Does System Choice Matter? Influence of Hospital Information Systems on Digital Maturity

Universität St. Gallen – School of Medicine
Prof. Dr. Alexander Geissler, Dr. David Ehlig, Dr. Jonas Subelack, and Jonas Backes

From insight to impact.

Introducing the project team

Prof. Dr. Alexander Geissler

Professor of Health Economics, Policy and Management

Dr. David Ehlig

Scientific Project Leader / PostDoc

Dr. Jonas Subelack,

Former Research Associate / PhD candidate

Jonas Backes, M.Sc.

Research Associate / PhD candidate

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Agenda for today

1 Background and research question

2 Data extraction and method

3 Results and takeaways

Worldwide, health systems dedicate resources to IT infrastructure with the goal of providing safer and more efficient care

Various countries launched initiatives to digitalize their health system... [1-4]

🇺🇸 United States HITECH Act

🇩🇪 Germany's Hospital Future Act

🇬🇧 NHS plan for digital health and social care

🇩🇰 Denmark's National Digital Health Strategy

... ...

...and expect various clinical and economic benefits for the system and its patients. [5,6]

✓ Improved administrative efficiency
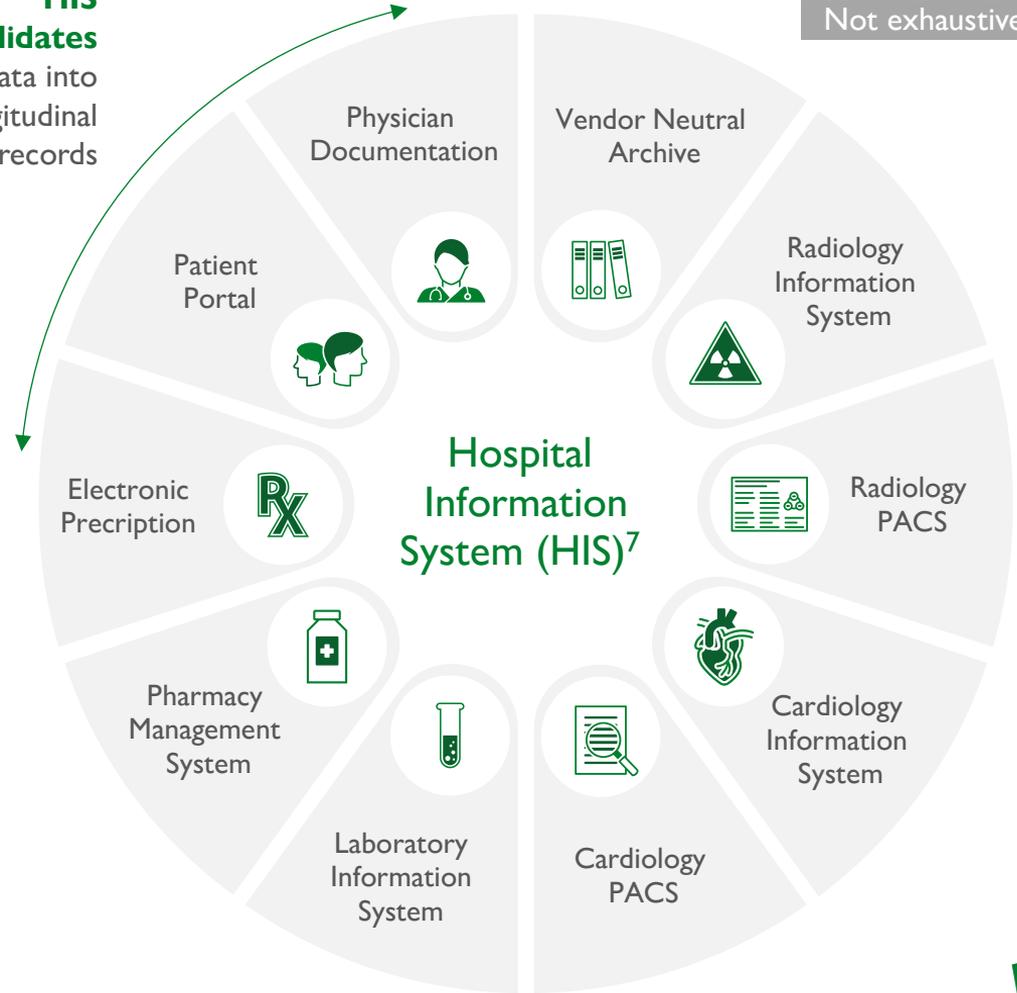
✓ Accelerated workflows

✓ Reduced medication errors

✓ Avoidance of redundant imaging

...

