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The dynamics of bank rates in a negative-rate environment – the Swiss case*

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Abstract

This paper documents the change in banks' interest rate setting behaviour in a negative-rate environment. In a positive-rate environment, the pricing of mortgages and deposits follows the dynamics of capital market rates for comparable maturities. When capital market rates fall below zero, the dynamic of mortgage and deposit rates changes. Because deposit rates tend to be sticky at zero and do not fall with short-term capital market rates into negative territory, banks' liability margin shrinks. In an attempt to preserve their overall interest margin, banks raise long-term mortgage rates in response to a decline in short-term capital market rates, while they continue to decrease long-term mortgage rates when long-term market rates fall. Overall, our results imply that a policy rate cut reduces bank rates less in a negative-rate environment than in a positive-rate environment.

JEL Classification: E43, E52, G21
Keywords: Interest rate pass-through, mortgages, monetary policy

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1 Introduction

After the global financial crisis, policy interest rates were lowered around the world, and in several economies, they have been set below zero to stimulate the economy and safeguard price stability. The recent COVID-19 pandemic has reinforced these developments.

Various channels transmit changes in monetary policy to the real economy. This paper contributes to the growing literature analysing the transmission of negative policy rates through bank rates. Given that the level of natural interest rates may have declined and policy rates therefore may need to be lower than before to be expansionary, understanding potential changes in the transmission of monetary policy is important.

More specifically, we examine potential changes in the dynamics of bank rates when the policy rate is set below zero. Banks' interest rate income, which mainly depends on the money that they earn on loans and the money that they spend on deposits, is the prime source of revenue for commercial banks. Bank rates normally move together with capital market rates (more specifically, interest rate swap rates) of comparable maturity (longer maturities for loans, shorter maturities for deposits), as the latter are often used as a pricing reference and for hedging interest rate risk (see, e.g., Zurbrügg (2016)).[1] While policy rates clearly can be set below zero and market rates can also be negative, banks have been rather hesitant to lower the deposit rate below zero. The reason for this is that customers can withdraw their funds in the form of cash. Thus, deposit rates tend to be sticky at the zero lower bound, which leads to a decrease in interest income of banks when mortgage rates decline. This reduces bank profitability, which may affect banks' interest rate setting – and hence the pass-through of monetary policy – as well as their willingness to provide loans.

We study empirically the change in bank rate dynamics using Swiss data. Studying the transmission of negative interest rates in Switzerland is of particular interest since the Swiss National Bank (SNB) has implemented a negative policy rate that clearly differs from zero (only Denmark has had an equally negative policy rate) for more than six years. In December 2014, the SNB announced negative rates at a level of -0.25%, to be effective at the end of January 2015 (Swiss National Bank (2014) and Swiss National Bank (2015a)). By then, the SNB had discontinued its minimum exchange rate against the euro and lowered the negative rate to -0.75% (Swiss National Bank, 2015b). This rate is charged on part of banks' reserves

[1] For simplicity, we use the term "market rates" for capital market rates and "bank rates" for banks' mortgage and deposit rates, even though these are determined in markets – for mortgages and deposits, respectively – as well.

with the SNB and has remained unchanged since.[2]

The SNB introduced negative interest rates to restore at least in part the usual market interest rate differential against other currencies. The lower Swiss franc money and capital market rates are relative to market rates abroad, the less pressure there is on the Swiss franc to appreciate. The SNB has emphasised that this exchange rate channel is the main mechanism through which its negative-rate policy is effective (Jordan, 2019a). Since credit growth in Switzerland has been robust, transmission via bank interest rates has not been in focus.

Our findings can be summarised as follows. First, we find that fixed-term mortgage rates co-move almost one-to-one with market rates of the same maturity if deposit rates are above the zero lower bound. Deposit rates themselves co-move with short-term market rates until they approach zero. The correlation is, however, smaller and the response more inertial than those of mortgage rates. Second, we find that bank deposit rates are indeed quite sticky at zero. Third, as bank deposit rates approach zero, the dynamic between market rates and lending rates changes in that both short- and long-term market rates help explain the pattern of longer-term bank lending rates. In particular, banks seem to compensate for the downward stickiness of deposit rates by raising lending rates when short-term market rates decline. Finally, we also document that mortgage rates have declined by more than market rates would have implied since 2015, which may reflect increased competition in the mortgage market.

The contribution of our paper to the literature is threefold. First, we simultaneously analyse interest rate pass-through from capital market rates to bank lending and deposit rates in a negative-rate environment. Second, by studying Swiss data, we examine a banking system that is highly deposit-financed in an environment with a very low policy rate that clearly differs from zero. Third, we focus on a negative-rate environment in which no quantitative measures aimed at boosting bank lending have been implemented, which helps to identify the empirical relationships. Much of the literature discussed below focusses on the euro area, where bank risk premia, which impact banks' funding costs and hence their interest rate setting, arguably have been influenced by unconventional policies, such as the targeted longer-term refinancing operations of the European Central Bank.

The rest of the paper is structured as follows. Section 2 reviews the academic literature on interest rate pass-through, and Section 3 gives an overview of the role of interest margins for banks' price setting for loans and deposits. Section 4 presents the data used in our analysis,

[2]The SNB exempts a large part of banks' reserves from the negative interest rate. This reduces the direct costs of negative interest rates for banks, but has no impact on the asset and liability margins discussed below.

while the econometric analyses are discussed in Section 5. Section 6 interprets the results from a monetary policy perspective, and Section 7 concludes.

2 Related literature

Interest rate pass-through to bank rates is generally explained with the mark-up theory of Rousseas (1985), according to which bank rates are determined by market rates to which a constant mark-up is added (for loans) or subtracted (for deposits).[3] This standard pass-through may break down when policy rates are cut below zero.

Brunnermeier and Koby (2019) show that a reduction of the policy rate beyond a certain point might increase rather than reduce banks' lending rates. Their analysis relies on the balance sheet channel of monetary policy, in which the net worth of banks is essential for the transmission of policy. When banks' gains from maturity transformation are small and banks' capital constraints are binding, the squeeze on net interest income caused by an interest rate cut cannot be compensated by an increase in lending volumes. Rather, banks could raise their lending rates and reduce their lending. As a result, an interest rate cut below this so-called reversal rate leads to a tightening of monetary conditions.

Eggertsson, Juelsrud, Summers, and Wold (2019) develop another mechanism whereby the reversal interest rate results from the lower bound on the deposit rate. As the central bank loses its ability to influence the deposit rate (because of the existence of cash), it cannot stimulate demand from savers via the traditional intertemporal substitution channel. Furthermore, as banks' funding costs are no longer responsive to the policy rate, the bank lending channel breaks down, and banks might increase their lending rates in response to a negative policy rate. Given that credit demand is interest rate sensitive, this, too, would lead to lower loan volumes.

From an empirical perspective, the evidence for the completeness and speed of interest rate pass-through is ambiguous and seems to vary across countries, products, market concentration, financial integration and risk premia (see Belke, Beckmann, and Verheyen (2013)). In a positive-rate environment, evidence suggests that changes in market rates are passed through completely and quickly to bank lending rates, but incompletely and slowly to deposit rates. For example, analyses by the European Central Bank (2009) and by Bernhofer and Van Treeck (2013) show

[3] Sopp (2018) questions the relevance of contemporaneous market rates as reference rates for deposits and argues that a moving average of market rates (reflecting the replication portfolio of non-maturing deposits) is an economically better founded reference rate than market rates. Because the deposit rate applies to a bank's entire deposit volume rather than only to new deposits, he shows that profit smoothing requires a replication portfolio approach and a smooth reference rate. Deviations of deposit rates from market rates might thus reflect profit smoothing rather than market imperfection or market power of banks.

that the long-term interest pass-through in the euro area prior to the global financial crisis was almost complete for lending rates but only approximately a third for deposit rates.

In a zero or negative-rate environment, the empirical evidence is much more diverse and ambiguous. One reason for the diverging assessments is that low policy rates are usually implemented in a context of rising risk premia and bank funding costs, which weakens the relationship between policy rates and lending rates. Illes, Lombardi, and Mizen (2015) argue that traditional interest rate pass-through models, which regress bank interest rates on policy or short-term market rates, are ill-suited to studying interest rate pass-through since the global financial crisis because the average funding costs of banks have increased. The authors show that if one accounts for the wedge between bank funding costs and policy rates, interest rate pass-through in the euro area did not change substantially during the crisis. Gambacorta, Illes, and Lombardi (2014) and an analysis by the Deutsche Bundesbank (2019) share the same conclusion.

By contrast, Aristei and Gallo (2014) and Hristov, Hülsewig, and Wollmershäuser (2014) find that the short-term interest rate pass-through to lending rates has been less complete since the global financial crisis. They explain this as resulting from an increase in the size of structural shocks, tighter collateral requirements and weaker competition among banks. Several micro studies confirm this economic intuition. Holton and Rodriguez d'Acri (2015) and Altavilla, Canova, and Matteo (2016) show that banks that are less financially stable have contributed the most to the weakening of interest rate pass-through. Darracq Paries, Moccero, Krylova, and Marchini (2014) identify bank funding costs as an important determinant for lending rates. Avouyi-Dovi, Horny, and Sevestre (2017) document that financially less stable countries have experienced larger changes in interest rate pass-through.

Unconventional policy measures complicate estimating the pass-through because they have only a small impact on policy rates but a larger impact on long-term rates and potentially also on banks' risk premia. To handle this problem, von Borstel, Eickmeier, and Krippner (2016) develop a shadow policy rate that captures both conventional and unconventional policy measures and estimate that the pass-through of unconventional policy stimulus to lending rates was less complete during the European sovereign debt crisis than of conventional policy rate changes prior to the crisis.

For an environment of negative policy rates, most empirical studies find that pass-through to banks' deposit rates has either been absent (Basten and Mariathasan (2020), Demiralp, Eisenschmidt, and Vlassopoulos (2019)) or limited to large depositors only. For instance, Altavilla, Burlon, Giannetti, and Holton (2019) show that sound banks in the euro area can pass negative rates on to their corporate depositors without experiencing a contraction in deposits. Findings on the pass-through of negative policy rates to bank lending rates are more diverse. Some studies support the reversal rate hypothesis. Heider, Saidi, and Schepens (2018) show that banks in the euro area with large customer sight deposits relative to their balance sheet size tend to lend relatively less and to riskier firms than banks with low ratios. In an analysis using Swedish data, Eggertsson, Juelsrud, Summers, and Wold (2019) show that the usual pass-through of the policy rate to bank rates breaks down once the policy rate turns negative. A policy rate cut to -50 basis points (bps) is estimated to increase lending rates by 15 bps, supporting their reversal rate hypothesis. Amzallag, Calza, Georgarakos, and Sousa (2019) find that Italian banks with a higher ratio of retail sight deposits over total assets have charged higher interest rates on fixed-rate mortgages after the onset of negative policy rates.

