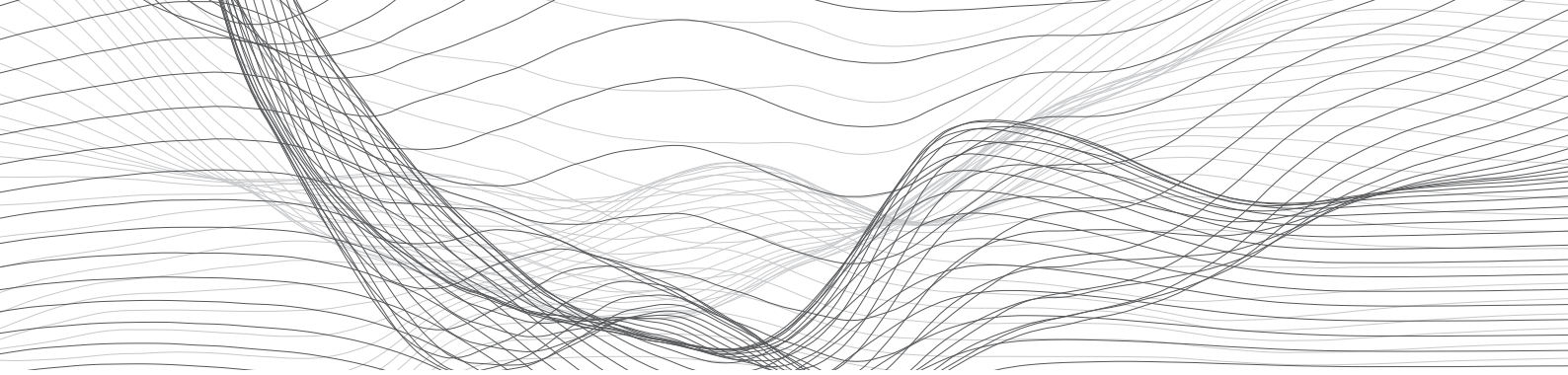

Consumer adoption and use of financial technology: "tap and go" payments

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Consumer Adoption and Use of Financial Technology: "Tap and Go" Payments*

Martin Brown Laura Felber Christoph Meyer

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Abstract

Financial intermediaries play an important role in consumer adoption and use of payment technology. Card schemes and card-issuing banks set rules for cashless payments between consumers and merchants. We document that these rules have a strong causal impact on the use of digital payment technology. We study an increase in the value limit for contactless cardholder verification ("tap-and-go" limit) that was introduced at the onset of the COVID-19 pandemic. Our analysis is based on anonymized, transaction-level data for a large sample of point-of-sale (POS) debit card payments between 2019 and 2021. We show that the increase in the "tap-and-go" limit caused a significant increase in the consumer use of contactless payments but only a minor increase in first-time adoption of this payment technology. Our results suggest that policy-makers are advised to consider the role of intermediaries and verification rules when evaluating payment innovations, such as instant payment systems or central bank digital currencies (CBDCs).

Keywords: Payment choice, financial intermediation, technology adoption, contactless payments, COVID-19

JEL Codes: D14, E42, G21, G23, G50. O33

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1. Introduction

Digitalization has dramatically changed how consumers search, select, and pay for everyday goods and services (Goldfarb and Tucker 2019). However, consumer use of digital payment technology varies substantially across and within countries (Bagnall et al. 2016; European Central Bank 2022). For monetary authorities, understanding consumer adoption and use of payment technology is crucial to the provision of safe, efficient and reliable payment systems. This is all the more true at present, as authorities have to evaluate innovations such as instant payment systems or central bank digital currencies (CBDCs).

In this paper, we provide novel evidence on the role of financial intermediaries in consumer adoption and use of digital payment technology. The role of financial intermediaries in payment systems is strongly debated. The payment market is a prime example of a two-sided market in which technology use depends on the interplay of consumer demand and merchant acceptance (Koulayev et al. 2016; Huynh et al. 2022). Card schemes and card-issuing banks play an intermediary role in this market, coordinating the actions of consumers and merchants. Previous research has focused largely on the fees charged by intermediaries and how this affects market efficiency (Rysman 2009; Rysman and Wright 2014; Wang 2023). We document a further important coordinating role of financial intermediaries in payment markets: Card schemes and banks set the rules for the verification of cashless payments. We show that changes to these rules can have a strong causal effect on the use of digital payment technology.

We study changes to the value limit for contactless cardholder verification of card payments ("tap-and-go" limit). Card schemes and card-issuing banks set the value limit below which contactless transactions require no further verification by the cardholder.[2] Consumers who hold

[2] 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

a contactless payment card can initiate point-of-sale (POS) payments by tapping the card at the payment terminal. A contactless card transaction is then instantly verified if the value of the transaction falls below the limit set by intermediaries. We call these contactless transactions "tap-and-go" payments, and the value limit for contactless cardholder verification is the "tap-and-go" limit. In 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 all be verified by a PIN code ("chip and PIN"). The "tap-and-go" limit for card payments was raised significantly in many countries at the onset of the COVID-19 pandemic. In Switzerland – the country we study – the "tap-and-go" limit was doubled from CHF 40 to CHF 80 in April 2020. This increase was coordinated by the main intermediaries in the Swiss payment industry (card schemes, card-issuing banks, acquirers) in dialog with the authorities. This change implied that the share of card payments eligible for "tap and go" suddenly increased from approximately 60% to 80%.

Contactless card payments are the most widespread innovation in digital payment technology in recent years. They are, in most countries, far more common than payments initiated by mobile phones or wearables (see, e.g., European Central Bank 2022). 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 privacy and security concerns.[3] First, there have been concerns that consumer payment data may be "skimmed" in crowded areas, for

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 10 November 2023)

[3] See, e.g., the following article: "Contactless Credit Cards and Payments: The Good, the Bad, and the Ugly" by Taylor Tepper, published in the New York Times on 7 May 2020: https://www.nytimes.com/wirecutter/money/contactless-payment/ (last accessed on 10 November 2023)

example, at the POS.[4] Second, there are concerns that if consumers lose a contactless card, the card may be easily used by third parties for conducting payments.[5] Our data indicate that prior to the pandemic, roughly one-third of consumers did not adopt contactless technology when conducting POS debit card payments, despite having access to it.

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 as well as the method for initiating the transaction (contactless vs. 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.

Our data document a significant increase in the adoption and use of contactless payments following the onset of the COVID-19 pandemic in spring 2020. The share of contactless transactions increases by 17 percentage points 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). At the onset of the pandemic, the increase in contactless payments was four times higher than the trend

[4] 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 10 November 2023)

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

growth prior to the pandemic outbreak.[6] The share of cards that were used at least once in contactless payments (adoption rate) increases by 18 percentage points 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. We conduct two analyses to assess the causal impact of the increased "tap-and-go" limit on the adoption and use of contactless payments. First, we exploit variation in the degree to which cardholders benefit from the increased limit: We compare cards with a high pre-pandemic share of transactions in the range between CHF 40 and CHF 80 to cards with few transactions in this range.[7] The results of this between-card analysis reveal stronger growth in the use 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 rise in contactless transactions between the Base period and Post-wave 1 period is 18.2 pp. For cards with a share of 9% (25th percentile), the rise in contactless transactions between the Base period and Post-wave 1 period is only 13.8 pp. By comparison, we find that first-time adoption of contactless payments in the Post-wave 1 period is only slightly higher for those cards that benefit most from the higher "tap-and-go" limit.

[6] The timing of the shift in contactless payments in Switzerland is in line with a surge in Google searches for "contactless payments" in English or "kontaktlos bezahlen" in German. See Appendix A1.

[7] Note that we cannot distinguish by cardholder but only by debit card in our data. However, we use cards and cardholders synonymously here, 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.

Second, we compare the use of contactless payments for transactions that are newly eligible for "tap and go" (CHF 40-80) to those transactions that were already eligible (below CHF 40) and those that are still not eligible (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 below CHF 40 transactions and 18 pp for above CHF 80 transactions.

In a further analysis, 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.[8] Our results suggest that regional pandemic intensity did not trigger an increase in either the adoption or use of contactless payments.

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 2022). Related to our study, Brown et al. (2022) document how the staggered rollout of contactless debit cards by banks affects cashless payments for small-value purchases. Auer et al. (2022) provide cross-country evidence for significant changes in consumer payment behavior during the COVID-19 pandemic.[9] Hyunh et al. (2022) emphasize

[8] Specifically, we can match merchant location to the intensity of COVID-19 cases at the labor market region level.

[9] 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.

the role of complementarities between consumer demand and merchant acceptance of payment technology in a two-sided payment market. 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. Berg et al. (2023) examine the impact of developments in cryptocurrencies and CBDCs on payment firms. We contribute to this literature by highlighting the important role of intermediaries in setting rules for cashless payments.

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 Guttmann-Kenney (2021) use anonymized credit card transaction data to examine the impact of local lockdowns on consumer spending in the UK.[10] 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.

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

2. Data and sample construction

2.1. Data

Our analysis is based on an anonymized, transaction-level dataset that covers the overwhelming majority of cashless card payments in Switzerland.[11] For each transaction, we observe the value in Swiss Francs (CHF)[12], 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. 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] At the card level, we observe a dummy indicating whether a card is issued domestically or abroad but no sociodemographic information on the cardholder. Our data do not cover ATM withdrawals by the debit cards we study.

The dataset employed for this study covers transactions at POS merchants conducted with debit cards issued by domestic banks for the period 2019.01 to 2021.07. We focus on debit card payments because – similar to many other European countries – these are the most widely used payment cards in Switzerland (Swiss National Bank, 2021; European Central Bank, 2022). We filter the dataset to cover the two main categories of discretionary consumer spending: retail trade (NACE: G47) and food and beverage services (NACE: G56). Applying these filters, the

[11] 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').

[12] CHF 1 = EUR 0.89 in 2019:01 and EUR 1.01 in 2022:07; CHF 1 = USD 0.99 in in 2019.1 and USD 0.97 in 2022:07.

[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*.

dataset consists of over three billion transactions. Figure A2-1 in the Appendix shows that the share of contactless transactions in our dataset is representative of POS debit card payments in Switzerland.

Switzerland during the COVID-19 pandemic offers a suitable laboratory to study the adoption and use of digital 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 reflects the cross-country average (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 contactless 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.[14]

Figure A2-2 in the Appendix presents aggregate summary statistics for payments in Switzerland during our observation period. The figure shows a negligible change in payment channels (e-commerce vs. POS) or card type used at the POS (credit card vs. debit card).[15] In contrast,

[14] 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.

[15] Aggregate data for debit card and credit card payments include transactions that are executed by a mobile-phone app that is linked to a card. Mobile-phone app transactions that are debited directly to a bank account or prefunded ("prepaid"), e.g., through the Swiss app by Twint, are not reported in these aggregate statistics.

the figure reveals significant growth of contactless payments with an upward shift at the onset of the pandemic when the "tap-and-go" limit was increased.