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Hospital Information Systems

as a central focus of these investments and the realization of benefits

HIS consolidates data into longitudinal records

- Physician Documentation
- Vendor Neutral Archive
- Radiology Information System
- Patient Portal
- Hospital Information System (HIS)[7]
- Radiology PACS
- Electronic Precription
- Cardiology Information System
- Pharmacy Management System
- Cardiology PACS
- Laboratory Information System

Note: PACS = Picture Archiving and Communication System
A. List of hospital information systems modules not exhaustive

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Today, the HIS market is highly fragmented, with both international and domestic providers offering heterogeneous systems

The hospital information system landscape is highly heterogenous and opaque,…

… leaving hospitals often with technical, operational, and strategic barriers[8-10]

Technical: lack of interoperability standards often necessitates custom interfaces

Operational: HIS platforms have evolved historically to prioritize billing over clinical functionality

Strategic: Lock-in constrains agility regarding module upgrades, pricing, and third-party integration

Thus, we came up with three research questions

Research Question 1

What is the current HIS market landscape in Germany, stratified by hospital characteristics?

Research Question 2

Which features of a HIS[A] have the greatest impact on hospitals' digital maturity?

Research Question 3

To what extent does the HIS provider choice predict hospitals' digital maturity?

Note: A. We develop five HIS features which include module utilization, integration ratio, external provider variation, maximum hospital size coverage, cloud offering.

Let's talk about data and methods

1 — Background and research question

2 — Data extraction and method

3 — Results and takeaways

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Methodological steps applied in our research

Extraction of HIS and hospital data

Creation of HIS features variables

Identification of HIS clusters and modeling

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Three data types have been extracted from the German DR project, which is a national hospital survey covering 234 questions

DigitalRadar[7]

1 **DigitalRadar (sub-)scores**
per hospital

- **Overall DR Score** ranges from 0 (not digitalized) to 100 (fully digitalized)

- **DR-score for seven sub-dimension** (e.g., clinical process, telehealth)

- **DR-score for four clinical workflows** (e.g., admission, treatment, discharge, admin.)

2 **General characteristics**
per hospital

- **Hospital type** (i.e., teaching, university, psychiatric)

- **Ownership status** (i.e., public, private non-profit, private for-profit)

- **Capacity** (i.e., number of beds), **IT FTE**, and **location** (i.e., federal state)

3 **HIS details**
per hospital

- **Name of HIS provider** utilized by respective hospital

- **IT module utilization** status (e.g., PACS, LIS) and vendor name

- **Integration status** of IT modules (i.e., (not) integrated or part of HIS suite)

Used for HIS feature creation

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We constructed five features to characterize HIS providers, derived from the DR dataset and external desk research

From desk research

$V_{1,p}$

Module utilization

Number of distinct modules that are integrated with HIS provider p out of 17 possible modules

$V_{2,p}$

Integration ratio

Ratio of connected external modules to total external systems across hospitals using HIS provider p

$V_{3,p}$

External provider variation

Count of distinct external module providers that are integrated with HIS provider p

$V_{4,p}$

Maximum hospital size coverage

Maximum number of beds among hospitals using HIS provider p

$V_{5,p}$

Only used for sensitivity analyses

Binary indicator if HIS is offered as cloud-based solution by provider p

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Our main methods included k-means clustering and OLS regression

