UNIVERSITÉ DE FRIBOURG
UNIVERSITÄT FREIBURG

Joël Vonlanthen

Swiss Real Estate Markets: Unraveling the Forces Shaping Market Dynamics

DOI : https://doi.org/10.51363/unifr.eth.2025.023

Joël Vonlanthen https://orcid.org/0000-0002-0907-356X

UNIVERSITÉ DE FRIBOURG
UNIVERSITÄT FREIBURG

Swiss Real Estate Markets:
Unraveling the Forces Shaping Market Dynamics

Doctoral Thesis

presented to the Faculty of Management, Economics and Social Sciences
at the University of Fribourg (Switzerland)

by

Joël Vonlanthen
from Fribourg, Switzerland

in fulfillment of the requirements for the degree of
Doctor of Philosophy in Economics (Ph.D.)

accepted by the Faculty of Management, Economics, and Social Sciences on
November 21, 2024 at the proposal of Prof. Dr. Sergio Rossi (First Advisor) and
Prof. Dr. Philippe Gugler (Second Advisor)

Fribourg, 2025

The Faculty of Management, Economics and Social Sciences of the University of Fribourg (Switzerland) neither approves nor disapproves the opinions expressed in a doctoral thesis. They are to be considered those of the author. (Decision of the Faculty Council of 23 January 1990)

Table of contents

Abstract

The dynamic nature of real estate markets highlights several crucial yet insufficiently explored areas in the existing real estate literature. Key gaps include the limited empirical investigation into how interest rate sensitivities vary across different interest rate types, locations, and real estate asset classes. Additionally, while any real estate valuation based on the income approach requires the incorporation of discount rates, their subjective nature introduces risks of miscalculation, potentially leading to suboptimal and inefficient valuations. Furthermore, there is a notable scarcity of theoretical and empirical evidence on the significance and applicability of sustainability ratings in the real estate industry.

This dissertation addresses three critical questions in the real estate literature and aims to provide practical insights for a broad range of stakeholders, including regulatory authorities, commercial real estate investors, appraisers, and private households. Our research is centered in Switzerland and offers a detailed analysis of the forces shaping real estate markets, with a specific focus on interest rates, discount rates in the Discounted Cash Flow (DCF) method, and Environmental, Social, and Governance (ESG) ratings. Through this targeted approach, we seek to bridge gaps in the existing literature and provide guidance for investigating the complexities of real estate markets.

The first study examines the relationship between interest rates and real estate prices in Switzerland from 2005 to 2018, analyzing six real estate types across 106 regions. Using various interest rate proxies, the study reveals a heterogeneous impact of interest rates on real estate prices, with variations across real estate types and Swiss regions. The second study investigates the determinants of discount rates within the DCF method, distinguishing between appraisal-based and transaction-based discount rates. The findings show that appraisers and investors attribute different levels of importance to the fundamental determinants of discount rates. Furthermore, the study reveals that locational and macroeconomic factors are more influential in residential real estate, while object-specific characteristics dominate in the commercial real estate segment. The third study assesses the association of ESG ratings with key metrics in the real estate industry. The analysis shows significant associations between ESG ratings and discount rates, rental incomes, and vacancy rates, indicating that the environmental rating stands out as the most essential sub-rating. Furthermore, the findings suggest potential signaling effects, as properties with higher ESG ratings show greater sensitivity to discount rates and vacancy rates.

Keywords

Real estate fundamentals, valuation process, sustainability, regional data

List of figures

List of tables

Acknowledgments

The path to completing this work has been one of profound learning, growth, and discovery, made possible by the encouragement and assistance of many persons and institutions. First and foremost, I would like to express my deepest gratitude to Prof. Sergio Rossi for providing me with the opportunity to conduct my Ph.D. studies under his supervision. He created the perfect environment for my research, offering invaluable assistance and support in all circumstances. His insightful advice and guidance were instrumental in the completion of this dissertation.

Furthermore, I am deeply grateful to the Department of Economics at the University of Fribourg for their comprehensive guidance and support throughout my studies, which greatly facilitated my research process. I would also like to extend my thanks to the participants of the SFI conferences in Gerzensee for their insightful comments on my research. Additionally, I am thankful to the anonymous referees of the *Swiss Journal of Economics and Statistics* and the *MDPI Journal Real Estate*, whose valuable comments enhanced the quality of my research.

I extend my gratitude to Wüest Partner for their support throughout the process of this dissertation. Wüest Partner provided me with exceptionally high-quality data, a rare resource that is often inaccessible to most real estate professionals. In addition, Wüest Partner afforded me the dialogue with numerous real estate investors, providing essential context for emerging questions in the Swiss real estate industry. Their supportive environment fostered my professional development and deepened my knowledge in real estate economics, valuation methods, and applied finance.

On a very personal note, I am more than grateful for your support, Carla. You brought me happiness, laughter, and endurance. Your reminders to cherish the simplest things have kept me grounded and motivated. I am also thankful to my family: Lya, Jan, Renate, and Michael. Your support, insightful discussions, and occasional diversions have been a constant source of strength and inspiration for me. Thank you all.

Chapter I: Introduction

1.1. Real estate markets in the Swiss context

Distinctive characteristics of real estate markets, grounded in the immovability, illiquidity and long-term nature of real estate assets, together with their sensitivity to locational characteristics or even macroeconomic events, lay the foundation for their unique dynamics. Within this realm, Swiss real estate markets demonstrated notable resilience during recent years. Between 2005 and 2022, the residential real estate segment, in particular, witnessed a substantial price surge. Median prices for owner-occupied flats (+79.9%) and houses (+66.4%) experienced noteworthy increases, while median rental prices per square meter for apartments (+16.7%) displayed a comparatively modest rise. The commercial real estate segment mirrored this trend, as median rental prices per square meter for office space increased by 15.3%, industrial real estate by 12.5%, while sales area experienced a more modest increase of only 1.8% (Wüest Partner, 2023). Notably, prices for income properties surged by 84.4% between 2005 and 2022 (IAZI, 2023).

Heterogeneous price developments among real estate prices may seem surprising at first glance, but are the consequence that prices for homeownership, rental prices or even prices for income properties are determined on different markets. Rental prices are formed on the user market by contrasting the supply for residential housing or commercial purposes with the respective demand. The space originating from the building stock corresponds to the supply, while households and firms using residential or commercial space represent the demand (DiPasquale and Wheaton, 1992). In contrast, prices for houses or owner-occupied flats are shaped on the market for homeownership, reflecting households' willingness to pay that is opposed with limited space for new construction. Additionally, the prices of income properties are formed in investor markets, where transactions are based on comparing anticipated revenues and costs, along with those of alternative investment classes (Theurillat et. al., 2015).

Understanding these distinct markets is crucial, as valuation methods tailored to each market provide valuable insights into the fundamental mechanisms driving real estate prices. In Switzerland, prices for homeownership are generally derived using hedonic pricing models, for example by banks for granting mortgages. These models operate on the assumption that individuals derive utility from housing, which can be priced. Accordingly, hedonic pricing models articulate the price of a particular object as a function of its specific characteristics or location, all of which exert an implicit impact on its value (McConnell and Walls, 2005). A similar approach is taken for rental prices, as determined on the user market, where a hedonic function is used to derive their values (Djurdjevic et al., 2008). Prices of income properties, in

contrast, are assessed through the income approach, which evaluates them based on their cash flows, as these properties are held as income-generating assets by commercial real estate investors.

Along with various other factors, the effectiveness of valuation methods across different asset classes depends on accurately assessing the influence of key macroeconomic forces that shape the distinctive dynamics of real estate markets. Notably, increased real estate prices during recent years aligned with constantly declining interest rates. Yields on 10-year government bonds saw a decline from 3.4% in June 2008 to -1.1% in 2019, subsequently rebounding into positive territory as of January 2022 (Swiss National Bank, 2024). Increased real estate prices during recent years were also accompanied with a consistently growing population and an enhanced overall economic performance. Over the period from 2005 to 2022, the Swiss population experienced a growth of 17.9% (Federal Statistical Office, 2023), and the Gross Domestic Product (GDP) per capita increased by 27.4% (Federal Statistical Office, 2023b). To accommodate economic and population growth between 2005 and 2022, investments in new construction surged by 19.4% during this period (Federal Statistical Office, 2023c). Despite the substantial surge in investments in Swiss real estate markets, average vacancy rates remained stable without any notable increase. Between 2005 and 2022, the average vacancy rates for residential real estate ranged between 1.0% and 1.3%, as reported by the Federal Statistical Office (2023d).

Apart from macroeconomic developments that typically influence real estate markets, Switzerland exhibits unique characteristics, particularly in its regulatory framework. For instance, the market for homeownership is influenced by the requirement for households to provide a 20% down payment when purchasing a property. Furthermore, homeowners can offset mortgage interest payments from taxes, but their imputed rents are subject to taxation (Federal Tax Administration, 2015). Rental prices, on the other hand, are affected by the Swiss rent control system. This system permits rent adjustments through the reference index, an average level of mortgage interest rates across Switzerland, or the Swiss Consumer Price Index (CPI). While commercial rental contracts frequently include an indexation to inflation up to 80%, residential rental contracts comprise an indexation of 40%. The investor market, on the contrary, may be influenced by the regulatory shift back in 1985, which mandated deposits into pension funds. Since then, institutional investors have systematically increased their investments in real estate markets, considering their suitability as alternative asset classes (Drechsel and Funk, 2017). Investors also benefit from the possibility to adjust rents either

when undertaking major renovations, incurring increased maintenance costs, or when a new tenancy starts (Hilber and Schöni, 2016).

Switzerland's federalist structure, where the federal state and 26 cantons operate as distinct fiscal jurisdictions, also exerts influence on its real estate markets. Under this structure, cantons have the authority to establish local regulations and delegate powers to municipalities, resulting in a diverse regulatory environment (Basten et al., 2017). A suitable example is the taxation of incomes, wealth or even properties, which vary considerably between cantons and among its municipalities. The federalist structure is also accompanied by the enactment of initiatives, whether on a cantonal or national level, contributing to the unique character observed among Swiss regions. For instance, in 2012, Swiss residents approved the Second Home Initiative (SHI), which prohibits the construction of new second homes in touristic municipalities (Hilber and Schöni, 2020). Recently, the canton of Basel City accepted the initiative "Ja zum ECHTEN Wohnschutz", which aims to implement an additional rent control mechanism for renovations and their cost transfer to rental prices (Regierungsrat Kanton Basel Stadt, 2022).

