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Consumer Adoption and Use of Payment Technology: Convenience Benefits vs. Security Concerns

Martin Brown, Laura Felber and Christoph Meyer

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Abstract

Convenience and security are the two key attributes that consumers consider when choosing between payment technologies. We examine how consumers react to an exogenous change to the convenience and security of digital payments. We study an increase in the 'tap-and-go' limit for contactless point-of-sale card payments. A higher 'tap-and-go' limit enables faster and easier verification for larger value transactions. However, a higher limit also increases security concerns, as the misappropriation of a card can lead to larger losses. Our analysis is based on anonymized transaction-level data for a large sample of debit card payments between 2019 and 2021. We reveal that the increase in the 'tap-and-go' limit caused a substantial increase in the consumer use of contactless payments, but had only a minor impact on first-time adoption. Our findings are consistent with a stylized model in which the convenience benefits of digital payments are largest for small-value on-the-fly transactions and security concerns are heterogeneous across consumers. In this framework, only consumers with weak security concerns adopt the technology and respond to subsequent improvements in its convenience.

Keywords: Payment choice, technology adoption, contactless payments, COVID-19.
JEL Codes: D14, E42, G21, G23, G50, O33.

*Brown: Study Center Gerzensee and University of St. Gallen, martin.brown@szgerzensee.ch; Felber: Swiss National Bank, laura.felber@snb.ch; Meyer: Swiss National Bank, christoph.meyer@snb.ch We thank seminar participants at the Swiss National Bank (SNB), the Bank of Canada, the National Bank of Romania, WHU School of Management, the University of Basel, the University of Zurich, Georgetown University and participants at the 2023 Swiss Winter Conference of Financial Intermediation, the 2023 Economics of Payments Conference, the 2024 International Conference on Payments and Securities Settlement (Eltville), the 2024 Annual SSES Congress, as well as Anneke Kosse (discussant), Tobias Berg, Thibaut Duprey, Andreas Freitag, Andreas Fuster, Emilia Garcia-Appendini, Marc Glowka, Robert Hunt, Kim Huynh, Charles Kahn, Winfried Königer, Sarah Lein, Filippo Mezzanotti, Cyril Monnet, Thomas Nellen, Michele Pelli, Kasper Roszbach, Fabienne Schneider, Enrico Sette, André Stenzel, Rolf Weder, and Michael Zimmert for helpful comments and discussions.

1 Introduction

The use of digital payment technology by consumers for everyday purchases varies substantially across and within countries (Bagnall et al., 2016; European Central Bank, 2022). Survey data suggest that security and convenience (speed and ease of use) are the two most important attributes to consumers when choosing between payment methods (see Figure A1 in Appendix A1). New payment technologies, such as contactless cards or instant payments, often improve convenience at the cost of security. It is thus crucial for monetary authorities and financial intermediaries to understand the consumer trade-off between the security and convenience of payment methods as they design and introduce innovations in digital payments.

In this paper, we provide unique evidence on the consumer trade-off between convenience benefits and security concerns of digital payment technology. We present a stylized model of payment technology choice and provide empirical support which is consistent with the model's key predictions: Consumers with low security concerns respond to changes in the convenience of payment technology, increasing their usage as convenience improves. By contrast, consumers with high security concerns do not adopt the technology and are insensitive to incremental improvements in its convenience. In the aggregate, convenience enhancing measures thus cause an increase in consumer use of payment technology, but have only a limited impact on first-time adoption.

We study an exogenous change to the 'tap-and-go' limit for contactless card payments at the point of sale (POS). Transactions below this limit require no additional verification by the card-holder after they are initiated by tapping the card at a payment terminal. Transactions above the limit require additional verification by entering a personal identification number (PIN) at the terminal. In Switzerland – the country we study – the 'tap-and-go' limit was doubled from CHF 40 to CHF 80 in April 2020.[2] An increase in the 'tap-and-go' limit improves the convenience of contactless payments, as it increases the range of transactions for which no additional verification is needed. At the same

[2] CHF 1 = USD 0.99 in January 2019 and USD 0.97 in July 2022; CHF 1 = EUR 0.89 in January 2019 and EUR 1.01 in July 2022.

time, a higher 'tap-and-go' limit increases the security concerns of using the technology. In particular, consumers may worry that a card that is physically stolen, or digitally 'skimmed', could be used for larger transactions by a third party.

Our analysis is based on an anonymized transaction-level dataset of debit card payments at POS merchants in Switzerland between 2019 and 2021. For each transaction, we observe the value, date and time of the transaction, as well as the method for initiating the transaction (contactless versus chip-based). Hashed ID numbers allow us to track cards and merchants across transactions. Our main analysis is based on a sample of constant card-merchant relationships covering more than 400,000 payment cards and nearly 18,000 merchants. For these cards and merchants, we study over 20 million transactions from constant calendar periods for the years 2019 to 2021. We thus compare the payment behavior of the same consumers purchasing from the same merchants during the same period of the year. We hereby minimize the concern that observed changes in payment choice are driven by structural changes or seasonality in consumption behavior rather than changes in payment behavior.

We derive our empirical hypotheses from a stylized model of payment technology choice for card payments at the POS. Consumers choose how to verify the card payment (contactless versus chip-based) for each transaction separately. We assume that the convenience benefits of 'tap and go' payments are larger for small-value on-the-fly purchases. We further assume that consumers have heterogeneous security concerns related to potential card misappropriation. Under these assumptions we expect that consumers with low security concerns adopt contactless payments, and use them especially for small-value payments. Consumers with high security concerns do not use contactless payments even for small-value payments. In this framework, an increase in the 'tap and go' limit thus increases the use of the contactless technology by consumers who have already adopted it. By contrast, the policy change has no impact on first-time adoption of contactless payments.

Our summary statistics document a substantial increase in both the adoption and use of contactless payments following the increase in the 'tap-and-go' limit in April 2020. The share of contactless transactions increases by 17 percentage points (pp) from 44% to 61% when we compare our Base period (weeks 20 to 28 in 2019) to our Post-wave 1 period (weeks 20 to 28 in 2020). The share of cards that were used at least once in contactless payments (adoption rate) increases by 18 pp from 68% to 86% between the Base period and Post-wave 1 period.

The increase in the 'tap-and-go' limit in April 2020 was triggered by the onset of the COVID-19 pandemic. It is plausible that, at this point in time, payment behavior was also influenced by pandemic-related hygiene concerns. Moreover, at the onset of the pandemic, there was an increase in the salience of cashless and contactless payments due to advertising campaigns by merchants, banks and card schemes.[3] Motivated by our stylized model, we conduct two separate analyses to identify the causal impact of the increased 'tap-and-go' limit on the adoption and the use of contactless payments.

In our first test, we study first-time adoption of the contactless technology. We compare the adoption of contactless payments for cardholders that benefit differentially from the increased 'tap-and-go' limit. In this between-card analysis, our card-level measure of treatment intensity is the share of transactions between CHF 40 and CHF 80 in the Base period - i.e., the share of transactions that become newly eligible to 'tap-and-go'. The results of this between-card analysis reveal a stronger growth in the adoption of contactless payments for those cards that benefit most from the higher 'tap-and-go' limit. On average, across cards in our sample, the pre-pandemic share of transactions between CHF 40 and CHF 80 is 23%. For cards with a pre-pandemic share of 31% (75th percentile), the rate of first-time adoption between the Base period and Post-wave 1 period is 23 pp. For cards with a share of 9% (25th percentile), the rate of first-time adoption is between the Base period and Post-wave 1 period is 15 pp. However, we can only attribute a small share of this effect to the limit increase, as we observe a similar difference in the speed of first-time adoption even before the onset of the pandemic.

[3] At the onset of the pandemic there was a surge in Google searches for 'contactless payments' in English or 'kontaktlos bezahlen' in German. See Appendix A2.

In our second test, we study the impact of the increased 'tap-and-go' limit on the usage rate of the contactless technology. We compare the use of contactless payments for transactions that are newly eligible for 'tap and go' (transactions between CHF 40 and CHF 80) to those transactions that were already eligible (transactions below CHF 40) and those that are still not eligible (transactions above CHF 80). The results of this within-card analysis reveal that newly eligible transactions experience stronger growth in contactless payments. Between the Base and the Post-wave 1 periods, the share of contactless transactions increases by 24 pp for transactions in the range between CHF 40 and CHF 80, compared to 16 pp for transactions below CHF 40 and 18 pp for transactions above CHF 80.This suggests convenience to have played the major role in boosting the usage of 'tap and go', since both transactions below CHF 40 and transactions between CHF 40 and CHF 80 would be affected by increased hygiene benefits, and transactions across all payment amounts would be affected by a salience effect.

In an extension, we benchmark the effect of the 'tap-and-go' limit against the contemporaneous shock to consumer demand for contactless transactions induced by pandemic-related hygiene concerns. At the onset of the COVID-19 pandemic, fear of contracting the coronavirus led many consumers to minimize physical contact in shops, restaurants and other service providers. We match geographical information on the location of the merchant to regional information on COVID-19 cases during the first wave of the pandemic. We then compare the growth of contactless payments at merchants that were differentially exposed to the pandemic. Our results suggest that regional pandemic intensity did not trigger an increase in either the adoption or use of contactless payments. This finding is consistent with survey evidence suggesting that hygiene concerns are much less relevant to consumer choice of payment method than convenience or security.

Our findings contribute primarily to the empirical literature studying the drivers of payment technology adoption and use by consumers (see, e.g., Klee, 2008; Wang and Wolman, 2016; Koulayev et al., 2016; Shy, 2023). Closely related to our study, Brown et al. (2022) document how the staggered rollout of contactless debit cards by banks increases the use of cards versus cash for small value purchases. However, they find no impact on the first-time adoption of card payments by cash payers. Higgins (2023) documents significant spillovers between consumers and merchants in the adoption of electronic payments. Crouzet et al. (2023) provide evidence for significant complementarities between merchants in payment technology adoption. Akana and Ke (2020) study the adoption of contactless card payments by U.S. consumers. Auer et al. (2022) provide cross-country evidence for significant changes in consumer payment behavior during the COVID-19 pandemic.[4] We contribute to this literature by providing novel evidence on how changes to the convenience and security concerns of cashless payments affects their adoption and use by consumers.

We also contribute to the literature examining the role of financial intermediaries in payments markets. Card schemes and banks play an intermediary role in this two-sided market, coordinating the adoption and use of payment instruments by consumers and merchants (Koulayev et al., 2016; Huynh et al., 2022). The industrial organization literature has focused largely on how fees charged to merchants and rewards offered to consumers affect market efficiency and welfare distribution (Rysman, 2009; Rochet and Tirole, 2011; Rysman and Wright, 2014; Agarwal et al., 2023; Wang, 2023). We provide evidence for a further important coordinating role of financial intermediaries in payment markets: card schemes and banks set the verifcation rules for cashless payments, which impact on the adoption and use of payment technology.

We further contribute to the literature using geocoded and time-stamped administrative data to analyze the effect of the COVID-19 pandemic and related public health measures on consumer behavior. Goolsbee and Syverson (2021) use mobile phone record data to study how consumer visits to stores are affected by fear of the pandemic compared to shutdown measures. Chetty et al. (2023) use anonymized payment card data to examine heterogeneous responses of U.S. consumers to the pandemic and the effects of cash stimulus payments on spending. Gathergood and Guttman-Kenney (2021) use anonymized credit card transaction data to examine the impact of local lockdowns on

[4]See Ardizzi et al. (2020), Jonker et al. (2022), and Garratt et al. (2020) for country-specific evidence for Italy, the Netherlands and the U.S., respectively.

consumer spending in the UK.[5] Related to our institutional setting, Kraenzlin et al. (2020) use geocoded and time-stamped card payment data to document significant regional shifts in consumer spending within Switzerland. We add to this literature by using geocoded and time-stamped card payment data to assess the effect of COVID-19-induced hygiene concerns on consumer demand for digital payments.

2 Empirical setting, hypotheses, and data

2.1 Empirical setting

We study contactless card payments at the POS in Switzerland between 2019 and 2021. Contactless card payments are the most widespread innovation in digital payment technology in recent years (see, e.g., (European Central Bank, 2022)). Moreover, as revealed by Figure 1, contactless card payments display the most substantial and persistent change to consumer payment behavior since the onset of the COVID-19 pandemic. [6]

[5]Several related papers have also been published in the CEPR Covid Economics Papers series: https://cepr.org/publications/covid-economics-papers (last accessed on November 10, 2023).

[6]See Auer et al. (2022) for comparable evidence for a broad range of countries.

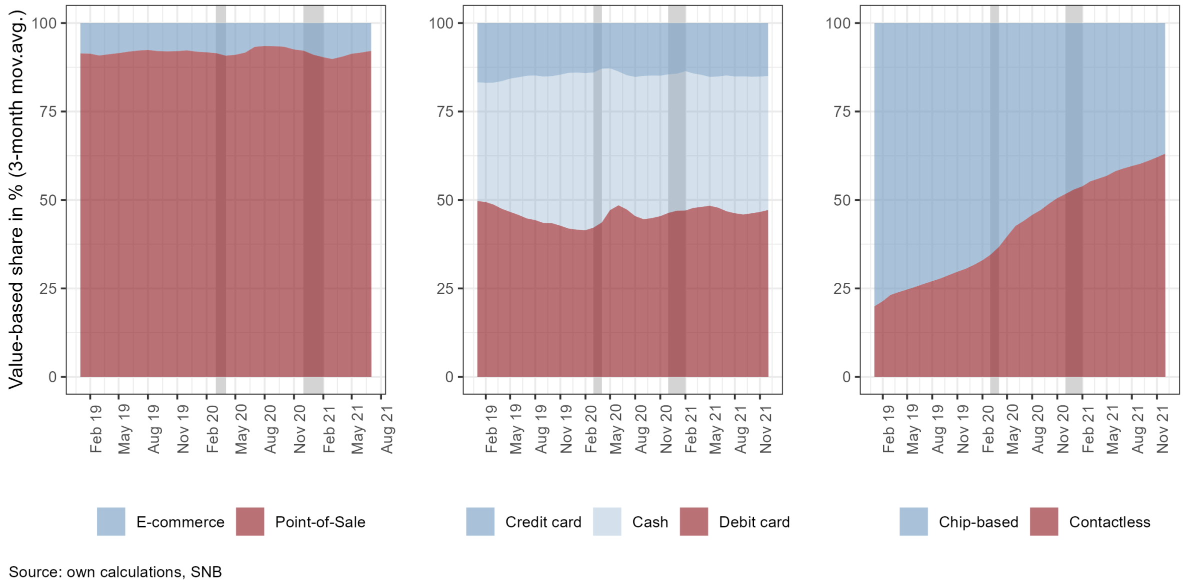

Figure 1: Payment channels, payment instruments, and methods in Switzerland between 2019 and 2021.

Notes: For payment channels (left panel), 'E-commerce' refers to online payment with cards, while 'Point-of-Sale' includes both card and cash payments. For payment instruments (middle panel), 'Cash' refers to cash withdrawals at ATMs in Switzerland. For payment methods (right panel) we contrast chip-based vs. contactless payments with debit cards. The two gray-shaded areas mark periods with pandemic-related restrictions ('lockdowns') in Switzerland. All data are retrieved from SNB's data web portal: `https://data.snb.ch/en` (last accessed on November 10, 2023).