K-mean clustering:
An unsupervised algorithm for clustering
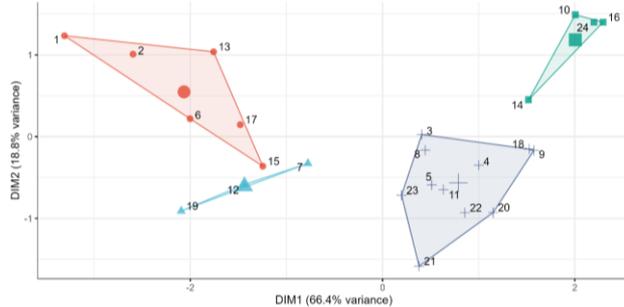
- Each cluster is defined by the mean of its points
- Assigns each point to the nearest centroid (start random)
- Recalculates centers and reassigns HIS provider until stable
- Minimum three clusters required
- Optimized based on Elbow-method and Silhouette score

OLS regression:
A supervised method to model relationships

$$DRS_i = \beta_0 + \sum_{j=1}^{4} \beta_j * HIS\_Feature_{ij} + C_i'\gamma + \varepsilon_i$$

$$DRS_i = \beta_0 + \sum_{k=1}^{K-1} \beta_k * HIS\_Cluster_{ik} + C_i'\gamma + \varepsilon_i$$

- Started by regressing HIS providers on total DR-score
- Conducted two multivariate OLS regression
- DR-score as the primary dependent variable
- DR sub-scores and workflow scores secondary
- OLS diagnostics: residual distribution, multicollinearity

So, what did we uncover?

1

Background and
research question

2

Data extraction
and method

3

Results and
takeaways

Overview of HIS variable results per provider

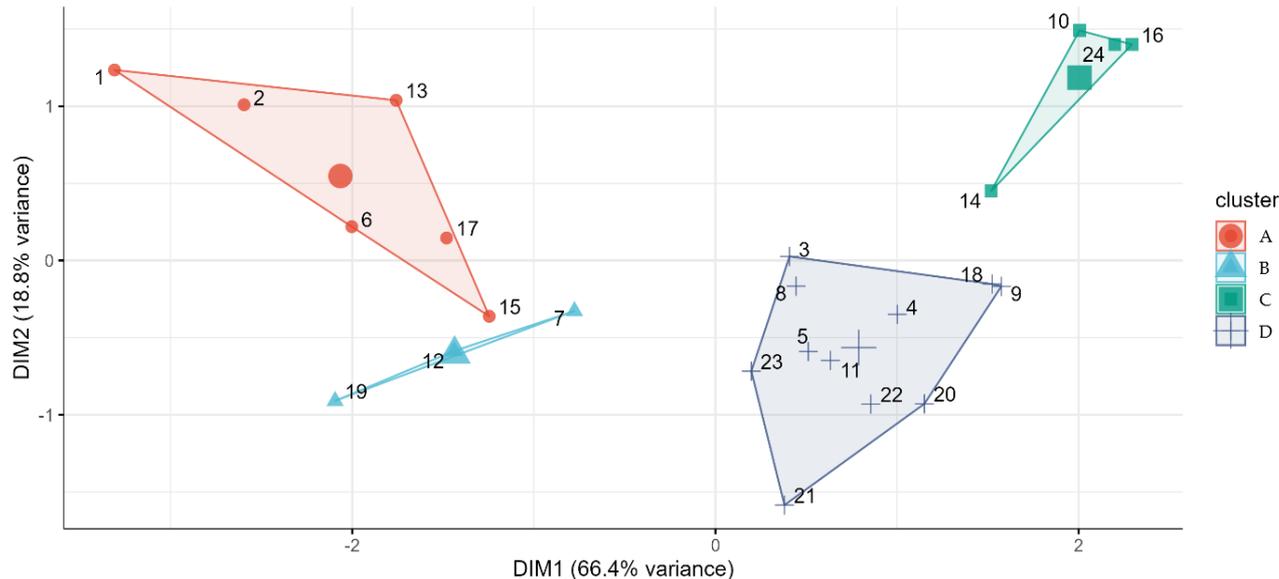| HIS ID	Running license(s)	HIS features				Extension
		Base model				
		1. Module Utilization (% / absolute)	2. Integration Ratio	3. External Provider Variation	4. Max. Hospital Size Coverage[A]	5. Cloud Offering
1	601	1.00 (17.00)	0.70	98	>700	Yes
2	312	0.94 (15.98)	0.70	87	>700	No
3	23	0.47 (7.99)	0.57	17	250–500	Yes
4	11	0.29 (4.93)	0.60	2	<250	No
5				10	501–700	No
6				71	>700	No
7				10	501–700	No
8				9	250–500	No
9				1	<250	No
10				0	<250	No
11				8	250–500	No
12				0	>700	Yes
13	149	0.94 (15.98)	0.60	68	>700	Yes
14	1	0.24 (4.08)	0.33	1	<250	No
15	41	0.53 (9.01)	0.84	42		
16	2	0.00 (0.00)	0.00	0		
17	78	0.71 (12.07)	0.75	53		
18	2	0.00 (0.00)	0.50	2		
19	138	0.88 (14.96)	0.85	0		
20	1	0.06 (1.02)	0.75	3		
21	2	0.24 (4.08)	1.00	4		
22	2	0.06 (1.02)	0.75	1		
23	3	0.41 (6.97)	0.76	8	250–500	No
24	1	0.00 (0.00)	0.00	0	<250	No
Mean[B]	66.96	0.43 (7.31)	0.60	20.00	64.96	0.25

