric department (care level 4))		**0.069****
p-value		**(0.006)**
95%-CI		**[0.019, 0.118]**
SE		**(0.025)**
Perinatal centers level II (care level 2) (Ref. category: regular obstetric department (care level 4)		0.012
p-value		(0.650)
95%-CI		[-0.040, 0.065]
SE		(0.027)
Perinatal focus (care level 3) (Ref. category: regular obstetric department (care level 4)		0.001
p-value		(0.978)

Ratio of observed to expected (O/E) cesarean births (2015-2019) (two-way fixed effects model)		
	CRE/mixed effects model	**CRE/mixed effects model with control variables**
95%-CI		[-0.042, 0.043]
SE		(0.022)
Teaching status: academic teaching hospital (Ref. category: Teaching status: no teaching assignment)		0.014
p-value		(0.483)
95%-CI		[-0.025, 0.052]
SE		(0.020)
Teaching status: University Hospital (Ref. category: Teaching status: no teaching assignment)		0.017
p-value		(0.622)
95%-CI		[-0.050, 0.083]
SE		(0.034)
Num.Obs.	2089	2089
R2	0.074	0.104
R2 Adj.	0.071	0.099
AIC	-1310.8	-1367.2
BIC	-1265.7	-1282.6
*+ p < 0.1, * p < 0.05, ** p < 0.01, *** p < 0.001*		

4.3.5 Instrument variable analyses

Two stage least squares estimator

For the first instrumental variable analysis, we employed the number of nursing staff (excluding midwives) per 1,000 deliveries as the IV for the number of physicians per 1,000 deliveries. We excluded departments with missing values on nursing staff (n = 11) and outliers (n = 3). Additionally, departments from one German private hospital group were excluded for the year 2015 (n = 38) since these hospitals provided staffing numbers on nursing staff at the hospital rather than the department level. Consequently, our analysis incorporated 2,037 observations from 516 departments.

Relevance

The number of nursing staff per 1,000 deliveries exhibited a significant positive correlation with the number of physicians per 1,000 deliveries (0.239, $p < 0.001$) (Appendix Table D.5). The F-statistic for the model was at 237.2 with robust standard errors. Traditionally, a value above 10 is assumed for the suitability of an instrument variable, but according to D. S. Lee et al. (2022), a value of 104 is considered a better significance threshold.

Excludability

While nursing professionals play a crucial role in the care of mothers and newborns within an obstetric department, they lack a direct decision-making role in the choice of the delivery mode. Unlike midwives and physicians, who may influence delivery decisions, nursing staff primarily engage in postnatal care. Additionally, nursing staff in obstetric departments provide guidance on newborn care and support mothers in the postpartum period. We view nursing staff as a reflection of the general staffing situation in the department, with the cesarean section ratio linked to the number of nursing staff solely through the number of physicians.

Exogeneity

Even though the IV, explanatory, and outcome variables existed within the same organizational context, the panel structure allowed us to detach time-persistent influences from the analysis. For instance, the perinatal level of care may impact the nursing staff level per birth in the department. Obstetric departments with higher care levels tend to have more nursing staff due to caring for preterm infants or newborns with health issues. Pre-selection occurs here, with hospitals admitting pregnant women at risk to those with a high perinatal care level. Panel estimators controlled for such biases, ensuring the fixed effects estimator's robustness. Influencing time-persistent factors like the organizational culture were also controlled for in the panel structure. In our assessment, nursing staff served as a suitable instrumental variable for physicians and their influence on the mode of delivery.

Results

With the employed IV, the effect size of the variable for the number of physicians per 1,000 deliveries increased to 0.014 ($p < 0.001$) in the univariate model (Table 4.5). This significant effect persisted in the multivariate model (0.016, $p < 0.001$). Overall, the effect size tripled compared to the fixed-effects and CRE models, and the within-R^2 increased to 0.060 and 0.059, respectively.

Table 4.5 Static IV models with two stage least square estimators.

Ratio of observed to expected (O/E) cesarean births (2015-2019) (two-way fixed effects model)		
	univariate model	**multivariate model**
Number of physicians per 1,000 deliveries	**0.014*** **	**0.016*** **
p-value	**(<0.001)**	**(<0.001)**
95%-CI	**[0.009, 0.019]**	**[0.009, 0.022]**
SE	**(0.003)**	**(0.003)**
Number of midwives per 1,000 deliveries		-0.002

Ratio of observed to expected (O/E) cesarean births (2015-2019) (two-way fixed effects model)		
	univariate model	**multivariate model**
p-value		(0.288)
95%-CI		[-0.005, 0.002]
SE		(0.002)
Number of deliveries per 1,000		0.016
p-value		(0.281)
95%-CI		[-0.013, 0.045]
SE		(0.015)
Num.Obs.	2037	2037
R2	0.060	0.059
R2 Adj.	-0.253	-0.256
AIC	-3399.5	-3386.4
BIC	-3388.3	-3363.9
Std.Errors	HC1	HC1
*+ p < 0.1, * p < 0.05, ** p < 0.01, *** p < 0.001*		

The residuals from the instrument variable analysis, encompassing endogenous information, signaled that the number of physicians per 1,000 deliveries was indeed endogenous ($p < 0.005$ for both models) (see Appendix Table D.6). Therefore, it appears prudent to employ an appropriate instrumental variable to attain a purely exogenous effect.

System generalized method of moments estimator

In a dynamic setting, considering the C-section ratio from past years to control for potential endogeneity, we utilized system generalized method of moments estimations. Although a comparison with estimators for the lagged variable from ordinary least squares (OLS) and fixed-effect models (Appendix Table D.7) revealed a tendency to favor a difference GMM estimation approach, as the outcome variable did not display strong time persistence. Given the unbalanced panel dataset with a brief time span of only five observation points, we opted for a system GMM approach. The results of the difference GMM model can be found in the appendix (Appendix Table D.8).

The univariate model showed a significant effect of the physician variable (0.004, $p < 0.001$) (Table 4.6). In the multivariate model, both without and with control variables, the significant effect for the physician variable persisted (0.004, $p < 0.001$). Furthermore, in the full model with control variables, the variable for the number of births became negatively significant (-0.037, $p < 0.001$). Notably, the volume variable attained significance due to its inclusion in the control variable for perinatal care level (not shown in the table). Specifically, the variable for perinatal centers level I displayed a significant positive effect (0.051, $p < 0.001$). The Hansen-Sargan test indicated a robust nonoverfitting of instrumental variables (p > 0.35 for all three models). The autocorrelation test for the second order yielded non-significant results for all three models (p < 0.001). While the Wald test for the coefficients exhibited significant effects of the joint independent and control variables in all three models (p < 0.001), the Wald test for the joint time dummies indicated no significant effect in all three models (p > 0.05).

Table 4.6 Dynamic IV models with system generalized method of moment estimators.

Ratio of observed to expected (O/E) cesarean births (2015-2019) (two-way fixed effects model)			
	univariate model	**multivariate model**	**multivariate model with control variables**
Lagged ratio of observed to expected ratio (O/E) of cesarean births	**0.485*****	**0.503*****	**0.489*****
p-value	**(<0.001)**	**(<0.001)**	**(<0.001)**
95%-CI	**[0.355, 0.616]**	**[0.374, 0.633]**	**[0.383, 0.596]**
SE	**(0.068)**	**(0.069)**	**(0.054)**
Number of physicians per 1,000 deliveries	**0.004*****	**0.004*****	**0.004****
p-value	**(<0.001)**	**(<0.001)**	**(0.002)**
95%-CI	**[0.002, 0.006]**	**[0.002, 0.007]**	**[0.001, 0.006]**
SE	**(0.001)**	**(0.001)**	**(0.001)**
Number of midwives per 1,000 deliveries		-0.002	-0.002
p-value		(0.164)	(0.105)
95%-CI		[-0.004, 0.001]	[-0.004, 0.000]
SE		(0.001)	(0.001)
Number of deliveries per 1,000		-0.010+	**-0.037*****
p-value		(0.095)	**(<0.001)**
95%-CI		[-0.022, 0.002]	**[-0.054, -0.020]**
SE		(0.006)	**(0.009)**
Ownership: public (Ref. category: Ownership private)			-0.015
p-value			(0.225)
95%-CI			[-0.039, 0.009]
SE			(0.013)
Ownership: non-profit (Ref. category: Ownership private)			-0.002
p-value			(0.906)
95%-CI			[-0.027, 0.024]
SE			(0.014)
Perinatal centers level I (care level 1) (Ref. category: regular obstetric department (care level 4))			**0.051*****
p-value			**(<0.001)**
95%-CI			**[0.024, 0.078]**
SE			**(0.014)**
Perinatal centers level II (care level 2) (Ref. category: regular obstetric department (care level 4)			0.016
p-value			(0.304)
95%-CI			[-0.014, 0.045]
SE			(0.016)
Perinatal focus (care level 3) (Ref. category: regular obstetric department (care level 4)			-0.010
p-value			(0.355)

Ratio of observed to expected (O/E) cesarean births (2015-2019) (two-way fixed effects model)			
	univariate model	multivariate model	multivariate model with control variables
95%-CI			[-0.033, 0.012]
SE			(0.012)
Teaching status: academic teaching hospital (Ref. category: Teaching status: no teaching assignment)			0.013
p-value			(0.224)
95%-CI			[-0.008, 0.034]
SE			(0.011)
Teaching status: University Hospital (Ref. category: Teaching status: no teaching assignment)			0.014
p-value			(0.263)
95%-CI			[-0.010, 0.037]
SE			(0.013)
Num.Obs.	2,520	2,520	2,520
Hansen-Sargan test/J-test (p-value)	6.983 (0.639)	11.725 (0.385)	12.310 (0.831)
Arellano–Bond Test/Autocorrelation test (1) (p-value)	-6.094 (<0.001)	-6.058 (<0.001)	-6.321 (<0.001)
Arellano–Bond Test/Autocorrelation test (2) (p-value)	-0.101 (0.919)	-0.094 (0.925)	-.253 (0.800)
Wald test for coefficients (p-value)	110.125 (<0.001)	148.589 (<0.001)	321.429 (<0.001)
Wald test for time dummies (p-value)	3.130 (0.372)	3.084 (0.379)	4.702 (0.195)
Std.Errors	HC1	HC1	HC1

*+ p < 0.1, * p < 0.05, ** p < 0.01, *** p < 0.001*

4.3.6 Outcome validation

We conducted the same analyses for departments primarily focused on obstetric care (n = 307) and found no significant correlations for any variables (Appendix Table D.9 and Table D.10). Additionally, we examined the crude cesarean section ratio (number of cesareans divided by the total number of deliveries) and observed similar positive relationships with the variable for the number of full-time equivalent physicians per 1,000 deliveries (Appendix Table D.11, Table D.12, and Table D.13). However, some instrumental variable analyses did not reveal a significant effect for the number of physicians per 1,000 deliveries (Appendix Table D.14 and Table D.15).

