# APPENDICES

## 1. Pre-Study Results on German Vaccination Systems/Portals

Germany with its 16 federal states had 16 different approaches in the vaccination organization with 474 vaccination centers respectively 0.31 million inhabitants per vaccination center. This means that the people had at least 16 different providers with at least 16 different vaccination portals for booking or pre-registration (see **Figure 3** for an overview).

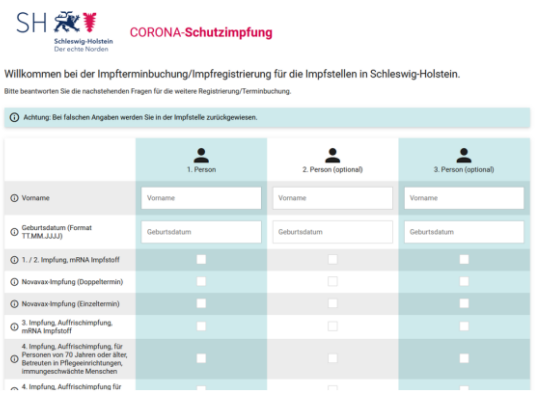
The daily vaccinations rates were analyzed regarding the hypothesis whether centralized or decentralized systems outperformed, i.e., eight decentralized vs eight centralized (see classification according to **Table 2**), over the period January 1st until June 30th 2021 (**Table 3**).

In a simple mean comparison hypothesis testing, no significant differences were found between centralized vs decentralized organizations. Decentralized and centralized organizations had both a mean of 0.5 daily vaccinations per 100, i.e., 15 vaccination per month (30 days), with a non-significant difference of the means.

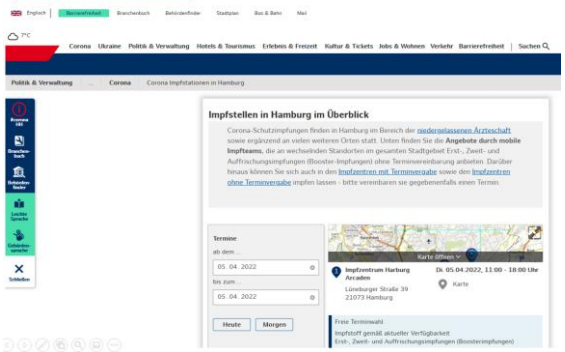
In addition, the size effect was tested since smaller, developed countries have in general the highest vaccination rate of over 90% full vaccination rates such as United Arabian Emirates (99%), Brunei (94%), Malta (93%), as well as Chile, Qatar, and Portugal (each 92%)[5]. Hence, the hypothesis was formulated that states with a smaller population have a higher vaccination rate compared to states with a larger population effect in the data, i.e., seven large vs nine smaller federal states with less than 4 mn inhabitants (cf. population size in **Table 2**) over the period January 1st until June 30th 2021 (**Table 4**).

The hypothesis was rejected since small and large federal states had also a mean of approx. 0.5 daily vaccinations per 100 and a non-significant difference of the means.
In the following, the vaccination portals of the 16 federal states are displayed.

### 1) Schleswig-Holstein




### 2) Hamburg



# 3) Niedersachsen

Geimpft sind wir stärker!

**Herzlich Willkommen auf dem offiziellen Impfportal des Landes Niedersachsen!**

*Welcome to the official vaccination portal of Lower Saxony! The content is currently in German. If you want to translate the content into another language, please use the browser's translator in Google Chrome or Microsoft Edge. The translation is also possible with the default browser on your smartphone.*

**Eine Terminticketbuchung und der Erhalt des digitalen Impfzertifikates ist auch über die Impfhotline 0800 99 88 66 5 möglich.**

Vielen Dank für Ihr Interesse an einer Schutzimpfung gegen COVID-19!

Impfungen gegen COVID-19 bleiben ausgesprochen wichtig. Sie schützen damit sich und andere vor einem schweren Krankheitsverlauf. Die **COVID-19-Schutzimpfung** ist kostenlos.