HIS is used in **312 hospitals** and has **high module use** (15.98/17), **strong integration (0.70)**, and connects with **87 external IT module providers**. It supports **large hospitals (>700 beds)** but **lacks cloud services**,

Across all HIS providers, average **module utilization is moderate** (43%, 7.31 modules) with a mean **integration ratio of 0.60**. On average, providers connect to **20 external systems**, serving a hospital size of ~65 beds, while 25% offering cloud solutions.

Nite: To avoid re-identification of HIS provider only hospital size ranges are displayed; absolute values are used for clustering and regression analyses. B. Mean for dummy variables calculated as proportion of 1 over total number of HIS providers (= 24). HIS variable values are calculated based on DigitalRadar hospital-level data (N=1,607) aggregated at the provider level. Features 1 to 4 are derived directly from survey responses. Variable 5 is extracted based on publicly available information. Values are used for k-means clustering analysis and normalized before conducting clustering.

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K-means clustering with our constructed HIS features resulted in 4 clusters with various characteristics

Clustering graph for k = 4 clusters based on HIS variable V1 to V4

Let's jump into the characteristic of each cluster

Note: Results of k-means clustering shown in a reduced two-dimensional space. Axes correspond to weighted combinations of HIS features that best summarize the information in two-dimensional space. Each point represents a single HIS provider, colored by membership to respective cluster. Lines are drawn around the provider cluster to illustrate boundaries. Large shapes within each cluster show centers.

K-means clustering with our constructed HIS features resulted in 4 clusters with various characteristics

Cluster	Number of HIS provider	Cluster centroids				Jaccard index	Description	Provider name[A]
		$V_{1,p}$	$V_{2,p}$	$V_{3,p}$	$V_{4,p}$			
		Module Utilization	Integration Ratio	External Provider Variation	Hospital Size Coverage			
Cluster A	6	0.79	0.74	69.83	1,513	0.79	High module utilization and integration ratio, high integration with external IT systems, deployed in large hospitals	CompuGroup Medical; Dedalus; Meierhofer; Nexus; SAP; Telekom Healthcare Solutions
Cluster B	3	0.86	0.78	3.33	1,903	0.57	Very high internal capability and scalability, but limited external system diversity, also used in large hospital environments	Mesalvo; Oracle Health; Self-developed solutions
Cluster C	4	0.10	0.08	0.25	69	0.68	Very low capability across all dimensions, minimal external connectivity, deployed in very small hospitals	MediTec; MKC IT; SOL Computer; TBS Computer-Systeme
Cluster D	11	0.22	0.68	5.91	250	0.77	Moderate integration ratio with low-to-moderate module utilization, used in smaller to mid-sized hospitals	AMC Advanced Medical Communication; ASPI Software; Bauer Informationssysteme; Cosymed; Getinge; GITG; IFU; K.I.S.; Medical Software (Savini); MediTech; PCS Professional Clinical Software

Note: Each row summarizes one of the four identified HIS provider clusters. To identify key characteristic cluster centroids within each HIS variable column can be compared. The description provides a summary of structural differences between provider clusters. A. Names sorted alphabetically within each cluster.

