Cash saves the day: How cash infrastructure enhances resilience during a card payment system outage

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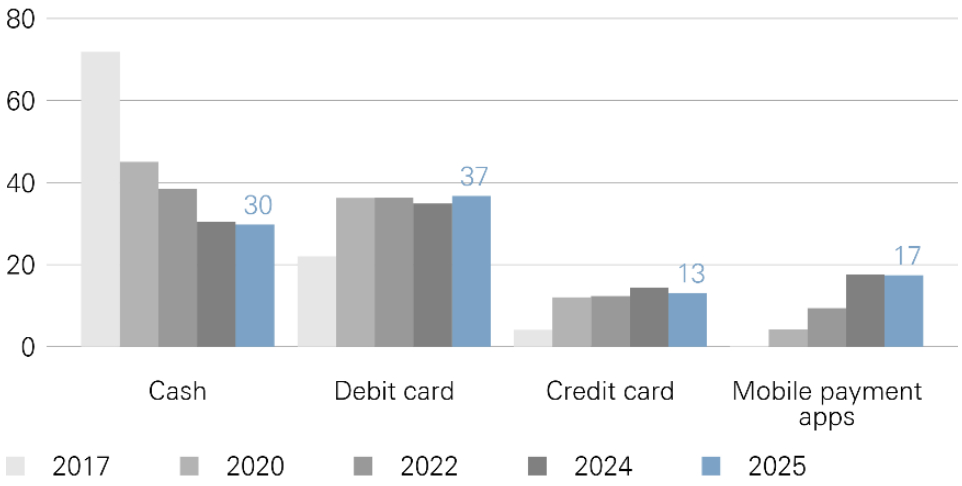
Motivation – Consumers are going cashless

Cashless POS payments increased from 28% to 70% between 2017 and 2025

IN-PERSON TRANSACTIONS BY PAYMENT METHOD

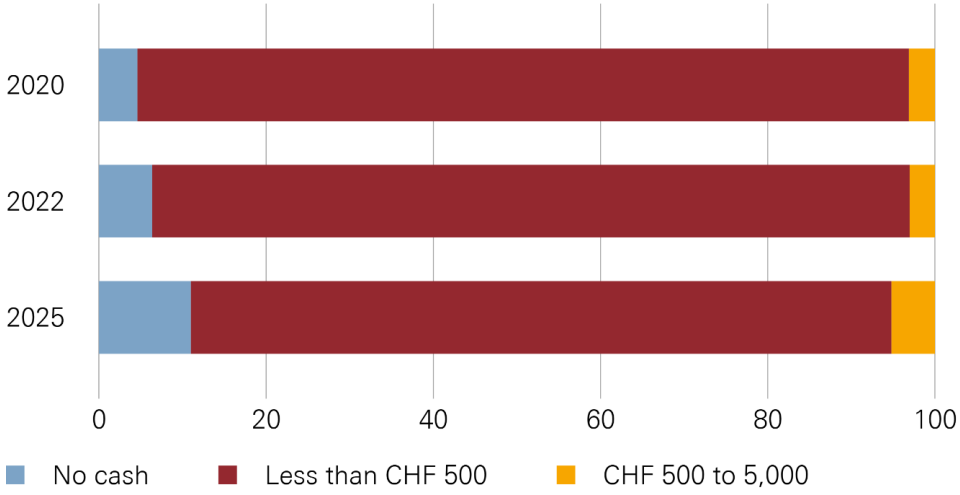
Volume shares in percent; from payment diary



10% of the Swiss population do not carry cash in their wallet (median amount 2022: CHF 85)