Other analyses are, however, less supportive of the reversal rate hypothesis. For example, Demiralp, Eisenschmidt, and Vlassopoulos (2019) find that European banks with substantial amounts of excess liquidity reacted to negative rates by increasing their holdings of safe assets such as government bonds and expanding their lending supply. Horvath, Kotlebova, and Siranova (2018) observe that although sovereign credit risk weakened interest rate pass-through, the ECB's quantitative easing policies counteracted this effect. They also find that negative interest rates did not reduce the responsiveness of bank rates to market rates. A study by the Deutsche Bundesbank (2019) shows that changes in the shadow policy rate (reflecting all unconventional measures) were passed through completely to bank lending rates up until 2016, although pass-through has weakened somewhat since. The authors reason that the lower bound just above zero on bank deposit rates might have been one major obstacle to further cuts in lending rates since the middle of 2016. Euro area banks attempted to counter declines in interest income through an expansion of their business volume and increased maturity transformation rather than through an increase in their lending rates. Finally, Altavilla, Burlon, Giannetti, and Holton (2019) show that banks charging negative rates on deposits provide more credit than other banks.

The literature on interest rate pass-through in Switzerland is limited. Cecchin (2011) shows that changes in market rates are transmitted quickly and completely to mortgage rates, although the adjustment shows some downward rigidity, suggesting the existence of imperfect competition up to 2007. Pass-through to mortgage rates seems to have become faster after the onset of the global financial crisis. Cecchin's analysis does not cover the introduction of negative interest rates by the SNB in 2015. Basten and Mariathasan (2020) document that deposit rates since then have not fallen below zero, while mortgage rates increased in response to the implementation of negative policy rates. Finally, Schelling and Towbin (2020) show that as market rates go negative, banks that are more reliant on deposits loosen their lending terms and lend more to corporates. Pass-through to lending rates for high-deposit banks is thus stronger.

3 Banks' interest rate setting behaviour

Our empirical findings let us conclude that the transmission from market rates to bank lending rates on the one hand and to deposit rates on the other is not independent when market rates turn negative. Understanding the pass-through of market rates to various bank rates thus requires an approach that accounts for the overall interest rate margin problem faced by banks. To clarify the relationship between the setting of lending and deposit rates, this section discusses the breakdown of banks' interest margin into its three components and the challenges raised by negative interest rates.

3.1 The three components of banks' interest margin

The interest margin captures the return a bank earns on interest-bearing assets and liabilities. In a positive-rate environment, the interest payment goes from the customer to the bank in the case of a bank asset (customer loan) and from the bank to the customer in the case of a bank liability (customer deposit). As a first approximation (i.e., with no hedging of interest rate risk), the interest margin corresponds to the difference between these two interest rate payments. For Swiss banks, mortgage loans are the most relevant interest-bearing asset position, while most banks are predominantly funded through customer deposits. As of 2019, mortgage loans reflect approximately 50% of Swiss banks' domestic assets, while customer deposits amount to approximately 65% of domestic liabilities.[4] Because of their importance for the transmission of monetary policy to the real economy, we focus below on mortgage and deposit rates.

The interest rate margin can be broken down into the asset, liability and structural margin (see e.g., Zurbrügg (2016)). The decomposition of the interest margin is determined by market rates, which are used by the bank to hedge the interest rate risk of the various products it offers; this decomposition enables the bank to allocate the different margin components to its business areas and thus measures their contribution to the bank's profitability.

[4]See Tables 4 and 5 in Swiss National Bank (2019a). Prior to the significant increase in bank reserves since 2008, mortgages made up about two-thirds of banks' domestic assets and customer deposits approximately 55% of banks' domestic liabilities.

The asset margin is the difference between the interest rate earned on an asset (e.g., a 10-year loan to a customer) and the interest rate cost of funding this asset. These costs depend on the funding strategy chosen by the bank. A straightforward – but costly – strategy would consist of issuing a bond with the same maturity as the loan, thus hedging both the interest rate risk and the liquidity risk of lending. The rate at which the bank issues bonds on the capital market would then be the reference rate for setting the lending rate, given some targeted asset margin. However, another strategy – typically chosen by banks – is to hedge the interest rate risk of lending by means of a fixed-rate payer interest rate swap (IRS) transaction with the maturity of the loan and to roll over the liquidity provision, the price of which on the money market corresponds to the floating rate received from the IRS transaction. Then, the reference rate that determines the lending cost is approximated with the IRS curve.[5]

The liability margin is the difference between the interest rate paid on a liability (e.g., a customer deposit) and the interest rate on the capital market for the same maturity. For the asset margin, the reference rate that determines this investment return is often approximated with the IRS curve. It is, however, not straightforward to determine the appropriate reference rate for banks' non-maturing liabilities, such as demand or saving deposits, because they do not have a definite maturity. Therefore, the appropriate reference rate is derived from a replication portfolio of rolling swap transactions with maturities chosen to match the economically relevant term for which customers' money is invested. The interest rate resulting from the rolling replication portfolio of IRS transactions is the reference rate used for the calculation of the liability margin.

The structural margin results from the interest rate risk (i.e., maturity transformation) taken by the bank. It depends on the slope of the yield curve and on the bank's hedging strategy. If the bank fully hedges the interest rate risk arising from its asset and liability positions by means of swap transactions with the same maturity, the structural margin is zero. By contrast, if the bank does not hedge the interest rate risk, the structural margin corresponds to the difference between the IRS rates relevant for the asset and liability positions. Subsequently, we focus on the asset and liability margins because the structural margin depends on the hedging behaviour, which is typically unknown and may significantly differ from one bank to another.

[5]The effective reference rate would include in addition to the IRS curve the bank-specific conditions on the money and the capital markets. For example, if a bank borrows at the 6-month LIBOR + 20 bps, then 20 bps are added to the IRS curve to reflect the true refinancing costs. If the bank funds part of its balance sheet with capital market issuances, such as bonds, part of these funding costs are also added to the reference rate.

3.2 Negative market rates and negative interest on reserves

The challenge posed by negative interest rates to the banks' interest rate margin is twofold. First, while the deposit rate generally has a lower bound at zero, the IRS rates at which deposits are invested may be negative, making the liability margin negative. Second, banks pay a negative interest rate on (part of the) reserves that they hold at the central bank, which reduces their interest asset margin. Of course, these two challenges are related, since the central bank pushes market rates below zero by applying a negative rate on (part of) banks' reserves; they are nevertheless distinct. The SNB grants banks exemption limits so that only part of their reserves are subject to negative interest.[6] Even a bank with large exemptions that does not pay a negative rate on its reserves is exposed to negative capital market rates.

The current paper focuses on the effect of negative IRS rates on banks' interest rate setting behaviour. The effect that the negative rate on (part of the) reserves could have on banks' interest rate setting behaviour is not explicitly taken into account, because it would require matching the interest rates of individual banks with their individual reserves exposed to the negative interest rate, which goes beyond the scope of this paper.[7]

4 Data

This paper uses bank and market rates at monthly frequency, covering the sample period from January 2000 to December 2019. Our sample thus starts when the SNB began implementing monetary policy by steering short-term interest rates (Swiss National Bank, 1999). We end the sample period before the onset of the COVID-19 pandemic to avoid distortions due to the public credit support programmes introduced during the pandemic.

Bank rates are obtained from the SNB's banking statistics.[8] Fixed-rate mortgage interest rates correspond to published interest rates for new loans and are reported for maturities from

[6] Only reserves above an exemption threshold are subject to the negative rate. For domestic banks, the threshold is a multiple of the minimum reserve requirement. Originally, the factor of multiplication was 20 and applied to the minimum reserve requirements as of the maintenance period 20 October to 19 November 2014; since November 2019, the factor has been applied to the 3-year moving average of current minimum reserve requirements. As of November 2019, the factor was increased from 20 to 25 and as of April 2020 from 25 to 30. For all other institutions without a minimum reserve requirement (e.g., foreign banks), the exemption threshold amounts to at least 10 million Swiss francs. For details, see Swiss National Bank (2019c).

[7] See, e.g., Schelling and Towbin (2020) and Fuhrer, Nitschka, and Wunderli (2020) for empirical evidence in this regard.

[8] Note that the SNB's banking statistics for fixed-rate mortgages are only available starting in December 2007. For the period before December 2007, we use data collected in an interest rate survey by VZ VermoegensZentrum AG. For a more detailed discussion on the data from VermoegensZentrum and the combination of the two datasets, see Cecchin (2011). Additional information on the SNB's banking statistics can be found at https://emi.snb.ch/de/emi/ZISAX.

1 to 15 years.[9] Deposit interest rates correspond to the rate paid by banks on saving accounts of retail customers.[10] In our analysis, we use aggregated rates by taking the median interest rate reported by banks. For the analysis of bank's individual interest rates, we use data from the SNB's banking statistics, i.e., from December 2007 onwards.

IRS rates are obtained from Bloomberg Ltd. We use fixed-floating IRS rates using the 6-month LIBOR as a floating leg. In an IRS contract, the two parties agree to exchange the fixed interest rate for the floating interest rate over the specified maturity. IRS are a very popular instrument to trade interest rate risks (see, e.g., the recent BIS Triennial Survey 2019), and the IRS curve is widely used by banks to price mortgage rates (see, e.g., Bicksler and Chen (1986), Moser (2017) or Maechler (2020)).[11] IRS rates are available at daily frequency, and we use a simple average over the last 5 working days prior to the month-end to avoid potential month-end effects and to consider the fact that banks may report mortgage rate conditions around (but not exactly at) the month-end. For the overall sample period, mortgage rates vary between approximately 1.0% and 6.0%, while the range for IRS rates is between -1.0% and 4.7% (see Table 1). The variation in the deposit rate is considerably smaller, with a range of approximately 0.0% to 1.6%.