2.2. Sample construction

Our objective is to identify the causal effect of the increased "tap-and-go" limit on consumer adoption and use of contactless card payments. We face three main empirical challenges. First, an increase in the observed adoption and use of contactless payments may be driven by increased availability of the technology (at the card or merchant level) rather than the adoption and use of already available technology. Second, observed changes in payment choice may be driven by changes in the underlying consumption structure rather than changes in payment behavior. Third, we need to disentangle the causal effect of the increased "tap-and-go" limit from the many other developments during our observation period that may have affected consumer demand for contactless payments, particularly pandemic-related hygiene concerns or the salience of the technology due to advertising campaigns by card schemes, banks or merchants. To minimize the first two concerns, we use a filtered sample of transactions from the underlying dataset. To disentangle the effect of the "tap-and-go" limit from other developments during our observation period, we conduct between-card and within-card difference-in-difference analyses, which are described in detail in Section 3.

We use a filtered sample of transactions from the underlying dataset to capture changes in payment behavior. First, we limit our dataset to include only transactions involving merchants with terminals that were capable of accepting 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.[16] Thus, we can assume that all

[16] 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.

transactions in our sample could have been initiated contactless (rather than chip-based) if the cardholder had chosen to do so. We can thus rule out 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.

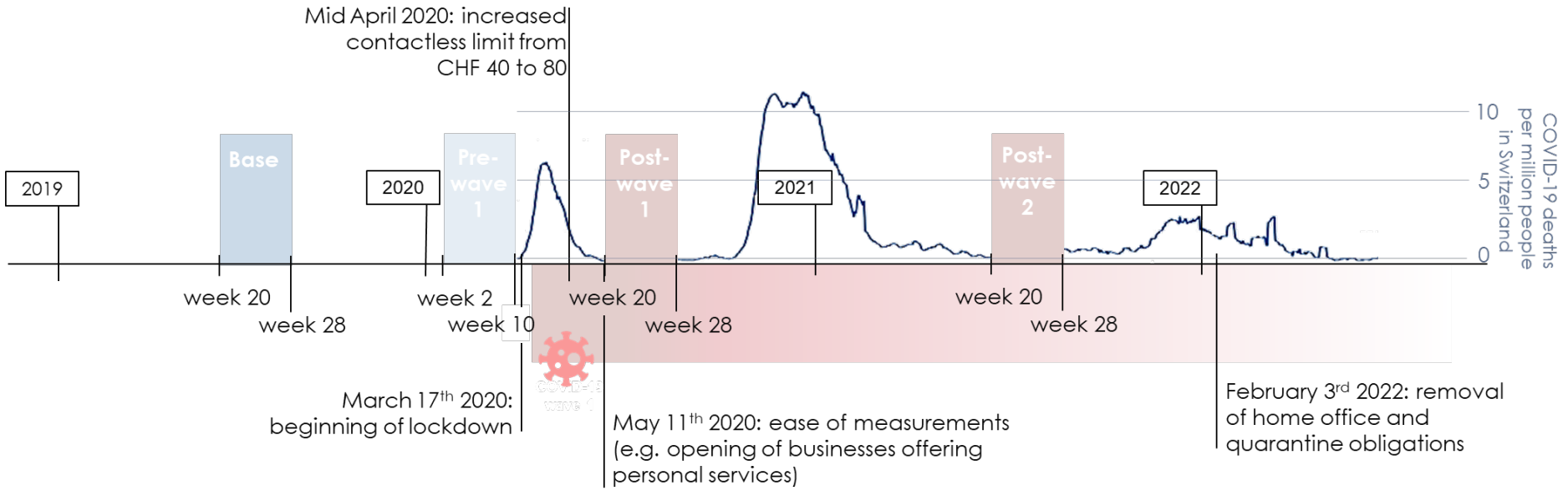
Second, we limit our dataset to a sample of constant card-merchant relationships over constant calendar periods.[17][18] We restrict our analysis to four nine-week periods (see Figure 1). We analyze the same calendar weeks (20-28) in 2019, 2020 and 2021. We choose this particular period of the year because 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).[19] 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.

[17] Our procedure is similar to the 'constant-merchant' approach proposed by Aladangady et al. (2022) that is applied 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'.

[18] 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.

[19] Appendix A3 provides information on the number of COVID-19 related deaths and cases in Switzerland over time.

Figure 1. Constant calendar periods applied for sample construction



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.

Table 1. Card-level summary statistics

Mean by period (n=406,550 cards)				
	Base period	Pre-wave 1	Post-wave 1	Post-wave 2
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%

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 (based on all transactions, not only based on transactions in our sample of constant card-merchant relationships). Merchant location (urban, rural and agglomeration areas) is based on zip code level mapping with publicly available statistics by the Swiss Federal Statistical Office.

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 services, food and beverage services, urban locations, rural locations, agglomeration locations, medium to small merchants, and large merchants is also stable across time.

2.3. Outcome variables

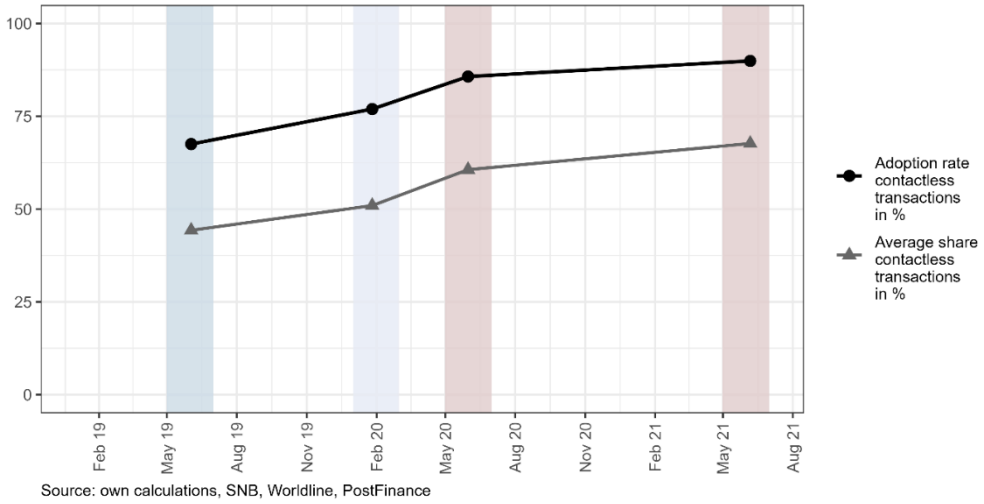
The main variable of interest in our analyses is the share of contactless transactions, i.e., the share of debit card transactions (in %) that are initiated contactless as opposed to chip-based. We construct the variable *ShareContactless* at either the card*period or merchant*period level. We further study the adoption rate of contactless payments. We construct an indicator variable *ContactlessAdopted* at the card*period level that takes value 1 if a cardholder has used the contactless technology up to and including the current observation period.[20]

Panel A in Figure 2 below presents the mean of our two outcome variables at the card*period level. Panel B in Figure 2 shows the card-level average share of contactless payments for Base period adopters (cards with contactless transactions in the Base period) as opposed to later adopters (cards with no contactless transactions in the Base period but with contactless transactions in the Pre-wave 1, Post-wave 1 or Post-wave 2 periods). Of our card sample (406,550 cards), two-thirds are adopters in the Base period (274,468 cards), and 38,330 are Pre-wave 1 period adopters. A further 35,648 cards adopt contactless technology by the Post-wave 1 period and 17,077 by the Post-wave 2 period – 41,027 remain nonadopters. Figure 2 reveals that the adoption rate and the use of contactless transactions accelerated between the Pre-wave 1 period and Post-wave 1 period.

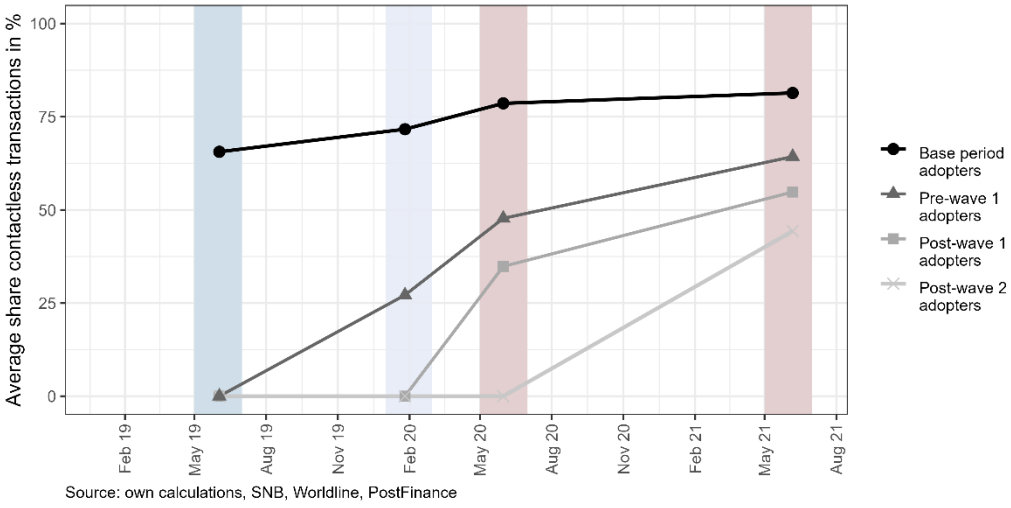
[20] Whether a card has adopted the contactless technology by a specific period is determined based on all transactions of that card, not only based on its transactions of our sample of constant card-merchant relationships.