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Descriptive statistics provide first hints on differences

	Total	HIS provider cluster			
	(N = 1,607)	Cluster A (N = 1,301)	Cluster B (N = 217)	Cluster C (N = 7)	Cluster D (N = 82)
DR-score					
Mean (SD)	38.24 (10.83)	38.55 (10.36)	40.68 (11.38)	21.76 (8.14)	28.14 (10.3)
DR-score dimension– Mean (SD)					
Structures & Systems	55.71 (17.26)	56.22 (16.33)	60.76 (17.4)	24.53 (10.8)	36.83 (17.11)
Resilience Mgmt. & Performance	45.38 (15.76)	45.24 (15.69)	48.23 (15.99)	40.32 (11.85)	40.36 (15.08)
Organizational Control & Data Management	40.64 (13.31)	40.61 (13.07)	44.8 (13.14)	20.88 (11.11)	31.89 (11.83)
Clinical Processes	38.76 (13.93)	39.58 (13.31)	39.82 (14.31)	15.09 (8.75)	24.87 (13.99)
Information Exchange	25.18 (10.15)	25.53 (9.91)	26.18 (10.7)	12.92 (8.52)	17.99 (9.28)
Telehealth	18.1 (14.03)	18.35 (14.12)	19.2 (12.74)	15.34 (17.74)	11.44 (13.99)
Patient Participation	5.25 (8.95)	4.84 (8.09)	8.29 (13.01)	6.56 (14.78)	3.46 (6.25)
DR Workflow-scores – Mean (SD)					
Administrative	43.96 (13.49)	43.97 (13.39)	47.14 (13.35)	31.38 (9.03)	36.52 (12.3)
Admission	22.27 (11.63)	22.56 (11.34)	24.06 (11.85)	16.07 (15.05)	13.57 (11.69)
Inpatient Treatment	34.17 (12.29)	34.83 (11.73)	35.18 (13.07)	13.86 (7.02)	22.81 (12.32)
Discharge	11.31 (10.02)	11.06 (9.45)	14.19 (12.68)	8.05 (13.18)	8.06 (8.92)
Hospital type (%)					
Teaching	878 (54.64)	727 (55.88)	135 (62.21)	1 (14.29)	15 (18.29)
University	54 (3.36)	31 (2.38)	22 (10.14)	0 (0.00)	1 (1.22)
Psychiatric	251 (15.62)	208 (15.99)	13 (5.99)	5 (71.43)	25 (30.49)
Ownership status (%)					
Public	604 (37.58)	530 (40.74)	42 (19.35)	3 (42.86)	29 (35.37)
Private non-profit	456 (28.38)	332 (25.52)	78 (35.94)	3 (42.86)	43 (52.44)
Private profit	547 (34.04)	439 (33.74)	97 (44.70)	1 (14.29)	10 (12.20)
Number of beds					
Mean (SD)	311.28 (315.77)	300.58 (270.99)	462.41 (501.43)	48.86 (59.75)	103.51 (122.68)
< 250 beds (%)	903 (56.2)	720 (55.34)	103 (47.47)	7 (100.00)	73 (89.02)
250 to 500 beds (%)	416 (25.9)	354 (27.21)	54 (24.88)	0 (0.00)	8 (9.76)
501 to 700 beds (%)	141 (8.8)	123 (9.45)	17 (7.83)	0 (0.00)	0 (0.00)
> 700 beds (%)	147 (9.1)	104 (7.99)	43 (19.82)	0 (0.00)	1 (1.22)
IT FTE per hospital bed					
Mean (SD)[A]	0.02 (0.03)	0.02 (0.03)	0.03 (0.02)	0.03 (0.03)	0.04 (0.05)

