Prof. Dr. rer. oec. Alexander Alscher

Covid-19 vaccination management: decentralised/centralised and digitally optimised

'The end of the pandemic is not the vaccines, but the vaccination' (Dai & Song, 2021, p. 455). The organisational implementation of vaccination is essentially a general economic (management) problem, as the resources for mass vaccination are limited, i.e. not only the supply of vaccines, but also the capacities of medical facilities and health personnel. Policy makers need to select and decide an optimal organisational strategy under these constraints to maximise the overall impact of mass vaccination (Kitagawa and Wang, 2021). This study focuses on the first phase of vaccination implementation, which refers to the 'willing vaccinees' who accounted for 50-70% of the population for Covid-19 vaccines in most industrialised countries (Mahase, 2021). Most countries reached 50% of full vaccination in July 2021, i.e. about half a year after the start of vaccination: Spain 58%, United Kingdom [UK] 57%, Netherlands 54%, Italy 52%, Germany 52%, USA 52%, Switzerland 51% and France 50%, with the exception of Poland 46% and Sweden 40%. We therefore define the first phase as the first half of 2021.

Importance of vaccination management

>> With the start of the first coronavirus vaccination campaigns in December 2020, some countries were able to reach almost full vaccination rates of over 90% by April 2022, such as the United Arab Emirates (99%), Brunei (94%), Malta (93%), Chile, Qatar and Portugal (92% each), but these smaller countries are not comparable to the larger industrialised countries and their efforts to manage the pandemic crisis, such as the United States [US] and the nine largest European countries by GDP (IMF, 2022, see Appendix 1): Germany, United Kingdom [UK], France, Italy, Spain, Netherlands, Switzerland, Poland, Sweden (see Appendix 1). All 10 countries used at least three of the four Western vaccine manufacturers: Johnson&Johnson [J], Moderna [M], Oxford/AstraZeneca [O], Pfizer/BioNTech [P] (see Appendix 2). Most of the countries (Germany, France, Italy, Spain, Netherlands, Poland) used vaccine doses from all four manufacturers, while the United States and Switzerland used the British Oxford/AstraZeneca and the United Kingdom and Sweden used the US Johnson&Johnson vaccine. Consequently, Moderna [M] and Pfizer/BioNTech [P] were used in all ten countries. The number oftotal vaccinations shows two patterns in the first vaccination phase of the first half of 2021 in the ten countries (see Table 1).

In general, the UK and the US had a starting advantage of about two weeks due to faster vaccine approval, as the first person was vaccinated in the UK (Margaret Keenan) on 8 December 2020 and in the US (Sandra Lindsay) on 14 December 2020. In the European Union [EU], the European Medicines Agency approved the first Covid-19 vaccination on 21 December 2020, and the start of vaccination in all EU countries began on 26 December 2020. However, the starting advantage is not the sole explanatory factor for the vaccination speed in the UK and the US, as both countries remained in the lead with a larger difference of 20-40 more doses per 100 inhabitants until April. This was followed by the European Union countries catching up from April to July. Germany in particular, which got off to a weak start and ranked #7 and #8 in the first three months, made up the missed difference, outperforming the other countries and catching up with the UK and the US.

Organisational forms in vaccination management

Global immunisation management

Although Western developed countries had similar vaccination policies during the Covid-19 pandemic (see vaccine selection and establishment of national vaccination strategies), there was a striking difference in the organisational structures of vaccination between centralised and decentralised vaccination systems. On the one hand, the UK managed a centralised vaccination process controlled by the National Health Service [NHS], while the US operated through thousands of independent vaccination providers in its decentralised healthcare system (Dai & Song, 2021). This means that the infrastructure to apply, book or register for a vaccine was also different from a single source in centralised systems to numerous online portals of different providers in the decentralised system. Germany, on the other hand, operated a hybrid of a decentralised and centralised vaccination organisation structure. While general pandemic management in Germany began at a decentralised crisis management level at the beginning of 2020 and was subsequently regulated centrally by the federal government (Kuhlmann & Franzke, 2021), vaccination management took the opposite course. The German Federal Government and the Ministry of Health adopted the National Vaccination Strategy centrally in October 2020 with regard to risk groups and vaccination sequence (BMG, 2020), and then the execution and implementation of vaccination centres was decentralised via the 16 federal states and from there partly to the local authorities (see Fig. 1).

German vaccination management

Germany pursued 16 different approaches in the organisation of vaccinations with 16 different platform operators for a total of 474 vaccination centres (see Table 2 and Appendix 3 (only available online) for the presentation of the individual vaccination portals).