Figure 2. Adoption and use of contactless payments

Panel A. Adoption rate and average share of contactless transactions



Panel B. Average share of contactless transactions of Base period, Pre-wave 1, Post-wave 1 and Post-wave 2 adopters



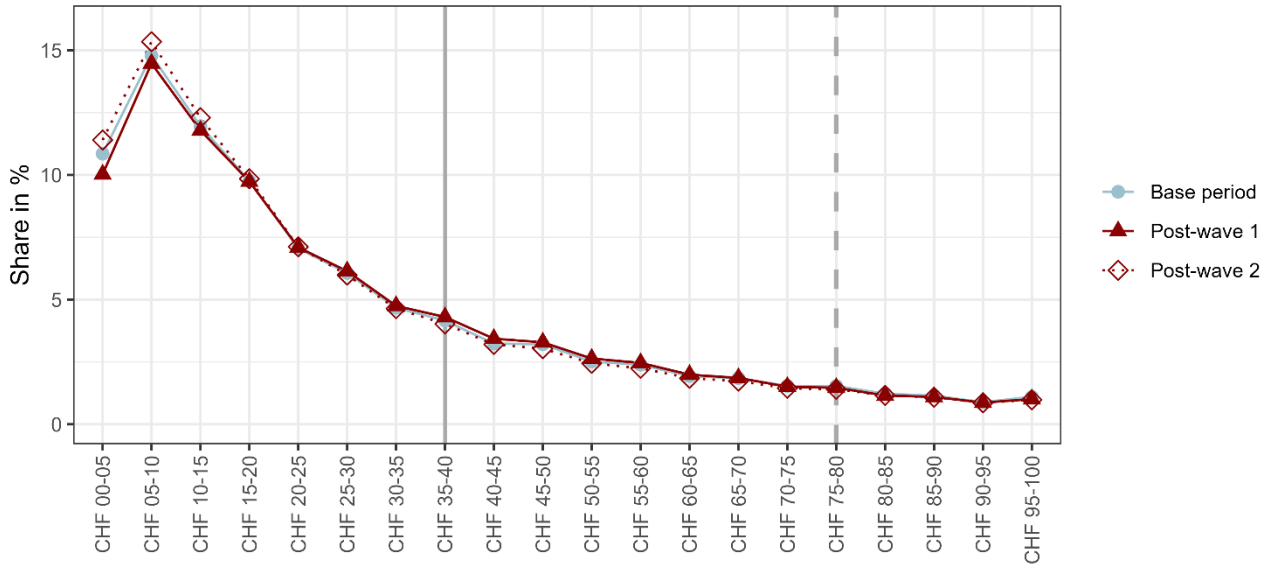
This figure reports the adoption and use of contactless payments at the card level. Panel A presents the mean of our two outcome variables, the average share of contactless transactions and the adoption rate, across cards, for each period. Panel B compares the average share of contactless transactions for cards that adopted contactless transactions by the Base period (at least one contactless transaction in the Base period, based on all transactions, not only based on transactions in our sample of constant card-merchant relationships) to cards that adopted the technology in Pre-wave 1 period, Post-wave 1 period or Post-wave 2 period.

3. The causal effect of an increased "tap-and-go" limit

In April 2020, the major intermediaries in the Swiss payment sector increased the "tap-and-go" limit for contactless verification of card payments from CHF 40 to CHF 80 for all cards at all merchants.

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 limit affected a significant share of cashless payments and reveals that the change in the "tap-and-go" limit had no notable impact on the composition of cashless payments 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 3. Distribution of transactions by value and observation period



Source: own calculations, SNB, Worldline, PostFinance

This figure shows the distribution of transactions in our sample by value for our three main observation periods (Base period, Post-wave 1 period vs. Post-wave 2 period). The vertical lines mark the old (solid) and new (dotted) value limits for contactless cardholder identification at CHF 40 and CHF 80, respectively.

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 convenience shock 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, and card schemes.

We conduct two difference-in-difference tests to identify the causal effect of the change to the "tap-and-go" limit on the adoption rate and usage rate of contactless payments. Our first test (Section 3.1) compares the growth of contactless payments between cards that benefit differentially from the increase in the "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.

Cardholders with different shares of "treated" transactions (CHF 40-80) are likely to differ in key sociodemographic attributes (age, income, education). With the onset of the pandemic, cardholders with high and low treatment intensities may thus have altered their payment behavior, even if the "tap-and-go" limit would not have changed. To address this identification concern, our second empirical test (Section 3.2) compares 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.[21]

3.1. Between-card analysis

Our first empirical test compares the growth of contactless payments between cards that benefit differentially from the increase in the "tap-and-go" limit. Our card-level measure of $TreatmentIntensity_i$ is the share of transactions between CHF 40 and CHF 80 in the Base period.

[21] 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).

The mean of this measure across cards is 22% (median 19%), with an interquartile range of 9% to 31%.[22]

We conduct a difference-in-difference test in which we compare cards with different treatment intensities before and after the increase in the "tap-and-go" limit. We estimate regression equation [1], where the outcome variable $ShareContactless_{i,t}$ measures the contactless use of card *i* in period *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.

$$[1] \qquad ShareContactless_{i,t} = a_i + \beta_1 * Post_t + \beta_2 * TreatmentIntensity_i * Post_t + \varepsilon_{i,t}$$

Identification in this test relies on the parallel-trends assumption: Consumers with different shares of cashless payments between CHF 40 and CHF 80 may have different levels of use of contactless payments. This is very likely because the typical transaction size of a consumer is likely to be correlated with key sociodemographic information such as income and age. We assume that without the change in the "tap-and-go" limit, the adoption and use of contactless payments would have developed similarly for cardholders with high and low treatment intensities.

Panel A of Figure 4 supports our parallel-trends assumption. The figure reports the average share of contactless transactions by period for cards with an above-median treatment intensity compared to the share of cards with a below-median treatment intensity. The trend growth appears very similar for both groups of cards between the Base period and the Pre-wave 1 period. Panel A of Figure 4 also suggests a substantial causal effect of the "tap-and-go" limit on the use of contactless payment technology. Following the increase of this limit in April 2020, the share of contactless transactions increases faster for cards that benefited most from the increase.

[22] 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.

Panel A in Table 2 presents our regression results for Equation [1]. Columns 1 and 2 compare the Post-wave 1 or Post-wave 2 period to the Base period. The results in Panel A show a significant causal effect of the "tap-and-go" limit on the use of contactless transactions. Cards with a higher treatment intensity experience a stronger increase in their share of contactless transactions from the Base period to the Post-wave 1 and Post-wave 2 periods. 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). Our estimates in Column 1 suggest that between the Base and Post-wave 1 periods, the share of contactless transactions increases by 13.8 pp for the former compared to 18.2 pp for the latter. Column 3 reports a placebo test in which the "post" period is set to Pre-wave 1. Here we also find a positive association between our card-level indicator of treatment intensity and the use of contactless payments. However, the economic magnitude of the estimate is substantially smaller than for the Post-wave 1 and Post-wave 2 periods. One possible explanation for this weak positive association is that users of the contactless technology started – pre pandemic and before the introduction of the increased verification limit – increasingly using "tap and PIN" for transactions above CHF 40.

Next, we test for the impact of the treatment intensity on the adoption of contactless payments. For the subsample of cards that did not have any contactless transactions by the Base period (Base period nonadopters), we estimate regression Equation [2], where the binary outcome variable $ContactlessAdopted_i$ measures the adoption of card i by the Pre-wave 1, Post-wave 1 or Post-wave 2 period. We estimate the following linear probability model separately for each period.

$$[2] \qquad ContactlessAdopted_i = \beta_0 + \beta_1 * TreatmentIntensity_i + \gamma * \boldsymbol{X_i} + \varepsilon_i$$

Again, $TreatmentIntensity_i$ captures the share of transactions of card i between CHF 40 and CHF 80 in the Base period. We account for heterogeneity across cardholders by controlling for available measures of spending behavior. Specifically, $\boldsymbol{X_i}$ includes the share of transactions below CHF 40, the share of retail transactions, the share of transactions at small to medium-sized merchants, and the

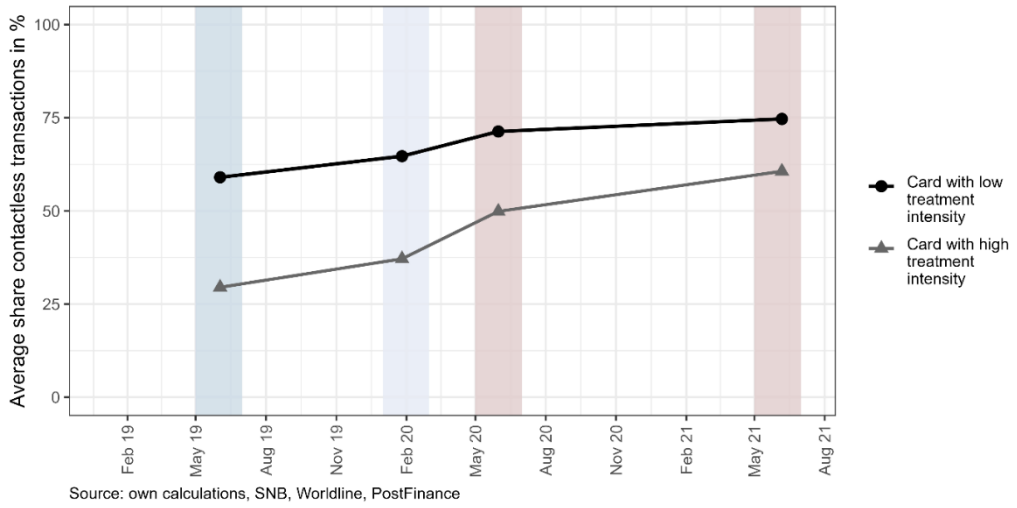
share of transactions at merchants in urban areas and the share of transactions at merchants in rural areas. All control variables are measured for the Base period. Summary statistics for each of these variables are presented in Table 1 above.

Panel B of Figure 4 shows that of the 132,082 cards that did not use contactless payments in the Base period, 29% adopted contactless payments in the Pre-wave 1 period, an additional 27% did so in the Post-wave 1 period and a further 13% adopted them in the Post-wave 2 period. The shares of new adopters in the Post-wave 1 and Post-wave 2 periods are higher for cards with an above-median treatment intensity (29% and 14%) than for cards with a below-median treatment intensity (24% and 12%). In contrast, the share of new adopters in the Pre-wave 1 period is lower for cards with an above-median treatment intensity (28%) than for cards with a below-median treatment intensity (31%).

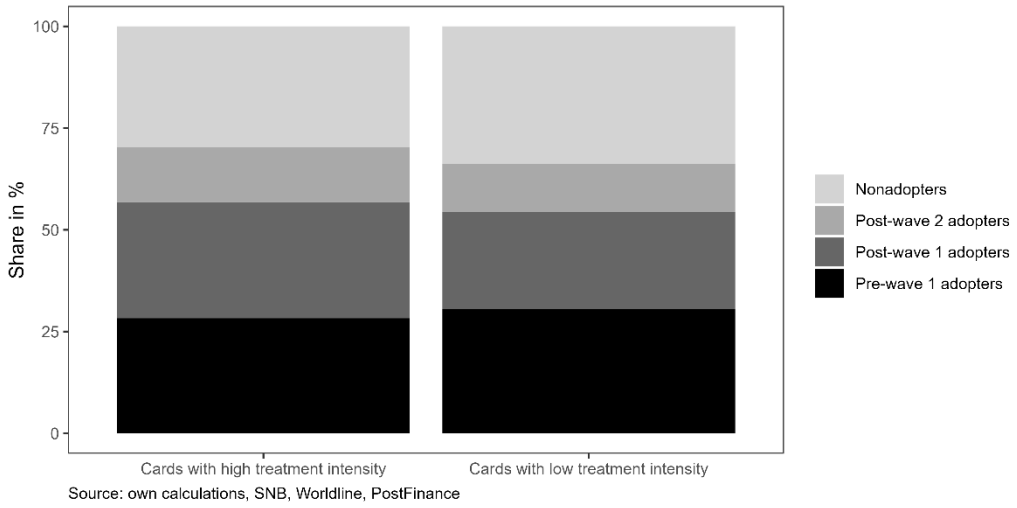
Panel B in Table 2 presents our regression results for Equation [2]. Columns 1 and 2 consider the cumulative adoption of contactless payment by the Post-wave 1 period and by the Post-wave 2 period, respectively (the full table of estimates is provided in Appendix A4). The results suggest a statistically significant effect of the "tap-and-go" limit on the adoption of contactless transactions. However, the economic magnitude of the effect is small. To gauge the magnitude of the effect, we again compare cards with a treatment intensity of 9% (25^{th} percentile) to cards with a treatment intensity of 31% (75^{th} percentile). Our estimates in Column 1 suggest that by Post-wave 1, the share of cards with first-time adoption of contactless payments is 28.4% for the former compared to 29.7% for the latter. The estimates in Column 2 suggest that by Post-wave 2, the share of cards with first-time adoption of contactless payments is 42.5% for the former compared to 44.3% for the latter. Column 3 presents the results of a placebo test, in which we consider first-time adoption by the Pre-wave 1 period. Here, we find that the adoption rate is not positively related to our indicator of treatment intensity. In contrast, there is a small, negative association between the share of transactions between CHF 40 and CHF 80 and the adoption of contactless payments.