CASH HELD IN WALLET

Shares in percent; from questionnaire

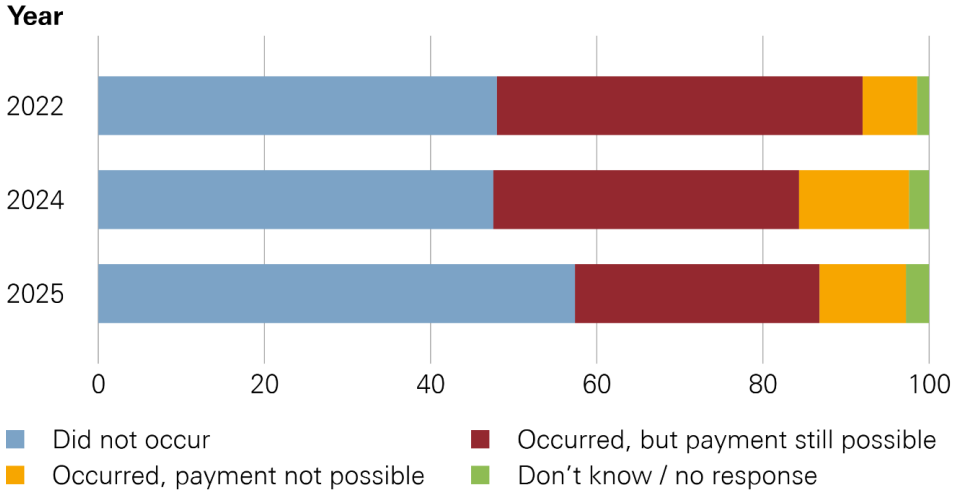


Motivation – Technical outages are common, but the effects of payment outages are understudied

Payment methods survey: ~50% of respondents experienced a technical disruption

TECHNICAL DISRUPTIONS

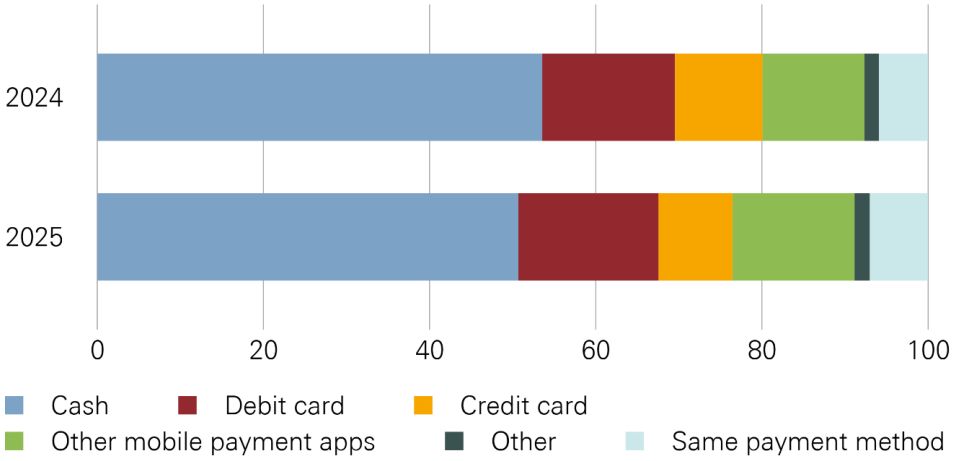
Shares in percent; from questionnaire



Cash plays an important role as backup payment method

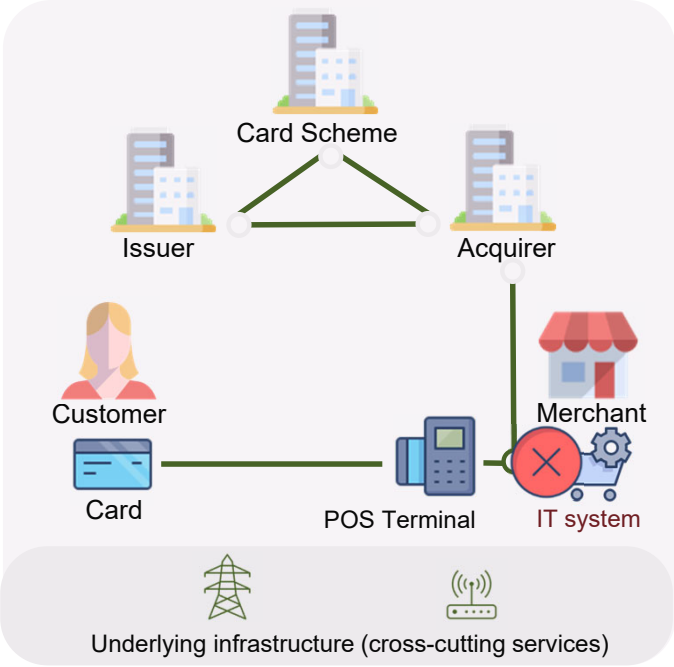
ALTERNATIVE PAYMENT METHOD IN THE EVENT OF TECHNICAL DISRUPTIONS

Shares in percent; from questionnaire



Research Question – How do consumers react to an outage of the card payment system?

