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Pre-Registration in COVID-19 Vaccination: The Case of Saarland

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ABSTRACT

Purpose: This study examines which vaccination organization system performed best in the COVID-19 pandemic to improve future vaccination organization.
Study design: The vaccination organization of every federal state is categorized as decentralized/centralized. The vaccination time series of the federal state with the highest vaccination rate is analysed by using the Event Study Methodology (ESM).
Findings: In Germany's federal state with the highest vaccination rate (i.e., Saarland), the change from a system of availability-based offerings to a pre-registration with preferences and automatic appointment allocation system was a significant performance factor.
Originality: A quasi-experimental study with a different vaccination organization is setup and the Event Study Methodology (ESM) is applied to the vaccination context.
Research limitations: This study is limited on the vaccination organization of high-developed countries with a comprehensive health system such as Germany.
Practical implications: A pre-registration and automatic appointment allocation system is recommended as best practice to policy makers and pandemic managers for their vaccination organization given the first half-year experience in the COVID-19 pandemic.
Social implications: A cumulative additional vaccination rate of 8.44 per 100 inhabitants and a 14% over performance is found. The implementation of this system for whole Germany would have resulted in 4% higher protection, estimated 26,596 less infections, US $ 7 million less hospitalization costs, and earlier relaxation of lockdown of two months.

Keywords: COVID-19 Pandemic Vaccination; Vaccination organization; Health policy; Pandemic supply management; Platform technology

INTRODUCTION

Lack of Research in Vaccination (Organization) Performance

The management and processes for handling pandemic crisis are eventually one of the biggest challenges for humankind since the COVID-19 pandemic brought the largest global recession since the Great Depression [1]. Vaccination has been perceived as key and most economical and effective approach to fighting the COVID-19 pandemic since its declaration [2,3]. How to setup the vaccination strategy is a general economic problem since resources for mass vaccination are constrained,

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i.e., not only the supply of vaccines but moreover also the medical facilities and healthcare workers capacity. Policy makers must select and decide an optimal allocation strategy under these constraints to maximize the overall effect of mass vaccination. “Yet, the endgame of the pandemic is not vaccines; it is vaccination” [4]. Dai T, et al. explicitly ask for research to understanding of best management practices such as prioritization policies, distribution strategy, appointment scheduling, and demand management [4]. There is still a missing analysis how countries and regions performed in their vaccination organization. According to Dai, the area of vaccination operation can be dissected into the three research streams of supply, demand, and matching supply with demand which we classify as vaccination organization [4]. For matching supply with demand, people seem to prioritize either virus spreaders and essential workers or those who were most at risk because of a pre-existing health condition while “first-come first-served”, highest willingness-to-pay or “lottery” approaches were not preferred [5]. However, there had been evidence from Ohio that conditional cash lotteries for vaccination incentive scheme increased vaccination by 1.5% and prevented at least one infection for every six vaccinations [6]. From a financial perspective, operating costs decrease with the size of the vaccination unit due to economies of scale in larger vaccination operations from 41% in GP practices to 8% in small centres, 4% in medium-sized, and 2% in large centres [7]. An analysis of vaccination rates of Western industrialized countries revealed that decentralized (e.g., United States) and centralized systems (e.g., United Kingdom) had comparable start peak performance and showed no significant differences [8]. There are still missing answers which organizational system performed best in the first phase of vaccination in the COVID-19 pandemic settings. Thus, this study follows an inductive empirical approach with the research question:

RQ: Which vaccination organization system performed best in the first phase of the vaccination process?

Different Vaccination Organizations

In general, a faster vaccination leads to a faster economic recovery. Thus, the speed of vaccination is quite important as it brought the countries out of lockdown and business containment settings so that the overall economy could rise to and even over its former size and scope. The first phase of the vaccination implementation refers to the vaccination of the ‘fraction of willing’ accounting for 50%-70% of the population for COVID-19 vaccines in most industrialized countries whereas the second phase of the vaccination addresses the vaccine hesitant group [9]. Most of the largest western, industrialized countries reached 50% of full vaccination in July 2021, i.e., approx. half a year after vaccination start [8]. Thus, we define the first phase as the first half year of 2021. Though those countries had similar vaccination policies started in the COVID-19 pandemic, e.g., using at least one of the four Western vaccination manufacturer Johnson and Johnson, Moderna, Oxford/AstraZeneca or Pfizer/BioNTech, approving them in December 2020, setting up national vaccination policies, there had been a striking difference in the vaccination organizations between centralized and decentralized vaccination systems.