Card schemes and card-issuing banks set the value limit below which contactless transactions require no further verification by the cardholder.[7] Consumers who hold a contactless payment card can initiate POS payments by tapping the card at the payment terminal. The transaction is then instantly verified if its value falls below the limit set by intermediaries. We call these contactless transactions 'tap-and-go' payments, and the value limit for contactless cardholder verification the 'tap-and-go' limit. By contrast, contactless payments above this value limit require additional cardholder verification, typically through entering a PIN code on the terminal ('tap-and-PIN'). Transactions that are initiated by inserting the card in the terminal (chip-based transactions) must

[7] The technical term for this is the 'cardholder verification method (CVM) limit'. In addition, card schemes may set contactless transaction limits above which the contactless initiation of a transaction is not possible. Moreover, card-issuing banks may set limits for the number of transactions that can be executed with no cardholder verification. For details, see, e.g., https://www.uspaymentsforum.org/wp-content/uploads/2020/10/Contactless-Limits-WP-FINAL-October-2020.pdf or https://www.moneytoday.ch/news/karten-die-interessanten-fakten-zur-angehobenen-limite-bei-kontaktlos-zahlungen/ (both last accessed on November 10, 2023).

all be verified by a PIN code ('chip-and-PIN'). Consumer payment surveys reveal that contactless transactions are viewed as more convenient than chip-based card transactions (European Central Bank, 2022; Swiss National Bank, 2021). However, contactless payments have faced barriers to adoption due to security concerns (Akana and Ke, 2020). First, there have been concerns that consumer payment data may be 'skimmed' in crowded areas.[8] Second, there are concerns that if consumers lose a contactless card, the card may be easily used by a third party for conducting illegitimate payments.[9]

Switzerland during the COVID-19 pandemic offers a suitable laboratory to study the adoption and use of contactless payment technology. First, the pre-pandemic structure of payments in Switzerland reflects that of many other advanced economies. Prior to the pandemic, 70% of all out-of-pocket transactions by Swiss consumers were paid in cash (Swiss National Bank, 2018), which is similar to the average for Eurozone countries (European Central Bank, 2020). The rise in contactless payments in Switzerland following the onset of the pandemic also is in line with the average across countries (Auer et al., 2022). Second, as in many other countries, consumers and merchants in Switzerland experienced an exogenous and significant shock to the scope of 'tap-and-go' payments shortly after the outbreak of the COVID-19 pandemic. The 'tap-and-go' limit was increased from CHF 40 to CHF 80 for all merchants and all debit cards in April 2020. Our data reveal that prior to this limit change, 60% of debit card transactions were in the range between CHF 0 and CHF 40 and thus eligible for 'tap and go'. The limit change implied that almost another fifth of transactions became eligible.[10]

[8] See, e.g., the following articles: https://www.bbc.com/news/technology-24743920.amp and https://www.euromoney.com/article/b12kjqynmgn6qx/security-questions-raised-over-contactless-card-payments (both last accessed on November 10, 2023)

[9] See, e.g., the following article: https://portswigger.net/daily-swig/touch-and-go-contactless-payment-security-controls-defeated-by-researchers (last accessed on November 10, 2023).

[10] SNB' payment survey (Swiss National Bank, 2018) reports that prior to the pandemic, 54% of discretionary spending conducted by cash and cashless means of payment was in the range between CHF 0 and CHF 20, with a further 24% between CHF 20 and CHF 50, and a further 13% between CHF 50 and CHF 100.

2.2 Hypotheses

We aim to study the impact of the increased 'tap and go' limit on the adoption and use of the contactless payments technology. We derive our empirical hypotheses from a stylized model of technology choice for card payments at the point of sale. Consider a consumer i who plans to make a total number of n_i payments. We assume that the value of her payments are distributed uniformly on $(0, \overline{y_i}]$ so that total spending of the consumer is $\frac{n_i}{2}\overline{y_i}$. The 'tap-and-go' limit for contactless payments y' is exogenously set at $\overline{y_i} \geq y' > 0$. The share of transactions which fall below the 'tap-and-go' limit for consumer i is thus $\frac{y'}{\overline{y_i}}$

For simplicity we assume that (i) there is universal merchant acceptance of cards for all payment values and (ii) that the consumer uses her payment card for all POS payments.[11] The decision of the consumer is to choose - for each transaction separately - the technology to initiate the card payment: contactless initiation (tapping the card at the terminal) or chip initiation (inserting the card in the terminal).

The convenience benefit of contactless initiation compared to chip-based initiation depends on (i) the size of the transaction, and (ii) whether the transaction requires further verification. First, we assume that the convenience benefit $B(y)$ is decreasing with the payment value y. The intuition here is that small-value payments often happen 'on-the-fly' where the benefit of quicker payments is most valued. Second, we assume that the convenience benefit for 'tap-and-go' payments is strictly higher than that for 'tap-and-PIN' payments by a constant term p for any payment value. We further assume that 'tap-and-PIN' payments are always more convenient than 'chip-and-PIN' payments, i.e., $B(y) - p > 0 \; \forall y$.

The consumer has security concerns that a third party could misappropriate her payment card and use it for illegitimate payments. The probability of misappropriation is proportional to the number of times the card is used. Importantly, the probability of misappropriation is higher for contactless initiated transactions compared to chip-based transactions as the card may not only be physically stolen, but could also be

[11] For reasons of simplicity, we abstract from the consumer decision to use cash or card, as is common in inventory models of cash demand Alvarez and Lippi (2017).

digitally 'skimmed'. Conditional on misappropriation, the expected loss to the consumer is increasing with the 'tap-and-go' limit as the card could be used for larger value transactions without further verification. Together, these considerations suggest that the consumer attributes an additional security cost $f_i(y')$ to each contactless transaction (compared to a chip-based transaction) which is increasing in the 'tap-and-go' limit.

For each transaction of value y the consumer will use contactless initiation (rather than chip-based initiation) if the following condition holds:

$$B(y) - p(y) - f_i(y') \geq 0$$

, whereby $p(y) = p$ for $y > y'$, and $p(y) = 0$ for $y \leq y'$.

We define y_i^* as the threshold payment value for which this condition holds with equality. For a given 'tap-and-go' limit this threshold value increases with $B(y)$, while it decreases with p and f_i. Importantly, if consumers differ in their security concerns related to contactless transactions f_i we should observe that – averaged across consumers – the share of contactless initiated transactions falls with the transaction value. Moreover, given the lower benefit of 'tap-and-PIN' compared to 'tap-and-go' payments, we should observe a kink in the average share of contactless transactions at the 'tap-and-go' limit.

Now consider an increase in the 'tap-and-go' limit from y' to y''. On the one hand, the increase leads to a higher convenience benefit (to the amount of p) for all transactions in the range $y \in (y', y'']$. On the other hand, the increase leads to an increase in the security cost associated with each contactless transaction; $f_i(y'') - f_i(y') \geq 0$.

The figure in Appendix A3 illustrates the impact of an increase in the 'tap-and-go' limit for consumers with different levels of security concerns. The figure shows that the impact of the limit increase depends strongly on how high the initial security concerns of a consumer are. Consumers with *very high* security concerns related to contactless payments will not adopt the technology even for very small transactions. Their payment behavior is thus unaffected by the 'tap-and-go' limit increase, implying no impact of the limit increase on first-time adoption. Consumers with *high* security concerns use contactless initiation only for very small transactions before the limit increase. For these consumers the share of contactless transactions declines with the limit increase as their security concerns grow with the higher limit. Consumers with *low* security concerns use contactless initiation for all transactions below the limit ('tap-and-go') as well as some transactions above the limit ('tap-and-PIN'). These are the consumers who increase their share of contactless transactions as the limit is increased, as they benefit from more 'tap-and-go' payments. Finally, consumers with *very low* security concerns use contactless initiation for small and large payments, independent of the 'tap-and-go' limit.

Based on the above reasoning, we establish two main empirical hypotheses:

Hypothesis 1: The increase in the 'tap-and-go' does not lead to first time adoption of the contactless technology.

Hypothesis 2: The increase in the 'tap-and-go' limit increases the use of contactless payment initiation only for those transactions which become eligible for 'tap-and-go' and only by those consumers who have already adopted the technology prior to the limit increase.

Our model assumes that there are no fixed costs to using contactless payments, i.e., costs of becoming familiar with the technology. If fixed 'adoption costs' exist, then the increased 'tap-and-go' limit may spur new adoption of the contactless technology. Specifically if consumers have many transactions between $40 - 80$ CHF which benefit from improved convenience, they may be more inclined to incur the fixed cost of adopting the technology. Our model highlights that the increased 'tap-and-go' limit increases the convenience benefits for some contactless transactions (between $40 - 80$ CHF) while it increases the security concerns for all contactless transactions. Note that if the increase in the security costs $f_i(y'') - f_i(y') \geq 0$ outweighs the improved convenience benefit p we may actually observe no increase in the use of the contactless technology at all.

These additional considerations lead us to our two alternative hypotheses:

Hypothesis 1A: The increase in the 'tap-and-go' leads to first-time adoption of the contactless technology, especially for consumers with many payments which become eligible for 'tap-and-go'.

Hypothesis 2A: The increase in the 'tap-and-go' limit does not increase the use of contactless payments, even for those transactions which become eligible for 'tap-and-go' and by consumers who already adopted the technology prior to the limit increase.

2.3 Data and sample construction

To test our empirical hypotheses we require data that allows cross-sectional comparisons between different cardholders as well as comparisons across different transaction ranges - that are differently affected by the benefits and costs of the limit change - for the same cardholders. Our analysis is based on an anonymized, transaction-level dataset that covers the overwhelming majority of cashless card payments in Switzerland.[12] For each transaction, we observe the value in Swiss Francs (CHF), the date and time, the purchase channel (POS vs. e-commerce) and the payment instrument (debit card vs. credit card vs. mobile app). For card payments at the POS, we observe the method for initiating the transaction (contactless vs. chip-based). Anonymized ID numbers allow us to track cards and merchants across transactions. For cards, we observe whether a card is issued domestically or abroad but no further sociodemographic information on the cardholder. For merchants, each transaction contains information on the location (up to the municipality or zip code level) as well as the sector of the merchant (NACE 2-digit level).[13] Our data do not cover ATM withdrawals.

The dataset employed for this study covers transactions at POS merchants between January 2019 and July 2021 conducted with debit cards issued by domestic banks. We

[12]The underlying dataset comprises transactions processed by Switzerland's largest acquirer Worldline Switzerland Ltd. (Worldline) and transactions conducted by cards issued by PostFinance Ltd. (PostFinance). Worldline transactions account for approximately two-thirds of Swiss card transactions (see Kraenzlin et al., 2020). In combination with the PostFinance card data, almost full coverage is achieved (see Felber and Beyeler (2023), for an indicative representation of 'market coverage').

[13]NACE (officially: Statistical Classification of Economic Activities in the European Community) is the industry standard classification system used in the European Union. There is a correspondence between NACE and the United Nations' International Standard Industrial Classification of all Economic Activities.

focus on debit card payments because – similar to many other European countries – these are by far the most widely used payment cards in Switzerland (Swiss National Bank, 2021; European Central Bank, 2022; Di Iorio et al., 2024). We cannot distinguish by cardholder but only by card in our data. However, as the Survey on Payment Methods (Swiss National Bank, 2021) and the Swiss Payment Monitor (Gehring et al., 2020) imply that a typical Swiss cardholder regularly uses one debit card, we can assume cards to equal cardholders and use the two terms synonymously. We further filter the dataset to cover the two main categories of discretionary consumer spending: retail trade (NACE code G47) and food and beverage services (NACE code G56). Applying these filters, the dataset consists of over three billion transactions. The figure in Appendix A4 shows that the share of contactless transactions in our dataset is representative of POS debit card payments in Switzerland.

We want to minimize the concern that observed changes in the adoption and use of contactless payments are driven by changes in the availability of the payment technology rather than consumers' choice to adopt and use it. We therefore limit our dataset to include only transactions involving merchants that accept contactless technology throughout our observation period. We then filter on cards for which we can infer that the issuing bank rolled out the contactless function to all their debit cards by 2019.[14] Thus, we can assume that all transactions in our sample could have been initiated contactless (rather than chip-based) if the cardholder had chosen to do so.

We also want to minimize the concern that observed changes in payment technology choice are driven by changes in spending behavior rather than changes in payment behavior. We therefore limit our dataset to a sample of constant card-merchant relationships over constant calendar periods.[15,16] By doing so we study the same cardholders purchasing

[14] Brown et al. (2022) examine the staggered roll-out of contactless debit cards in Switzerland during the period between 2016 and 2018 and document no significant impact on consumer cash demand.

[15] Our procedure is similar to the 'constant-merchant' approach proposed by Aladangady et al. (2022) that is applied to the same card data as in our study in Felber and Beyeler (2023). Aladangady et al. (2022) develop daily spending indices at retailers and restaurants in the U.S. based on payment data. To correct their card data for shifts in market shares of the payment processor providing them with the data, the authors only retain 'constant merchants'.

[16] Note that for a small share of merchants, only information at the cantonal level is available. We filter these merchants and retain only those with zip code information.

from the same merchants at the same period of the year. We restrict our analysis to four nine-week periods (see Figure 2). We analyze the same calendar weeks (weeks 20 to 28) in 2019, 2020 and 2021. We choose this particular period of the year because in 2020, it follows the reopening of shops and service providers in Switzerland after the lockdown imposed during the first wave of the COVID-19 pandemic (Post-wave 1 period). The same period in 2019 constitutes our Base period. The same period in 2021 allows us to track payment behavior after the next main wave of the pandemic (Post wave 2 period).[17] In addition, to conduct parallel trend analysis for payment behavior before the pandemic, we add the (Pre-wave 1) period of calendar weeks 2-10 in 2020. We examine transactions for 975,306 card-merchant relationships that we observe in each of the four observation periods. Our final dataset covers over 20 million transactions conducted by 406,550 different payment cards at 17,885 different merchants.

Table 1 presents card-level summary statistics by period. The table confirms that the structure of consumption is fairly stable over time for our sample of transactions. The number of transactions per period and card varies between 11.5 and 13.5. We see an increase in the number of transactions in the Post-wave 1 period, which is likely due to consumers catching up on 'nonessential' purchases after the first COVID-19-related lockdown. The share of small (below CHF 40), medium (between CHF 40 and CHF 80) and large (above CHF 80) value transactions is stable across periods. The average transaction size lies between CHF 50 and CHF 54, which is well aligned with the average transaction size for discretionary spending in Switzerland, as reported by the SNB's Survey of Payment Methods (Swiss National Bank, 2021). The share of transactions in retail trade, food and beverage services, urban locations, rural locations, agglomeration locations, medium to small merchants, and large merchants is also stable across time.

The main variable of interest in our analyses is the share of contactless transactions, i.e., the share of debit card transactions (in %) that are initiated contactless ('tap-and-go' or 'tap-and-PIN') as opposed to chip-based ('chip-and-PIN'). We construct the

[17] The figures in Appendix A5 provide information on the number of COVID-19 related deaths and cases in Switzerland over time.

variable *ShareContactless* at either the card times period or merchant times period level. We further study the adoption rate of contactless payments. We construct an indicator variable *ContactlessAdopted* at the card times period level that takes value 1 if a cardholder has used the contactless technology up to and including the current observation period.[18] Table 1 reveals that both the use and adoption rate of contactless transactions is increasing over time, but accelerates with the onset of the pandemic.

[18] Whether a card has adopted the contactless technology by a specific period is determined based on all transactions of that card, not only based on its transactions of our sample of constant card-merchant relationships.

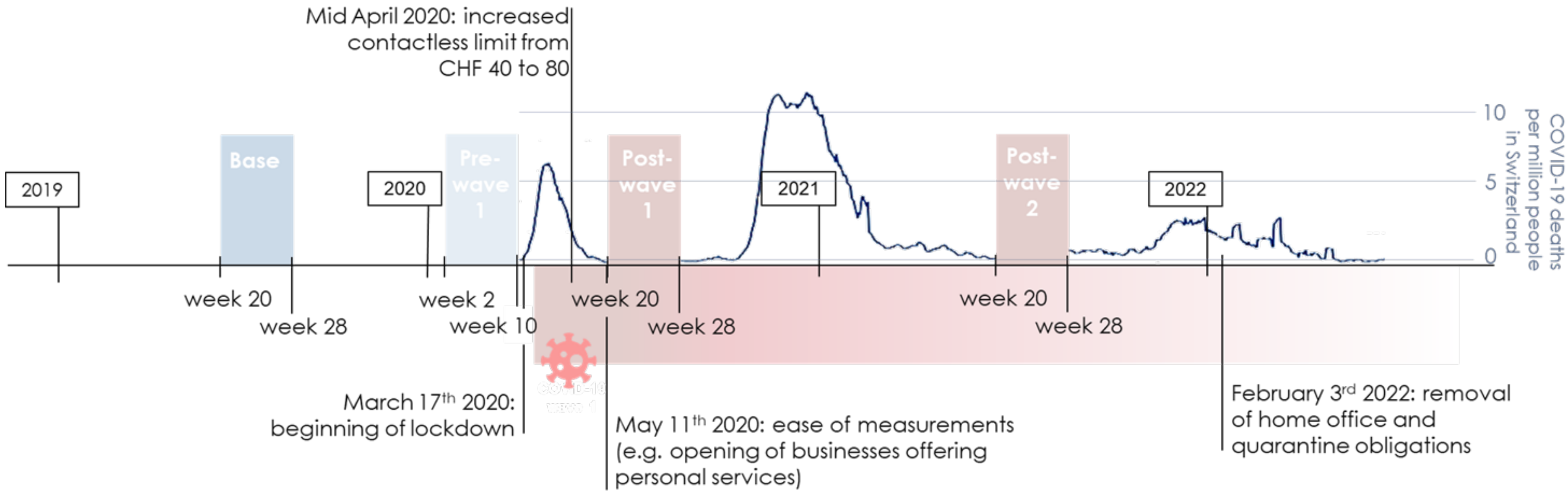

Figure 2: Constant calendar periods applied for sample construction.