Wenn Sie bereits zweimal **gegen COVID-19 geimpft** sind, können Sie die 3. Impfung, unter Umständen auch die 4. Impfung wahrnehmen **(Auffrischimpfung oder Boosterimpfung)**. So sind Sie wieder bestmöglich vor einer Infektion mit dem Coronavirus SARS-CoV-2 und vor einem schweren Krankheitsverlauf geschützt.

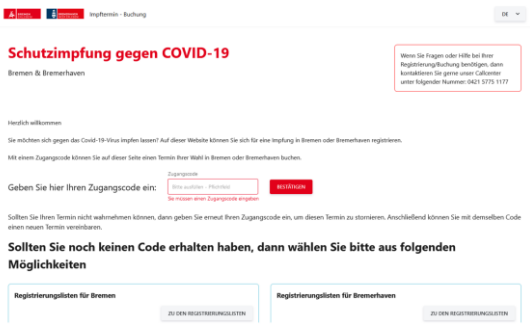
**Hier im Impfportal können Sie deshalb Terminktickets für eine Impfung gegen COVID-19 bei einem mobilen oder stationären Impfteam (MITs/SITs) buchen. Viele Kommunen bieten freie Impfungen auch ohne vorherige Terminabsprache an.**

**Sie haben Fragen zum COVID-19-Impfangebot im Land Niedersachsen oder allgemeine Fragen zum Coronavirus? Dann stehen Ihnen diese Informationskanäle zur Verfügung.**

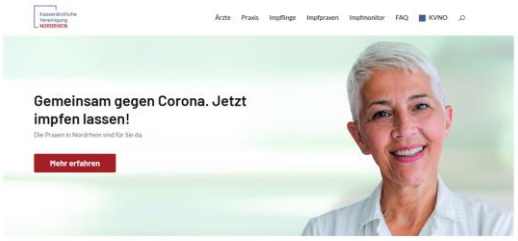
Die COVID-19-Schutz- und Auffrischimpfungen sind und bleiben der wirksamste Weg sich selbst und Ihre Mitmenschen vor einem schweren COVID-19-Krankheitsverlauf zu schützen. Weitere Informationen hierzu erhalten Sie in unseren Informationskanälen rund um Corona in Niedersachsen.

Zurück | Weiter | Datenschutz | Impressum

# 4) Bremen



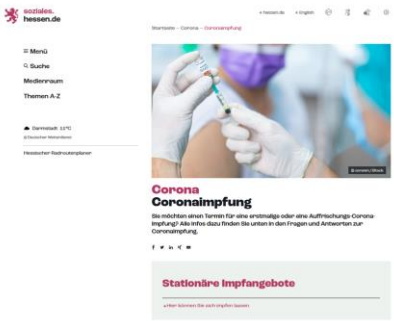

# 5) Nordrhein-Westfalen




## Erfolgreich im Kampf gegen Corona

Bis zum 30. September 2021 wurden in den Impfzentren und Arztpraxen in Nordrhein mehr als 12 Millionen Impfungen durchgeführt. Nach der Schließung der Impfzentren erhalten Sie Ihre Impfung ab sofort bei Ihrem/r Haus- oder Facharztärztin. Sollten Sie keinen festen Haus oder Facharzt haben, finden Sie unter https://coronaimpfung.nrw/impfregister → eine Liste der Praxen, die Sie für einen Impftermin kontaktieren können.