1.2. Emerging questions in Swiss real estate markets

The numerous factors affecting Swiss real estate markets are intrinsically linked to the emergence of new questions, a connection that resonates with the broader landscape of change. Given Switzerland's distinctive characteristics, encompassing structural circumstances and regulations, an initial question coincides with the onset of the global financial crisis and subsequent shifts in worldwide and Swiss monetary policies. The general decrease in interest rates has substantially lowered mortgage interest rates, consequently making homeownership more affordable through declined mortgage rates and financing costs. Simultaneously, investors in commercial real estate have redirected their investments toward the real estate sector, seeking higher yields amidst limited alternative opportunities. As a matter of fact, Swiss pension funds have augmented the proportion of direct investments in real estate from 12.2% (CHF 56.9 billion) in 2005 to 17.6% (CHF 204.1 billion) in 2021 (Federal Statistical Office, 2008:2022). In consequence, the disproportionate redirection of investments into the Swiss real estate market has heightened vulnerabilities and increased risks to financial stability (Swiss National Bank, 2021). The observed trends in Swiss real estate markets, marked by declining interest rates and rising real estate prices, prompt questions about their underlying connection. Specifically:

- *What are the macroeconomic transmission mechanisms through which changes in interest rates influence real estate prices?*
- *How does the impact of interest rate fluctuations differ across various real estate types?*

- *Is there spatial heterogeneity in the influence of interest rates on real estate prices across different geographic locations?*

In addition to the overarching influence of aggregated demand and supply factors on real estate prices, valuation-based mechanisms also contribute to the observed dynamics in real estate markets, especially in the context of income properties. In Switzerland, commercial real estate investors are mandated to have their portfolios evaluated annually by appraisal companies, which commonly employ the Discounted Cash Flows (DCF) method to determine the market value of income properties. The discount rate holds particular relevance in this regard as it reflects variations in interest rates, contributing to the observed volatility in income property prices in recent years.

While there are some guidelines regarding discount rates, the absence of publicly available data sources makes it a perceived black box, implying that the discount rate often includes uncertainties and may be susceptible to subjectivity. The significance of discount rates becomes evident in the context of prevailing accounting standards. For instance, under the International Financial Reporting Standard (IFRS), increased market values of income properties lead to book gains, which can be employed to leverage external capital (PWC, 2016, p. 97). Subsequently, these gains may be reinvested in new income properties, with financing facilitated by Swiss banks. Since 2015, the mortgage volume of Swiss banks has been growing by 25%, reaching a volume of CHF 1'200 billion in 2022 (Moneypark.ch, 2022). As a result, real estate markets have become increasingly important in terms of financial stability, especially because disruptions in these markets have repeatedly triggered chain reactions that not only affected the banking system but also had broader implications for the whole economy. Given this context, some questions arise, including:

- *What are the underlying factors that drive discount rates in the DCF method?*
- *What factors influence discount rates in the context of appraisal-based and transaction-based methodologies?*
- *To what extent does the influence of fundamental determinants on discount rates differ among various segments within Swiss real estate markets?*

Real estate markets are also affected by structural transformations, notably the increasing significance placed on sustainability considerations. This trend has prompted governments to institute new regulatory frameworks, thereby influencing the investment decisions of both investors and households. The inherent connection between sustainability measures and their regulation prompts questions about their association with market outcomes within the domain of real estate. Among these measures, Environmental, Social, and Governance (ESG) ratings emerge as particularly pertinent, given their widespread adoption in the real estate industry. The inclusion of measurable locational characteristics among the three pillars of ESG further

emphasizes fundamental questions regarding the essence of ESG ratings for specific real estate assets. In particular:

- *What are the channels through which ESG ratings may affect key metrics associated with real estate assets?*
- *In what manner, if any, does the association between ESG ratings and key metrics vary among sub-ratings?*
- *Does broad sustainability coverage and targeted financial relevance intersect?*

In light of these considerations, a deeper understanding of the fundamental drivers of real estate markets has become increasingly important for key stakeholders in real estate markets. This dissertation builds upon the multifaceted forces influencing Swiss real estate markets and comprises three studies that delve into current topics within the realm of real estate economics. The first study (Interest rates and real estate prices: a panel study) focuses on connection between interest rates and their effect on real estate prices. The ensuing study, titled "On the determinants of discount rates in the discounted cash flow method: a counterfactual analysis", provides an analysis of a pivotal component within real estate valuation – namely, the discount rate – with a particular emphasis on its determinants. The concluding study (ESG ratings and real estate key metrics: a case study) explores the widespread concept of ESG ratings and how this is associated with key metrics of income properties.

1.3. Focus of the dissertation

The dissertation begins by addressing a notable trend and seeks to provide deeper insights into the complex connection between interest rates and real estate prices. While this fundamental connection benefits from a broad array of empirical findings, crucial questions remain unanswered. Specifically, we aim to elucidate the channels through which channels interest rates influence real estate prices, how this varies across different real estate types, while also addressing spatial differences of this fundamental linkage.

Building on the insights gained from the initial study, further questions emerge, particularly regarding the observed redistribution of financial resources among commercial real estate investors toward income-producing real estate assets. Expanding upon this, the second study delves into the complexities of income property market values, which are primarily derived using the income approach. Given the regulatory landscape in Switzerland affecting cash flows, fluctuations in income property market values are largely contingent on discount rates. This study aims to shed light on this crucial factor, exploring its dynamics in relation various object-specific, locational, or macroeconomic variables.

The third study addresses a pressing question for commercial real estate investors in Switzerland – that is, the association between sustainability ratings and key metrics of income

properties. In a competitive market for sustainability, characterized by an increasing number of providers and upcoming regulatory initiatives, the study systematically examines potential channels through which a specific type of a sustainability rating – ESG ratings – may be associated with key metrics of income properties.

Each study in this dissertation examines fundamental aspects of real estate, including the sensitivity of real estate prices to interest rates, determinants of discount rates in real estate valuations, and the growing significance of sustainability ratings. Our research is centered in Switzerland, employing statistical estimation methods to address the underlying research question and drawing on high-quality data sourced from federal administrations (Swiss National Bank, Federal Statistical Office), or Wüest Partner AG, a leading real estate consulting firm in Switzerland.

1.3.1. Interest rates and real estate prices: a panel study

In our first study, we analyze the trends observed in Swiss real estate markets spanning over the past two decades, specifically the phenomena of decreasing interest rates and increasing real estate prices. The connection of interest rates and real estate prices is a well-known question in the real estate literature. Examples are given by Adams and Füss (2010), who analyzed the long-term effect of macroeconomic variables on real estate prices in 15 countries over a period of 30 years, or by Belke and Keil (2017), who analyzed the impact of fundamental determinants on apartment and house prices in Germany between 1990 and 2010.

The existing literature addressing the connection between interest rates and real estate prices can be clearly subdivided into cross-country and country-specific studies, offering multifaceted empirical approaches to analyzing this connection. Interest rates, in this regard, are represented very heterogeneously, suggesting that interest rates affect real estate prices through numerous channels, which has insufficiently been analyzed in the relevant literature. Additionally, empirical evidence for the fundamental linkage between interest rates and real estate prices mainly exists for the residential real estate segment, whereas the commercial real estate segment is largely unexplored.

We first highlight and discuss the characteristics of Swiss real estate markets. As a matter of fact, Switzerland possesses unique characteristics that help explaining price developments across real estate markets, but also that differentiate them from other industrialized countries. Besides these characteristics, Swiss real estate markets were affected by several noteworthy historical events. Among those events, a fundamental change can be traced back to the year 2008, when the global financial crisis and subsequent monetary policies significantly impacted Swiss real estate markets. Interest rates, lowered to stimulate the weakening economy, reached

all-time lows in the subsequent years. This increased the demand for homeownership, triggered valuation-based leverages, and prompted institutional investors to shift their investments into the real estate sector in search of yields due to limited alternative opportunities.

The foundation of the first study lies in the connection between interest rates and real estate prices from a macroeconomic standpoint. We meticulously discuss how different interest rates potentially affect real estate prices and pinpoint three measurable macroeconomic channels through which our interest rate representatives influence real estate prices: a valuation-based channel incorporating the computational application of the risk-free rate in discount rates, a financing-based channel capturing the impact of interest rate levels via mortgage interest rates, and an investment-based channel emerging as commercial investors redirect their financial resources into real estate markets. These influencing channels are empirically tested on real estate prices of six distinct real estate types, together with four metrics gauging interest rates. In particular, we consider price developments of rental apartments, owner-occupied flats, houses, office spaces, industrial real estate, and sales area against yields on 10-year government bonds, 10-year fixed mortgage rates, variable mortgage rates, and a newly introduced variable, the *spread*, which compares net initial returns with yields on governmental bonds.

Real estate markets are essentially local markets, as individuals, guided by Tiebout's (1956) concept, select regions based on an optimal mix of taxes and public goods. This underlying principle extends to the commercial real estate segment, wherein real estate prices mirror entry costs that businesses incur to avail themselves of local amenities (Gyourko, 2009). Building on this, we assess the type-specific interest rate sensitivity across Swiss regions. Amid the diverse geographical levels in Switzerland suitable to regional analysis, we focus on the MS-regions (*Mobilité Spatiale*), which can be consolidated into 8 monitoring regions. The primary advantage of the MS-regions lies in their ability to consider the enduring heterogeneity of the Swiss landscape, encompassing geographical distinctions and language differences, elements that traditionally influence and steer real estate markets.

From an econometric standpoint, we analyze the period from the first quarter of 2005 to the fourth quarter of 2018, employing a fixed-effect panel regression model over a MS-region level. This estimation approach proves suitable, as it accommodates a unique characteristic of real estate markets: their immobility, tying them to specific locations. Consequently, when estimating price developments at a local level, a region-specific effect for each MS-region driving real estate prices can be aggregated into a time-invariant regional effect. Removing this specific regional effect then facilitates the estimation of specific determinants, with a particular focus on the effect of interest rate representatives on real estate prices.