4.4 Discussion

Existing literature highlights the global increase in cesarean section rates, often attributed to non-medical factors, including maternal preferences and organizational influences. While previous studies have examined individual and hospital-level factors affecting C-section rates, such as physician characteristics, hospital ownership, and caseload, there is limited focus on the interactions within obstetric departments, particularly regarding medical staffing. In this study, we conducted an initial investigation of the roles played by physicians, midwives, and the number of births and C-section in German combined obstetrics and gynecological departments from 2015 to 2019, encompassing over 60% of births in the country. Our study addressed gaps in previous research by employing a longitudinal approach, controlling for both medical and organizational factors, and accounting for methodological biases related to medical indications.

Across various models and study designs, our findings consistently revealed a significant positive correlation between the number of full-time equivalent physicians per delivery in integrated obstetric and gynecological departments and the risk-adjusted observed-to-expected cesarean delivery ratio. Intriguingly, multiple instrumental variable analyses hinted at a potential causal effect for this relationship. These results challenge the notion that cesarean sections are a preferable management strategy during staff shortages (Kolip et al., 2012). While our study design does not allow us to pinpoint the cause of this effect, the absence of a significant within-effect in solo departments, along with the significantly lower risk-adjusted cesarean rates in solo departments compared to integrated departments, suggests that specialization may be a contributing factor. This would evidence towards a specialization argument for obstetric care (Science Media Center Germany, 2020).

Noteworthy, other studies have reported an inverse effect for the number of physicians per delivery. For instance, Zibri et al. (Zbiri et al., 2018) examined eleven French hospitals from 2008 to 2014, while Gombolay et al. (Gombolay et al., 2019) conducted an extensive cross-sectional analysis for 2014 in a tertiary care medical center in Boston. The disparity in hospital populations, national characteristics of hospital structures, and methodological approaches could explain these contradictory findings. Overall, the importance of staffing levels is recognized by physician managers in quality research (Plough et al., 2018).

Caution is warranted when interpreting the greater effect size for the 2SLS-estimators, as the instrument variable (nursing staff per 1,000 deliveries) may introduce bias, potentially overestimating the effect. Additionally, since the system and difference GMM estimators revealed comparable effect size for the number of physicians per delivery on the cesarean section ratio, the difference GMM estimators potentially lack statistical power. Hence, concerns about misleading effects with the system GMM estimator are of minor significance.

The objective of minimizing cesarean sections itself is open to debate. C-sections should be performed when medically necessary or at the request of the woman giving birth. Emphasizing the reduction of C-sections could lead to compromised care quality if a C-section is medically needed but not performed. The fact that the average risk-adjusted cesarean ratio was 0.98—two percent below the expected number of C-sections—suggests that there may already be an underprovision of C-sections in Germany. Conversely, the underperformance might also indicate potential issues with the risk adjustment computation. With the introduction to the Robson indicator from 2020 onwards, risk adjustment will become more internationally comparable. This will allow for a better assessment of whether the original indicator was sufficiently suitable. Overall, among the available quality indicators (Appendix Table D.1), we believe that the risk-adjusted cesarean ratio is particularly well-suited for comparing obstetric care quality. Other indicators, such as infant mortality, were either not collected or too rare to be reliable, as in the case of maternal mortality (fewer than 25 cases per year).

Beyond our focus on delivery methods, higher staffing levels have been associated with better quality of care and higher patient satisfaction in obstetrician care (Turner et al., 2022). Effective communication between patients and clinicians contributes to reducing high cesarean section rates (Gallagher et al., 2022). Evidence from a Cochrane review suggests that continuous support during labor – one-to-one intrapartum support compared with usual care – is associated with a lower rate of cesarean sections, emphasizing the potential impact of staffing levels on provider-patient communication (Bohren et al., 2017). Therefore, from this perspective, higher staffing levels in the department should theoretically result in a lower ratio of cesarean sections.

While only a few models established an effect for the number of deliveries when examined together with the number of physicians per birth, other studies have reported such associations (Mark A. Clapp et al., 2014; Ghafari-Saravi et al., 2022; Han et al., 2017; Zbiri et al., 2018), while other did not (M. A. Clapp et al., 2018). Additionally, the "practice-makes-perfect hypothesis", widely observed in health quality research (Hentschker & Mennicken, 2018; Huguet, 2020) and obstetrics care (Chen & Pan, 2022), indicates that hospitals with more births perform fewer cesarean sections. Our results underscore the importance of not solely focusing on the overall number of deliveries within a department. Instead, they underscore the importance of relating the number of deliveries to the number of doctors within the department.

Regarding the number of midwives per births, we could not identify a significant effect of the estimator on the cesarean section ratio. Numerous studies report a correlation between midwifery-led delivery or the volume of midwives in an obstetric department and lower cesarean section rates compared to obstetric care at birth (Carlson et al., 2018; Hamlin et al., 2021; Hanahoe, 2020; Hoxha et al., 2019; Martin-Arribas et al., 2022; Rivo et al., 2018; Sandall et al., 2016; Souter et al., 2019; Thiessen et al., 2016; Zbiri et al., 2018). However, other studies did not report such a correlation (Kearney et al., 2017; Sandall et al., 2016).

In Germany, labor in a hospital is often supervised by a physician, limiting the influence of midwives on the decision of the delivery method compared to other countries. Although midwife-led delivery rooms exist, where midwives perform birth without physician supervision, this approach has been seldom researched (Andraczek et al., 2023; Berger, 2020) and is not separately documented in the quality reports.

4.4.1 Strengths and limitations

This analysis relies on secondary data obtained from German hospitals, specifically from quality reports not originally intended for research purposes but rather aimed at enhancing transparency in inpatient care. While the study identified a potential impact of the number of physicians on the risk-adjusted C-section ratio, it is important to note that information regarding the processes and distribution of physicians' tasks within combined obstetric and gynecological departments remains unknown.

The use of aggregated panel data at the department level introduces an element of ambiguity in the data on physician staffing. While midwives are reasonably assumed to be primarily engaged in obstetric care, the clarity of physician allocation between obstetric and gynecological care is less apparent. However, assuming a consistent situation over time within each department aids in mitigating the potential ambiguity inherent in the study population. Nevertheless, the identified patterns necessitate further investigation into the workflow of combined obstetric and gynecological departments, and the possibility of an omitted variable bias cannot be ruled out (Ullah et al., 2021).

Additionally, the absence of details on physician characteristics in the data is a limitation. Research indicates that gender may influence cesarean delivery rates, with female physicians performing fewer cesarean deliveries and exhibiting a lower preference for them (Hoxha et al., 2020). While male physician tend to perform non-medically indicated cesarean section (relative indications) on maternal request more willingly than their female counter parts (Rivo et al., 2018). Our results remain valid under the assumption that the distribution of physicians by gender or other influential factors at the physician level did not systematically vary across departments throughout the study period.

Furthermore, the results of the analysis hold true if no systematic changes in the socio-cultural composition of the patient population and no systematic changes in patient requests for cesarean sections occurred within the study period.

Workload variations between working days and weekends, as well as day and night shifts, may impact medical treatment decisions and quality aspects (Freeman et al., 2017). Although annual average data were employed, the assumption that these aspects vary randomly between departments is crucial for the presented results to hold true.

Low explanatory power is a common issue in volume-based studies (Friedman et al., 2016; Joaquim et al., 2022) and within-department analyses in obstetric care (Friedman et al., 2016; Joaquim et al., 2022). For static IV analyses using nursing staff as an instrument for physician staffing, joint confounders on all variables could not be ruled out, given that all variables originated from the same organization. The panel structure, while beneficial in isolating time- and department-specific influences, may not eliminate all influencing factors that could account for the higher observed effect size in the 2SLS models.

In the data for 2016, there was a noticeable reduction in the number of departments. This discrepancy was evident in other study at the topic as well (Zipfel & Weidmann, 2022). Upon closer examination of the data, it became apparent that the absent departments were predominantly from the federal state of North Rhine-Westphalia. Specifically, we identified more than 70 departments that were present in the data for both 2015 and 2017 but conspicuously absent in 2016. Despite efforts to address this issue through consultation with the regulatory authorities (IQTIG), obtaining these missing data retroactively or generating them from other sources within the quality reports proved unfeasible. Consequently, the data for the year 2016 contain a bias due to the absence of these departments.

Remarkably, a considerable number of missing values pertaining to midwives were noted, despite regulatory mandates requiring their presence at all hospital births in Germany. The imperative for a midwife's attendance extends to all hospital births, including cesarean sections (§ 4 Abs 1. - Hebammengesetz). However, certain departments reported the presence of attending midwives, leading to the exclusion from the study. A notable percentage of hospitals indicated either a complete absence of midwives or reported them outside obstetric departments. A recurring observation was that departments slated for closure in the subsequent year failed to furnish any data on medical staff for the preceding year. This phenomenon can be attributed to the time lag of over a year in the data collection and compilation process. The overall data quality in this aspect is suboptimal, potentially serving as a source of bias.

Finally, it is crucial to recognize that healthcare, particularly obstetric care, is significantly influenced by cultural, policy, and local factors (Betrán et al., 2018; Kingdon et al., 2018; K.-S. Lee & Kwak, 2014; Smith et al., 2022). The complex and divergent nature of the relationship between these factors underscores the challenge of drawing general and cross-national conclusions from the study results (Gombolay et al., 2019).

4.4.2 Implications for practice

The findings underscore that within integrated gynecological and obstetric departments, a higher number of physicians per delivery significantly correlated with more observed risk-adjusted C-sections than expected. The dual provision of gynecological and obstetric care in one department poses a challenge, potentially contributing to an elevated C-section ratio with an increased number of physicians per birth as each physician may be less acquainted with obstetric care.

As a practical approach, directing attention towards focus and specialization within the medical team could yield a reduction in the C-section ratio, potentially involving intra-department staff reallocation allowing for a more specialized workforce between the two areas of responsibility. This approach does not necessarily imply reducing the total number of physicians but rather enhancing specialization between obstetrics and gynecology care.