When analysing the distribution of vaccination centres, Neumeier (2022) classified the catchment area for the individual vaccination centres. However, this does not always match the centralised and decentralised organisation of how the federal state manages vaccination appointments. In most federal states where

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Kumulierte Impfquote in den 10 größten westlichen Industrieländern												
	Januar 21		Februar 21		März 21		April 21		Mai 21		Juni 21	
Rang	Land	VaccR	Land	VaccR	Land	VaccR	Land	VaccR	Land	VaccR	Land	VaccR
1	GBR	15	GBR	31	GBR	53	USA	80	GBR	97	GBR	116
2	USA	11	USA	27	USA	52	GBR	73	USA	95	USA	103
3	CHE	4	CHE	9	CHE	18	DEU	36	DEU	61	DEU	90
4	ESP	3	POL	9	FRA	18	ESP	35	ITA	59	ESP	90
5	ITA	3	SWE	9	ITA	17	FRA	35	ESP	58	NLD	89
6	SWE	3	ESP	8	ESP	17	ITA	34	CHE	58	CHE	87
7	POL	POL	NLD	8	DEU	17	CH	33	FRA	57	ITA	86
8	DEU	3	DEU	8	POL	17	SWE	32	NLD	56	FRA	85
9	FRA	3	ITA	7	SWE	16	POL	30	SWE	54	SWE	80
10	NLD	2	FRA	7	NLD	14	NLD	29	POL	53	POL	77

Table 1: *Cumulative vaccination rate in the 10 largest western industrialised countries. Source: Alscher, 2023a. Legend: Country abbreviations according to ISO code.*

a federal catchment area was found, a centralised system with a central vaccination platform was used, such as in the seven federal states of Schleswig-Holstein (CTS Eventim), Hamburg (Behörde), Bremen (Digital Guest Solution GmbH), Saarland (samedi GmbH), Berlin (Doctolib GmbH), Saxony (T-Systems) and Thuringia (KVT Notdienst gGmbH). And a decentralised system was introduced in most of the federal states where the catchment areas of the districts were given, such as in the five federal states of North Rhine-Westphalia, Hesse, Rhineland-Palatinate, Bavaria and Mecklenburg-Western Pomerania. However, there were deviations.

Three organisational approaches to vaccination management

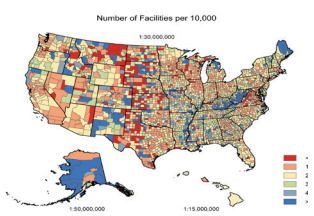
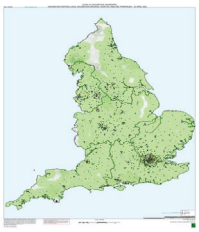
Impfmanagement	US	Deutschland	UK
Organisation	**Dezentralisiert**	**gemischt** (De-/Zentralisiert)	**Zentralisiert**
Anbieter	US-Regierung mit Krankenhäusern, Ärzten, Pharmakonzernen, Supermärkten, kommunalen Impfstellen	Bundesregierung und Länderregierungen (seit April 2021 auch Ärzte)	N*HS (National Health Service)*
Impfstandorte	> 70'000	474 (+ 65'000 Ärzte seit 04/2021)	2'057
Distribution	 (UPMC, 2020)	 (Neumeier, Stefan, 2022, p. 44)	 (NHS, 2020)
Priorisierung	Zuerst Medizinpersonal, dann Alter	Alter, Pflegebedürftige, Medizinpersonal, dann spezielle Gruppen	Erst Pflegebedürftige, dann Alter und Medizinpersonal
Impfbereitschaft	67% (Malik et al., 2020)	*75% (BMG 2021)*	74% (Sherman et al., 2022)

Fig. 1: *Three organisational approaches to vaccination management. Source: Alscher, 2023a.*

In Lower Saxony there were district catchment areas, but a centralised booking platform provided by Majorel (Arvato Systems, a Bertelsmann subsidiary). Conversely, there were also federal states with decentralised multiple vaccination services, such as Baden-Württemberg, Saxony-Anhalt and Brandenburg. The immunisation rate per federal state is shown below (see Table 3).

Rhineland-Palatinate and Thuringia had the best vaccination start, although the vaccination figures were still quite low. Bremen, the smallest federal state, was in the top three places throughout the entire period. In the last 4 months, Saarland stood out (see also Appendix 4), which did not get off to a good start, but made up for this deficit and overtook all other federal states in the further course of the period. Over the 181-day period from 1 January 2021 to 30 June 2021, Saarland achieved the highest daily vaccination rate on 71 days, followed by Rhineland-Palatinate with 39 days, Bremen with 29 days, Thuringia with 21 days, Mecklenburg-Western Pomerania with 18 days and Schleswig-Holstein with 3 days. For this reason, this study focuses on the federal state of Saarland to understand how the top performance was achieved.