Table 1: Descriptive statistics

	mean	median	sd	min	max	count
imor^{5Y}	2.652	2.600	1.296	1.050	5.700	240
imor^{7Y}	2.918	3.005	1.294	1.100	5.875	240
imor^{10Y}	3.218	3.400	1.274	1.170	6.000	240
irs^{1Y}	0.755	0.430	1.343	-0.950	4.000	240
irs^{3Y}	1.088	1.075	1.406	-1.020	4.260	240
irs^{5Y}	1.387	1.615	1.405	-0.940	4.370	240
irs^{7Y}	1.645	1.920	1.387	-0.820	4.490	240
irs^{10Y}	1.934	2.265	1.363	-0.600	4.660	240
idep	0.489	0.380	0.445	0.025	1.590	240

Table 1 provides descriptive statistics of mortgage, deposit and IRS rates. All interest rates are in percent. $imor^i$ = mortgage rate of maturity i; irs^j = interest rate swap of maturity j; $idep$ = deposit rate. The sample period is from January 2000 to December 2019.

For our analysis, we divide the sample into three parts, reflecting the episodes of positive, zero and negative policy rates of the SNB as well as the resulting movements of the average

[9] Note that we focus on published interest rates, as no actually contracted lending rates are available. "Published interest rates" indicates that these rates are available, e.g., on the website or in customer brochures. Rates are thus indicative and do not necessarily correspond to actual rates on newly granted loans.

[10] Note that no data for wholesale clients are available.

[11] According to the BIS Triennial Survey 2019, IRS account for approximately 50% of all traded Swiss franc interest rate derivatives (excluding overnight index swaps). See https://www.bis.org/statistics/rpfx19.htm.

deposit rate of banks, which is key for our proposed pricing mechanism of banks' interest rates. The first subsample covers the positive-rate period, from January 2000 to July 2009, when both policy and bank rates were firmly in positive territory and thus unconstrained. The second subsample captures the zero-rate period and begins in August 2009, after the policy rate of the SNB was lowered aggressively and when the average deposit rate of banks fell below previous all-time lows to 0.4%. Thus, for this period, banks' deposit rates approach zero and potentially become stickier as they start to be constrained if banks do not want to lower their deposit rates below zero. The zero-rate period ends in December 2014. The last subsample, i.e., the negative-rate period, begins in January 2015, when the SNB introduced the negative rate on part of banks' reserves and the average deposit rate of banks declined to 0.1%, i.e., very close to zero and thus potentially constrained. The last sample period ends in December 2019.

Figure 1 shows the SNB's policy rates. From 2000 to mid-2019, the SNB implemented monetary policy using a target range for the 3-month Swiss franc LIBOR, normally ensuring that the market rate stayed in the middle of this corridor (for details, see Swiss National Bank (1999)). At its monetary policy assessment in June 2019, the SNB decided to keep interest rates unchanged but introduced its own policy rate, which replaced the target range for the 3-month Swiss franc LIBOR (Jordan, 2019b). Over the full sample period, roughly two interest rate cycles can be observed. While in 2003 the SNB's LIBOR target range only temporarily reached the zero lower bound, the target range touched zero after the global financial crisis and became negative as of January 2015.

Figure 1: SNB's policy rates

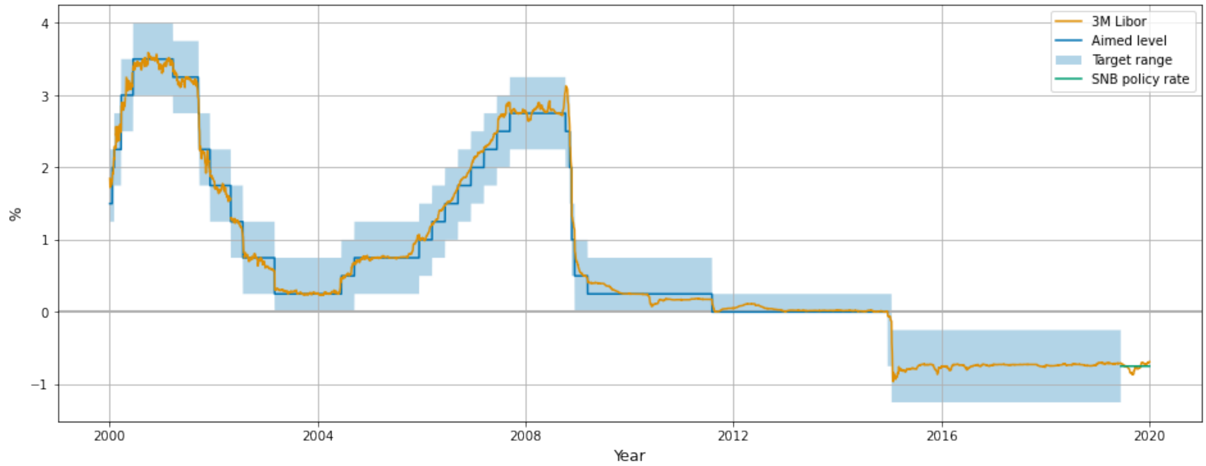

Figure 1 depicts the SNB's 3-month LIBOR target range, the targeted level, the SNB policy rate (since June 2019) and the effective 3-month LIBOR. The sample period lasts from January 2000 to December 2019.

Figure 2: Development of rates

Figure 2 depicts the development of 10-year mortgage rates, 10-year and 3-year IRS and deposit rates. The vertical dashed lines indicate subsamples that are defined as follows: 1) positive-rate environment = January 2000 to July 2009; 2) zero-rate environment = August 2009 to December 2014; 3) negative-rate environment = January 2015 to December 2019.

Figure 3: Interest rate margin

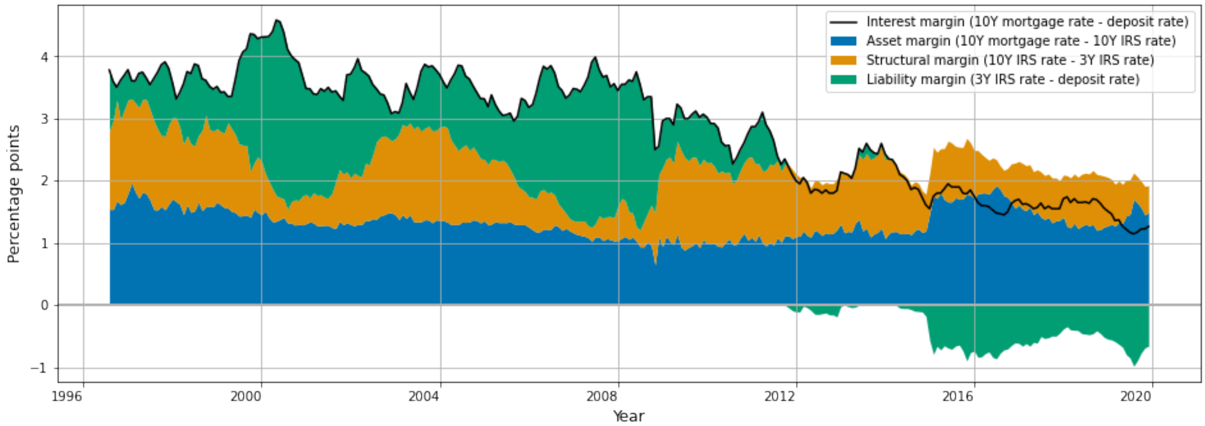

Figure 3 provides a simple approximation of the interest rate margin based on a fixed-rate 10-year mortgage rate and bank deposit rates. The 3-year IRS is used as a replication for customer deposits, and interest rate risk is assumed not to be hedged. The black line indicates the overall interest margin. The blue area corresponds to the asset margin, the green area to the liability margin and the orange area to the structural margin.

Figure 2 shows banks' deposit and 10-year mortgage rates together with the 3- and 10-year IRS rates. The pass-through of the interest rate cut in January 2015 to IRS rates was strong and fast: between December 2014 and February 2015, the 3-year IRS rate fell by 65 bps and the 10-year IRS rate by 46 bps. The deposit rate is least volatile and stays above zero even as the policy rate and market rates turn negative.

Based on the data in Figure 2, we approximate banks' margins according to the breakdown discussed in the previous section. The black line in Figure 3 shows the (instantaneous) interest margin.[12] It was roughly stable up to the global financial crisis and has declined since. The asset margin, computed as the difference between 10-year mortgage and IRS rates, displayed little variability before 2015, reflecting that mortgage rates moved closely with the maturity-matched IRS rate. To approximate the liability margin, we use the 3-year maturity as a proxy for the average replication portfolio (Zurbrügg, 2016). The liability margin, i.e., the difference between the 3-year IRS rate and the deposit rate, varied more, due to the sluggishness of the deposit rate. The liability margin first turned negative in 2011, meaning that banks at that point ceased to earn money on new customers' deposits.[13] In January 2015, when the SNB introduced negative

[12] Figure 3 shows the interest margin of new businesses at current interest rates. A bank's effective interest income, however, results from the bank's entire portfolio of past transactions.

[13] Banks continue to earn money on their overall customers' deposits as long as the reference rate determined by their replication portfolio is above their deposit rate. As past positive IRS tranches are gradually replaced by new negative IRS tranches, the reference rate of the replication portfolio and thereby the liability margin falls. Moreover, banks earn money on the fees that they charge their customers, which, according to anecdotal evidence, have increased. Additionally, our statement refers to savings accounts of retail customers. Customers with large

rates and market rates fell, the asset margin increased, and the liability margin turned clearly negative. It thus appears that banks raised their mortgage rates when they started making losses on their deposits. Furthermore, since that point in time, the asset margin has displayed more variability than before.

The structural margin simply depicts the difference between 10-year and 3-year IRS rates and reflects the slope of the yield curve. It tends to evolve inversely to the interest rate cycle, increasing with lower policy rates and decreasing with higher policy rates.[14] This margin is earned by the bank only to the extent that the bank leaves the interest rate risk unhedged. However, we do not analyse whether the introduction of negative interest rates has affected the hedging behaviour of banks and implicitly assume that they fully hedge their interest-rate risk by focusing on the asset and liability margins.

5 Econometric analysis

In their most basic form, bank rates can be thought of as being a function of banks' cost of funds, which are often approximated via market rates (see the literature in the tradition of Rousseas (1985) or, e.g., De Bondt (2005) for a more recent discussion). The relationship can be expressed as follows:

$$ibank_t^i = \mu_t^i + \beta^i imarket_t^i, \tag{1}$$

where $ibank_t^i$ is the bank lending or deposit rate of maturity i and $imarket_t^i$ the market rate with the same maturity, all at time t. If banks keep their margin over the market rate stable, the mark-up μ_t^i that they charge is a constant, and β^i is equal to one. In practice, bank rates may respond less than one-to-one to market rates, so that β^i is smaller than one. Moreover, the mark-up μ_t^i may vary over time in a market with imperfect competition.