On the poles of the organizational axis were US and UK. UK managed a centralized vaccination system steered through the body of the National Health Service (NHS) where US operated in their decentralized healthcare system through thousands of independent vaccination providers [4]. This means that also the infrastructure to apply, book, or register for a vaccine was different from a singular source in centralized systems to numerous online portals of different providers in the decentralized system. In the US, “almost everyone has to actively seek vaccination” whereas in the UK, “residents are notified by the NHS when it’s their turn to get vaccinated” [9]. Decentralized “pull model” systems, where the people have to actively book vaccine appointments, seems inefficient and inequitable when vaccine demand is far higher than supply [4]. In contrast, centralized “push model” systems seem to be the better approach where citizens enter a pre-registration portal including a centrally managed waitlist and notifications as implemented also by the fast vaccinating country Israel [10]. In addition to the black and white of centralized and decentralized systems, Germany implemented a mix of decentralized-centralized vaccination organization. In the general pandemic management in Germany starting early 2020, sub-national and local authorities became the key actors of crisis management in the beginning and afterwards, centralized government regulation gained in importance with functional orientation and increased vertical coordination [11]. The vaccination management was reverse. The German government and health ministry passed the National Vaccination Strategy in October 2020 about risk groups and vaccination orders, and the execution and implementation of vaccination centres had been delegated to the 16 federal states and from there also partially to local authorities in larger federal states [12]. Germany reached “peak performance” in vaccination management in June 2021 with almost 30% of the population with one dose in one month. Therefore, Germany with its 16 different organized states is used in a quasi-experimental research setting for detecting key elements for over-performance in different organizational vaccination systems [8].

MATERIALS AND METHODS

In the first phase of the vaccination phase, the total vaccinations are much more important than the full vaccination. According to Kim and Lee [2] this is based on three assumptions:

1. The first dose provides good enough protection (the first dose’s efficacy is higher than the marginal efficacy gains from the second dose).
2. Protection after the first dose does not wane too quickly.
3. Delaying the second dose does not lower the efficacy of full vaccination.

Thus, the performance of the vaccination management is operationalized as the relative number of total vaccinations. This main outcome variable is calculated by the number of vaccinations per area (country or state) per time period (month or day) divided by the total population times 100.

Vaccination Rate (VaccR) = total vaccinations per time period / population × 100

The number of vaccinated people is protected from the disease to a high percentage (depending on the efficacy of the vaccine) and prevents other people from getting infected and spreading further Corona viruses [13]. Since every positive COVID-19 case can lead to further infections, increases the (health) costs for society, blocks hospital capacities, and leads to further health complications, the cumulative number of total vaccinations is an appropriate measure to prevent further spread of the virus. Supported by research, the total number of first vaccinations is much more important than the total number of full vaccinations in US and Europe [2]. It is arguable that only the number of first doses may count but, since the paper aims to analyse the overall performance of vaccination, the number of total vaccinations including first and second doses is considered.

The vaccination data of Germany was provided by the Robert Koch Institute, a German federal government agency and research institute responsible for disease control and prevention [14] (see Appendix 1). In a pre-study (see Appendix 1), it is shown that neither decentralized nor centralized systems showed significant differences in performance on a country-level (of Western industrialized countries) or on the federal state level in Germany [8]. In order find performance drivers in the vaccination organization, the vaccination rates of the federal states were compared and the federal state with the highest vaccination rates of the first half year was selected, i.e., federal state Saarland (see Appendix 2). Over the period of 181 days from January 1st, 2021, until June 30th, 2021, Saarland ranked 71 days as the #1 with the highest daily vaccination rate versus Rhineland-Palatinate with 39 days, Bremen 29 days, Thuringia 21 days, Mecklenburg-West Pomerania 18 days, and Schleswig-Holstein three days [14]. For this reason, this study focusses on the federal state Saarland to understand how this peak performance was achieved. For the federal state (Saarland) data, the times series of numerical number of online bookings and appointments were provided by the eHealth company samedi GmbH from the federal state of Saarland. The data was recorded, analysed, visualized with statistic programs R-4.2.0, R Studio 2022.02.2, and Microsoft Excel.