Vaccination organisation in Saarland

The federal state of Saarland set up four vaccination centres (plus mobile vaccination teams) for its approximately one million inhabitants and opted for the digital vaccination platform of samedi GmbH on 27 November 2020 (samedi, 2021a). The specialised company samedi, founded in 2008 in Germany, is a leading provider of e-health software for patient portals (incl. appointment booking, check-in, notifications for patients, appointment scheduling & resource planning, video consultations, online forms) used by more than 40,000 individual healthcare providers to coordinate over 30 million patients in Germany, Austria and Switzerland (samedi, 2021b). The samedi digital health platform was adapted for the vaccination process with the top-level domain 'www.impfen-saarland.de' (see Appendix 5), further load balancers were added

RKI-ID	Bundesland	Pop. (Mio.)	Größe	Impforganisation	Portalanbieter	Impfportal
1	Schleswig-Holstein	2,9	klein	**zentralisiert**	CTS Eventim	https://ticket.impfen-sh.de/sh/start/termine
2	Hamburg	1,9	klein	**zentralisiert**	Authority/ KBV	https://www.hamburg.de/corona-impfstationen/
3	Niedersachsen	8,0	groß	**zentralisiert**	Majorel (Arvato)	https://www.impfportal-niedersachsen.de/portal/#/appointment/public
4	Bremen	0,7	klein	**zentralisiert**	Digital Guest Sol. GmbH	https://impfzentrum.bremen.de/
5	Nordrhein-Westfalen	17,9	groß	dezentralisiert	*mehrere*	https://termin.corona-impfung.nrw
6	Hessen	6,3	groß	dezentralisiert	*mehrere*	https://impfterminservice.hessen.de
7	Rheinland-Pfalz	4,1	groß	dezentralisiert	Land	https://impftermin.rlp.de/de/
8	Baden-Württemberg	11,1	groß	dezentralisiert	*mehrere*	https://www.dranbleiben-bw.de/#impfangebote
9	Bayern	13,1	groß	dezentralisiert	Accenture/BayIMCO	https://impfzentren.bayern/
10	**Saarland**	1,0	klein	**zentralisiert**	**samedi GmbH**	https://www.impfen-saarland.de/
11	Berlin	3,7	klein	**zentralisiert**	Doctolib	https://www.doctolib.de/institut/berlin/ciz-berlin-berlin
12	Brandenburg	2,5	klein	dezentralisiert	Land	https://brandenburg-impft.de/corona/de/corona-schutzimpfung/#
13	Mecklenburg-Vorpommer	1,6	klein	dezentralisiert	Land	https://www.corona-impftermin-mv.de/
14	Sachsen	4,1	groß	**zentralisiert**	T-Systems	https://sachsen.impfterminvergabe.de/
15	Sachsen-Anhalt	2,2	klein	dezentralisiert	*mehrere*	https://coronavirus.sachsen-anhalt.de/hotlines/
16	Thüringen	2,1	klein	**zentralisiert**	KVT Notdienst gGmbH	https://www.impfen-thueringen.de/terminvergabe/index.php
	TOTAL	83,2		gemischt		