- The Swiss grocery retail market is dominated by two major chains (~80% cum. market share)
- One of them experienced a **nationwide one-day outage** of its card payment system on a Monday in October 2022
  - What type of day-long outage?
- Aim of this study: to quantify **effect of lost card payments on** consumer reaction channels, especially **ATM withdrawals**



Literature – We offer an empirical analysis of a retail payment system outage and its effects

Outage analysis/detection in **large-value payment systems**	**Studies** on outages of retail payment systems and consumer payment behavior
• Periods of inactivity in FedWire (Klee, 2010) • Outage detection algorithms in TARGET2 (Glowka et al., 2017) validated with outage reports (Arjani and Heijmans, 2020) • Simulation of cyber attacks in FedWire (Eisenbach et al., 2022) • Anomaly detection in Lynx (Desai et al., 2025)	• Disruption scenarios in card payment systems (Khiaonarong, et al., 2022) • Cascading operational failures in retail payment systems (Allen, 2021) • Banks' physical footprint and financial technology adoption (Mariani et al., 2023) • Keep calm and carry cash: lessons on the unique role of physical currency across four crises (Fealla and Zamora-Pérez, 2025) • On the resilience of payment methods (Alvarez et al., 2026)
Outage analysis in **retail payment systems**	**Empirical analysis** of consumer behavior in a retail payment system outage

Data – Transaction-level card payment and ATM withdrawal data (Period 2020-22)

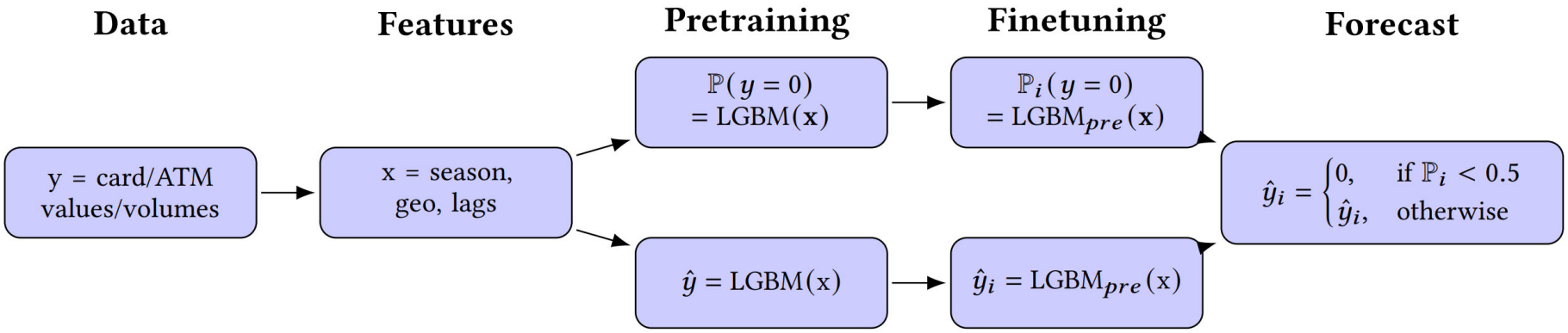
	Daily trx.	No. of stores or ATMs	Coverage of trx.	Daily median *volume* per store/ATM	Daily median *value* per store/ATM	Avg. *value* of individual trx.
Card payments	~5,000,000	26,956	~80%	29	CHF 1,360	CHF 47
ATM withdrawals	~300,000	5,628	~95%	51	CHF 17,750	CHF 348

Table 1: Summary statistics card payments and ATM withdrawals per store or ATM

Data source: SNB, Worldline, PostFinance, SIX BBS

Method – We forecast daily card payments and ATM withdrawals across all retail stores and ATMs

- Forecasting task: Daily value/volume card payments and ATM withdrawals for every single store/ATM (~32,000 models)
- Training protocol: 2020–2021 base period, quarterly rolling forecasts through 2022
- Model: LightGBM (computationally efficient) with pretraining on all data → finetuning per store/ATM
- Two-step prediction: Classify zero-payment days, then, if payments occurred, estimate value/volume



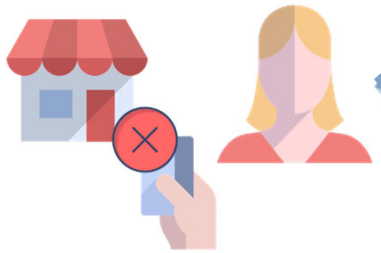
Evaluation results – Models accurately forecast card payments and ATM withdrawals

	Card Payments		ATM withdrawals	
	Volume	Value	Volume	Value
R^2	83.1%	80.1%	60.9%	64.5%
$MASE_{lag}$	31.7%	35.1%	52.5%	55.2%
$Accuracy_{zeros}$	98.1%	98.1%	-	-
$F1_{zeros}$	92.6%	92.6%	-	-
AUC	92.6%	98.7%	-	-

Tab. 2: Performance metrics for forecast card payments and ATM withdrawals

Data source: SNB, Worldline, PostFinance, SIX BBS

Method – We quantify card losses and consumer reaction channels using forecast residuals



