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Interest rates and real estate prices: a panel study

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Abstract

This study examines the connection between interest rates and real estate prices in Switzerland. In considering median prices of six real estate groups consisting of rental apartments, owner-occupied flats, houses, office space, industrial real estate and sales area between the first quarter of 2005 and the fourth quarter of 2018 across 106 Swiss regions, we studied their connection with four interest rate proxies: yields on governmental bonds with 10-year maturity, fixed mortgage rates with 10-year maturity, variable mortgage rates and a newly introduced variable indicating the spread between net initial returns and yields on governmental bonds. Not only do our results show how real estate groups react to specific interest rate representatives, but also how this effect varies between Swiss regions.

Keywords Real estate fundamentals, Real estate prices, Monetary policy, Regional data, Panel study

1 Introduction

Real estate prices are known to be influenced by a variety of determinants from different spatial levels. Next to object-specific characteristics, the quality of local public goods, the proximity to transport opportunities or even local building restrictions may explain real estate prices on a local level. Apart from local determinants, developments in real estate prices can also be attributed to macroeconomic phenomena affecting the overall economy. Prominent examples are the development of gross domestic product (GDP), population growth or changes in monetary policy. The latter is the focus of this study, in particular the relationship between interest rates and real estate prices.

Among the numerous instruments available to central banks for conducting monetary policy, interest rates play a key role in real estate markets. For instance, the level of interest rates affects the time value of money, which in turn is reflected in discount rates that are applied computationally to determine real estate prices of income properties. Beside this rather valuation-based argumentation to explain developments in real estate prices, interest rates affect real estate prices through a financing perspective by means of mortgage interest rates. Additionally, potential interest rate effects on real estate prices may also arise through the investment behavior of commercial real estate investors. In particular, a rational investor compares risk-free yields on governmental bonds with potential returns that can be achieved in real estate markets. The resulting *spread* is directly linked to the level of interest rates and captures the investment perspective through which interest rates affect real estate prices.

All these potential influencing channels increase in importance with regard to recent developments in Swiss real estate markets. Between 2005 and 2018, median square meter prices of owner-occupied flats (+48.9%) and houses (+37.0%), median rental prices per square meter and year for rental apartments (+13.6%), office space (+7.1%), industrial real estate (+31.5%) and sales area (+7.2%) have reached all-time highs. During the same time frame, the interest rate environment has changed massively. For instance, yields on governmental bonds with 10-year maturity decreased by 2.3%.

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The goal of this study is to empirically measure the impact of interest rates on real estate prices in Switzerland. We consider six different real estate groups consisting of rental apartments, owner-occupied flats, houses, office space, industrial real estate and sales area. Whereas much research exists concerning the residential housing segment, the commercial real estate segment has rarely been analyzed empirically, especially within Switzerland. Since interest rates are a broad term, we apply multifaceted representations of the latter using four different proxies: yields on governmental bonds with 10-year maturity, fixed mortgage rates with 10-year maturity, variable mortgage rates and a certain measure for the *spread* between net initial returns on real estate objects and governmental bonds. All four representations of interest rates pursue the goal of capturing specific characteristics of Swiss real estate markets and potential channels through which interest rates affect real estate prices.

The relationship between price developments of numerous real estate segments and multifaceted representations of interest rates was analyzed by means of a fixed-effect panel regression model, capturing quarterly data between 2005 and 2018 for 106 regions in Switzerland. Our contribution to the relevant literature is summarized as follows: First, we provide an in-depth analysis about how different types of interest rates affect segment-specific real estate prices. Second, using a unique dataset in combination with a largely unexplored regionalization type, we contribute to the identification of fundamental drivers of real estate prices. Third, whereas the widespread approach to assessing the impact of local or macroeconomic determinants on real estate prices relies on vector autoregression models, we contribute to the empirical literature by demonstrating how a fixed-effect panel regression model can be applied reasonably to analyze price development across heterogeneous regions.

The remainder of this study is structured as follows. The second section is devoted to a description of Swiss real estate markets. The third section reviews recent events in the monetary policy of Switzerland, while focusing on interest rates. In the following section, we explain developments of real estate prices for the underlying six real estate segments. After a brief review of literature in the fifth section, the sixth section explains the empirical strategy. Finally, in the last section we will present and discuss the empirical results.

2 Characteristics of Swiss real estate markets

In 2018, approximately 8.5 million people were living in Switzerland and around one-third of Swiss residents reside within the three largest agglomerations: 1.3 million (Mio.) in Zurich, 600 thousand in Geneva and 550 thousand in Basel. Another third lives in agglomerations and a final third in rural areas (Schweizerischer Städteverband (SSV), 2020, pp. 19, 20). The spatial–political structure of Switzerland can broadly be divided into 26 cantons, 143 districts and 2202 municipalities (Federal Statistical Office, 2005, pp. 19–23). Whereas cantons and municipalities are political entities, districts are purely administrative units. Since political entities represent an earmarked spatial level in political and regulatory terms, a number of additional regional classifications have been established in order to characterize the Swiss landscape with respect to spatial–social phenomena. Appropriate examples are geographical boundaries, language differences, confessional divisions or urban–rural distinctions. The eight greater regions, or monitoring regions, which are classified according to the largest urban centers in Switzerland, constitute the most superordinated regions of analysis in Switzerland.[1] These eight regions are displayed in Fig. 1 and build upon a subordinated region of analysis—the MS-region (*mobilité spatiale*). The initial goal of these MS-regions was the development of comparable micro-regions across the country. At present, MS-regions are considered the most important units of analysis in Switzerland at the microregional level. The resulting 106 MS-regions enable a fitting spatial grouping of Switzerland but overlap with spatial–political borders, such as cantons for example[2] (Federal Statistical Office, 2005, pp. 65–67; 73–74).

With a GDP per capita of about 85 thousand Swiss Francs (CHF) in 2018, Switzerland belongs to the most prosperous nations in the world (Federal Statistical Office, 2020a). Unlike in other developed countries, prosperity is not translated into high homeownership rates (Goodmann & Mayer, 2018). In 2018, only 36.6% of Swiss residents lived within their own living space, indicating that the large majority is represented by tenants (Federal Statistical Office, 2019a). Low homeownership rates are directly displayed in the composition of the Swiss housing stock: Single-family houses (1.0 Mio.) or multi-family houses (0.5 Mio.) play a subordinated role in Swiss real estate markets compared to residential apartments (4.5 Mio.)[3] (Federal Statistical Office, 2019b). An explanation for the persistent low homeownership rates can be found

[1] The definition of monitoring regions was established by Wüest Partner AG.

[2] In total, there are 14 overlaps of cantons with MS-regions, of which seven are considered as actually intercantonal regions: Grenchen, Laufental, Murten, Wil SG, Aarau, Broye and La Chaux-de-Fonds (Federal Statistical Office, 2005, p. 74).

[3] The difference between residential apartments and single- or multi-family houses consists primarily in the form of ownership. Whereas family houses are real estate objects in homeownership, residential apartments are rental objects.

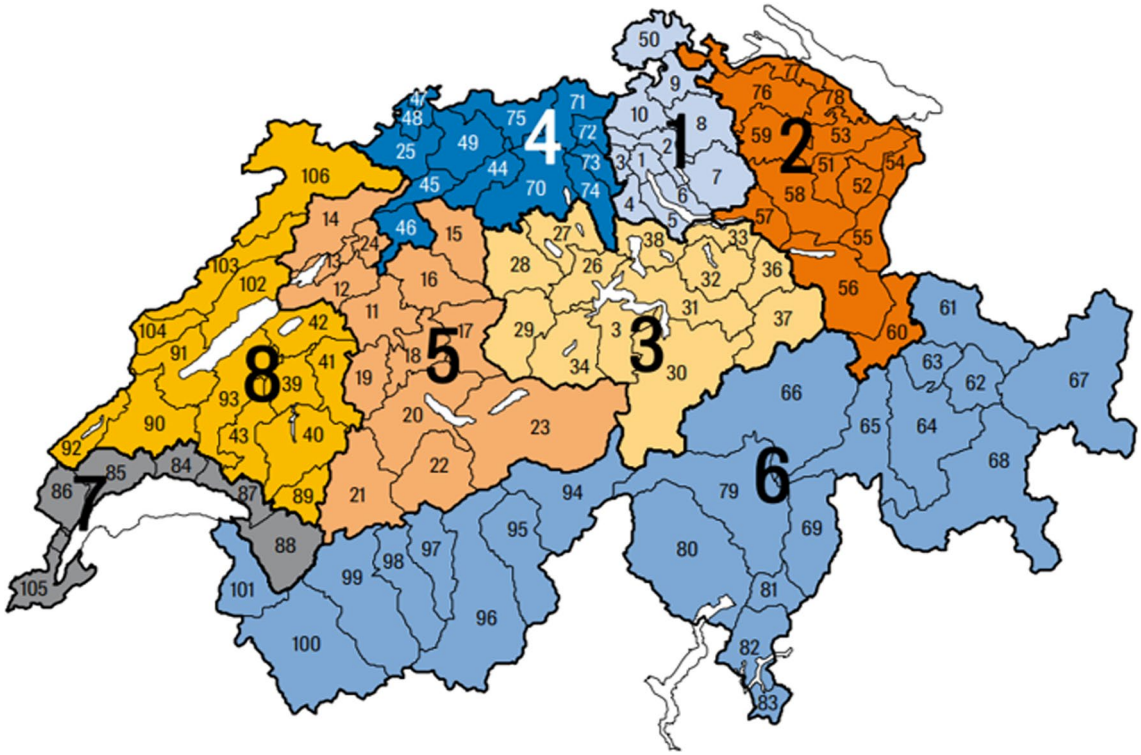

Fig. 1 MS-regions and monitoring regions of Switzerland. *Notes*: Monitoring regions according to Wüest Partner AG are shown in large letters: 1 = Zurich, 2 = East Switzerland, 3 = Central Switzerland, 4 = North Switzerland, 5 = Berne, 6 = South Switzerland, 7 = Geneva, 8 = West Switzerland. MS-Regions according to the Federal Statistical Office (2005) are displayed in small letters. *Source*: Wüest Partner (2016)

in the stringent lending practices by Swiss banks. A 20% down payment is required when purchasing a property and debt services, consisting of interest and amortization, cannot exceed one-third of households' income (Bourassa et al., 2010). Structural circumstances given by the overrepresentation of residential apartments result in real estate investors dominating Swiss real estate markets. From a value-based perspective, approximately 67% of total residential properties are private-owned, whereas 17% are owned by institutional investors, such as by pension funds and insurances (Federal Office for the Environment, 2015, pp. 4, 5).

The structural condition of low homeownership rates results in a sustainable demand for rental apartments, which is directly reflected in low average vacancy rates ranging around 1% between 2005 and 2010. Since 2010, however, Swiss average vacancy rates have risen up to 1.62%. It can generally be observed that urban cantons, such as Zurich, Zug or Basel City, are traditionally characterized by low vacancy rates below 1%. In rural cantons, such as Appenzell Innerrhoden (I. RH.), Appenzell Ausserrhoden (A. RH.) or Jura, vacancy rates around 2.0% between 2010 and 2018 are considered normal (Federal Statistical Office, 2020b).

The overall rise in vacancy rates can to a certain extent be attributed to the rise of construction investments, including public maintenance projects. Between 2014 and 2018, average construction investments rose by around 1% compared to the previous years. Particularly notable is the development of investments in new buildings in the French-speaking part of Switzerland, such as cantons Valais, Vaud and Geneva, with annual growth exceeding 3% between 2010 and 2018 (Federal Statistical Office, 2020c).