An insightful analysis of departments surpassing the reference value (90th percentile) reveals that these departments (n = 118) exhibit an average of 15.1 physicians per 1,000 deliveries, accompanied by 872.5 births and 358.9 C-sections (41.1 %). In contrast, inconspicuous departments (n = 1,971) exhibit an average of 12.3 physicians per 1,000 deliveries, along with 1132.9 births and 344.2 C-sections (30.4 %). A targeted reduction of physicians per 1,000 births by 3, aligning with the inconspicuous department average, could anticipate a modest reduction of .012 in the observed expected C-sections, based on our results. On the other hand, departments in the 10th percentile (n = 217) deployed on average 10.9 physicians per 1,000 deliveries, accompanied by 1,216.5 births and 259.7 C-sections (21.3%). Importantly, as we estimated within-effects the effect size is smaller as a between comparison would suggest as they incorporate department individual effects. As for departments that already have low C-section rates (and a potential underperformance of C-sections) it is unclear whether a further increase in the number of deliveries per physician would lead to improved quality of care.

These implications suggest that a nuanced approach to physician staffing, coupled with a strategic focus on specialization and a potential realignment of resources, could contribute to achieve the objective of the quality indicator of minimizing C-sections within integrated obstetric and gynecological departments. If the goal, as articulated in the quality indicator, is to minimize the occurrence of cesarean section births, it is essential to consider additional factors beyond the number of physicians per birth presented in this analysis. The assessment must also consider the preferences of the woman giving birth and relevant medical considerations, ensuring that these crucial aspects are not disregarded. It is vital that a narrow focus on reducing the cesarean section rate does not compromise the health of women and infants.

4.5 Conclusion

Our examination of integrated German obstetric and gynecological departments revealed a noteworthy and robust positive association between the number of physicians per birth and an elevated ratio of observed-to-expected cesarean sections. Additionally, instrumental variable analysis indicated a potential causal effect. However, given the reliance on annual, aggregated averages and the inherent uncertainties despite the instrumental analysis employed, a cautious approach is essential when interpreting causality. Preliminary interpretations suggest that specialization, as indicated by the number of deliveries per physician, may influences the cesarean section ratio within integrated obstetric and gynecological departments.

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Appendix

A Appendix to Chapter 1

Table A.1 Questionnaire (German and English translation).

Questionnaire (German, original version)

Wie gut haben Sie sich Anfang März mit Ihrer Praxis auf eine Epidemie vorbereitet gefühlt? [pand_pre]	sehr schlecht [1] schlecht [2] teils teils [3] gut [4] sehr gut [5]
Wie stellte sich Anfang März Ihr Bestand an Schutz- und Hygienematerialien dar?	
FFP-2 und FFP-3 Masken [PPE_FFPmasks]	für unsere Praxis nicht relevant [0]; völlig unzureichend [1]; unzureichend [2]; ausreichend [3]; völlig ausreichend [4]
Mund-Nasen-Schutz [PPE_medmasks]	für unsere Praxis nicht relevant [0]; völlig unzureichend [1]; unzureichend [2]; ausreichend [3]; völlig ausreichend [4]
Einmalhandschuhe [PPE_gloves]	für unsere Praxis nicht relevant [0]; völlig unzureichend [1]; unzureichend [2]; ausreichend [3]; völlig ausreichend [4]
Hände- und Flächendesinfektionsmittel [PPE_dis]	für unsere Praxis nicht relevant [0]; völlig unzureichend [1]; unzureichend [2]; ausreichend [3]; völlig ausreichend [4]
Schutzbrillen [PPE_glasses]	für unsere Praxis nicht relevant [0]; völlig unzureichend [1]; unzureichend [2]; ausreichend [3]; völlig ausreichend [4]
Schutzanzüge [PPE_suit]	für unsere Praxis nicht relevant [0]; völlig unzureichend [1]; unzureichend [2]; ausreichend [3]; völlig ausreichend [4]
Gesichtsschutzschilder [PPE_shields]	für unsere Praxis nicht relevant [0]; völlig unzureichend [1]; unzureichend [2]; ausreichend [3]; völlig ausreichend [4]
Waren Ihnen vor dem Ausbruch der Corona-Pandemie Anfang März Pandemie- oder Epidemiepläne bekannt? [plan_knowledge]	Ja [1] Nein [0]

Haben Ihnen diese Pandemie- oder Epidemiepläne für die Bewältigung der Corona-Pandemie geholfen? [plan_helpful]	Ja [1] Nein [0]
Wie alt sind Sie? [age]	unter 30 Jahre [1] 31 bis 40 Jahre [2] 41 bis 50 Jahre [3] 51 bis 60 Jahre [4] über 60 Jahre [5]
Welchem Geschlecht fühlen Sie sich zugehörig? [gender]	männlich [1] weiblich [2] divers [3]
Sind Sie in der Praxis selbstständig oder angestellt tätig? [empl]	selbstständig [1] angestellt [2]

Questionnaire (English, translation)

How prepared did you feel at your practice for a pandemic in early March? [pand_pre]	very bad [1] bad [2] moderate [3] good [4] very good [5]
As of early March, what was your inventory of the following protective and hygienic materials?	
FFP-2/3 masks [PPE_FFPmasks]	not relevant [0]; completely insufficient [1]; insufficient [2]; sufficient [3]; completely sufficient [4]
medical masks [PPE_medmasks]	not relevant [0]; completely insufficient [1]; insufficient [2]; sufficient [3]; completely sufficient [4]
surgical gloves [PPE_gloves]	not relevant [0]; completely insufficient [1]; insufficient [2]; sufficient [3]; completely sufficient [4]
Hand and surface disinfectants [PPE_dis]	not relevant [0]; completely insufficient [1]; insufficient [2]; sufficient [3]; completely sufficient [4]
safety glasses [PPE_glasses]	not relevant [0]; completely insufficient [1]; insufficient [2]; sufficient [3]; completely sufficient [4]

protective suit [PPE_suit]	not relevant [0]; completely insufficient [1]; insufficient [2]; sufficient [3]; completely sufficient [4]
face shields [PPE_shields]	not relevant [0]; completely insufficient [1]; insufficient [2]; sufficient [3]; completely sufficient [4]
Were you aware of any pandemic or epidemic plans prior to the Corona pandemic outbreak in early March? [plan_knowledge]	Yes [1] No [0]
Did these pandemic or epidemic plans help you manage the Corona pandemic? [plan_helpful]	Yes [1] No [0]
How old are you? [age]	30 years and younger [1] 31 to 40 years [2] 41 to 50 years [3] 51 to 60 years [4] older than 60 years [5]
Which gender do you feel you belong to? [gender]	male [1] female [2] none-binary [3]
Are you self-employed or employed in the practice? [empl]	self-employed [1] employed [2]

Table A.2 Key sociodemographic characteristics.

Variables	n (%)
Age (n = 507)	
30 years and younger [1]	-
31 to 40 years [2]	56 (11.05)
41 to 50 years [3]	129 (25.44)
51 to 60 years [4]	207 (40.83)
older than 60 years [5]	115 (22.68)
missings	1
Gender (n = 508)	
male [1]	265 (52.16)
female [2]	242 (47.64)
none-binary [3]	1 (.00)
missings	-
Employment status (n = 505)	
self-employed [1]	458 (90.69)
employed [2]	47 (9.31)
missings	3
Federal states (n = 501)	
Baden-Württemberg [1]	71 (14.17)

Bavaria [2]	93 (18.56)
Berlin [3]	23 (4.59)
Brandenburg [4]	5 (1.00)
Bremen [5]	3 (.60)
Hamburg [6]	8 (1.60)
Hesse [7]	64 (12.77)
Mecklenburg-Western Pomerania [8]	13 (2.59)
Lower Saxony [9]	45 (8.98)
North Rhine-Westphalia [10	95 (18.97)
Rhineland-Palatinate [11]	12 (2.40
Saarland [12]	11 (2.20)
Saxony [13]	26 (5.19)
Saxony-Anhalt [14]	11 (2.20)
Schleswig-Holstein [15]	16 (3.19)
Thuringia [16]	5 (1.00)
missings	7
Practice type (n = 506)	
Single practice [1]	249 (49.21)
Group practice [2]	257 (50.79)
missings	2
Practice location (n = 503)	
<5.000 inhabitants [1]	103 (20.48)
>5.000-20.000 inhabitants [2]	123 (24.45)
>20.000-100.000 inhabitants [3]	130 (25.84)
>100.000 inhabitants [4]	147 (29.22)
missings	5

B Appendix to Chapter 2

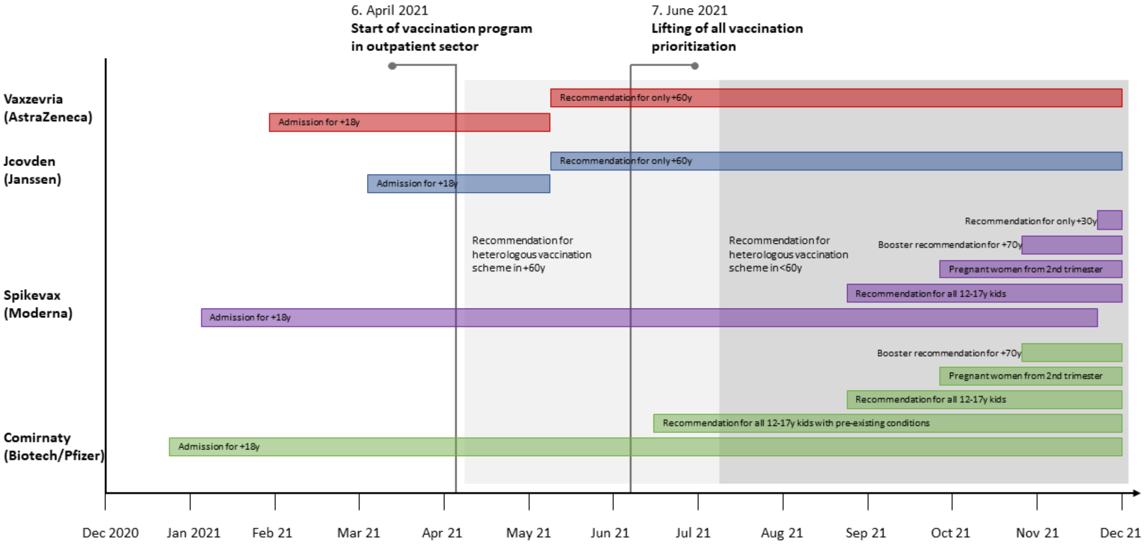

Figure B.1 Timeline vaccine approval and German vaccination campaign 2020-2021.

