Information Integration, Coordination Failures, and Quality of Prescribing

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Motivation

- Organizations aim to improve the coordination of individuals' interdependent decisions to achieve more desirable outcomes (Gibbons and Roberts 2012)
- The difficulty for improving coordination is that information is incomplete and dispersed among decision makers (Hayek 1945).
- Policy challenge: trade-off between coordination and competition
  - Coordinated choices through integrated networks of firms can create weaker incentives to keep prices low.
  - Competitive markets may keep prices low, but with the well-documented drawbacks of fragmentation.
- Information integration:
  - Can promote coordination without harming competition (in theory) if implemented in an interoperable environment (Baicker and Levy 2013)
  - Only little prior empirical evidence – large-scale implementation of such systems has been difficult and costly.

- Can information integration affect decision making and improve coordination between decision makers?

- Can information integration narrow regional differences in outcomes resulting from coordination failures?

This paper

- Study the effects of a nationwide and interoperable information technology on coordination, regional differences, and underlying mechanisms.
- Setting: health care
    - Fragmented patient's care delivery: multiple organizations and physicians, and each physician has different knowledge of the patient's medical history (Arrow 1963; Cebul et al. 2008).
    - Economic burden of coordination failures: $27.2 - $78.2 billion in the U.S. (Shrank et al. 2019).
    - Trade-off between coordination and competition exist (Baicker and Levy 2013).
- Empirical strategy: the staggered introduction of a nationwide electronic prescribing system in Finland.
    - Replaced care providers' incompatible information systems with a fully integrated nationwide database.

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This paper

- Use administrative data on one of the most common and harmful combinations of prescription drugs: blood thinners (warfarin) and anti-inflammatory drugs (NSAIDs) such as ibuprofen and aspirin.
  - Warfarin: widely prescribed esp. for older patients to prevent serious conditions such as strokes and heart attacks.
  - The medical guidelines clearly caution against using warfarin with NSAIDs because of the increased risk of major bleeding complications.
  - Yet, nearly 15 percent of warfarin patients had an interacting prescription before the adoption of e-prescribing (2007–2009).

- Our data identify interacting prescriptions obtained from multiple physicians over time, allowing us to provide direct evidence of the potential implications of information integration on coordination.

Related literature

- Policies to improve coordination
    - Monetary incentives, organizational or management structures (hospital-physician integration, ACOs, hospitalists, quality report cards) (Gaynor et al. 2004, Cebul et al. 2008)
      $\rightarrow$ Can create coordination competition trade-off (Baicker and Levy 2013)
    - Information integration: empirical evidence is limited (Bloom et al., 2014) particularly in the context of interoperable systems.
      $\rightarrow$ Setting of our paper.
- The effect of health information technology (McCullough et al 2010; McCullough et al. 2016; Miller and Tucker 2011; Agha 2014; Böckerman et al. 2019)
    - Focus on health outcomes, not physicians' treatment choices or coordination. $\rightarrow$ Our focus: coordination.
    - Most evidence is from the U.S with non-interoperable information technologies. Non-interoperable technology can harm competition (Baicker and Levy 2013). $\rightarrow$ The technology in our setting is interoperable.

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- Fragmentation is a fundamental characteristic of decentralized health care systems with a patient's care divided between multiple physicians and organizations (Cebul et al. 2008)

- A canonical model by Becker and Murphy (1992) to illustrate:
  - How such division of labor affects the quality of care (prescribing)
  - How information integration affects the trade-off in the division of labor between the productivity gains and coordination costs

Theory of health care production and coordination costs

- Provision of quality of care conditional on the inputs used in treatment process: the physical or human capital K and number of treating physicians n

- Health care production function for patient i is

$$y_i = B_i(K, X, n; \theta) - C_i(n; \lambda), \qquad (1)$$

where y_i is the quality output, B_i is the gross output or benefit, which depends on the inputs and patient characteristics X through parameter θ, which determines the marginal productivity of division labor.

Theory of health care production and coordination costs

- The source of inefficiency arises from coordination costs C_i:
  - Higher C_i implies lower quality of care is produced from the same amount of inputs.
  - C_i also depend on an exogenous parameter λ describing a physician's ability to acquire medical information from other physicians.
- Coordination costs increase with the cost of information acquisition and sharing between physicians ($\frac{\partial C_i}{\partial \lambda} > 0$), for example through communication (Garicano 2000).
- Note, that cost of information acquisition and sharing between physicians can occur even in the absence of other types of coordination costs such as those related to free riding (Holmströn 1982) and incomplete contracting (Hart 2017).