To validate decisive events in the vaccination process and to exclude external events, the vaccination time series of a federal state was compared with the vaccination time series of the other federal states of the country by using the Event Study Methodology (ESM). ESM is a statistical method to examine the impact of an event on the performance or development of an entity. Initially, it was invented by Ball and Brown to measure the impact on the value of the firm by calculating abnormal returns attributable to the event cleared by the price fluctuation of the market as a whole [15]. The method has been vastly used in Finance research where daily Abnormal Returns (AR) of the target i are calculated with the following equation [16]:

$$\mathbf{AR = R_{iT} - (a_i + b_i \times R_{mi})}$$

where a_i and b_i are the Ordinary Least Squares (OLS) parameter estimates obtained from the regression of the return of the target (R_{it}) on the corresponding market return (R_{mi}) over an estimation period (T) preceding the event. Subsequently, the abnormal returns are standardized (SAR) and summed up over several days k (the event window) to derive the Cumulative Abnormal Return (CAR) for the target i[1]:

$$CAVR_i = \sum_{t=1}^{k} SAVR_i \text{ with SAVR = VaccR}_{iT} - (a_i + b_i \cdot \text{VaccR}_{mi})$$

ESM has been also applied to other social research topics such as operations and supply chain management or recently also to analyse events and drivers in the spread of COVID-19 vaccinations [17,18]. Since the vaccination rate (see VaccR formula above) is already standardized due to the divisor of the population, the cumulative additional vaccination rate (CAVR) is calculated as the sum of the Standardized Additional Vaccination Rate (SAVR):

$$CAVR_i = \sum_{t=1}^{k} SAVR_i \text{ with SAVR = VaccR}_{iT} - (a_i + b_i \cdot \text{VaccR}_{mi})$$

The Vaccination Rate of the Market (VaccRm) is modelled by three approaches:

1. The vaccination rate of the other federal states (i.e., whole Germany without Saarland)
2. The vaccination rate of the other centralized states (i.e., same organization effect)
3. The vaccination rate of the other small federal states (i.e., same size effect)

The models are calculated by using OLS (ordinary least squares) linear regression. Since time series regression has auto correlated residuals due to the upward trend of the vaccination number, Newey-West Standard Errors are used in the regression. To validate the use of OLS linear regression and correlation analysis, the data was checked on normal distribution using the Jacque Berra test[2]. The data of Saarland and the three data sets of the Vaccination Rate of the German market have all p-values of 0.00 in the Jacque Berra tests so that the data is approved as normal distributed and applicable to OLS regression.

RESULTS

The federal state of Saarland implemented a digital vaccination platform for the approximately 1 million inhabitants based on the e-health platform samedi which is used by more than 40,000 individual healthcare providers for coordination over 30 million patients in Germany, Austria and Switzerland [19,20]. The digital health platform samedi was customized for the vaccination process with the top-level domain "www.impfen-saarland.de" to manage the following vaccination journey [21,22] (see Appendix 3):

1. Vaccination appointment booking (pre-registration)
2. Inivitation email (with QR code) and short message reminder
3. Security QR code checkin
4. Admission management (checkin forms)
5. Waiting list with data security compliant patient calls
6. Vaccination cabin allocation
7. Monitoring list
8. Vaccination documentation with vaccination batch and employee code scan
9. Government data reporting (see Appendix 4).

The prime minister of Saarland, Tobias Hans, said at the federal government statement on January 8th 2021: "We were among

[1]If multiple entities are included in the sample, each CAR must be adjusted by the factor $1/K^{0.5}$.

[2]Under the null hypothesis of normality, the test statistic of the Jarque-Bera test follows a chi-square distribution with two degrees of freedom. JB = (n/6) * (skewness ^ 2 + (curtosis ^ 2) / 4) ~ X^2 (2).

the first to allow online booking at all. We were also among the first to start vaccinating at vaccination centres" [23]. The health minister of Saarland, Monika Bachmann, added: "We are very pleased that all the work on recording vaccine data using QR codes and embedding it in the vaccination documentation has been running so smoothly both the appointment booking and a largely digital workflow were established in cooperation with the workflow-based solution from samedi" [19].