If interest rates are set according to Equation 1, the adjustment to a change in the market rate is immediate. The literature often estimates the first-difference version of Equation 1, i.e.,

$$\Delta ibank_t^i = c^i + \beta^i \Delta imarket_t^i + \varepsilon_t^i, \tag{2}$$

where $\Delta\mu_t^i$ is assumed to be a constant c^i. Thus, this specification allows for a trend in μ_t^i. We estimate this type of equation in Section 5.1, using for mortgages a panel across different

deposits have increasingly been paying negative interest to banks.

[14] On the impact of the introduction of the negative policy rate on capital market rates, see Grisse, Krogstrup, and Schumacher (2017), Grisse and Schumacher (2018) and Brandão-Marques, Casiraghi, Gelos, Kamber, and Meeks (2021).

maturities i.

This first-difference approach does not allow for more drawn-out responses of bank rates to market rates, implicitly being based on the strong assumption that pass-through occurs within the same period. If bank rates exhibit a long-run relationship with market rates and different short-run dynamics, an error correction model of the type

$$\begin{aligned}\Delta ibank_t^i &= -\alpha^i(ibank_{t-1}^i - \beta^i imarket_{t-1}^i) + \gamma_1^i \Delta ibank_{t-1}^i + \ldots \\ &\quad + \delta_0^i \Delta imarket_t^i + \delta_1^i \Delta imarket_{t-1}^i + \ldots + \eta_t^i + \varepsilon_t^i, \end{aligned} \tag{3}$$

is appropriate. We use this setup in Section 5.2. This type of model fits Swiss interest rates well until deposit rates reach the zero lower bound. Moreover, we report results based on aggregate bank rates, covering the sample period 2000 until 2019, as well as based on bank-specific interest rates, using the shorter sample period from December 2007 onwards.

5.1 First-difference regressions

5.1.1 Aggregated bank rates

As a first step, we establish formally the decrease in the co-movement between aggregated bank and IRS rates. For the fixed-rate mortgage rates, we run the following fixed effects regression:

$$\Delta imor_t^i = \beta_{mor}^i \Delta irs_t^i + year_t + month_t + \varepsilon_t^i. \tag{4}$$

We estimate the relationship conditional on the maturity i using the most popular fixed-rate mortgage rate maturities, i.e., the 5-, 7- and 10-year maturities. The coefficient of interest is β_{mor}^i. It measures the effect of a change in the IRS rate (Δirs_t^i) on the change in the maturity-matched mortgage rate ($\Delta imor_t^i$) at time t with maturity i. To control for potential calendar and year effects, we include corresponding dummy variables.

Table 2 shows that the impact of a change in the IRS rate on the maturity-matched mortgage rate is approximately 0.70 and statistically significant. In other words, the effect indicates that a change in the IRS rate by +100 bps results in a change of about +70 bps in the mortgage rate. This finding is robust to different specifications of fixed effects, as illustrated in Columns 4–6 for the 10-year maturity.

In Table 3, we provide evidence that the coefficient declines through the different subsamples. For the positive-rate environment, the relationship is estimated to be approximately 0.8, while

Table 2: Mortgage rate regression

	(1) Δ imor^{5Y}	(2) Δ imor^{7Y}	(3) Δ imor^{10Y}	(4) Δ imor^{10Y}	(5) Δ imor^{10Y}	(6) Δ imor^{10Y}
Δ irs^{5Y}	0.71***					
	(0.06)					
Δ irs^{7Y}		0.73***				
		(0.06)				
Δ irs^{10Y}			0.73***	0.73***	0.73***	0.74***
			(0.05)	(0.05)	(0.05)	(0.05)
Constant	0.03	0.01	0.00	0.01	-0.01	-0.00
	(0.03)	(0.03)	(0.03)	(0.02)	(0.02)	(0.00)
Observations	239	239	239	239	239	239
Adjusted R^2	0.685	0.662	0.674	0.695	0.685	0.704
Period	all	all	all	all	all	all
Year FE	Yes	Yes	Yes	No	Yes	No
Month FE	Yes	Yes	Yes	Yes	No	No

Table 2 provides the mortgage rate regression results by maturity bucket. The dependent variable is the monthly yield change in the mortgage rate for a specific maturity bucket (5-, 7- and 10-year). The independent variable is the monthly yield change in the maturity-matched IRS. Heteroscedasticity-robust standard errors are reported (in parentheses). ***, ** and * denote statistical significance (two-tailed) at the 1%, 5%, and 10% significance levels, respectively. The sample period is from January 2000 to December 2019.

the point estimates are marginally higher, with values of approximately 0.85 in the zero-rate environment. For the negative-rate period, the point estimates decline considerably to a range between 0.2 and 0.4. This suggests that in the negative-rate environment, a decline by 100 bps in market rates appears to cause only a moderate decline of 20 to 40 bps in mortgage rates. Underlying this result is the assumption that the response of the mortgage rate is completed within the month and that no other variables influence it. Moreover, as deposit rates gradually decline over time, this result is also obtained when we condition on different levels of the deposit rate.

Table 3: Mortgage rate regression by sample period

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	Δ imor^{5Y}	Δ imor^{7Y}	Δ imor^{10Y}	Δ imor^{5Y}	Δ imor^{7Y}	Δ imor^{10Y}	Δ imor^{5Y}	Δ imor^{7Y}	Δ imor^{10Y}
Δ irs^{5Y}	0.80***			0.88***			0.21***		
	(0.07)			(0.04)			(0.04)		
Δ irs^{7Y}		0.81***			0.85***			0.31***	
		(0.07)			(0.04)			(0.05)	
Δ irs^{10Y}			0.78***			0.87***			0.44***
			(0.07)			(0.04)			(0.05)
Constant	-0.01	-0.03	-0.04	0.01	0.00	0.02	0.02	0.05*	0.06**
	(0.03)	(0.04)	(0.04)	(0.02)	(0.02)	(0.02)	(0.02)	(0.03)	(0.03)
Observations	114	114	114	65	65	65	60	60	60
Adjusted R^2	0.721	0.680	0.655	0.925	0.909	0.911	0.466	0.485	0.671
Period	Positive	Positive	Positive	Zero	Zero	Zero	Negative	Negative	Negative
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Month FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Table 3 provides the mortgage rate regression results by maturity bucket and sample period. The dependent variable is the monthly yield change in the mortgage rate for a specific maturity bucket (5-, 7- and 10-year). The independent variable is the monthly yield change in the maturity-matched IRS. Heteroscedasticity-robust standard errors are reported (in parentheses). ***, ** and * denote statistical significance (two-tailed) at the 1%, 5%, and 10% significance levels, respectively. The overall sample period is from January 2000 to December 2019.

Table 4: Deposit rate regression

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
	Δ idep	Δ idep	Δ idep	Δ idep	Δ idep	Δ idep	Δ idep	Δ idep	Δ idep	Δ idep	Δ idep	Δ idep
Δ irs^{1Y}	0.02*			0.02			-0.01			0.03**		
	(0.01)			(0.01)			(0.04)			(0.02)		
Δ irs^{3Y}		0.03			0.03			0.00			0.02	
		(0.02)			(0.02)			(0.03)			(0.01)	
Δ irs^{5Y}			0.03*			0.03			-0.01			0.02*
			(0.01)			(0.02)			(0.03)			(0.01)
Constant	-0.01	-0.00	-0.00	-0.03	-0.03	-0.03	-0.04*	-0.04*	-0.04*	-0.01	-0.01*	-0.01*
	(0.03)	(0.03)	(0.03)	(0.05)	(0.05)	(0.05)	(0.02)	(0.02)	(0.02)	(0.00)	(0.01)	(0.01)
Observations	239	239	239	114	114	114	65	65	65	60	60	60
Adjusted R^2	0.177	0.182	0.180	0.194	0.198	0.198	0.046	0.045	0.048	0.210	0.173	0.172
Period	all	all	all	Positive	Positive	Positive	Zero	Zero	Zero	Negative	Negative	Negative
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Month FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Table 4 provides the deposit rate regression results for different IRS rates. The dependent variable is the monthly yield change in the deposit rate. The independent variable is the monthly yield change in the IRS with maturity i. Heteroscedasticity-robust standard errors are reported (in parentheses). ***, ** and * denote statistical significance (two-tailed) at the 1%, 5%, and 10% significance levels, respectively. The overall sample period is from January 2000 to December 2019.

For the analysis of the transmission of IRS rates to deposit rates, we run variations of the regression:

$$\Delta idep_t = \beta^i_{dep} \Delta irs^i_t + year_t + month_t + \varepsilon^i_t, \tag{5}$$

where β^i_{dep} measures the effect of a change in the IRS rate (Δirs^i_t) on the change in the deposit rate ($\Delta idep_t$). We again include month and year fixed effects. In contrast to fixed-term mortgages, there is no fixed maturity for deposits and therefore no obvious IRS maturity to be used in the estimation. Since the legal contract on deposit accounts is often on sight (overnight), a short maturity might be appropriate. However, the use of a longer maturity might be reasonable since deposits de facto remain on banks' books for a considerable amount of time. For this first simple analysis, we are agnostic in this regard and use market rates for maturities of 1, 3 and 5 years.

Table 4 reveals that the estimated β_{dep} is quite low and statistically mostly not significant at the 5% significance level for all IRS maturities. This is the case overall but also for the specific subsamples.[15]

5.1.2 Individual bank rates

To provide further evidence that the transmission from IRS to bank rates declines when deposit rates approach zero, we run first-difference regressions on data for individual banks. Exactly as in Equations 4 and 5, we estimate the relationship conditional on the maturity using the most popular maturities, but at bank level. Limited data availability shifts the beginning of our sample from January 2000 to December 2007. To account for the panel dimension of the dataset, we additionally include bank fixed effects, and standard errors are clustered at bank level.