1.3.2. On the determinants of discount rates in discounted cash flow valuations: a counterfactual analysis

Changes in monetary policy affect real estate prices through numerous channels, which also hinges on the real estate segment under consideration. To delve deeper into this connection, the second study focuses on income-generating properties, typically valued through the income approach, which consists of two primary components: a depiction of cash flows and a discount rate. The latter proves to be particularly interesting, primarily due to the complexity of determining accurate discount rates. This complexity arises from the variations in discount rates among different valuation methodologies, the limited availability of publicly accessible data pertaining to discount rates, and the divergent weightings assigned to the components of discount rates by the various stakeholders involved.

Essentially, the conversion of rental incomes generated on the user market in market values of income properties takes place on the investor market via the discount rate. The discount rate reflects the probability with which an expected rental income will be realized and correspond to the return a given investor can expect under normal market conditions. A rational investor compares this expected return with an alternative risk-free investment. While yields of governmental bonds indicate the expected return for a relatively risk-free investment, investments in income properties comprise risk, for which the investor must be compensated. As a result, the discount rate, or the required rate of return more generally, consists of a compensation for lost liquidity, inflation, and risk-taking.

The pivotal role of discount rates in influencing the market values of income properties may elucidate the frequent exploration of the determinants of discount rates in real estate literature. In fact, most studies pursued the strategy to directly estimate assets' discount rate considering versatile explaining factors. Examples include Chuangdumrongsomsuk and Fuerst (2017), who analyzed the determinants of office capitalization rates (cap rates) in several American cities between 2000 and 2013, or by Letdin et al. (2023), who focused on retail property transactions from 2005 to 2019 in the United States (US). Among those discount rates, cap rates are by far the most frequently analyzed type of a discount rates. Only very few studies analyzed the determinants of discount rates in the DCF method, which is the most frequently applied valuation method for income properties in Switzerland. Thus, we aim to close the existing gap in the relevant literature, facilitating more informed investment decisions and refined valuation practices, thereby enhancing the understanding of the valuation process in the real estate industry.

The second study centers discount rates for income properties in Switzerland between 2007 and 2020. The analysis builds upon a unique dataset, compromising market transactions together with expert-based valuations. While appraisal-based discount rates are directly extracted from the underlying dataset, they compromise appraisers' expert knowledge but may not accurately display assets' heterogeneous character, current market tendencies, or investors' perception of risk. In fact, an alternative discount rate is often identified when the evaluated income property has been traded in open market transactions, thereby allowing the implicit derivation of transaction-based discount rates.

Leveraging upon this fruitful dataset, we conduct a comprehensive counterfactual analysis about the fundamental determinants of appraisal-based and transaction-based discount rates. The analysis encompasses object-specific, locational, and macroeconomic variables, aligning with consensus in the real estate literature. In conducting our analysis of the fundamental drivers of appraisal-based and transaction-based discount rates across the full sample, as well as the residential and commercial real estate segments, we critically assess their sensitivity to numerous factors contributing to fluctuations in income properties' market values.

1.3.3. ESG ratings and real estate key metrics: a case study

Our third study addresses the broader topic of sustainability and its intersection with real estate markets. Among the frequently published certificates or eco-labels, ESG ratings became increasingly important for management competence, non-financial performance and risk management (Kiernan, 2007). ESG ratings aim to quantify specific components from the perspective of risk or opportunity and represent an analytical framework to quantify the degree to which an industry, an asset, or a portfolio is operating in a sustainable manner. However, ESG ratings are not subject to direct regulation by governmental bodies or international organizations, but various initiatives have been established to enhance their transparency, accuracy, and consistency. Furthermore, numerous ESG providers have entered the market, but their ratings are often not comparable, given the differences in sub-rating inclusion and the use of varying weighting approaches (Tsang et al., 2023).

Specifically in Switzerland, the significance of sustainability criteria began in 2019 when the Swiss parliament endorsed the Swiss Climate Policy 2050, aiming to achieve carbon neutrality by 2050 (Federal Council, 2019). Following this, awareness of sustainability experienced a rapid upswing, driven further by the recent adoption of the executive order on climate reporting for sizable Swiss companies by the Federal Council (2022). Swiss institutions, such as the Swiss Financial Market Supervisory Authority (FINMA), monitor enacted regulations by the Swiss Parliament or the Federal Council and issue guidelines about the

integration and communication of ESG ratings for financial institutions. Furthermore, pension funds are obliged to provide regular updates on the ESG performance of their investments, rendering ESG ratings a vital guide for the real estate industry's sustainable journey by directing stakeholders to more informed decisions.

As a matter of fact, the real estate industry grapples with fundamental questions about the essence of ESG ratings, driven by providers' focus on developing ratings based on location-based indicators. The absence of clear regulatory frameworks and the complexity of integrating these ratings with financial materiality leave the association between ESG ratings and real estate key metrics largely unexplored, raising pivotal questions about their relevance and practicality. Building on this, the third study examines whether and through which channels ESG ratings may be associated with key metrics in the real estate industry. Focusing on income properties in Switzerland from 2019 to 2022, we leveraged appraisal and transaction processes of these assets and identified four key metrics that are potentially associated with ESG ratings: appraisal-based and transaction-based discount rates, rental incomes, and vacancy rates.

As tangible assets bound to a specific location, the considered key metrics may be affected by a wide range of transmission processes. Rental incomes, for instance, may systematically reflect location-based sustainability attributes that are capitalized through hedonic pricing mechanisms (Feige et al., 2013). Conversely, vacancy rates could indicate the improved quality of a location through a demand-side effect (Fuerst and McAllister, 2011). Whether and how ESG ratings align with financial relevance may also be reflected in the risk premium captured by appraisal-based or transaction-based discount rates, which indicate appraisers' or investors' perception of risk.

Our assessment is based on approximately 6'300 expert-based DCF valuations together with roughly 850 real market transactions in Switzerland between 2019 and 2022. Both datasets are enriched with an ESG rating, encompassing a wide range of indicators that real estate experts attribute to the broader topic of sustainability. In employing an Ordinary Least Squares (OLS) post Least Absolut Shrinkage and Selection Operator (LASSO) estimation procedure, we aim to identify and quantify the association between the considered ESG ratings and the four key metrics under consideration.

To deepen our understanding of the association between ESG ratings and key metrics, our analysis is conducted at both aggregated and disaggregated levels. Initially, we focus on an aggregated level, employing a data-driven approach to examine associations derived from total ESG ratings. We also explore potential signaling effects emanating from varying levels of the total ESG ratings, acknowledging that an association between real estate assets and ESG ratings

may not be linear. At the disaggregated level, analysis scrutinizes the sub-ratings for the environment, governance, and society. This dual-level analysis not only allows us to critically assess the findings from the aggregated level, but also provides nuanced insights into how broad sustainability coverage intersects with targeted financial relevance.

1.4. Contribution of the dissertation

Motivated by the growing complexity and significance of real estate markets, this dissertation endeavors to provide nuanced perspectives on pivotal questions essential for key stakeholders in real estate markets, regulatory authorities, appraisers, commercial real estate investors, and private households. In the course of our analysis, our contribution encompasses a comprehensive examination of the significance of real estate fundamentals to elucidate the underlying forces and mechanisms that intricately shape the Swiss real estate markets.

1.4.1. The interest sensitivity of real estate prices

Our first study provides a comprehensive analysis of the impact of interest rates on real estate prices, a topic of critical importance to policymakers, commercial investors, and appraisers alike. Despite extensive literature on this subject, existing studies often rely on varied approximations of interest rates and insufficiently explore the channels through which this fundamental connection operates. Notably, there remains a significant gap in the literature, particularly in Switzerland, regarding how interest rate sensitivity varies across different real estate types and regions.

Focusing on Swiss real estate markets, the first study aims to close these gaps by discerning the impact of four interest rate types on price developments of six real estate prices, thereby exploring the channels through which these influences operate. Our findings reveal that the relationship between interest rates and real estate prices is not characterized by a singular effect but rather by a remarkably diverse array of effects, each tied to the specific real estate types under consideration. This nuanced understanding offers valuable insights, providing a more refined framework for anticipating market responses to interest rate changes.

In conducting an isolated analysis of the residential housing segment, we deepen our understanding of how fluctuations in mortgage interest rates impact homeownership prices, particularly examining the effects of both fixed and variable mortgage rates on houses and owner-occupied flats. Our analysis about rental prices for apartments suggest a smaller, but nevertheless, significant response to fluctuations in interest rates. Upon closer examination, we find that even within Switzerland's prevailing rent control system, residential rental prices are

positively associated with the *spread*. This provides quantitative evidence that the divergence between net initial returns and government bonds counteracts locally binding regulations.

By applying our estimation approach to the commercial real estate segment, encompassing office space, industrial real estate, and sales areas, we uncover how this segment responds to shifts in interest rates. Our findings indicate that only specific real estate types within this segment consistently respond to shifts in interest rates, suggesting that other fundamental drivers, such as firms' performance and their interaction with monetary policy stance, also exert an influence on the commercial real estate segment. This contribution enhances the understanding of the diverse factors impacting commercial real estate, providing guidance for navigating this complex market.

Finally, our initial study makes a valuable contribution by estimating the interest rate sensitivities of various real estate types across Swiss regions. We observed that the heterogeneous effects of interest rates become even more pronounced when considering different Swiss regions. This detailed analysis provides important recommendations for policymakers, offering quantitative insights into how real estate markets respond to interest rate fluctuations.

1.4.2. Unraveling discount rate dynamics

Our second study contributes by undertaking a thorough analysis of the fundamental determinants that influence discount rates in the DCF method. Despite being Switzerland's most widely used valuation method for appraising the market value of income properties, the existing literature lacks empirical findings on this crucial aspect. The discount rate in the DCF method introduces a notable level of subjectivity, suggesting that these rates are susceptible to uncertainty and potential misjudgment. Furthermore, there is a substantial gap in our understanding of how the impact of fundamental determinants on discount rates differ between residential and commercial real estate, and also how appraisers or investors assign weights to these fundamental drivers, especially in the context of Switzerland.

