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A decade of the Swiss electronic vaccination Record: Some insights based on an exploratory data analysis

Kevin Sorg *, Hamid Khobzi

Institute of Information Systems, University of Bern, 3012 Bern, Switzerland

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ABSTRACT

Background: The importance of electronic health records (EHR) is apparent in the academic literature. An electronic vaccination record (EVR) is a particular type of EHR that aims to replace a traditional vaccination booklet.
Purpose: This study investigates the adoption of the EVR by the Swiss population over the course of nearly a decade and shows what factors could be the potential reason for differences in the adoption of the EVR in different cantons.
Method: An exploratory data analysis comprised of multiple data visualizations and cluster analysis was performed on a unique dataset collected from multiple sources.
Main Findings: The overall rate of adoption was very limited (~3%) for the whole population in nearly a decade. The adoption had a noticeable rise in 2013, then a gradual decline till 2017 when the adoption took an increasing pattern onwards. Regional differences were found in the adoption of the Swiss EVR. These differences are very likely to be due to clear distinctions regarding pharmacies and physicians in those cantons.
Conclusion: This study provides useful insights regarding the Swiss EVR that could be beneficial for the successful implementation of similar technological solutions.

1. Introduction

The World Health Organization's (WHO) emphasis on infectious diseases and the need for research in this area is apparent more than ever [1]. The best-known example at the time of writing this paper is COVID-19, which has triggered a global pandemic that has literarily affected everything from the general economy to everyday lives [2]. In this regard, the usage of electronic vaccination records (EVR), which is an instance of personal health records, is of high relevance. Many experts consider electronic health record (EHR) systems the foundation for a safer and more efficient healthcare system [3]. The use of information technology in the healthcare setting mainly happened through EHR [4]. Häyrinen et al. [5] defined EHR as a repository of patient data in a digital form, accessible only by authorized users and exchanged and stored securely. An EVR can operate either as a module of an EHR [e.g., [6,7]] or stand-alone like the Swiss EVR. Nevertheless, many EHR systems have been constructed and rolled out only to fail [8]. Hence, implementing an EHR system like the EVR system is not trivial at all.

This study focuses on the case of EVR in Switzerland, which was implemented in April 2011 [9] and was never widely adopted by the Swiss population. This project was a central element of Health 2020, a comprehensive health strategy of Switzerland's Federal Council [9]. However, in 2021, it was announced that the Swiss EVR is discontinued due to security issues and lack of funds for continued operation [10]. The process of health information technology adoption could be viewed from various standpoints for the Swiss EVR. Prior research suggests that shared electronic patient records are innovations that must be accepted by medical staff and patients as well as be embedded in organizational and inter-organizational routines [11].

The Swiss EVR offered multiple advantages compared to the traditional vaccination booklet, such as keeping track of vaccination history easier and making recommendations for future vaccinations. Prior research suggests professional networks of physicians, hospitals, and physicians' practices play a role in the usage and adoption of HER [12]. Similarly, besides individual patients, physicians and pharmacies could also register for Swiss EVR on behalf of patients.

Although EHR has been reasonably researched in the literature, EVR has not received much attention. Accordingly, this study investigates

* Corresponding author at: Mittelstrasse 40, 3012 Bern, Switzerland.
E-mail address: kevin.sorg@outlook.com (K. Sorg).

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how the Swiss EVR was adopted over time in Switzerland and its cantons by conducting an exploratory data analysis (EDA) using a unique dataset. Moreover, this paper seeks to find a potential explanation for the differences between cantons regarding making more use of the Swiss EVR than others.

2. Material and methods

This study relies on multiple data resources. Firstly, the number of Swiss EVR account registered per month (*Adoption Rate*) for the years 2011 to 2020 were provided for all 26 cantons by Data Provider A. Secondly, the number of vaccine sales at the level of self-dispensing physicians and pharmacies in Switzerland was provided by Data Provider B. Due to the confidentiality agreement, the two data providers are referred to as Data Provider A and Data Provider B. The vaccines' sales were recorded per canton for each year from 2010 to 2020. Data Provider B provided sales data by ZIP codes, but due to privacy and data protection reasons, it maps the data to 227 bricks throughout Switzerland. The sales on these bricks are then mapped to the 26 cantons of Switzerland. Accordingly, small cantons like Glarus, Obwalden, Uri, and Appenzell-Innerrhoden contained no sales in the underlying data. Finally, another dataset was obtained from the Swiss Federal Statistical Office (FSO), which included demographic data (i.e., statistics that describe the population structure in the different Swiss cantons). This data covers the period from 2011 to 2018 (i.e., the most recent year for which such data was available). Some attributes that we leveraged from this data in our analysis were related to the demographics of patients across all cantons by different population characteristics like nationality, urban versus non-urban regions, and the number of physicians and pharmacies. All the data were combined for further analysis Table 1 summarizes all variables that are used in the analysis.