Note: Values are mean (SD) for continuous variables and frequency (%) for categorical variables. The total column summarizes overall hospital characteristics across all four HIS provider clusters. Percentages refer to the proportion of hospitals within each HIS provider cluster. Only the three federal states with the highest number of hospitals are displayed. A. Log-transformed and winsorized at 5% for regression analyses to correct skewness and outliers.

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Integration ratio and module utilization show a positive correlation with DRS, whereas Clusters D and C exhibit a negative correlation.

Ordinary least squares regression results for HIS features and clusters predictors (N = 1,607)

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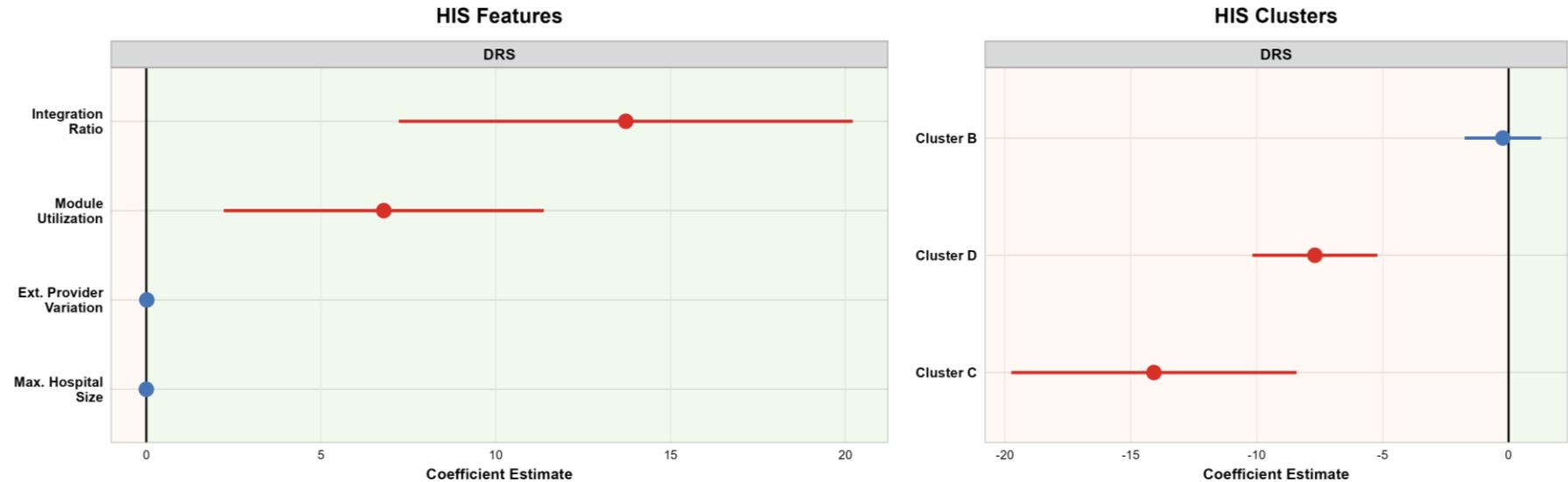
Clusters C and D also show negative associations with several DR sub-scores and workflow scores