Given the pivotal role of the discount rate on market values of income properties, our contribution relies on an in-depth analysis about the fundamental drivers of appraisal-based and transaction-based discount rates. The latter are implicitly derived by combining appraisers' expert knowledge with actually achieved transaction prices. While appraisal-based discount rates illuminate the methodology employed by appraisers in determining discount rates, transaction-based discount rates provide insights into how investors perceive risks. Thus, our counterfactual analysis of the determinants of appraisal-based and transaction-based discount

rates yields novel insights into the Swiss valuation process and its implications for market trends.

We further refined our analysis by considering residential and commercial real estate separately. This segmentation allows us to undertake a nuanced investigation, illuminating how the determinants of discount rates differ across different real estate segments. Moreover, our approach extends to understanding the divergent weightings assigned to specific components by both appraisers and investors within these distinct segments. The outcomes of our investigation advocate for a diverse weighting approach between appraisers and investors. This divergence underscores the complexity and individuality with which these two key stakeholders evaluate and prioritize different factors when determining discount rates.

Among the numerous findings regarding the fundamental determinants of discount rates, the quantification of interest rate sensitivity stands out as particularly pertinent, especially given the recent upswing in target interest rates, both globally and in Switzerland since 2022. This investigation sheds light on the intricate interplay between the growth potentials of income properties' market value and the fluctuations in discount rates, thereby creating a connection with Swiss mortgage markets for commercial real estate investors. This nuanced understanding contributes valuable insights to policymakers concerned with financial stability, offering a comprehensive perspective on the interconnected dynamics of interest rates, income property market values, and their implications for economic and financial policy.

1.4.3. Assessing ESG ratings in the realm of income properties

In response to the growing emphasis on sustainability in real estate markets, our third study delves into key questions surrounding the relevance and practicality of ESG ratings. While existing literature provides valuable insights into the significance of eco-labels and various real estate metrics at the property level, the association between these metrics and ESG ratings has primarily been studied in the context of Real Estate Investment Trusts (REITs). This leaves a significant gap in understanding the association between ESG ratings and key metrics for income properties, especially within Swiss real estate markets. Additionally, there is a significant gap in the discourse regarding the detailed analysis of underlying sub-ratings, and how they intersect with financial materiality.

We contribute to the existing literature by offering a comprehensive analysis of the core components of ESG ratings. As one of the first to explore this area in depth, we deconstruct the total ESG rating into its individual sub-ratings, offering a thorough examination of the foundational elements of these ratings. The deconstruction of ESG ratings into various aggregation levels, combined with a data-driven estimation approach, offers insights into the

conceptual origins of sustainability aspects and their potential transmission into financial materiality within real estate markets. These findings are pertinent to both regulatory authorities and real estate practitioners, enhancing the understanding of the fundamental dynamics within real estate markets.

Diving deeper, our contribution includes an assessment using four distinct key metrics: appraisal-based and transaction-based discount rates, rental incomes, and vacancy rates. These key metrics derived from the appraisal and transaction processes not only enhance the robustness of our findings but also allow us to identify influencing channels from a broader perspective. The distinctiveness of the key metrics considered sheds light on the unique characteristics of real estate markets, while also paving the way for future research by offering a practical approach to identifying the channels through which sustainability characteristics may influence the real estate industry.

Furthermore, our third study offers in-depth insights into a relatively unexplored category of ESG ratings. Amid ongoing regulatory developments, we contribute to the field by critically evaluating the relevance and practical application of these ratings within the real estate sector, thereby elucidating and examining their fundamental characteristics. The findings of our study provide a strategic framework that could help better align ESG rating developments with market realities in the real estate industry.

Abbreviations

Abbreviation	Meaning
CPI	Consumer Price Index
DCF	Discounted Cash Flow
ESG	Environment, Society, and Governance
FINMA	Swiss Financial Market Supervisory Authority
GAAP	Generally Accepted Accounting Principles
GDP	Gross Domestic Product
IFRS	International Financial Regulation Standards
LASSO	Least Absolut Shrinkage and Selection Operator
MS	*Mobilité Spatiale*
OLS	Ordinary Least Squares
REIT	Real Estate Investment Trusts
US	United States

References

Adams, Z., Füss, R. (2010). Macroeconomic determinants of international housing markets. *Journal of housing economics, Vol. 19, No. 1, pp. 38-50, DOI: https://doi.org/10.1016/j.jhe.2009.10.005*.

Basten, C., Von Ehrlich, M., Lassmann, A. (2017). Income taxes, sorting and the costs of housing: evidence from municipal boundaries in Switzerland. *The economic journal, Vol. 127, No. 601, pp. 653-687.*

Belke, A., Keil, J. (2017). Fundamental determinants of real estate prices: a panel study of German regions. *Ruhr economic papers, No. 731, ISBN: 978-3-86788-851-6, RWI - Leibniz-Institut für Wirtschaftsforschung, Essen DOI: https://doi.org/10.4419/86788851*.

Chuangdumrongsomsuk, M., Fuerst, F. (2017). Determinants of cap rates in U.S. office markets. *Journal of real estate literature, Vol. 25, No. 2, pp. 267-282.*

DiPasquale, D.,Wheaton, W.C. (1992). The markets for real estate assets and space: a conceptual framework. *Real estate economics, Vol.20, No. 2, pp. 181-198.*

Djurdjevic, D., Eugster, C., Haase, R. (2008). Estimation of hedonic models using a multilevel approach: an application for the Swiss rental market. *Swiss journal of economics and statistics, Vol. 144, No. 4, pp. 679-701.*

Drechsel, D., Funk, A. (2017). Time-varying and regional dynamics in Swiss housing markets. *Swiss society of economics and statistics, Vol. 153. No. 1, pp. 37-72.*

Federal Council (2019). Climate protection: Federal Council adopts Switzerland's long-term climate strategy. *Available online: https://www.admin.ch/gov/de/start/dokumentation/medienmitteilungen.msg-id-82140.html (accessed on February 2024).*

Federal Council (2022). Federal Council brings ordinance on mandatory climate disclosures for large companies into force as of 1 January 2024. *Available online: https://www.admin.ch/gov/en/start/documentation/media-releases.msg-id-91859.html (accessed on March 2024).*

Federal Statistical Office (2008:2022). Pension fund statistics - Key figures 2000-2006 / 2017-2021. *Neuchâtel, Switzerland, Available online: https://www.bfs.admin.ch/bfs/de/home/statistiken/kataloge-datenbanken.assetdetail.346530.html (accessed on December 2023).*

Federal Statistical Office (2023). Permanent resident population by canton. *Available online: https://www.bfs.admin.ch/bfs/de/home/statistiken/bevoelkerung/stand-entwicklung.assetdetail.32229209.html (accessed on January 2024).*

Federal Statistical Office (2023b). Gross domestic product per capita. *Available online: https://www.bfs.admin.ch/bfs/en/home/statistics/national-economy/national-accounts/gross-domestic-product.assetdetail.32257500.html (Accessed on January 2024).*

Federal Statistical Office (2023c). Construction expenditure and construction inventory by type of construction and by canton. *Available online: https://www.bfs.admin.ch/bfs/de/home/aktuell/neue-veroeffentlichungen.assetdetail.26645952.html (accessed on January 2024).*

Federal Statistical Office (2023d). Vacant apartments. Development. *Available online: https://www.bfs.admin.ch/bfs/de/home/statistiken/bau-wohnungswesen/wohnungen/leerwohnungen.assetdetail.32406429.html (accessed on January 2024).*

Federal Tax Administration (2015). Die Besteuerung der Eigenmietwerte, Stand der Gesetzgebung: 1. Januar 2015. *3003 Bern, Switzerland.*

Feige, A., Mcallister, P., Wallbaum, H. (2013). Rental price and sustainability ratings: which sustainability criteria are really paying back? *Construction management and economics, Vol. 31, No. 4, pp. 322-334, DOI: https://doi.org/10.1080/01446193.2013.769686*.

Fuerst, F., McAllister, P. (2011). The impact of energy performance certificates on the rental and capital values of commercial property assets. *Energy Policy, Vol. 39, No. 10, pp. 6608-6614.*

Gyourko, J. (2009). Understanding commercial real estate: just how different from housing is it? *NBER working paper serie, Working Paper 14708*.

Hilber, A.L., Schöni, O. (2016). Housing policies in the United Kingdom, Switzerland, and the United States: lessons learned. *US Department of housing and urban development, Washington, DC, USA, Vol. 18, No. 3, pp. 291-332.*

Hilber, A.L., Schöni, O. (2020). On the economic impacts of constraining second home investments. *Journal of urban economics, Vol. 118, No. 1*.

IAZI (2023). SWX IAZI Price index for real estate. *Available online: https://www.iazicifi.ch/produkt/swx-iazi-indizes (accessed on November 2023)*

Kiernan, M. (2007). Universal owners and ESG: leaving money on the table? *Corporate governance: An international review, Vol. 15, pp. 478-485.*

Letdin, M., Sirmans, G., Smersh, G., Zhou, T. (2023). The role of tenant characteristics in retail cap rate variation. *Journal of real estate finance and economics, DOI: https://doi.org/10.1007/s11146-023-09958-9.*

McConnell, V., Walls, M. (2005). The value of open space: evidence from studies of nonmarket benefits. *Lincoln istitute of land policy*.

Moneypark (2022). The Swiss mortage market 2022. *Available online: https://mpcdn.ch/media/pdf/press_releases/MoneyPark_Hypothekarmarktstudie_2022.pdf (accessed on January 2024).*

PWC (2023). Applying IFRS for the real estate industry. *Available online: https://www.pwc.ch/en/publications/2023/Applying%20IFRS%20for%20the%20real%20estate%20industry.pdf (accessed on September 2023).*

Regierungsrat Kanton Basel Stadt (2022). Neue Wohnschutzbestimmungen treten per 28. Mai 2022 in Kraft. *Available online: https://www.bs.ch/medienmitteilungen/2022-neue-wohnschutzbestimmungen-treten-28-mai-2022-kraft (accessed on March 2024).*

Swiss National Bank (2021). Mortgage and real estate markets: current developments pose risks to financial stabilit. *Key Note Speech, Firtz Zurbrügg, University of Lucerne*.