We conducted an EDA to explore the patterns of the Swiss EVR adoption and to identify possible groups of cantons and relationships between the examined data attributes and the implemented Swiss EVR. According to Döring and Bortz [13], explorative data analysis and descriptive statistics are used to identify potential and perhaps unexpected effects and patterns in the data. The analysis is done using Tableau and the R programming language in two parts. First, we used multiple data visualizations to illustrate some patterns associated with the EVR adoption across different Swiss cantons and over the course of time for the whole county. Then, we performed a cluster analysis to understand the differences between Swiss cantons based on the key data attributes. A k-means clustering method was utilized to segment cantons based on data attributes. Each cluster contained cantons that are similar in the adoption rate, vaccine sales, the number of physicians and pharmacies, and the population. The elbow heuristic was applied to identify the optimal number of clusters for the k-means algorithm [14].

Table 1
Data attributes.

Data Attributes	Definition	Data Source
Adoption Rate	Number of registered Swiss EVR accounts	Data Provider A
Vaccines Sales	Number of packs sold in the retail vaccines market	Data Provider B
Region	26 cantons of Switzerland	FSO
0–19	Population of people in the youngest age group	FSO
20–64	Population of people between the youngest and oldest age group	FSO
64-more	Population of people in the oldest age group	FSO
Male	Population of men	FSO
Female	Population of women	FSO
Swiss	Population of Swiss people	FSO
Foreign	Population of foreign people	FSO
Urban	Population of people living in urban regions	FSO
Suburban	Population of people living in suburban regions	FSO
Rural	Population of people living in rural regions	FSO
Physicians	Number of general practitioners	FSO
Pharmacies	Number of pharmacies	FSO
Bachelor	Population with a bachelor's degree	FSO
Master	Population with a master's degrees	FSO

3. Results

3.1. EDA via data visualization

From April 2011 to March 2020, 274′094 Swiss EVR accounts were set up in total. Excluding Liechtenstein or Swiss expatriate citizens, a total of 266′177 Swiss EVR accounts have been created throughout Switzerland. According to FSO, Switzerland's permanent resident population at the end of the first quarter of 2020 (i.e., March 2020) was 8′619′259 inhabitants [15]. Hence, about 3% of the entire Swiss population had registered on the Swiss EVR. During this time window, an average of about 2′465 Swiss EVR accounts per month was created throughout Switzerland. Taking 26 cantons into account, an average of 95 Swiss EVR accounts per canton were created every month. A boxplot (Fig. 1) was drawn to observe the differences between various cantons. We can observe which cantons are responsible for the lower or larger adoption rates per month. The cantons of Zurich, Bern, Vaud, Geneva, Aargau, Ticino, Fribourg, and Sankt Gallen stand out compared to other cantons. The larger population of these cantons could be the reason. The first box in the boxplot (i.e., the one without a label) is related to the EVR accounts that contained no valid Postal code.

Fig. 2 shows the average monthly *Adoption Rate* for all of Switzerland from 2011 to 2020. It is clear that in the years 2013, 2014, 2018, and 2019 there were some extraordinary events considering the outliers. These outliers are very likely to be the outcome of events like the European Immunization Week [16], which seemingly might have affected the adoption of the Swiss EVR. This is more apparent in Fig. 3, since the first-ever considerable increase in adoption per population happened in April 2013, when the European Immunization Week took place (i.e., the 4th week of April). Fig. 3 shows the rate of adoption per population for each canton in each month and each year. Moreover, the median monthly adoption rate rose in 2013, then dropped in 2014 and 2015, and only then could increase again gradually in the next years, excluding 2020, which is because data only covers the first quarter of 2020.