Notes: This figure illustrates the four periods applied to build our sample of constant card-merchant relationships during our observation period between January 2019 and July 2021. Our Base period covers the nine calendar weeks 20 to 28 in 2019. Our Post-wave 1 (Post-wave 2) period covers the same calendar weeks in 2020 (2021). Our Pre-wave 1 period covers calendar weeks 2 to 10 in 2020, i.e., the weeks immediately before the onset of the COVID-19 pandemic in Switzerland. The figure further illustrates the intensity of the COVID-19 pandemic (as measured by deaths per million people) during our observation period.

	Base period	Pre-wave 1	Post-wave 1	Post-wave 2
ShareContactless	44%	51%	61%	68%
ContactlessAdopted	0.68	0.77	0.86	0.90
Number of transactions	11.5	12.7	13.5	12.4
Average value (CHF) per transaction	51.1	50.3	54.2	52.3
Share of transactions below CHF 40	59%	60%	57%	59%
Share of transactions between CHF 40 and CHF 80	23%	23%	23%	23%
Share of transactions above CHF 80	18%	17%	19%	19%
Share of retail transactions	97%	97%	97%	97%
Share of food and beverage transactions	3%	3%	3%	3%
Share of transactions at small to medium sized merchants	36%	36%	37%	37%
Share of transactions at large merchants	64%	64%	63%	63%
Share of transactions at merchants in urban areas	78%	78%	78%	78%
Share of transactions at merchants in rural areas	8%	8%	8%	8%
Share of transactions at merchants in agglomeration areas	14%	14%	14%	14%

Table 1: Card-level summary statistics: mean by period (n=406,550 cards).

Notes: This table reports summary statistics at the card level (mean across cards) by period (Base, Pre-wave 1, Post-wave 1, Post-wave 2). Retail transactions are transactions conducted at merchants with NACE code G47. Food and beverage transactions are transactions conducted at merchants with NACE code G56. Small to medium (vs. large) merchants are those below (vs. above) the 90th percentile according to the number of transactions is based on zip code level mapping with publicly available statistics by the Swiss Federal Statistical Office.

Sources: own calculations, SNB, Worldline, PostFinance

3 The causal effect of an increased ‘tap-and-go’ limit

Figure 3 displays the distributions of transactions by size for our Base, Post-wave 1 and Post-wave 2 periods. The figure shows that the increase in the ’tap-and-go’ limit affected a significant share of cashless payments. However, the change in the limit had no notable impact on the composition of transactions in our sample. The figure also reveals that there was no bunching at the ‘tap-and-go’ limits before or after the change in the limit (vertical lines). This suggests that – within our chosen sample of constant card-merchant relationships – cardholders did not adapt their spending behavior to the changed convenience of contactless payments.

Figure 4 displays the share of contactless transactions by transaction size for our Base, Post-wave 1 and Post-wave 2 periods. The figure reveals three observations, which are consistent with our stylized model. First, the share of contactless transactions (‘tap-and-go’; ‘tap-and-PIN’) decreases with transaction size. Second, there is a (minor) discontinuity in the share of contactless transactions at the old (new) ‘tap-and-go’ limit in the Base (Post1 and Post2) observation period. Third, the increase in the contactless share of payments over time is strongest for the range of transactions between the old (40 CHF) and new (80 CHF) ‘tap-and-go’ limit.

Figure 5 reports the distributions of the Base period share of contactless transactions by cardholders for our Base, Post-wave 1 and Post-wave 2 periods. The figure reveals a further observation which is consistent with our stylized model: The increase in the contactless share of payments is strongest for those consumers who partially adopted the technology prior to the limit change. Specifically, between the Base period and Post-wave 1 period the increase in the share of contactless transactions is 39 pp for those consumers with an initial share in the Base period between 10-30%. By comparison for those consumers without contactless payments in the Base period we observe an increase by 23 pp.

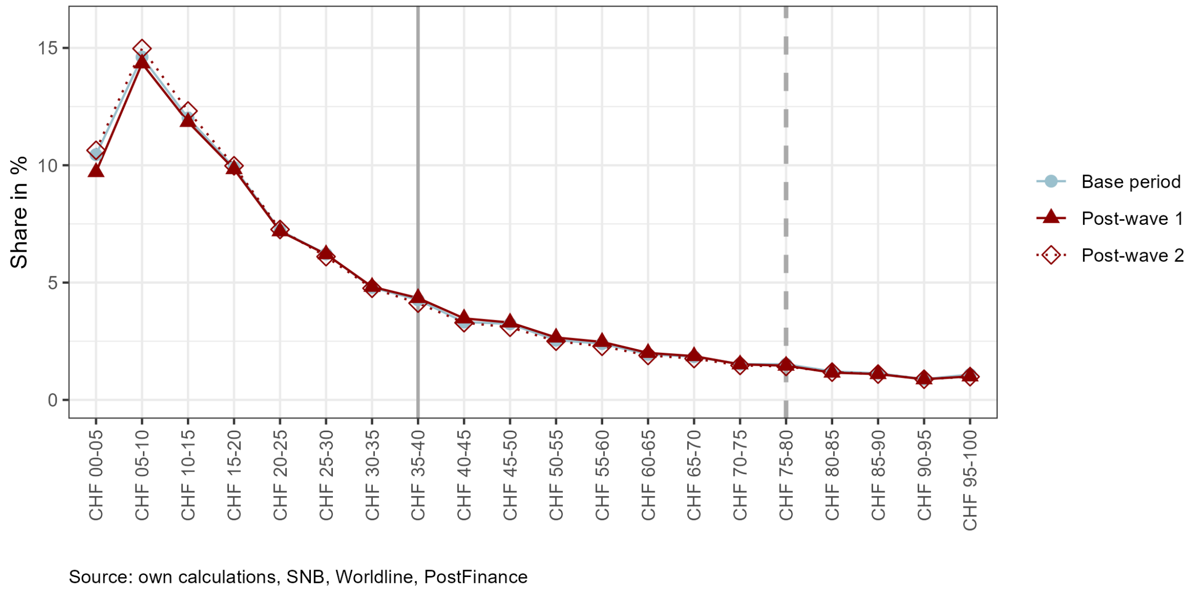

Figure 3: Distribution of transactions by value and observation period.

Notes: This figure shows the distribution of transactions in our sample by value for our three main observation periods. The vertical lines mark the old (solid) and new (dashed) value limits for contactless cardholder identification at CHF 40 and CHF 80, respectively.

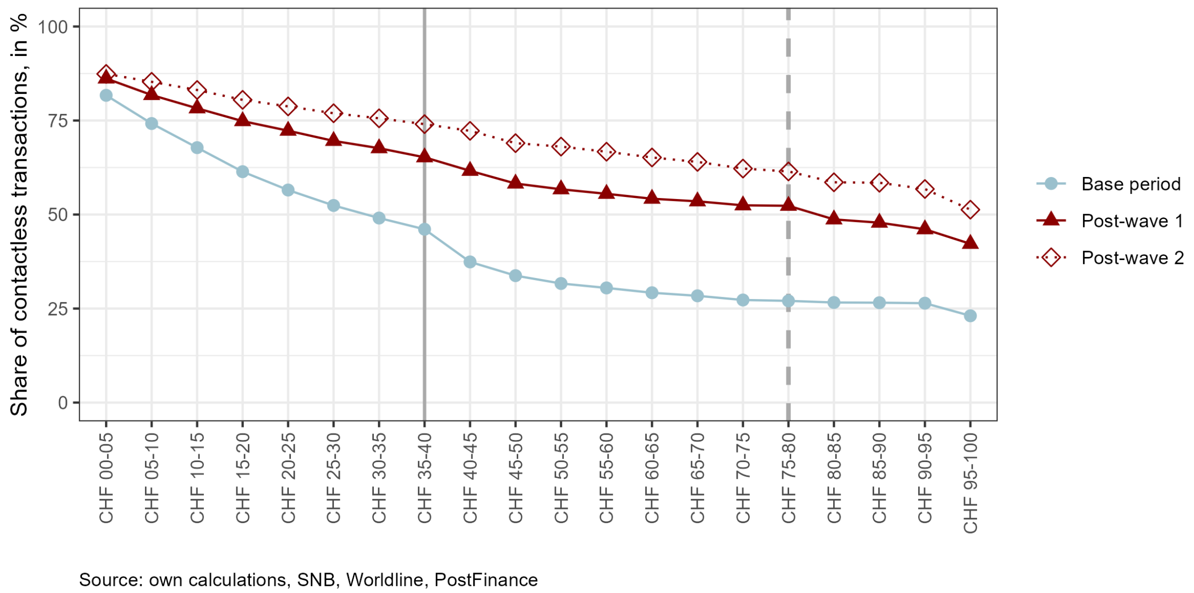

Figure 4: Share of contactless transactions by value and observation period.

Notes: This figure shows the share of contactless transactions in our sample by value for our three main observation periods. The vertical lines mark the old (solid) and new (dashed) value limits for contactless cardholder identification at CHF 40 and CHF 80, respectively.

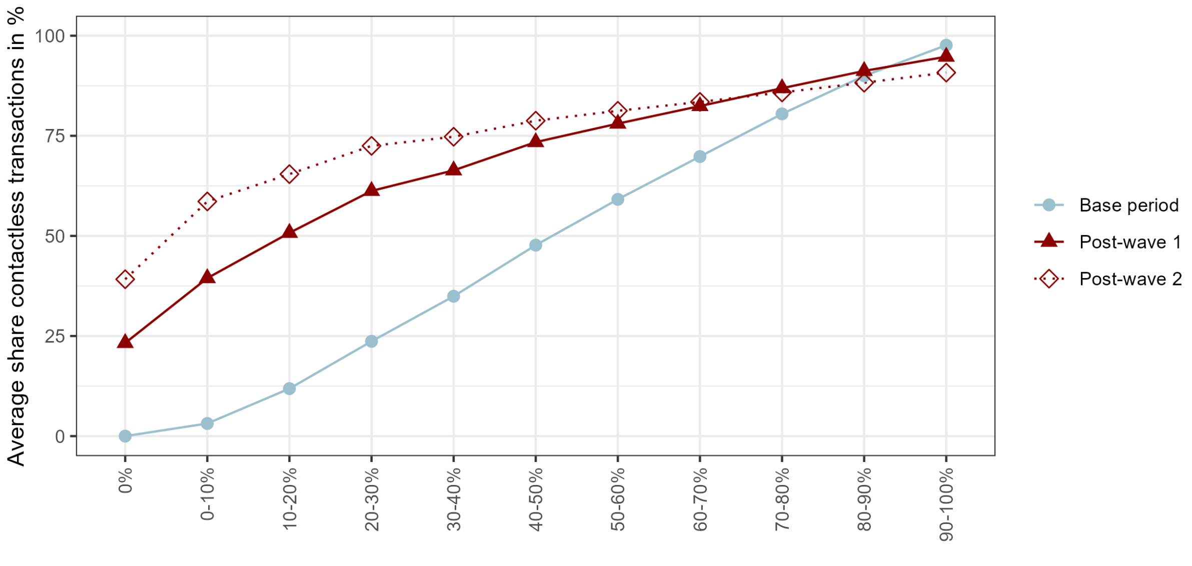

Figure 5: Distribution of the share of contactless transactions by cardholders' contactless share in the Base period and by observation period.

Notes: This figure shows cards' average share of contactless transactions in our sample by cards' contactless share in the Base period (x-axis) and for our three main observation periods. The share of contactless transactions in the Base period is determined based on all transactions of cards, not only based on their transactions of our sample of constant card-merchant relationships.

Figures 4 and 5 also reveal two observations which are not in line with our main hypotheses. In Figure 4 we observe an increase in the contactless share for transaction sizes which were not affected by the increased 'tap-and-go' limit. In Figure 5 we observe a substantial degree of first-time adoption of the contactless technology.[19] These findings suggest that there are confounding factors, leading to a general increase in contactless transactions, even in our constant card-merchant sample. The increase in the 'tap-and-go' limit in Switzerland in April 2020 corresponded to similar changes in verification limits in other OECD countries, which were all triggered by the onset of the COVID 19 pandemic. It is very likely that at this point in time, payment behavior was influenced not only by the change to the 'tap-and-go' limit but also by pandemic-related hygiene concerns. Moreover, at the onset of the pandemic, there was an increase in the salience of cashless and contactless payments due to advertising campaigns by merchants, banks,

[19] Figure 5 also reveals that consumers with high initial shares of contactless payments in the Base period displays a slight decline in their average contactless shares over time. This observation also contrasts the predictions of our model which would suggest no change in the use of contactless payments for consumers with very low security concerns. From an empirical perspective this finding can be explained by minor changes to the composition of purchases over time, even in our constant card-merchant sample.

and card schemes. To identify the causal effect of the change to the 'tap and-go' limit on the adoption rate and usage rate of contactless payments, we therefore conduct two difference-in-difference tests. Both tests are motivated by the cross-sectional predictions of our stylized model (Section 2.2).

In our first test (Section 3.1), we study first-time adoption of the contactless technology. Our main hypothesis (H1) is that the increase in the 'tap-and-go' limit has no impact on adoption. Our alternative hypothesis (H1A) is that, due to fixed costs of adoption of the contactless technology, the limit increase will lead to first-time adoption by those consumers with a large share of transactions that are newly eligible for 'tap-and-go'. We thus compare the adoption of contactless payments for cardholders that benefit differently from the increased 'tap-and-go' limit. In this between-card analysis, our card-level measure of treatment intensity is the share of transactions between CHF 40 and CHF 80 in the Base period.

In our second test (Section 3.2), we study the impact of the increased 'tap-and-go' limit on the usage rate of the contactless technology. Our main hypothesis (H2) is that the use of the contactless technology increases only for those transactions which become eligible for 'tap-and-go'. Moreover, for these transactions the usage rate of contactless payments should only increase among those consumers who had already adopted the technology prior to the limit increase. Our alternative hypothesis (H2A) is that due to increased security concerns there is no increase in the use of contactless payments when the 'tap-and-go' limit increases. These predictions motivate a within-card difference-in-difference test, comparing the share of contactless payments for the same cardholders across different transaction value ranges. Our 'treated' transactions in this within-card exercise are all transactions that became newly eligible for 'tap and go', i.e., transactions in the range between CHF 40 and CHF 80.[20] We replicate this test separately for cardholders which have and have not adopted contactless payments in our Base period.

[20]Note that by increasing the value limit to CHF 80 in the post-pandemic period, on average 23% of payments per card became newly eligible for contactless cardholder verification (see Table 1).

3.1 Adoption of Contactless Payments

Our first empirical test compares the adoption of contactless payments between cards that benefit differentially from the increase in the 'tap-and-go' limit. We conduct a difference-in-difference test where we test for the impact of the treatment intensity on the adoption of contactless payments. We estimate regression Equation [1], where the binary outcome variable $ContactlessAdopted_i$ measures the adoption of contactless payments by card i by the Pre-wave 1, Post-wave 1 or Post wave 2 period. Our card-level measure of $TreatmentIntensity_i$ is the share of transactions between CHF 40 and CHF 80 in the Base period. The mean of this measure across cards is 22% (median 19%), with an interquartile range of 9% to 31%.[21] We estimate the following linear probability model separately for each period:

$$[1]\ ContactlessAdopted_{i,t} = \alpha_i + \beta_1 * Post_t + \beta_2 * TreatmentIntensity_i * Post_t$$

$$+ \boldsymbol{\gamma} * \boldsymbol{X_i} * Post_t + \epsilon_{i,t}$$

The variable $Post_t$ equals 0 for the Base period and equals 1 for one of the following periods: Post wave 1 period or Post-wave 2 period. The card-fixed effects α_i capture time-invariant cardholder characteristics. It is plausible that cardholder characteristics have time-varying effects on consumption and thus payment behavior during the pandemic. Although our sample of constant card-merchant relationships over constant calendar periods addresses that concern (see Table 1), we control for available measures of spending behavior ($\boldsymbol{X_i}$). Specifically, $\boldsymbol{X_i}$ includes the number of transactions, the average value of transactions, the share of food and beverage transactions, the share of transactions at small to medium-sized merchants, and the share of transactions at merchants in urban and rural compared to agglomeration areas. All control variables are measured for the Base period. Summary statistics for each of these variables are presented in Table 1

[21] Table 1 shows that the card-level mean based on the transactions in our constant card-merchant relationships between CHF 40 and CHF 80 is 23% and that this share is stable across our observation periods. To determine our measure of $TreatmentIntensity$, we consider all transactions of the cards in our sample, not only those in the constant card-merchant relationships.

above. We interact all control variables $\boldsymbol{X_i}$ with the variable $Post_t$ to account for any time-varying impacts of spending behavior on the adoption of contactless payments.