Swiss National Bank (2024). Spot interest rates on Swiss confederation bond issues for selected maturities. *Available online: https://data.snb.ch/en/topics/ziredev/chart/rendeidglfzch (accessed on Feburary 2024).*

Theurillat, T., Rérat, P., Crevoisier, O. (2015). The real estate markets: players, institutions and territories. *Urban studies, Vol. 52, No. 8, pp. 1414-1433.*

Tiebout, C. (1956). A pure theory of local expenditures. *Journal of political economy, pp. 416-424.*

Tsang, A., Frost, T., Cao, H. (2023). Environmental, social, and governance (ESG) disclosure: a literature review. *The British accounting review, Vol. 55, No. 1, DOI: https://doi.org/10.1016/j.bar.2022.101149.*

United Nations (2004). Who cares wins: connecting financial markets to a changing world. *Available online: www.unepfi.org/fileadmin/events/2004/stocks/who_cares_wins_global_compact_2004.pdf (accessed on December 2023).*

Wüest Partner (2023). Median real state prices across different real estate segments. *Internal data source.*

Chapter II - Interest Rates and Real Estate Prices: a Panel Study*

Abstract: This study examines the connection between interest rates and real estate prices in Switzerland. In considering median prices of six real estate types 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 study 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. Our results highlight a heterogeneous connection between real estate prices and interest rates, varying across real estate types and Swiss regions.

Keywords

Real estate fundamentals, real estate prices, monetary policy, regional data, panel study

*Updated version of the paper published in the *Swiss Journal of Economics and Statistics (2023). DOI: https://doi.org/10.1186/s41937-023-00111-0*

2.1. 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%.

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 types 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. The relationship between price developments of real estate groups and representations of interest rates is analyzed using a fixed-effect panel regression model, capturing quarterly data between 2005 and 2018 for 106 regions in Switzerland.

Our contribution to the literature is summarized as follows. First, we provide an in-depth analysis about how different interest rate representatives affect type-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 (VAR) 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 heterogenous regions.

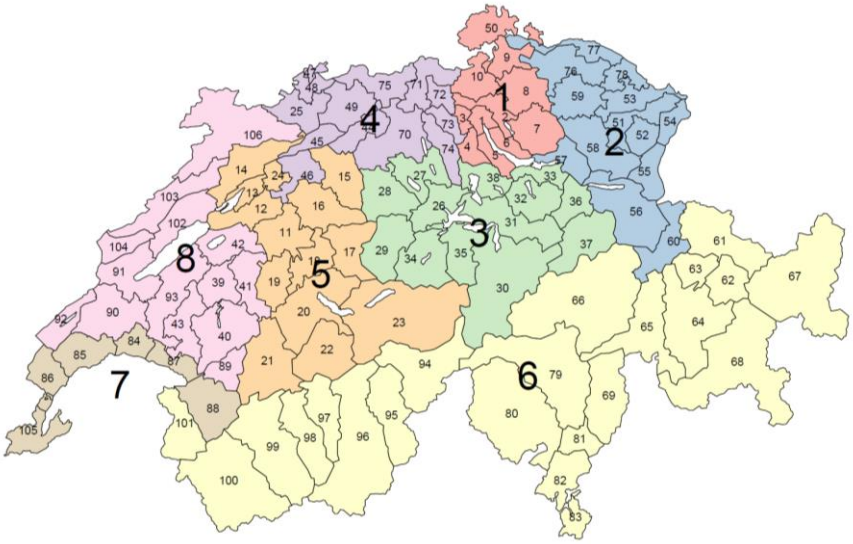
The remainder of this study is structured as follows. The second section is devoted to a description of Swiss real estate markets. The third section reviews recent events in the monetary policy of Switzerland, while focusing on interest rates. In the following section, we explain developments of real estate prices for the underlying six real estate types. 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 results.

2.2. 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 8 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 8 regions are displayed in Figure 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 (Federal Statistical Office, 2005, pp. 65-67; 73-74)[2].

Figure 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 AG (2021).

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 and 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]

[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 7 are considered as actually intercantonal regions: Grenchen, Laufental, Murten, Wil SG, Aarau, Broye and La Chaux-de-Fonds (Federal Statistical Office, 2005, pp. 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.

(Federal Statistical Office, 2019b). An explanation for the persistent low homeownership rates can be found 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

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

taxes, some cantons, such as Zurich, Schwyz, or Zug, renounce them, whereas others 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 and 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. Thus, Switzerland ranks among the countries with the highest mortgage debt-to-GDP ratios in the world (Hilber and Schöni, 2016).

Another example of a regulatory standard is the persisting rent control system. Accordingly, 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 2008 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 2008 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, pp. 15).

2.3. 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 the of policy rate, or the target rate more generally. Since June 2019, the Swiss Average Rate Overnight (SARON) 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" (Maechler and 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 Offered Rate (Libor) for Swiss franc investments was the guiding benchmark for credit relationships in Switzerland. The absence of underlying money market transactions, along with the fact that the United Kingdom's (UK) Financial Conduct Authority (FCA) will no longer support Libor after 2021, led to its replacement by SARON.

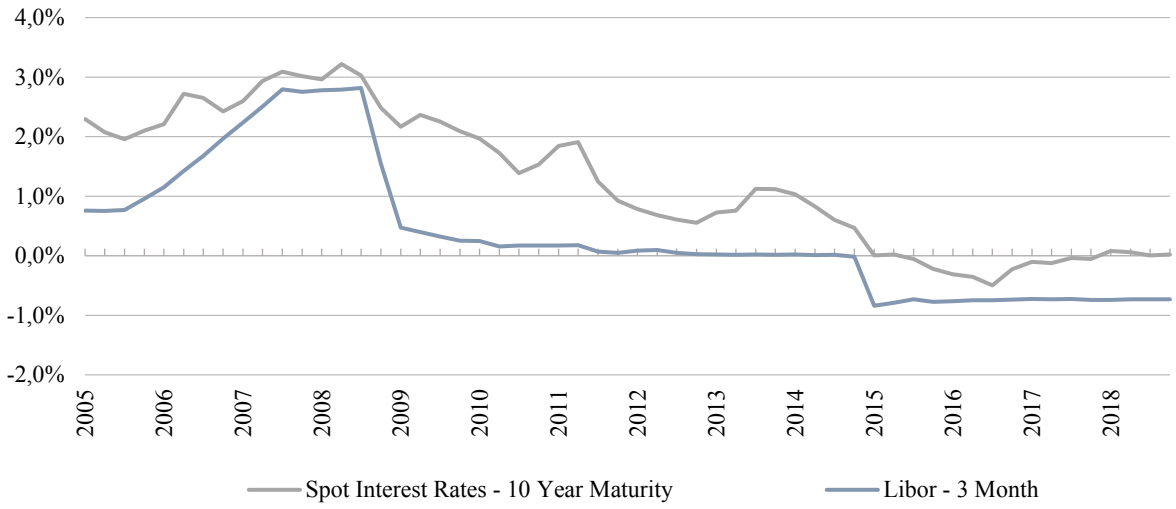
The SNB conducts its monetary policy through transactions in the financial market. These transactions can broadly be divided into open market operations and standing facilities[5]. Due to its constitutional mandate to ensure price stability, the SNB intervenes through open market operations and thereby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

[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.

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 lowered its 3-month Libor rate to between 0.0% and 0.25% (SNB, 2011).

Figure 2: Spot interest rates and Libor target rates



Notes: 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.

The years from 2011 to 2015 were marked by deflationary expectations and declining 3-month Libor rates, which fell to between -1.25% and -0.25%, along with a minimum exchange rate that prompted significant intervention by the SNB 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 U.S. 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, along with the exit negotiations between the UK and the EU, introduced systemic risk, leading to an overvaluation of the Swiss franc and heightening the need for the SNB to intervene in financial markets. Uncertainty and global risks prompted the SNB to continue its expansionary policy in 2016, keeping the 3-month Libor rate unchanged at 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).

2.3.1. 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 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 represents the impact of the SNB's monetary policy decisions on Swiss real estate markets. As represented in Figure 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, the financing-based channel captures the impact of the interest rate level through mortgage interest rates on real estate prices[6]. 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-based 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 often

[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.

use multiple mortgage types to finance homeownership. 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, 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 ($R_t = yearly\ rent\ /P_t$). Solving this definition of a return for real estate prices (P_t) explains the latter as the ratio between yearly rents and the return ($P_t = yearly\ rent\ /R_t$). 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)[8] (Chaney and 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:

$$R_p = \underbrace{R_t - R_f}_{spread} \tag{2.1}$$

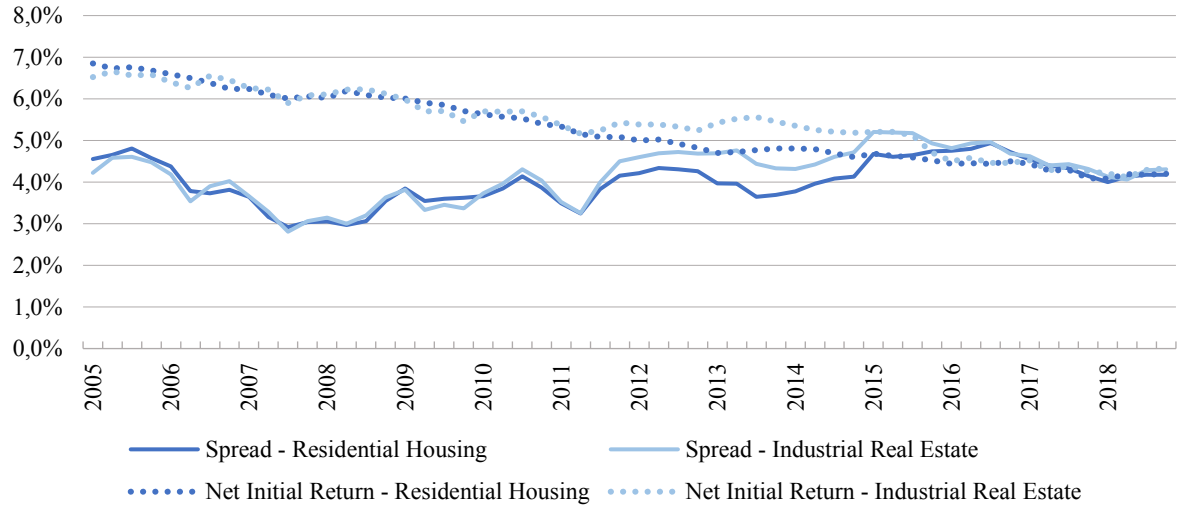
Where the difference between returns and the risk-free rate represents the *spread*. The relevance of this measure crucially depends on whether the respective real estate object is held as an investment object or not. In the context of the underlying study, the *spread* is expected to contain explanatory power for rental prices of rental apartments and industrial real estate because only for these types 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 notable observation is that the *spread* for residential and industrial real estate increased, despite a decline in their respective net initial returns. This can be explained by the definition of the *spread*, which indicates that yields on government bonds declined more rapidly than net initial returns in Swiss real estate markets.