Figure 4. The effect of the "tap-and-go" limit on contactless payments: Between-card analysis

Panel A. Average share of contactless transactions



Panel B. Adoption of contactless payments



Panel A of this figure shows the average share of contactless transactions separately for cards with high and low treatment intensities of the raised "tap-and-go" limit. Cards with high (low) treatment intensity are those with a higher (lower) share of transactions between CHF 40 and CHF 80 in the Base period (all transactions, not only transactions in constant card-merchant relationships) than the median of all cards (19%). In our full sample, there are n=202,901 (n=203,649) cards with high (low) treatment intensity. Panel B 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.

Table 2. The "Tap-and-go" limit: Between-card analysis

Panel A. Share of contactless transactions

Outcome variable:	Share contactless transactions (in %) – *ShareContactless*		
Base period vs.	Post-wave 1	Post-wave 2	Pre-wave 1
TreatmentIntensity * Post	0.20***	0.40***	0.04***
	(0.00)	(0.00)	(0.00)
Post	12.03***	14.48***	5.87***
	(0.06)	(0.08)	(0.05)
Mean outcome variable in period (Base period)	61% (44%)	68% (44%)	51% (44%)
Card fixed effects	Yes	Yes	Yes
Cards	406,550	406,550	406,550
Observations	813,100	813,100	813,100
R2, adjusted R2	0.85, 0.70	0.77, 0.54	0.91, 0.82

Panel B. Adoption of contactless transactions

Outcome variable:	Adoption of contactless transactions (indicator) – *ContactlessAdopted*		
ContactlessAdopted in	Post-wave 1	Post-wave 2	Pre-wave 1
(Intercept)	0.5064***	0.6060***	0.3060***
	(0.02)	(0.0162)	(0.02)
TreatmentIntensity	0.0004***	0.0005***	-0.0001**
	(0.00)	(0.0001)	(0.00)
Mean outcome variable in period	0.56	0.69	0.29
Card controls	Yes	Yes	Yes
Cards	132,082	132,082	132,082
Observations	132,082	132,082	132,082
R2, adjusted R2	0.002, 0.002	0.001, 0.001	0.009, 0.009

This table presents estimated coefficients for *ShareContactless* in our regression Equation [1] for (Panel A) and *ContactlessAdopted* in our regression Equation [2] (Panel B). Columns 1 to 3 in both panels compare the outcome variable in the Base period to that in the Post-wave 1, Post-wave 2 and Pre-Wave 1 period, respectively. Heteroskedasticity-robust standard errors are presented in parentheses. *, **, *** indicate significance at the 10%, 5%, and 1% level, respectively.

Overall, our between-card analysis suggests a strong causal effect of the increased "tap-and-go" limit on the use but only a small effect on first-time adoption of contactless payments.

3.2. Within-card analysis

Our second empirical test compares the use of contactless payments within each card across different transaction value ranges. As our "treated" transactions, we consider all transactions that became newly eligible for "tap and go" (transactions between CHF 40 and 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). Our within-card test allows us to disentangle the increased convenience benefit due to the higher "tap-and-go" limit from the effect of potential hygiene concerns or salience effects during the pandemic. The increase in the "tap-and-go" limit implies an improvement in the convenience benefits of contactless payments for transactions between CHF 40 and CHF 80 only. By comparison, 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 [3], where the outcome variable is $ShareContactless_{i,j,t}$ of card i for transaction size range j in period t. The dummy variable $Treated_j$ equals 1 for transactions in the range between CHF 40 and CHF 80 (treated transactions) 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.

$$[3] \qquad ShareContactless_{i,j,t} = \alpha_i + \beta_1 * Treated_j + \beta_2 * Post_t + \beta_3 * Treated_j * Post_t + \varepsilon_{i,j,t}$$

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. Panel A of Figure 5 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 (pretreated) 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.

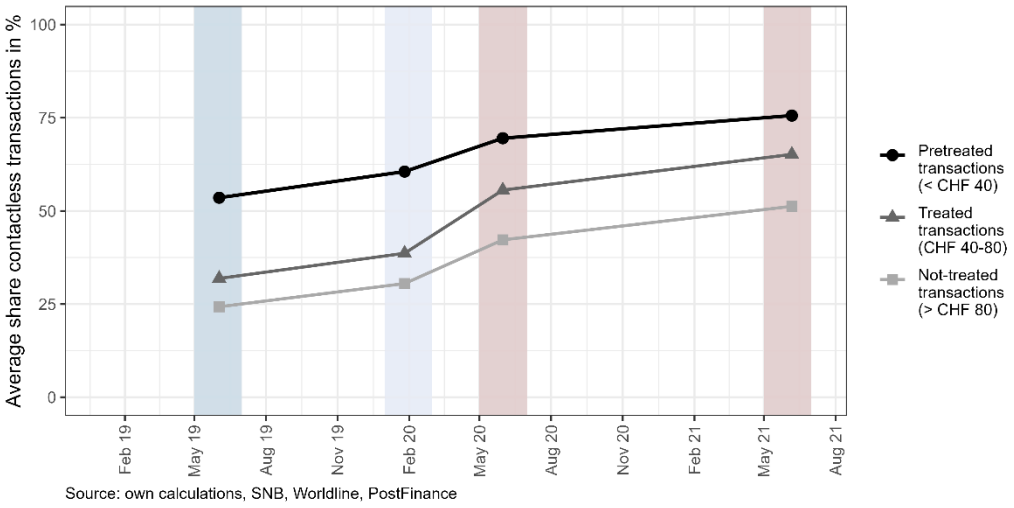
Figure 5 suggests a substantial causal effect of the "tap-and-go" limit on the share of contactless payments. Following the increase of this limit in April 2020, the contactless share of cards increases significantly faster for treated transactions than for pretreated or not-treated transactions. Comparing the Post-wave 1 period to the Base period in Panel A of 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. Panel B of the figure 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 [3]. Panel A reports a comparison of treated and not-treated transactions. Panel B reports a comparison of treated and pretreated transactions. In both panels, we limit our analysis to cards for which we observe transactions for pretreated, treated and not-treated transactions in all four periods.[23] In both panels, Columns 1 and 2 compare the Post-wave 1 or Post-wave 2 to the Base period. Column 3 reports a placebo test in which the "post" period is set to Pre-wave 1. The results in Panel A 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 Panel B.

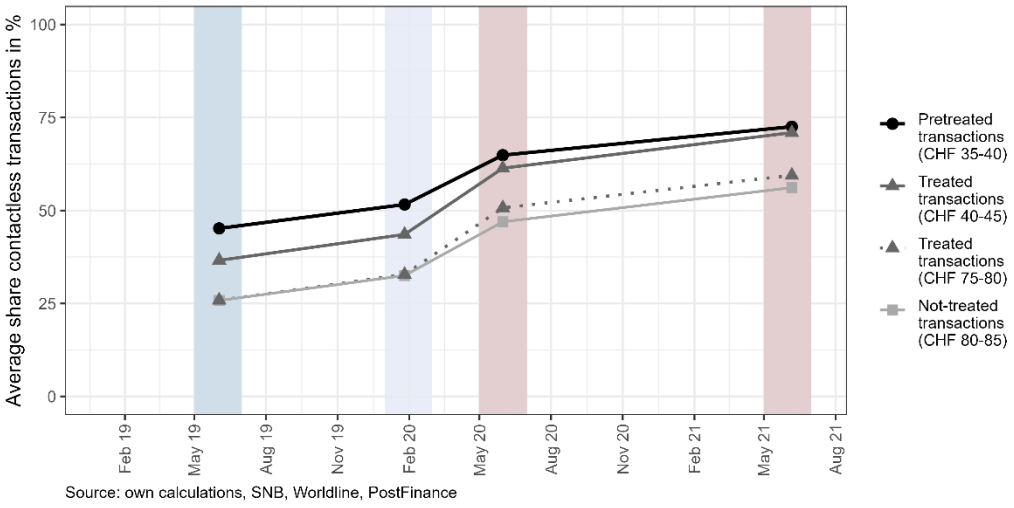
[23] As a robustness check, we relax our identification but enlarge our sample: In Appendix A5, we estimate regression Equation [3] without card fixed effects on our full sample. The regression results confirm the main findings from Table 3.

Figure 5. The effect of the "tap-and-go" limit on contactless payments: Within-card analysis

Panel A. Full sample of transactions



Panel B. Transactions in narrow ranges around "tap-and-go" limits



This figure compares the mean of our outcome variable *ContactlessShare* by observation period and transaction value. Treated transactions are those between CHF 40 and CHF 80, and pretreated transactions are those below CHF 40. Not-treated transactions are those above CHF 80. Panel A presents all treated, pretreated and not-treated transactions. Panel B compares the treated to the pretreated transactions in narrow bands around the old "tap-and-go" limit (CHF 35-40 and CHF 40-45 bands) as well as the treated to the not-treated transactions in narrow bands around the new "tap-and-go" limit (CHF 75-80 and CHF 80-85 bands).