Theory of health care production and coordination costs

- Productivity gains from division of labor are captured by the positive marginal product of the number of physicians ($\frac{\partial B_i}{\partial n} > 0$) and determined by θ.

- The division of labor can improve the output by reducing excess workload, filling staffing gaps with temporary workers, or allowing providers to specialize into narrower set of tasks in the treatment of complex comorbidities.

- However, as the number of treating physicians increases, coordination costs also increase ($\frac{\partial C_i}{\partial n} > 0$).

Theory of health care production and coordination costs

- Information integration can mitigate this trade-off in the division of labor by decreasing the coordination costs.
- Adoption of such systems is an exogenous shock to the information acquisition parameter which decreases λ to $\tilde{\lambda}$ ($0 < \tilde{\lambda} < \lambda$), *ceteris paribus*.
- Consequently coordination costs decrease ($C_i(n^*; \tilde{\lambda}) < C_i(n^*; \lambda)$), where n^* is the (pre-determined) qulibrium division of labor.
- Thus, we hypothesize that the quality output increases, especially when the patient is treated by multiple physicians instead of only one physician.

Finnish health care system

- Decentralized single-payer health care system
  - Primary care: organized by municipalities ($N = 304$ in 2014)
    - Municipalities vary in their ability to organize services, substantial differences in health care services between rural and urban regions (THL 2019).
  - To organize specialized health care, each municipality belongs to a hospital district ($N = 20$), provision concentrated in cities.
  - Private and employer-sponsored health care: approx. 10 percent of health care costs in 2014 (THL 2019).
- Before information integration:
  - Incompatible information systems within a region or even single health care unit.
  - Patient prescription history was not available in uniform and electronic format accessible or transferable to different primary care units.

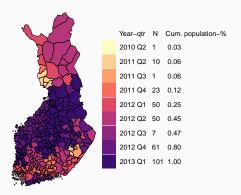| Year–qtr	N	Cum. population–%
2010 Q2	1	0.03
2011 Q2	10	0.06
2011 Q3	1	0.06
2011 Q4	23	0.12
2012 Q1	50	0.25
2012 Q2	50	0.45
2012 Q3	7	0.47
2012 Q4	61	0.80
2013 Q1	101	1.00

Figure 1: The staggered adoption of a nationwide electronic prescribing system (in primary care) across all municipalities in Finland. ▶ Correlation table

Figure 2: In comparison to incompatible information systems, e-prescribing systems provide more comprehensive information on prescriptions across multiple physicians and organizations involved in a patient's care.
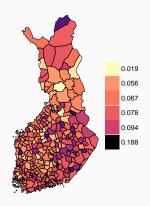**Interoperable system and designed to improve the quality of prescribing and coordination.**

Administrative data

- Prescription Data: the universe of Warfarin and NSAID prescriptions covered by the National Health Insurance Scheme during 2007–2014.
- Main patient population: patients with at least one Warfarin prescription.
    - Our results are robust to using NSAID patients as a population.
- The data include 1.7 million prescriptions for 250 000 Warfarin patients.
- Key advantage: track a patient's prescriptions and physicians over time, even if physicians or providers changed.

Outcomes

- Harmful drug combination: an indicator that equals to one if an NSAID prescription overlaps with a Warfarin prescription.
- We do not observe individual prescription lengths (prescribed daily doses).
  - Proxy prescription lengths using defined daily doses (DDDs) filled at pharmacies, "average prescription length".
  - One defined daily dose (DDD) equals to one day.
- Interacting prescriptions might be obtained from different physicians.
- Other outcomes: duration of overlapping use, quantity of prescribing, patient health (bleeding diagnosis) using additional Discharge Data for warfarin patients during 2007–2014.

Evidence for coordination failures in prescribing

	0.019
	0.056
	0.067
	0.078
	0.094
	0.188

Notes: The average regional probability of co-prescribing interacting drugs (NSAIDs) for warfarin patients in the pre-adoption period 2007-2009.