Conducting the regression at bank level allows us also to control for the possibility that different banks reached the zero lower bound for their deposit rates at different points in time. To conduct the regression analysis separately for different levels of bank deposit rates, we use the deposit rate ranges used for the definition of our sample periods, i.e., with thresholds at 0.4% and 0.1%, corresponding to the zero- and negative-rate periods.[16] Table 5 provides the results

[15] Note that we do not find a statistically significant relationship when we account for the absolute size (large and small) and direction (increase or decrease) of the change in IRS rates.

[16] One might be concerned about a situation, for example, in which a bank had already lowered its deposit rate close to zero while the SNB policy rate was still clearly positive. Considering only banks' deposit rates, this situation would be reported as a zero-rate environment, while it is still the positive-rate environment as defined in Section 4. However, the results are unchanged if we both condition on the level of banks' deposit rates *and* restrict the sample to the time periods considered in the estimation based on aggregate data. Thus, the aforementioned

for mortgage rates. When deposit rates are above 0.4%, the regression coefficient is between 0.8 and 0.9, indicating an almost one-to-one relationship between changes in capital market and mortgage rates. For deposit rates below 0.4% but above 0.1%, the relationship declines somewhat but remains relatively high, with point estimates between 0.5 and 0.7. However, when deposit rates decline below 0.1%, the regression coefficients decline considerably, with point estimates between 0.2 and 0.5. Consequently, the analysis of aggregated and individual bank data suggests that the behaviour of mortgage rates is not well explained by contemporaneous changes in maturity-matched market rates when deposit rates approach zero.

Finally, we also conduct the deposit rate regression using bank-level data for the different levels of the deposit rate. Unlike the results in Table 4, two out of three coefficients turn statistically significant for the positive-rate and zero-rate periods, while they remain statistically insignificant for the negative-rate period. With point estimates ranging between 0.01 and 0.02, they remain, however, economically rather small for the positive- and zero-rate periods.[17]

theoretical situation does not seem to be relevant given our data.

[17]The more pronounced response of mortgage rates than of deposit rates could be due to stronger competition in this field (customers are likely to be more interest rate sensitive with respect to mortgages than regarding deposits) and to the fact that mortgage rates apply only to new contracts, whereas deposit rates apply for the entire stock of deposit accounts. Note that similar results are obtained when we condition on sample periods instead of the level of deposit rates for both the mortgage and deposit rate regression (available upon request).

Table 5: Mortgage rate regression conditional on deposit rate – bank level

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	Δ imor^{5Y}	Δ imor^{7Y}	Δ imor^{10Y}	Δ imor^{5Y}	Δ imor^{7Y}	Δ imor^{10Y}	Δ imor^{5Y}	Δ imor^{7Y}	Δ imor^{10Y}
Δ irs^{5Y}	0.83***			0.52***			0.21***		
	(0.02)			(0.02)			(0.02)		
Δ irs^{7Y}		0.86***			0.62***			0.35***	
		(0.02)			(0.02)			(0.02)	
Δ irs^{10Y}			0.83***			0.70***			0.49***
			(0.02)			(0.02)			(0.03)
Constant	0.03***	0.02**	0.02*	0.14***	0.12**	0.05	0.05***	0.06***	0.05***
	(0.01)	(0.01)	(0.01)	(0.04)	(0.05)	(0.06)	(0.00)	(0.00)	(0.00)
Observations	992	992	992	3045	3045	3045	2753	2753	2753
Adjusted R^2	0.848	0.841	0.814	0.485	0.613	0.667	0.170	0.321	0.441
Deposit rate	(0.4%, ∞)	(0.4%, ∞)	(0.4%, ∞)	(0.1%, 0.4%]	(0.1%, 0.4%]	(0.1%, 0.4%]	(-∞,0.1%]	(-∞,0.1%]	(-∞,0.1%]
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Month FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Bank FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Table 5 provides the mortgage rate regression results using banks' individual rates and conditional on the maturity bucket and the level of the deposit rate. The dependent variable is the monthly yield change in the mortgage rate by bank k for a specific maturity bucket (5-, 7- and 10-year). The independent variable is the monthly yield change in the maturity-matched IRS. Standard errors (reported in parentheses) are clustered at the bank level. ***, ** and * denote statistical significance (two-tailed) at the 1%, 5%, and 10% significance levels, respectively. The sample period is from December 2007 to December 2019.

Table 6: Deposit rate regression conditional on deposit rate – bank level

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	Δ idep	Δ idep	Δ idep	Δ idep	Δ idep	Δ idep	Δ idep	Δ idep	Δ idep
Δ irs^{1Y}	0.01**			0.00			-0.00		
	(0.01)			(0.00)			(0.00)		
Δ irs^{3Y}		0.02*			0.01**			0.00	
		(0.01)			(0.01)			(0.01)	
Δ irs^{5Y}			0.02***			0.01**			-0.00
			(0.01)			(0.01)			(0.01)
Constant	-0.05***	-0.05***	-0.05***	-0.57***	-0.57***	-0.57***	-0.01***	-0.01***	-0.01***
	(0.01)	(0.02)	(0.01)	(0.07)	(0.07)	(0.07)	(0.00)	(0.00)	(0.00)
Observations	992	992	992	3045	3045	3045	2753	2753	2753
Adjusted R^2	0.109	0.110	0.110	0.276	0.277	0.277	0.059	0.058	0.059
Deposit rate	(0.4%, ∞)	(0.4%, ∞)	(0.4%, ∞)	(0.1%, 0.4%]	(0.1%, 0.4%]	(0.1%, 0.4%]	(-∞,0.1%]	(-∞,0.1%]	(-∞,0.1%]
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Month FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Bank FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Table 6 provides the deposit rate regression results using banks' individual rates and conditional on the maturity bucket and the level of the deposit rate. The dependent variable is the monthly yield change in the deposit rate by bank k. The independent variable is the monthly yield change in the IRS with maturity i. Standard errors (reported in parentheses) are clustered at the bank level. ***, ** and * denote statistical significance (two-tailed) at the 1%, 5%, and 10% significance levels, respectively. The sample period is from December 2007 to December 2019.

5.2 Error correction approach

5.2.1 Aggregated bank rates

The analysis above has focused only on short-run dynamics and on contemporaneous changes in interest rates, implicitly assuming that pass-through occurs within the same period. In the following, we take into account both short-run and long-run relations between the different interest rates and use an error correction framework as in Equation 3.

More specifically, we follow Pesaran and Shin (1998) and Pesaran, Shin, and Smith (2001) and use autoregressive distributed lag (ARDL) models, which can be reformulated as error correction models.[18] In general, an ARDL(p, q) model for a bank rate $ibank_t^i$ is defined as

$$a^i(L)ibank_t^i = c^i(L)imarket_t^i + \varepsilon_t^i\,, \tag{6}$$

where $a^i(L)$ and $c^i(L)$ are suitably defined lag polynomials of order p and q, respectively, $imarket_t^i$ is a scalar (or vector) of market rates and ε_t^i is an error term with zero mean. Under certain conditions, the model can be rewritten in error correction format as

$$\Delta ibank_t^i = -\alpha^i(ibank_{t-1}^i - \beta^{i'} imarket_{t-1}^i) + \sum_{j=1}^{p-1} \gamma_j^i \Delta ibank_{t-j}^i + \sum_{j=0}^{q-1} \delta_j^{i'} \Delta imarket_{t-j}^i + \varepsilon_t^i\,, \tag{7}$$

where $\alpha^i \equiv a^i(1)$, $\beta^i \equiv \frac{c^i(1)}{a^i(1)}$ and γ_j^i and δ_j^i are derived from the underlying parameters of the original model.[19] Equation 7 is a generalisation of Equation 3, and it includes a constant and can contain a trend.

In our case, $ibank_t^i$ corresponds to either the 10-year mortgage rate $imor_t^{10Y}$ or the deposit rate $idep_t$, while in the basic model, $imarket_t^i$ is the IRS rate of the corresponding maturity, i.e., 10 years for the 10-year mortgage rate and 3 years for the deposit rate.[20] We estimate the models for the three subsamples, where the lag order p and q is determined based on the Schwarz criterion and cross-checked to eliminate any serial correlation in the residuals.

The results are presented in Table 7. For the mortgage rate, the F-bounds tests indicate cointegration for all subsamples,[21] so that the error correction formulation is indeed admissible.

[18] ARDL or error correction models are regularly used in the study of interest rate pass-through; see, for example, De Bondt (2005) and Sopp (2018).

[19] For more details on the ARDL model and some derivations, see Hassler and Wolters (2006).

[20] As indicated above, the 3-year maturity is often used as a proxy for the average replication portfolio of a Swiss bank (Zurbrügg, 2016). We present robustness checks with the 1- and 5-year IRS rates in the deposit-rate equation in Appendix A.

[21] ARDL models, in principle, can accommodate both stationary and non-stationary variables, and correspond-

Table 7: ARDL models for bank rates in error correction representation – simple model

	(1) $\Delta imor^{10Y}$	(2) $\Delta imor^{10Y}$	(3) $\Delta imor^{10Y}$	(4) $\Delta idep$	(5) $\Delta idep$	(6) $\Delta idep$
Long-run dynamics						
α	0.396***	0.962***	0.378***	0.059***	0.087**	0.144***
β_{10Y}	0.860***	0.938***	0.480***	–	–	–
β_{3Y}	–	–	–	0.595***	0.094	0.014
Trend	-0.005***	0.003***	-0.009***	–	–	–
Short-run dynamics						
ARDL spec.	(2,2)	(2,0)	(1,1)	(1,3)	(1,0)	(1,1)
F-bounds test	5.396**	285.953***	13.645***	9.299***	2.706	6.126**
Observations	115	65	60	115	65	60
Adjusted R^2	0.89	0.93	0.79	0.34	0.07	0.35
Period	Positive	Zero	Negative	Positive	Zero	Negative

Table 7 provides the estimates of the ARDL model in error correction representation for the simple model using only one IRS rate as the main explanatory variable. The subsamples are defined as follows: 1) positive-rate environment = January 2000 to July 2009; 2) zero-rate environment = August 2009 to December 2014; 3) negative-rate environment = January 2015 to December 2019. ***, ** and * denote statistical significance (two-tailed) at the 1%, 5%, and 10% significance levels, respectively.

Moreover, the long-run coefficient β^i for the first two subsamples is similar to the estimates in Section 5.1 and estimated at approximately 0.9. This indicates that using a simple model that assumes only a contemporaneous response of the mortgage rate to the market rate seems appropriate. In the negative-rate period, the coefficient in Table 7 is estimated at 0.5, which is slightly larger than the short-run estimate reported in Table 3. This is a first indication that it seems to be important to take into account more complex pass-through dynamics in a negative-rate environment. We also identify a significant trend in mortgage rates, an issue that we return to in Section 6.2.