Identification in this test relies on the parallel-trends assumption: Consumers with different shares of card payments between CHF 40 and CHF 80 may have very different adoption rates of the contactless technology in the Base period. This is plausible because the typical transaction size of a consumer is likely to be correlated with key sociodemographic information such as age. Our identifying assumption is that without the change in the 'tap-and-go' limit and conditional on our time-varying control variables, the adoption rate of contactless payments would have developed similarly for cardholders with high and low treatment intensities between the Base period and the Post-wave 1 (Post-wave 2) period.

Figure 6 reveals that the share of cards which have adopted contactless payments by the Base period differs significantly between cards with above-median treatment intensity (57%) and below-median treatment intensity (78%). Moreover, even before the onset of the pandemic the adoption rate is converging between the two groups. However, between the Pre-wave 1 period and Post-wave 1 period this convergence accelerates suggesting a causal effect of the increased 'tap-and-go' limit on the adoption of contactless payments in our sample.

Table 2 presents our regression results for Equation [1] (the full table of estimates is provided in Appendix A6). Columns 1 and 2 consider the cumulative adoption of contactless payments by the Post-wave 1 period and by the Post-wave 2 period, respectively. Column 3 presents the results of our placebo test, in which we consider first-time adoption by the Pre-wave 1 period. The results confirms a statistically significant impact of treatment intensity on adoption rates both before and after the increase of the 'tap-and-go' limit. To gauge the magnitude of the effect, we compare cards with a treatment intensity of 9% (25th percentile) to cards with a treatment intensity of 31% (75th percentile).[22] Our estimates in Column 1 suggest that by Post-wave 1, the share

[22] Again we calculate these marginal effects for a card with the mean number of transactions and mean transaction value in the Base period

of cards which have adopted contactless payments increases by 23 pp for the former compared to 15 pp for the latter. The estimates in Column 2 suggest that by Post-wave 2, the share of cards which have adopted contactless payments increases by 29 pp for the former compared to 19 pp for the latter. The share of cards with first time adoption of contactless transactions is thus 1.5 times higher for cards with a high compared to a low treatment intensity.

By comparison, the Column 3 placebo results suggest that from the Base period to the Pre-wave 1 period, the share of cards which have adopted contactless payments increases by 11 pp for the former compared to 8 pp for the latter. Thus, as illustrated by Figure 6 the adoption of contactless transactions was increasing considerably faster (by a factor of 1.4) for cards high treatment intensity already well before the onset of the pandemic. Therefore, our estimates suggest that only a minor share of the observed increase in contactless adoption after the onset of the pandemic can be attributed to the increased 'tap-and-go' limit. These findings provide support for our first main hypothesis (H1): the increase in the 'tap-and-go' limit has no (substantial) effect on first-time adoption. Through the lens of our stylized model, our findings suggest that any fixed costs to adopting contactless payments are limited.

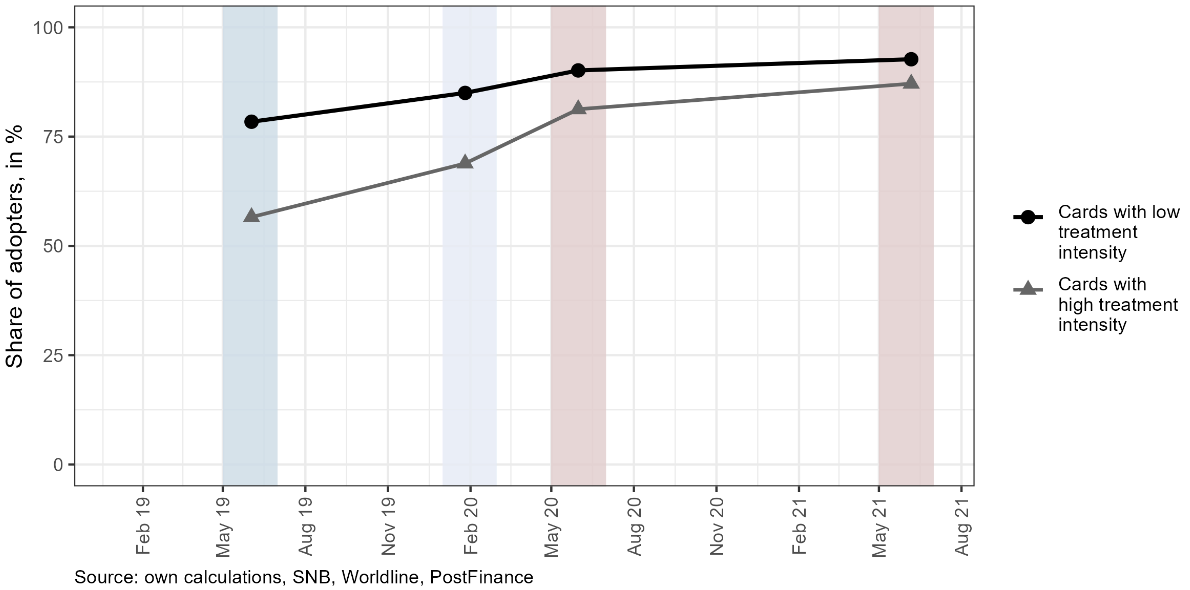

Figure 6: Adoption of contactless payments: adoption rate of cards with high compared to cards with low treatment intensity.

Notes: This figure shows the first-time adoption among those cards that did not use contactless payments in the Base period (n=132,082). Among these cards, we again compare cards with a high treatment intensity (n=88,093) to cards with a low treatment intensity (n=43,989). Pre-wave 1 adopters are cards that have no contactless transactions in the Base period but have at least one transaction by the Post-wave 1 period. Post-wave 1 (Post-wave 2) adopters are cards that have no contactless transactions in the Base and Pre-wave 1 (Base, Pre-wave 1 and Post-wave 1) periods but have at least one transaction by the Post-wave 1 (Post-wave 2) periods. Nonadopters do not have any contactless transactions in any period.

Outcome variable:	*ContactlessAdopted*	*ContactlessAdopted*	*ContactlessAdopted*
Base period vs.	Post-wave 1	Post-wave 2	Pre-wave 1
TreatmentIntensity * Post	0.0037***	0.0047***	0.0015***
	(0.00)	(0.00)	(0.00)
Post	0.1217***	0.1420***	0.0734***
	(0.0018)	(0.0020)	(0.0013)
Mean outcome variable in period (Base period)	0.86 (0.68)	0.90 (0.68)	0.77 (0.68)
Card fixed effects	Yes	Yes	Yes
Card times period controls	Yes	Yes	Yes
Cards	406,550	406,550	406,550
Observations	813,100	813,100	813,100
R^2, adjusted R^2	0.80, 0.61	0.76, 0.52	0.90, 0.79

Table 2: The adoption of contactless payments: between-card analysis.

Notes: This table presents estimated coefficients for *ContactlessAdopted* (indicator) in Equation [1]. Heteroskedasticity-robust standard errors are presented in parentheses. *, **, *** indicate significance at the 10%, 5%, and 1% level, respectively.

Sources: own calculations, SNB, Worldline, PostFinance

3.2 Use of Contactless Payments

Our second empirical test compares the share of contactless payments for the same cardholders across different transaction value ranges. The test is replicated separately for cardholders which have and have not adopted contactless payments in the Base period.

As our 'treated' transactions, we consider all transactions that became newly eligible for 'tap and go' (transactions between CHF 40 and CHF 80). We compare these transactions to those that were already eligible (transactions below CHF 40) and those that were still not eligible (transactions above CHF 80). This within-card test allows us to disentangle the increased convenience benefit due to the higher 'tap-and-go' limit from related security concerns. As illustrated by our stylized model, the increase in the 'tap-and-go' limit implies a higher convenience benefit of contactless payments only for transactions between CHF 40 and CHF 80. By contrast, all transactions would be affected by any increase in security concerns due to the limit increase. This within-card analysis also allows us to disentangle the effect of improved convenience from that of potential hygiene concerns or salience effects during the pandemic. Both transactions below CHF 40 and transactions between CHF 40 and CHF 80 would be affected by increased hygiene benefits. Moreover, transactions across all payment amounts would be affected by a salience effect.

We conduct a difference-in-difference test in which we compare the treated transactions to control transactions before and after the change in the 'tap-and-go' limit. We estimate regression Equation [2], where the outcome variable is $ShareContactless_{i,j,t}$ of card i for transaction size range j in period t:

$$[2]\ ShareContactless_{i,j,t} = \alpha_i + \beta_1 * Treated_j + \beta_2 * Post_t + \beta_3 * Treated_j * Post_t + \epsilon_{i,j,t}$$

The dummy variable $Treated_j$ equals 1 for treated transactions in the range between CHF 40 and CHF 80 and equals 0 either for pretreated (below CHF 40) or not treated (above CHF 80) transactions. The variable $Post_t$ equals 0 for the Base period and equals 1 for one of the following periods: Post-wave 1 period or Post-wave 2 period.

Identification again relies on the parallel-trends assumption. Each cardholder may use contactless payments to different degrees for purchases of different transaction sizes. We assume, however, that without the change in the 'tap-and-go' limit, the use of contactless transactions by each cardholder would have developed similarly across all transaction ranges for the same card. Figure 7 supports this assumption. The figure reports the average share of contactless transactions for treated, pretreated and not-treated transactions. The figure reveals that before the pandemic, the average share of contactless transactions increased at a very similar rate for all three groups of transactions. Unsurprisingly, the average share of contactless transactions was significantly higher in the Base period for transactions below CHF 40 than for transactions between CHF 40 and CHF 80 or transactions above CHF 80. However, the trend growth of this share was very similar for all three groups of transactions between the Base period and the Pre-wave 1 period.

Figure 7 suggests a substantial causal effect of the 'tap-and-go' limit on the share of contactless payments. Following the increase of this limit in April 2020, the contactless share of cards increases significantly faster for treated transactions than for pretreated or not-treated transactions. Comparing the Post-wave 1 period to the Base period in the figure, we see that the share of contactless transactions increases by 24 pp for the treated transactions compared to 18 pp (16 pp) for the not treated (pretreated) transactions. Figure 8 confirms this finding for transactions in narrow ranges around the old (CHF 40) and new (CHF 80) 'tap-and-go' limits.

Table 3 presents our estimates for regression Equation [2]. Columns (1-3) report a comparison of treated and not-treated transactions. Columns (4-6) report a comparison of treated and pretreated transactions. We limit our analysis to cards for which we observe transactions for pretreated, treated and not-treated transactions in all four periods.[23] Columns 1 (4) and 2 (5) compare the Post wave 1 or Post-wave 2 to the Base period. Columns 3 (6) report a placebo test in which the 'post' period is set to Pre-wave 1. The results in columns(1-3) confirm a significant causal effect of the 'tap-and-go' limit on the share of contactless transactions. Comparing the results across columns 1 and 2, we find that this effect is driven almost entirely by the immediate response for treated transactions by the Post-wave 1 period. These results are confirmed in columns (4-6).

[23] As a robustness check, we relax our identification but enlarge our sample: In Appendix A7, we estimate regression Equation [2] without card fixed effects on our full sample. The regression results confirm the main findings from Table 3.

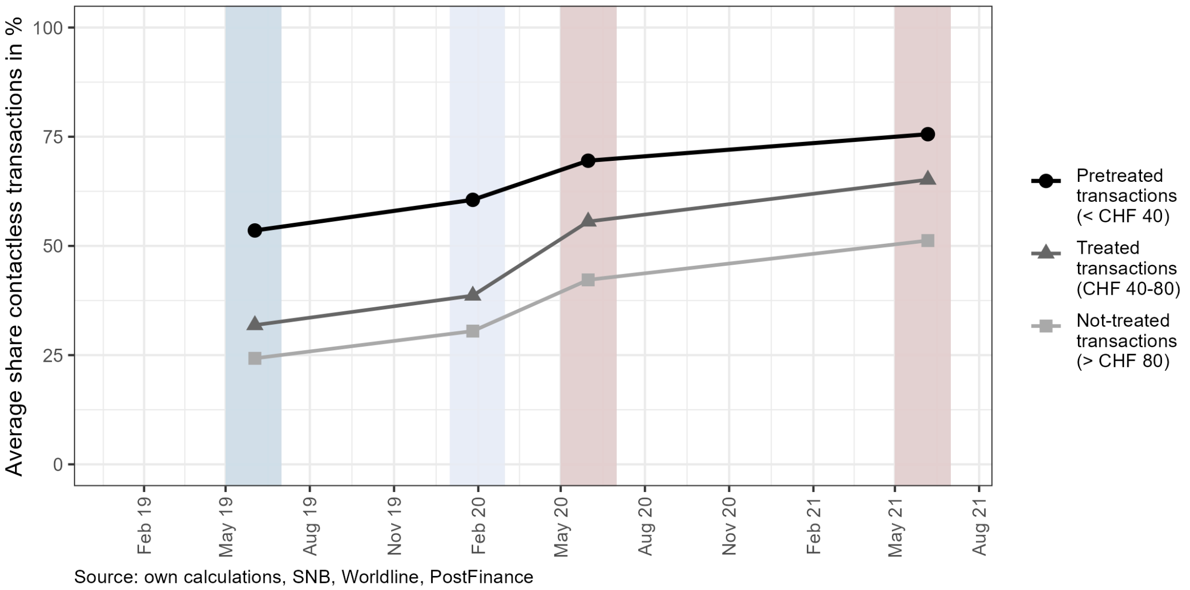

Figure 7: The effect of the 'tap-and-go' limit on contactless payments: within-card analysis, full sample of transactions.

Notes: This figure compares the mean of our outcome variable *ShareContactless* by observation period and transaction value.

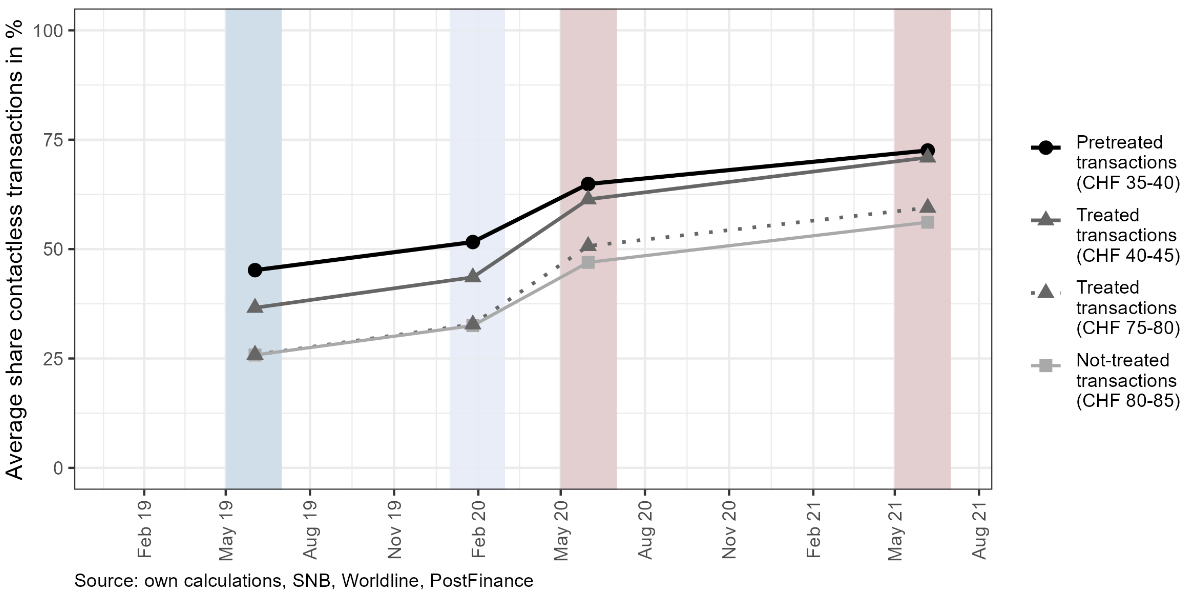

Figure 8: The effect of the 'tap-and-go' limit on contactless payments: within-card analysis, transactions in narrow ranges around the old and new 'tap-and-go' limits.

Notes: This figure compares the mean of our outcome variable *ShareContactless* by observation period and transaction value.