Evidence for coordination failures in prescribing

Table 1: Regional Variation in Interaction Probability, by Quantile

Quantile	Mean	Min	Max	SD	N	Share of rural areas
1	0.048	0.019	0.059	0.010	76	0.632
2	0.066	0.059	0.072	0.004	75	0.413
3	0.079	0.072	0.088	0.005	77	0.558
4	0.112	0.089	0.188	0.022	76	0.803
Total	0.076	0.019	0.188	0.027	304	0.602

Notes: This table reports summary statistics for the average probability of co-prescribing interacting drugs (NSAIDs) for warfarin patients by their municipality of residence in the pre-adoption period 2007-2009. The table also reports the share of rural regions by the quantile of this regional interaction probability.

Summary statistics for Warfarin patients, 2007-2009 (pre-adoption)

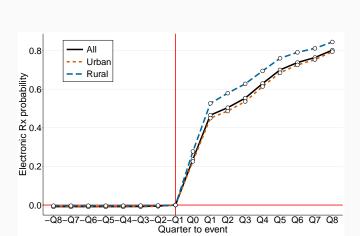|	Rural		Urban	
	Mean	SD	Mean	SD
Panel A. Quality of prescribing				
Share of patients with				
a warfarin-NSAID interaction	0.167		0.154	
Panel B. Utilization and patient variables				
Warfarin DDDs per patient	382.999	283.287	390.705	292.427
NSAID DDDs per patient	59.056	163.520	51.092	145.929
Age (on the date of prescribing)	72.327	12.177	70.666	13.421
Panel C. Physician variables				
Share of prescriptions by				
unspecialized physicians	0.548		0.458	
Different prescriber	0.531	0.499	0.515	0.500
	N		N	
Observations (prescriptions)	101,424		382,823	
Patients	25,623		99,380	
Physicians	6357		16,390	
Municipalities	183		121	

Econometric approach

- The effect of staggered adoption of the nationwide e-prescribing system across municipalities over four years on the measure of the quality of prescribing.
- Event study specification for prescription i in municipality m at time (quarter) t:

$$y_{imt} = \sum_{\tau=-8}^{8} \delta_\tau D_{\tau,mt} + X_{imt}'\beta + \alpha_m + \gamma_t + \epsilon_{imt}, \qquad (2)$$

  - $D_{\tau,mt}$: indicator for the period relative to the adoption period of e-prescribing in municipality m.
    - Additional DiD estimations, Goodman-Bacon analysis (to confirm that negative weights do not arise for later-treated units).
  - Identification: early-adopting municipalities vs. later-adopting municipalities. Binning of endpoints in event study (Schmidheiny and Siegloch, 2019).
  - Intention-to-treat analysis, as the take-up of e-prescriptions by physicians and patients was voluntary during our observation period.
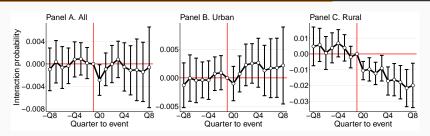
Outline of the results

- Quality of prescribing: average effects and regional heterogeneity
- Mechanisms:
    - Information environment (specialization)
    - Coordination (changes in treating physician)
- Utilization: intensive and extensive margins
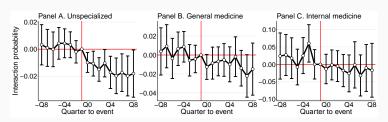- Health outcome
- Robustness

Figure 3: Probability of Warfarin-NSAID Interaction in Rural Municipalities, by Municipality Type

- Urban regions: no statistically significant effects, can rule out effects larger than 9 percent compared to the mean.
- Rural regions: 36 percent decrease compared to the mean in the long run.
- Largest improvements in previously low-performing regions (typically rural). ▸ Results

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Mechanisms: physician specialization

- Unspecialized physicians supply a disproportionate amount of prescriptions in rural regions (55 vs. 46 percent in urban regions).
- They have less education and are more likely to work in primary care settings compared to more specialized physicians (e.g., internists).
- Hence, their typical patients might be less complex.
- They might have less knowledge on interactions/treatments of internal diseases (warfarin), especially in rural regions where:
    - Lack of specialists limits the ability of non-specialists to learn from specialists.
    - Temporary workers, who may not know their patients or colleagues well, are often used to fill staffing gaps.