Nevertheless, the available vaccination slots were instantly booked which led to stress, frustration, and anger-a phenomenon which had been seen globally: "If you've tried to get a COVID-19 vaccine appointment, you know how frustrating the process can be. People are spending hour's obsessively refreshing websites, hoping an appointment will open up somewhere [10]." For this reason, the new approach of a "vaccination pre-registration list" was developed by samedi and implemented in Saarland on January 2021. The citizens registered with their preferences (i.e., vaccination category, location, daytime, weekday, partner code) and after collecting pre-registration for several days, the order of the registered people was randomized and according to a smart algorithm allocated according to the given preferences. Saarland's Prime Minister Hans stated "The vaccination list that we have since January has also been well received. 42,000 people are currently registered there. As soon as sufficient vaccines are available again, the vaccination dates will be randomly assigned from the list". The first allocation from pre-registration to appointments took place on January 27th 2021, with an official notarization so that a fair and just allocation process was guaranteed [24]. The vaccination process in Saarland was then managed as follows:

Pre-registration Booking -> Appointment Allocation and Notification -> Vaccination Date

Pre-registration Booking (as the input variable) fluctuated randomly (in bulk movements) when people felt the urge to register for the vaccination slot to get a vaccination appointment. The Appointment Allocation (as the mediating variable) could be accordingly even allocated thanks to the big backlog of collected pre-registrations. The Vaccination Date slots (as the actual output) were also quite evenly distributed in the beginning and then went up due to the additional doctor vaccination. The pre-registration booking was set for any date in the future. The appointment dates and vaccination dates took place at the same time. In April 2021, the German government changed and amended the vaccination strategy and included 65,000 medical doctors who independently received appointments and made vaccinations in their own practice. Hence, two events were decisive in the vaccination process of Saarland a) change from appointment booking to pre-registration on January 27th 2021 and b) extend vaccination (centres) by including decentralized GP vaccination on April 05th 2021 [21]. Based on the two events, three sprints are classified in the vaccination organization (see Appendix 5 incl. statistically significant tests of the three sprints): Sprint 1 "Appointment Booking" [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] (**Figure 1**).

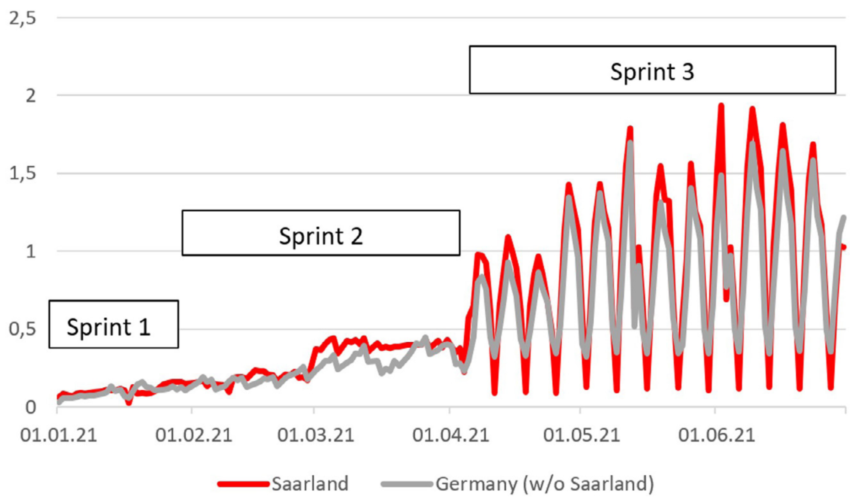


Figure 1: Time series of daily vaccination rate (VaccR) of Saarland compared to Germany

Saarland showed a highly significant over performance ($p<0.01$) in Sprint 2 and a significant over performance (p-value <0.1) in Sprint 3 regarding the time series of daily vaccination rate (VaccR) in Saarland vs. Germany without Saarland (**Table 1**).