Card loss: Card residuals at stores with highly negative z-score, i.e., < -1.5sd

Competitior store: Card residuals at propensity-score-matched stores in the same postal code

Postpone: Card residuals at outage-affected stores the day after

ATM: residuals on the outage day

Use cash on hand

Cancel purchase

Method – We causally identify consumer reactions to the outage via lost card payments

- Event study design: Outage → loss card payments → consumer reactions
- Double-debiased ML: Residual-on-residual regression controls for high-dimensional confounders (Frisch-Waugh-Lovell)
- Regression specification: District-level regressions with per-capita residuals and district fixed effects

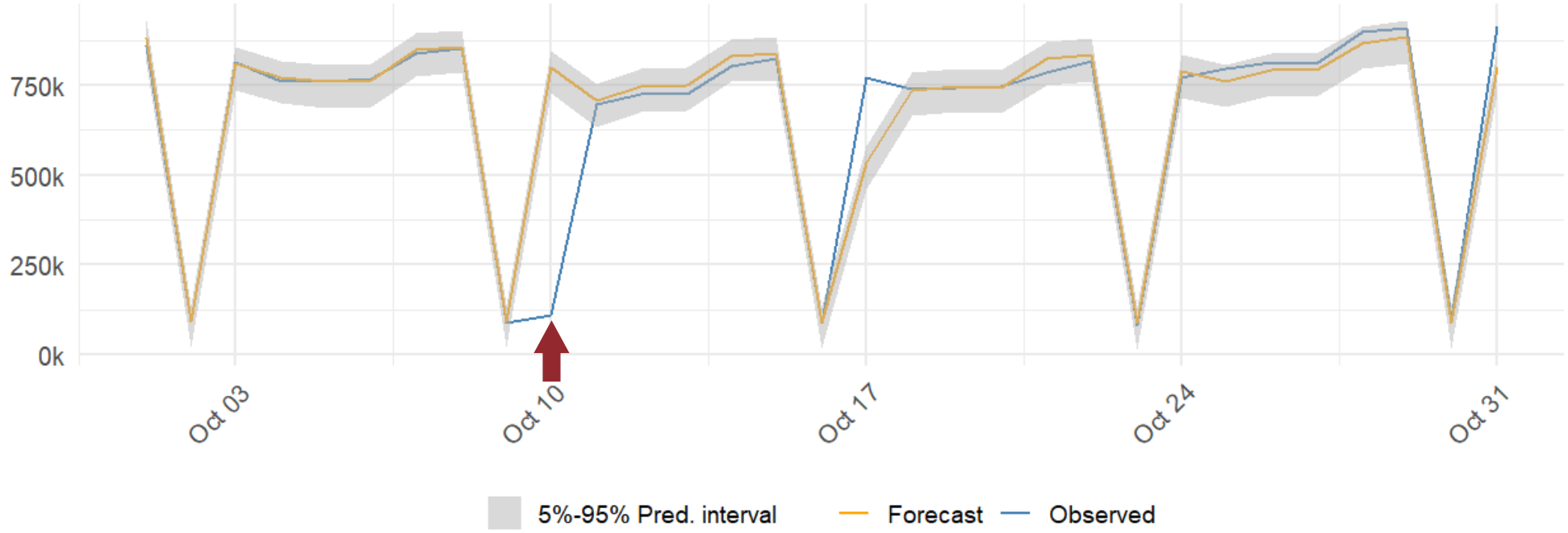
$$\boxed{\text{ATM residuals}^{pc}_{t_{\text{out}},d} = \alpha + \beta_{\text{ATM}} \cdot \text{Loss card}^{pc}_{t_{\text{out}},S_{\text{out}},d} + \gamma_d + \varepsilon_d,}$$

$$\text{Card residuals competition}^{pc}_{t_{\text{out}},S_{\text{match}},d} = \alpha + \beta_{\text{competition}} \cdot \text{Loss card}^{pc}_{t_{\text{out}},S_{\text{out}},d} + \gamma_d + \varepsilon_d,$$

$$\text{Card residuals day after}^{pc}_{t_{\text{out}}+1,S_{\text{out}},d} = \alpha + \beta_{\text{day after}} \cdot \text{Loss card}^{pc}_{t_{\text{out}},S_{\text{out}},d} + \gamma_d + \varepsilon_d,$$