Next to low homeownership rates and vacancy rates, Swiss real estate markets can be characterized by the underlying taxes. Due to the federal system, a number of taxes are levied on each spatial–political level. Appropriate examples are income and property taxes. Across all spatial–political levels, the level of income, the number of children and the marital status represent the basis for income taxes. As a result, the respective tax rate varies considerably between Swiss regions. Taking the example of a married couple with two children and a yearly gross income of 100 thousand Swiss Francs, taxes in percentage of the

yearly gross income vary from 1.25% in Canton Zug to 9.25% in canton Neuchâtel[4] (Federal Statistical Office, 2018). The heterogeneity in the Swiss tax system can not only be observed on the basis of the respective tax rates, but also whether the corresponding tax is levied at all. Regarding property taxes, some cantons, such as Zurich, Schwyz or Zug, renounce property taxes, whereas other cantons do not. The same is true for the taxation of capital gains. In general, capital gain taxes for real estate objects bear an inverse relationship with holding period—that is, decrease with the duration of ownership (Bourassa et al., 2010).

From a historical point of view, a number of noteworthy regulatory changes and politically motivated events affected Swiss real estate markets. An example is the obligation to deposit into pension funds since 1985, the introduction of real estate transfer taxes in 1992 or the provision of housing construction subsidies by the federal government in 1993. Another example is the introduction of the free labor movement agreement with the European Union (EU) in 2007, through which numerous immigration barriers have been removed (Drechsel & Funk, 2017). In addition to these historical events, several regulatory standards are shaping Swiss real estate markets. A fitting example is the equal treatment of owners and tenants, according to which homeowners can deduct their mortgage interest rates from taxes but their imputed rents are taxed (Federal Tax Administration, 2015). Imputed rents are generally considered as the amount that a property owner would earn if it was rented to a third party. In exchange, interest on debt and maintenance costs can be deducted from income taxes. Although Switzerland's tax policies have little bias in favor of homeownership, they create strong incentives to never fully repay mortgage debts. In consequence, Switzerland has one of the highest mortgage debt-to-GDP ratios in the world (Hilber & Schöni, 2016).

Another example of a regulatory standard is the persisting rent control system, according to which rent adjustments can be accomplished either by use of the reference index or the Swiss consumer price index (CPI). The reference index reflects the average level of mortgage interest rates across Switzerland and serves as a benchmark value for landlords and tenants to justify rent adjustments. A reduction of the reference index would imply that tenants can enforce a rent reduction and vice versa for an increasing reference index.

Beside legal changes, however, it was the financial crisis in 2007 and the associated monetary policy that substantially affected Swiss real estate markets. In order to supply the weakening economy with cheap money, interest rates significantly declined since 2007 and reached all-time lows during recent years. As a result, the costs of financing real estate objects significantly declined and, due to a lack of investment opportunities, institutional investors shifted their investments into the real estate sector in search of yields. According to the Federal Statistical Office, pension funds' total share of real estate assets increased from 16.6% in 2008 (90 billion CHF) to 20.3% in 2018 (177 billion CHF). The investment behavior of pension funds clearly indicates that governmental bonds are substituted against real estate assets. This becomes apparent when considering that pension funds decreased their asset allocation of governmental bonds from 40.8% in 2008 to 31.4% in 2018 (Federal Statistical Office, 2020d, p. 15).

3 Interest rates

Next to the definition of price stability and inflation forecasts, the policy rate represents the third element of the Swiss National Bank's (SNB) monetary policy strategy (Jordan et al., 2009). Central banks possess the authority to conduct monetary policy and thereby to determine the level of policy rate, or the target rate more generally. Since June 2019, the SARON (Swiss Average Rate Overnight) has become the representative benchmark for the SNB to "keep the secured short-term Swiss franc money market rates close to the SNB policy rate" (Machler & Moser, 2020). The SARON is a secured overnight rate, which is based on the most liquid segment of the Swiss franc money market. It is calculated from concluded transactions and tradable prices from the interbank repo market. Prior to June 2019, the 3-month London Interbank Offer Rate (Libor) for the Swiss franc investments was the guiding benchmark for credit relationships in Switzerland. The absence of underlying money market transactions and the fact that the United Kingdom's Financial Conduct Authority will no longer support the Libor after 2021 led to its replacement by the SARON.

The SNB conducts its monetary policy through transactions in the financial market. These transactions can broadly be divided into open market operations and standing facilities.[5] Due to its constitutional mandate to ensure price stability, the SNB intervenes through open market operations and thereby influences current interest rates. As explained above, these are short-term interest rates or, in other words, daily interest rates. Since

[4] The figures shown rely on official numbers published by the Federal Statistical Office (2018) and include federal, cantonal, municipal and church taxes.

[5] Open market operations include repo transactions and the issuance of SNB bills. In contrast, standing facilities consist of liquidity-shortage financing facilities, for which the SNB sets the conditions at which other banks may obtain short-term liquidity.

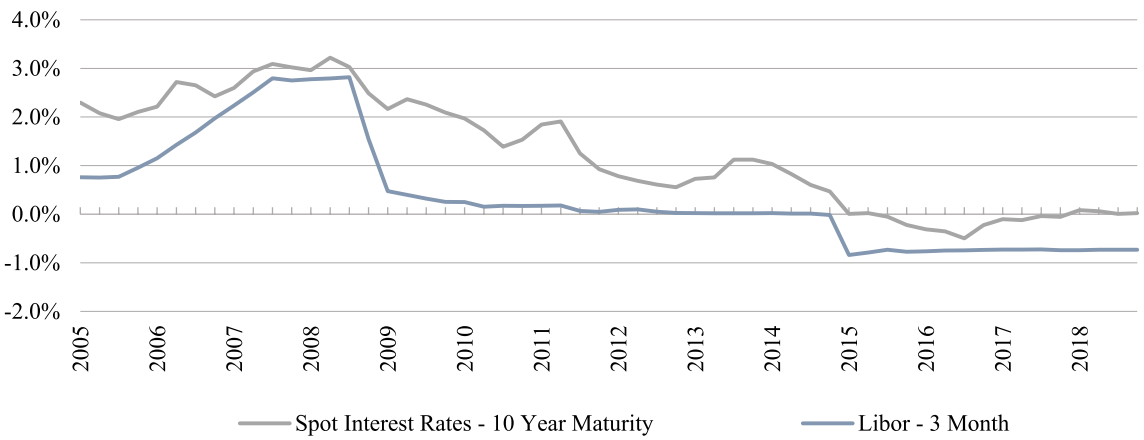

Fig. 2 Spot interest rates and Libor target rates. Spot interest rates with 10-year maturity and 3-month Libor rate have been averaged on a quarterly level. The displayed time frame ranges from 2005 Q1 to 2018 Q4. Source: data.snb.ch

real estate objects are characterized by their durability, a wide time frame is of particular interest for real estate markets. Therefore, the real estate literature generally uses spot interest rates, or yields on governmental bonds more generally, as a proxy for interest rates.

When considering the development of interest rates in Fig. 2, represented by spot interest rates with 10-year maturity and 3-month Libor rates, it becomes apparent that monetary policy went through challenging times. In 2005, favorable growth prospects accelerated the economy, leading the SNB to raise its 3-month Libor rate slightly in 2006 up to 2.5%. In 2007, troubles in global financial markets pushed back growth expectations for the real GDP. As the effects of the financial crisis emerged in the following year, the SNB answered with an expansionary monetary policy. In particular, the SNB lowered the 3-month Libor rate in order to support the markets with liquidity. As uncertainty dominated the markets, the Swiss franc appreciated and deflationary pressure emerged (SNB, 2005–2010). In response, the SNB introduced the minimum exchange rate of CHF 1.20 per Euro in September 2011 and dropped its 3-month Libor rate to between 0.0 and 0.25% (SNB, 2011).

The years from 2011 to 2015 were characterized by deflationary expectations, declining 3-month Libor rates toward between −1.25 and −0.25% as well as the minimum exchange rate, for which the SNB heavily intervened in the foreign exchange market. In January 2015, the SNB abolished the minimum exchange rate due to the significant depreciation of the euro against the US dollar (SNB, 2011–2015). The abolition of the minimum exchange rate led to a significant drop of the CHF-EUR exchange rate. In addition, upcoming elections in several EU-countries and exit negotiations between the UK and the EU-induced systemic risk, which resulted in an overvaluation of the Swiss franc and therefore an additional need for the SNB to engage in financial markets. Uncertainty and global risks caused the SNB to proceed with its expansionary policy in 2016 and left the 3-month Libor rate unchanged between −1.25 and −0.25% (SNB, 2016).

Growth expectations for the Swiss and global economy persisted in 2018 and 2019. In response, the conditional inflation forecast slightly increased until 2019 and many central banks around Switzerland eased their expansionary monetary policy. However, the SNB still expected momentum to remain modest over the short term and thus kept their interest rates on sight deposits unchanged at −0.75% (SNB, 2019).

3.1 Framing influencing channels

The historical review reveals that the SNB had to adapt its monetary policy to constantly changing circumstances, with interest rates serving as a control instrument. In the course of this study, we will analyze four different representatives for interest rates and their connection to real estate prices: Yields on governmental bonds with 10-year maturity, fixed mortgage interest rates with 10-year maturity, variable mortgage interest rates and a certain measure for the *spread* between net initial returns and yields on governmental bonds.

Framing influencing channels through which interest rates affect real estate prices play a decisive role in distinguishing their impact from overall monetary policy decisions. Between 2005 and 2018, the 3-month Libor rate served as a key instrument to conduct monetary policy and thus represents the impact of the SNB's monetary policy decisions on Swiss real estate markets. As represented in Fig. 2, the policy rate is not directly reflected in specific interest rate representatives, which effectively

drive real estate prices. Based on this, we identified three measurable channels through which our interest rate representatives affect real estate prices from a macroeconomic perspective: a valuation-based channel, a financing-based channel and an investment-based channel. Whereas the valuation-based channel accounts for the fact that the risk-free rate is computationally applied in discount rates to derive real estate prices,[6] the financing-based channel captures the impact of the interest rate level through mortgage interest rates on real estate prices. Finally, the investment-based channel arises through commercial investors shifting their financial resources into real estate markets.

Yields on governmental bonds are expected to reflect the impact of the overall interest rate level on real estate prices through a valuation- and an investment-based channel. The valuation-based channel results from the appearance of risk-free rates in the discount rate, which has a direct impact on real estate prices. In contrast, the level of governmental bonds can reasonably be considered as a measure for opportunity costs, which represents the investment-based channel.

Mortgage rates reflect the impact of interest rates on real estate prices through the financing-based channel. In Switzerland, three groups of mortgage contracts exist: Fixed-rate mortgages, variable mortgages and money market mortgages. The persistence of different mortgage types renders it difficult to unify mortgage interest rates, especially because Swiss households tend to finance homeownership by use of several mortgage types. However, developments in recent years clearly indicate a preference of Swiss households for long-term fixed mortgages[7] (Moneypark.ch, 2021).

In order to investigate the influence of the investment-based channel specifically, we apply a newly introduced variable called the *spread*. Let R_t denote the return at time t, which is defined as yearly rents divided by the object-specific price ($R_t = \text{yearly rent}/P_t$). Solving this definition of a return for real estate prices (P_t) explains the latter as the ratio between yearly rents and the return ($P_t = \text{yearly rent}/R_t$). In fact, the real estate literature generally defines returns, or the discount rate in this context, as being composed of the risk-free rate (R_f) and a risk premium (R_p) (Chaney & Hoesli, 2012). Whereas the risk-free rate captures the compensation for lost liquidity, the risk premium accounts for risk-taking arising through investments in the real estate market (Leskinen et al., 2020). Thus, returns can be written as $R_t = R_f + R_p$ or equivalently:

$$R_p = \underbrace{R_t - R_f}_{spread} \tag{3.1}$$

where the difference between returns and the risk-free rate represents the *spread*. The relevance of this measure crucially depends on whether the respective real estate object is held as an investment object or not. In the context of the underlying study, the *spread* is expected to contain explanatory power for rental prices of rental apartments and industrial real estate because only for these segments corresponding net initial returns are available. For real estate objects in homeownership, such as houses and owner-occupied flats, the *spread* may not accurately explain their price dynamics because these objects are not commercially held as an asset.

Figure 3 illustrates the development of the *spread* for residential housing and industrial real estate. Particularly, notable is the drop in net initial returns in the group of residential housing and industrial real estate between 2005 and 2018. This decline in net initial returns is attributable to the overall rise in real estate prices, which will be discussed in the subsequent section. Another interesting observation is that the *spread* for residential and industrial real estate increased despite the fact that net initial returns for both segments declined. Explanations for this can be found in the definition of the *spread*, which suggests that yields on governmental bonds declined at a faster pace than net initial returns in Swiss real estate markets.