Table 1: T-Test of mean comparison between Saarland and Germany• (•without Saarland)

	Sprint 1		Sprint 2		Sprint 3	
	Saarland	Germany•	Saarland	Germany•	Saarland	Germany•
Mean	0.0948063	0.0919034	0.289397	0.2437724	0.9254223	0.8261305
Variance	0.0006817	0.0010669	0.0128119	0.0082482	0.2349722	0.1506531
Observations	23	23	59	59	87	87

Degrees of freedom	42	0	111	0	164	0
t-statistic	0.3329287	0	2.4148774	0	1.4913869	0
p-value	0.3704222	0	0.00868711***		0.06889046*	

Note: *p<0.05, **p<0.01, ***p<0.00

To examine the effect of the implementation of the pre-registration list as a decisive event for sprint 2, the vaccination rate is compared to the "general market" of vaccination in Germany by using the Event Study Methodology (ESM). In this way, external factors are filtered out such as in our case political or economic effects. The Cumulative Additional Vaccination Rate (CAVR) is calculated over the time frame of Sprint 2 from January 27th 2021 until April 4th 2021 (i.e., 59 working days) (**Table 2**).

Table 2: Event study results (cumulative additional vaccination rate) of Saarland in sprint 2

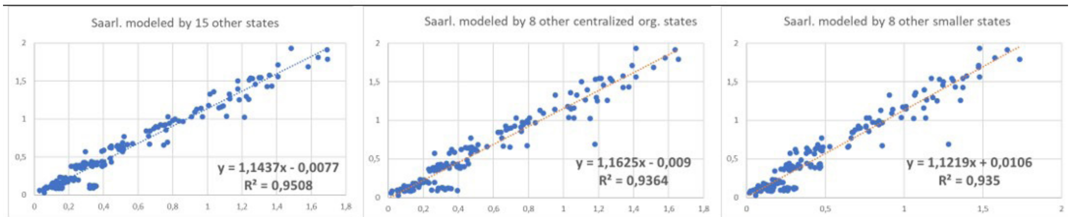
Market model (VaccRm)	CAVR of Saarland	Mean (SAVR)	SD (SAVR)	p-value H0 (μi=0)
a) all 15 states	8.39	0.14	0.09	0.05**
b) 7 centralized org. states	7.58	0.13	0.08	0.06*
c) 8 small states	8.86	0.14	0.09	0.06*

Note: *p<0.05, **p<0.01, ***p<0.00

The time services of vaccination of Saarland compared to the market model (based on the 15 German states) delivered a Cumulative Additional Vaccination Rate (CAVR) of 8.39 over 59 days (i.e., Standardized Additional Vaccination Rate (SAVR) of 0.14 vaccinations per 100 in-habitants more per day times 59 days equals 8.39). The general higher vaccination rate was also confirmed given the two other models based on the other 8 centralized organized states (i.e., CAVR of 7.58) and based on the other 8 smaller states (i.e., CAVR of 8.86). Given the general mean vaccination rate of Saarland in sprint 2 of 0.28 vaccinations per 100 inhabitants, half of the vaccination rate (i.e., 0.14) may be explained by the implementation of the pre-registration list.

In addition, we used the three market models to simulate the Saarland vaccination over the whole first phase (January 1st-June 30th 2021) (**Figure 2**).

Market model by all other 15 states	Market model by 8 centralized vaccination states	Market model by 8 small federal states



Regression *(linear, NeweyWest st.e.)*			**Regression** *(linear, NeweyWest st.e.)*			**Regression** *(linear, NeweyWest st.e.)*		
R²	0,951		R²	0,936		R²	0,935	
adj, R²	0,950		adj, R²	0,936		adj, R²	0,935	
std. error	0,111		std. error	0,126		std. error	0,127	
	Constant	*Coefficient*		*Constant*	*Coefficient*		*Constant*	*Coefficient*
value	-0,008	1,144	*value*	-0,009	1,163	*value*	0,011	1,122
std. error	0,013	0,029	std. error	0,011	0,028	std. error	0,013	0,023
t-statistic	-0,599	39,210	*t-statistic*	-0,775	41,389	*t-statistic*	0,832	38,066
p-value	0,550	0,000***	*p-value*	0,440	0,000***	*p-value*	0,407	0,000***

Figure 2: Modelling vaccination in Saarland by other German federal states

In all three models, the constant in the linear regression is not significant which means that Saarland did not head any other start advantage or anything initially resident in the federal state which was completely different from the other federal states. The entire vaccination development is very well explained by the movement and vaccination process of the other states. Everything which happened in Germany, i.e., political or socio-economic influences on the vaccination, had the same impact on the time series of the daily vaccination rate (VaccR). Since the model of the other 15 states showed the best fit with an R^2 of 95% (compared to 94% of the other models), this model is used for the following discussion. The coefficient value is 1.14 which means that Saarland was 14% better than the rest of Germany, i.e., if in Germany 100 inhabitants were vaccined, Saarland vaccinated 114 people.