Table 3. The "tap-and-go" limit: Within-card analysis

Panel A. Treated (CHF 40-80) vs. not-treated transactions (above CHF 80)

Outcome variable:	Share of contactless transactions (in %) – *ShareContactless*		
Base period vs.	Post-wave 1	Post-wave 2	Pre-wave 1
Treated * Post	8.14***	9.28***	0.18
	(0.17)	(0.20)	(0.13)
Post	18.08***	28.58***	7.07***
	(0.11)	(0.14)	(0.09)
Treated	4.28***	4.28***	4.28***
	(0.11)	(0.13)	(0.09)
Mean outcome variable in period (Base period)	49% (27%)	60% (27%)	34% (27%)
Card fixed effects	Yes	Yes	Yes
Cards	65,072	65,072	65,072
Observations	260,288	260,288	260,288
R2, adjusted R2	0.76, 0.68	0.70, 0.60	0.85, 0.80

Panel B. Treated (CHF 40-80) vs. pretreated transactions (below CHF 40)

Outcome variable:	Share of contactless transactions (in %) – *ShareContactless*		
Base period vs.	Post-wave 1	Post-wave 2	Pre-wave 1
Treated * Post	4.87***	7.25***	-0.93***
	(0.17)	(0.20)	(0.15)
Post	21.36***	30.60***	8.17***
	(0.12)	(0.14)	(0.11)
Treated	-13.77***	-13.77***	-13.77***
	(0.13)	(0.14)	(0.11)
Mean outcome variable in period (Base period)	60% (36%)	70% (36%)	44% (36%)
Card fixed effects	Yes	Yes	Yes
Cards	65,072	65,072	65,072
Observations	260,288	260,288	260,288
R2, adjusted R2	0.76, 0.68	0.70, 0.60	0.82, 0.76

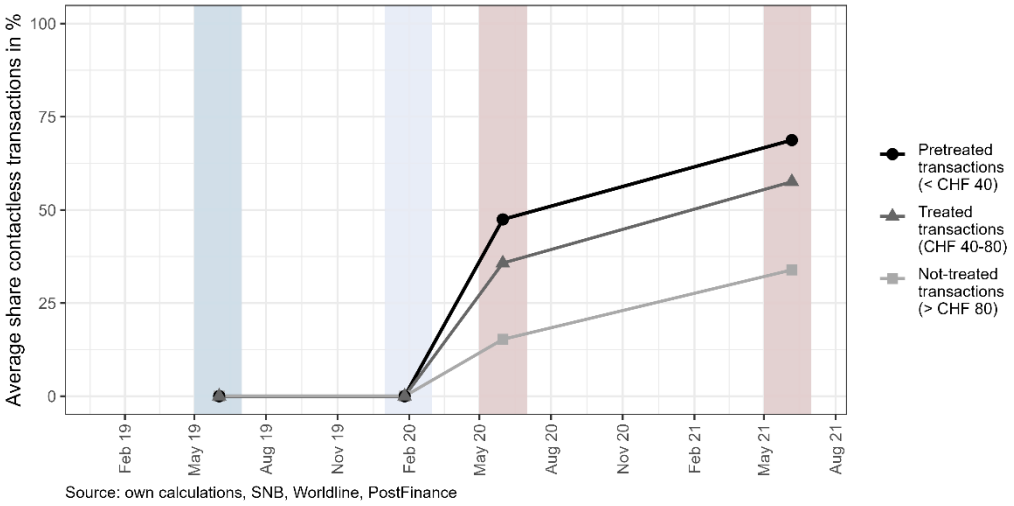
This table presents estimated coefficients for *ContactlessShare* in our regression Equation [3]. Panel A compares the treated transactions (transactions between CHF 40 and CHF 80) to the not-treated transactions (transactions above CHF 80). Panel B compares the treated transactions to the pretreated transactions (transactions below CHF 40). Both panels present regressions 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.

Figure 6 replicates our within-card analysis of the increased "tap-and-go" limit for new adopters of contactless technology only. The figure reports the share of contactless transactions by transaction size for the subsample of Post-wave 1 adopters (Panel A) and Post-wave 2 adopters (Panel B). We observe a strong take-up of contactless technology for all transactions that are eligible for "tap and go". Small-value transactions (below CHF 40 transactions) that were eligible for "tap and go" before the pandemic actually report a stronger initial take-up than those transactions that were newly eligible for "tap and go" (between CHF 40 and CHF 80 transactions). This finding is consistent with our previous finding that the increased "tap-and-go" limit only has a minor causal effect on first-time adoption of contactless payments.

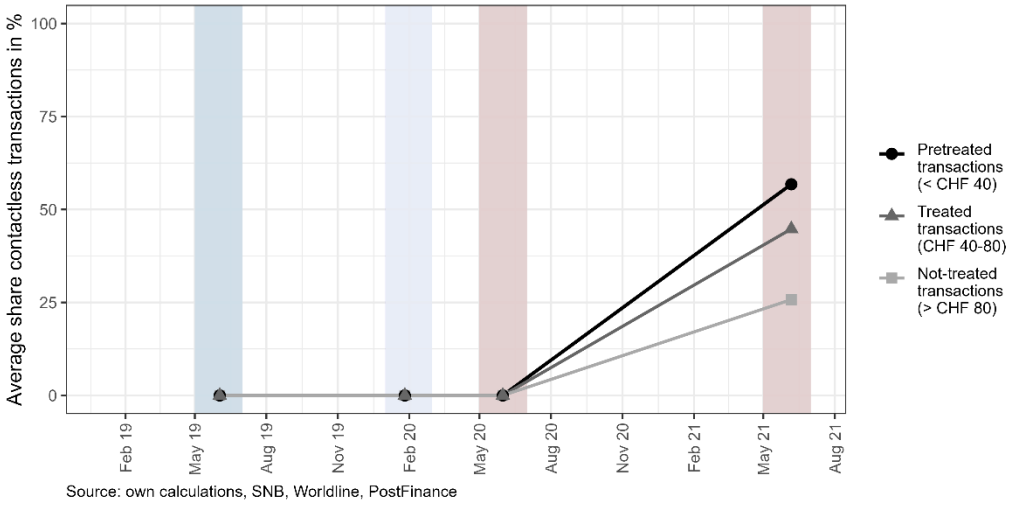
Last, a comparison of the not-treated (above CHF 80) transactions to the pretreated (below CHF 40) transactions in Panel A of Figure 5 allows us to make some inference about the relative importance of other drivers of the use of contactless payments during the first wave of the pandemic. We conjecture 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.

Figure 6. The effect of the "tap-and-go" limit on contactless payments: Within-card analysis for Post-wave 1 and Post-wave 2 adopters

Panel A. Full sample of transactions, Post-wave 1 adopters only



Panel B. Full sample of transactions, Post-wave 2 adopters only



This figure compares the average share of contactless payments for post-pandemic adopters by observation period and transaction value. Treated transactions are those between CHF 40 and CHF 80, pretreated transactions are those below CHF 40, and not-treated transactions are those above CHF 80. Panel A 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. Panel B presents 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.

4. Hygiene concerns and contactless payments

In Section 3, we identified the causal effect of the "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 examine how hygiene-related concerns impacted contactless payments during the COVID-19 pandemic. This allows us to benchmark the effects of the "tap-and-go" limit change 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 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 payment did not change with the pandemic.

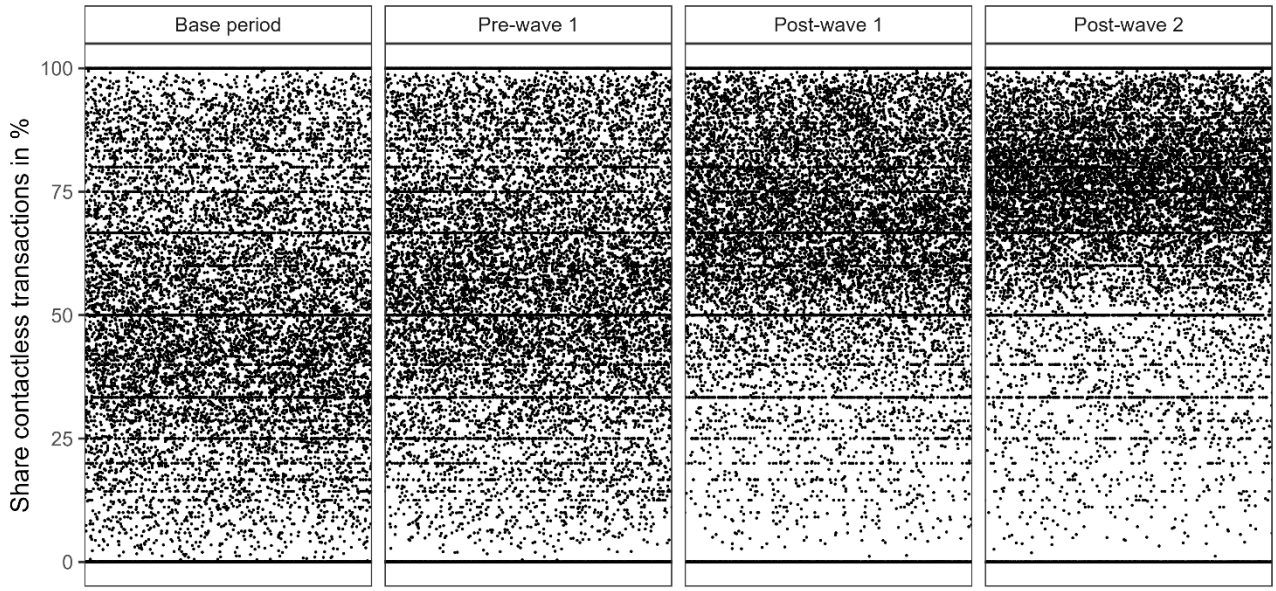
Our analysis in this section is based on observations at the merchant*period level. Using information on the location of each merchant, we can match our transaction-level payment data to regional information on pandemic intensity. As discussed in Section 2, our sample covers nearly

[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 Appendix Figure A2-2). 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 10 November 2023).

18,000 merchants. We match each merchant to one of the 101 labor market regions in Switzerland.[25] This allows us to match our payment data to regional information on pandemic activity, i.e., the number of COVID-19 cases in the region where the merchant is located.

Figure 7 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 7. Share of contactless transactions at the merchant level



Source: own calculations, SNB, Worldline, PostFinance

This figure shows the share of contactless transactions for each merchant in our sample and for each of our four observation periods. Every dot in each panel of the figure represents one merchant*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

[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 10 November 2023).

available only at the cantonal level. 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 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. Figure A6 in the Appendix presents our regional measure of COVID-19 exposure and reveals substantial variation in regional pandemic intensity during the first wave. In Figure A7 in the Appendix, 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 regression 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. 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.

$$[4] \quad ShareContactless_{m,t} = \alpha_m + \beta_1 * Post_t + \beta_2 * CovidExposure_m * Post_t + \boldsymbol{\gamma} * \boldsymbol{X_m} * Post_t + \varepsilon_{m,t}$$

Regional variation in 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

[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 10 November 2023).

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 km2), 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 prevented by law for a considerable period during the pandemic. 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. Table A8-1 in the Appendix presents summary statistics for our regional-level data.