The fact that developments in the policy rate are mirrored in our interest rate representatives raises the question about the pass-through of altered monetary policies on real estate markets. A recent study by Koeniger et al. (2021) found that an unexpected cut of 25 basis points in the policy rate reduces mortgage rates in Switzerland by 22 basis points within two months. The transition speed of the policy rate on interest rate representatives does, however, not necessarily imply that real estate prices are equally affected. In fact, persistent lags arising through the adjustment of computationally applied discount rates, selling processes on real estate markets or the growing popularity of fixed-rate mortgage during recent

[6] In the context of the discount rate in real estate valuations, the risk-free rate can without loss of generality be equated with yields on governmental bonds. As a component of the discount rate, the risk-free rate plays a key role in explaining real estate prices that are evaluated using the income approach. A widespread approach in Switzerland is represented by the discounted cash flows method, in which future incomes and costs are discounted to the present to derive real estate prices of income properties.

[7] Moneypark.ch analyzed around 15′000 mortgage agreements and find that fixed mortgages with 10-year maturity are by far the most popular mortgage type in Switzerland. Their share grew from 52% in 2016 to 55% in 2020. In addition, money market mortgages account for a negligible amount of mortgage agreements (10% in 2016).

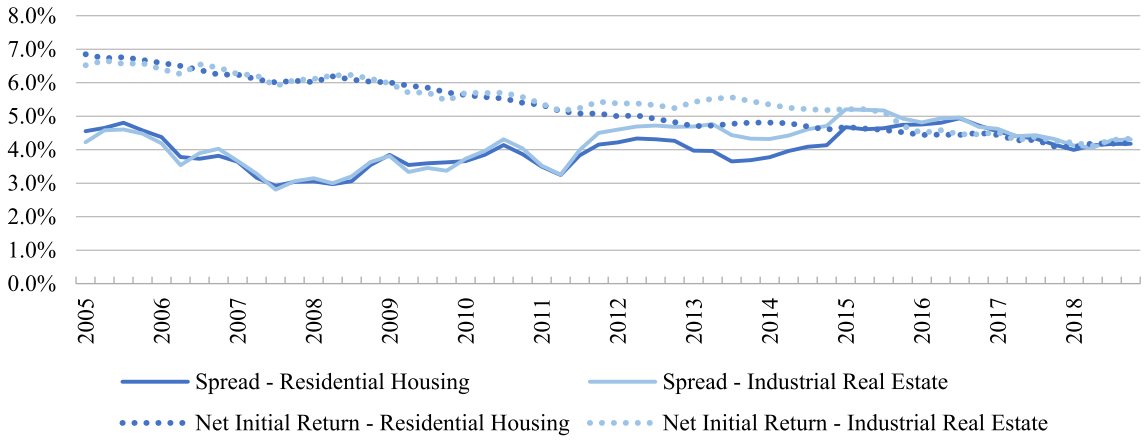

Fig. 3 Net initial returns and the spread. *Notes*: Net initial returns (*source*: Wüest Partner AG) comprise yearly returns, whereas real estate specific costs, such as refurbishment or running costs, have been deducted. Net initial returns are available for residential housing and industrial real estate. The spread for residential housing and industrial real estate has been calculated in subtracting yields on governmental bonds with 10-year maturity (*source*: data.snb.ch) from net initial returns of the respective real estate segment. The displayed time frame ranges from 2005 Q1 to 2018 Q4

years[8] slow the pass-through of interest rate changes on real estate prices.

In Fig. 4, we analyzed the co-movement of our interest rate representatives and the policy rate, as represented by the 3-month Libor rate. In accordance with Koeniger et al. (2021), we find that changes in the 3-month Libor rate are quickly translated into interest rates that are relevant for real estate markets. Empirical evidence for this can be derived from a regression of yields on governmental bonds with 10-year maturity, fixed mortgage rates with 10-year maturity, variable mortgage rates or the *spread* separately on a constant and the 3-month Libor rate. Although a decreasing correlation between our interest rate representatives and the policy rate at low levels can be observed, between 2005 and 2018 our interest rate representatives suffer from a minor effect delay induced through altered monetary policy.

4 Real estate prices

We consider six different real estate segments that can broadly be subdivided into residential housing and commercial real estate. Residential housing includes rental apartments, owner-occupied flats and houses, whereas commercial real estate refers to office, industrial real estate and sales area. Real estate prices are proxied using either median square meter (sqm) prices for houses and owner-occupied flats or median square meter rental prices per year for the remaining real estate segments.

Figure 5 displays the development of median real estate prices for residential housing between 2005 and 2018. Median square meter prices of owner-occupied flats increased from CHF 3'565 in the first quarter of 2005 to CHF 5'309 in the fourth quarter of 2018 (+48.9%) and square meter house prices from CHF 3'761 to CHF 5'153 (+37.0%) within the same time period. Numerous macroeconomic indicators contributed to the considerable rise in real estate prices for homeownership. Between 2005 and 2018, Swiss population grew from 7.4 to 8.5 Mio. residents. This population growth in combination with limited space for new construction increased prices for homeownership. In a similar fashion, the real GDP per capita grew from CHF 69'986 in 2005 to CHF 84'518 in 2018. Thus, Swiss residents not only grew in numbers but also benefitted from sustained growth in the overall economic performance. The significant rise in real estate prices for homeownership can also be attributed to declining financing costs induced through decreasing mortgage interest rates. Surprisingly, average homeownership rates remained largely unaffected between 2010 and 2018, ranging around 36.0% (Federal Statistical Office, 2021), which could be evidence for ongoing substitution effects between renting and buying the living space.

Average rental prices for rental apartments across Switzerland display a comparably small growth of only 13.6%, i.e., from CHF 159/sqm in the first quarter of 2005 to CHF 181/sqm in the fourth quarter of 2018. Between 2005 and 2013, rental prices rose from CHF 159/sqm to CHF 183/sqm, but since then have not shown any further appreciation. Explanations for this development can be found in the rise of overall construction activities within

[8] For instance, changes in the policy rate have a stronger impact on cash flows of existing mortgagors with adjustable-rate mortgage contracts. The impact of altered policy rates further depends on whether fixed-rate mortgages can be refinanced or home equity can be released.

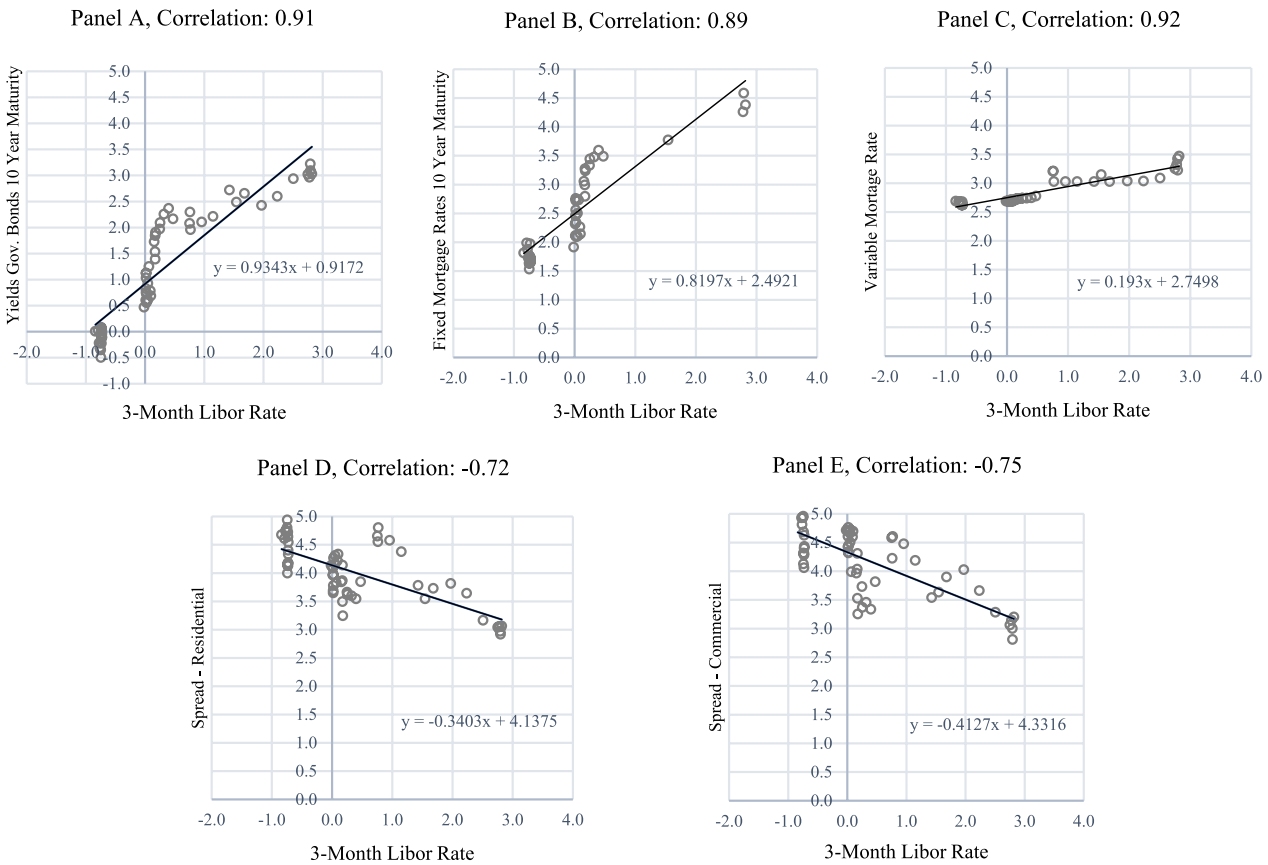

Fig. 4 Co-movement of real estate interest rates and the policy rate. *Notes*: Coefficients displayed within each panel are the results of a linear regression of interest rate representatives (vertical axis) on 3-month Libor rates (horizontal axis). The spread is defined according to Eq. (3.1), all the remaining interest rate representatives were taken from the SNB (data.snb.ch). Time series were averaged on a quarterly level. The represented time frame rages from 2005 Q1 to 2018 Q4 for Panel **A**, **C**, **D**, **E**, and from 2008 Q1 to 2018 Q4 for Panel **B**

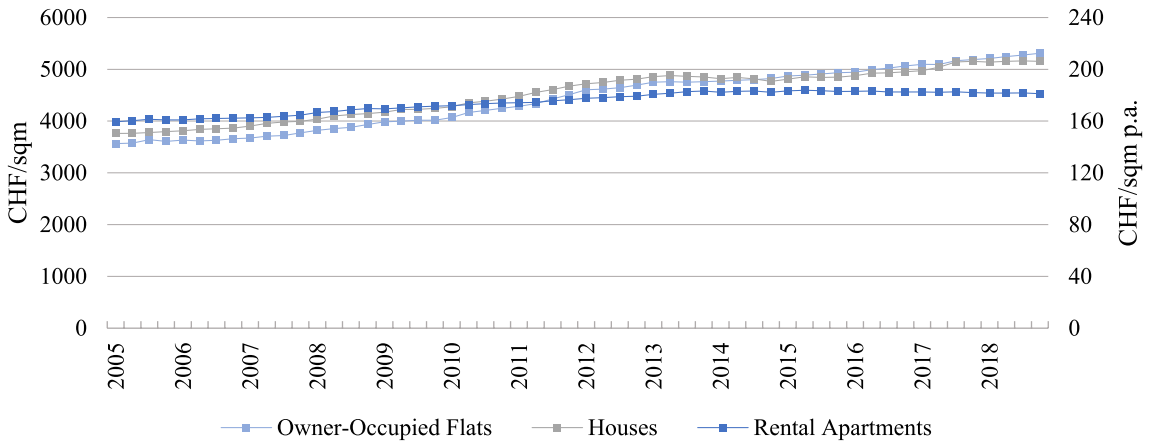

Fig. 5 Residential housing—real estate prices. *Notes*: Average median real estate prices across 106 MS-regions of Switzerland for houses, owner-occupied flats and rental apartments between 2005 Q1 and 2018 Q4. The left axis indicates the price development of houses and owner-occupied flats (CHF/sqm), whereas the right axis refers to yearly rental prices per square meter (CHF/sqm p.a.). *Source*: Wüest Partner AG