DISCUSSION

Implications for Economy and Society

The performance of the vaccination organization depends on various internal factors such as setup, running, and managing the staff which is subject to the management of the federal state. External political and socio-economic influences as well as distribution of the vaccines also played a role although the vaccination doses distribution had been overall the same in Germany. The federal state Saarland had a weak start in terms of vaccination rate in the first month and did neither change vaccination management nor vaccination staff but changed the vaccination system (see Appendix 2). Saarland changed the digital platform from appointment booking to pre-registration and automatic allocation respectively in other words, how people were brought in the process for vaccination changed in January [21]. This event marks a decisive turning point. Prime minster of Saarland Tobias Hans emphasized it in March 2021 that with "a rate of around 12 for the first vaccinations, we are at the top of all federal states" and in June 2021 "our previous record in Saarland is quite impressive [25]. For the second vaccinations, we lead the ranking with about 32%. In no other federal state do so many people have full vaccination protection as in Saarland" [26]. This frontrunner performance resulted also in the first unfreezing of the lockdown measures in Germany and the return to normal socio-economic activity. Reuters reported on March 25th 2021 that "Saarland is the first federal state [in Germany] to plan state-wide relaxation of the corona restrictions [since it] is "nationwide top" for the initial vaccinations" [27]. Given that the overall German regulations of the federal emergency lockdown expired on June 30th 2021, Saarland won more than two months of earlier freedom and relaxation compared to the other federal states. These numbers may have a large social and economic impact. Based on literature, two month earlier relaxation means (i) 10% less decline in GDP growth rate (cf. "GDP growth rate will decline 5% for each month of partial economic shutdown" and (ii) less burden of extra complete lock-down and social distancing costs of 775 € per citizen per month [28,29]. For the whole country Germany, this would have meant GDP decline of almost 423 € billion and costs of € 64 billion. However, as we have seen in the subsequent economic development, economies caught up the loss of 2020 quite fast and achieved even higher economic activity (GDP) than in the years before.

But vaccinated people also cause less infection and accordingly less COVID-19 related death so that a higher vaccination rate has a massive impact on health welfare and health costs. Just the number of 8.84 cumulative additional vaccination rate (over 59 working days related to 100 inhabitants) seems to be quite high compared to other results such as the 1.5% higher vaccination rate from conditional cash lotteries as shown in Ohio, US [6]. Given the average 7-day-incidence (between January 27th and April 4th) of 84 new infections on 100,000 inhabitants in Germany, there had been accordingly 668,576 new COVID-19 infections in Germany in this time frame [14]. [3]The calculated Cumulative Additional Vaccination Rate (CAVR) of 8.84 implied an average protection rate of 3.98% over the whole period. [4]Thus, we may estimate the number of less infections through vaccination as about 26,596 (i.e. the 668,576 new infections times 3.98% mean protection rate).

Based on the COVID-19 Infection-Hospitalization Ratio (IHR) of 2.1%, the hospitalization number of the possibly protected but now infected was 638 people representing costs of US $ 7.2 million (based on overall median hospital costs US$ 11,267 per COVID-19 patient over 6 days) [30,31]. Given the overall symptomatic case fatality risk (the probability of dying after developing symptoms) of COVID-19 of 1.4% (substantially lower than initially confirmed case fatality risk of 4.5%), this represents 372 less COVID-19 related death in Germany over the two month [32]. Compared to the 18,614 excess death in 8 larger European countries in the first 5 months of the Corona outbreak which implies an average of 465 excess death per country per month, this number of 372 over 2 month does not seem to be that small [33].

Implications for Pandemic Management and Policy Makers

The implementation of a pre-registration and allocation portal seems to be a small step given the overall efforts and costs of the whole vaccination such as purchasing vaccines doses, setting up mass vaccination sites, hiring and training people, and managing the operations. However, the impact is significant with a higher vaccination rate, higher protection, less new infections, less death, faster relaxation of the lockdown regulation, and bringing the economy faster again into full speed. Whereas most vaccination appointment systems, either by state or local health department, were "only as good as the buy-in" and not capable of directing people to the available locations and vaccine hotlines stopped functioning, Dai contends the superiority of the "vaccination push" model of pre-registration, waitlist, and notification compared to the traditional "pull" model of booking vaccine appointments [4,10]. Apart from Israel which implemented this system, there has also be evidence from US where the federal state West Virginia used a state wide pre-registration system [34,35]. West Virginia had been more successful at vaccinating its population than almost every other state in the beginning [36]. The same as in the case of Saarland, West Virginia's system controls the process from pre-registration to appointment where almost all residents are required to use the state system and select their preferences for communication through texts, email, or

[3]New Infections = 7-day-incidence/100.000/7 days * time period * population = 84/100,000/7 days * 67 days * 83.156mn = 668,576.