Ordinary least squares regression results for HIS clusters (N = 1,607)
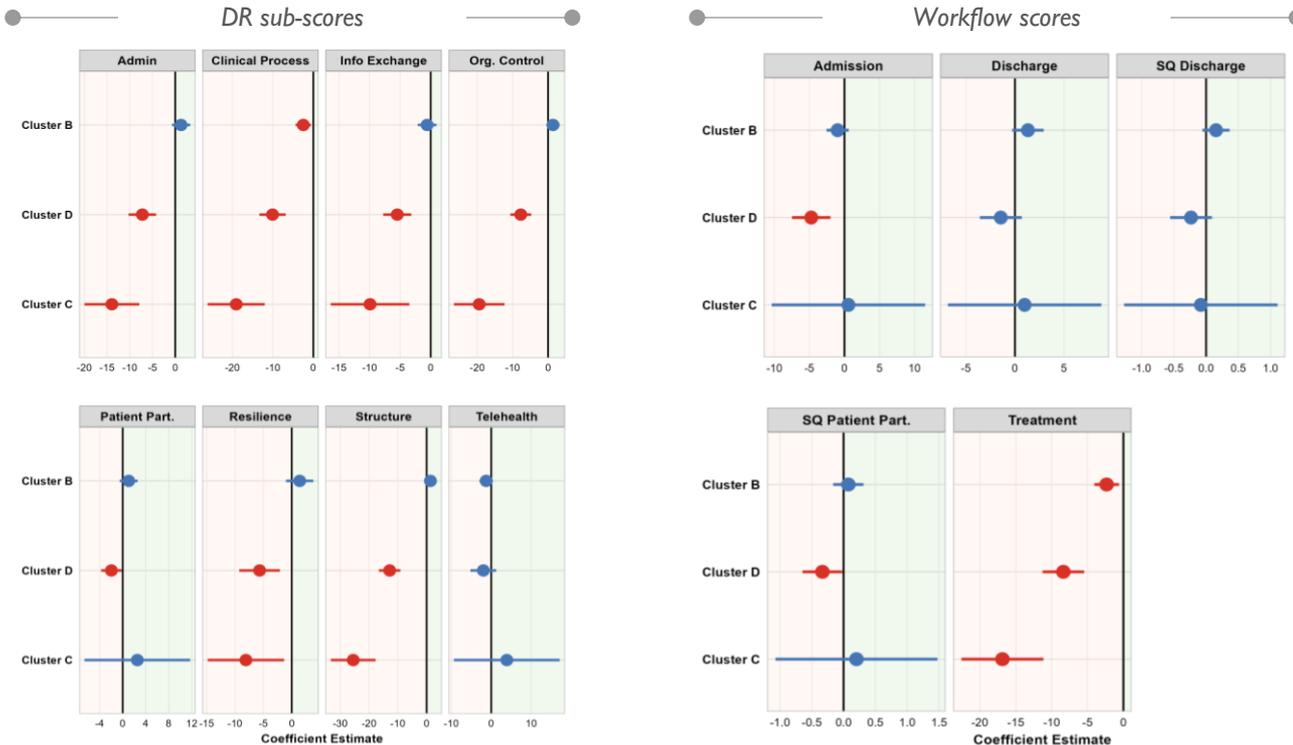
Observations

- Hospitals with Cluster C and D provider often linked to lower maturity scores

- While discharge workflow steps are relatively unaffected, the choice of cluster plays a major role in shaping the digital maturity of the treatment workflow.

HIS choice as a strategy to enhance hospitals' digital maturity

Key takeaways

1 The German HIS market is highly fragmented (24 providers), yet a few large vendors dominate larger hospitals

2 HIS provider choice is associated with hospital digital maturity, even after controlling for size, ownership, and resources

3 Esp- broad IT module scope and higher interoperability (proxied by integration ratio) are positively associated with higher DR scores

4 Hospitals often remain on legacy systems due to costs, risks, and complexity, but these systems may slow digital development[11,12]

5 Hospitals should treat HIS procurement as a strategic decision, evaluating vendors on our HIS features before deciding

6 Policymakers should recognize that HIS ecosystem constrains digital maturity and encourage shifting away from outdated systems

Thank you for listening! Questions?

Prof. Alexander Geissler

alexander.geissler@unisg.ch

Dr. David Ehlig

david.ehlig@unisg.ch

Dr. Jonas Subelack

Jonas Backes

jonas.backes@unisg.ch

Universität St.Gallen (HSG)
School of Medicine
St. Jakob-Strasse 21
9000 St.Gallen

med.unisg.ch

Universität St.Gallen

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