3.2. EDA via cluster analysis

According to the elbow heuristic, five clusters ($k = 5$), with a within-cluster sum of squares by cluster of 87.5%, represented the optimal number of clusters. The results of the analysis are shown in Fig. 4. It should be noted that the unknown regions in the data are not included in the analysis. The characteristics of each cluster are reported in Table 2. The single number presented at the top of each cell is the average value for each data attribute (e.g., the average number of pharmacies, average rural population, etc.) in each cluster. The two numbers presented in brackets are the minimum and maximum values for each data attribute in each cluster. These numbers are rounded to be presented as integer numbers.

It can be clearly seen that cluster C1 (i.e., the canton of Zurich) distinguishes itself from all other cantons and clusters. What is noticeable about cluster C2 is its wide range of physicians and pharmacies. In eastern Switzerland, there is generally a rather large number of self-dispensing physicians, whereas western Switzerland and also Ticino are characterized by a rather large amount of pharmacies. Cluster C3 consists of the cantons of Bern and Vaud with the second-largest mean values after cluster C1. The next cluster, cluster C4, consists of rather smaller cantons. Finally, cluster C5 consists of several different cantons spread all over Switzerland, and some are very different in their characteristics.

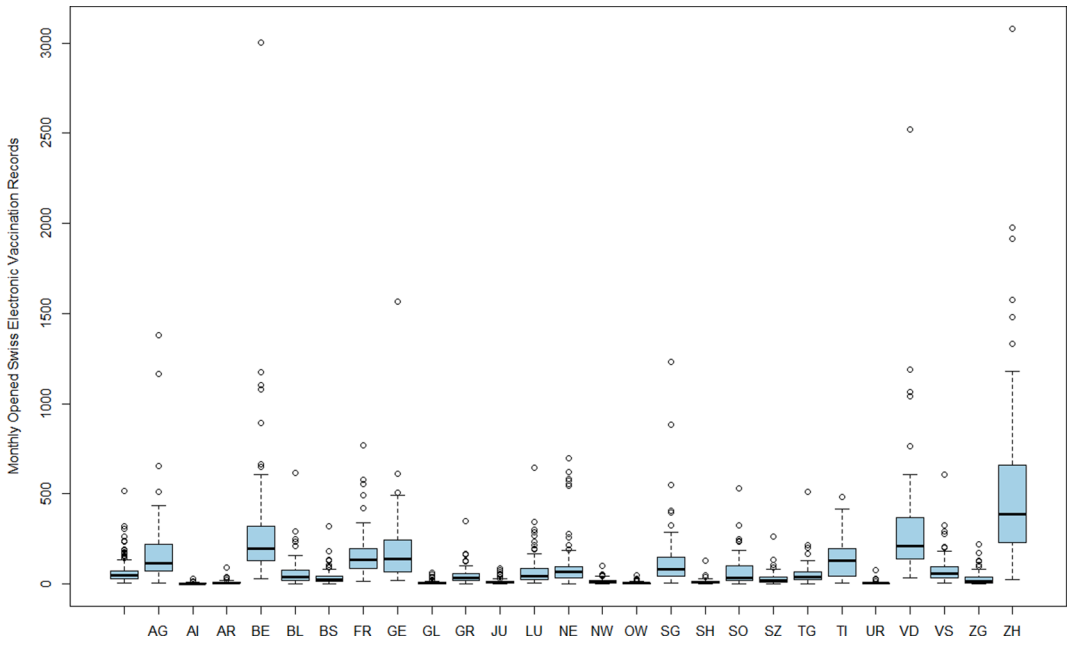

Fig. 1. Average monthly Adoption Rate for all cantons from 2011 to 2020.