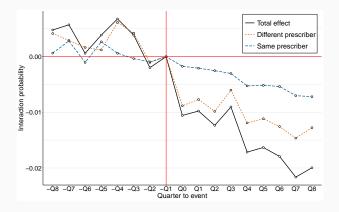**Figure 4:** Probability of Warfarin-NSAID Interaction in Rural Municipalities, by Physician Speciality

Mechanisms: coordination and information integration

- E-prescribing should improve coordination and information flows between multiple physicians involved in a patient's care.

- Outcome decomposition:

  Coordination Failure =
  $$\begin{cases} 0 & \text{if no interaction} \\ 0 & \text{if interaction and same prescribing physician} \\ 1 & \text{if interaction and different prescribing physician} \end{cases}$$

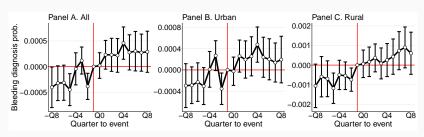- Additional analysis: different vs. same pharmacy. ▶ Results

Different vs. same physician, rural municipalities

Robustness

- Heterogeneity by age.
- One-way interaction: NSAID is prescribed on top of warfarin, rather than using a two-way interaction (warfarin on top of NSAIDs or the other way round) as an outcome
- Patient FE, Hospital-district trends, ATC trend, exclude private visits, use data from all NSAID patients.
- 50% increase/decrease in Rx length, exclude interactions under 10 and over 100 days, use patient specific average prescribing intervals as proxy for Rx length.
- Duration of overlapping use.
- Aggregated municipality-level data.
- Placebo: benzodiazepine and warfarin.
- Goodman-Bacon analysis.
- Nonrandom attrition caused by mortality.

Health outcome: bleeding diagnosis

Figure 5: Quarterly probability of a bleeding diagnosis for warfarin patients (mean probability: 0.2 percent).

- No evidence of direct health benefits in terms of bleeding diagnosis.
- The effects seem to be driven increased utilization of warfarin (e-prescriptions are also much easier to renew than paper prescriptions, Böckerman et al.). ▸ Results

Conclusion

- We study a large-scale policy of health information integration between care providers, using administrative data on the rollout of a nationwide e-prescribing system in Finland.
- No statistically significant effects on average or (urban/semi-urban) regions.
- Integration integration improves the quality of prescribing and coordination in previously low-performing (rural) regions.
    - Co-prescribing of harmful drug combinations reduces by approx. 35 percent in rural regions.
    - Driven by interacting prescriptions received from multiple physicians.
    - The resulting direct health benefits, in terms of bleeding diagnoses, seem to be marginal.
- Key factors from theoretical model: the division of labor, coordination cost, and human capital (e.g., physician expertise).
- Information integration improves coordination and narrows regional differences in health care delivery and reduces the cost of physician switches (pro-competitive).
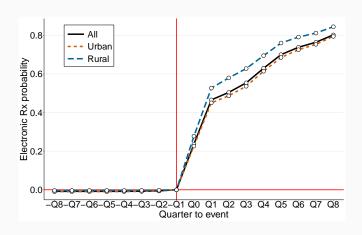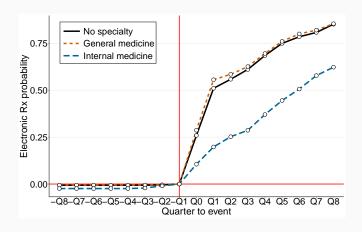
Thank you!
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Appendix

Correlation Between Adoption Time and Municipality Characteristics `▸ Back`

	2008	2009	2010
Log(population)	−0.093	−0.088	−0.089
	(0.091)	(0.088)	(0.091)
Log(primary care costs)	0.126	0.141	0.091
	(0.115)	(0.140)	(0.086)
Percentage over 65 years	−0.009	−0.007	−0.006
	(0.013)	(0.011)	(0.010)
Percentage 15–64 years	−0.019	−0.016	−0.018
	(0.021)	(0.018)	(0.019)
Drug reimbursement index	0.008	0.006	0.006
	(0.007)	(0.006)	(0.007)
Morbidity index	−0.007	−0.006	−0.006
	(0.006)	(0.006)	(0.006)
Mortality index	−0.0004	0.001	0.001
	(0.001)	(0.001)	(0.001)
Log(outpatient visits in psychiatry)	−0.008	−0.013	−0.006
	(0.016)	(0.022)	(0.013)
Log(psychiatric inpatient periods of care)	0.086	0.015	0.013
	(0.074)	(0.027)	(0.026)
Semi-urban municipality	0.044	0.038	0.036
	(0.040)	(0.038)	(0.037)
Rural municipality	−0.056	−0.064	−0.069
	(0.087)	(0.096)	(0.098)
Observations	299	298	298
Hospital district FE	Yes	Yes	Yes