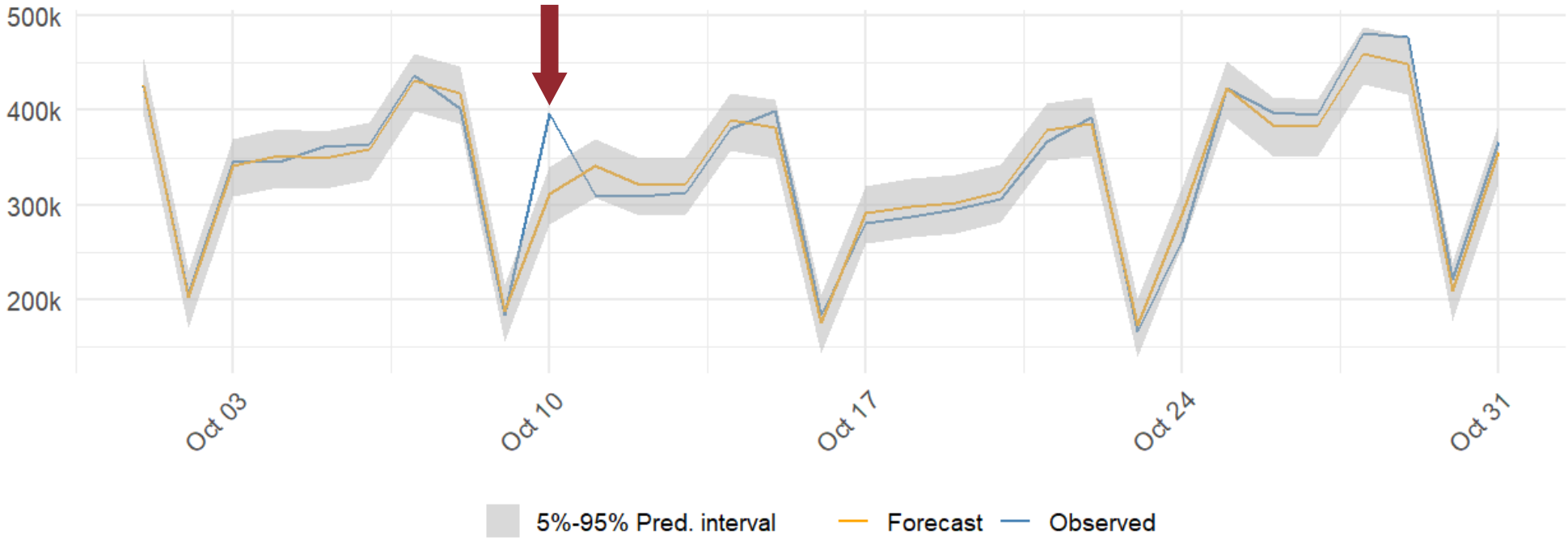
Results – Outage-affected stores lost ~90% of card payments in terms of volume and value

Volume of daily observed and forecast card payments for outage-affected stores



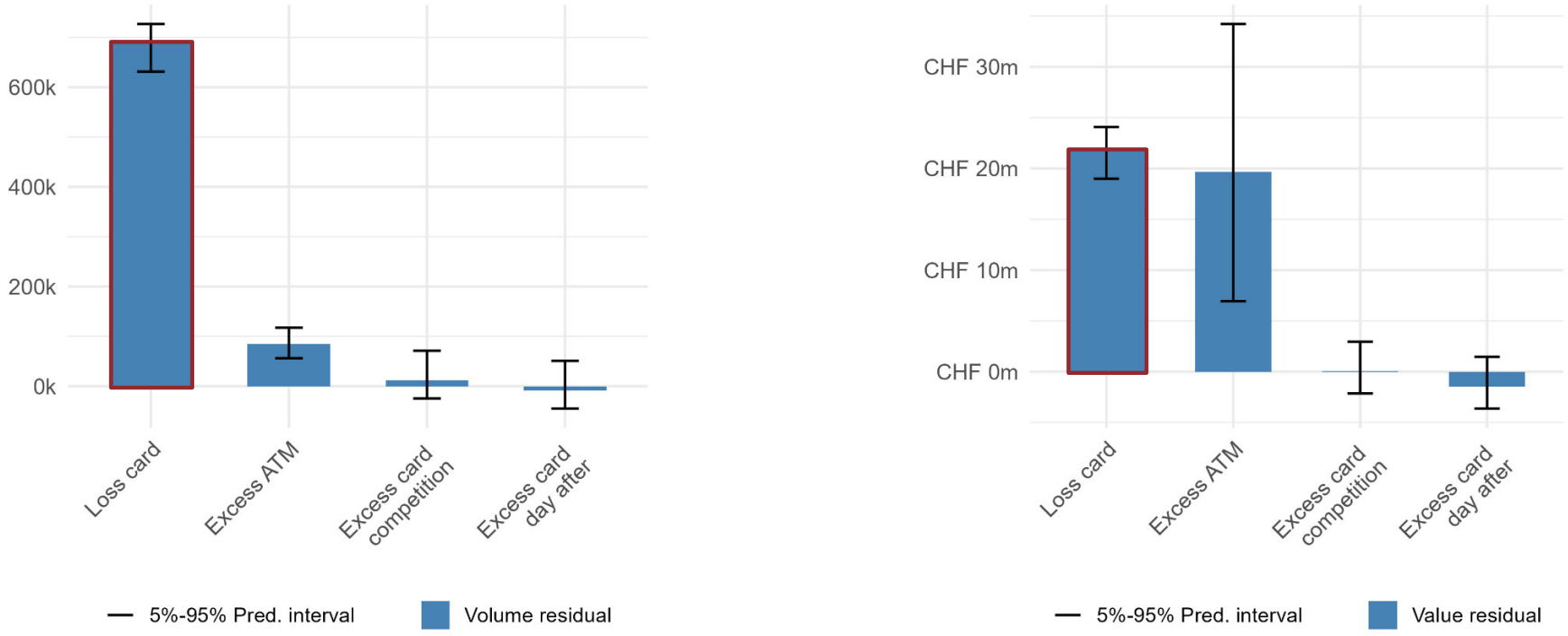
Results – ATM withdrawals increased by 27% in volume on the outage day