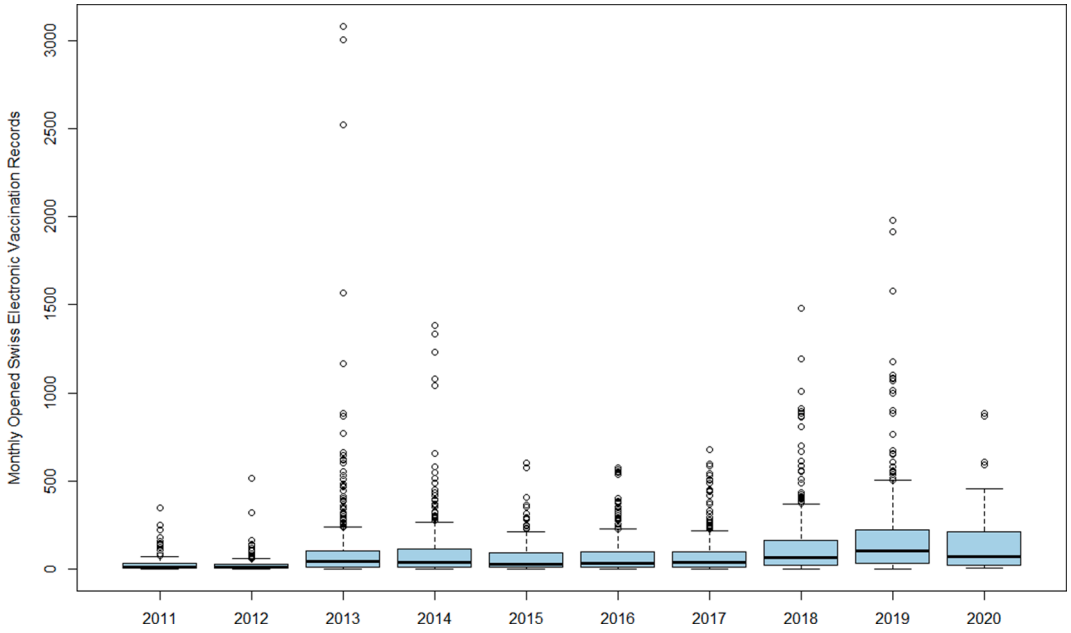

Fig. 2. Average monthly Adoption Rate for Switzerland from 2011 to 2020.

4. Discussion

This study provides insights regarding the adoption of the Swiss EVR in a period of nearly a decade in Switzerland and its cantons. Findings provide a pivotal understanding of this unique case, which, to the best of our knowledge, has not been investigated before. Findings reveal that the adoption of Swiss EVR was a very slow and long-lasting process. This is in line with what Agarwal et al. [17] suggested, that health information technology adoption is, in general, relatively slow in its development. Furthermore, only about 3% of the Swiss population had registered on the Swiss EVR from April 2011 until the end of March 2020. This level of adoption is extremely low compared to the adoption of the SwissCovid app. The SwissCovid app had more than a million registrations (nearly 12% of the Swiss population) from August to mid-September 2020 [18]. This example contradicts the suggestion of Agarwal et al. [17] regarding the health information technology adoption pace. This is most likely due to the extraordinary worldwide situation in 2020 caused by COVID-19, which would be an interesting phenomenon to investigate.

Considering individual cantons, their adoption rate, and their population size, there are clear cantonal and regional differences. This might be due to the fact that there are more pharmacies in western