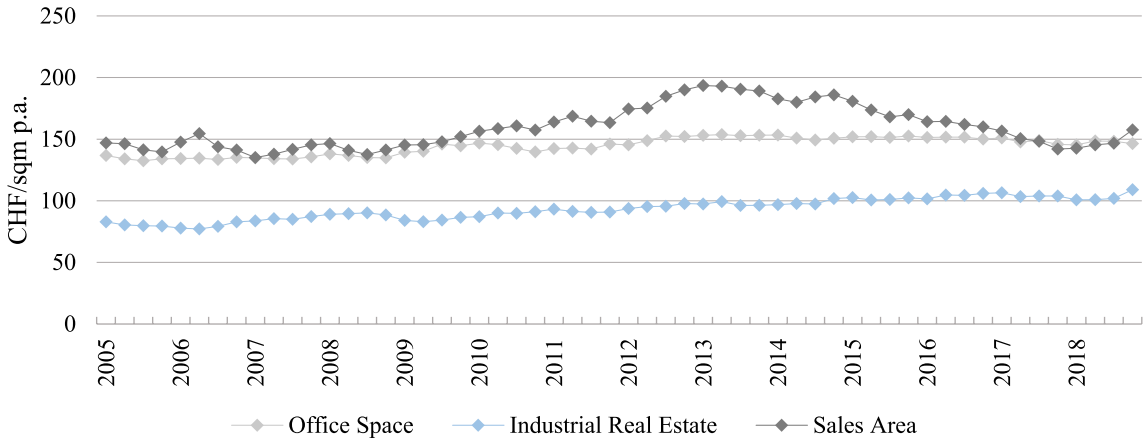

Fig. 6 Commercial real estate—real estate prices. *Notes*: Average median real estate prices, measured in rental prices per square meter and year (CHF/sqm p.a.), across 106 MS-regions of Switzerland for office space, sales area and industrial real estate between 2005 Q1 and 2018 Q4. *Source*: Wüest Partner AG

the same time period, which led to increasing vacancy rates up to 1.62% in 2018 across Switzerland (Federal Statistical Office, 2020b). In addition, the Swiss rent control system, according to which rent adjustments hinge on the development of the CPI and the reference index for mortgage interest rates, prevented rental prices from rising. Between 2010 and 2018, inflation rates moved around a fairly low level, ranging between 0.9 and − 0.5% (Federal Statistical Office, 2020e), and the reference index decreased from 2.8% in 2010 to 1.5% in 2018 (Federal Office for Housing, 2021).

Considering next the development of median square meter prices for commercial real estate, consisting of offices, sales area and industrial real estate, between the first quarter of 2005 and the fourth quarter of 2018 as displayed in Fig. 6. Similar to prices of residential housing, an appreciation of real estate prices can be observed. Industrial real estate is characterized by the largest price appreciation, whose median rental prices per year have risen by 31.5% between 2005 (CHF 80/sqm) and 2018 (CHF 109/sqm). Within the same time period, median rental prices for office (7.1%) and sales area (7.2%) appreciated to a smaller extent. Whereas rental prices for office and industrial real estate are characterized by an almost linear upswing, rental prices for sales area mirror a relatively strong price upswing between 2005 (146 CHF/sqm) and 2013 (193 CHF/sqm), followed by a downwards trend afterward. We attribute price development in sales area to structural changes, with online outlets being preferred to physical sales space. In contrast, the general rise in rental prices for office and industrial real estate is attributable to the economic structure of Switzerland. More than three quarters of all companies in Switzerland operate in the tertiary, i.e., the service sector (Federal Statistical Office, 2020f).

Yet another characteristic of Switzerland is the persistent heterogeneity. For the sake of the argument, Fig. 7 highlights median real estate prices for the six real estate segments under consideration in the fourth quarter of 2018 across Swiss cantons. Particularly, remarkable is the co-movement of prices from different real estate segments across Swiss cantons. Urban cantons, such as Geneva, Zug, Zurich and Basel City, in which approximately one-third of the Swiss population lives, display the highest real estate prices across all real estate segments. In contrast, rural cantons, such as Jura, Neuchâtel, or Appenzell I. RH, exhibit the lowest real estate prices across Swiss cantons. The heterogeneity of real estate prices among Swiss cantons persists across all real estate segments and suggests the presence of vastly different real estate markets.

5 Review of literature

Model-based studies suggest that fundamental determinants of real estate prices can be traced back to a set of specific variables. For example, Hott (2009) derived a fundamental house price equation that explains house prices as a function of aggregated income, population, mortgage rates and construction activities. Although there are only a handful of theoretically founded fundamental determinants of real estate prices, the empirical literature offers a broad variety of candidate regressors explaining real estate prices from a macroeconomic perspective. A first example is given by Adams and Füss (2010), which analyzed the long-term effect of macroeconomic variables on real estate prices in 15 countries

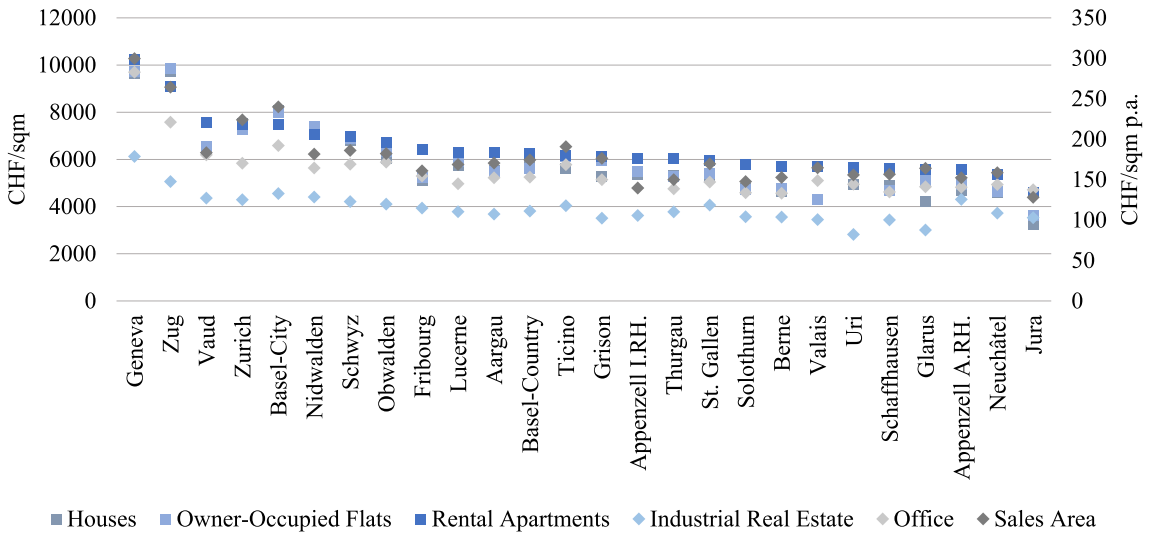

Fig. 7 Real estate prices (2018 Q4) across Swiss Cantons. *Notes*: Average median real estate prices in 2018 Q4 for six different real estate segments within 26 Swiss cantons. The left axis indicates the prices of houses and owner-occupied flats (CHF/sqm) and the right axis refers to rental prices per square meter and year (CHF/sqm p.a.). *Source*: Wüest Partner AG

over a period of 30 years. Their empirical results indicate that economic activity and construction costs are positively associated with house prices. In addition, the researchers found that a 1% increase in long-term interest rates decreases house prices by 0.3%. In another comprehensive study comprising 47 advanced and emerging market economies between 1970 and 2015, Sutton et al. (2017) estimated the impact of short- and long-term interest rates on house prices. The researchers explained the change in house prices as a function of past changes in house prices, real GDP growth, demographic factors as well as real and nominal interest rates. In applying a linear regression model and accounting for lags of quarterly and annual lengths, they found that real house prices in the USA increased by about 8% after three years in response to a 1% decline in nominal short-term rate. Interestingly, significant effects of short-term interest rates were detected in countries in which securitization of homes is less prevalent.

Another study by Tripathi (2019) established an overview about the numerous potential macroeconomic determinants of house prices. In considering 43 countries between 1970 and 2017, the researcher incorporated rent levels, GDP measures, price-to-income and rent ratios, urbanization measures, inflation, employment in services, real exchange rates, the share of working-aged residents and broad money to a random-effect regression model. While the sign of most coefficients are in accordance with economic intuition, Tripathi (2019) did not find any significant effect of real interest rates on real house prices. This observation can to a certain extent be explained by the heterogeneity of underlying countries, which is a topic that has been addressed by Égert and Mihaljek (2007). In distinguishing between 19 Organization for Economic Co-operation and Development (OECD) countries and eight transitional economies of Central and Eastern Europe, they analyzed whether conventional fundamental determinants of real estate markets could explain house price developments. Égert and Mihaljek (2007) applied a panel dynamic OLS and reported that the GDP per capita and real interest rates are robustly associated with house prices in the OECD and eastern Europe countries. Their empirical results suggest that interest rate elasticities of house prices are more than twice as high in transition economies (−5%) than in OECD countries (−2%).

Cross-country studies are confronted with a trade-off between data availability and its comparability, i.e., to control for all the relevant demand and supply determinants explaining price developments from an aggregated perspective. Country studies may circumvent this trade-off as their spatial scope comprises one single country. A fitting example is given by Belke and Keil (2017), who analyzed the impact of fundamental determinants on apartment and house prices in Germany between 1990 and 2010 using a dataset consisting of 127 German regions. In deploying a fixed-effect panel regression model, Belke and Keil (2017) found that interest rates, represented by yields on governmental bonds with a maturity of 10 years, are positively associated with real estate prices. They reported that a 1% increase in interest rates raises house prices by about 5% and prices for

rental apartments by between 2 and 4.5%, depending on the model considered. The researchers argued that the positive connection between interest rates and real estate prices may arises from the monetary policy stance und business cycles, such that higher interest rates coincide with higher demand for housing and real estate prices.

A similar question, although with a different methodology, was addressed by Berlemann and Freese (2013), who analyzed the impact of monetary policy on prices from different real estate segments in Switzerland. In applying a vector autoregression (VAR) model to a dataset consisting of quarterly GDP values, 3-month target Libor rate,[9] the money stock and the Swiss Performance Index between 1987 and 2008, the researchers concluded that the residential housing segments respond very heterogeneously to altered monetary policy. Whereas an increase in the 3-month Libor rate is inversely related to prices of houses and owner-occupied flats, a direct relationship has been detected for rental prices of apartments. Berlemann and Freese (2013) argued that this result may be an indication for substitution effects between buying and renting induced through monetary policy. Apart from this, commercial property prices, consisting of office, industry and sales area, are barely affected by changes in the Libor rate.

The fact that specific real estate segments respond differently to altered monetary policies is confirmed by Drechsel and Funk (2017). Using a Bayesian VAR to analyze intertemporal and regional effects of mortgage rate shocks as well as of demand and supply conditions between 1982 and 2013, the researchers concluded that residential rental prices are more susceptible to altered mortgage interest rates than prices of houses and owner-occupied flats. Additionally, Drechsel and Funk (2017) reported a heterogeneous response of real estate prices to mortgage or supply and demand shocks across Swiss regions. Compared to other Swiss regions, they observed that real estate prices in Zurich and Geneva responded more quickly to altered supply and demand shocks.