[4]Mean Protection Rate = (additional vaccinated at the end + additional vaccinated at start)/2*vaccination efficacy rate = (8.84 + 0) / 2 * 90%) = 3.98%.

voicemails over regular phone lines [10]. Policy makers should invest time and effort to design the vaccination process such as in Saarland where citizen registered with their preferences (i.e., vaccination category, location, daytime, weekday, partner code) [21]. After having collected pre-registration from the citizens, the vaccination system may allocate fair and randomized according to the given preferences. Thus, policy makers and pandemic managers for vaccination can match supply with demand in an agile manner and manage vaccination slots to the citizens a few days in advance rather than scheduling appointments weeks out when the supply isn't certain and when then no-shows are more likely to happen under long lead times [37]. No-shows in the vaccination process would even lead to quite an economic damage because of the limited durability of the vaccine's doses which have been also a political issue in the later phases of the vaccination organization in Germany. As Dai concludes that in the "efficiency-equity trade-off," moving away from the traditional, inefficient and inequitable sign-up model in limited vaccine supply times to establishing one-stop pre-registration systems is one key to resolving the painful vaccine scheduling process [10]. This study gives further evidence for this recommendation based on the significant cumulative additional vaccination rate in the federal state of Saarland.

Combining the digital platform of pre-registration and automatic appointment allocation, focusing on special technology acceptance factors (such as the usability and click flow), and implementing more (cost) effective large vaccination centres seems to be a best practice for the first phase of the vaccination process for the next pandemic [7,38,39]. The later addition of decentralized elements with the GP/doctor vaccination was presented as a further effective move to use best-of-both worlds of centralized and decentralized vaccination organizations. For the COVID-19 pandemic which has now gone over the first phase, the challenge in the following phases seems to be more to target the vaccine hesitant group by leveraging novel methods of communication and dissemination through social media and partnerships or through special offers such as conditional cash lotteries [6,40].

CONCLUSION

The focus of this study is limited to the 16 German federal states as an example for Western industrialized countries. Future research may compare the results with other political vaccination regimes such as in Asia oder Middle East. In addition, the results may be compared with other regions such as the 250 primary care trusts in the NHS of UK and in the 50 federal states of the US. Though West Virginia was mentioned with a similar digital organization like Saarland, there might be more evidence for the pre-registration and allocation system. In addition, other federal states with exceptionally low vaccination rates could be a promising avenue of researching vaccine hesitancy. Finally, this study was limited to the first phase, i.e., the first half year of the COVID-19 vaccination. Other dynamics and other challenges in the subsequent development of the pandemic and vaccination organization offer another wide range of research which might also challenge the findings of this study. The change in the vaccination organization from a booking to a pre-registration and automatic allocation system, as localized in the federal state of Saarland, lead to a cumulative additional vaccination rate of 8.84 over approx. Two months and an over performance of 14% compared to the other 15 German states. The extrapolation on Germany yields an estimation of 26,596 less infections, 372 less excess death, and at least US $ 7.2 million less hospitalization costs. To conclude, this study gives strong evidence for policy makers to implement digital platforms with pre-registration and automatic allocation as a key element in fighting the next pandemic outbreaks.

Highlights

- Event Study Methodology (ESM) is applied to measure vaccination performance
- Digital vaccination registration with 14% over performance and 8.44% additional vaccination rate
- Extrapolation on Germany with 4% higher protection and 26,596 less infections
- Recommendation for policy makers to digitally design the vaccination process

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CONFLICT OF INTEREST

The author is managing director of samedi GmbH and conducted this research while on sabbatical leave from samedi GmbH without receiving payment for this research. No other conflict of interest is declared.

ETHIC STATEMENT

Not applicable since no direct research was performed on humans.

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