[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. Money market mortgages account for a negligible amount of mortgage agreements (10% in 2016).

[8] This definition simplifies discount rates, which typically also consider inflation adjustments.

Figure 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 type. The displayed time frame ranges from 2005 Q1 to 2018 Q4.

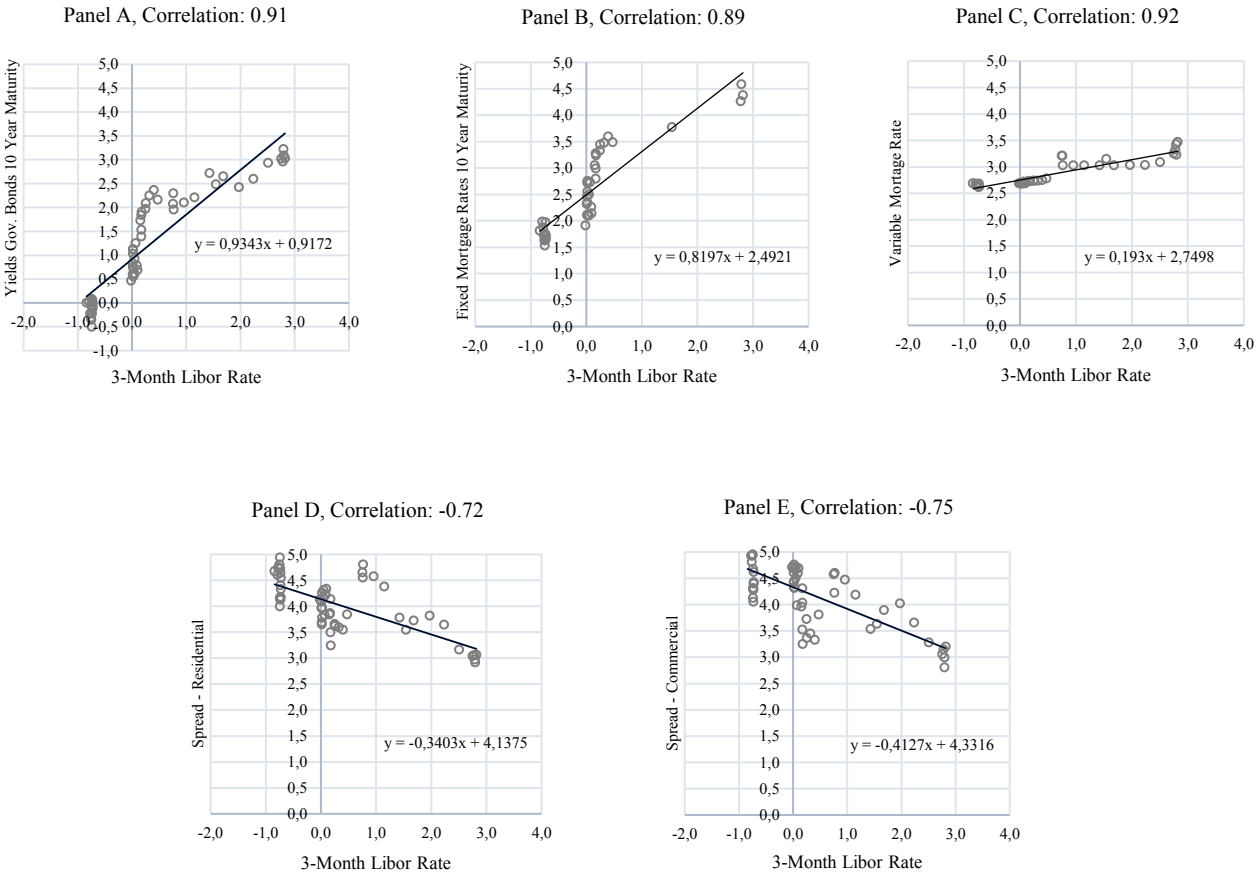
The fact that developments in the policy rate are mirrored in our interest rate representatives raises the question about the pass-through of altered monetary policies on real estate markets. A recent study by Koeniger et al. (2021) found that an unexpected 25 basis point cut in the policy rate leads to a 22 basis point reduction in mortgage rates in Switzerland 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 from the adjustment of computationally applied discount rates, selling processes in real estate markets, and the growing popularity of fixed-rate mortgages in recent years slow the pass-through of interest rate changes to real estate prices[9].

In Figure 4, we analyze 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 found 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

[9] 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.

rate at low levels is observable, from 2005 to 2018, our interest rate representatives experience a slight delay in effect due to changes in monetary policy.

Figure 4: Co-movement of interest rate representatives 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 Equation 2.1, 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.

2.4. Real estate prices

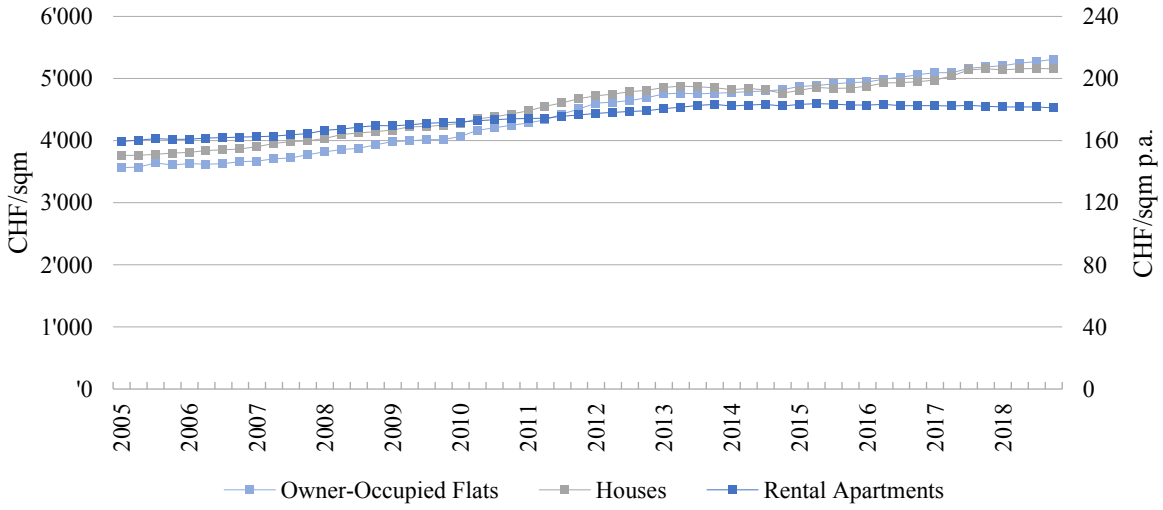
We consider six different real estate types that can broadly be subdivided into the residential housing and commercial real estate segments. Residential housing includes rental apartments, owner-occupied flats, and houses, whereas commercial real estate refers to office, industrial real estate, and sales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

Figure 5 displays the development of median real estate prices for residential housing between 2005 and 2018. Median prices per sqm 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%). During the same time period, prices per sqm for houses rose from CHF 3’761 to CHF 5’153 (+37.0%).

Numerous macroeconomic indicators contributed to the considerable rise in real estate prices for homeownership. Between 2005 and 2018, Swiss population grew from 7.4 Mio. 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.

Figure 5: Residential real estate – real estate prices

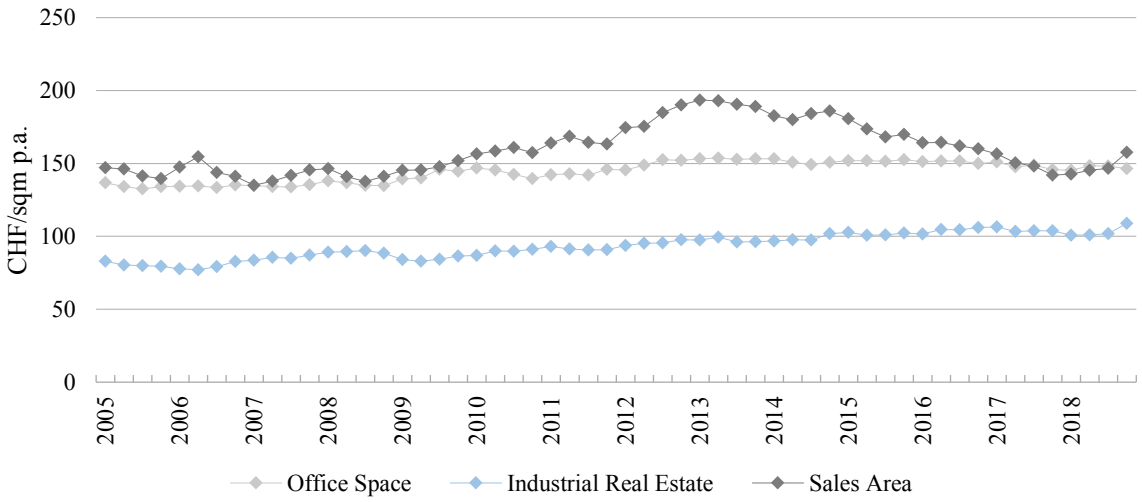


Notes: Average median real estate prices across 106 MS-regions of Switzerland for houses, owner-occupied flats, and rental apartments between 2005 Q1 and 2018 Q4. The left axis indicates the price development of houses and owner-occupied flats (CHF/sqm), whereas the right axis refers to yearly rental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

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 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).