## 6) Hessen

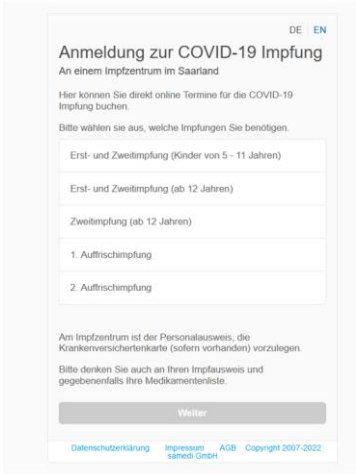



## 7) Rheinland-Pfalz

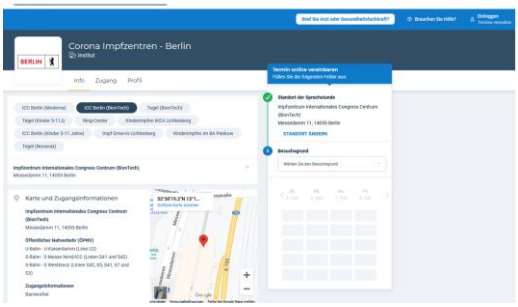

## 8) Baden-Württemberg

## 9) Bayern


## 10) Saarland




## 11) Berlin



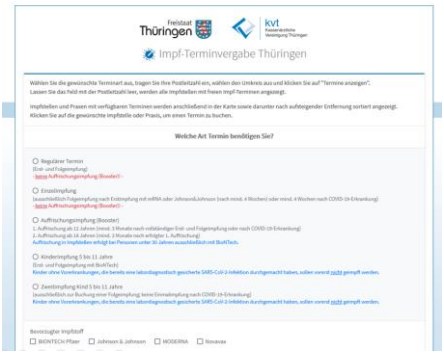

## 12) Brandenburg

## 13) Mecklenburg-Vorpommern


## 14) Sachsen


## 15) Sachsen-Anhalt

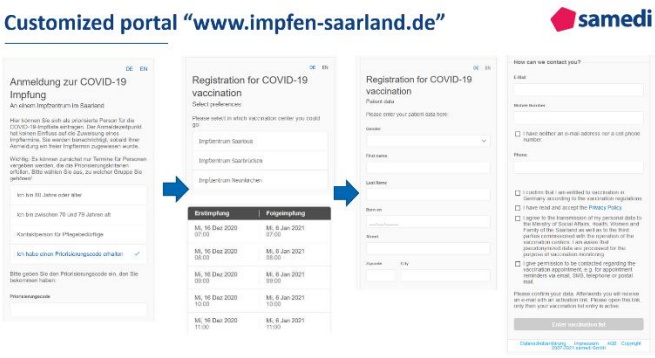
## 16) Thüringen




## 2. Vaccination Rates of federal States in Germany

| January 21 | | | February 21 | | | March 21 | | | Apr 21 | | | May 21 | | | June 21 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Rank | State | Vacc.R. | Rank | State | Vacc.R. | Rank | State | Vacc.R. | Rank | State | Vacc.R. | Rank | State | Vacc.R. | Rank | State | Vacc. |
| 1 | Rhineland-Palat. | 3,96 | 1 | Thuringia | 8,55 | 1 | Thuringia | 19,04 | **1** | **Saarland** | **39,68** | **1** | **Saarland** | **67,58** | **1** | **Saarland** | **100,06** |
| 2 | Mecklenburg-Wf | 3,94 | 2 | Rhineland-Palat. | 8,51 | 2 | Bremen | 18,79 | 2 | Bremen | 38,28 | 2 | Bremen | 66,89 | 2 | Bremen | 98,40 |
| 3 | Bremen | 3,62 | 3 | Bremen | 8,40 | **3** | **Saarland** | **18,22** | 3 | Thuringia | 37,36 | 3 | North Rhine- | 64,29 | 3 | North Rhine- | 95,61 |
| 4 | Schleswig-Holste | 3,54 | 4 | Hamburg | 8,34 | 4 | Berlin | 17,75 | 4 | North Rhine-We: | 37,18 | 4 | Schleswig-Hc | 62,76 | 4 | Schleswig-Ho | 94,49 |
| 5 | Berlin | 3,43 | 5 | Berlin | 8,08 | 5 | Rhineland-Palat. | 17,54 | 5 | Mecklenburg-Wf | 36,98 | 5 | Rhineland-Pa | 61,93 | 5 | Mecklenburg | 91,87 |
| 6 | Brandenburg | 3,29 | 6 | Schleswig-Holstei | 7,98 | 6 | Schleswig-Holste | 17,33 | 6 | Rhineland-Palat. | 36,87 | 6 | Mecklenburg | 61,75 | 6 | Rhineland-Pa | 90,63 |
| 7 | Bavaria | 3,25 | 7 | Bavaria | 7,96 | 7 | Bavaria | 17,05 | 7 | Bavaria | 35,47 | 7 | Thuringia | 60,88 | 7 | Lower Saxon | 89,52 |
| 8 | Hamburg | 3,23 | 8 | Saxony | 7,78 | 8 | Brandenburg | 17,04 | 8 | Lower Saxony | 35,46 | 8 | Baden-Württ | 60,05 | 8 | Baden-Württ | 89,30 |
| **9** | **Saarland** | **3,08** | 9 | North Rhine-Wes | 7,68 | 9 | North Rhine-We: | 17,02 | 9 | Schleswig-Holste | 34,99 | 9 | Lower Saxon | 59,58 | 9 | Berlin | 89,00 |