Table B.1 Questionnaire (German and English translation).

Questionnaire (German, original version)

Welcher Fachrichtung gehören Sie an?	Allgemeinmedizin und Hausärzt*innen für innere Medizin [1], Innere Medizin: Kardiologie [2], Innere Medizin: Gastroenterologie [3], Pädiatrie [4], Gynäkologie [5], HNO [6], Zahnmedizin [7], Pneumologie [8]
Sind Sie in der Praxis selbstständig oder angestellt tätig?	selbstständig [1], angestellt [2]
In welcher KV-/KZV-Region befindet sich Ihre Praxis?	Baden-Württemberg [1], Bayern [2], Berlin [3], Brandenburg [4], Bremen [5], Hamburg [6], Hessen [7], Mecklenburg-Vorpommern [8], Niedersachsen [9], Nordrhein [10], Rheinland-Pfalz [11], Saarland [12], Sachsen [13], Sachsen-Anhalt [14], Schleswig-Holstein [15], Thüringen [16], Westfalen-Lippe [17]
Wie alt sind Sie?	unter 30 Jahre [1], 31 bis 40 Jahre [2], 41 bis 50 Jahre [3], 51 bis 60 Jahre [4], über 60 Jahre [5]
Welchem Geschlecht fühlen Sie sich zugehörig?	männlich [1], weiblich [2], divers [3]
Seit wie vielen Jahren sind Sie im ambulanten Bereich tätig?	Freitext
Wie sind Sie Impfungen im Allgemeinen gegenüber eingestellt?	sehr positiv [1], positiv [2], negativ [3], sehr negativ [4]
Wie sind Sie den Impfungen gegen COVID-19 gegenüber eingestellt?	sehr positiv [1], positiv [2], negativ [3], sehr negativ [4]
Wie sicher schätzen Sie aus Ihren Erfahrungen in Ihrem Praxisalltag die aktuell in Deutschland zugelassenen Impfstoffe gegen COVID-19 hinsichtlich ihrer Nebenwirkungen ein?	

Comirnaty (BioNTech/Pfizer)	sehr unsicher [1], eher unsicher [2], eher sicher [3], sehr sicher [4], kann ich nicht beurteilen [5]
Spikevax (Moderna)	sehr unsicher [1], eher unsicher [2], eher sicher [3], sehr sicher [4], kann ich nicht beurteilen [5]
Vaxzevria (Astra Zeneca)	sehr unsicher [1], eher unsicher [2], eher sicher [3], sehr sicher [4], kann ich nicht beurteilen [5]
COVID-19 Vaccine Janssen (Johnson & Johnson)	sehr unsicher [1], eher unsicher [2], eher sicher [3], sehr sicher [4], kann ich nicht beurteilen [5]
Wie sicher schätzen Sie aus Ihren Erfahrungen in Ihrem Praxisalltag den Impfstoff Comirnaty (BioNTech/Pfizer) hinsichtlich seiner Nebenwirkungen für Kinder und Jugendliche zwischen 12 und 17 Jahren ein?	sehr unsicher [1], eher unsicher [2], eher sicher [3], sehr sicher [4], kann ich nicht beurteilen [5]
Sind Sie selbst vollständig gegen COVID-19 geimpft?	ja [1], nein [2]
Wurden in Ihrer Praxis zu irgendeinem Zeitpunkt Patient*innen gegen COVID-19 geimpft?	ja [1], nein, aber ich habe Patient*innen an ein Impfzentrum oder eine andere Praxis verwiesen [2], nein [3]
Wie schätzen Sie die Impfquote unter Ihren Patient*innen ein? (in Prozent)	Angaben in Prozent
Wie schätzen Sie die Impfquote unter Ihren Patient*innen zwischen 12 und 17 Jahren ein? (in Prozent)	Angaben in Prozent
Wie gehen Sie mit Patient*innen oder deren gesetzlichen Vertretung um, die eine COVID-19-Impfung ablehnen?	
Ich akzeptiere die Entscheidung ohne weitere Diskussion.	trifft gar nicht zu [1], trifft eher nicht zu [2], teils/teils [3], trifft eher zu [4], trifft voll und ganz zu [5]
Ich empfehle ihnen, sich einen anderen Arzt zu suchen.	trifft gar nicht zu [1], trifft eher nicht zu [2], teils/teils [3], trifft eher zu [4], trifft voll und ganz zu [5]
Ich versuche, sie in einem ausführlichen Gespräch zu überzeugen.	trifft gar nicht zu [1], trifft eher nicht zu [2], teils/teils [3], trifft eher zu [4], trifft voll und ganz zu [5]
Ich zeige Empathie für ihre Bedenken.	trifft gar nicht zu [1], trifft eher nicht zu [2], teils/teils [3], trifft eher zu [4], trifft voll und ganz zu [5]
Ich kläre neutral über die individuellen Risiken auf, die mit dem Auslassen der Impfung verbunden sind.	trifft gar nicht zu [1], trifft eher nicht zu [2], teils/teils [3], trifft eher zu [4], trifft voll und ganz zu [5]
Ich kläre über die Folgen einer ausgelassenen Impfung für den Gemeinschaftsschutz (Herdenimmunität) auf.	trifft gar nicht zu [1], trifft eher nicht zu [2], teils/teils [3], trifft eher zu [4], trifft voll und ganz zu [5]
Bitte denken Sie nun an ein typisches Aufklärungsgespräch zur Corona-Impfung. Wie sicher fühlen Sie sich in Bezug auf Ihre eigenen Fähigkeiten...	
mit Patient*innen oder deren gesetzlichen Vertretung über Impfungen zu sprechen?	sehr unsicher [1], eher unsicher [2], teils/teils [3], eher sicher [4], sehr sicher [5]
über die Risiken von Impfungen zu sprechen?	sehr unsicher [1], eher unsicher [2], teils/teils [3], eher sicher [4], sehr sicher [5]
Informationen über Impfungen bereitzustellen?	sehr unsicher [1], eher unsicher [2], teils/teils [3], eher sicher [4], sehr sicher [5]

schwierige Fragen von impfskeptischen Patient*innen oder deren gesetzliche Vertretung zu beantworten?	sehr unsicher [1], eher unsicher [2], teils/teils [3], eher sicher [4], sehr sicher [5]
Im Vergleich zu anderen typischen Impfaufklärungsgesprächen, ist ein typisches Corona-Impfaufklärungsgespräch für mich...	viel leichter [1], leichter [2], weder schwieriger noch leichter [3], schwieriger [4], viel schwieriger [5]
Das Paul-Ehrlich-Institut verlangt von Ärzt*innen, Verdachtsfälle von Impfkomplikationen nach IfSG zu melden. Wie leicht oder schwer fällt es Ihnen, solche Verdachtsfälle in Bezug auf die COVID-19-Impfung unter Ihren Patient*innen zu erkennen?	sehr leicht [1], leicht [2], teils/teils [3], schwer [4], sehr schwer [5], kann ich nicht beurteilen [6]
Haben Sie solche Verdachtsfälle in Bezug auf die COVID-19-Impfung beim Paul-Ehrlich-Institut gemeldet?	ja, alle [1], ja, manche [2], nein, keine gemeldet [3], nein, keine gesehen [4]

Questionnaire (English, translation)

Which specialist do you belong to?	general practice [1], internal medicine: cardiology [2], internal medicine: gastroenterology [3], pediatrics [4], gynecology [5], ENT [6], dentistry [7], pneumology [8]
Are you self-employed or employed in the practice?	self-employed [1], employed [2]
In which region is your practice located? (Based on region of the German Associations of Statutory Health Insurance Physicians)	Baden-Württemberg [1], Bavaria [2], Berlin [3], Brandenburg [4], Bremen [5], Hamburg [6], Hessen [7], Mecklenburg-Western Pomerania [8], Lower Saxony [9], North Rhine [10], Rhineland-Palatinate [11], Saarland [12], Saxony [13], Saxony-Anhalt [14], Schleswig-Holstein [15], Thuringia [16], Westphalia-Lippe [17]
How old are you?	30 years and younger [1], 31 to 40 years [2], 41 to 50 years [3], 51 to 60 years [4], older than 60 years [5]
Which gender do you feel you belong to?	male [1], female [2], none-binary [3]
How many years have you been working in the out-patient sector?	Free text field
What is your attitude toward vaccinations in general?	very positive [1], positive [2], negative [3], very negative [4]
What is your attitude toward COVID-19 vaccination?	very positive [1], positive [2], negative [3], very negative [4]
Based on your experience in your daily practice, how safe do you consider the COVID-19 vaccines currently licensed in Germany regarding adverse events?	
Comirnaty (BioNTech/Pfizer)	very unsafe [1], rather unsafe [2], rather safe [3], very safe [4], I can't assess [5]
Spikevax (Moderna)	very unsafe [1], rather unsafe [2], rather safe [3], very safe [4], I can't assess [5]
Vaxzevria (Astra Zeneca)	very unsafe [1], rather unsafe [2], rather safe [3], very safe [4], I can't assess [5]
COVID-19 Vaccine Janssen (Johnson & Johnson)	very unsafe [1], rather unsafe [2], rather safe [3], very safe [4], I can't assess [5]
Based on your experience in your daily practice, how safe do you consider the vaccine Comirnaty (BioNTech/Pfizer) regarding its adverse effects for children and adolescents aged between 12 and 17 years?	very unsafe [1], rather unsafe [2], rather safe [3], very safe [4], I can't assess [5]
Are you fully vaccinated against COVID-19?	yes [1], no [2]