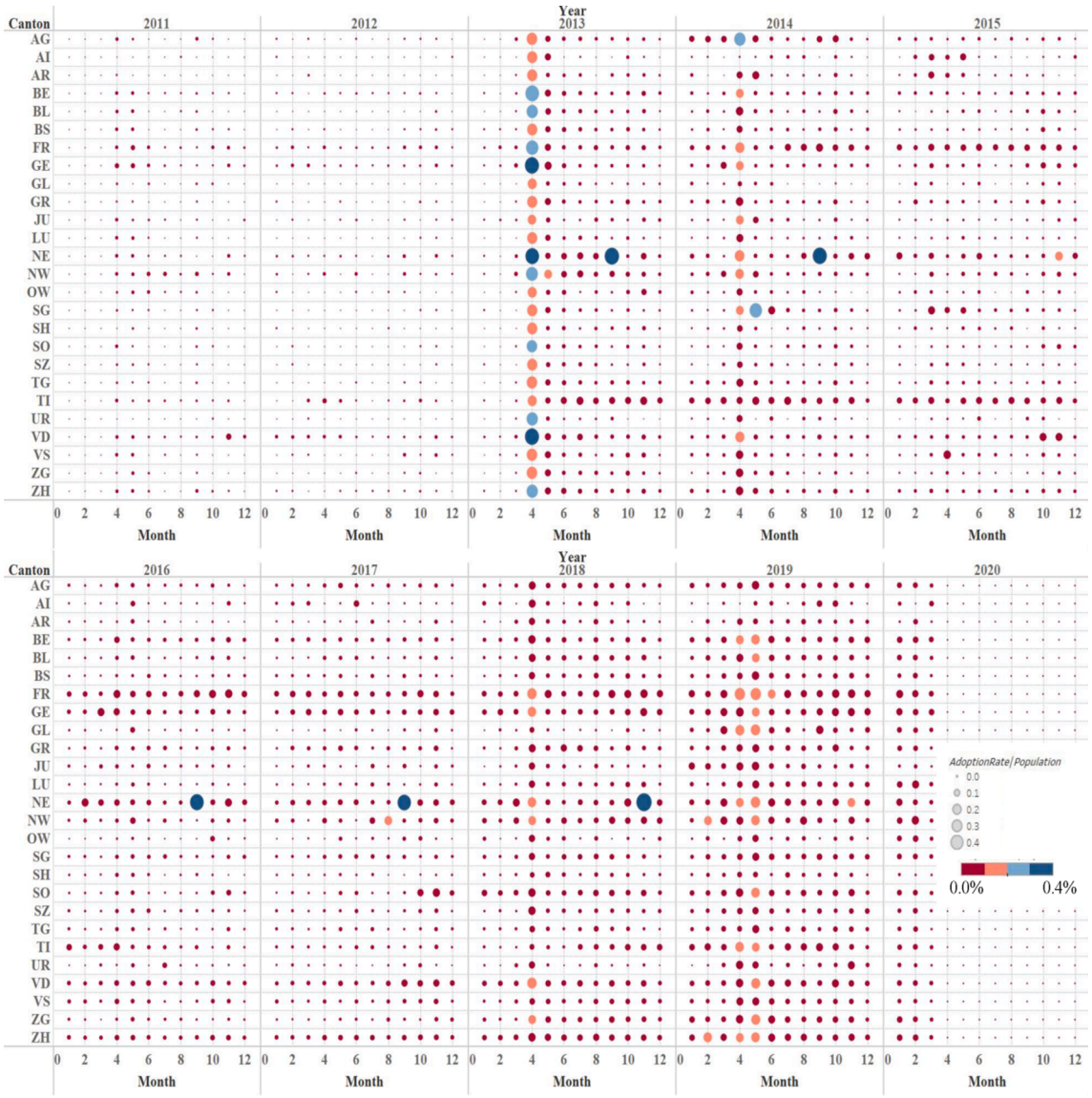

Fig. 3. The average rate of adoption per population (%) for each canton over time.

Switzerland and the canton of Ticino, while in eastern and central Switzerland, there are more self-dispensing physicians. If we consider the adoption rates and the proportions of pharmacies and physicians, the results might suggest that there is rather a higher adoption rate in the regions with more pharmacies. Physicians and pharmacies could have played a potential role in raising awareness and increasing the adoption of the Swiss EVR. For instance, by considering the factors that might affect physicians in their decision to adopt EHR [19], better policies could be made in regard to the development of EHR. This might be in line with human factors that lead to the success of EHR, including "perceived benefits and incentives" and "perceived changes to the healthcare ecosystem," as suggested by Fennelly et al. [20]. If all end-users (i.e., patients, physicians, and pharmacies) had perceived the positive impact of EVR on their workload and patient care, or their concerns regarding data privacy and security, their interaction with one another, or their roles would have been addressed properly, the EVR might have a higher adoption by the stakeholders.

Besides the existence of unknown regions in data and unknown vaccine sales in small cantons due to the brick scheme used by Data Provider B, the results are also limited by the available data attributes in this study. Since the number of data attributes is limited, unexpected correlations may still exist between the adoption rate and other potential data attributes. Also, the generalizability of the results may be limited to Switzerland. As Fennelly et al. [20] suggested, such factors should be considered with keeping the national context in mind. Therefore, similar studies for other countries would contribute to the generalizability of the findings.

5. Conclusion

This paper focused on EVR, which can be of great relevance in the case of vaccination against infectious diseases such as COVID-19. The Swiss EVR, with its advantages over a traditional vaccination booklet, could play an important role in vaccination throughout Switzerland. However, the Swiss EVR was never adopted widely and was discontinued in 2021 due to security vulnerabilities and lack of funds. Using an exploratory data analysis, this paper provides insights about this particular case that can be beneficial for the successful implementation of similar technological solutions in healthcare.