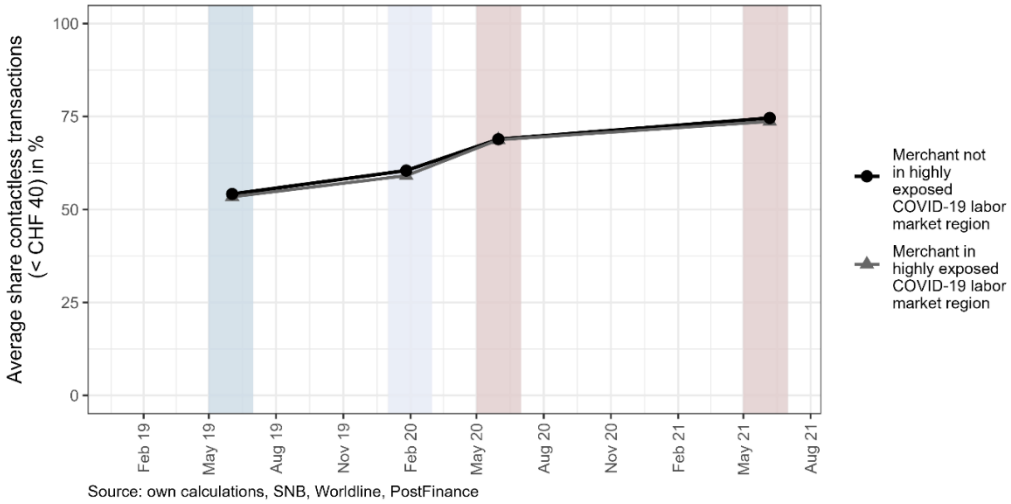
Figure 8 displays the average share of contactless payments (for transactions below CHF 40) by period for merchants located in regions with high and low COVID-19 exposure. We classify merchants as those with high COVID-19 exposure if they are located in regions with an above-median number of cases. The 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 8 suggests no effect of regional COVID-19 exposure on the use of contactless payment technology.

Table 4 presents our regression results for Equation [4].[27] 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

[27] See Table A8-2 in the Appendix for a regression table showing coefficients of all control variables.

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

Figure 8. Merchants with high vs. low COVID-19 exposure



This figure reports the mean share of contactless transactions for transactions with a value below CHF 40 across merchants. The figure compares 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. Merchants and COVID-19 exposure

Outcome variable:	Share of contactless transactions (in %) – *ShareContactless*		
Base period vs.	Post-wave 1	Post-wave 2	Pre-wave 1
Transaction range		below CHF 40	
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 * period controls	Yes	Yes	Yes
Region * period controls	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

This table reports estimated coefficients for regression Equation [4]. The outcome variable is *ContactlessShare* for transactions with a value below CHF 40 at the merchant*period level. Columns 1-3 compare the Base period to Post-wave 1, Post-wave 2 and Pre-wave 1, respectively. Heteroskedasticity-robust standard errors are presented in parentheses. *, **, *** indicate significance at the 10%, 5%, and 1% level, respectively.

Did hygiene concerns encourage the first-time adoption of contactless payments? In Figure A8 in the Appendix, we replicate Figure 8, and in Table A8-3 in the Appendix, we replicate Table 4 for transactions from two subsamples of cards: pre-pandemic users and pre-pandemic non-users of contactless payments. For both subsamples, our findings mirror those presented in Figure 8 and Table 4, albeit with varying magnitude and precision of our coefficient of interest.

Did hygiene concerns affect the use of contactless payments for particular types of merchants? In Table A8-4 in the Appendix, we 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.

5. Discussion

The role of financial intermediaries in payment systems is strongly debated. The payments market is a prime example of a two-sided market in which technology use depends on the interplay of consumer demand and merchant acceptance. Card schemes and issuing banks play an intermediary role in this market, coordinating the actions of consumers and merchants. Previous research has emphasized how the fees charged by card schemes to consumers, merchants and banks affect payment market efficiency. We provide a new perspective on the role of card schemes and issuing banks as intermediaries: they set rules for the verification of cashless payments. As we document in this paper, these rules have a substantial causal effect on the use of payment technology.

We study consumer adoption and use of contactless card payments. 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 changes in 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 changes in the consumption structure by limiting our sample to transactions for constant card-merchant relationships and constant calendar periods.

We examine the impact of the April 2020 increase in the contactless cardholder verification ("tap-and-go") limit from CHF 40 to CHF 80. Cardholders who benefitted most from the increased limit display a stronger increase in their contactless payments. Moreover, transactions that were newly eligible for "tap and pay" reveal a stronger growth in contactless payments than transactions that were either previously eligible or remained ineligible. However, while the "tap-and-go" limit significantly increases the use of contactless payments, it has only a minor effect on first-time adoption of this payment technology.

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. Our results suggest that policy-makers and payment system intermediaries are advised to consider how convenient the identity verification of retail payments with these new payment instruments may be. In particular, our results suggest that the value limit for "instant verification" of payments will affect the intensity of use by consumers who adopt the technology. However, increasing the convenience of identity verification in payment transactions may not have a major impact on adoption, i.e., first-time use of the technology.

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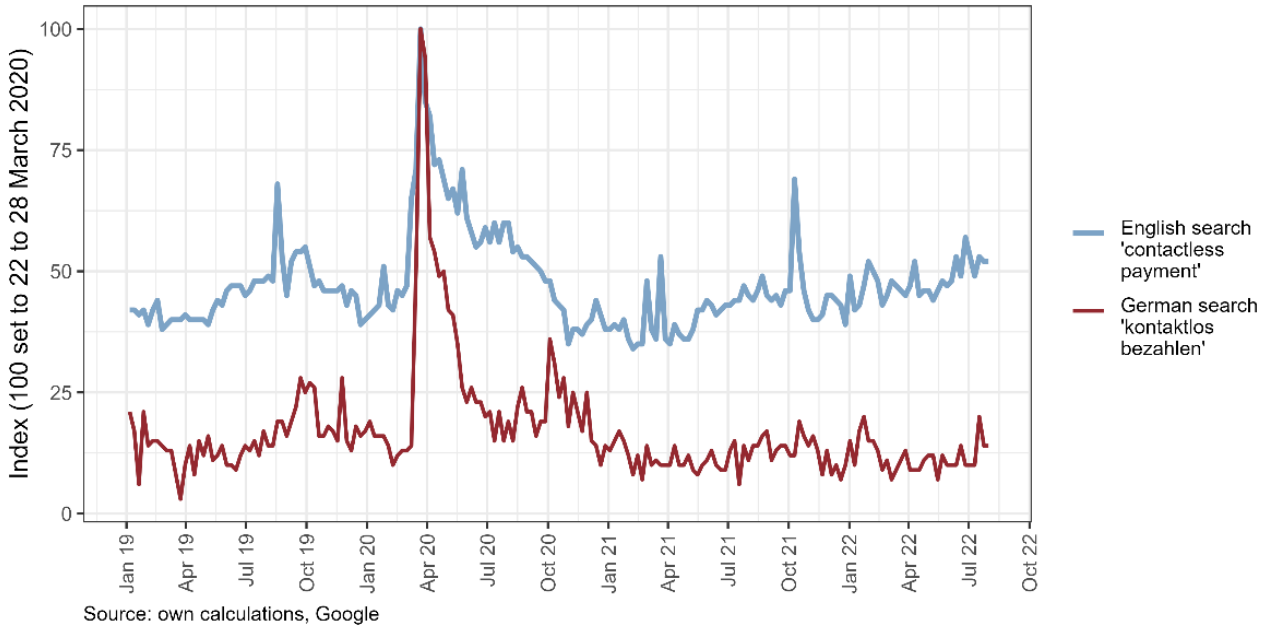
Appendix

A1. Google Trends Analytics

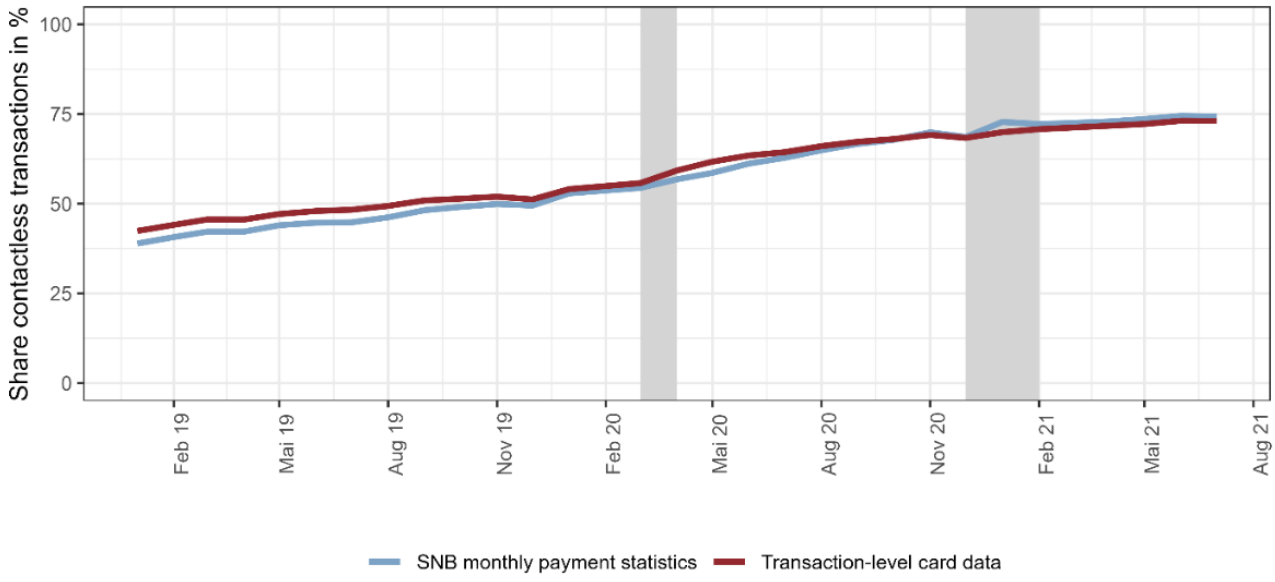
Figure A1 Google searches for contactless payments



Note: The weekly data can be retrieved from Google Trends Analytics: https://trends.google.com/trends/explore?date=today%205-y&hl=en (last accessed on 10 November 2023). The search terms entered were “Contactless payment” and “Kontaktlos bezahlen”. We filtered “Worldwide”, “Last 5 years”, “All categories” and “Web Search”.

A2. Aggregated monthly statistics and transaction-level data

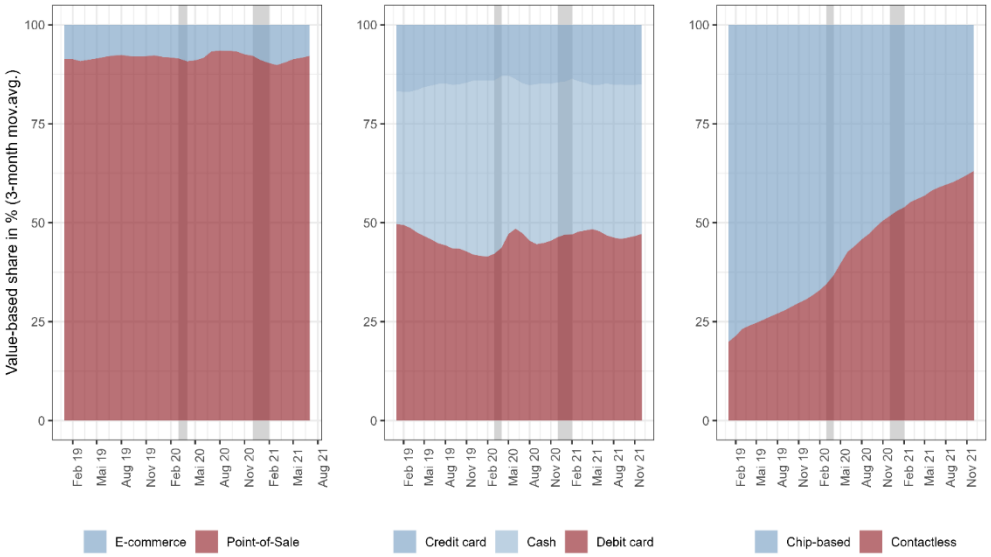
Figure A2-1. Share contactless debit-card transactions – comparison of SNB monthly statistics with transaction-level data



Source: own calculations, SNB, Worldline, PostFinance

Note: 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 10 November 2023), section "Capital market and payment transactions" and subsection "Payment transactions".