Have any patients been vaccinated against COVID-19 in your practice at any time?	yes [1], no vaccination in own practice but referral of patients to other practices or vaccination centers [2], no [3]
How do you rate the vaccination rate among your patients? (in percent)	Data in percent
How do you rate the vaccination rate among your patients aged 12 to 17? (in percent)	Data in percent
How do you address patients or their legal representatives who refuse a COVID-19 vaccination?	
I accept the decision without further discussion.	Does not apply at all [1], rather does not apply [2], partly/partly [3], rather applies [4], fully applies [5]
I recommend they look for another doctor.	Does not apply at all [1], rather does not apply [2], partly/partly [3], rather applies [4], fully applies [5]
I try to convince them in a detailed consultation.	Does not apply at all [1], rather does not apply [2], partly/partly [3], rather applies [4], fully applies [5]
I show empathy for their concerns.	Does not apply at all [1], rather does not apply [2], partly/partly [3], rather applies [4], fully applies [5]
I provide neutral information about the individual risks of vaccination omission.	Does not apply at all [1], rather does not apply [2], partly/partly [3], rather applies [4], fully applies [5]
I educate about the consequences of omitted vaccination for community protection.	Does not apply at all [1], rather does not apply [2], partly/partly [3], rather applies [4], fully applies [5]
Please think of a typical consultation about the corona vaccination. How confident are you in your ability to...	
talk to patients or legal representatives about vaccines?	not at all confident [1], rather unconfident [2], partly/partly [3], rather confident [4], very confident [5]
talk about the risks of vaccines?	not at all confident [1], rather unconfident [2], partly/partly [3], rather confident [4], very confident [5]
provide vaccines information resources?	not at all confident [1], rather unconfident [2], partly/partly [3], rather confident [4], very confident [5]
answer difficult questions from vaccine hesitant patients or their legal representatives about vaccines?	not at all confident [1], rather unconfident [2], partly/partly [3], rather confident [4], very confident [5]
Compared to other typical vaccination consultations, a typical COVID-19 vaccination consultation for me is...	much easier [1], easier [2], neither more difficult nor easier [3], more difficult [4], much more difficult [5]
The Paul-Ehrlich-Institut requires doctors to report suspected cases of vaccination complications according to the German Infection Protection Act. How easy or difficult is it for you to identify such suspected cases in regard to COVID-19 vaccination among your patients?	very easy [1], easy [2], partly/partially [3], difficult [4], very difficult [5], I can' t assess [6]
Have you reported such suspected cases in relation to the COVID-19 vaccination to the Paul-Ehrlich-Institute?	yes, all reported [1], yes, some reported [2], no, none reported [3], no, none seen [4]

C Appendix to Chapter 3

Additional information on quality reports of German hospitals

Under the commission of the Federal Joint Committee (Gemeinsamer Bundesausschuss), the Institute for Quality Assurance and Transparency in Health Care (IQTIG) develops, operationalizes, and annually recommends which quality indicators should be included from 2015 onward (IQTIG – Institut für Qualitätssicherung und Transparenz im Gesundheitswesen, 2022b). IQTIG defines ratios for selected quality indicators and evaluates and reviews the reported results. Until 2015, the Institute for Applied Quality Promotion and Research in Health Care (aQua) was responsible for this task. From 2012 to 2015, only quality indicators for the inpatient sector were examined; since 2016, cross-sectoral procedures have also been integrated (IQTIG – Institut für Qualitätssicherung und Transparenz im Gesundheitswesen, 2016b).

Alongside quality indicators with reference ranges, there are sentinel event indicators. Each case identified by in such a quality indicator requires a statement from the hospital (e.g., maternal mortality during labor, quality indicator 331). Besides confirmed quality issues, there may be other reasons for a conspicuous result, such as a patient population with a high-risk potential, a special care situation, or isolated documentation problems. Over time, more and more risk adjustments have been introduced in the assessment of the quality indicators to further increase the evaluation's quality (IQTIG – Institut für Qualitätssicherung und Transparenz im Gesundheitswesen, 2020b). In the event of confirmed quality deficiencies in care, it is the hospitals' duty to immediately initiate improvement measures so that medical care again meets the quality requirements (IQTIG – Institut für Qualitätssicherung und Transparenz im Gesundheitswesen, 2020b).

Matching of data sets

Overall, 551 medical directors (45%) responded to the ATräk survey in 2008. For these hospitals, we compiled data on quality indicator assessment, and the organizational characteristics of ownership, number of beds, and teaching status from the quality reports for the years 2012–2019. By this mechanism, we generated a panel data set for our analysis. Each hospital was assigned an identification code, and each site within a hospital was assigned a site number in the quality reports. We manually matched the remaining and questionable cases following a machine linkage. We used the addresses of the hospitals and sites, bed numbers, and the names of responsible quality managers and medical and care directors. Manual linkage was performed independently by two individual researchers. Disputed assignments were determined in a joint decision. Each hospital and site were, thus, assigned its own master code, which formed the basis for the panel study. Linking information for the ATräk study was obtained from address data and manually verified again independently by two researchers. Overall, we excluded hospitals from the original ATräk study from our analysis if they published no quality report between 2012 and 2019, as well as if they submitted quality reports for multiple sites of one hospital so that uncertainty prevailed about the allocation of data at the department and hospital levels.

D Appendix to Chapter 4

Table D.1 Obstetric quality indicators for the period 2015-2019.

QI-ID	Indicator Description	Years	Quality Goal
330	Antenatal corticosteroid therapy for preterm births with a prepartum inpatient stay of at least two calendar days	2015 - 2019	Frequent initiation of antenatal corticosteroid therapy (lung maturation induction) in births with a gestational age of 24+0 to under 34+0 weeks, excluding stillbirths, and with a prepartum inpatient stay of at least two calendar days
50046	Administration of antibiotics in cases of premature rupture of membranes	2015	Not listed in 2015
50045	Perioperative antibiotic prophylaxis in cesarean section deliveries	2015 - 2019	High rate of perioperative antibiotic prophylaxis in cesarean section deliveries
52243	Cesarean births	2015	Not listed in 2015
52249	Ratio of observed to expected rate (O/E) of cesarean births	2015 - 2019	Low rate of cesarean births
1058	Decision-to-delivery interval over 20 minutes in emergency cesarean sections	2015 - 2019	Rarely a decision-to-delivery interval of more than 20 minutes in emergency cesarean sections
319	Measurement of umbilical artery pH in singleton live births	2015	Not listed in 2015
321	Acidosis in mature singletons with umbilical artery pH measurement	2015 - 2019	Low rate of acidosis in singleton live births with umbilical artery pH measurement
51397	Ratio of observed to expected rate (O/E) of acidosis in mature singletons with umbilical artery pH measurement	2015 - 2019	Low rate of acidosis in singleton live births with umbilical artery pH measurement
51826	Acidosis in preterm singletons with umbilical artery pH measurement	2015	Not listed in 2015
51831	Ratio of observed to expected rate (O/E) of acidosis in preterm singletons with umbilical artery pH measurement	2015 - 2019	Low rate of acidosis in singleton live births with umbilical artery pH measurement
318	Presence of a pediatrician at preterm births	2015 - 2019	Frequent presence of a pediatrician at the birth of preterm live births with a gestational age of 24+0 to under 35+0 weeks
1059	Critical outcome in mature newborns	2015	Not listed in 2015
51803	Quality index for critical outcome in mature newborns	2015 - 2019	Rare occurrences of child deaths, 5-minute Apgar score below 5, pH below 7, and Base Excess < -16 in mature newborns
51808_51803	Level 1: Ratio of observed to expected rate (O/E) of child deaths	2018, 2019	Not specified
51813_51803	Level 2: Ratio of observed to expected rate (O/E) of children	2018, 2019	Not specified

	with a 5-minute Apgar score below 5		
51818_51803	Level 3: Ratio of observed to expected rate (O/E) of children with Base Excess below -16	2018, 2019	Not specified
51823_51803	Level 4: Ratio of observed to expected rate (O/E) of children with acidosis (pH < 7.00)	2018, 2019	Not specified
322	Third- or fourth-degree perineal tear in spontaneous singleton deliveries	2015	
51181	Ratio of observed to expected rate (O/E) of third- or fourth-degree perineal tears in spontaneous singleton deliveries	2015 - 2017	Low number of mothers with third- or fourth-degree perineal tears in spontaneous singleton deliveries
323	Third- or fourth-degree perineal tear in spontaneous singleton deliveries without episiotomy	2015	Not listed in 2015
324	Third- or fourth-degree perineal tear in spontaneous singleton deliveries with episiotomy	2015	Not listed in 2015
52244	Mothers and children discharged home together	2015	Not listed in 2015
52254	Ratio of observed to expected rate (O/E) of mothers and children discharged home together	2015	Not listed in 2015
331	Maternal mortality in the context of perinatal surveys	2015 - 2019	Rare occurrences of maternal deaths
181800	Quality index for fourth-degree perineal tears in singleton deliveries	2018, 2019	Low number of mothers with fourth-degree perineal tears in spontaneous or vaginal-assisted singleton deliveries
181801_181800	Level 1: Ratio of observed to expected rate (O/E) of fourth-degree perineal tears in spontaneous singleton deliveries	2018, 2019	Not specified
181802_181800	Level 2: Ratio of observed to expected rate (O/E) of fourth-degree perineal tears in vaginal-assisted singleton deliveries	2018, 2019	Not specified

Figure D.1 Ratio deliveries to full inpatient cases.

Table D.2 Comparison of births and cesarean sections between integrated and solo obstetric departments.

	Study Population (integrated departments)			**Solo Departments**		
	Deliveries (All mothers who have had at least one birth of a child)	Cesarean deliveries	C-section rate	Deliveries (All mothers who have had at least one birth of a child)	Cesarean deliveries	C-section rate
2015	444,555	139,940	31.48	90,690	28,866	31.83
2016	420,158	130,253	31.00	93,824	27,489	29.30
2017	492,692	151,074	30.66	91,709	28,149	30.69
2018	499,258	152,461	30.54	98,282	28,996	29.50
2019	479,176	147,067	30.69	107,058	32,398	30.26
Σ / Ø	2,335,839	720,795	30.87	481,563	145,898	30.32

Table D.3 Descriptive description solo obstetric departments.