Outcome variable:	*ShareContactless*	*ShareContactless*	*ShareContactless*	*ShareContactless*	*ShareContactless*	*ShareContactless*
Base period vs.	Post-wave 1	Post-wave 2	Pre-wave 1	Post-wave 1	Post-wave 2	Pre-wave 1
Control group	not-treated	not-treated	not-treated	pre-treated	pre-treated	pre-treated
$Treated * Post$	8.14***	9.28***	0.18	4.87***	7.25***	-0.93***
	(0.17)	(0.20)	(0.13)	(0.17)	(0.20)	(0.15)
Post	18.08***	28.58***	7.07***	21.36***	30.60***	8.17***
	(0.11)	(0.14)	(0.09)	(0.12)	(0.14)	(0.11)
Treated	4.28***	4.28***	4.28***	-13.77***	-13.77***	-13.77***
	(0.11)	(0.13)	(0.09)	(0.13)	(0.14)	(0.11)
Mean outcome variable in						
period (Base period)	49% (27%)	60% (27%)	(34% (27%)	60% (36%)	70% 36%)	44% (36%)
Card fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Cards	65,072	65,072	65,072	65,072	65,072	65,072
Observations	260,288	260,288	260,288	260,288	260,288	260,288
R^2, adjusted R^2	0.76, 0.68	0.70, 0.60	0.85, 0.80	0.76, 0.68	0.70, 0.60	0.82, 0.76

Table 3: The use of contactless payments: within-card analysis, treated transactions (between CHF 40 and CHF 80) vs. not-treated transactions (above CHF 80) or vs. pre-treated transactions (below CHF 40)

Notes: This table presents estimated coefficients for *ShareContactless* (in %) in Equation [2]. The regressions are based on a sample of cards with transactions in all value ranges in all five periods only. Heteroskedasticity-robust standard errors are presented in parentheses. *, **, *** indicate significance at the 10%, 5%, and 1% level, respectively.

Sources: own calculations, SNB, Worldline, PostFinance

In line with our second main hypothesis (H2), our results so far confirm a sizable impact of the increased limit on the use of contactless payments for those transactions which become eligible for 'tap-and-go'. Our model also predicts that this increase in the usage rate of contactless payments is driven by those cardholders which had already adopted contactless payments prior to the limit change. In Appendix A8 we document that this is the case. We replicate our within-card analysis of the increased 'tap-and-go' limit for three separate groups of cardholders. We hereby distinguish those cardholders who adopted contactless payments by the Base period, the Post-wave 1 period, or the Post-wave 2 period, respectively. Figures A7, A8 and A9 report the share of contactless payments by transaction size for the subsample of Base period, Post-wave 1, and Post-wave 2 adopters, respectively. For the sample of Base period adopters we confirm that the increase in the share of contactless payments is largest for the newly eligible 'tap and go' transactions. By contrast, for the Post-wave 1 and Post-wave 2 adopters, small-value transactions (below CHF 40) that were eligible for 'tap and go' before the pandemic display a stronger initial take-up than those transactions that were newly eligible for 'tap and go' (between CHF 40 and CHF 80).

A comparison of the not-treated (above CHF 80) transactions to the pre-treated (below CHF 40) transactions in Figure 7 allows us to make some inference about the relative importance of other drivers of the use of contactless payments during the first wave of the pandemic. We conjecture that both types of transactions are equally affected by the increased salience of contactless payments due to advertising by merchants, banks, and card schemes. In contrast, we conjecture that pretreated (below CHF 40) transactions offer stronger hygiene-related benefits than not-treated (above CHF 80) transactions, as the former allow for 'tap and go', while the latter do not. In the figure, we observe that contactless payments develop similarly for both sets of transactions. This suggests that salience may be the more important driver of the increased use of contactless technology than hygiene concerns.

4 Hygiene concerns and contactless payments

In Section 3, we identified the causal effect of a higher 'tap-and-go' limit on the adoption and use of contactless payments. In doing so, we attempted to control for any effect of pandemic-related hygiene concerns, which may have affected payment behavior by cardholders in our sample. In this section, we extend our analysis to explicitly examine how hygiene-related concerns impacted contactless payments during the COVID-19 pandemic. This allows us to benchmark the effects of the increased 'tap-and-go' limit to those of a widely perceived shock to consumer demand for payment technology. The analysis in this section also allows us to assess the external validity of our estimates in Section 3, as it allows us to gauge the uniqueness of the pandemic circumstances for the effect of the 'tap-and-go' limit on the adoption and use of contactless payments.

We again employ our sample of transactions for merchants and cards that already had access to contactless technology in 2019. We again limit our sample to transactions for a sample of constant card-merchant relationships and constant calendar periods between 2019 and 2021.[24] In addition, in this section, we limit our sample to transactions below CHF 40. These transactions were already eligible for 'tap and go' before the onset of the pandemic. Thus, these are transactions that allow the consumer to avoid touching the payment terminal and for which the convenience of contactless payments did not change with the pandemic.

Our analysis in this section is based on observations at the merchant*period level. Using information on the location of each merchant, we can match our transaction-level payment data to regional information on pandemic intensity. As discussed in Section 2, our sample covers nearly 18,000 merchants. We match each merchant to one of the 101 labor market

[24]One potential concern with our sample of card-merchant relationships is that we may not cover consumers with the strongest hygiene concerns. The reason being that these consumers may have moved to e-commerce shopping for their regular purchases (or asked friends and family to do their shopping) and thus do not show up at POS merchants during the pandemic. Aggregate payment data suggest, however, that this sample selection issue is unlikely to have had a strong effect on our results, as the use of e-commerce is limited in Switzerland (see Figure 1). More disaggregated data show that the share of e-commerce compared to the share of POS purchases for groceries increased during the pandemic but remained at a negligible level: https://monitoringconsumption.com/acquiring-data-by-merchant-category/ (last accessed on November 10, 2023).

regions in Switzerland.[25]

Figure 9 presents the share of contactless transactions by merchant and observation period. In line with our card-level evidence above, the figure shows that at the onset of the pandemic, there was a significant increase in the number of merchants with high shares of contactless transactions.

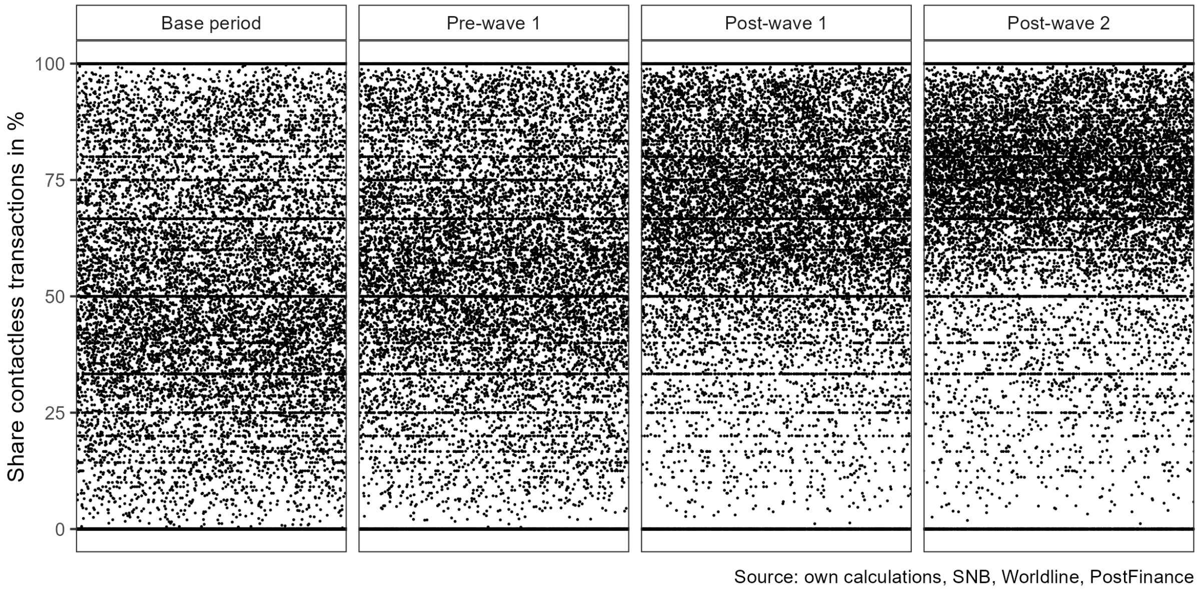

Figure 9: Share of contactless transactions at the merchant level.

Notes: This figure shows the share of contactless transactions by cards in our constant card-merchant sample across all value ranges for each merchant in our sample individually and for each of our four observation periods. Every dot in each panel of the figure represents one merchant times period observation. Within each panel, merchants are sorted horizontally by their hashed ID number.

Our empirical strategy relies on the assumption that pandemic-related hygiene concerns vary across regions and are correlated with the actual number of COVID-19 cases per region. For Switzerland, daily information on pandemic intensity, e.g., the number of COVID-19 cases and related deaths, is available only at the level of the 26 cantons. However, ranges for the aggregate number of cases during the first wave of the pandemic (February to May 2020) have been published at the municipal level.[26] We aggregate

[25] For a description of the Swiss labor market regions, see the website of the Swiss Federal Statistical Office: https://www.bfs.admin.ch/bfs/en/home/statistics/territory-environment/nomenclatures/lma.html (last accessed on November 10, 2023).

[26] The number of cases per municipality were published by the German-language daily newspaper Neue Zürcher Zeitung (NZZ), see https://www.nzz.ch/visuals/wie-stark-ihre-gemeinde-vom-coronavirus-betroffen-ist-ld.1568968 (last accessed on November 10, 2023).

the average of the municipal level ranges to the level of labor market regions and obtain a continuous measure of COVID-19 exposure for the merchants in each region. Appendix A9 presents our regional measure of COVID-19 exposure and reveals substantial variation in regional pandemic intensity during the first wave. In Appendix A10, we further report household survey data on hygiene concerns during the first wave of the pandemic. We find that subjective hygiene concerns vary across regions and are strongly correlated with the actual incidence of COVID-19 cases.

We conduct a difference-in-difference test in which we compare the share of contactless transactions before and after the onset of the pandemic for merchants in regions that are differently exposed to COVID-19. We estimate Equation [4], where the outcome variable $ShareContactless_{m,t}$ measures the share of contactless transactions (for transactions below CHF 40) at merchant m in period t:

$$[4]\ ShareContactless_{m,t} = \alpha_m + \beta_1 * Post_t + \beta_2 * CovidExposure_m * Post$$

$$+ \boldsymbol{\gamma} * \boldsymbol{X_m} * Post_t + \epsilon_{m,t}$$

The variable $CovidExposure_m$ is equal to the number of cases per 1,000 inhabitants from February to May 2020 in the region where the merchant is located. The variable $Post_t$ equals 0 for the Base period and equals 1 for each of the following periods: Post-wave 1 period or Post-wave 2 period. We also run a placebo test in which we compare the Base period to the Pre-wave 1 period.

Pandemic intensity may be correlated with sociodemographic characteristics and economic structure at the regional level. It is plausible that regional differences in sociodemographic characteristics and economic structure have time-varying effects on consumption and therefore possibly also on payment behavior during the pandemic. Our sample of transactions from constant card-merchant relationships for constant calendar periods minimizes the concern of time-varying changes in the consumption structure (see Table 1). Nevertheless, for our analysis in this section, we match the merchants' locations (zip codes) to publicly available geo-spatial information on the population density (urban vs. rural vs. agglomeration as well as the number of people per km^2), the demographic structure of the population, the language area and the distance to the country border – the latter being a measure for cross-border shopping tourism, which was restricted by law for a considerable period during the pandemic.[27] Moreover, we match the merchants' locations to the share of foreign card payments, which is an indicator of tourism. These zip code-level variables are captured in the vector of control variables $\boldsymbol{X_m}$ in Equation [4]. The vector $\boldsymbol{X_m}$ also includes merchant size as a merchant-level control. Finally, we control for merchant-level exposure to the increased 'tap-and-go' limit by including the average share of transactions in the CHF 40 to CHF 80 range during the Base period for cards frequenting these merchants. Summary statistics for our regional-level data can be found in Appendix A11.

Figure 10 displays the average share of contactless payments (for transactions below CHF 40) by period for merchants located in regions with high and low COVID-19 exposure. We classify merchants as those with high COVID-19 exposure if they are located in regions with an above-median number of cases. The trend growth of the contactless share appears very similar for both groups of merchants between the Base period and the Pre-wave 1 period. Moreover, Figure 10 suggests no effect of regional COVID-19 exposure on the use of contactless payment technology.

[27] The data on the travel time to the next border crossing have been prepared by an external data analytics company on behalf of SNB. See Burstein et al. (2024) for recent evidence on cross-border shopping.

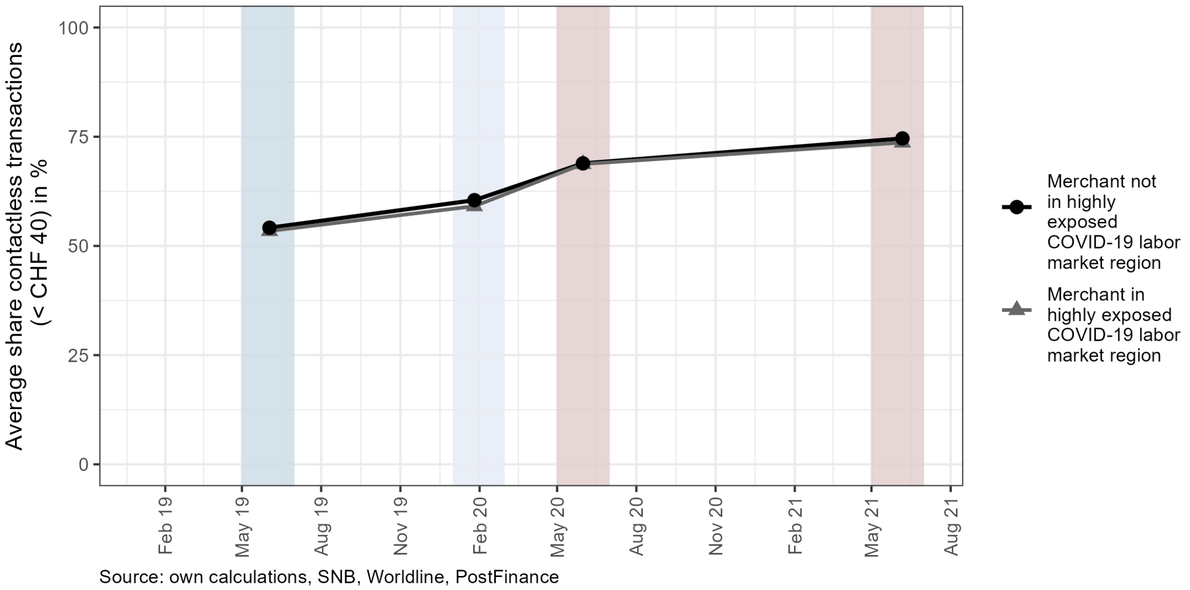

Figure 10: Share of contactless transactions at merchants with high compared to merchants with low COVID-19 exposure.

Notes: This figure reports the mean share of contactless transactions for transactions with a value below CHF 40 across merchants. The figure compares the contactless share of merchants with high exposure to COVID-19 to those with low exposure. Merchants with high COVID-19 exposure (n=8,942) are those located in regions with the number of COVID-19 cases being higher than the Swiss median, which according to our labor market-level numbers, is 2.07 per 1,000 inhabitants from February to May 2020. Merchants with low COVID-19 exposure (n=8,943) are those located in regions with fewer COVID-19 cases than the Swiss median.

Table 4 presents our regression results for Equation [4].[28] Columns 1 and 2 compare the Post-wave 1 period and Post-wave 2 period, respectively, to the Base period. Column 3 reports a placebo test in which the 'post' period is set to the Pre-wave 1 period. The estimates for our coefficient of interest $CovidExposure * Post$ suggest no positive effect of local COVID-19 exposure on the use of contactless payments. In contrast, controlling for the time-varying effects of our sociodemographic controls, we find that contactless payments increased more slowly in those areas that were more exposed to the pandemic. However, the economic magnitude of this effect is very small: Comparing merchants in a region at the 25th percentile of $CovidExposure$ (1.6) to those in a region at the 75th percentile (5.7), we find that the former saw an increase in contactless payments of only 0.8 pp more than the latter between the Base period and Post-wave 1 period.[29] Recall

[28]See Appendix A11 for a regression table showing coefficients of all control variables.
[29]We calculate these treatment effects for merchants at the mean of all control variables X_m

that the average increase over time between these two periods was 16 pp (see Section 3.2).

Did hygiene concerns affect the use of contactless payments for particular types of merchants? In Appendix A11, we further replicate our Table 4 Column 1 results by merchant language region and merchant location (urban vs. rural vs. agglomeration). For all subsamples, our findings mirror those presented in Table 4, albeit again with varying magnitude and precision of our coefficient of interest.