Figure A2-2. Development of payments in Switzerland 2019-2021: aggregated monthly statistics



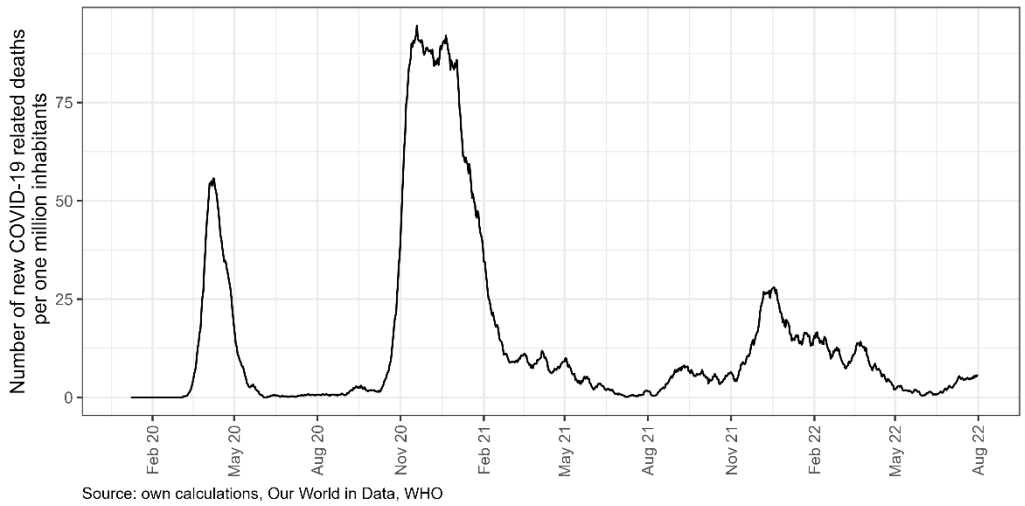
Source: own calculations, SNB

Note: “E-commerce” refers to online payments with cards, while “Point-of-Sale” includes both card and cash payments. “Cash” refers to cash withdrawals at ATMs in Switzerland. The panel on the right includes only chip-based and contactless payments with debit cards. The two gray-shaded areas mark periods with pandemic-related restrictions ("lockdowns") in Switzerland. All data come from the SNB's data web portal: https://data.snb.ch/en (last accessed on 10 November 2023), section “Capital market and payment transactions” and subsection “Payment transactions”.

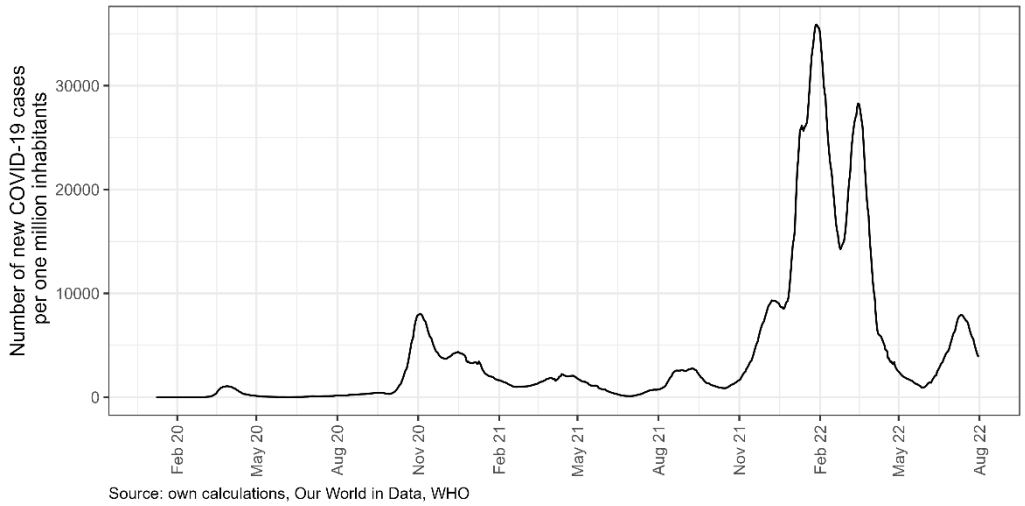
A3. COVID-19 in Switzerland: Deaths and cases

Figure A3. Number of COVID-19-related deaths and cases in Switzerland over time

Panel A: COVID-19-related deaths



Panel B: COVID-19 cases



Note: The 7-day moving average data of confirmed cases and 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 10 November 2023).

A4. Between-card analysis: Full regression table

Table A4. Adoption of contactless transactions: Full regression table

Outcome variable:	Adoption contactless transactions (indicator variable) – *ContactlessAdopted*		
ContactlessAdopted in	Post-wave 1	Post-wave 2	Pre-wave 1
(Intercept)	0.5064***	0.6060***	0.3060***
	(0.02)	(0.02)	(0.02)
TreatmentIntensity	0.0004***	0.0005***	-0.0001**
	(0.00)	(0.00)	(0.00)
Base period share of transactions below CHF 40	0.0006***	0.0003***	0.0010***
	(0.00)	(0.00)	(0.00)
Base period share of retail transactions	0.0004**	0.0007***	-0.0005***
	(0.00)	(0.00)	(0.00)
Base period share of transactions at small to medium-sized merchants	-0.0002***	-0.0001***	-0.0001***
	(0.00)	(0.00)	(0.00)
Base period share of transactions in urban areas	-0.0001***	-0.0002***	0.0001
	(0.00)	(0.00)	(0.00)
Base period share of transactions in rural areas	-0.0002***	0.0000	-0.0002***
	(0.00)	(0.00)	(0.00)
Mean outcome variable in period	0.56	0.69	0.29
Cards	132,082	132,082	132,082
Observations	132,082	132,082	132,082
R2, adjusted R2	0.002, 0.002	0.001, 0.001	0.009, 0.009

Note: Heteroskedasticity-robust standard errors are presented in parentheses. *, **, *** indicate significance at the 10%, 5%, and 1% level, respectively.

A5. Within-card analysis: Pooled regression

Table A5. The "tap-and-go" limit: Treated vs. control transactions

Panel A. Treated (CHF 40-80) vs. not-treated transactions (above CHF 80)

Outcome variable:	Share of contactless transactions (in %) – *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
R2, adjusted R2	0.07, 0.07	0.12, 0.12	0.01, 0.01

Note: Heteroskedasticity-robust standard errors are presented in parentheses. *, **, *** indicate significance at the 10%, 5%, and 1% level, respectively.

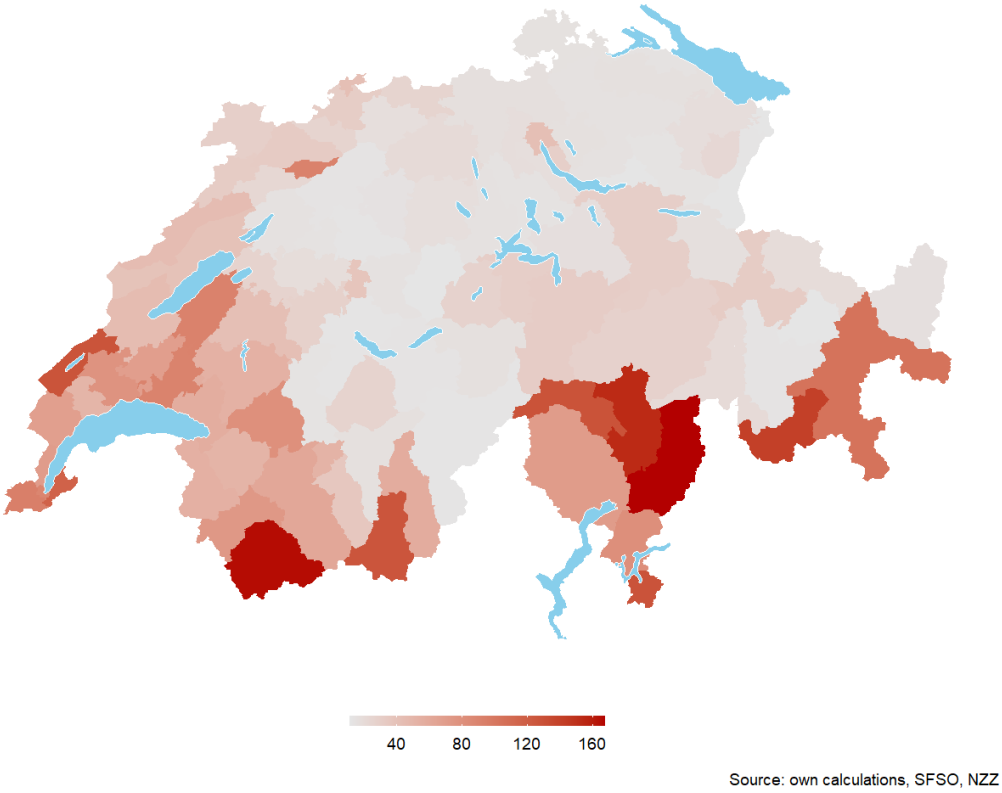
Panel B. Treated (CHF 40-80) vs. pretreated transactions (below CHF 40)

Outcome variable:	Share of contactless transactions (in %) – *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
R2 , adjusted R2	0.08, 0.08	0.12, 0.12	0.06, 0.06

Note: Heteroskedasticity-robust standard errors are presented in parentheses. *, **, *** indicate significance at the 10%, 5%, and 1% level, respectively.