The change in interest rate setting becomes even more obvious when we consider the deposit rate. In the positive-rate environment, the F-bounds test indicates cointegration, and long-run pass-through is estimated at approximately 0.6. This is considerably stronger than the pass-through shown in Table 4. The adjustment process for the deposit rate thus seems to be more

ing tests for cointegration do not require pre-testing for the order of integration (only exclusion of an order larger than 1).

drawn out than Equation 5 assumes. In the zero- and negative-rate environments, the long-run coefficient for the deposit rate becomes small and insignificant.[22] This reflects the fact that the deposit rate barely moves in these time periods.

The error correction loading α captures the speed with which banks adjust their rates to deviations from the long-run relation. Overall, the estimates are rather stable over the different subsamples, with the adjustment speed of the mortgage rate considerably higher than that of deposit rates. This reflects the sluggish nature of deposit rate movements, not least because mortgages rates apply to a flow of new mortgages while deposit rates apply to a stock of old and new deposits. Competition may also contribute to the fast speed of adjustment of mortgage rates. One notable exception regarding the similarity of adjustment speeds is the zero-rate period in the case of the mortgage rate: the coefficient more than doubles in comparison with that in the positive-rate period. This could be related to the global financial crisis and the resulting large financial volatility during that period.

In the next step, we start from the previous observation that the long-run pass-through of short-run IRS rates to deposit rates seems to break down in the zero- and negative-rate environments because deposit rates are constrained by the zero lower bound. Without compensating adjustments in other bank rates, a decline in the 3-year IRS rate would lead to a deterioration of bank profits, which banks arguably try to avoid. Since we also observe changes in the coefficients in the equation for the 10-year mortgage rate in the third subsample, and given the increase in mortgage rates when the policy rate was cut below zero (see Figure 3), we conjecture that in such an environment, the lending rate compensates for the stickiness of the deposit rate. To test for this, we estimate an extended ARDL model for the mortgage rate, where we include both the 10-year and 3-year IRS rates as exogenous variables:

$$\Delta imor_t^{10Y} = -\alpha(imor_{t-1}^{10Y} - \beta_{10Y} irs_{t-1}^{10Y} - \beta_{3Y} irs_{t-1}^{3Y}) + \sum_{j=1}^{p-1} \gamma_j \Delta imor_{t-j}^{10Y} + \sum_{j=0}^{q-1} \delta_j \Delta irs_{t-j}^{10Y} + \sum_{j=0}^{r-1} \kappa_j \Delta irs_{t-j}^{3Y} + \varepsilon_t^{10Y} . \tag{8}$$

The resulting estimates for the three subsamples can be found in Table 8.[23] In the positive and zero-rate environment, the coefficient on the 10-year IRS rate is close to one, while the 3-year IRS rate has no impact on the 10-year mortgage rate. In the negative-rate environment, however, the estimate is considerably larger and statistically significant. We estimate β_{3Y} as -0.3, while β_{10Y} is estimated as 0.6. The latter estimate is somewhat larger than the estimate

[22]This is consistent with the F-bounds test not indicating cointegration for the zero-rate environment.

[23]We also conducted first-difference regressions for the 10-year maturity while including changes in the 3-year IRS as additional variable. The results are qualitatively similar to those described in this subsection.

Table 8: ARDL models for bank rates in error correction representation – extended model

	(1) $\Delta imor^{10Y}$	(2) $\Delta imor^{10Y}$	(3) $\Delta imor^{10Y}$
Long-run dynamics			
α	0.490***	0.969***	0.437***
β_{10Y}	0.941***	0.979***	0.636***
β_{3Y}	-0.048	-0.074	-0.317**
Trend	-0.004***	0.002***	-0.009***
Short-run dynamics			
ARDL spec.	(2,2,2)	(2,0,0)	(1,1,1)
F-bounds test	5.594**	220.740***	9.328***
Observations	115	65	60
Adjusted R^2	0.90	0.94	0.80
Period	Positive	Zero	Negative

Table 7 provides the estimates of the ARDL model in error correction representation for the extended model, where both short- and long-run IRS rates are used as main explanatory variables for lending rates. The subsamples are defined as follows: 1) positive-rate environment = January 2000 to July 2009; 2) zero-rate environment = August 2009 to December 2014; 3) negative-rate environment = January 2015 to December 2019. ***, ** and * denote statistical significance (two-tailed) at the 1%, 5%, and 10% significance levels, respectively.

that we obtain if we do not include the 3-year IRS rate. Moreover, in this subsample, the fit of Equation 8 is slightly better than that of Equation 7. The fact that the 3-year IRS rate enters the mortgage rate equation significantly, with the opposite sign of that on the 10-year IRS rate, implies that a reduction in the short-run IRS rate leads in the long run to an increase in the mortgage rate in the negative-rate environment. These new dynamics for mortgage rates, however, are apparent only for the negative-rate environment and not already in the zero-rate period, where we also observe a breakdown in the relation between the deposit and 3-year IRS rates. This might indicate that the shift to the extended dynamics is a gradual process and that it only comes into force when the liability margin clearly turns negative. Only then do banks need to compensate for the negative contribution of the liability side to profits.

5.2.2 Individual bank rates

The estimated shift in dynamics might by blurred by the fact that we work with aggregate data. Consequently, to cross-check the previous results and to exploit the dynamics of individual bank's rate setting, we also estimate a panel ARDL model. The corresponding results are given in Table 9. In the estimation, we condition on the level of the individual bank's deposit rate and include bank fixed effects.[24] Overall, these results are in line with our baseline findings, for both the simple and extended models.[25] In the simple model, the estimated effect of the 10-year IRS rate on the mortgage rate weakens noticeably in the negative-rate environment, while the deposit rate cannot respond anymore in that environment, as it is stuck at the zero lower bound. In the extended model, the shift in dynamics when the mortgage rate also responds to the 3-year IRS rate already becomes apparent in the zero-rate environment. The estimated coefficient is significant, though still small, but becomes noticeably larger in the negative-rate period. Using individual banks' data, thus, seems to help to clarify the change in dynamics at the zero lower bound.[26]

[24] Please note that we use a balanced panel for the analysis in this subsection. Moreover, the conditioning is consistent with the estimation in the previous subsection. In particular, the positive-rate environment is defined as an environment in which the deposit rate is larger than 0.4%. Unfortunately, this estimation is not possible for the deposit rate, as there is not enough variation in the variables in that case.

[25] Analogously to the first-difference regressions, the results of the error correction approach remain unchanged if we not only condition on the level of the banks' deposit rates but also restrict the sample to the respective time periods considered in the estimation based on aggregate data.

[26] Similar findings result when we use fixed sample periods for all banks. The results are available from the authors upon request.

Table 9: Panel ARDL models for individual bank rates in error correction representation – conditional on level of deposit rate

	Simple model					Extended model		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	$\Delta imor_k^{10Y}$	$\Delta imor_k^{10Y}$	$\Delta imor_k^{10Y}$	$\Delta idep_k$	$\Delta idep_k$	$\Delta imor_k^{10Y}$	$\Delta imor_k^{10Y}$	$\Delta imor_k^{10Y}$
Long-run dynamics								
α	1.007***	0.498***	0.380***	0.353***	0.196***	1.039***	0.503***	0.454***
β_{10Y}	–	0.922***	0.464***	–	–	0.909***	0.952***	0.753***
β_{3Y}	–	–	–	0.084***	0.000***	0.012	-0.056**	-0.532***
Trend	0.005***	-0.003***	0.009***	–	–	0.004***	-0.003***	0.008***
Short-run dynamics								
ARDL spec.	(1,1)	(1,1)	(1,1)	(1,1)	(2,2)	(1,1,1)	(1,1,1)	(1,1,1)
Observations	586	1607	1839	1607	1839	586	1607	1839
Period	all	all	all	all	all	all	all	all
Deposit rate (in %)	$(0.4, \infty)$	$(0.1, 0.4]$	$(-\infty, 0.1]$	$(0.1, 0.4]$	$(-\infty, 0.1]$	$(0.4, \infty)$	$(0.1, 0.4]$	$(-\infty, 0.1]$

Table 9 provides the estimates of the panel ARDL model in error correction representation for both the simple model using only one IRS rate as the main explanatory variable and the extended model using two IRS rates. ***, ** and * denote statistical significance (two-tailed) at the 1%, 5%, and 10% significance levels, respectively.

6 Implications for monetary policy

6.1 The effect of deposit rate stickiness

Our results suggest a change in transmission when short-term market rates fall below the lower bound for deposit rates (typically zero): Deposit rates respond to short-term market rates as long as they are above zero, but as deposit rates approach zero, their reaction to changes in short-term market rates becomes weaker. Once deposit rates reach zero, they hardly move at all even if short-term market rates turn negative. Mortgage rates appear to compensate for this, responding to both short- and long-term market rates. Specifically, when the deposit rate is at the zero lower bound and the liability margin turns clearly negative, a decline in long-term market rates still causes mortgage rates to fall, while a decline in short-term market rates causes mortgage rates to rise. This implies that the IRS curve is no longer a simple reference for bank rates.[27]

Our model does not include the monetary policy rate. Since policy rate changes impact short-term market rates and, if the cut is expected to persist, long-term market rates as well, impulse responses showing the impact of market on bank rates can be used to assess whether transmission has changed in a negative-rate environment. We illustrate the change in bank rate dynamics using impulse responses for a change in market rates for the three subsamples. We assume (a) a 100-bps drop in the 3- and 10-year IRS rates (blue lines in the simulations), which would result from a cut in the policy rate that is expected to persist, and (b) a drop only in the 3-year IRS rate by 100 bps (red lines), which would reflect a policy rate cut that is regarded as temporary. Under (a), we thus simulate a parallel downward shift of the yield curve, while under (b), the yield curve steepens because its short end drops. Figures 4 to 6 show for our three subsamples the impact of such market rate movements. For the deposit rate, we use the estimates based on the simple model reported in Table 7; for the lending rates, we base the impulse responses on the results of the extended model in Table 8.