We conclude that hygiene concerns were not a major driver of the increased use of contactless payments after the onset of the pandemic.

Transaction range:	below CHF 40	below CHF 40	below CHF 40
Outcome variable:	*ShareContactless*	*ShareContactless*	*ShareContactless*
Base period vs.	Post-wave 1	Post-wave 2	Pre-wave 1
$CovidExposure * Post$	-0.20*	-0.33**	0.00
	(0.08)	(0.10)	(0.07)
Mean outcome variable in period (Base period)	69% (54%)	74% (54%)	60% (54%)
Merchant fixed effects	Yes	Yes	Yes
Period fixed effects	Yes	Yes	Yes
Merchant times period controls	Yes	Yes	Yes
Region times period controls	Yes	Yes	Yes
Merchants	15,436	15,363	15,394
Observations	30,872	30,726	30,788
R^2, adjusted R^2	0.86, 0.73	0.81, 0.62	0.89, 0.78

Table 4: Merchants and COVID-19 exposure.

Notes: This table reports estimated coefficients for regression Equation [4]. The outcome variable is *ShareContactless* for transactions with a value below CHF 40 at the merchant times period level. Heteroskedasticity-robust standard errors are presented in parentheses. *, **, *** indicate significance at the 10%, 5%, and 1% level, respectively.

Sources: own calculations, SNB, Worldline, PostFinance

5 Conclusion

Consumer adoption and use of digital payment technology involves a trade-off between improved convenience versus security concerns. We examine how consumers react to an exogenous change to the convenience and perceived security of a prominent payment method: contactless card payments. As we document in this paper, improved convenience causes a substantial increase in the use of digital payment technology. On the other hand, payment technology innovations which increase convenience seem to have only a minor effect on first time adoption. Our findings are consistent with a stylized model in which convenience benefits of contactless payments are largest for small-value, on-the-fly transactions and consumers have heterogeneous security concerns. They are also consistent with the finding of Brown et al. (2022) who document that the earlier introduction of contactless cards had no notable impact on the first-time use of payment cards by cash-payers.

We examine the impact of the increased 'tap-and-go' limit for point-of-sale debit card payments, which was implemented on a global scale by card schemes at the onset of the COVID-19 pandemic. In Switzerland, the country we study, this limit increased from CHF 40 to CHF 80 in April 2020, implying that one-fifth of all debit card payments suddenly became eligible for 'tap-and-go'. Transactions that were newly eligible for 'tap-and-go' reveal a stronger growth in contactless payments than transactions that were either previously eligible or remained ineligible. This effect is entirely driven by cardholders, who had already adopted the contactless payment technology prior to the pandemic. While we also observe a strong increase in the share of cardholders who adopt contactless payments, this increase can only be weakly attributed to the increased 'tap-and-go' limit.

Our analysis is based on anonymized, transaction-level data for more than 400,000 payment cards and almost 18,000 merchants in Switzerland between 2019 and 2021. We address concerns over confounding changes to the availability of the payment technology by limiting our sample to merchants and cards with access to the technology from 2019 onwards. We alleviate concerns over confounding changes to the consumption structure by limiting our sample to transactions for constant card-merchant relationships and constant calendar periods.

We benchmark our findings against the contemporaneous rise in hygiene concerns affecting the demand for contactless payments. Using information on merchant location, we match our payment data to data on COVID-19 cases from February to May 2020 at the level of labor market regions. Our results suggest that region-specific hygiene concerns did not trigger an increase in the use or adoption of contactless payments in 2020.

Our findings speak to the current policy debate regarding the promotion of instant payment systems or the introduction of CBDCs. Policy-makers are eager to foster payment technologies which are highly convenient for consumers, but at the same time policy makers face consumer security concerns. Our results suggest that design features which make digital payment technologies more convenient promote their use by consumers who have a low relative concern for security. However, if policy makers aim to encourage universal adoption of new payment technologies, our results suggest that improved convenience alone, without addressing security concerns, may not be sufficient.

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Appendix

A1 Importance of payment instrument attributes according to survey data

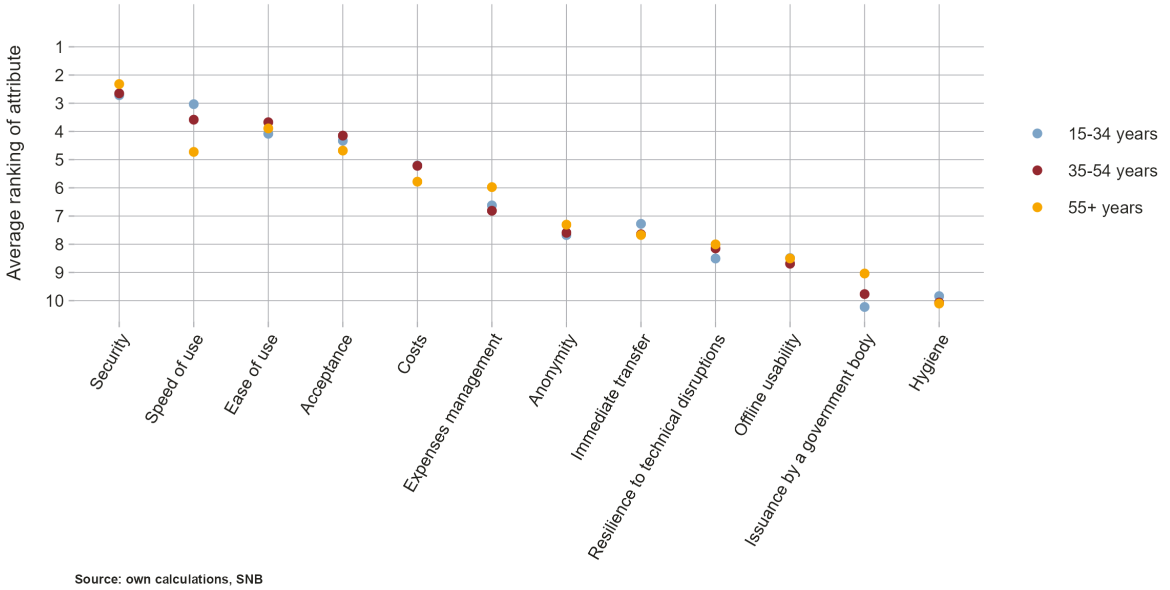


Figure A1: Consumer ranking of importance of payment instrument attributes by age group.

Notes: This figure reports the average ranking of 12 attributes of payment instruments by age group as reported in the 2022 Payment Methods Survey of Private Individuals in Switzerland (Swiss National Bank (2023)). Rank 1 (12) is the most (least) important attribute

A2 Google Trends Analytics

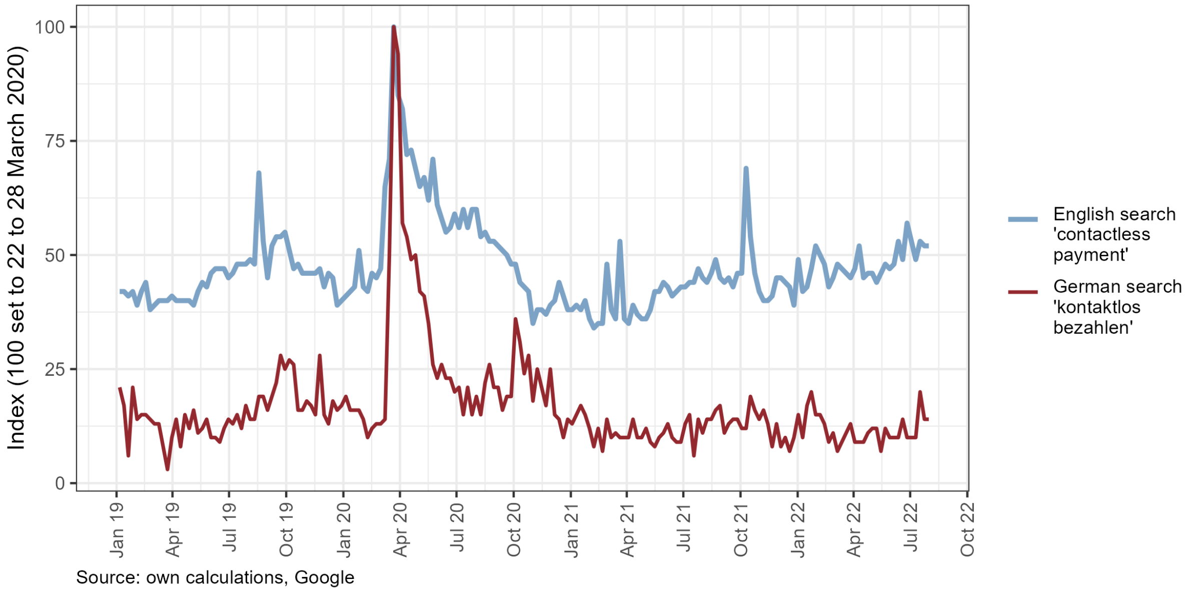
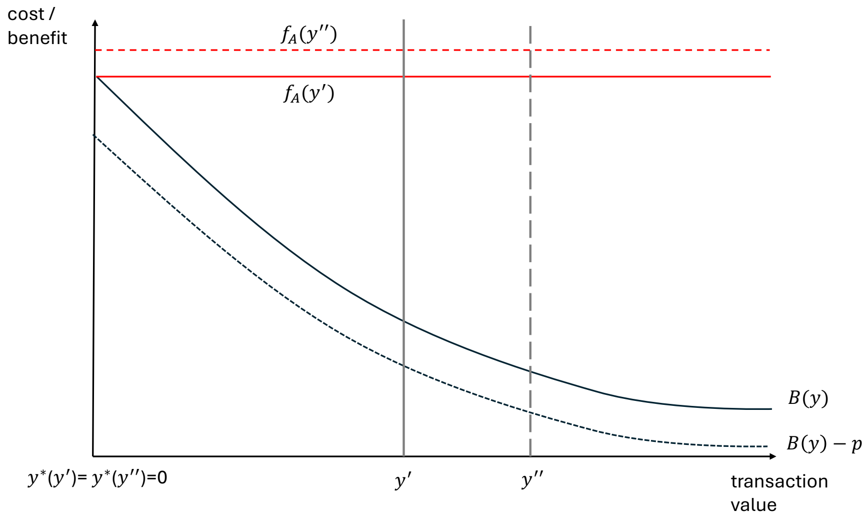


Figure A2: Google searches for contactless payments.

Notes: The weekly data can be retrieved from Google Trends Analytics, with the search terms 'Contactless payment' and 'Kontaktlos bezahlen': https://trends.google.com/trends/ (last accessed on November 10, 2023). We filtered 'Worldwide', 'Last 5 years', 'All categories' and 'Web Search'.

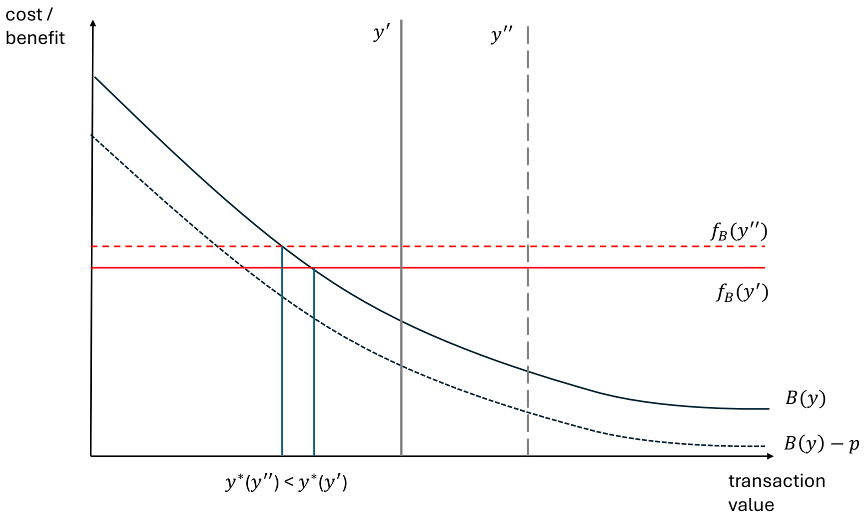
A3 Illustrations hypotheses



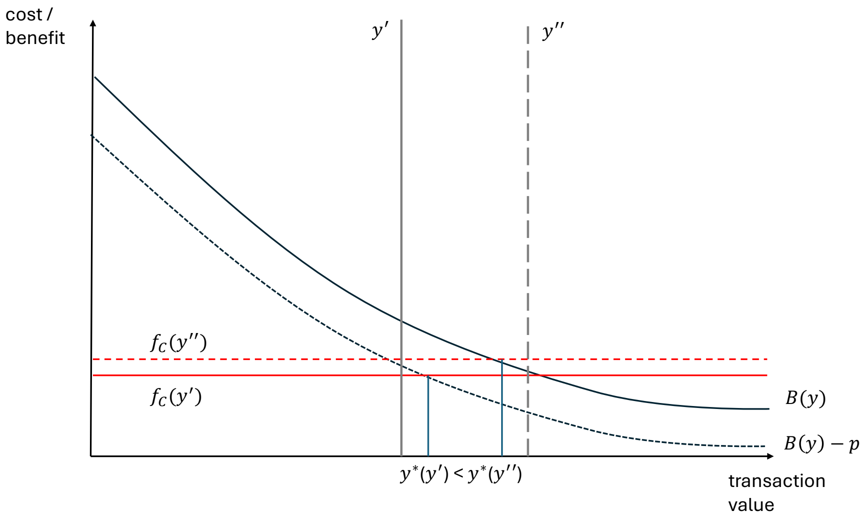
Panel A

Figure A3: The tap-and-go limit and the consumer threshold for contactless payment initiation.

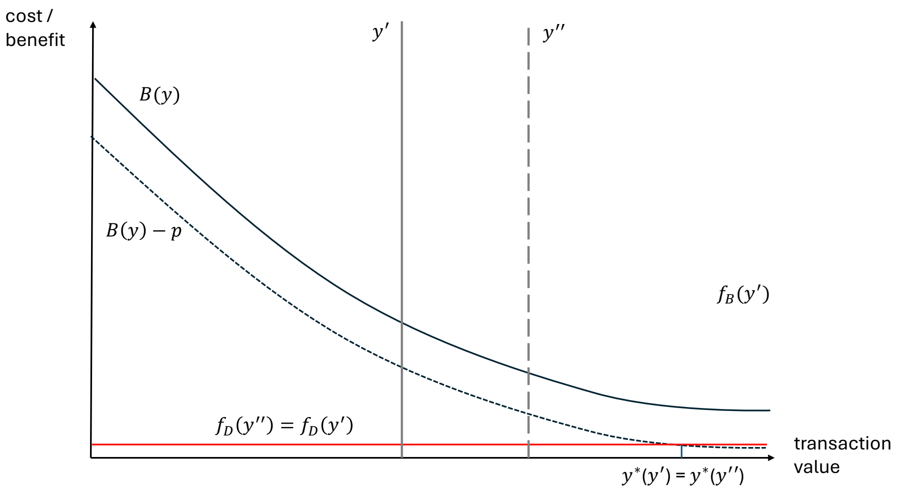
Notes: This figure illustrates how an increase in the tap-and-go limit affects the adoption and use of contactless payment initiation. Panel A shows the example of a consumer with very high security concerns who does not adopt the contactless technology before or after the limit increase. Panel B shows the example of a consumer with high security concerns, who only uses the contactless technology for very small payments before the change in the tap-and-go limit. For this consumer the change does not alter her payment behavior. Panel C presents the case of a consumer with low security concerns who pays contactless for some transactions which require an additional PIN entry (tap-and-pin) before the change. This consumer increases the range of payments for which she initiates contactless as the tap-and-go-limit is increased. Finally, Panel D presents the case of a consumer with very low security concerns which are insensitive to the tap-and-go limit. This consumer uses contactless payment initiation above the new limit both before and after the limit increase. In all panels the line $B(y)$ represents the convenience benefit of 'tap and go' payments while the line $B(y) - p$ represents the convenience benefit of 'tap and pin' payments.