Table 2: *Overview of the 16 different vaccination organisations in Germany.*

Januar 21			Februar 21			März 21			April 2021			Mai 21			Juni 21		
Rang	Land	Vacc.R.	Rang	Land	Vacc.R.	Rang	Land	Vacc.R.	Rang	Land	Vacc.R.	Rang	Land	Vacc.R.	Rang	Land	Vacc.R.
1	Rheinland-Pf.	3,96	1	Thüringen	8,55	1	Thüringen	19,04	**1**	**Saarland**	**39,68**	**1**	**Saarland**	**67,58**	**1**	**Saarland**	**100,06**
2	Mecklenburg-VP	3,94	2	Rheinland-Pf.	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	Thüringen	37,36	3	Nordrhein-W	64,29	3	Nordrhein-W	95,61
4	Schleswig-Holste	3,54	4	Hamburg	8,34	4	Berlin	17,75	4	Nordrhein-West	37,18	4	Schleswig-Hc	62,76	4	Schleswig-Hc	94,49
5	Berlin	3,43	5	Berlin	8,08	5	Rheinland-Pf.	17,54	5	Mecklenburg-VP	36,98	5	Rheinland-Pf	61,93	5	Mecklenburg	91,87
6	Brandenburg	3,29	6	Schleswig-Holstei	7,98	6	Schleswig-Holste	17,33	6	Rheinland-Pf.	36,87	6	Mecklenburg	61,75	6	Rheinland-Pf	90,63
7	Bayern	3,25	7	Bayern	7,96	7	Bayern	17,05	7	Bayern	35,47	7	Thüringen	60,88	7	Niedersachse	89,52
8	Hamburg	3,23	8	Sachsen	7,78	8	Brandenburg	17,04	8	Niedersachsen	35,46	8	Baden-Württ	60,05	8	Baden-Württ	89,30
9	**Saarland**	**3,08**	9	Nordrhein-Westp	7,68	9	Nordrhein-West	17,02	9	Schleswig-Holste	34,99	9	Niedersachse	59,58	9	Berlin	89,00
10	Thüringen	3,07	10	Mecklenburg-VP	7,68	10	Niedersachsen	16,99	10	Hamburg	34,72	10	Bayern	59,40	10	Bayern	87,99
11	Nordrhein-West	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	Sachsen-Anhalt	34,60	12	Hessen	59,10	12	Hamburg	87,14
13	Baden-Württeml	2,66	13	Hessen	6,90	13	Baden-Württem	16,52	13	Berlin	34,50	13	Hamburg	58,27	13	Sachsen-Anh	86,13
14	Sachsen-Anhalt	2,60	14	Brandenburg	6,87	14	Sachsen	16,24	14	Hessen	34,29	14	Sachsen	57,68	14	Thüringen	85,96
15	Sachsen	2,58	15	Niedersachsen	6,80	15	Sachsen-Anhalt	15,62	15	Sachsen	33,82	15	Sachsen-Anh	57,42	15	Brandenburg	83,46
16	Niedersachsen	2,50	16	Sachsen-Anhalt	6,09	16	Mecklenburg-VP	15,59	16	Brandenburg	33,22	16	Brandenburg	56,62	16	Sachsen	82,56

Table 3: *Ranking based on the cumulative vaccination rate (VaccR) (RKI, 2022).*

to manage the traffic and configured to organise the following vaccination steps (M&K, 2021):
(1) Booking the vaccination appointment (registration),
(2) Invitation email (with QR code) and text message reminder,
(3) Security check via QR code at check-in,
(4) Admission management (check-in forms),
(5) Waiting list with data protection-compliant patient call,
(6) Allocation of the vaccination booth,
(7) Monitoring list,
(8) Vaccination documentation with scan of vaccine batches and employee codes and
(9) Reporting the data to the government (see also Appendix 6 or Alscher et al. (2022)).

The Minister President of Saarland, Tobias Hans, said during the government statement on 8 January 2021: 'We were among the first to make online registration possible at all. We were also among the first to start vaccinating in vaccination centres' (Hans, 2021a). The Saarland Minister of Health, Monika Bachmann, added: 'We are very pleased that all the work involved in recording vaccination data using QR codes and integrating them into the vaccination documentation is running so smoothly ... Both the appointment booking and a largely digital workflow were established in cooperation with the workflow-based solution from samedi' (samedi, 2021a).

Nevertheless, the available vaccination slots were immediately fully booked, leading to stress, frustration and anger - a phenomenon that was observed worldwide (Dai, 2021b). For this reason, the new approach of a 'vaccination registration list' was developed and implemented in January 2021. Saarland Minister President Hans explained: 'The vaccination list, which we have had since 11 January, has also been well received. There are currently 42,000 people on it. As soon as sufficient vaccines are available again, the vaccination dates will be randomly assigned from the list' (Hans, 2021b). Citizens signed up with their preferences (i.e. vaccination category, location, time of day, day of week, partner code), and after two weeks of collecting sign-ups, all sign-ups were randomised and allocated according to an intelligent algorithm based on the stated preferences.

The first allocation of registrations to dates took place on 27 January 2021, with official certification, ensuring a fair and equitable allocation process.

The vaccination process in Saarland was then managed as follows: Registration [Booking]
-> Appointment allocation [Appointment]
-> Vaccination date [Vaccination]

The registrations (input) fluctuated randomly depending on the current mood and media coverage. Thanks to the large backlog of collected registrations, the vaccination dates could be allocated evenly, so that ultimately the vaccination dates (output) were distributed fairly evenly. In April 2021, the federal government amended and supplemented the vaccination strategy and included 65,000 doctors who received appointments independently and carried out vaccinations in their practices. This heralded the end of the completely centralised vaccination approach in the vaccination centres. This resulted in 3 phases in the vaccination process in Saarland in the first half of the year (see Fig. 2).
- Sprint 1) Online vaccination appointment selection: 1 January - 26 January 2021
- Sprint 2) Start of online registration and appointment allocation: 27 January - 4 April 2021
- Sprint 3) Inclusion of decentralised vaccinations in doctors' surgeries: 5.4.-30.6.2021

Results

Vaccination management performance is measured as the relative number of total vaccinations per area (country or state) per unit of time (month or day) divided by the total population times 100:

Vaccination coverage rate (VaccR) = total number of vaccinations per unit of time / population * 100

Research shows that the total number of first vaccinations in the US and Europe is more important than the total number of complete vaccinations (D. Kim & Lee, 2022), so the total number of vaccinations is used as the key metric.