| 10 | Thuringia | 3,07 | 10 | Mecklenburg-WP | 7,68 | 10 | Lower Saxony | 16,99 | 10 | Hamburg | 34,72 | 10 | Bavaria | 59,40 | 10 | Bavaria | 87,99 |
| 11 | North Rhine-We: | 3,00 | **11** | **Saarland** | **7,44** | 11 | Hessen | 16,82 | 11 | Baden-Württeml | 34,62 | 11 | Berlin | 59,17 | 11 | Hessen | 87,91 |
| 12 | Hessen | 2,93 | 12 | Baden-Württemb | 7,23 | 12 | Hamburg | 16,82 | 12 | Saxony-Anhalt | 34,60 | 12 | Hessen | 59,10 | 12 | Hamburg | 87,14 |
| 13 | Baden-Württeml | 2,66 | 13 | Hessen | 6,90 | 13 | Baden-Württeml | 16,52 | 13 | Berlin | 34,50 | 13 | Hamburg | 58,27 | 13 | Saxony-Anha | 86,13 |
| 14 | Saxony-Anhalt | 2,60 | 14 | Brandenburg | 6,87 | 14 | Saxony | 16,24 | 14 | Hessen | 34,29 | 14 | Saxony | 57,68 | 14 | Thuringia | 85,96 |
| 15 | Saxony | 2,58 | 15 | Lower Saxony | 6,80 | 15 | Saxony-Anhalt | 15,62 | 15 | Saxony | 33,82 | 15 | Saxony-Anha | 57,42 | 15 | Brandenburg | 83,46 |
| 16 | Lower Saxony | 2,50 | 16 | Saxony-Anhalt | 6,09 | 16 | Mecklenburg-Wf | 15,59 | 16 | Brandenburg | 33,22 | 16 | Brandenburg | 56,62 | 16 | Saxony | 82,56 |

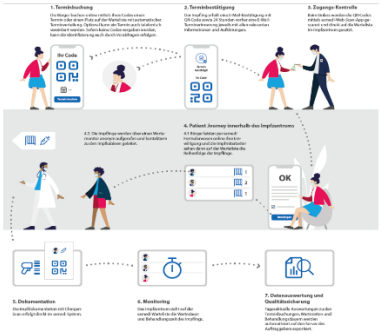
## 3. User Interface for Vaccination Pre-Registration at Federal State Saarland




[5]Cf. https://www.nytimes.com/interactive/2021/world/covid-vaccinations-tracker.html, recorded 04/28/2022.

## 4. Illustration of Vaccination Procedure at Federal State Saarland

**Digital Vaccination Management for federal state Saarland**



**Digital admission, appointment, checkin, workflow, documentation, reporting processes:**

1. Online Appointment & Vaccination registration with automat. Appointment allocation
2. Inivitation email and short message reminder
3. Email QR-Code for security checkin (incl. ecard-Scan)
4. Internal patient process management:
   - Admission (checkin forms)
   - Waiting list with data security compliant patient calls
   - Vaccination cabins
   - Monitoring area
5. Vaccination documentation with scan
6. Online government reporting (RKI)
7. Official digital vaccination certificates

## 5. Three Sprints in the Vaccination Organization of the Federal State Saarland

Two events were decisive in the vaccination process of Saarland:

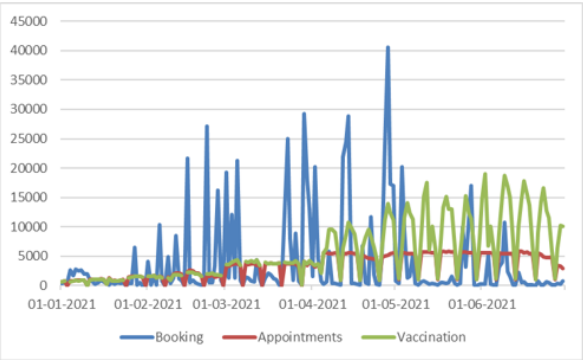
1. Change from appointment booking to pre-registration: January 27th 2021
2. Extend vaccination (centers) by including GP vaccination: April 05th 2021

Given the two events, three sprints are classified: Sprint 1 “Appointment Booking” (from 01/01/2021-01/26/2021), Sprint 2 “Pre-registration and Allocation” (01/27/2021-04/04/2021), and Sprint 3 “Including GP/Doctor vaccination” (04/05/2021-06/30/2021). A simple mean value test was performed to statistically confirm the theoretical differentiation of the three sprints (**Figure 4**) (**Table 5**).

All null hypotheses having the same mean are rejected on a 95% significance level so that the three sprints are confirmed to be different. In general, sprint 2 shows a triple high vaccination rate compared to sprint 1 (i.e., +214%) and sprint 3 again tripled compared to sprint 2 (i.e., +225%). In the first two sprints, the mean of the appointments almost equals the mean of the vaccination number per day (i.e., sprint 1: 895 vs 894 and in sprint 2: 2.738 vs 2.801). As the GP/doctor vaccination started in April 2021, this changed and only half of the vaccination was generated through pre-registration booking and appointment allocation in the central vaccination centers. The other half was done in a decentralized way by the GP and doctors in their practices.

| RKI-ID | Federal State | Inhabitants (in mn) | Area (sqm) | # Vacc. centers | Inhabitants (mn)/center | Catchment (Neumeier 2022) | Vaccination approach | Provider for vaccination booking | Link for booking/registration |
|---|---|---|---|---|---|---|---|---|---|
| 1 | Schleswig-Holstein | 2,9 | 15.801 | 28 | 0,10 | federal | **centralized** | CTS Eventim | https://ticket.impfen-sh.de/sh/start/termine |
| 2 | Hamburg | 1,9 | 755 | 1 | 1,85 | federal | **centralized** | Authority/ KBV | https://www.hamburg.de/corona-impfstationen/ |
| 3 | Lower Saxony | 8,0 | 47.710 | 50 | 0,16 | county | **centralized** | Majorel (Arvato) | https://www.impfportal-niedersachsen.de/portal/#/appointment/public |
| 4 | Bremen | 0,7 | 419 | 3 | 0,23 | federal | **centralized** | Digital Guest Sol. GmbH | https://impfzentrum.bremen.de/ |
| 5 | North Rhine-Westphalia | 17,9 | 34.112 | 53 | 0,34 | county | decentralized | *several* | https://termin.corona-impfung.nrw |
| 6 | Hessen | 6,3 | 21.116 | 28 | 0,22 | county | decentralized | *several* | https://impfterminservice.hessen.de |
| 7 | Rhineland-Palat. | 4,1 | 19.858 | 32 | 0,13 | county | decentralized | Authority | https://impftermin.rlp.de/de/ |
| 8 | Baden-Württemberg | 11,1 | 35.748 | 53 | 0,21 | federal | decentralized | *several* | https://www.dranbleiben-bw.de/#impfangebote |
| 9 | Bavaria | 13,1 | 70.542 | 125 | 0,11 | county | decentralized | Accenture/BayIMCO | https://impfzentren.bayern/ |
| 10 | Saarland | 1,0 | 2.571 | 4 | 0,25 | federal | **centralized** | Samedi | https://www.impfen-saarland.de/ |
| 11 | Berlin | 3,7 | 891 | 6 | 0,61 | federal | **centralized** | Doctolib | https://www.doctolib.de/institut/berlin/ciz-berlin-berlin |
| 12 | Brandenburg | 2,5 | 29.654 | 14 | 0,18 | federal | decentralized | Authority | https://brandenburg-impft.de/corona/de/corona-schutzimpfung/# |
| 13 | Mecklenburg-WP | 1,6 | 23.295 | 16 | 0,10 | county | decentralized | Authority | https://www.corona-impftermin-mv.de/ |
| 14 | Saxony | 4,1 | 18.450 | 15 | 0,27 | federal | **centralized** | T-Systems | https://sachsen.impfterminvergabe.de/ |
| 15 | Saxony-Anhalt | 2,2 | 20.457 | 14 | 0,16 | federal | decentralized | *several* | https://coronavirus.sachsen-anhalt.de/hotlines/ |
| 16 | Thuringia | 2,1 | 16.202 | 32 | 0,07 | federal | **centralized** | KVT Notdienst gGmbH | https://www.impfen-thueringen.de/terminvergabe/index.php |
| | TOTAL | 83,2 | 357.581 | 474 | 0,31 | mixed | mixed | | |