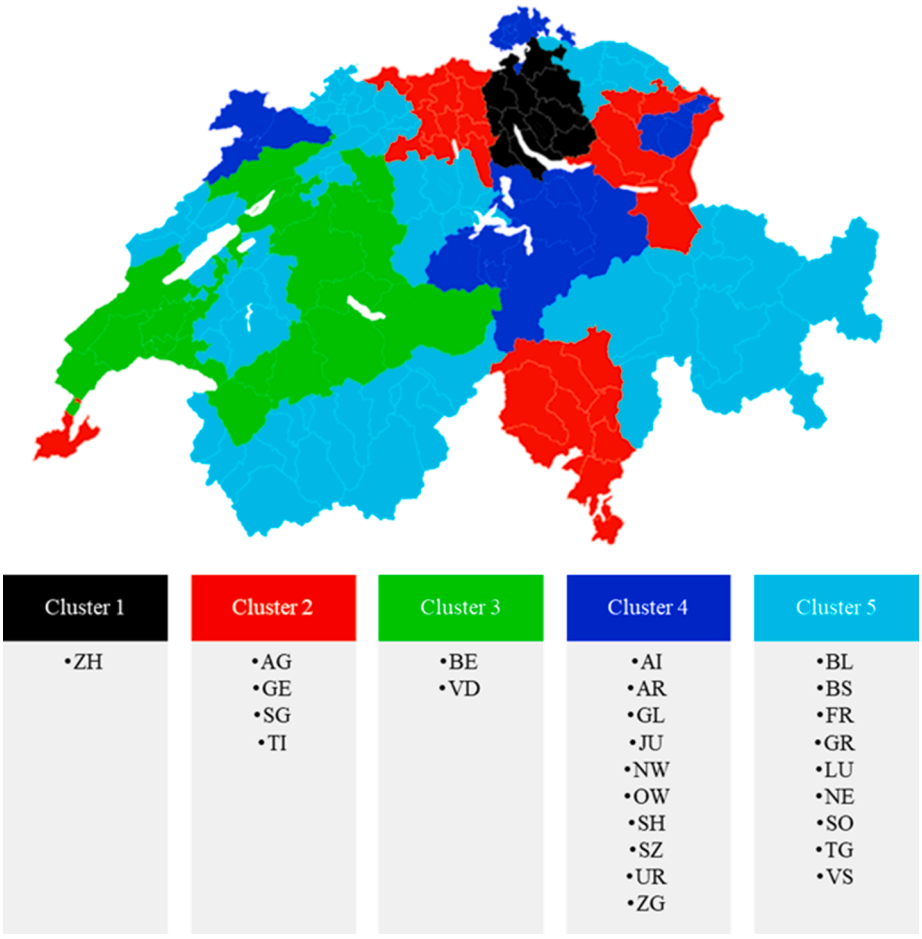

Fig. 4. Cluster analysis results for Swiss cantons.

Table 2
Description of clusters based on key attributes. (* These columns' values are presented in thousands).

Cluster	Cantons' Count	Adoption Rate	Vaccines Sales*	Physicians	Pharmacies	Urban*	Suburbs*	Rural*
C1	1	4′815 [770, 10′055]	256 [215, 347]	1,108 [1′095, 1′115]	235 [226, 246]	1′122 [1′071, 1′174]	325 [312, 337]	10 [10,10]
C2	4	1′590 [143, 4′143]	75 [52, 101]	352 [262, 509]	138 [50, 247]	359 [242, 459]	103 [41, 206]	56 [0, 102]
C3	2	3′130 [635, 5′518]	145 [98, 197]	690 [502, 839]	204 [169, 249]	509 [467, 543]	220 [205, 230]	183 [77, 262]
C4	10	115 [1, 609]	9 [0, 31]	49 [10, 209]	11 [1, 75]	42 [0, 187]	13 [0, 53]	16 [0, 34]
C5	9	759 [49, 2′566]	39 [22, 78]	191 [129, 265]	59 [24, 192]	149 [63, 238]	62 [0, 134]	64 [0, 148]

6. Summary table

What was already known on the topic
- The professional networks of physicians and hospitals and physicians' practices play a substantial role in the usage and adoption of EHR.
- Health information technology adoption is a relatively slow process and may face resistance from some stakeholders like physicians.

What this study added to our knowledge
- Regional factors, physicians, and pharmacies can play an important role in the success of EVR.
- EDA and cluster analysis are useful approaches to investigate and evaluate EVR or other EHR systems.
- The narrative around the unique case of Swiss EVR.

CRediT authorship contribution statement

Kevin Sorg: Conceptualization, Methodology, Software, Validation, Formal analysis, Investigation, Data curation, Writing – original draft, Visualization. **Hamid Khobzi:** Conceptualization, Methodology, Software, Validation, Writing – review & editing, Visualization, Supervision.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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