A6. Cumulated COVID-19 cases per labor market region

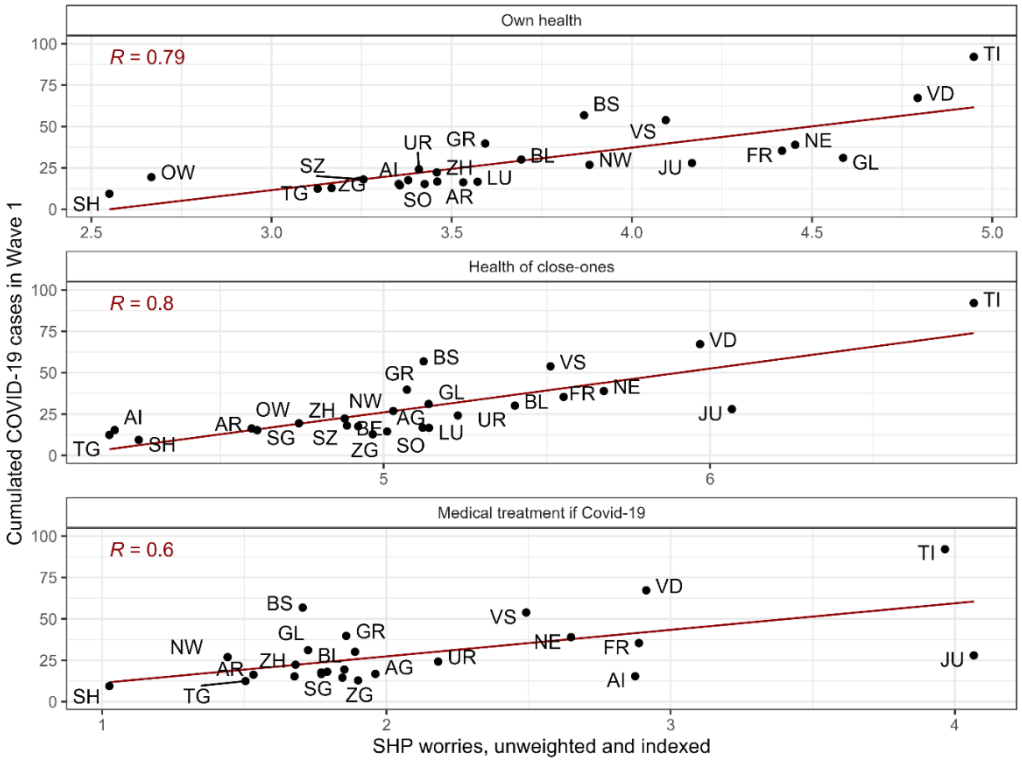
Figure A6. Cumulative COVID-19 cases from February to May 2020
(per labor market region and 10,000 inhabitants)



Note: 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 10 November 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).

A7. Regional survey data on COVID-19 case concerns

Figure A7. Regional COVID-19 cases and hygiene concerns



Note: 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 10 November 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 10 November 2023).

A8. Hygiene concerns: summary statistics and additional results

Table A8-1. Summary statistics per labor market region (n= 101)

	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%

Note: 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. Foreign/domestic card transactions are calculated for retail trade (NACE 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.

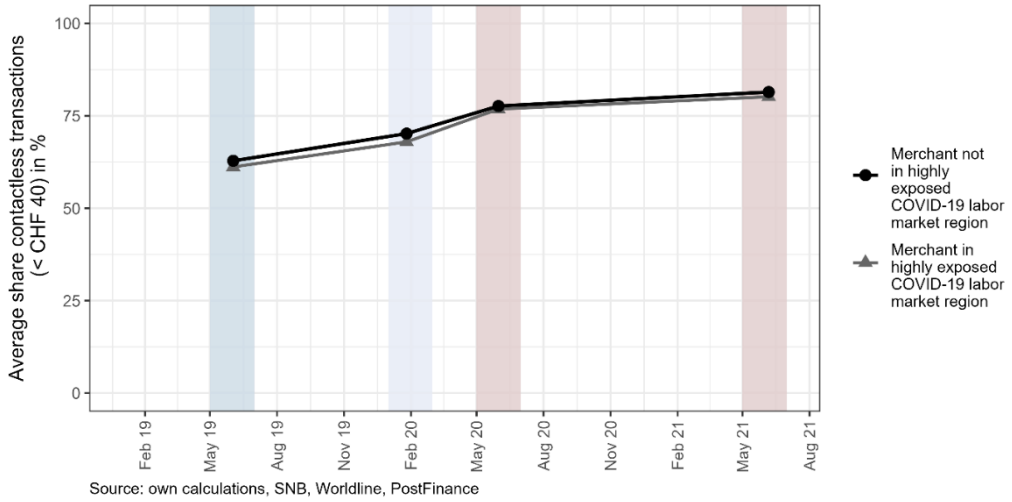
Table A8-2. Merchants and COVID-19 exposure: Full regression table

Outcome variable:	Share of contactless transactions (in %) – *ShareContactless*		
Base period vs.	Post-wave 1	Post-wave 2	Pre-wave 1
Transaction range		below CHF 40	
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

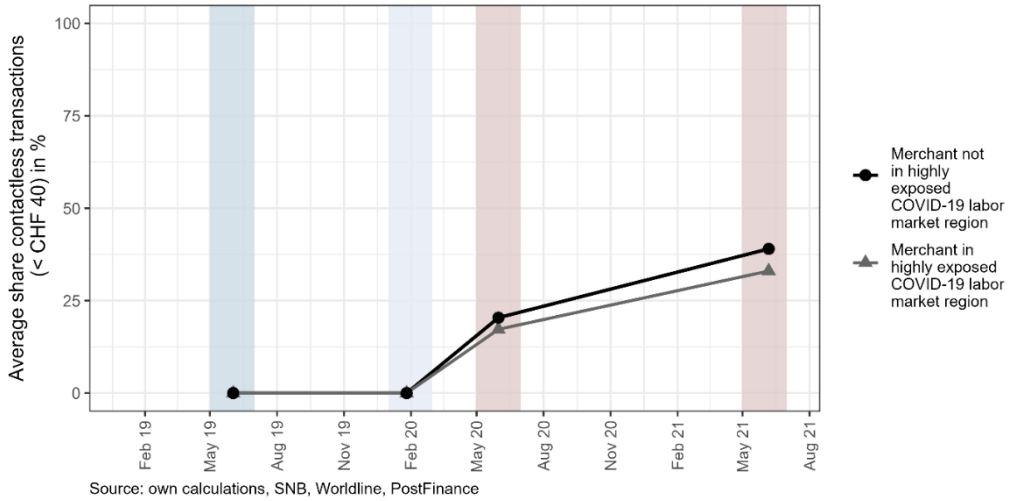
Note: Heteroskedasticity-robust standard errors are presented in parentheses. *, **, *** indicate significance at the 10%, 5%, and 1% level, respectively.

Figure A8: Merchants and COVID-19 exposure: Pre-pandemic users vs. non-users

Panel A. Users of contactless payments in the pre-pandemic period



Panel B. Non-users of contactless payments in the pre-pandemic period



Note: Merchants with high COVID-19 exposure (n= 6,032) 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= 6,125) are those located in regions with fewer COVID-19 cases than the Swiss median. Pre-pandemic users have at least one contactless transaction in the Base period or Pre-wave 1 period. Pre-pandemic non-users have no contactless transaction in the Base period or Pre-wave 1 period (based on all transactions, not only based on transactions in our sample of constant card-merchant relationships).

Table A8-3. Merchants and COVID-19 exposure: Pre-pandemic users vs. non-users

Panel A. Users of contactless payments in the pre-pandemic period

Outcome variable:	Share of contactless transactions (in %) – *ShareContactless*		
Base period vs.	Post-wave 1	Post-wave 2	Pre-wave 1
Transaction range		below CHF 40	
CovidExposure * Post	-0.28**	-0.17	-0.05
	(0.08)	(0.10)	(0.08)
Mean outcome variable in period (Base period)	78% (62%)	81% (63%)	69% (63%)
Merchant fixed effects	Yes	Yes	Yes
Period fixed effects	Yes	Yes	Yes
Merchant * period controls	Yes	Yes	Yes
Region * period controls	Yes	Yes	Yes
Merchants	14,914	14,833	14,878
Observations	29,828	29,666	29,756
R2, adjusted R2	0.86, 0.71	0.80, 0.59	0.88, 0.75

Panel B. Non-users of contactless payments in the pre-pandemic period

Outcome variable:	Share of contactless transactions (in %) –*ShareContactless*	
Base period vs.	Post-wave 1	Post-wave 2
Transaction range	below CHF 40	
CovidExposure * Post	-0.28**	-0.43**
	(0.09)	(0.13)
Mean outcome variable in period (Base period)	19% (0%)	36% (0%)
Merchant fixed effects	Yes	Yes
Period fixed effects	Yes	Yes
Merchant * period controls	Yes	Yes
Region * period controls	Yes	Yes
Merchants	9,754	9,642
Observations	19,508	19,284
R2, adjusted R2	0.62, 0.24	0.71, 0.41

Note: Pre-pandemic users have at least one contactless transaction in the Base period or Pre-wave 1 period (based on all transactions, not only based on transactions in our sample of constant card-merchant relationships). Pre-pandemic non-users have no contactless transactions in the Base period or Pre-wave 1 period. Heteroskedasticity-robust standard errors are presented in parentheses. *, **, *** indicate significance at the 10%, 5%, and 1% level, respectively.

Table A8-4. Merchants and COVID-19 exposure: Heterogeneity

Outcome variable:	Share of contactless transactions (in %) – *ShareContactless*				
Base period vs.	Post-wave 1				
Transaction range	below CHF 40				
Merchant subsample	German	French/Italian	Rural	Urban	Agglomeration
*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	10390	5,046	1,830	11,331	2,275
Observations	20780	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	0.85, 0.70

Note: Heteroskedasticity-robust standard errors are presented in parentheses. *, **, *** indicate significance at the 10%, 5%, and 1% level, respectively.

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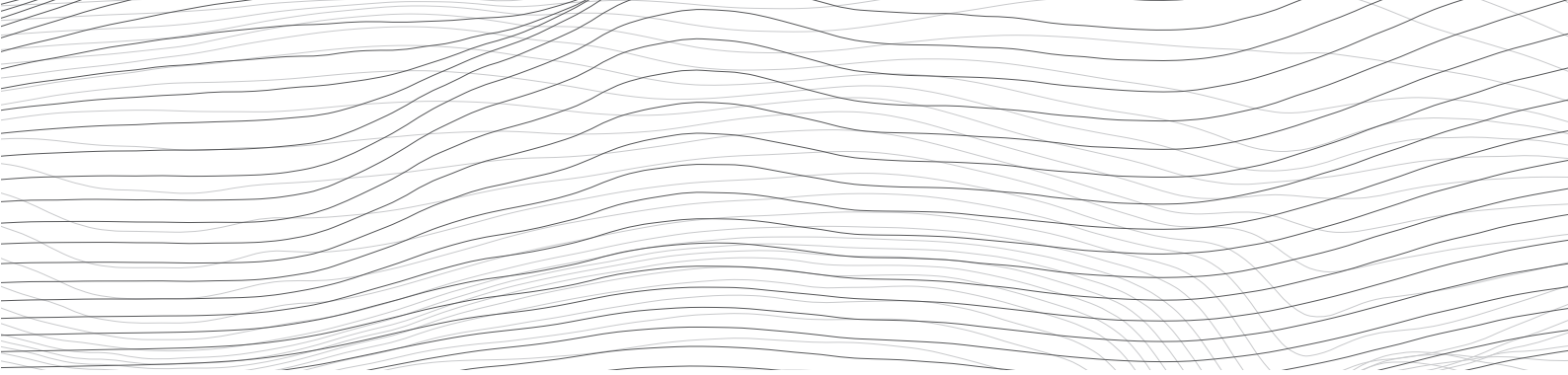

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