Volume of daily observed and forecasted ATM withdrawals



Results – There was an aggregated loss of 700k card payments worth CHF 22mn and 85k excess ATM withdrawals worth CHF 20mn

Loss card sales and consumer reaction channels: (a) ***volume*** and (b) ***value***

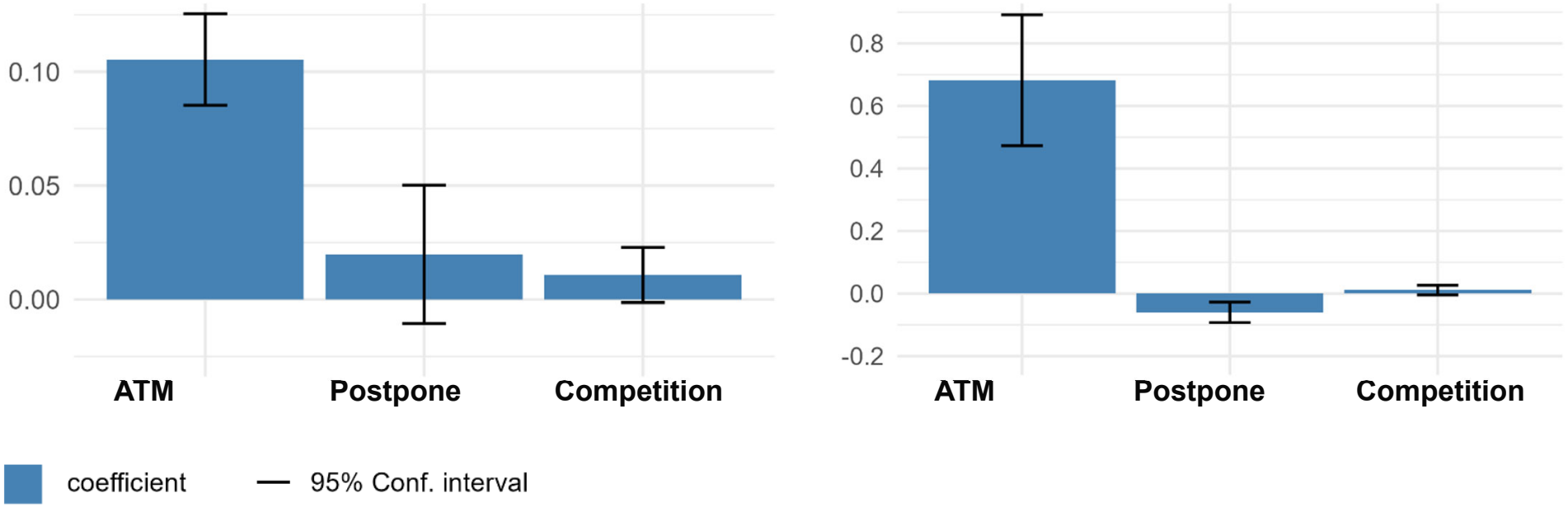


Results – For 100 lost card payments, there were 11 additional ATM withdrawals - small effects on other consumer reaction channels

Value: For CHF 100 lost card payments, there were CHF 68 additional ATM withdrawals