Summarizing the relevant literature leads to the conclusion that interest rates are represented very heterogeneously. The presence of different interest rate representations suggests that interest rates affect real estate prices through various channels, which is a topic that has rarely been analyzed in the corresponding real estate literature. Furthermore, the vast majority of the relevant studies focused on the residential housing segment. This raises the question whether, or to which extent, learnings about the fundamental determinants of real estate prices can be translated toward the commercial real estate segment. In fact, one fundamental difference is that real estate prices of the commercial real estate segment tend to depend on firms' performances (Benjamin et al., 2020). This fundamental difference to the residential real estate segment is, however, balanced by the fact that the level of real estate prices, independent of their segment, reflect entry fees for a specific region that firms and households must pay to access local amenities (Gyourko, 2009). Therefore, and because the relevant literature lacks empirical findings in this regard,[10] we presume that the fundamental drivers from an aggregated perspective of prices for the commercial real estate segment are fairly similar to the ones driving residential real estate prices.

6 Empirical strategy

Our empirical strategy to assess the relationship between interest rates and real estate prices builds upon three elements. The first element consists of a multifaceted representation of interest rates. We consider yields of governmental bonds with 10-year maturity, fixed mortgage interest rates with 10-year maturity, variable mortgage interest rates and our definition of the *spread*. The second element relies on a diversified representation of real estate prices consisting of six different real estate segments: rental apartments, owner-occupied flats, houses, office space, sales area and industrial real estate. The third element builds upon the persisting heterogeneity of Swiss real estate markets that is addressed in considering variations across all 106 MS-regions in Switzerland. We combine all three elements in deploying a fixed-effect panel regression model between the first quarter of 2005 and the fourth quarter of 2018 that controls for regional fixed effects in order to analyze the impact of interest rates on real estate prices.

6.1 Data

Table 1 describes the variables used in the subsequent analysis, while descriptive statistics are attached in Table 4 ("Appendix A.1"). Real estate prices were provided by Wüest Partner AG, which collects and evaluates transaction prices and publicly available rental prices for various spatial levels in Switzerland. Next to the spatial availability, data for real estate prices are published on a quarterly basis, which allows a detailed analysis of price developments.

With the exception of the *spread*, all interest rate representatives were taken from the SNB's publicly available

[9] Since the researchers were interested in the effect of monetary policy on real estate prices, Berlemann and Freese (2013) approximated interest rates with the 3-month target Libor rate.

[10] To the best of our knowledge, Berlemann and Freese (2013) belong to the minority which studied the commercial real estate in Switzerland.

Table 1 Variable description

Variable name Description	Source
Median rental prices Per square meter and year. Relevant for: Apartments, office space, sales area and industrial real estate	Wüest Partner AG
Median prices Per square meter. Relevant for: Houses, owner-occupied flats	Wüest Partner AG
Yields governmental bonds (10 Y) Yields on governmental bonds with 10-year maturity (%)	Swiss National Bank
Variable mortgage rates Average variable mortgage interest rates (%)	Swiss National Bank
Fixed mortgage rates (10 Y) Fixed mortgage interest rates with 10-year maturity (%)	Swiss National Bank
Spread Indicates the difference between net initial returns and yields on governmental bonds with 10-year maturity (%). Relevant for: Rental apartments and industrial real estate	Wüest Partner AG
Supply number Number of advertised real estate objects divided by the group-specific stock (%). Relevant for: Office space, sales area, industrial real estate	Wüest Partner AG
Vacancy rates Number of vacant object relative to housing stock (%). Relevant for: Houses, owner-occupied flats and rental apartments	Federal Statistical Office
Location and market rating Rating: Min = 1, Max = 5. Relevant for: Rental apartments, houses, owner-occupied flats, office, sales area, industrial real estate	Wüest Partner AG
Investment per resident Total investments (in thousand Swiss Francs), including public expenditures per resident	Federal Statistical Office
Population growth	Federal Statistical Office
Firm stock Total firm stock (in thousand) measured by the number of ltd's	Wüest Partner AG
Housing stock Total housing units (in thousand)	Wüest Partner AG
Economic structure Number of firms in the services sector relative to the firm stock (%)	Federal Statistical Office
Building applications Number of building applications per resident. Relevant for: Rental apartments, houses, owner-occupied flats	Wüest Partner AG/Federal Statistical Office

The description refers to all variables used in the empirical analysis. "Location and market rating," "Vacancy rates," "Supply number" and "Building applications" are relevant for several real estate segments and represent more than one variable. "Building applications" is the only variable, which combines two sources (building applications from Wüest Partner AG and the number of residents from the Federal Statistical Office). With the exception of our interest rate representatives, which only vary on a national level, all variables are available for each MS-region. Data taken from the Swiss National Bank are available on a monthly basis and have been average on a quarterly level

database. The *spread* is defined as the difference between net initial returns and yields on governmental bonds with 10-year maturity. Net initial returns are provided by Wüest Partner AG and comprise incomes, whereas object-specific costs, such as costs for insurance and maintenance, were deducted. So, defined net initial returns provide information about actually achieved returns of real estate investors in Switzerland.

Yields on governmental bonds will be used in our baseline regression model. Just as for fixed and variable mortgage interest rates, we expect an inverse relationship with segment-specific real estate prices. The application of our definition of the *spread* is limited to rental apartments and industrial real estate because corresponding net initial returns are exclusively available for these two real estate segments. Since a divergence of net initial returns and yields on governmental bonds should increase the attractivity of investing in real estate markets, we expect a direct relationship between the *spread* and corresponding real estate prices.

As we consider six real estate segments, we use two separate variables to represent vacancy rates. For the residential housing segment, we apply officially published numbers by the Federal Statistical Office.[11] Official vacancy rates for commercial real estate are unfortunately non-existent for Switzerland. For that reason, we proxy vacancy rates in the commercial real estate segment by means of the supply number, which is defined

[11] The data source provides information about the number of vacant rental apartments, houses and owner-occupied flats, which are then divided by the segment-specific housing stock.

as the number of advertised real estate objects divided by the segment-specific stock.[12] Since a relatively high vacancy rate or supply number is a sign of a local oversupply or weakening demand, we expect a negative relationship with real estate prices.

We include the market and location rating (1 = worst, 5 = best), as provided by Wüest Partner AG, to account for the persisting heterogeneity across Swiss regions. This variable is the result of a systematic analysis of measurable local-specific characteristics[13] and highlights the quality of the market and the location for each specific real estate segment between Swiss regions. The market and location rating is a suitable variable to quantify the quality of locations from a macroeconomic perspective, since it comprises several indicators that are difficult to aggregate, but nevertheless important to control for. Examples of such indicators are the local tax level, the accessibility or the infrastructure. We expect a positive impact of the location and market rating on segment-specific real estate prices, reflecting the capitalization of local amenities into real estate prices.

Construction activities are represented by total investments in reconstruction and new construction as a share per resident. Data was taken from the Federal Statistical Office, which classifies investments into a number of subgroups, from which the total was taken for the analysis. The resulting variable captures public and private spendings across time and Swiss regions. According to economic intuition, we expect a negative impact of construction activities on real estate prices, as the associated shift in supply decreases real estate prices.

The size of real estate markets, represented by the number of firms and the housing stock,[14] is expected to control for price effects arising through the density of the respective region. Both data sources were taken from the Federal Statistical Office. For the residential and commercial segment, we expect prices to be higher in densely populated regions.

After all, the present dataset contains a wide range of fundamental drivers characterizing Swiss real estate markets between the first quarter of 2005 and the fourth quarter of 2018 for six different real estate segments. The quality of the dataset is further characterized by the small number of sources. All the data were taken from federal administrations (SNB, Federal Statistical Office) or Wüest Partner AG, which is one of the leading real estate consulting firms in Switzerland. The small number of sources standardizes the dataset and enables comparisons of specific variables across different real estate segments.

6.2 Methodology

We apply a fixed-effect panel regression model to measure the impact of interest rates on real estate prices for six different real estate segments in Switzerland. In doing so, we control for aggregated demand and supply determinants that traditionally drive real estate prices from a macroeconomic perspective. With the exception of interest rates representatives, each variable in the subsequent empirical analysis varies across time (t) and across MS-regions (i). These characteristics of the dataset are ultimately reflected in the baseline panel regression equation:

$$\boldsymbol{P}^{\boldsymbol{j}}_{\boldsymbol{it}} = \alpha_i + \beta_1 \boldsymbol{M}^{\boldsymbol{j}}_{\boldsymbol{it}} + \beta_2 \boldsymbol{m_t} + u_{it} \tag{3.2}$$

Real estate prices ($\boldsymbol{P}^{\boldsymbol{j}}_{\boldsymbol{it}}$) are represented by quarterly median rental prices per square meter for each real estate segment (j) consisting of rental apartments, sales area, office space and industrial real estate or by square meter prices for owner-occupied flats and houses. α_i represents region-specific fixed effects for each MS-region in Switzerland. $\boldsymbol{M}^{\boldsymbol{j}}_{\boldsymbol{it}}$ is a vector of geographical and time-varying determinants of real estate prices across real estate segment (j) as represented by the location and market rating, investment per resident, the firm and housing stock, population growth, vacancy rates or the supply number. $\boldsymbol{m_t}$ specifies local-invariant interest rate representatives and u_{it} is an error term.

The fixed-effect panel regression, also known as the *within*-estimator, considers the variation of variables over time and estimates the individual-specific deviations from their time-averaged values. Since idiosyncratic means are removed from the estimation equation, the strict exogeneity assumption required for consistency is relaxed.[15] A crucial assumption refers to the presence of some unobserved time-invariant heterogeneity α_i across individuals in the panel dataset. If this assumption holds, the fixed-effect approach limits the sources of potential biases (Collischon & Eberl, 2020).

In the context of the present study, the intuition behind α_i is linked to a central characteristic of real estate objects:

[12] Since the commercial real estate segment is traditionally characterized by a low number of tenant changeovers with long contract durations, we do not expect to incorrectly proxy vacancy rates by means of the supply number.

[13] The market and location rating comprises measurements for the accessibility, infrastructure, demography, labor market, municipality type, tax burden, construction market, supply market, vacancy risk, price developments and institutional investors.

[14] The housing stock includes rental apartments, houses and owner-occupied flats. Firms are represented by the number of corporations and limited liability companies.

[15] Consistency in a fixed-effect panel regression model requires that time-varying predictors do not correlate with time-varying error term.

Table 2 Fixed-effect panel regression—residential housing

Segments	**Rental apartments**		**Houses**			**Owner-occupied flats**		
Dependent variable	**Log of median sqm rental price**		**Log of median sqm prices**			**Log of median sqm prices**		
Variables	**(1)**	**(2)**	**(1)**	**(2)**	**(3)**	**(1)**	**(2)**	**(3)**
Location and market rating	0.0244*** (0.0067)	0.0244*** (0.0067)	0.0421*** (0.0095)	0.0421*** (0.0095)	0.0604*** (0.0111)	0.0426*** (0.0114)	0.0425*** (0.0114)	0.0634*** (0.0113)
Investment per resident	0.0275*** (0.0059)	0.0275*** (0.0059)	0.0070 (0.0106)	0.0070 (0.0106)	0.0042 (0.0124)	0.0274** (0.0086)	0.0274** (0.0086)	0.0240* (0.0110)
Housing stock	0.0021 (0.0012)	0.0021 (0.0012)	0.0054** (0.0017)	0.0055** (0.0017)	0.0049** (0.0017)	0.0058** (0.0019)	0.0058** (0.0019)	0.0048* (0.0020)
Vacancy rate	−0.0034 (0.0041)	−0.0034 (0.0041)	−0.0382* (0.0175)	−0.0383* (0.0175)	−0.0229 (0.0148)	0.0070 (0.0205)	0.0069 (0.0206)	0.0007 (0.0218)
Population growth	−0.0168 (0.0089)	−0.0168 (0.0089)	−0.0138 (0,0156)	−0.0138 (0.0156)	−0.0046 (0.0116)	−0.0605*** (0.0170)	−0.0605*** (0.0170)	−0.0363* (0.0157)
Yields governmental bonds (10 Y)	−0.0039*** (0.0010)		−0.0065*** (0.0011)			−0.0152*** (0.0013)		
Variable mortgage rates				−0.0146*** (0.0041)			−0.0228*** (0.0048)	
Spread residential		0.0043*** (0.0009)						
Fixed mortgage rates (10 Y)					−0.0101*** (0.0012)			−0.0183*** (0.0017)
Year dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Quarter dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Region fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Adj. R^2	0.764	0.764	0.850	0.850	0.795	0.895	0.895	0.865
N	5936	5936	5936	5936	4664	5936	5936	4664

Displayed coefficients are the results of a panel fixed-effect regression model including regional fixed effects for each MS-region. Robust standard errors are displayed in brackets. In models (1) and (2), the time frame was limited to 56 quarters from 2005 Q1 to 2018 Q4. In model (3) for houses and owner-occupied flats, the time frame was limited to 44 quarters from 2008 Q1 to 2018 Q4. Signif. codes: "***" 0.001, "**" 0.01, "*" 0.05, "" 0.1

They cannot be displaced and are therefore bound to the specific location. Whereas object-specific characteristics in combination with local characteristics play a crucial role when estimating object-specific real estate prices,[16] explaining a regional price level requires macroeconomic and local characteristics only. This builds on the intuition that regional-specific effects for each MS-region driving real estate prices can be aggregated into a time-invariant regional effect (α_i). Removing this particular regional effect then allows for estimation of specific determinants, whereas the effect of interest rate representatives on real estate price is of particular interest of this study.