Characteristic	**Overall N = 308[1]**	**2015 N = 61[1]**	**2016 N = 57[1]**	**2017 N = 61[1]**	**2018 N = 62[1]**	**2019 N = 67[1]**
Risk-adjusted cesarean ratio	0.95 / 0.95 (0.18)	0.97 / 0.99 (0.17)	0.92 / 0.92 (0.19)	0.95 / 0.96 (0.18)	0.94 / 0.94 (0.18)	0.95 / 0.96 (0.19)
Number of deliveries	1,563.52 / 1,474.50 (709.62)	1,486.72 / 1,293.00 (716.81)	1,646.04 / 1,603.00 (785.32)	1,503.43 / 1,464.00 (634.92)	1,585.19 / 1,523.00 (681.82)	1,597.88 / 1,520.00 (734.48)
Number of C-sections	473.69 / 437.00 (249.22)	473.21 / 436.00 (253.57)	482.26 / 437.00 (282.01)	461.46 / 433.00 (225.98)	467.68 / 426.50 (229.55)	483.55 / 448.00 (259.85)
Number of full-time equivalent physicians	9.66 / 8.34 (4.96)	9.28 / 8.25 (5.03)	9.73 / 8.60 (5.59)	9.19 / 8.04 (4.22)	9.74 / 8.56 (4.56)	10.32 / 8.34 (5.36)
Number of full-time equivalent physicians per 1,000 deliveries	6.82 / 5.82 (3.31)	7.03 / 6.08 (3.68)	6.72 / 5.79 (3.52)	6.79 / 5.48 (3.33)	6.68 / 5.70 (3.03)	6.89 / 6.16 (3.09)
Number of full-time equivalent midwives	13.39 / 12.79 (7.38)	13.22 / 12.30 (8.20)	13.72 / 12.80 (8.02)	12.61 / 12.64 (6.77)	13.24 / 12.89 (6.85)	14.12 / 13.60 (7.17)

Characteristic	Overall N = 308[1]	2015 N = 61[1]	2016 N = 57[1]	2017 N = 61[1]	2018 N = 62[1]	2019 N = 67[1]
Number of full-time equivalent midwives per 1,000 deliveries	9.07 / 9.20 (3.80)	9.57 / 9.19 (4.84)	8.95 / 8.86 (4.14)	8.70 / 9.29 (3.24)	8.79 / 9.08 (3.23)	9.32 / 9.52 (3.41)
Number of full-time equivalent nursing staff	17.65 / 15.88 (9.93)	18.05 / 16.00 (9.89)	18.81 / 15.80 (12.93)	16.39 / 15.14 (7.99)	17.97 / 16.66 (10.31)	17.13 / 16.19 (8.26)
missing	1	0	0	0	0	1
Number of full-time equivalent nursing staff per 1,000 deliveries	12.17 / 10.93 (5.92)	13.51 / 12.29 (7.67)	12.23 / 10.54 (6.33)	11.41 / 10.94 (4.42)	12.25 / 10.58 (6.17)	11.53 / 11.09 (4.45)
missing	1	0	0	0	0	1
Ownership						
non-profit	176 (57.14%)	34 (55.74%)	29 (50.88%)	34 (55.74%)	38 (61.29%)	41 (61.19%)
private	31 (10.06%)	6 (9.84%)	8 (14.04%)	5 (8.20%)	5 (8.06%)	7 (10.45%)
public	101 (32.79%)	21 (34.43%)	20 (35.09%)	22 (36.07%)	19 (30.65%)	19 (28.36%)
Teaching status						
no teaching assignment	39 (12.66%)	8 (13.11%)	6 (10.53%)	10 (16.39%)	9 (14.52%)	6 (8.96%)
academic teaching hospital	247 (80.19%)	51 (83.61%)	47 (82.46%)	47 (77.05%)	47 (75.81%)	55 (82.09%)
university hospital	22 (7.14%)	2 (3.28%)	4 (7.02%)	4 (6.56%)	6 (9.68%)	6 (8.96%)
Perinatal care level						
regular obstetric department (care level 4)	102 (33.12%)	18 (29.51%)	23 (40.35%)	19 (31.15%)	20 (32.26%)	22 (32.84%)
perinatal focus (care level 3)	31 (10.06%)	6 (9.84%)	4 (7.02%)	7 (11.48%)	7 (11.29%)	7 (10.45%)
perinatal centers level II (care level 2)	48 (15.58%)	11 (18.03%)	8 (14.04%)	10 (16.39%)	9 (14.52%)	10 (14.93%)
perinatal centers level I (care level 1)	127 (41.23%)	26 (42.62%)	22 (38.60%)	25 (40.98%)	26 (41.94%)	28 (41.79%)

[1] n (%); Mean / Median (SD)

Table D.4 Uni- and multivariate panel models with two-ways random effects on risk-adjusted C-section ratio.

	Ratio of observed to expected (O/E) cesarean births (2015-2019) (two-way random effects model)			
		Univariate models		**multivariate model**
Intercept	**0.893*** **	**0.964*** **	**1.022*** **	**0.918*** **
p-value	**(<0.001)**	**(<0.001)**	**(<0.001)**	**(<0.001)**
95%-CI	**[0.852, 0.934]**	**[0.924, 1.004]**	**[0.994, 1.051]**	**[0.852, 0.984]**
SE	**(0.021)**	**(0.020)**	**(0.014)**	**(0.034)**
Number of physicians per 1,000 deliveries	**0.007*** **			**0.007*** **
p-value	**(<0.001)**			**(<0.001)**
95%-CI	**[0.004, 0.010]**			**[0.003, 0.010]**
SE	**(0.002)**			**(0.002)**
Number of midwives per 1,000 deliveries		0.002		0.000

	Ratio of observed to expected (O/E) cesarean births (2015-2019) (two-way random effects model)			
	Univariate models			**multivariate model**
p-value		(0.327)		(0.912)
95%-CI		[-0.002, 0.005]		[-0.004, 0.004]
SE		(0.002)		(0.002)
Number of deliveries per 1,000			**-0.036*** **	-0.017
p-value			**(<0.001)**	(0.135)
95%-CI			**[-0.056, -0.015]**	[-0.039, 0.005]
SE			**(0.010)**	(0.011)
Num.Obs.	2089	2089	2089	2089
R2	0.061	0.000	0.019	0.059
R2 Adj.	0.061	0.000	0.019	0.057
AIC	-1282.3	-1158.3	-1201.5	-1279.1
BIC	-1265.3	-1141.3	-1184.5	-1250.9
Std.Errors	HC1	HC1	HC1	HC1
+ p < 0.1, * p < 0.05, ** p < 0.01, *** p < 0.001				

Table D.5 First stage least square regression for number of nursing staff per 1,000. deliveries as an instrument variable for number of physicians per 1,000 deliveries.

	First stage regression (fixed effects)
Number of nursing staff per 1,000. deliveries	**0.239*** **
p-value	**(<0.001)**
95%-CI	**[0.208, 0.269]**
SE	**(0.016)**
Num.Obs.	2037
R2	0.329
R2 Adj.	0.106
AIC	9101.9
BIC	9113.1
F-statistic	237.206
Std.Errors	HC1
+ p < 0.1, * p < 0.05, ** p < 0.01, *** p < 0.001	

Table D.6 Endogeneity check for instrument variable on risk-adjusted C-section ratio.

	Ratio of observed to expected (O/E) cesarean births (2015-2019) (two-way fixed effects model)	
	univariate model	**multivariate model**
Number of physicians per 1,000 deliveries	**0.014*** **	**0.014*** **
p-value	**(<0.001)**	**(<0.001)**
95%-CI	**[0.009, 0.019]**	**[0.009, 0.019]**

	Ratio of observed to expected (O/E) cesarean births (2015-2019) (two-way fixed effects model)	
	univariate model	**multivariate model**
SE	**(0.003)**	**(0.003)**
Number of midwives per 1,000 deliveries		-0.001
p-value		(0.627)
95%-CI		[-0.004, 0.002]
SE		(0.002)
Number of deliveries per 1,000		0.001
p-value		(0.933)
95%-CI		[-0.024, 0.026]
SE		(0.013)
Endogenous part from the IV	**-0.006***	**-0.006***
p-value	**(0.023)**	**(0.021)**
95%-CI	**[-0.012, -0.001]**	**[-0.012, -0.001]**
SE	**(0.003)**	**(0.003)**
Num.Obs.	2037	2037
R2	0.066	0.067
R2 Adj.	-0.246	-0.247
AIC	-3436.6	-3433.6
BIC	-3419.7	-3405.5
Std.Errors	HC1	HC1
+ p < 0.1, * p < 0.05, ** p < 0.01, *** p < 0.001		

Table D.7 Comparison of effect size lagged variable for OLS, fixed effect and difference GMM estimator on risk-adjusted C-section ratio.

	Ratio of observed to expected (O/E) cesarean births (2015-2019) (two-way fixed effects model)		
	OLS	**Panel model with fixed effects**	**difference GMM**
Intercept	0.144***		
p-value	(<0.001)		
95%-CI	[0.111, 0.177]		
SE	(0.017)		
Lagged ratio of observed to expected ratio (O/E) of cesarean births	**0.864*** **	0.046	**0.510*** **
p-value	**(<0.001)**	(0.241)	**(<0.001)**
95%-CI	**[0.837, 0.891]**	[-0.031, 0.123]	**[0.265, 0.754]**
SE	**(0.014)**	(0.039)	**(0.125)**
Number of physicians per 1,000 deliveries	0.000	**0.004***	0.003
p-value	(0.769)	**(0.045)**	(0.239)
95%-CI	[-0.001, 0.001]	**[0.000, 0.007]**	[-0.002, 0.007]
SE	(0.001)	**(0.002)**	(0.002)
Number of midwives per 1,000 deliveries	0.000	0.002	0.003
p-value	(0.884)	(0.336)	(0.150)
95%-CI	[-0.001, 0.001]	[-0.002, 0.006]	[-0.001, 0.006]

	Ratio of observed to expected (O/E) cesarean births (2015-2019) (two-way fixed effects model)		
	OLS	**Panel model with fixed effects**	**difference GMM**
SE	(0.001)	(0.002)	(0.002)
Number of deliveries per 1,000	-0.006*	-0.013	-0.008
p-value	(0.037)	(0.670)	(0.844)
95%-CI	[-0.012, 0.000]	[-0.074, 0.048]	[-0.089, 0.072]
SE	(0.003)	(0.031)	(0.041)
Num.Obs.	1479	1479	1024
R2	0.753	0.012	
R2 Adj.	0.752	-0.427	
AIC	-2916.6	-4015.8	
BIC	-2884.8	-3989.3	
Std.Errors	HC1	HC1	
+ p < 0.1, * p < 0.05, ** p < 0.01, *** p < 0.001			

Table D.8 Uni- and multivariate panel models with two-ways difference generalized method of moment estimators on risk-adjusted C-section ratio.