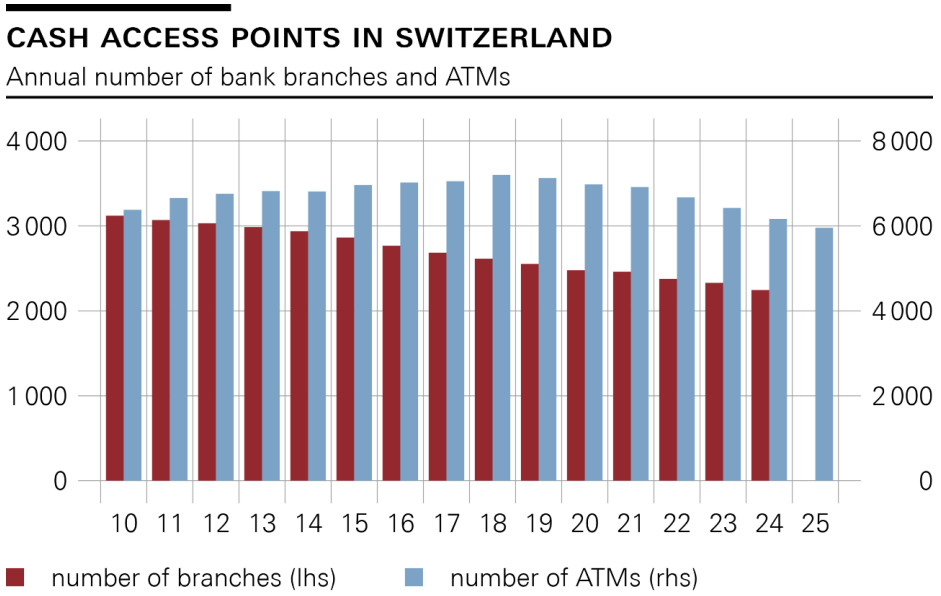
District regression results (base specification) of effect of loss card payments on consumer reaction channels

(a) ***volume*** $\hat{\beta}$ (b) ***value*** $\hat{\beta}$



Discussion – Cash can support payment resilience during a retail payment system outage

- In the Swiss October 2022 case, cash demand strongly increased after a retail payment system outage
- People who withdraw cash due the outage, seem to have increased precautionary cash holdings
- Cash access points in Switzerland are declining
- Central banks invest in offline functionality for cashless payment instruments (e.g., digital euro)



Thank you for your attention!

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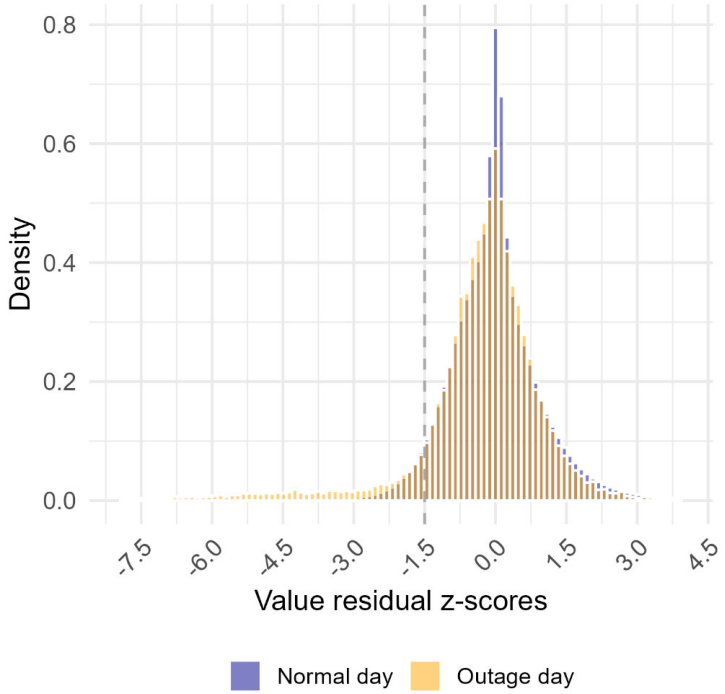
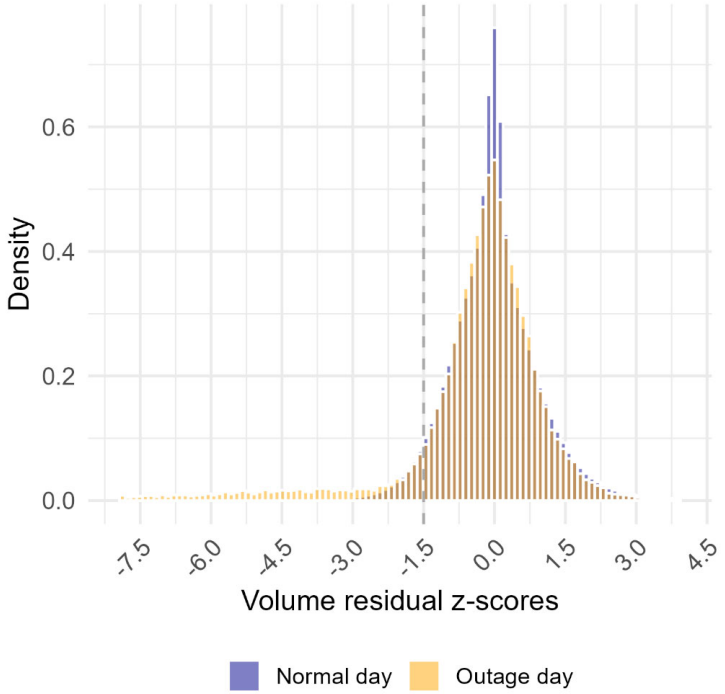
Results – Merchants with -1.5 std and less card payments value and volume are assumed to have an outage