While we expect to absorb a major share of the price development across Swiss MS-regions with aggregated supply and demand determinants, ruling out potential effects arising through time effects becomes particularly important since real estate prices in Switzerland almost monotonically increased within the considered time frame. To address these time trends, we include year and quarter dummies for the entire time frame. Additionally, we adapt the heteroskedasticity-consistent covariance estimator as proposed by Arellano (1987). Apart from that, standard assumptions apply in the results displayed below.

7 Empirical results

Model (1) of Table 2 summarizes the results from our baseline regression model for residential housing, in which interest rates are represented as yields on governmental bonds with 10-year maturity. Particularly, notable is the significant negative impact of our so defined interest rate representative on median real estate prices across all real estate segments. Prices of owner-occupied flats exhibit the largest impact in response to altered interest rates. Decreasing interest rates by 1 percentage points (pp) increases their prices by about 1.5% on average in Switzerland. With regard to houses, the corresponding interest effect is less than half as high (0.7%) and even smaller for rental apartments (0.4%). When putting these

[16] Examples are hedonic pricing models to estimate prices for homeownership or the discounted cash flow method to derive prices of income properties.

estimates into the context of the decline in yields on governmental bonds by about 2.3 pp between 2005 and 2018, our results suggest that the development of our so defined interest rate representative is associated with an increase in real estate prices between 3.5% (owner-occupied flats) and 0.9% (rental apartments) for the residential housing segment. This accounts for the general upswing in real estate prices.

The market and location rating enters with a positive sign into our baseline regression model of Table 2. The impact of the location and market rating is considerably larger for houses and owner-occupied flats than for rental apartments, which suggest that local quality criteria are more heavily capitalized into prices for homeownership. Overall investments in real estate markets have a positive impact on prices for residential housing. We interpret this result as evidence for the sustained demand in the residential housing segment, whereas additional supply is quickly absorbed.

The results in model (1) provide evidence that the density of real estate markets is positively contributing to the prevailing price level in the residential housing segment. Similar to the location and market rating, prices for homeownership display a higher sensitivity to the density of the local real estate market than rental prices for rental apartments. Interestingly, population growth reflects a largely counterintuitive and insignificant impact on real estate prices. We attribute this observation to the persistent heterogeneity across all MS-regions and that real estate prices are affected rather by the density of the regional market than by population growth.

In model (2) of Table 2, we investigate whether the negative interest rate effect reported in model (1) persists with a differentiated segment-specific representation of interest rates. We apply our definition of the *spread* for rental apartments and variable mortgage interest rates for houses and owner-occupied flats. Our estimation reveals that a rise by 1 pp in the *spread* increases median rental prices by approximately 0.4%. We associate the *spread* with the group of demand shifters, which arises whenever net initial returns decline at a slower pace than yields on governmental bonds. The effect is nonetheless surprisingly pronounced since under Swiss law rental prices should follow the development of the reference index, which has fallen from 3.5% in 2008 to 1.5% in 2018.

Variable mortgage interest rates enter with negative sign into our estimation equation for houses and owner-occupied flats. Corresponding estimates gained in size compare to yields on governmental bonds in model (1) of Table 2, which is due to the considerably smaller volatility of variable mortgage interest rates.[17] Nevertheless, the drop in variable mortgage rates of about 1 pp between 2005 and 2018 increased house prices by 1.5% and prices for owner-occupied flats by 2.3%. We attribute this effect to the decline in financing costs for homeownership, which boosted demand for homeownership and, as a result, its prices.

In model (3) of Table 2, we further analyze the financing-based channel with fixed mortgage rates affecting real estate prices for homeownership.[18] Corresponding estimates indicate that a decline by 1 pp in fixed mortgage rates increases median square meter prices for houses by 1.0% and of owner-occupied flats by 1.8%. Between the first quarter of 2008 and the fourth quarter of 2018, fixed mortgage rates with 10-year maturity decreased by 2.9 pp. Thus, and holding everything else constant, the overall decline in fixed mortgage rates within the considered time frame raised house prices by approximately 3.0% and prices of owner-occupied flats by 5.3%. The decline in financing costs for homeownership is, however, not translated into homeownership rates in Switzerland. Between 2010 and 2018, average homeownership rates remained at an unchanged level of 36% (Federal Statistical Office, 2021). This rules out substitution effects between renting or owning but merely leaves capitalization effects as a result of increased demand induced through declining financing costs.

Move on to the commercial real estate segment. We apply the same empirical strategy to explain rental prices for offices, industrial real estate and sales area capturing 106 MS-regions of Switzerland between 2005 and 2018. Consider first the results from our baseline model (1) in Table 3, in which interest rates are represented by governmental bonds with 10-year maturity. Office rental prices increase by about 0.4% in response to a decline in governmental bonds by 1 pp, suggesting a very similar interest rate sensitivity as rental prices for rental apartments [model (1) in Table 2]. In opposite, rental prices of industrial real estate and sales area display a direct connection to yields on governmental bonds.

While commercial real estate prices tend to react differently to interest rates, similarities to the residential housing segment are given by effect of the location and market rating, which enters with a positive sign into our estimation equation. In fact, commercial real estate prices display a higher sensitivity to the quality of the respective market compared to prices of residential housing. The sign of overall investments in model (1) indicates that rising investments in real estate markets are associated with a shift in aggregated supply, which negatively

[17] Since the first quarter of 2012, variable mortgage rates remained at a fairly constant level ranging between 2.7 and 2.6%.

[18] Fixed mortgage rates are only available as of 2008. In consequence, the time frame under consideration was limited to 44 quarters.

Table 3 Fixed-effect panel regression—commercial real estate

Segments	**Office**	**Industrial real estate**		**Sales area**
Dependent variable	**Log of median sqm rental price**	**Log of median sqm rental price**		**Log of median sqm rental price**
Variables	**(1)**	**(1)**	**(2)**	**(1)**
Location and market rating	0.1202***	0.2045***	0.2045***	0.1866***
	(0.0194)	(0.0147)	(0.0147)	(0.0207)
Investment per resident	− 0.0084	− 0.0107	− 0.0108	− 0.0148
	(0.0111)	(0.0115)	(0.0115)	(0.0172)
Firm stock	0.0099*	− 0.0227***	− 0.0227***	0.0150*
	(0.0046)	(0.0065)	(0.0065)	(0.0075)
Supply number	0.0028***	0.0082***	0.0083***	0.0080*
	(0.0007)	(0.0020)	(0.0020)	(0.0035)
Population growth	− 0.0533**	− 0.0224	− 0.0224	− 0.0565*
	(0.0203)	(0.0236)	(0.0236)	(0.0266)
Yields governmental bonds (10 Y)	− 0.0039*	0.0077**		0.0104***
	(0.0018)	(0.0025)		(0.0024)
Spread commercial			0.0010	
			(0.0021)	
Year Dummies	Yes	Yes	Yes	Yes
Quarter Dummies	Yes	Yes	Yes	Yes
Region fixed effects	Yes	Yes	Yes	Yes
Adj. R^2	0.578	0.614	0.614	0.535
N	5936	5936	5936	5936

Displayed coefficients are the results of a panel fixed-effect regression model including regional fixed effects for each MS-region. Robust standard errors are displayed in brackets. In models (1) and (2), the time frame was limited to 56 quarters from 2005 Q1 to 2018 Q4. Signif. codes: "***" 0.001, "**" 0.01, "*" 0.05, "." 0.1

affects commercial real estate prices. Corresponding estimates are, however, largely insignificant.

Mixed results arise from the size of the regional market, as represented by the regional number of firms. Median rental prices for office and sales area are positively related with the number of local firms, whereas the opposite effect can be observed in the industrial real estate segment. Thus, we do not find consistent evidence that the density of local firms is translated into commercial real estate prices. The same holds true for population growth, which barely explains price developments in the commercial real estate segment.

Interestingly, the supply number enters with a positive sign into the estimation equation for each real estate type in the commercial real estate segment. Since the supply number is defined as the number of advertised real estate objects divided by the corresponding stock, the positive sign gives rise to the conjecture that investors rent offers are set independent of the current supply number. Explanations include a traditionally longer advertising duration for commercial real estate objects, which is priced by investors.

In model (2) of Table 3, we further investigate whether the positive price impact of the *spread* persists in the industrial real estate segment, for which this variable can reasonably be applied.[19] Just as for rental apartments, using the *spread* to explain rental prices of industrial real estate provides the anticipated results. A rise by 1 pp in the *spread* increases industrial real estate prices by approximately 0.1%. Nevertheless, the insignificant estimate suggests that this relationship does not follows a robust pattern. Just as already observed in the residential housing segment, changing interest rate representatives does not significantly affect the coefficients of the remaining variables. This observation is linked to our estimation strategy, in which interest rate representatives display a considerable smaller correlation to the remaining variables.[20]

Comparing the estimation results between the residential housing and commercial real estate segment suggests that the interest rate effect cannot be generalized without further investigation. We speculate that prices of commercial real estate segment may depend more on

[19] Net initial returns are exclusively available for rental apartments and the industrial real estate segment.

[20] Explanation include that interest rates only vary on a national level, whereas the remaining variables vary between MS-regions.

firms' performances than on changes in interest rates.[21] Explanations include that commercial real estate prices primarily tend to rely on factors characterizing aggregate demand. In fact, the considerably higher sensitivity of commercial real estate prices to the location a market rating supports this observation. Further explanations refer to the monetary policy stance, through which the level of interest rates is likely to coincide with firms' performances. In particular, during a time frame of decreasing interest rates, firms may benefit from the possibility to finance new investments through equity capital, which offsets our expected interest rate effects on real estate prices. Finally, we speculate that segment-specific regulation may also contribute to the results obtained. In contrast to the residential housing segment, commercial rental contracts usually include a fixed contractual term. In consequence, commercial rental prices are relatively unaffected by changes in the interest environment, at least in the medium term. Contractual differences also become apparent regarding the indexation to inflation. Whereas commercial rental contracts frequently include an indexation to inflation up to 80%, residential rental contracts comprise an indexation of 40%.

The results reported in Table 3 are to some extent in line with Berlemann and Freese (2013), who found that Swiss real estate prices from the commercial real estate segment are largely unaffected by changes in the policy rate. This supports our observation that the interest rate effect depends to a large extent on the real estate segment under consideration and thus cannot readily be aggregated. Furthermore, the considerable smaller adjusted R^2 in our estimation results for the commercial real estate segment (Table 3) compared to the residential housing segment (Table 2) reveals that a significant share of price developments in the commercial real estate segment remains unexplained by the considered fundamental determinants.