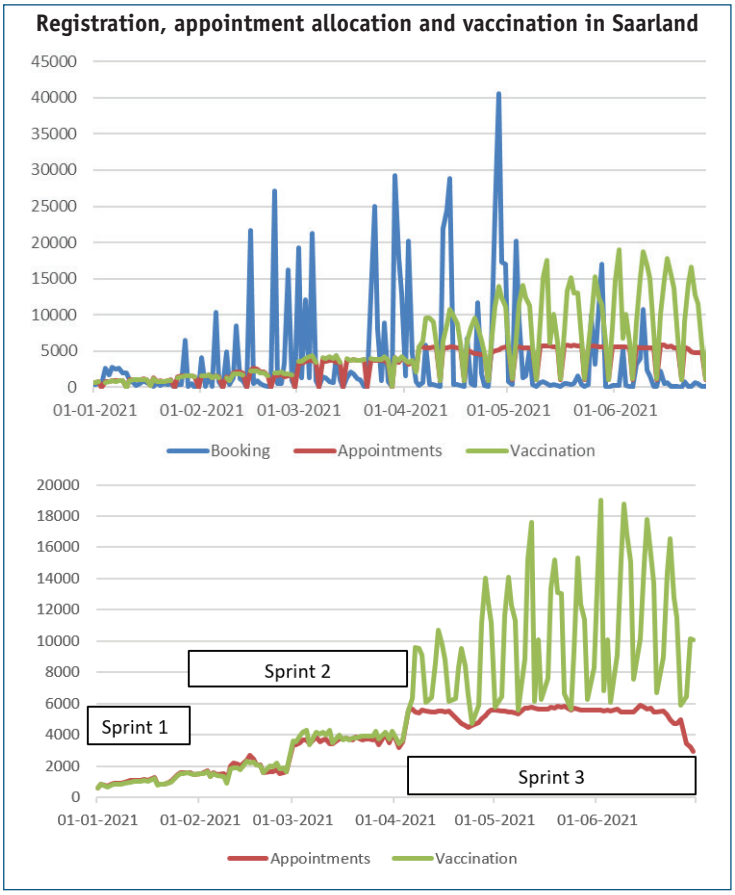


Fig. 2: *Registration, appointment allocation and vaccination in Saarland. The first booking was made on 24 December 2020 and the first vaccination took place on 27 December 2020, but for reasons of comparability the first vaccination phase was defined as 1 January to 30 June 2021. Source: Alscher, 2023b.*

Evaluation in global immunisation management

In terms of vaccination performance, the UK's fast start speed was followed by the US catching up and Germany's final rally in the first half of the vaccination process (see Tab. 4).

Germany achieved a 'top performance' in vaccination management in June 2021 with a vaccination rate of almost 30% of the population having received a dose within one month. For this reason, the vaccination processes of the federal states in Germany are analysed to understand how Germany achieved this performance.

Results in German vaccination management

Based on the structure of Germany with 8 decentralised and 8 centralised vaccination organisations (see Table 3) with relatively equal vaccine resources, it was possible to investigate whether the organisational form or the size of the federal state has an effect on the vaccination rate (see Table 5).

Vaccination rate per 100 inhabitants per month in the USA, Germany and the UK								
Land/Mon.	**Jan**	**Feb**	**Mrz**	**Apr**	**Mai**	**Jun**	**Max**	**Min**
USA	9.7	15.2	25.5	27.5	15.3	7.7	27.5	7.7
DEU	2.8	4.5	9.4	18.6	25.2	29.6	29.6	2.8
GBR	14.6	16.8	21.7	20.3	23.6	18.9	23.6	14.6

Table 4: *Vaccination rate per 100 inhabitants per month in the USA, Germany and the UK. Source: Ourworldindata, 2022. legend: Country abbreviations according to ISO code.*

No significant differences were found between centralised and decentralised organisations. Both organisational forms had a mean value of 0.5 daily vaccinations per 100, i.e. 15 vaccinations per month (30 days), with a non-significant difference in the mean values. The 'size effect' was also not significant, as both the small and the large federal states had a mean value of approx. 0.5 daily vaccinations per 100. Based on the vaccination success of the federal state of Saarland (see Table 3), their development was analysed.