	Ratio of observed to expected (O/E) cesarean births (2015-2019) (two-way fixed effects model)		
	univariate model	**multivariate model**	**multivariate model with control variables**
Lagged ratio of observed to expected ratio (O/E) of cesarean births	0.544***	0.534***	0.537***
p-value	(<0.001)	(<0.001)	(<0.001)
95%-CI	[0.299, 0.790]	[0.293, 0.776]	[0.293, 0.781]
SE	(0.130)	(0.128)	(0.130)
Number of physicians per 1,000 deliveries	0.004	0.002	0.002
p-value	(0.107)	(0.293)	(0.313)
95%-CI	[-0.001, 0.008]	[-0.002, 0.007]	[-0.002, 0.007]
SE	(0.002)	(0.002)	(0.002)
Number of midwives per 1,000 deliveries		0.003	0.003
p-value		(0.192)	(0.182)
95%-CI		[-0.001, 0.006]	[-0.001, 0.006]
SE		(0.002)	(0.002)
Number of deliveries per 1,000		-0.013	-0.012
p-value		(0.759)	(0.777)
95%-CI		[-0.094, 0.068]	[-0.093, 0.069]
SE		(0.042)	(0.042)
Ownership: public (Ref. category: Ownership private)			-0.047
p-value			(0.356)
95%-CI			[-0.142, 0.049]
SE			(0.050)
Ownership: non-profit (Ref. category: Ownership private)			-0.025

	Ratio of observed to expected (O/E) cesarean births (2015-2019) (two-way fixed effects model)		
	univariate model	multivariate model	multivariate model with control variables
p-value			(0.655)
95%-CI			[-0.130, 0.081]
SE			(0.055)
Perinatal centers level I (care level 1) (Ref. category: regular obstetric department (care level 4))			0.054
p-value			(0.150)
95%-CI			[-0.020, 0.128]
SE			(0.038)
Perinatal centers level II (care level 2) (Ref. category: regular obstetric department (care level 4)			0.023
p-value			(0.648)
95%-CI			[-0.074, 0.121]
SE			(0.051)
Perinatal focus (care level 3) (Ref. category: regular obstetric department (care level 4)			-0.030
p-value			(0.342)
95%-CI			[-0.091, 0.032]
SE			(0.031)
Teaching status: academic teaching hospital (Ref. category: Teaching status: no teaching assignment)			-0.004
p-value			(0.863)
95%-CI			[-0.054, 0.046]
SE			(0.025)
Teaching status: University Hospital (Ref. category: Teaching status: no teaching assignment)			-0.003
p-value			(0.918)
95%-CI			[-0.056, 0.051]
SE			(0.027)
Num.Obs.	1,031	1,031	1,031
Hansen-Sargan test/J-test (p-value)	3.351 (0.646)	3.415 (0.636)	3.710 (0.592)
Arellano–Bond Test/Autocorrelation test (1) (p-value)	-5.461 (<0.001)	-5.504 (<0.001)	-5.476 (<0.001)
Arellano–Bond Test/Autocorrelation test (2) (p-value)	-0.088 (0.930)	-.086 (0.931)	-108 (0.914)
Wald test for coefficients (p-value)	21.518 (<0.001)	23.198 (<0.001)	53.958 (<0.001)
Wald test for time dummies (p-value)	2.385 (0.497)	2.119 (0.379)	1.982 (0.576)
Std.Errors	HC1	HC1	HC1

+ p < 0.1, * p < 0.05, ** p < 0.01, *** p < 0.001

Table D.9 Uni- and multivariate panel models with two-way fixed effects on risk-adjusted c-section ratio in solo obstetric departments.

	Ratio of observed to expected (O/E) cesarean births (2015-2019) (two-way fixed effects model) in solo obstetric departments			
	Univariate models	**Univariate models**	**Univariate models**	**Multivariate models**
Number of physicians per 1,000 deliveries	-0.003			-0.003
p-value	(0.562)			(0.546)
95%-CI	[-0.013, 0.007]			[-0.013, 0.007]
SE	(0.005)			(0.005)
Number of midwives per 1,000 deliveries		0.001		0.001
p-value		(0.699)		(0.710)
95%-CI		[-0.006, 0.009]		[-0.006, 0.009]
SE		(0.004)		(0.004)
Number of deliveries per 1,000			-0.009	-0.008
p-value			(0.865)	(0.875)
95%-CI			[-0.107, 0.090]	[-0.111, 0.095]
SE			(0.050)	(0.052)
Num.Obs.	308	308	308	308
R2	0.003	0.002	0.000	0.005
R2 Adj.	-0.539	-0.539	-0.542	-0.550
AIC	-967.4	-967.2	-966.7	-964.2
BIC	-959.9	-959.8	-959.2	-949.3
Std.Errors	HC1	HC1	HC1	HC1
+ p < 0.1, * p < 0.05, ** p < 0.01, *** p < 0.001				

Table D.10 Uni- and multivariate panel models with two-ways random effects on risk-adjusted C-section ratio in solo obstetric departments.

	Ratio of observed to expected (O/E) cesarean births (2015-2019) (two-way random effects model) in solo obstetric departments			
		Univariate models		**multivariate model**
Intercept	0.948***	0.950***	0.965***	0.950***
p-value	(<0.001)	(<0.001)	(<0.001)	(<0.001)
95%-CI	[0.862, 1.033]	[0.841, 1.059]	[0.879, 1.052]	[0.737, 1.163]
SE	(0.044)	(0.055)	(0.044)	(0.108)
Number of physicians per 1,000 deliveries	0.001			0.001
p-value	(0.837)			(0.874)
95%-CI	[-0.008, 0.010]			[-0.010, 0.012]
SE	(0.005)			(0.005)

	Ratio of observed to expected (O/E) cesarean births (2015-2019) (two-way random effects model) in solo obstetric departments			
		Univariate models		**multivariate model**
Number of midwives per 1,000 deliveries		0.000		0.000
p-value		(0.927)		(0.946)
95%-CI		[-0.010, 0.011]		[-0.011, 0.012]
SE		(0.005)		(0.006)
Number of deliveries per 1,000			-0.007	-0.003
p-value			(0.802)	(0.919)
95%-CI			[-0.060, 0.046]	[-0.067, 0.060]
SE			(0.027)	(0.032)
Num.Obs.	308	308	308	308
R2	0.015	0.004	0.001	0.001
R2 Adj.	0.012	0.001	-0.002	-0.009
AIC	-177.5	-175.7	-175.5	-172.6
BIC	-166.3	-164.6	-164.3	-154.0
Std.Errors	HC1	HC1	HC1	HC1
+ p < 0.1, * p < 0.05, ** p < 0.01, *** p < 0.001				

Table D.11 Uni- and multivariate panel models with two-way fixed effects on crude C-section/birth ratio.

	Ratio of c-section to all births (2015-2019) (two-way fixed effects model)			
	Univariate models	**Univariate models**	**Univariate models**	**Multivariate models**
Number of physicians per 1,000 deliveries	**0.002*** **			**0.001***
p-value	**(<0.001)**			**(0.017)**
95%-CI	**[0.001, 0.002]**			**[0.000, 0.002]**
SE	**(0.000)**			**(0.001)**
Number of midwives per 1,000 deliveries		0.001		0.000
p-value		(0.148)		(0.571)
95%-CI		[0.000, 0.001]		[-0.001, 0.001]
SE		(0.000)		(0.000)
Number of deliveries per 1,000			**-0.024****	-0.013
p-value			**(0.001)**	(0.118)
95%-CI			**[-0.039, -0.009]**	[-0.029, 0.003]
SE			**(0.007)**	(0.008)
Num.Obs.	2089	2089	2089	2089
R2	0.011	0.003	0.008	0.013
R2 Adj.	-0.320	-0.330	-0.324	-0.318

	Ratio of c-section to all births (2015-2019) (two-way fixed effects model)			
	Univariate models	Univariate models	Univariate models	Multivariate models
AIC	-10093.2	-10076.2	-10086.1	-10094.7
BIC	-10081.9	-10064.9	-10074.8	-10072.1
Std.Errors	HC1	HC1	HC1	HC1
+ p < 0.1, * p < 0.05, ** p < 0.01, *** p < 0.001				

Table D.12 Endogeneity check for instrument variable on crude C-section/birth ratio.

	Ratio of c-section to all births (2015-2019) (two-way fixed effects model)	
	univariate model	multivariate model
Number of physicians per 1,000 deliveries	**0.004*** **	**0.006*** **
p-value	**(<0.001)**	**(<0.001)**
95%-CI	**[0.002, 0.006]**	**[0.004, 0.008]**
SE	**(0.001)**	**(0.001)**
Number of midwives per 1,000 deliveries		0.000
p-value		(0.443)
95%-CI		[-0.001, 0.001]
SE		(0.001)
Number of deliveries per 1,000		**0.031*** **
p-value		**(<0.001)**
95%-CI		**[0.022, 0.040]**
SE		**(0.005)**
Endogenous part from the IV	**-0.003***	**-0.003** **
p-value	**(0.015)**	**(0.008)**
95%-CI	**[-0.005, 0.000]**	**[-0.005, -0.001]**
SE	**(0.001)**	**(0.001)**
Num.Obs.	2037	2037
R2	0.032	0.102
R2 Adj.	-0.291	-0.199
AIC	-7520.7	-7669.4
BIC	-7503.8	-7641.3
Std.Errors	HC1	HC1
+ p < 0.1, * p < 0.05, ** p < 0.01, *** p < 0.001		

Table D.13 Dynamic IV models with system generalized method of moment estimators on crude C-section/birth ratio.