7.1 Robustness check

In order to estimate the impact of interest rate representatives on real estate prices, our empirical strategy controlled for a set of specific demand and supply determinants affecting real estate prices on a local level. In addition, we controlled for regional fixed effects and time trends to absorb a major share of price developments across Swiss MS-regions. In this section, we analyze whether the presented results from the previous section persist when including further potential drivers of real estate prices. Of course, the selection of variables is linked to the spatial scope and time frame of the present study.[22]

During a period of declining interest rates, financing real estate objects becomes less expensive, which increases demand for housing. In the context to this study, building applications may be an important control variable as they represent a suitable measure to approximate the demand for housing within a given MS-region. Building applications are largely unexplored by the relevant literature and are exclusively available for different real estate groups of the residential housing segment. Against our expectations, we do not find consistent effects of building applications on real estate prices within this particular segment (see "Appendix A.2"). Comparing these estimation results with Table 2 does further reveal that the estimates of our interest rate representatives and control variables remain relatively unaffected by the inclusion of building applications.

More than three quarters of firms in Switzerland operate in the service sector. However, regional differences reveal that the sector-specific composition of firms varies considerably between MS-regions.[23] Building on this, we investigated whether a certain measure for the economic structure is systematically mirrored in real estate prices. Our variable for the economic structure is defined as the number of firms in the service sector relative to the firm stock within a particular MS-region.[24] In the group residential housing, we largely obtain insignificant results and the sign of this particular variable varies considerably between real estate types (see "Appendix A.3"). A similar conclusion can be drawn when applying our variable for the economic structure to the commercial real estate segment (see "Appendix A.4"). While we do not find evidence that real estate prices are affected by the sector-specific composition of firms, it is possible that the outcome was influenced by factors such as the time frame considered or the empirical strategy.[25] Furthermore, adding this variable to our empirical strategy does neither affect the magnitude nor the significance of the remaining variables.

[21] To the best of our knowledge, reliable data indicating firms performances on a disaggregated level are unfortunately not available for the considered time frame in this study.

[22] In particular, data availability for each MS-region within the time period between 2005 and 2018 limited the incorporation of further potential drivers of real estate prices.

[23] While highest share of firms operating in the service sector is located in the MS-region *Zug* (75%), the MS-region *Val-de-Travers* displays the lowest share (25%).

[24] A similar variable as a representative of fundamental drivers of real estate prices has previously been analyzed by Belke and Keil (2017). The authors defined the economic structure as the number of persons working in the service sector divided by the sum of persons working in the manufacturing and agriculture sectors.

[25] Although the sector-specific composition of firms varies considerably between MS-regions, changes within regions during the considered time frame may be absorbed by our fixed-effect regression strategy.

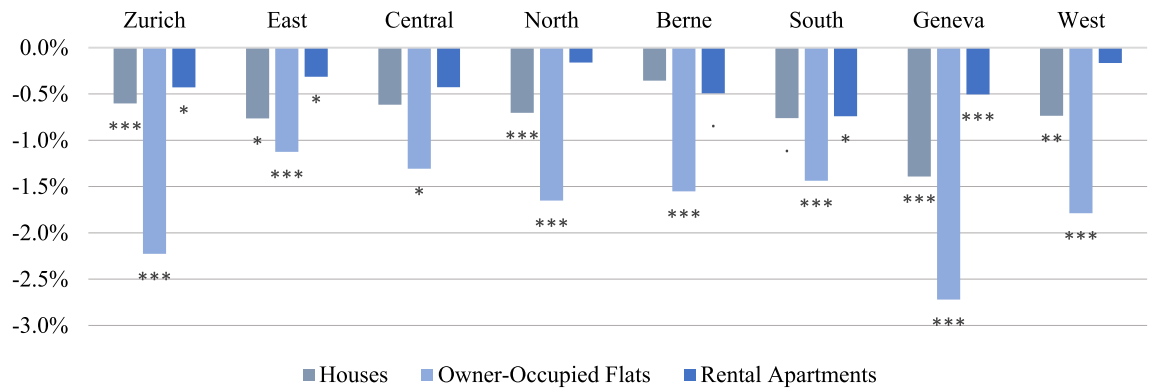

Fig. 8 Residential housing—interest rate effect across Swiss monitoring. *Notes*: Displayed coefficients correspond to yields on governmental bonds with 10-year maturity for each monitoring region in Switzerland. The coefficients are the results of a fixed-effect panel regression capturing 106 Swiss MS-regions between 2005 Q1 and 2018 Q4 (56 quarters) analogous to the baseline regression model in Table 2 model 1. Signif. codes: "***" 0.001, "**" 0.01, "*" 0.05, "." 0.1

We suspect that counterintuitive or insignificant impacts of the variables just mentioned can be attributed to the spatial scope of our empirical analysis. Since we considered all of the 106 MS-regions in Switzerland between 2005 and 2018, the impact of some local-specific variables suffers from its variability across locations. For that reason, our empirical strategy considered only fundamental determinants of real estate prices, on which the real estate literature agrees upon.

7.2 Spatial differences

In order to further analyze the impact of interest rates, this section examines their impact across 8 Swiss monitoring regions. The latter represent suitable regions of analysis as they are composed of specific MS-regions (see Fig. 1). For the sake of the argument, we apply our baseline regression model and analyze the impact of yields on governmental bonds with 10-year maturity for each one of the considered real estate segments.

Figure 8 summarizes our so defined interest rate effect on median real estate prices for houses, owner-occupied flats and rental apartments. As shown in Fig. 8, interest rate effects differ not only between Swiss monitoring regions but also between segments. The highest interest rate effects are observed in Zurich and Geneva, where a decline by 1 pp in yields on governmental bonds raised prices for owner-occupied flats by 2.7% (Geneva) and 2.2% (Zurich). Interestingly, the interest rate effect on house prices is comparatively small in Zurich (0.6%), while it is even higher in Geneva (1.4%) or in the south of Switzerland (0.8%). A similar picture as for houses is evident in the group of rental apartments, where the highest interest rate effects are located in Geneva and the south of Switzerland. In these regions, a decline by 1 pp in interest rates raised rental prices by 0.7% (South) and 0.5% (Geneva).

Spatial differences of the interest rate effect suggest the presence of vastly different real estate markets. We presume that the heterogeneous impact of interest rates between Swiss regions can be traced back to other fundamental mechanisms affecting real estate prices. The highest interest rate effects are observed in Zurich and Geneva, which also represent the most densely populated regions, comprising 1.9 Mio. residents (1.3 Mio. in Zurich, 600 thousand in Geneva) or approximately one quarter of the Swiss population in 2018. A higher interest rate sensitivity of real estate prices may therefore be an indication that these regions are characterized by an inelastic supply of housing, through which changes in interest rates result in a larger price effect.

A different picture emerges when applying the same empirical strategy for the commercial real estate segment (Fig. 9). The largest interest rate sensitivity of office rental prices can be found in central Switzerland and in Geneva. Our results suggest that a decline by 1 pp in yields on governmental bonds raised rental prices for office space by 1.7% in central Switzerland and by 0.9% in Geneva. In the group of industrial real estate and sales area, we obtain inconsistent results. Corresponding interest rate effects are largely insignificant and display a large variation between regions. We interpret this as evidence for our presumption that the reported interest effect largely hinge on the considered real estate segment.

8 Conclusion

The goal of this study was to analyze the impact of interest rates on real estate prices. Using data about six different real estate segments across all 106 MS-regions of

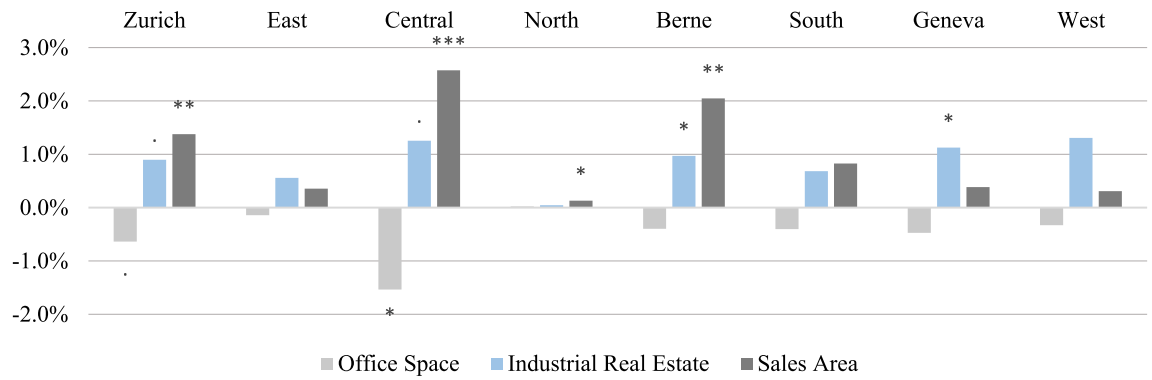

Fig. 9 Commercial real estate—interest rate effect across Swiss monitoring regions. Notes: Displayed coefficients correspond to yields on governmental bonds with 10-year maturity for each monitoring region in Switzerland. The coefficients are the results of a fixed-effect panel regression capturing 106 Swiss MS-regions between 2005 Q1 and 2018 Q4 (56 quarters) analogous to the baseline regression model in Table 3 model 1. Signif. codes: "***" 0.001, "**" 0.01, "*" 0.05, "." 0.1

Switzerland between 2005 and 2018, we examined the impact of four different interest rate representatives on median real estate prices: Yields on governmental bonds with 10-year maturity, fixed mortgage rates with 10-year maturity, variable mortgage interest rates and the *spread*. In deploying a fixed-effect panel regression model with region-specific fixed effects, we were able to control for the persisting heterogeneity of Swiss real estate markets.

In the segment of residential housing, we find robust connections between all interest rates representatives and real estate prices. Prices of houses and owner-occupied flats are particularly susceptible to changes in variable and fixed mortgage interest rates. According to our estimations, a decline by 1 pp in variable mortgage interest rates increases median houses prices by 1.5% and prices for owner-occupied flats by 2.3%. In a similar fashion, a reduction of fixed mortgage interest rates by 1 pp increases median house prices by 1.0% and median prices of owner-occupied flats by 1.8%. The interest rate level of different mortgage types plays a crucial role in explaining real estate prices for homeownership, as they represent the financing-based channel, through which interest rates affect real estate prices.

Residential rental prices are less vulnerable to altered interest rates. We find that a decline by 1 pp in yields on governmental bonds raised median rental prices for apartments by 0.4%. Additionally, our results suggest that the *spread*, which is defined as the difference between yields on governmental bonds and net initial returns, is positively associated with the rise in overall rental apartment prices. Rental apartment prices increased by about 0.4% in response to an increase by 1 pp in the so defined *spread*. This result is remarkable since Switzerland has a powerful rent control system, according to which the development of rental apartment prices should follow the reference index and the CPI. Hence, our results indicate that a divergence of net initial returns and governmental bonds counteract locally binding regulations.

We then applied our empirical strategy to the largely unexplored commercial real estate segment in Switzerland. In analyzing median rental prices of office space, industrial real estate and sales area we identified a less conclusive relationship between our interest rate representatives and real estate prices. Whereas an inverse relationship between yields on governmental bonds and office rental prices has been detected, rental prices for industrial real estate and sales area display the opposite sign. We also find weak support that the *spread* contributes to increasing rental prices in the group of industrial real estate.

In applying our baseline model separately for each one of the eight monitoring regions in Switzerland, we find that regions comprising large urban cities are characterized by a higher interest rate sensitivity. This contrasts the commercial real estate segment, in which we observed a very heterogeneous connection between interest rates and real estate prices. The latter underpins our observation that interest rate effects depend on the real estate segment under consideration and thus cannot readily be aggregated.

To ensure comparability, our analysis was limited to the impact of fundamental determinants on real estate prices in Switzerland. Against this background, future research should use the possibilities of the constantly growing supply of high-quality data in order to further analyze the impact of macroeconomic determinants on real estate prices. Especially in the commercial real estate segment, open questions about the influence of macroeconomic

determinants on real estate prices still exist. Furthermore, the relationship between interest rates and real estate prices will remain a topic of great importance for policy makers. Although Swiss banks have a stringent verification process for the granting of mortgages, it remains to be seen how a potential rise in interest rates will affect real estate prices for homeownership.