Panel B



Panel C



Panel D

A4 Aggregated monthly statistics and transaction-level data

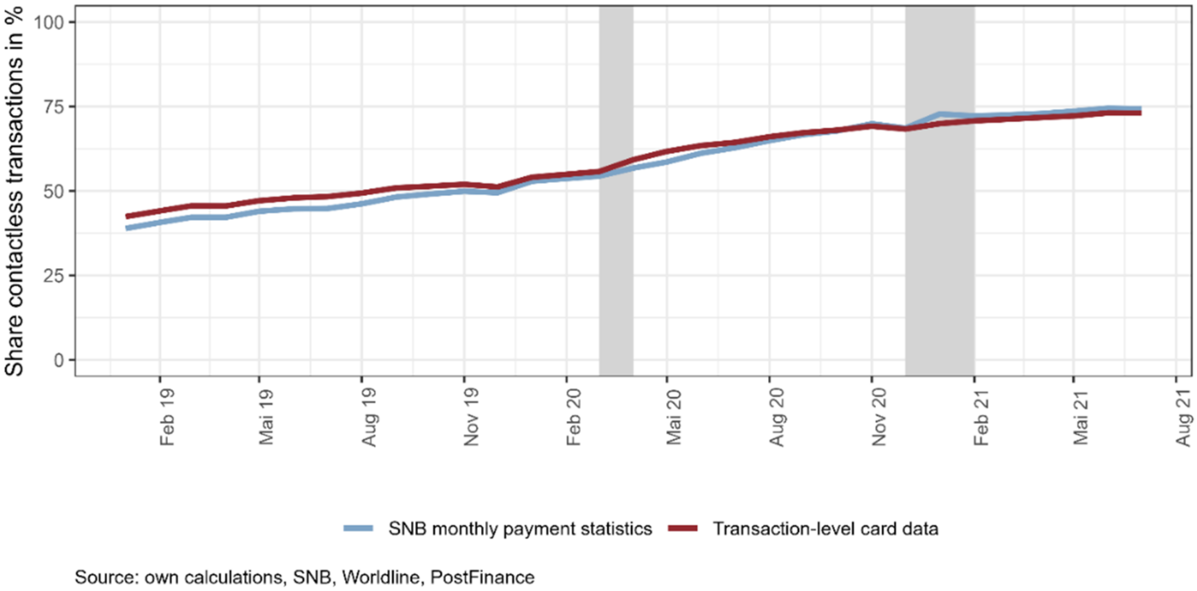


Figure A4: Share contactless debit-card transactions – comparison of SNB monthly statistics with transaction-level data.

Notes: These shares of contactless debit card transactions are calculated on a volume basis. The SNB's monthly payment statistics come from the SNB's data web portal: https://data.snb.ch/en (last accessed on November 10, 2023).

A5 COVID-19 in Switzerland: deaths and cases

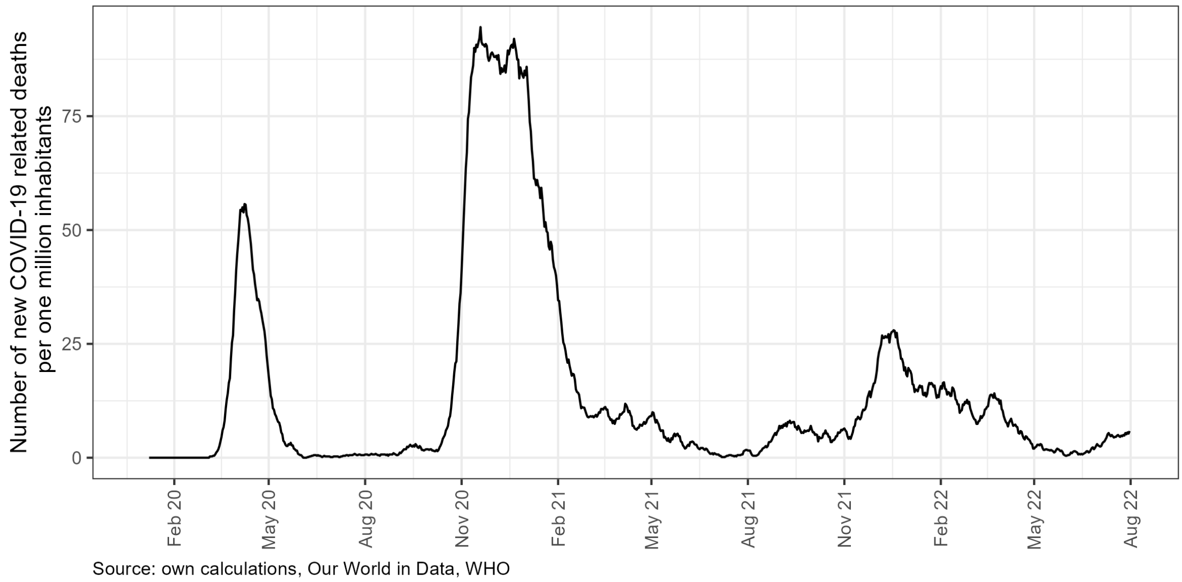


Figure A5: Number of COVID-19-related deaths and cases in Switzerland over time: COVID-19-related deaths.

Notes: The seven-day moving average data of confirmed deaths are taken from the 'Our World in Data COVID-19 Data Explorer' that relies on WHO data (WHO COVID-19 Dashboard): https://ourworldindata.org/explorers/coronavirus-data-explorer (last accessed on November 10, 2023).

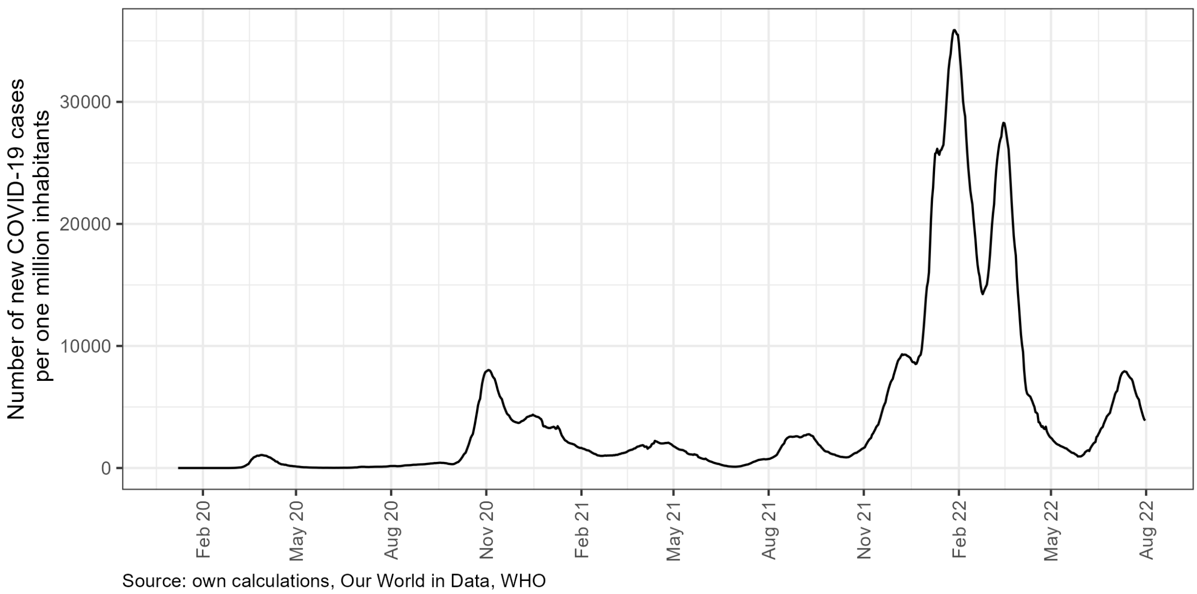


Figure A6: Number of COVID-19-related deaths and cases in Switzerland over time: COVID-19 cases.

Notes: The seven-day moving average data of confirmed cases are taken from the 'Our World in Data COVID-19 Data Explorer' that relies on WHO data (WHO COVID-19 Dashboard): https://ourworldindata.org/explorers/coronavirus-data-explorer (last accessed on November 10, 2023).

A6 Adoption: full regression tables

Outcome variable:	*ContactlessAdopted*	*ContactlessAdopted*	*ContactlessAdopted*
Base period vs.	Post-wave 1	Post-wave 2	Pre-wave 1
TreatmentIntensity * Post	0.0037***	0.0047***	0.0015***
	(0.00)	(0.00)	(0.00)
Post	0.1217***	0.1420***	0.0734***
	(0.0018)	(0.0020)	(0.0013)
Base period number of transactions * Post	-0.0019***	-0.0024***	-0.0011***
	(0.00)	(0.00)	(0.00)
Base period average value of transactions * Post	0.0004***	0.0006***	0.0001***
	(0.00)	(0.00)	(0.00)
Base period share of food and beverage transactions * Post	-0.1241***	-0.1549***	-0.0597***
	(0.0020)	(0.0022)	(0.0016)
Base period share of transactions at small to medium-sized merchants * Post	0.0057***	0.0117***	0.0030***
	(0.0011)	(0.0012)	(0.0009)
Base period share of transactions in urban areas * Post	-0.0258***	-0.0318***	-0.0090***
	(0.0014)	(0.0015)	(0.0011)
Base period share of transactions in rural areas * Post	0.0226***	0.0362***	0.0070***
	(0.0022)	(0.0024)	(0.0017)
Mean outcome variable in period (Base period)	0.86 (0.68)	0.90 (0.68)	0.77 (0.68)
Card fixed effects	Yes	Yes	Yes
Card times period controls	Yes	Yes	Yes
Cards	406,550	406,550	406,550
Observations	813,100	813,100	813,100
R^2, adjusted R^2	0.80, 0.61	0.76, 0.52	0.90, 0.79

Table A1: Adoption of contactless transactions: full regression table.

Notes: This table presents estimated coefficients for *ContactlessAdopted* (in %) in Equation [1]. Heteroskedasticity-robust standard errors are presented in parentheses. *, **, *** indicate significance at the 10%, 5%, and 1% level, respectively.

Sources: own calculations, SNB, Worldline, PostFinance

A7 Use of contactless payments: pooled regression

Outcome variable:	*ShareContactless*	*ShareContactless*	*ShareContactless*
Base period vs.	Post-wave 1	Post-wave 2	Pre-wave 1
(Intercept)	24.27***	24.27***	24.27***
	(0.10)	(0.10)	(0.10)
$Treated * Post$	5.76***	6.34***	0.52***
	(0.18)	(0.18)	(0.18)
Post	17.96***	26.96***	6.23***
	(0.14)	(0.14)	(0.14)
Treated	7.60***	7.60***	7.60***
	(0.13)	(0.13)	(0.13)
Mean outcome variable in period (Base period)	50% (29%)	59% (29%)	35% (29%)
Card fixed effects	No	No	No
Cards	349,504	346,954	341,899
Observations	965,823	940,266	934,833
R^2, adjusted R^2	0.07, 0.07	0.12, 0.12	0.01, 0.01

Table A2: The 'tap-and-go' limit: within-card analysis, treated (between CHF 40 and CHF 80 transactions) vs. not-treated transactions (above CHF 80 transactions), pooled regression.

Notes: This table presents estimated coefficients for *ShareContactless* (in %) in Equation [3]. The regressions are based on the full sample of cards. Heteroskedasticity-robust standard errors are presented in parentheses. *, **, *** indicate significance at the 10%, 5%, and 1% level, respectively.

Sources: own calculations, SNB, Worldline, PostFinance

Outcome variable:	*ShareContactless*	*ShareContactless*	*ShareContactless*
Base period vs.	Post-wave 1	Post-wave 2	Pre-wave 1
(Intercept)	53.54***	53.54***	53.54***
	(0.08)	(0.07)	(0.08)
$Treated * Post$	7.75***	11.26***	-0.26
	(0.16)	(0.16)	(0.16)
Post	15.97***	22.04***	7.02***
	(0.11)	(0.10)	(0.11)
Treated	-21.67***	-21.67***	-21.67***
	(0.12)	(0.11)	(0.12)
Mean outcome variable in period (Base period)	63% (44%)	71% (44%)	51% (44%)
Card fixed effects	No	No	No
Cards	399,006	398,532	398,060
Observations	125,3038	1,234,082	1,238,870
R^2, adjusted R^2	0.08, 0.08	0.12, 0.12	0.06, 0.06

Table A3: The 'tap-and-go' limit: within-card analysis, treated (between CHF 40 and CHF 80 transactions) vs. pretreated transactions (below CHF 40 transactions).

Notes: This table presents estimated coefficients for *ShareContactless* (in %) in our regression Equation [3]. The regressions are based on the full sample of cards. Heteroskedasticity-robust standard errors are presented in parentheses. *, **, *** indicate significance at the 10%, 5%, and 1% level, respectively.

Sources: own calculations, SNB, Worldline, PostFinance

A8 Use of contactless payments: Base period vs. Post-wave 1 , Post-wave 2 period adopters

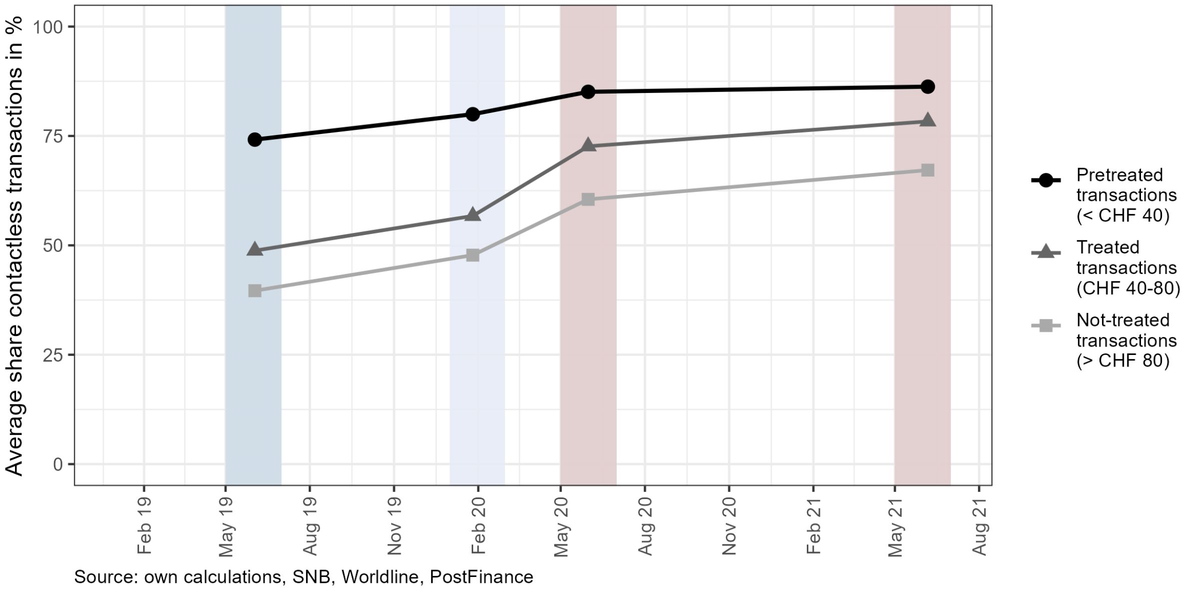


Figure A7: The effect of the ‘tap-and-go’ limit on contactless payments: within-card analysis for Base period adopters, full sample of transactions.

Notes: This figure compares the average share of contactless payments for base period adopters by observation period and transaction value. The figure presents findings for cards that had at least one contactless transaction in the Base period

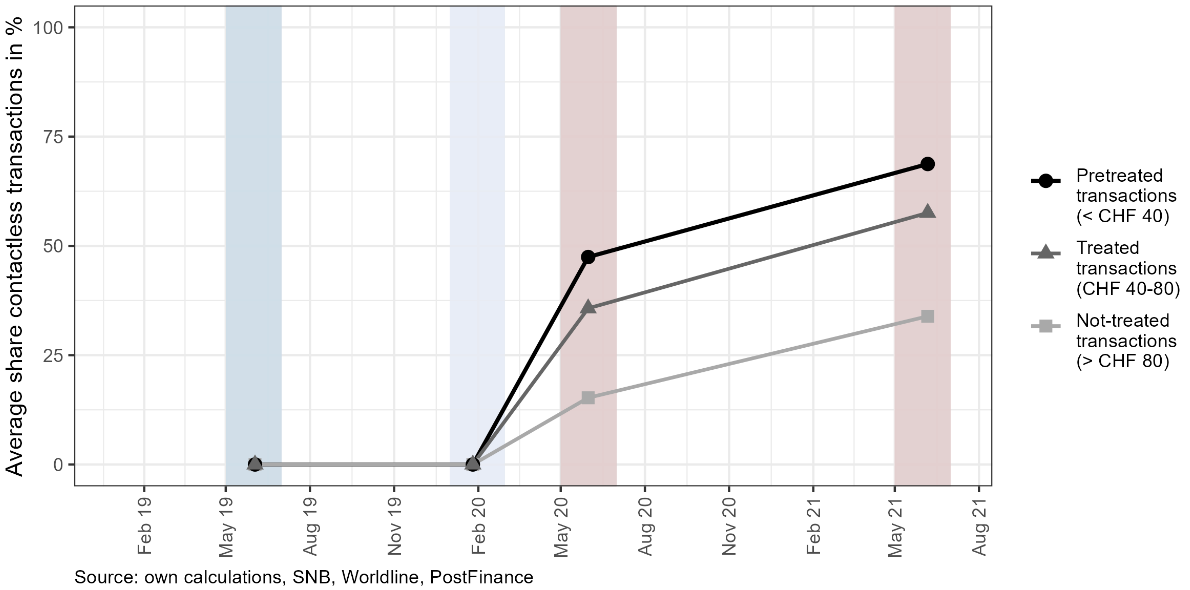


Figure A8: The effect of the 'tap-and-go' limit on contactless payments: within-card analysis for Post-wave 1 adopters, full sample of transactions.