Figure 4 shows the simulations for the positive-rate environment. The left plot shows the response of the mortgage rate and the right plot the response of the deposit rate. The mortgage rate responds only to the parallel shift in the yield curve, which thus also implies a reduction

[27] Note that the choice to compensate the negative liability margin with a higher asset margin is probably driven by a policy decision of each individual bank rather than by a mechanical response that is uniform across the industry as a whole. The extent to which a bank's internal interest rate curve deviates from the market's IRS curve depends on its effective refinancing costs (deposit or capital-market based) and the negative interest rates that it pays on its reserves. Those market participants funding themselves via the capital market may have an advantage and may be able to offer mortgages at more favourable conditions.

Figure 4: Response of bank rates to shocks to IRS rates – positive-rate environment

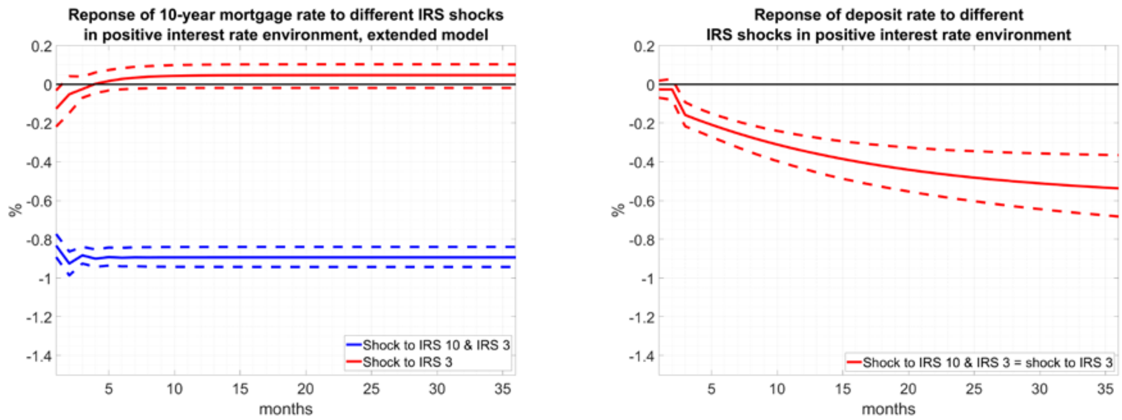

Figure 4 depicts the response of the 10-year mortgage rate and deposit rate, respectively, to a permanent reduction of 100 bps in either both the 10-year and 3-year IRS rates or only the 3-year IRS rate over a horizon of three years (36 months) in the positive-rate environment (January 2000 – July 2009). The response for the deposit rate is calculated based on the estimates given in Table 7 for the simple model using only a single capital market rate as the main explanatory variable. For the mortgage rate, we use the estimates for the extended model presented in Table 8. Dashed lines indicate 95% bootstrap confidence bands.

in the 10-year market rate. Pass-through is relatively fast and close to complete: A year after the shock, the mortgage rate is 89 bps lower and stable. The mortgage rate does not respond to steepening of the yield curve when only short-term market rates move. The corresponding response is not significantly different from zero.

The deposit rate reacts to both kinds of movements in the yield curve since they both lower the short-term market rate. Pass-through is slower and less complete: Three years after the shock, the deposit rate is 54 bps lower and stable. This is in line with our assumption that banks use a replication portfolio with a maturity of three years to infer the reference rate for deposits.

Figure 5: Response of bank rates to shocks to IRS rates – zero-rate environment

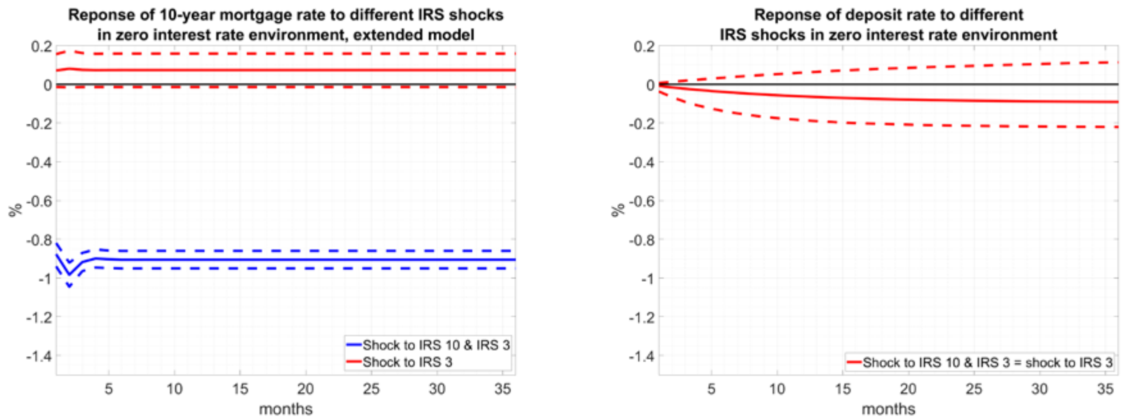

Figure 5 depicts the response of the 10-year mortgage rate and deposit rate, respectively, to a permanent reduction of 100 bps in either both the 10-year and 3-year IRS rates or only the 3-year IRS rate over a horizon of three years (36 months) in the zero-rate environment (August 2009 – December 2014). The response for the deposit rate is calculated based on the estimates given in Table 7 for the simple model using only a single capital market rate as the main explanatory variable. For the mortgage rate, we use the estimates for the extended model presented in Table 8. Dashed lines indicate 95% bootstrap confidence bands.

Figure 5 shows the impulse responses in the zero-rate environment. The mortgage rate again reacts only to the parallel shift in the yield curve. Pass-through is as strong as in the positive-rate environment. The deposit rate again responds much more slowly, and its reaction is considerably weaker and insignificant over the entire horizon. Given that banks are reluctant to lower the deposit rate below zero, the room for adjustment is constrained.

In the negative-rate environment, the deposit rate continues to be stuck at the zero lower bound. In Figure 6, the impulse response on the right is again not significantly different from zero, and the point estimate is even weaker. In response to a steepening of the yield curve when only the short-term market rate drops, the mortgage rate compensates for the stickiness of the deposit rate and increases by 32 bps. This result is close to the estimates reported in Eggertsson, Juelsrud, Summers, and Wold (2019), who show, using Swedish data, that a policy rate cut raises lending rates in a negative-rate environment. In response to a parallel downward shift in the yield curve, the mortgage rate declines, albeit less strongly than in the earlier subsamples. A reduction in the 3- and 10-year IRS rates by 100 bps results in a decline in the mortgage rate of 32 bps.

Figure 6: Response of bank rates to shocks to IRS rates – negative-rate environment

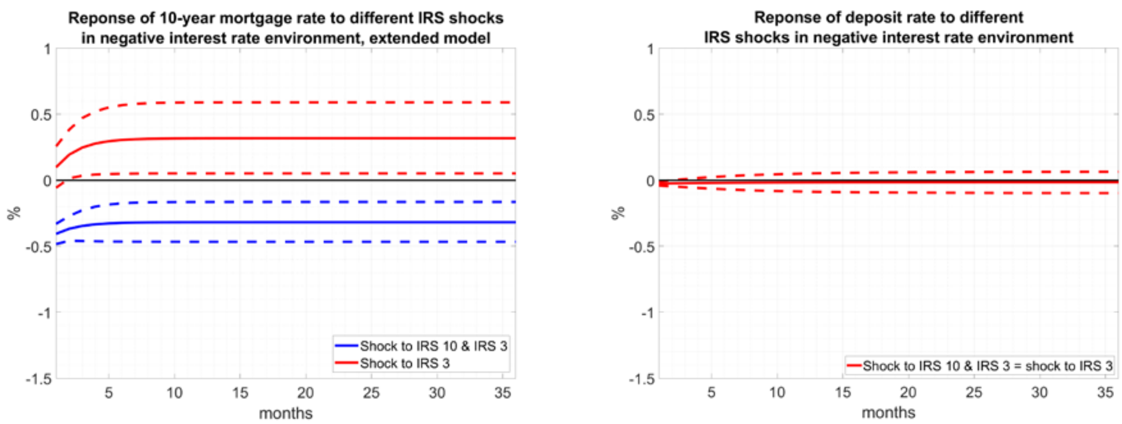

Figure 6 depicts the response of the 10-year mortgage rate and deposit rate, respectively, to a permanent reduction of 100 bps in either both the 10-year and 3-year IRS rates or only the 3-year IRS rate over a horizon of three years (36 months) in the negative-rate environment (January 2015 – December 2019). The response for the deposit rate is calculated based on the estimates given in Table 7 for the simple model using only a single capital market rate as the main explanatory variable. For the mortgage rate, we use the estimates for the extended model presented in Table 8. Dashed lines indicate 95% bootstrap confidence bands.

6.2 Further monetary policy considerations

How important is our finding that pass-through to bank rates becomes weaker in a negative-rate environment, and what does it imply for the transmission of monetary policy? The following additional observations are of importance.

First, for small open economies such as Switzerland, monetary policy transmission via bank interest rates is far less important than the exchange rate channel (see, for example, Jordan (2019a)). Ceteris paribus, lower Swiss interest rates depreciate the exchange rate (see, e.g., Grisse (2020) and Fink, Frei, Maag, and Zehnder (2020)) and thereby stimulate economic activity and increase the inflation rate. For the exchange rate channel to work, policy rate changes must be transmitted to money and capital market rates, which has been the case in Switzerland also in the negative-rate environment (see Grisse, Krogstrup, and Schumacher (2017) and Grisse and Schumacher (2018)). For large and more closed economies, of course, the exchange rate channel is weak, so the change in banks' interest rate setting matters more than in small open economies.

Second, had banks continued to set their interest rates as in the positive-rate environment, mortgage growth might have been stronger than the robust growth that has been observed in Switzerland over the past decades. Given that vulnerabilities have developed in the mortgage and housing markets (see Swiss National Bank (2020)), stronger credit growth would have been unwelcome.

Third, banks have not responded by cutting their mortgage supply, either, even though the reversal rate debate predicts that this should happen once the policy rate becomes "too" negative. Thus, the reversal rate, if it exists, has not been reached in Switzerland. Figure 7 shows that mortgage growth in Switzerland has not changed markedly and, in particular, has not turned negative since 2015.[28] Overall, aggregate data indicate that banks' total interest income has remained broadly constant as a smaller interest margin has been compensated by higher volumes (see Swiss National Bank (2019b)). This pattern is in line with the findings of Fuhrer, Nitschka, and Wunderli (2020), who show that banks compensate for lower profitability inter alia by increasing their lending volumes.