Finally, we want to stress the fact that rising real estate prices are a phenomenon observable around the globe. Next to insufficient construction to keep up with the increased demand for housing or overall changes in monetary policy, the "savings glut" is considered a driving force of globally rising real estate prices. The origins of the "savings glut" can be traced back to growing savings, spurred by increasing private pension provision in industrialized countries and rising prosperity in emerging markets. Among those investment opportunities, real estate objects remain an attractive investment option due to their durability and safety. Therefore, it would be wrong to attribute the entire upswing in real estate prices to monetary policy. On the contrary, it appears that price dynamics in real estate markets observed during recent years represent a new reality of the twenty-first century.

Appendix

A.1.

See Table 4.

Table 4 Descriptive statistics

Variable	Min	Max	Mean	Median	SD
Rental prices apartments (CHF/sqm p.a.)	118.27	346.03	191.24	186.37	37.15
Prices owner-occupied flats (CHF/sqm.)	2364.80	13,353.46	5429.45	5016.81	1742.09
Prices houses (CHF/sqm.)	2618.94	11,547.05	5146.95	4839.26	1553.40
Rental prices office space (CHF/sqm p.a.)	97.67	481.67	171.10	163.47	43.75
Rental prices industrial real estate (CHF/sqm p.a.)	45.23	191.25	102.09	100.81	24.09
Rental prices sales area (CHF/sqm p.a.)	101.99	462.02	189.42	177.10	54.68
Yields governmental bonds (10 Y) (%)	−0.49	3.22	1.26	1.12	1.12
Variable mortgage rates (%)	2.62	3.47	2.82	2.69	0.23
Fixed mortgage rates (10 Y) (%)	1.53	4.58	2.51	2.29	0.82
Spread residential (%)	2.92	4.94	4.01	4.04	0.52
Spread commercial (%)	2.81	5.20	4.18	4.31	0.61
Market rating rental apartments	1.00	4.90	2.99	3.00	9.43
Market rating owner-occupied flats	1.00	4.90	2.99	3.00	9.43
Market rating houses	1.00	4.90	2.99	3.00	9.43
Market rating office space	1.00	4.90	2.99	3.00	9.43
Market rating industrial real estate	1.00	4.90	2.99	3.00	9.42
Market rating sales area	1.00	4.90	2.99	3.00	9.43
Investment per resident (tsd.)	0.33	5.87	1.42	1.31	0.56
Housing stock (tsd.)	3.64	237.11	38.78	29.26	37.30
Firm stock (tsd.)	0.12	28.81	3.03	1.84	4.16
Vacancy rate rental apartments (%)	0.02	4.17	0.93	0.80	0.60
Vacancy rate houses and owner-occupied flats (%)	0.00	2.39	0.30	0.24	0.24
Supply number office space (%)	0.00	40.62	4.42	3.33	4.37
Supply number industrial real estate (%)	0.00	15.40	0.94	0.65	1.06
Supply number sales area (%)	0.00	34.12	1.19	0.78	1.51
Population growth (%)	−0.56	0.87	0.21	0.21	0.20
Economic structure (%)	0.25	0.74	0.48	0.47	0.09
Building applications rental apartments	0.00	18.25	2.77	2.37	2.21
Building applications owner-occupied flats	0.00	43.86	3.08	2.38	2.94
Building applications houses	0.01	27.48	1.98	1.69	1.52

All displayed values reflect variations across 106 MS-regions of Switzerland between 2005 Q1 and 2018 Q4. Fixed mortgage interest rates are only available for a limited time frame between 2008 Q1 and 2018 Q4

A.2.
See Table 5.

Table 5 Fixed-effect panel regression—residential housing

Segments	**Rental apartments**		**Houses**			**Owner-occupied flats**		
Dependent variable	**Log of median sqm rental price**		**Log of median sqm prices**			**Log of median sqm prices**		
Variables	**(1)**	**(2)**	**(1)**	**(2)**	**(3)**	**(1)**	**(2)**	**(3)**
Location and market rating	0.0243*** (0.0066)	0.0243*** (0.0066)	0.0421*** (0.0095)	0.0421*** (0.0095)	0.0607*** (0.0111)	0.0425*** (0.0114)	0.0425*** (0.0114)	0.0638*** (0.0112)
Investment per resident	0.0265*** (0.0057)	0.0265*** (0.0057)	0.0071 (0.0106)	0.0071 (0.0106)	0.0041 (0.0124)	0.0263** (0.0087)	0.0262** (0.0087)	0.0226* (0.0109)
Housing stock	0.0021 (0.0012)	0.0021 (0.0012)	0.0054** (0.0017)	0.0054** (0.0017)	0.0049** (0.0017)	0.0058** (0.0019)	0.0058** (0.0019)	0.0048* (0.0020)
Vacancy rate	−0.0035 (0.0041)	−0.0035 (0.0041)	−0.0386* (0.0176)	−0.0386* (0.0176)	−0.0221 (0.0150)	0.0094 (0.0212)	0.0094 (0.0213)	0.0044 (0.0216)
Population growth	−0.0153 (0.0087)	−0.0153 (0.0087)	−0.0137 (0.0155)	−0.0137 (0.0155)	−0.0048 (0.0116)	−0.0599*** (0.0171)	−0.0599*** (0.0171)	−0.0352* (0.0158)
Building applications	0.0010 (0.0006)	0.0010 (0.0006)	−0.0004 (0.0016)	−0.0004 (0.0016)	0.0008 (0.0013)	0.0008 (0.0007)	0.0008 (0.0007)	0.0010 (0.0006)
Yields governmental bonds (10 Y)	−0.0.0038*** (0.0009)		−0.0066*** (0.0011)			−0.0148*** (0.0013)		
Variable mortgage rates				−0.0146*** (0.0041)			−0.0224*** (0.0046)	
Spread residential		0.0043*** (0.0009)						
Fixed mortgage rates (10 Y)					−0.0098*** (0.0013)			−0.0176*** (0.0017)
Year dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Quarter dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Region fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Adj. R^2	0.765	0.764	0.850	0.850	0,795	0.895	0.895	0.865
N	5936	5936	5936	5936	4664	5936	5936	4664

Displayed coefficients are the results of a panel fixed-effect regression model including regional fixed effects for each MS-region. Robust standard errors are displayed in brackets. In models (1) and (2), the time frame was limited to 56 quarters from 2005 Q1 to 2018 Q4. In model (3) for houses and owner-occupied flats, the time frame was limited to 44 quarters from 2008 Q1 to 2018 Q4. Signif. codes: "***" 0.001, "**" 0.01, "*" 0.05, "." 0.1

A.3.
See Table 6.

Table 6 Fixed-effect panel regression—residential housing

Segments	**Rental apartments**		**Houses**			**Owner-occupied flats**		
Dependent variable	**Log of median sqm rental price**		**Log of median sqm prices**			**Log of median sqm prices**		
Variables	**(1)**	**(2)**	**(1)**	**(2)**	**(3)**	**(1)**	**(2)**	**(3)**
Location and market rating	0.0250*** (0.0065)	0.0250*** (0.0065)	0.0423*** (0.0094)	0.0423*** (0.0094)	0.0609*** (0.0107)	0.0430*** (0.0113)	0.0430*** (0.0113)	0.0639*** (0.0109)
Investment per resident	0.0280*** (0.0060)	0.0280*** (0.0060)	0.0071 (0.0106)	0.0071 (0.0106)	0.0043 (0.0123)	0.0277** (0.0087)	0.0277** (0.0087)	0.0240*** (0.0011)
Housing stock	0.0021 (0.0011)	0.0021 (0.0011)	0.0055** (0.0017)	0.0055** (0.0017)	0.0049** (0.0017)	0.0059** (0.0019)	0.0059** (0.0019)	0.0049*** (0.0020)
Vacancy rate	− 0.0023 (0.0042)	− 0.0023 (0.0042)	− 0.0384* (0.0175)	− 0.0385* (0.0175)	− 0.0236 (0.0146)	0.0057 (0.0208)	0.0055 (0.0209)	0.0003 (0.0217)
Population growth	− 0.0149 (0.0084)	− 0.0149 (0.0084)	− 0.0135 (0.0157)	− 0.0136 (0.0157)	− 0.0037 (0.0120)	− 0.0589*** (0.0167)	− 0.0589*** (0.0167)	− 0.0358*** (0.0150)
Economic structure	− 0.1654 (0.1455)	− 0.1648 (0.1454)	− 0.0254 (0.1584)	− 0.0248 (0.1583)	0.0732 (0.1866)	− 0.1404 (0.2032)	0.1384 (0.2031)	0.0376*** (0.0248)
Yields governmental bonds (10 Y)	− 0.0040*** (0.0010)		− 0.0065*** (0.0011)			− 0.0153*** (0.0013)		
Variable mortgage rates				− 0.0146*** (0.0041)			− 0.0228*** (0.0046)	
Spread residential		0.0043*** (0.0009)						
Fixed mortgage rates (10 Y)					− 0.0102*** (0.0013)			− 0.0184*** (0.0016)
Year dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Quarter dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Region fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Adj. R^2	0.766	0.766	0.850	0.850	0,795	0.896	0.895	0.865
N	5936	5936	5936	5936	4664	5936	5936	4664

Displayed coefficients are the results of a panel fixed-effect regression model including regional fixed effects for each MS-region. Robust standard errors are displayed in brackets. In models (1) and (2), the time frame was limited to 56 quarters from 2005 Q1 to 2018 Q4. In model (3) for houses and owner-occupied flats, the time frame was limited to 44 quarters from 2008 Q1 to 2018 Q4. Signif. codes: "***" 0.001, "**" 0.01, "*" 0.05, "." 0.1

A.4.

See Table 7.

Table 7 Fixed-effect panel regression—commercial real estate

Segments	**Office**	**Industrial real estate**		**Sales area**
Dependent variable	**Log of median sqm rental price**	**Log of median sqm rental price**		**Log of median sqm rental price**
Variables	**(1)**	**(1)**	**(2)**	**(1)**
Location and market rating	0.1220***	0.2042***	0.2042***	0.1860***
	(0.0185)	(0.0147)	(0.0147)	(0.0205)
Investment per resident	−0.0072	−0.0112	−0.0112	−0.0129
	(0.0106)	(0.0117)	(0.0117)	(0.0167)
Firm stock	0.0105*	−0.0229***	−0.0229***	0.0161*
	(0.0041)	(0.0064)	(0.0064)	(0.0066)
Supply number	0.0027***	0.0083***	0.0083***	0.0085*
	(0.0007)	(0.0020)	(0.0020)	(0.0034)
Population growth	−0.0481*	−0.0244	−0.0244	−0.0465
	(0.0188)	(0.0241)	(0.0242)	(0.0257)
Economic structure	−0.4660*	0.1648	0.1637	−0.8001*
	(0.2176)	(0.2176)	(0.2175)	(0.3575)
Yields governmental bonds (10 Y)	−0.0043*	0.0078**		0.0097***
	(0.0019)	(0.0025)		(0.0025)
Spread commercial			0.0010	
			(0.0021)	
Year dummies	Yes	Yes	Yes	Yes
Quarter dummies	Yes	Yes	Yes	Yes
Region fixed effects	Yes	Yes	Yes	Yes
Adj. R^2	0.584	0.614	0.614	0.543
N	5936	5936	5936	5935

Displayed coefficients are the results of a panel fixed-effect regression model including regional fixed effects for each MS-region. Robust standard errors are displayed in brackets. In models (1) and (2), the time frame was limited to 56 quarters from 2005 Q1 to 2018 Q4. Signif. codes: "***" 0.001, "**" 0.01, "*" 0.05, "." 0.1

Abbreviations

Appenzell I. RH.	Appenzell Innerrhoden
Appenzell A. RH.	Appenzell Ausserrhoden
CPI	Consumer price index
CHF	Swiss Francs
EU	European Union
GDP	Gross domestic product
Libor	London Interbank Offer Rate
Mio.	Million
MS	Mobilité spatiale
OECD	Organization for Economic Co-operation and Development
SARON	Swiss average rate overnight
SNB	Swiss National Bank
Sqm	Square meter
VAR	Vector autoregression model

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Author contributions
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Declarations

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The authors declare that they have no competing interests.

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