Notes: This figure compares the average share of contactless payments for post-pandemic adopters by observation period and transaction value. The figure presents findings for cards that had no contactless transaction in the Base and Pre-wave 1 periods but at least one contactless transaction in the Post-wave 1 period.

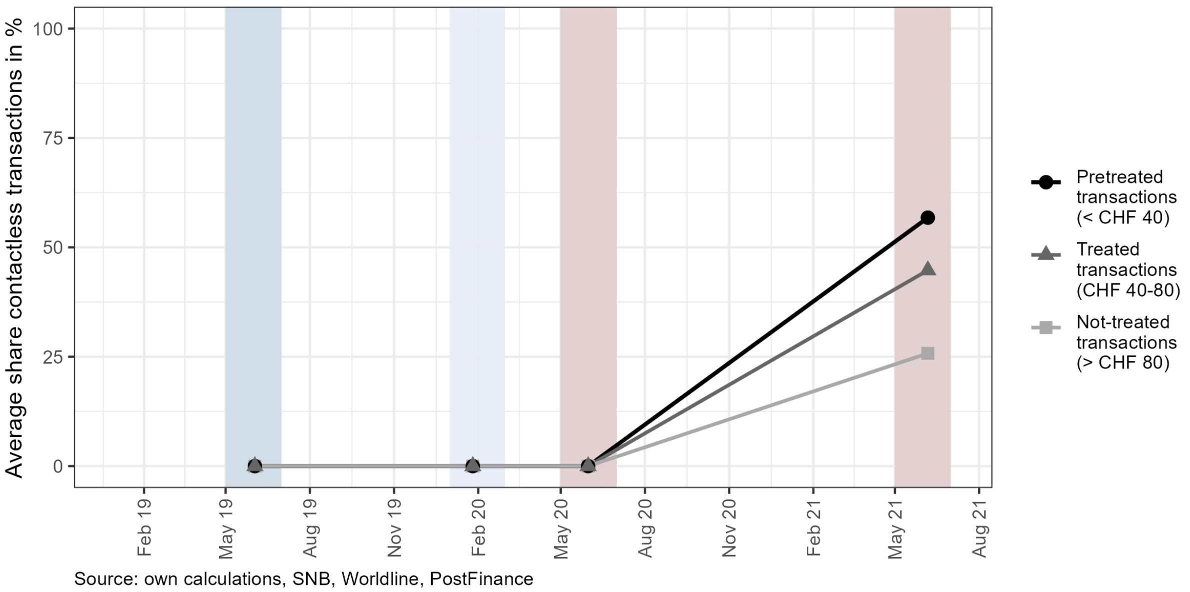


Figure A9: The effect of the 'tap-and-go' limit on contactless payments: within-card analysis for Post-wave 2 adopters, full sample of transactions.

Notes: This figure compares the average share of contactless payments for post-pandemic adopters by observation period and transaction value. The figure findings for cards that had no contactless transactions in the Base, Pre-wave 1 and Post-wave 1 periods but at least one contactless transaction in the Post-wave 2 period.

A9 Cumulated COVID-19 cases per labor market region

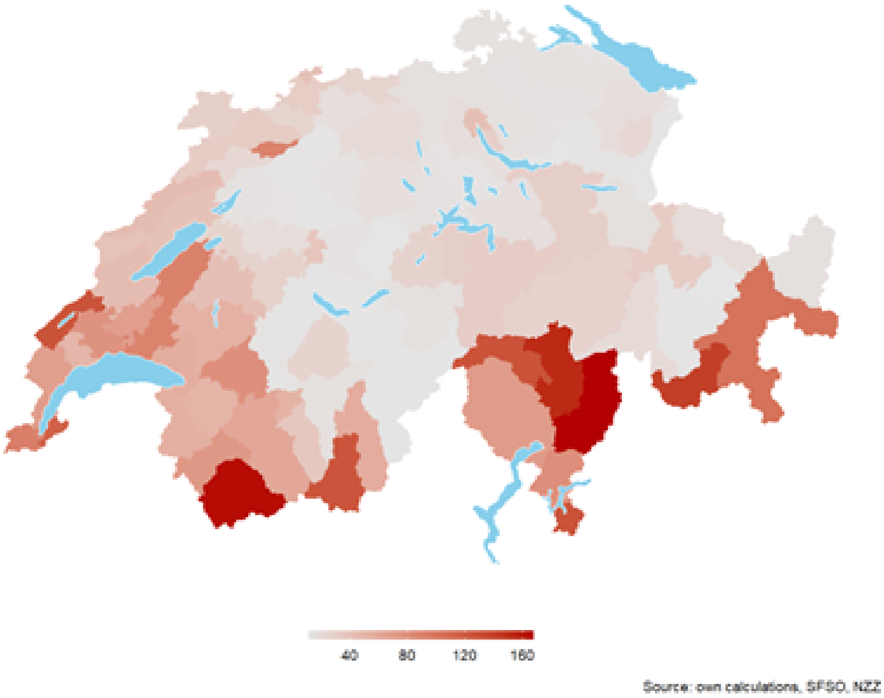


Figure A10: Cumulative COVID-19 cases from February to May 2020 (per labor market region and 10,000 inhabitants).

Notes: The number of cases per municipality was published by the German-language daily newspaper Neue Zürcher Zeitung (NZZ), see https://www.nzz.ch/visuals/wie-stark-ihre-gemeinde-vom-coronavirus-betroffen-ist-ld.1568968 (last accessed on November 10, 2023). The data are aggregated at the labor market region level, and the matching of municipalities to labor market regions is based on matching tables of the Swiss Federal Statistical Office (SFSO).

A10 Regional survey data on COVID-19 case concerns

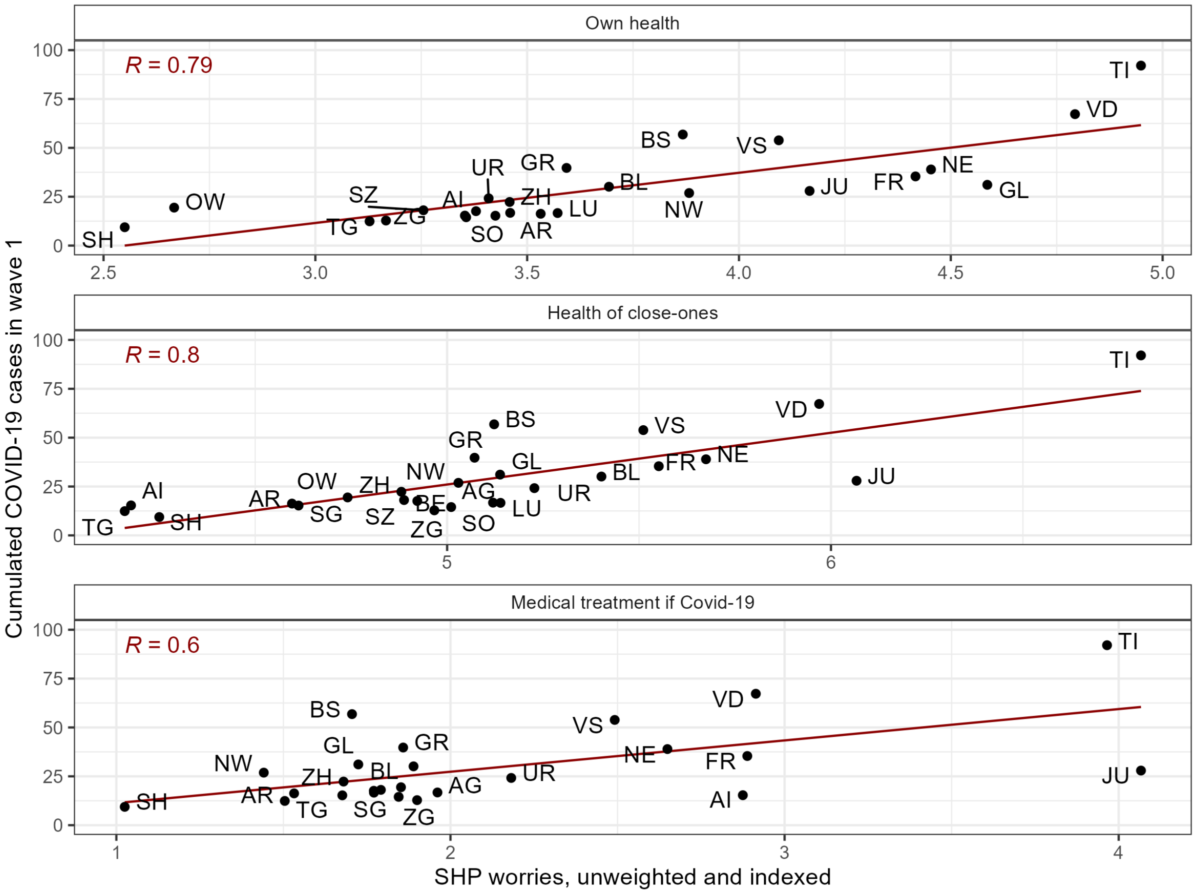


Figure A11: Regional COVID-19 cases and hygiene concerns.

Notes: The number of cases per municipality from February to May 2020 was published by the German-language daily newspaper Neue Zürcher Zeitung (NZZ), see https://www.nzz.ch/visuals/wie-stark-ihre-gemeinde-vom-coronavirus-betroffen-ist-ld.1568968 (last accessed on November 10, 2023). The data are aggregated at the cantonal level, and the matching of municipalities to cantons is based on matching tables of the Swiss Federal Statistical Office (SFSO). The Swiss Household Panel (SHP) COVID-19 survey was fielded in May-June 2020 and provides consumer-level information on how the pandemic affected everyday life for a representative sample of Swiss households (health conditions, work, finances, time use, etc.). As indicators of hygiene concerns, we employ measures of household worries related to own health condition and that of others. Details of the survey and a summary of preliminary findings are available here: https://forscenter.ch/projects/fors-covid-19-surveys/ (last accessed on November 10, 2023).

A11 Hygiene concerns: summary statistics and additional results

	mean	min	p25	p50	p75	max
Number of merchants in sample	177	17	40	112	250	1178
COVID-19 exposure	4.3	1.2	1.6	2.8	5.7	16.8
Exposure to tap-and-go limit change	25%	16%	22%	25%	26%	33%
Share of merchants in French- or Italian -speaking areas	38%	0%	0%	0%	100%	100%
Share of merchants in German-speaking areas	62%	0%	0%	100%	100%	100%
Share of merchants in urban areas	55%	0%	31%	65%	79%	100%
Share of merchants in rural areas	30%	0%	1%	15%	52%	100%
Share of merchants in agglomeration areas	15%	0%	0%	10%	20%	100%
Share of medium to small-sized merchants	93%	81%	90%	94%	97%	100%
Share of large merchants	7%	0%	3%	6%	10%	19%
Average distance to border (minutes)	38.1	3.0	19.4	32.2	52.9	95.3
Average share of population below age 20	20%	15%	18%	20%	21%	26%
Average share of population above age 20	80%	74%	79%	80%	82%	85%
Average share of foreign card transactions	5%	0%	1%	4%	7%	29%
Average share of domestic card transactions	95%	71%	93%	96%	99%	100%

Table A4: Summary statistics per labor market region (n= 101).

Notes: COVID-19 exposure is measured as the number of cases per 1,000 persons from February to May 2020. Small to medium (vs. large) merchants are those below (vs. above) the 90th percentile according to the number of transactions. Distance to border measured in travel time (minutes) by car. The data on the travel time to the next border crossing have been prepared by an external data analytics company on behalf of SNB. Foreign/domestic card transactions are calculated for retail trade (NACE code G47) only. Exposure to the ‘tap-and-go’ limit change is the share of transactions between CHF 40 and CHF 80 in the Base period of cards frequenting the merchants, i.e., the average share of the ‘treated’ transactions that became newly eligible for ‘tap and go’ (transactions between CHF 40 and CHF 80) in April 2020.

Sources: own calculations, SNB, Worldline, PostFinance

Transaction range:	below CHF 40	below CHF 40	below CHF 40
Outcome variable:	*ShareContactless*	*ShareContactless*	*ShareContactless*
Base period vs.	Post-wave 1	Post-wave 2	Pre-wave 1
CovidExposure ∗ *Post*	-0.20*	-0.33**	0.00
	(0.08)	(0.10)	(0.07)
Post	6.68***	4.39	3.91*
	(1.81)	(2.12)	(1.59)
Exposure to tap-and-go limit change ∗*Post*	0.34***	0.65***	0.11***
	(0.02)	(0.03)	(0.02)
Merchant in French- or Italian-speaking area ∗*Post*	3.18***	3.59***	-0.70
	(0.54)	(0.65)	(0.50)
Medium to small-sized merchant ∗*Post*	1.86***	2.80***	-0.17
	(0.20)	(0.25)	(0.18)
Merchant in rural area ∗*Post*	-1.06	-0.12	0.07
	(0.49)	(0.59)	(0.43)
Merchant in agglomeration area ∗*Post*	-0.74	-0.76	-0.32
	(0.43)	(0.51)	(0.37)
Population density ∗*Post*	0.00	0.00*	0.00
	(0.00)	(0.00)	(0.00)
Distance to border (minutes) ∗*Post*	0.02**	0.04***	0.00
	(0.01)	(0.01)	(0.01)
Share of foreign card transactions ∗*Post*	-0.16***	-0.14***	-0.03
	(0.03)	(0.04)	(0.03)
Share of population below age 20 ∗*Post*	-0.04	-0.02	0.00
	(0.08)	(0.09)	(0.07)
Mean outcome variable in period (Base period)	69% (54%)	74% (54%)	60% (54%)
Merchant fixed effects	Yes	Yes	Yes
Merchants	15,436	15,363	15,394
Observations	30,872	30,726	30,788
R2, adjusted R2	0.86, 0.73	0.81, 0.62	0.89, 0.78

Table A5: Merchants and COVID-19 exposure: full regression table.

Notes: This table reports estimated coefficients for regression Equation [4] (full regression table). The outcome variable is *ShareContactless* for transactions with a value below CHF 40 at the merchant times period level. Heteroskedasticity-robust standard errors are presented in parentheses. *, **, *** indicate significance at the 10%, 5%, and 1% level, respectively.

Sources: own calculations, SNB, Worldline, PostFinance

Transaction range:	below CHF 40	below CHF 40	below CHF 40	below CHF 40	below CHF 40
Merchant subsample:	German	French/Italian	Rural	Urban	Agglomeration
Outcome variable:	*ShareContactless*	*ShareContactless*	*ShareContactless*	*ShareContactless*	*ShareContactless*
Base period vs.	Post-wave 1	Post-wave 1	Post-wave 1	Post-wave 1	Post-wave 1
$CovidExposure * Post$	0.43*	-0.35***	-0.13	-0.24	-0.09
	(0.16)	(0.09)	(0.14)	(0.11)	(0.21)
Mean outcome variable in period (Base period)	71% (56%)	66% (50%)	56% (40%)	73% (58%)	61% (45%)
Merchant fixed effects	Yes	Yes	Yes	Yes	Yes
Time fixed effects	Yes	Yes	Yes	Yes	Yes
Merchant * period controls	Yes	Yes	Yes	Yes	Yes
Region * period controls	Yes	Yes	Yes	Yes	Yes
Merchants	10,390	5,046	1,830	11,331	2,275
Observations	20,780	10,092	3,660	22,662	4,550
R2, adjusted R2	0.87, 0.74	0.85, 0.70	0.89, 0.77	0.85, 0.69	0.89, 0.78

Table A6: Merchants and COVID-19 exposure: heterogeneity.

Notes: This table reports estimated coefficients for regression Equation [4] for different merchant types (language region and location). The outcome variable is $ShareContactless$ for transactions with a value below CHF 40 at the merchant times period level. Heteroskedasticity-robust standard errors are presented in parentheses. *, **, *** indicate significance at the 10%, 5%, and 1% level, respectively.

Sources: own calculations, SNB, Worldline, PostFinance