Figure 6: Commercial real estate – real estate prices

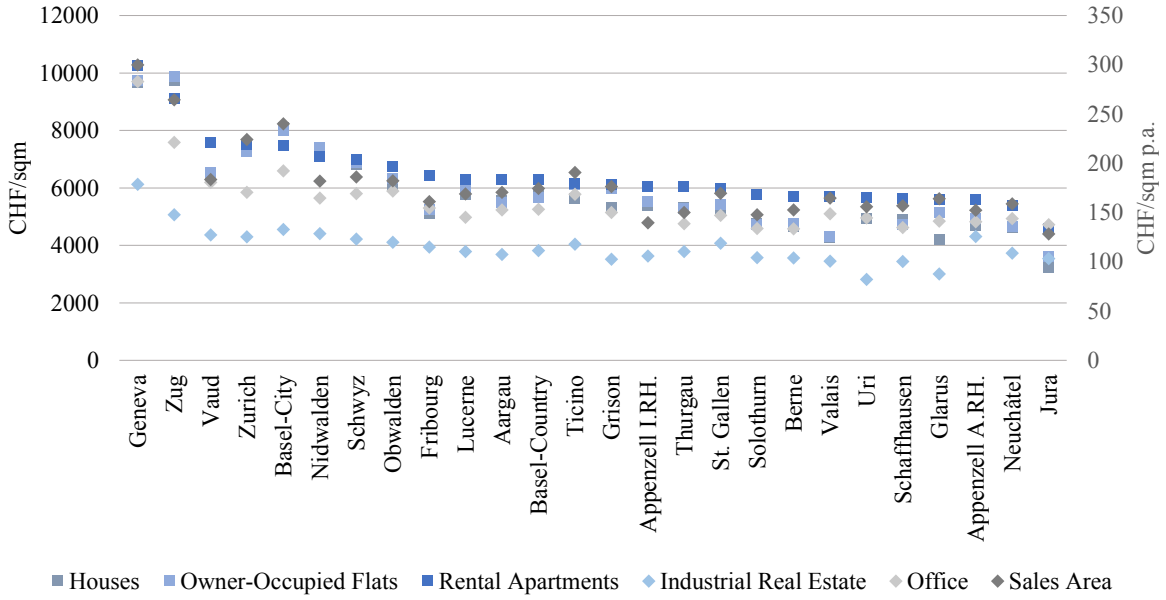


Notes: Average median real estate prices, measured in rental prices per sqm and year (CHF/sqm p.a.), across 106 MS-regions of Switzerland for office space, sales area, and industrial real estate between 2005 Q1 and 2018 Q4. Source: Wüest Partner AG.

Next, we examine the development of median prices per sqm for commercial real estate – comprising office space, sales area, and industrial real estate – between the first quarter of 2005 and the fourth quarter of 2018, as shown in Figure 6. Similarly to prices of residential housing, an appreciation of real estate prices can be observed. Industrial real estate has experienced the largest price appreciation, with median rental prices rising by 31.5% from CHF 80 per sqm in 2005 to CHF 109 per sqm in 2018. 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 afterwards. 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. Figure 7 illustrates the median real estate prices for the six real estate types under consideration in the fourth quarter of 2018 across Swiss cantons. Especially remarkable is the co-movement of prices from different real estate types 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 types. 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 types and suggests the presence of vastly different real estate markets.

Figure 7: Real estate prices across Swiss cantons



Notes: Average median real estate prices in 2018 Q4 for six different real estate types 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 sqm and year (CHF/sqm p.a.). Source: Wüest Partner AG.

2.5. 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 few theoretically founded fundamental determinants of real estate prices, the empirical literature presents a wide range of candidate regressors that explain 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 over a period of 30 years. Their

results indicate that economic activity and construction costs are positively associated with house prices. In addition, the authors found that a 1 percentage points (pp) 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 authors 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 United States (US) increased by about 8% after three years in response to a 1 pp decline in the 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, the authors did not found 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 Ordinary Least Squares (OLS) model and reported that the GDP per capita and real interest rates are robustly associated with house prices in the OECD and eastern European countries. Their 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, the authors 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 pp increase in interest rates raises house prices by about 5% and rental apartment prices by between 2% and 4.5%, depending on the model used. The authors 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 VAR model to a dataset consisting of quarterly GDP values, 3-month target Libor rate, the money stock and the Swiss Performance Index (SPI) between 1987 and 2008, the authors concluded that the residential housing segments respond very heterogeneously to altered monetary policy[10]. 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. The authors 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 demand and supply conditions between 1982 and 2013, the authors concluded that residential rental prices are more susceptible to changes in mortgage interest rates than prices of houses and owner-occupied flat. Additionally, the authors reported a heterogenous 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 of whether, and to what extent, learnings about the fundamental determinants of real estate prices can be

[10] Since the authors 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.

applied to 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, 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[11].

2.6. 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 types: 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 by deploying a fixed-effects panel regression model, covering the period from the first quarter of 2005 to the fourth quarter of 2018, which controls for regional fixed effects to analyze the impact of interest rates on real estate prices.

2.6.1. Data

Table 1 describes the variables used in the subsequent analysis, while summary 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 is 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 database. The *spread* is defined as the difference between net initial returns and yields on governmental bonds with 10-year maturity. Net initial returns, provided by Wüest

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

Partner AG, include income, while object-specific costs, such as insurance and maintenance, are 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 type-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 types. 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.

Table 1: Variable description

Variable Name Description	**Source**
Median rental prices: Median rental prices per sqm and year. Relevant for: apartments, office space, sales area, and industrial real estate.	Wüest Partner AG
Median prices: Median prices per sqm. Relevant for: houses and 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, and industrial real estate.	Wüest Partner AG
Vacancy rates: Number of vacant objects relative to the housing stock (%). Relevant for: houses, owner-occupied flats, and rental apartments.	Federal Statistical Office
Market and location rating: Rating: Min = 1, Max = 5. Relevant for: rental apartments, houses, owner-occupied flats, office, sales area, and 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

Notes: The description refers to all variables used in the empirical analysis. "Location and market rating", "'Vacancy rates", "Supply number", and "Building applications" are relevant across several real estate types and account for multiple type-specific variables within each category. "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 SNB are available on a monthly basis and have been average on a quarterly level.

As we consider six real estate types, we use two separate variables to represent vacancy rates. For the residential housing segment, we apply officially published numbers by the Federal Statistical Office[12]. 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 as the number of advertised real estate objects divided by the type-specific stock[13]. 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 and highlights the market and location quality for each real estate type across Swiss regions[14]. 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 type-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, 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[15]. 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 from the first quarter of 2005 to the fourth quarter of 2018 across six

[12] The data source provides information about the number of vacant rental apartments, houses and owner-occupied flats, which are then divided by the respective housing stock.
[13] 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.
[14] The market and location rating accounts for location-specific elements such as the municipality type, tax burden, labor market conditions, and price developments.
[15] The housing stock includes rental apartments, houses, and owner-occupied flats. Firms are represented by the number of corporations and limited liability companies.

different real estate types. The quality of the dataset is further enhanced by the limited number of sources. All data were obtained from federal administrations (SNB, Federal Statistical Office) or Wüest Partner AG. This small number of sources standardizes the dataset and facilitates comparisons of specific variables across different real estate types.

2.6.2. 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 types 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:

$$P_{it}^{j} = \alpha_i + \beta_1 M_{it}^{j} + \beta_2 m_t + u_{it} \tag{2.2}$$

Real estate prices (P_{it}^{j}) are represented by quarterly median rental prices per sqm for each real estate type (j) consisting of rental apartments, sales area, office space, and industrial real estate or by prices per sqm for owner-occupied flats and houses. α_i represents region-specific fixed effects for each MS-region in Switzerland. M_{it}^{j} is a vector of geographical and time varying determinants of real estate prices across real estate type (j) as represented by the location and market rating, investments per resident, the firm and housing stock, population growth, vacancy rates, or the supply number. 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[16]. 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 and Eberl, 2020).

In the context of this study, the intuition behind α_i is linked to a central characteristic of real estate objects: 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, explaining a regional price level requires

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

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.

2.7. 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 types. Prices of owner-occupied flats exhibit the largest impact in response to altered interest rates. Decreasing interest rates by 1 pp increases their prices by about 1.5% on average in Switzerland. With regard to houses, the corresponding interest effect is only about half as large (0.7%) and even smaller for rental apartments (0.4%). When putting these 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.

The market and location rating enters with a positive sign into our baseline regression Model 1 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 suggests 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 the fact that real estate prices are influenced more by the density of the regional market than by population growth.

Table 2: Fixed-effect panel regression – residential housing

Real estate type:	Rental Apartments		Houses			Owner-Occupied Flats		
Dependent variable:	log of median sqm rental prices		log of median sqm prices			log of median sqm prices		
Model:	(1)	(2)	(1)	(2)	(3)	(1)	(2)	(3)
Market and location rating	0.0244***	0.0244***	0.0421***	0.0421***	0.0604***	0.0426***	0.0425***	0.0634***
	(0.0067)	(0.0067)	(0.0095)	(0.0095)	(0.0111)	(0.0114)	(0.0114)	(0.0113)
Investment per resident	0.0275***	0.0275***	0.0070	0.0070	0.0042	0.0274**	0.0274**	0.0240*
	(0.0059)	(0.0059)	(0.0106)	(0.0106)	(0.0124)	(0.0086)	(0.0086)	(0.0110)
Housing stock	0.0021.	0.0021.	0.0054**	0.0055**	0.0049**	0.0058**	0.0058**	0.0048*
	(0.0012)	(0.0012)	(0.0017)	(0.0017)	(0.0017)	(0.0019)	(0.0019)	(0.0020)
Vacancy rate	-0.0034	-0.0034	-0.0382*	-0.0383*	-0.0229	0.0070	0.0069	0.0007
	(0.0041)	(0.0041)	(0.0175)	(0.0175)	(0.0148)	(0.0205)	(0.0206)	(0.0218)
Population growth	-0.0168.	-0.0168.	-0.0138	-0.0138	-0.0046	-0.0605***	-0.0605***	-0.0363*
	(0.0089)	(0.0089)	(0.0156)	(0.0156)	(0.0116)	(0.0170)	(0.0170)	(0.0157)
Yields governmental bonds (10 Y)	-0.0039***		-0.0065***			-0.0152***		
	(0.0010)		(0.0011)			(0.0013)		
Variable mortgage rates				-0.0146***			-0.0228***	
				(0.0041)			(0.0048)	
Spread residential		0.0043***						
		(0.0009)						
Fixed mortgage rates (10 Y)					-0.0101***			-0.0183***
					(0.0012)			(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
Adjusted R^2	0.764	0.764	0.850	0.850	0.795	0.895	0.895	0.865
Observations	5936	5936	5936	5936	4664	5936	5936	4664

*Notes: 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 is limited to 56 quarters from 2005 Q1 to 2018 Q4. In Model 3 for houses and owner-occupied flats the time frame is limited to 44 quarters from 2008 Q1 to 2018 Q4. Variables are defined according to Table 1. Signif. codes: '***' 0.001, '**' 0.01, '*' 0.05, '.' 0.1*

In Model 2 of Table 2, we investigate whether the negative interest rate effect reported in Model 1 persists with a differentiated type-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 a negative sign into our estimation equation for houses and owner-occupied flats. Corresponding estimates gained in magnitude compare to yields on governmental bonds in Model 1 of Table 3, which is due to the considerably smaller volatility of variable mortgage interest rates[17]. Nevertheless, the decline 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 prices sqm 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%. However, the decline in financing costs for homeownership has not translated into increased 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.