**Figure 3:** Provider of vaccination booking/pre-registration in Germany accross federal states



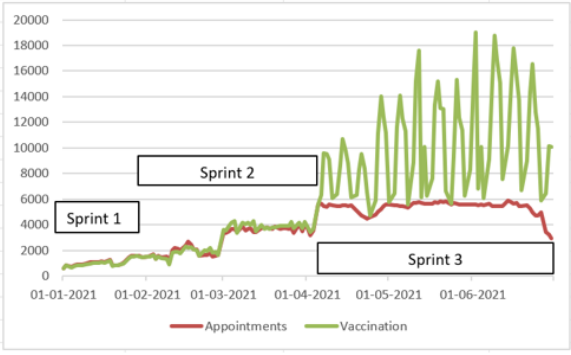



**Figure 4:** Booking, appointments, and vaccination time series in Saarland[6]

**Note:** Time series of all days in the left diagram, appointments and vaccinations without Sundays in the right diagram

[6]The first booking was done on December 24th, 2020, and the first vaccination took place on December 27th, 2020, but to account for comparability the first vaccination phase was defined from January 1st until June 30th, 2021 (see Introduction part) and the first (trial) days were neglected.

**Table 3**: Daily vaccination rate per 100 inhabitants in categorized German federal states

| States | Mean (μ) | Stand.Dev. (SD) | *t-Stat.* $H_0$ ($\mu_C=\mu_D$) | p-value |
|---|---|---|---|---|
| **Centralized** | 0.491176 | 0.416776 | -0.17237 | 0.431622 |
| **Dezentralized** | 0.498833 | 0.428254 | (n=181, DF=360) | |

**Table 4**: Daily vaccination rate per 100 inhabitants in categorized German federal states

| States | Mean (μ) | Stand.Dev. (SD) | *t-Stat.* $H_0$ ($\mu_C=\mu_D$) | p-value |
|---|---|---|---|---|
| **Large** | 0.492528 | 0.431227 | -0.11656 | 0.453637 |
| **Small** | 0.497765 | 0.423665 | (n=181, DF=360) | |

**Table 5**: Mean, Standard Deviation (STD) and simple mean testing of daily appointment and vaccination sprints

| Appointments (daily) | | | | | | Vaccinations (daily) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Sprint** | **Mean (μ)** | **SD** | **Test** | **t-stat.** | **p-value** | **Mean (μ)** | **SD** | **Test** | **t-stat.** | **p-value** | **Daily VaccR** |
| 1 | 895 | 372 | $H_0$ ($\mu_1=\mu_2$) | 2.36 | 0.009*** | 894 | 315 | $H_0$ ($\mu_1=\mu_2$) | 2.71 | 0.003*** | 0.09 |
| 2 | 2'738 | 983 | $H_0$ ($\mu_2=\mu_3$) | 2.06 | 0.02** | 2'801 | 1'157 | $H_0$ ($\mu_2=\mu_3$) | 5.45 | 0.000*** | 0.28 |
| 3 | 4'764 | 1'587 | 0 | 0 | 0 | 9'101 | 4'767 | 0 | 0 | 0 | 0.93 |