Fourth, Switzerland has seen an increase in competition in the mortgage market. More competition tends to improve transmission of monetary policy. Stronger competition is not directly linked to the negative rate but is instead due to low global interest rates, of which the low Swiss policy rate is a symptom. Pension funds and insurance companies, looking for

[28] There were two noticeable slowdowns, in 2013 and 2014, when macroprudential measures to limit excessive risk-taking were taken.

investments with positive yields, have begun offering mortgages more competitively, thus putting additional pressure on banks' interest rate income. Growth of mortgages granted by pension funds and insurance companies turned positive in 2008, after a prolonged phase of contraction, and began exceeding the growth rate of bank mortgages in 2015 (see Figure 7). By 2019, the market share of pension funds and insurance companies had increased to 5.4%.

Figure 7: Annual growth rate of mortgage lending

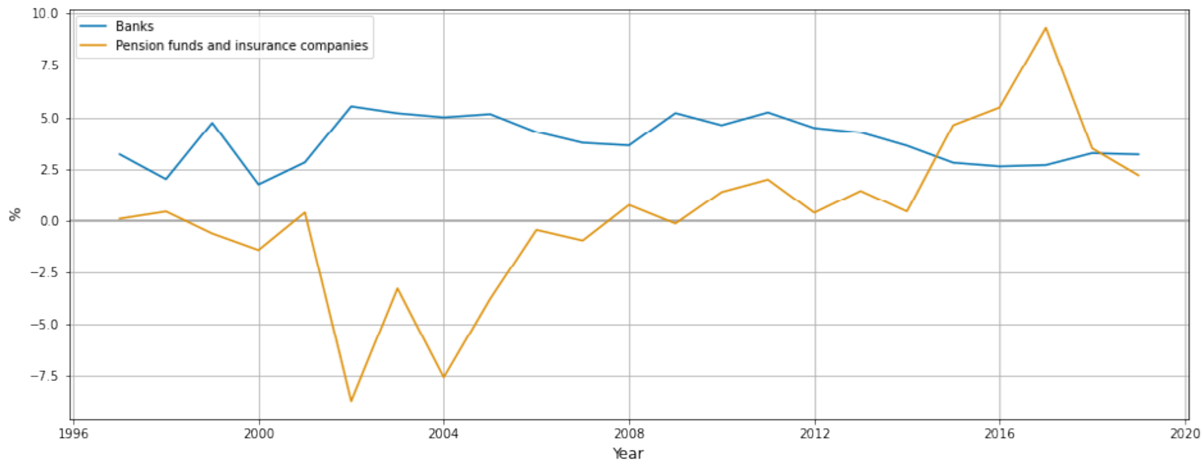

Figure 7 depicts the annual growth rate of mortgage lending of banks as well as pension funds and insurance companies. The sample period runs from 1997 to 2019. Data sources: FINMA, Swiss Federal Statistical Office.

Finally, looking forward, banks' setting of deposit rates may change over time. In Switzerland, commercial banks currently charge negative interest on large customer deposits, and banks seem to be lowering the threshold of what they consider large deposits that should be subject to negative rates. Ernst & Young (2020) report that in 2019, only 21% of banks categorically excluded the possibility of passing on negative rates to their deposit customers. In 2015, that fraction was 70%. In the study, more than half of the banks moreover indicated that they would like to reduce the threshold for negative rates. Apart from passing on negative rates to their customers and thus crossing the zero lower bound on deposit rates, banks can also change their funding structure, relying less on deposits and more on the issuance of bonds, which can yield negative rates and nevertheless be attractive for large commercial investors.

7 Conclusions

Based on Swiss data, this paper shows that banks' interest rate setting behaviour changes when the deposit rate reaches zero. In a positive-rate environment, the pricing of mortgages and deposits follows the dynamics of capital market rates for comparable maturities. When capital market rates fall below zero, the dynamic of mortgage and deposit rates changes. While deposit rates are sticky at zero and no longer respond to short-term capital market rates, mortgage rates start to respond to long- as well as short-term capital market rates, reflecting banks' attempt to preserve their interest margin. As a consequence, a policy rate cut can translate to a higher or lower mortgage rate, depending on its effect on the slope of the yield curve. Overall, our results imply that a policy rate cut reduces bank rates less in the negative-rate environment than in the positive-rate environment.

Future research on the transmission of negative interest rates via banks may want to explore whether banks start to adjust their funding structure more towards capital market products and how this impacts their passing on of the negative interest rate to depositors. Moreover, it would be interesting to study whether banks increase their exposure to interest rate risk to compensate for the negative margin on liabilities in a negative-rate environment.

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A Appendix: Robustness checks

Error correction approach with different maturities. In our error correction analysis, we use a maturity of 3 years for the short-term IRS rate. We here provide the results for 1-year and 5-year IRS rates, respectively. The corresponding results using the 1-year IRS rate are provided in Table A1 for the simple model and in Table A2 for the extended model. The results using the 5-year IRS rate can be found in Table A3 for the simple model and in Table A4 for the extended model. Overall, these results are in line with our baseline findings.

Table A1: ARDL models for bank rates in error correction representation – 1-year IRS rate, simple model

	(1) $\Delta imor^{10Y}$	(2) $\Delta imor^{10Y}$	(3) $\Delta imor^{10Y}$	(4) $\Delta idep$	(5) $\Delta idep$	(6) $\Delta idep$
Long-run dynamics						
α	0.396***	0.962***	0.378***	0.031***	0.098**	0.126***
β_{10Y}	0.860***	0.938***	0.480***	–	–	–
β_{1Y}	–	–	–	0.598***	0.286	-0.079
Trend	-0.005***	0.003***	-0.009***	–	–	–
Short-run dynamics						
ARDL spec.	(2,2)	(2,0)	(1,1)	(1,3)	(1,0)	(1,1)
F-bounds test	5.396**	285.953***	13.645***	5.599*	2.846	4.753
Adjusted R^2	0.89	0.93	0.79	0.41	0.07	0.35
Period	Positive	Zero	Negative	Positive	Zero	Negative

Table A1 provides the estimates of the ARDL model in error correction representation using the 1-year IRS rate as the short-term capital market rate for the simple model using only one IRS rate as the main explanatory variable. The subsamples are defined as follows: 1) positive-rate environment = January 2000 to July 2009; 2) zero-rate environment = August 2009 to December 2014; 3) negative-rate environment = January 2015 to December 2019. ***, ** and * denote statistical significance (two-tailed) at the 1%, 5%, and 10% significance levels, respectively.

Table A2: ARDL models for bank rates in error correction representation – 1-year IRS rate, extended model

	(1)	(2)	(3)
	$\Delta imor^{10Y}$	$\Delta imor^{10Y}$	$\Delta imor^{10Y}$
Long-run dynamics			
α	0.543***	0.927***	0.408***
β_{10Y}	0.925***	0.968***	0.589***
β_{1Y}	-0.037*	-0.160*	-0.741***
Trend	-0.005***	0.002***	-0.008***
Short-run dynamics			
ARDL spec.	(2,4,4)	(1,1,1)	(1,1,0)
F-bounds test	4.079*	10.851***	16.398***
Adjusted R^2	0.90	0.93	0.84
Period	Positive	Zero	Negative

Table A2 provides the estimates of the ARDL model in error correction representation using the 1-year IRS rate as the short-term capital market rate for the extended model, where both short- and long-run IRS rates are used as the main explanatory variables for lending rates. The subsamples are defined as follows: 1) positive-rate environment = January 2000 to July 2009; 2) zero-rate environment = August 2009 to December 2014; 3) negative-rate environment = January 2015 to December 2019. ***, ** and * denote statistical significance (two-tailed) at the 1%, 5%, and 10% significance levels, respectively.

Table A3: ARDL models for bank rates in error correction representation – 5-year IRS rate, simple model

	(1)	(2)	(3)	(4)	(5)	(6)
	$\Delta imor^{10Y}$	$\Delta imor^{10Y}$	$\Delta imor^{10Y}$	$\Delta idep$	$\Delta idep$	$\Delta idep$
Long-run dynamics						
α	0.396***	0.962***	0.378***	0.078***	0.074**	0.157***
β_{10Y}	0.860***	0.938***	0.480***	–	–	–
β_{5Y}	–	–	–	0.665***	0.051	0.019
Trend	-0.005***	0.003***	-0.009***	–	–	–
Short-run dynamics						
ARDL spec.	(2,2)	(2,0)	(1,1)	(1,3)	(1,0)	(1,1)
F-bounds test	5.396**	285.953***	13.645***	12.095***	2.560	7.380**
Adjusted R^2	0.89	0.93	0.79	0.36	0.06	0.36
Period	Positive	Zero	Negative	Positive	Zero	Negative

Table A3 provides the estimates of the ARDL model in error correction representation using the 5-year IRS rate as the short-term capital market rate for the simple model using only one IRS rate as the main explanatory variable. The subsamples are defined as follows: 1) positive-rate environment = January 2000 to July 2009; 2) zero-rate environment = August 2009 to December 2014; 3) negative-rate environment = January 2015 to December 2019. ***, ** and * denote statistical significance (two-tailed) at the 1%, 5%, and 10% significance levels, respectively.

Table A4: ARDL models for bank rates in error correction representation – 5-year IRS rate, extended model

	(1) $\Delta imor^{10Y}$	(2) $\Delta imor^{10Y}$	(3) $\Delta imor^{10Y}$
Long-run dynamics			
α	0.573***	0.965***	0.518***
β_{10Y}	0.966***	0.989***	0.764***
β_{5Y}	-0.074	-0.064	-0.415**
Trend	-0.004***	0.002***	-0.009***
Short-run dynamics			
ARDL spec.	(2,0,2)	(2,0,0)	(3,1,1)
F-bounds test	25.014***	214.594***	11.872***
Adjusted R^2	0.90	0.94	0.81
Period	Positive	Zero	Negative

Table A4 provides the estimates of the ARDL model in error correction representation using the 5-year IRS rate as the short-term capital market rate for the extended model, where both short- and long-run IRS rates are used as the main explanatory variables for lending rates. The subsamples are defined as follows: 1) positive-rate environment = January 2000 to July 2009; 2) zero-rate environment = August 2009 to December 2014; 3) negative-rate environment = January 2015 to December 2019. ***, ** and * denote statistical significance (two-tailed) at the 1%, 5%, and 10% significance levels, respectively.

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