Analysis of vaccination management in Saarland

Based on the three sprints in the federal state of Saarland:

- Sprint 1 'Appointment booking' (from 01.01.2021-01.26.2021) ,
- Sprint 2 'Allocation of registration' (27/01/2021-04/04/2021)
- Sprint 3 'Including GP/physician vaccination' (05.04.2021-06.30.2021) samedi showed a significant increase in the vaccination rate in Sprint 2 and Sprint 3 compared to the rest of Germany (see Fig. 3).

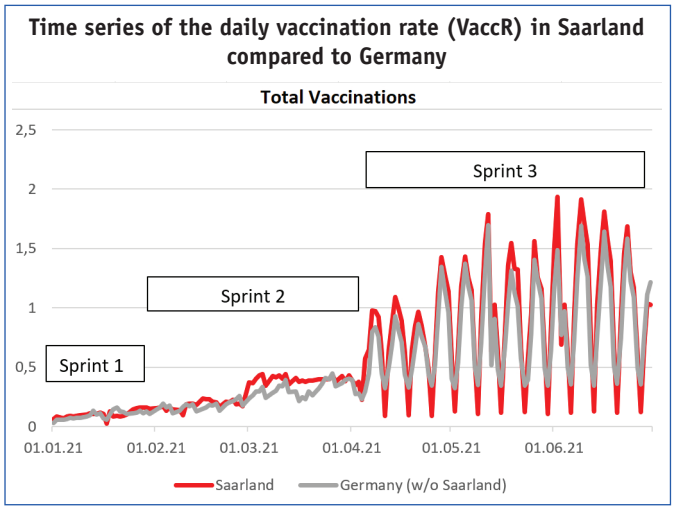


Fig. 3: *Time series of the daily vaccination rate (VaccR) of the Saarland compared to Germany (RKI, 2022)*

In sprint 1, there was no significant difference in the daily vaccination rate (VaccR) of the Saarland of 0.092 compared to Germany with 0.095, while in sprint 2 the Saarland had a vaccination rate of 0.289 vs. 0.243 (p-value 0.009) and in sprint 3 Saarland with 0.925 vs. 0.826 (p-value 0.07) showed a significant difference to the other 15 federal states in Germany (Alscher, 2023b). In order to analyse the effect of the introduction of the registration list as a decisive event in Sprint 2, the vaccination rate was compared with the 'general market' for vaccination in Germany. Based on the Event Study Methodology (ESM), a cumulative additional vaccination rate of 8.39 in sprint 2 (over 59 days) was shown (Alscher, 2023b). This generally higher vaccination rate was also confirmed in comparison with the eight centrally organised states and the other eight smaller states. In view of this significant increase in the vaccination rate in the federal state of Saarland in Sprint 2, the resounding success of Saarland can be explained by the introduction of the registrar and terminal location solution. Over the entire period (1 January to 30 June 2021), the time series of the daily vaccination rate (VaccR) of the Saarland could be compared to the other 15 states as well as to the 8 centralised and the 8 smaller federal states (see Fig. 3).

Based on a convincing model quality (R^2 of 95%), it could be shown that the Saarland was 14% better than the average of the other 15 federal states in Germany. This means that if 100 inhabitants were vaccinated in Germany, 114 were vaccinated in Saarland.

Research discussion

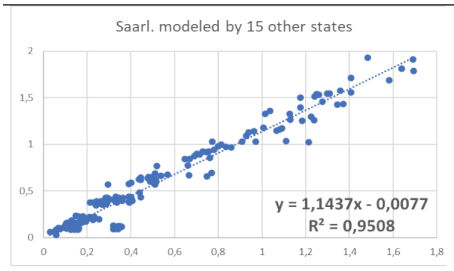
The entire vaccination organisation consisted of many components, such as the construction, operation and administration of the vaccination facilities with the procurement of vaccine doses, and was influenced by many external political and socio-economic factors. The establishment of a vaccination portal seems like a small step when considering the total effort and cost of the entire vaccination process, such as purchasing