By Pre-adoption Interaction Rate
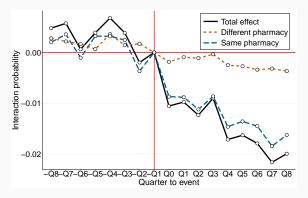
Table 2: Effects of E-prescribing on Warfarin-NSAID Interaction, by Municipalities' Pre-adoption Interaction Rate

	1st quartile	2nd quartile	3rd quartile	4th quartile
	(1)	(2)	(3)	(4)
Short-run	-0.001	-0.000	-0.005^{**}	-0.011^{***}
	(0.002)	(0.002)	(0.002)	(0.004)
Long-run	-0.001	-0.002	-0.009^{***}	-0.015^{**}
	(0.003)	(0.003)	(0.003)	(0.006)
Mean outcome	0.035	0.042	0.049	0.065
Observations	395,028	594,113	505,052	195,313

By Physician Specialization

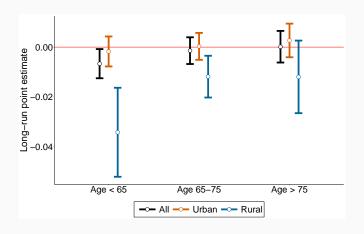|	All municipalities	Urban	Rural
Panel A. Unspecialized			
Short-run	−0.002	0.000	−0.012***
	(0.001)	(0.001)	(0.003)
Long-run	−0.004*	−0.001	−0.018***
	(0.002)	(0.002)	(0.005)
Mean outcome	0.043	0.042	0.047
Observations	917,214	709,548	207,666
Panel B. General medicine			
Short-run	−0.003	−0.002	−0.008
	(0.002)	(0.002)	(0.006)
Long-run	−0.004	−0.002	−0.010
	(0.003)	(0.003)	(0.007)
Mean outcome	0.040	0.038	0.049
Observations	337,702	266,726	70,976
Panel C. Internal medicine			
Short-run	−0.001	0.001	−0.023
	(0.004)	(0.005)	(0.015)
Long-run	0.001	0.004	−0.030
	(0.007)	(0.007)	(0.024)
Mean outcome	0.056	0.055	0.063
Observations	73,862	63,477	10,385

Figure 6: Probability of Warfarin-NSAID Interaction in Rural Municipalities, Different Versus Same Pharmacy
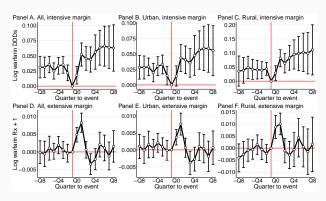
▸ Back

- Physicians/pharmacists may be more careful with very old patients
- Elderly frequently consume multiple drugs
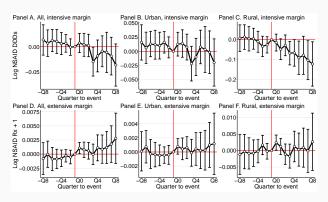- More NSAID density at the "younger" side of age distribution

Quantity of Warfarin Prescribing: Intensive and Extensive Margins

Defined daily doses of a warfarin prescription (Panels A–C) and the quarterly probability of a warfarin prescription (Panels D–F). Prescription size increases in rural regions – no change in the number of prescriptions.

Quantity of NSAID Prescribing: Intensive and Extensive Margins

Panel A. All, intensive margin · Panel B. Urban, intensive margin · Panel C. Rural, intensive margin · Panel D. All, extensive margin · Panel E. Urban, extensive margin · Panel F. Rural, extensive margin

Defined daily doses of an NSAID prescription (Panels A–C) and the quarterly probability of an NSAID prescription (Panels D–F). Smaller NSAID prescriptions in rural regions after the reform. ▶ Back