Z-scores normalized value residual on outage and normal days

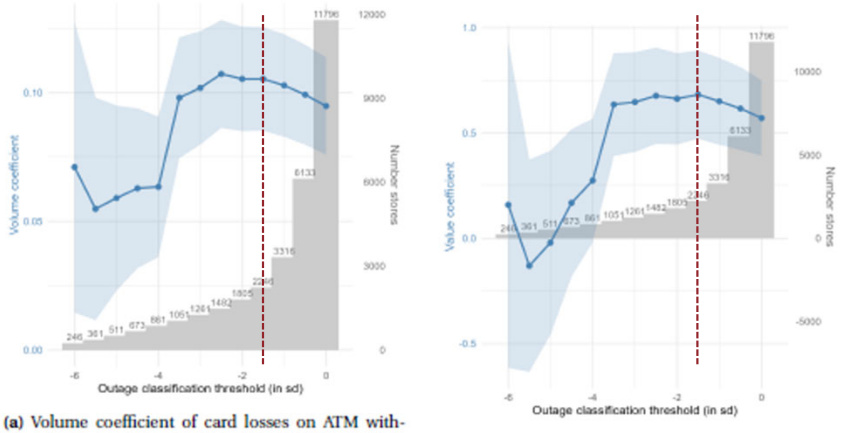


Z-scores normalized volume residual on outage and normal days



Robustness check – Stable results around the 1.5-sd threshold

Regressions' ***β coefficient***

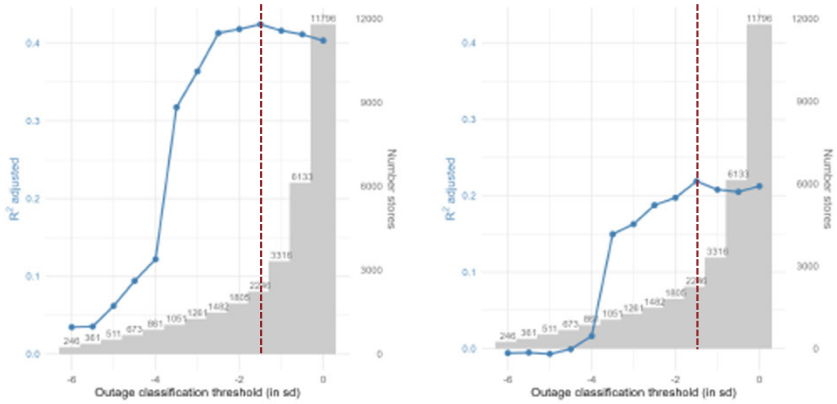


(a) Volume coefficient of card losses on ATM withdrawal residuals regression depending on outage threshold.

(b) Value coefficient of card losses on ATM withdrawal residuals regression depending on outage threshold.

Figure 10: Sensitivity analysis of card loss coefficients on ATM withdrawal residuals to the outage store classification threshold (base specification), with store counts and 95% confidence intervals.

Regressions' ***R^2***



(a) Volume adjusted R^2 of card losses on ATM withdrawal residuals regression depending on outage threshold.

(b) Value adjusted R^2 of card losses on ATM withdrawal residuals regression depending on outage threshold.

Figure 11: Sensitivity analysis of the adjusted R^2 of card losses on ATM withdrawal residuals regression (base specification) and store count depending on outage store classification thresholds (in standard deviations).