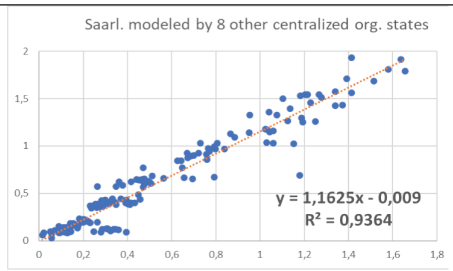
Daily vaccination rate per 100 inhabitants in Germany from 1.1.-30.6.2021					
Länder	**Mittelwert (μ)**	**Stand. Abw.**	**Länder**	**Mittelwert (μ)**	**Stand. Abw.**
Zentralisiert	0.4912	0.4168	**Groß**	0.4978	0.4237
Dezentralisiert	0.4988	0.4283	**Klein**	0.5394	0.4723
t-Stat. $H_0(\mu_Z=\mu_D)$	0.02		t-Stat. $H_0(\mu_Z=\mu_D)$	0.10	18.9

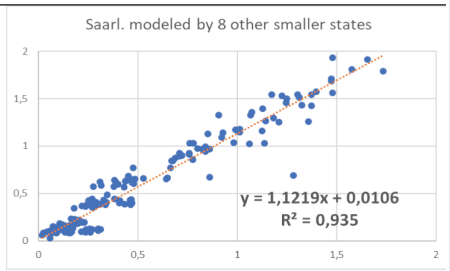
Table 5: *Daily vaccination rate per 100 inhabitants in Germany from 1.1.-30.6.2021. Source: Alscher, 2023b.*

Modelling of the vaccination rate of the Saarland by the other German federal states

Marktmodell mit 15 Bundesländern	Marktmodell mit 8 zentralisierten Ländern	Marktmodell mit 8 kleineren Ländern







Regression (linear)			*Regression (linear)*			*Regression (linear)*		
R^2	0,951		R^2	0,936		R^2	0,935	
adj, R^2	0,950		adj, R^2	0,936		adj, R^2	0,935	
std. error	0,111		std. error	0,126		std. error	0,127	
	Konstante	*Koeffizient*		*Konstante*	*Koeffizient*		*Konstante*	*Koeffizient*
Wert	-0,008	1,144	*Wert*	-0,009	1,163	*Wert*	0,011	1,122
std. error	0,014	0,020	std. error	0,015	0,023	std. error	0,015	0,023
t-statistic	-0,569	56,780	*t-statistic*	-0,583	49,593	*t-statistic*	0,687	48,993
p-value	0,570	0,000	*p-value*	0,561	0,000	*p-value*	0,493	0,000

Fig. 4: *Modelling of the vaccination rate of the Saarland by the other German federal states. Source: Alscher, 2023b.*

vaccine doses, setting up mass vaccination centres, hiring and training staff and managing the activities. However, the impact is quite impressive, as the vaccination rate is significantly higher and faster, resulting in higher protection, fewer new infections, fewer deaths, faster relaxation of lockdown measures and a quicker recovery of the economy. While most systems for arranging vaccination appointments, whether at state or local level, were 'only as good as the uptake' and unable to direct people to available locations, and vaccination hotlines were no longer working (Dai & Song, 2021), Dai (2021b) points to the superiority of the 'vaccination push' model with pre-registration, waiting list and notification compared to the traditional 'pull' model of booking vaccination appointments. Aside from Israel, which has adopted this system (Sato, 2021), there is also evidence from the US, where the state of West Virginia uses a statewide pre-registration system (West Virginia Department of Health, 2021). West Virginia was initially more successful in vaccinating its population than almost all other states (Dai, 2021a). Similar to Saarland, West Virginia's system manages the process from pre-registration to appointment, where nearly all residents are required to use the state system and select their preferences for communicating via text, email, or voice messages over regular phone lines (Dai, 2021b).

The peak performance in Saarland led not only to faster medical care, but also to the first lifting of lockdown measures in Germany and a return to normal socio-economic activities. Reuters reported on 25 March 2021 that 'Saarland is the first state [in Germany] to plan a nationwide easing of coronavirus restrictions ... [as it] is the nation's leader in initial vaccinations' (Reuters, 2021). Considering that the nationwide emergency lockdown regulations expired on 30 June 2021, Saarland has gained freedom and relaxation more than two months earlier than the other federal states. In addition, vaccinated people cause fewer infections and therefore fewer Covid-19-related deaths, so a higher vaccination rate has a huge impact on health protection and healthcare costs. The figure of 8.84 cumulative additional vaccination rates (over 59 working days per 100 inhabitants) alone seems quite high compared to other results such as the 1.5% higher vaccination rate due to conditional cash lotteries in Ohio, USA (Barber & West, 2022). With an average 7-day incidence (between 27 January and 4 April) of 84 new infections per 100,000 inhabitants in Germany (RKI, 2022), there were 668,576 new Covid-19 infections in Germany during this period. The calculated cumulative additional vaccination rate of 8.84 implies an average protection rate of 3.98% over the entire period. The number of infections reduced by the vaccination can therefore be estimated at 26,596 (i.e. the 668,576 new infections multiplied by the 3.98% protection rate). Based on the Covid-19 infection-to-hospitalisation ratio of 2.1% (Menachemi et al., 2021), the number of hospitalisations of the potentially protected but now infected individuals amounted to 638, representing a cost of Euro 6.1 million (Ohsfeldt et al., 2021; based on the median total hospital costs of US$11,267 per Covid-19 patient over 6 days and a dollar/euro exchange rate of 0.8433 on 30 June 2021). Given the overall symptomatic fatality risk (the probability of dying after the onset of symptoms) of Covid-19 of 1.4% (Wu et al., 2020, significantly lower than the initial confirmed fatality risk of 4.5%), this means 372 fewer Covid-19-related deaths in Germany in the two months. Compared to the 18,614 excess deaths in eight major European countries in the first 5 months of the corona outbreak