	Ratio of observed to expected (O/E) cesarean births (2015-2019) (two-way fixed effects model)		
	univariate model	multivariate model	multivariate model with control variables
Lagged C-section to delivery ratio	0.426***	0.518***	0.530***
p-value	(<0.001)	(<0.001)	(<0.001)

	Ratio of observed to expected (O/E) cesarean births (2015-2019) (two-way fixed effects model)		
	univariate model	**multivariate model**	**multivariate model with control variables**
95%-CI	[0.273, 0.578]	[0.392, 0.644]	[0.416, 0.643]
SE	(0.075)	(0.062)	(0.061)
Number of physicians per 1,000 deliveries	**0.001****	**0.002*****	**0.001****
p-value	**(0.002)**	**(<0.001)**	**(0.007)**
95%-CI	**[0.000, 0.002]**	**[0.001, 0.003]**	**[0.000, 0.002]**
SE	**(0.000)**	**(0.000)**	**(0.000)**
Number of midwives per 1,000 deliveries		0.000	0.000
p-value		(0.689)	(0.396)
95%-CI		[-0.001, 0.001]	[-0.001, 0.000]
SE		(0.000)	(0.000)
Number of deliveries per 1,000		**0.009****	**-0.010****
p-value		**(0.002)**	**(0.006)**
95%-CI		**[0.003, 0.014]**	**[-0.016, -0.004]**
SE		**(0.003)**	**(0.004)**
Ownership: public (Ref. category: Ownership private)			-0.004
p-value			(0.434)
95%-CI			[-0.013, 0.005]
SE			(0.005)
Ownership: non-profit (Ref. category: Ownership private)			0.001
p-value			(0.835)
95%-CI			[-0.008, 0.010]
SE			(0.005)
Perinatal centers level I (care level 1) (Ref. category: regular obstetric department (care level 4))			**0.035*****
p-value			**(<0.001)**
95%-CI			**[0.022, 0.048]**
SE			**(0.007)**
Perinatal centers level II (care level 2) (Ref. category: regular obstetric department (care level 4)			**0.021*****
p-value			**(<0.001)**
95%-CI			**[0.010, 0.032]**
SE			**(0.006)**
Perinatal focus (care level 3) (Ref. category: regular obstetric department (care level 4)			0.002
p-value			(0.570)
95%-CI			[-0.005, 0.010]
SE			(0.004)
Teaching status: academic teaching hospital (Ref. category: Teaching status: no teaching assignment)			0.001
p-value			(0.711)

	Ratio of observed to expected (O/E) cesarean births (2015-2019) (two-way fixed effects model)		
	univariate model	**multivariate model**	**multivariate model with control variables**
95%-CI			[-0.006, 0.009]
SE			(0.004)
Teaching status: University Hospital (Ref. category: Teaching status: no teaching assignment)			0.012
p-value			(0.154)
95%-CI			[-0.002, 0.026]
SE			(0.009)
Num.Obs.	2,520	2,520	2,520
Hansen-Sargan test/J-test (p-value)	10.672 (0.299)	21.704 (0.027)	21.474 (0.256)
Arellano–Bond Test/Autocorrelation test (1) (p-value)	-5.698 (<0.001)	-6.056 (<0.001)	-6.031 (<0.001)
Arellano–Bond Test/Autocorrelation test (2) (p-value)	-0.607 (0.544)	-0.284 (0.777)	-.400 (0.689)
Wald test for coefficients (p-value)	53.519 (<0.00 1)	136.851 (<0.001)	381.974 (<0.001)
Wald test for time dummies (p-value)	7.748 (0.052)	5.141 (0.162)	8.580 (0.035)
Std.Errors	HC1	HC1	HC1
+ p < 0.1, * p < 0.05, ** p < 0.01, *** p < 0.001			

Table D.14 Comparison of effect size lagged variable for OLS, fixed effect and difference GMM estimator on crude C-section/birth ratio.

	Ratio of c-section to all births (2015-2019) (two-way fixed effects model)		
	OLS	**Panel model with fixed effects**	**difference GMM**
Intercept	0.029***		
p-value	(<0.001)		
95%-CI	[0.021, 0.037]		
SE	(0.004)		
Lagged C-section to delivery ratio	**0.876*** **	-0.007	**0.503*** **
p-value	**(<0.001)**	(0.826)	**(<0.001)**
95%-CI	**[0.854, 0.898]**	[-0.074, 0.059]	**[0.289, 0.716]**
SE	**(0.011)**	(0.034)	**(0.109)**
Number of physicians per 1,000 deliveries	0.000	0.001+	0.001
p-value	(0.167)	(0.055)	(0.413)
95%-CI	[0.000, 0.001]	[0.000, 0.002]	[-0.001, 0.002]
SE	(0.000)	(0.001)	(0.001)
Number of midwives per 1,000 deliveries	0.000	0.001	0.001
p-value	(0.421)	(0.160)	(0.336)
95%-CI	[0.000, 0.001]	[0.000, 0.002]	[-0.001, 0.002]
SE	(0.000)	(0.001)	(0.001)

	Ratio of c-section to all births (2015-2019) (two-way fixed effects model)		
	OLS	**Panel model with fixed effects**	**difference GMM**
Number of deliveries per 1,000	0.001	-0.014	-0.014
p-value	(0.183)	(0.201)	(0.447)
95%-CI	[-0.001, 0.004]	[-0.036, 0.008]	[-0.050, 0.022]
SE	(0.001)	(0.011)	(0.018)
Num.Obs.	1489	1489	
R2	0.799	0.020	
R2 Adj.	0.798	-0.416	
AIC	-6218.6	-7555.6	
BIC	-6186.8	-7529.0	
Std.Errors	HC1	HC1	
+ p < 0.1, * p < 0.05, ** p < 0.01, *** p < 0.001			

Table D.15 Uni- and multivariate panel models with two-ways difference generalized method of moment estimators on crude C-section/birth ratio.

	Ratio of c-section to all births (2015-2019) (two-way fixed effects model)		
	univariate model	**multivariate model**	**multivariate model with control variables**
Lagged C-section to delivery ratio	0.522***	0.503***	0.511***
p-value	(<0.001)	(<0.001)	(<0.001)
95%-CI	[0.310, 0.734]	[0.289, 0.716]	[0.295, 0.727]
SE	(0.108)	(0.109)	(0.110)
Number of physicians per 1,000 deliveries	0.001	0.001	0.001
p-value	(0.117)	(0.413)	(0.433)
95%-CI	[0.000, 0.003]	[-0.001, 0.002]	[-0.001, 0.002]
SE	(0.001)	(0.001)	(0.001)
Number of midwives per 1,000 deliveries		0.001	0.001
p-value		(0.336)	(0.310)
95%-CI		[-0.001, 0.002]	[-0.001, 0.002]
SE		(0.001)	(0.001)
Number of deliveries per 1,000		-0.014	-0.013
p-value		(0.447)	(0.471)
95%-CI		[-0.050, 0.022]	[-0.050, 0.023]
SE		(0.018)	(0.019)
Ownership: public (Ref. category: Ownership private)			0.000
p-value			(0.995)
95%-CI			[-0.051, 0.051]
SE			(0.026)
Ownership: non-profit (Ref. category: Ownership private)			0.003
p-value			(0.899)
95%-CI			[-0.038, 0.043]
SE			(0.021)

	Ratio of c-section to all births (2015-2019) (two-way fixed effects model)		
	univariate model	multivariate model	multivariate model with control variables
Perinatal centers level I (care level 1) (Ref. category: regular obstetric department (care level 4))			0.009
p-value			(0.367)
95%-CI			[-0.011, 0.029]
SE			(0.010)
Perinatal centers level II (care level 2) (Ref. category: regular obstetric department (care level 4)			0.008
p-value			(0.594)
95%-CI			[-0.020, 0.035]
SE			(0.014)
Perinatal focus (care level 3) (Ref. category: regular obstetric department (care level 4)			-0.011
p-value			(0.334)
95%-CI			[-0.032, 0.011]
SE			(0.011)
Teaching status: academic teaching hospital (Ref. category: Teaching status: no teaching assignment)			-0.006
p-value			(0.509)
95%-CI			[-0.022, 0.011]
SE			(0.008)
Teaching status: University Hospital (Ref. category: Teaching status: no teaching assignment)			-0.004
p-value			(0.675)
95%-CI			[-0.021, 0.013]
SE			(0.009)
Num.Obs.	1,031	1,031	1,031
Hansen-Sargan test/J-test (p-value)	1.937 (0.858)	1.704 (0.888)	1.685 (0.891)
Arellano–Bond Test/Autocorrelation test (1) (p-value)	-6.098 (<0.001)	-6.225 (<0.001)	-6.240 (<0.001)
Arellano–Bond Test/Autocorrelation test (2) (p-value)	-0.365 (0.715)	-0.494 (0.622)	-0.405 (0.686)
Wald test for coefficients (p-value)	28.950 (<0.001)	30.083 (<0.001)	56.313 (<0.001)
Wald test for time dummies (p-value)	9.975 (0.019)	9.845 (0.020)	9.890 (0.020)
Std.Errors	HC1	HC1	HC1

+ p < 0.1, * p < 0.05, ** p < 0.01, *** p < 0.001

Table D.16 Example of a depiction for calculating the expected risk-adjusted cesarean section rate by IQTIG for 2018 (IQTIG – Institut für Qualitätssicherung und Transparenz im Gesundheitswesen, 2019a, p. 19; own translation).

Reference probability: 14.205 % (odds: 0.165)					
Risk Factor	**Regression Coefficient**	**Standard Error**	**Z-Value**	**Odds Ratio**	**95% Confidence Interval**

Constant	-1.798342673800550	0.004	-408.407	-	-
Age 35 - 38 years	0.034231814566637	0.008	4.439	1.035	1.019 - 1.051
Age > 38	0.286484745408656	0.011	24.971	1.332	1.302 - 1.362
Birth Risk: Amnion Infection Syndrome (suspected)	2.647566531445380	0.040	66.591	14.120	13.061 - 15.264
Birth Risk: Diabetes Mellitus	0.354402849335064	0.014	24.645	1.425	1.386 - 1.466
Birth Risk: Premature Birth	0.356693940042668	0.018	20.341	1.429	1.380 - 1.479
Birth Risk: Hypertensive Pregnancy Disorder or HELLP Syndrome	1.471801217071380	0.018	81.161	4.357	4.205 - 4.515
Birth Risk: Pathological CTG. poor fetal heart sounds. or acidosis during birth (detected by FBS)	0.922892533667843	0.007	124.693	2.517	2.480 - 2.553
Birth Risk: Placenta Praevia	3.414601549901360	0.061	55.693	30.405	26.962 - 34.287
Birth Risk: Breech Position	3.585447507902870	0.018	199.288	36.069	34.820 - 37.364
Birth Risk: Face/Forehead Presentation	1.942056761249630	0.063	30.713	6.973	6.160 - 7.893
Birth Risk: Transverse/Oblique Position	6.515521815847840	0.268	24.293	675.546	399.356 - 1142.746
Birth Risk: Previous Cesarean Section or other Uterus Operations	1.994488346490800	0.016	122.135	7.348	7.117 - 7.587
Multiple Pregnancy	1.453148908289270	0.024	59.963	4.277	4.078 - 4.485
Mother's Record: Hypertension or Proteinuria	0.241446328929522	0.025	9.548	1.273	1.212 - 1.338
Mother's Record: Placental Insufficiency	0.735298957679869	0.031	23.853	2.086	1.964 - 2.216
Mother's Record: Previous Cesarean Section or Uterus Operations	0.294514404293640	0.016	17.888	1.342	1.300 - 1.387

Declaration of Sources

Eidesstattliche Erklärung
nach § 8 Abs. 3 der Promotionsordnung vom 17.02.2015

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