(Hanly et al., 2021), which means an average of 465 excess deaths per country per month, this number of 372 does not seem so low.

Based on the results, it is recommended that political decision-makers organise the vaccination process in a similar way to that in Saarland, where citizens register their preferences (i.e. vaccination category, location, time of day, day of the week, partner code). Once citizens have registered, the vaccination system can allocate them fairly and randomly according to their stated preferences. In this way, policy makers and pandemic managers can flexibly match supply and demand for vaccination and allocate vaccination slots to citizens a few days in advance, rather than scheduling appointments for weeks in advance when supply is uncertain and no-shows

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are more likely with long lead times (Dantas et al., 2018). No-shows in the vaccination process would even lead to significant economic damage due to the limited shelf life of vaccine doses, which also became a political issue in the later stages of vaccination organisation in Germany.

The combination of the digital platform for registration and automatic terminal location with the much more (cost-) effective large vaccination centres (see Garattini, Badinella Martini et al., 2020; Schulenburg, 2021) is recommended in the first phase of the vaccination process for the next pandemic. The later addition of decentralised elements with vaccination by GPs proved to be another effective step to get the best of both worlds, centralised and decentralised vaccination, which have been successfully implemented separately in the UK and the US. As the Covid-19 pandemic progressed, the challenge was to activate the vaccine-unwilling group, which could be achieved primarily through communication and dissemination methods via social media and partnerships (Wallia et al., 2021) or through special offers such as conditional cash raffles (Barber & West, 2022).

Conclusion

In this study, the vaccination rates of Western countries as well as Germany and Saarland in the first six months of the coronavirus vaccination campaign were analysed. This raises follow-up research questions, on the one hand, the comparison with other political vaccination regimes such as in Asia or the Middle East and, on the other hand, an extension of the research to the follow-up period, i.e. the vaccination of vaccination hesitants and potential vaccination refusers. In addition, future research could also analyse the differences in the seven regions or 250 Primary Care Trusts in the UK NHS and the 50 states in the USA. In the US, the state of West Virginia has implemented a similar digital organisation to Saarland, demonstrating the benefits of a registration and terminal location vaccination system. In order to understand the success of vaccination management even better, the role and use of health care workers (see Alscher & Wissing, 2023) in particular would need to be analysed in more detail, as well as the exact interaction of citizens with the platform (in the context of 'usability', see Alscher & Wissing, 2024).

In this paper, it was shown that centralised vaccination organisations (as in the UK) had an initial advantage, but decentralised vaccination (as in the USA) performed just as well with an even higher monthly vaccination rate. In addition, Germany, which implemented a mixed approach of centralised and decentralised systems, even achieved the highest monthly vaccination rates compared to the other countries. A comparison of the German federal states showed no significant difference between centralised and decentralised vaccination organisations and no significant difference between small and large countries. However, there was a clear overperformance in the federal state of Saarland, which switched its vaccination organisation from a booking to a registration and terminal location system, which led to a cumulative additional vaccination rate of 8.84 over a period of approx. 2 months and

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an overperformance of 14% compared to the other federal states. Extrapolation to Germany resulted in an estimated 26,596 fewer infections, 372 fewer excess deaths and at least -6.1 million less hospitalisation costs. To summarise, this study provides clear evidence for policy makers to use digital platforms with registration and automatic terminal location as a key element in combating the next pandemic outbreaks. <<

Author's statement

The author is the CEO of samedi and conducted this research while on leave from samedi without receiving compensation for this research. There is no other conflict of interest.

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Appendix

The appendix provided by the author can be viewed and downloaded online. Short link: https://t1p.de/mtfca

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