Moving 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. Considering 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, indicating a similar sensitivity to interest rates as observed in rental prices for 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.

[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 is limited to 44 quarters.

While commercial real estate prices tend to react differently to interest rates, similarities to the residential housing segment are given by the 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 suggests that rising investments in real estate markets are associated with a shift in aggregate supply, which negatively impacts commercial real estate prices. Corresponding estimates are, however, largely insignificant.

Table 3: Fixed-effect panel regression – commercial real estate

Real estate type:	Office	Industrial Real Estate		Sales Area
Dependent variable:	log of median sqm rental prices	log of median sqm rental prices		log of median sqm rental prices
Model:	(1)	(1)	(2)	(1)
Market and location 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
Adjusted R^2	0.578	0.614	0.614	0.535
Observations	5936	5936	5936	5936

*Notes: 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 is limited to 56 quarters from 2005 Q1 to 2018 Q4. Variables are defined according to Table 1. Signif. codes: '***' 0.001, '**' 0.01, '*' 0.05, '.' 0.1*

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 for industrial real estate[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 indicates that this relationship lacks a consistent pattern. 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 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 and 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. While commercial rental contracts often incorporate an inflation indexation of up to 80%, residential rental contracts usually feature 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

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

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.

2.7.1. 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 into our estimation approach. Of course, the selection of variables is linked to the spatial scope and time frame of the 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 types 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, Table 5). 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

[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%).

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, Table 6). A similar conclusion can be drawn when applying our variable for the economic structure to the commercial real estate segment (see Appendix A.4, Table 7). 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.

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.

2.7.2. Spatial differences

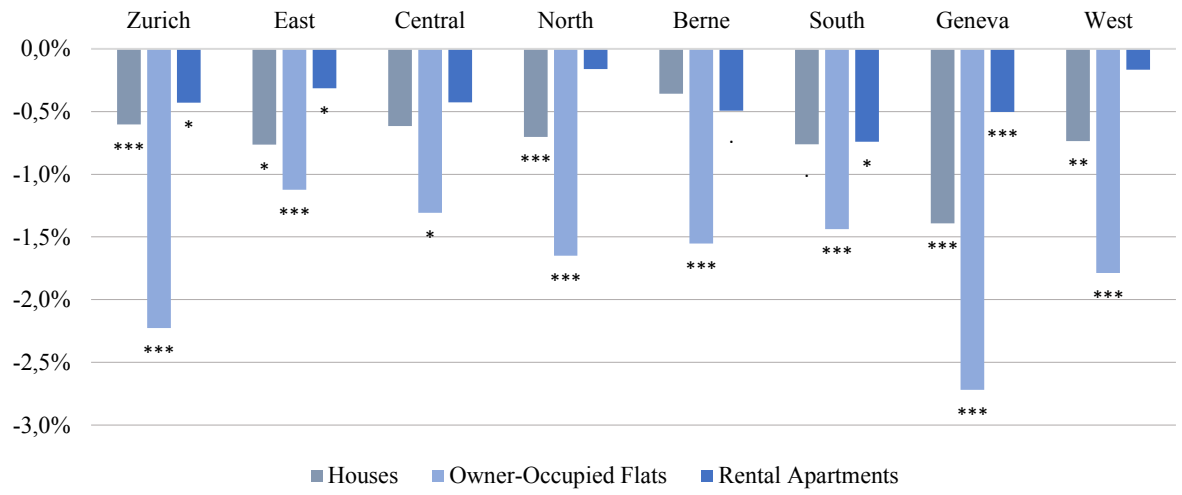
In order to further analyze the impact of interest rates, this section examines their impact across 8 Swiss monitoring regions. The latter represent suitable regions of analysis as they are composed of specific MS-regions (see Figure 1). For the sake of the argument, we apply our baseline regression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

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 Figure 8, interest rate effects not only differ between Swiss monitoring regions, but also between real estate types. The highest interest rate effects are observed in Zurich and Geneva, where a decline by 1 pp in yields on governmental bonds raises 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 rental apartments, where the highest interest rate effects are

[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.

located in Geneva and the south of Switzerland. In these regions, a decline by 1 pp in interest rates raises rental prices by 0.7% (South) and 0.5% (Geneva).

Figure 8: Residential housing – interest rate effect across Swiss monitoring regions

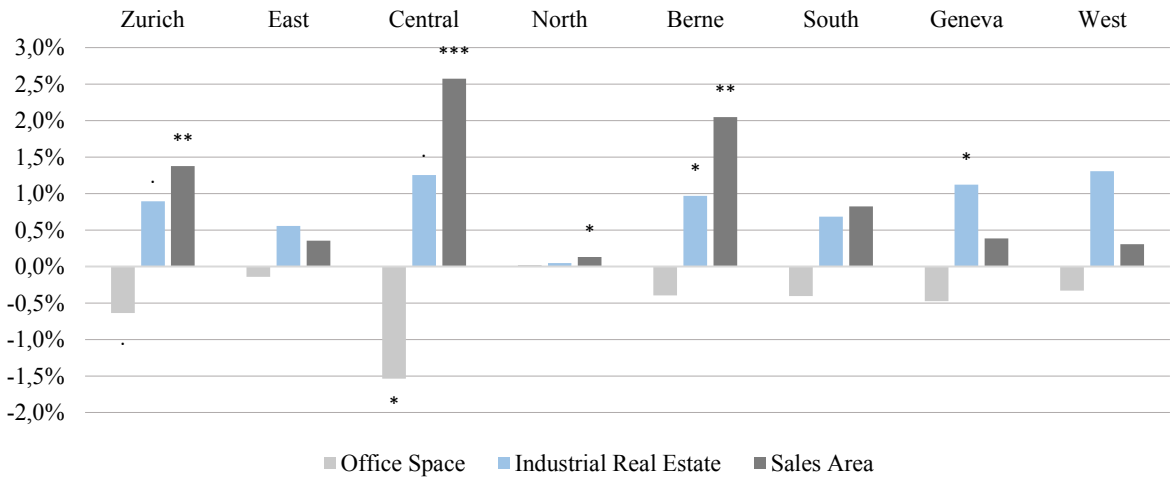


*Notes: Displayed coefficients correspond to yields on governmental bonds with 10-year maturity for each monitoring region in Switzerland. The coefficients are the results of a fixed-effect panel regression capturing 106 Swiss MS-regions between 2005 Q1 and 2018 Q4 (56 quarters) analogous to the baseline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

Spatial differences of the interest rate effect suggest the presence of vastly different real estate markets. We presume that the heterogenous 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. Consequently, a higher sensitivity of real estate prices to interest rates may indicate that these regions are characterized by an inelastic housing supply, leading to larger price fluctuations in response to changes in interest rates.

A different picture emerges when applying the same empirical strategy for the commercial real estate segment (Figure 9). The largest interest rate sensitivity of office rental prices can be found in central Switzerland and 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 supporting our presumption that the reported interest effect largely hinges on the specific real estate segment considered.

Figure 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*

2.8. Conclusion

This study analyzed the impact of interest rates on real estate prices. Using data from six different real estate types across all 106 MS-regions of 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* – the difference between yields on governmental bonds and net initial returns. In deploying a fixed-effect panel regression model with region-specific fixed effects, we controlled for the persistent heterogeneity across Swiss real estate markets.

In the group 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%. Similarly, a reduction in fixed mortgage interest rates by 1 pp increases median house prices by 1.0% and the 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 rental apartment prices increase by approximately 0.4%

in response to a 1 pp rise in the *spread*. Thus, even within Switzerland's prevailing rent control system, the divergence between net initial returns and government bonds may counteract locally binding regulations.

In applying our empirical strategy to the largely unexplored commercial real estate segment in Switzerland, we find a less conclusive relationship between our interest rate representatives and real estate prices. Whereas an inverse relationship is detected between yields on government bonds and office rental prices, rental prices for industrial real estate and sales areas display the opposite trend. 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 8 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 heterogenous 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 be readily 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 implement a stringent verification process for mortgage approvals, the impact of a potential rise in interest rates on real estate prices for homeownership remains uncertain.

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 21st century.

Abbreviations

Abbreviation	Meaning
Appenzell I. RH.	Appenzell Innerrhoden
Appenzell A. RH.	Appenzell Ausserrhoden
CPI	Consumer Price index
CHF	Swiss Francs
EU	European Union
FCA	Financial Conduct Authority
GDP	Gross Domestic Product
Libor	London Interbank Offer Rate
Mio.	Million
MS	*Mobilité Spatiale*
OECD	Organization for Economic Co-operation and Development
OLS	Ordinary Least Squares
SARON	Swiss Average Rate Overnight
SNB	Swiss National Bank
SPI	Swiss Performance Index
Sqm	Square meter
UK	United Kingdom
US	United States
VAR	Vector Autoregression Model

References

Adams, Z., Füss, R. (2010). Macroeconomic determinants of international housing markets. *Journal of housing economics, Vol. 19, No. 1, pp. 38-50, DOI: https://doi.org/10.1016/j.jhe.2009.10.005*.

Arellano, M. (1987). Computing robust standard errors for within-groups estimators. *Oxford bulletin of economics and statistics, department of Economics, university of Oxford, Vol. 49. No. 1, pp. 431-434.*

Belke, A., Keil, J. (2017). Fundamental determinants of real estate prices: a panel study of German regions. *Ruhr economic papers, No. 731, ISBN: 978-3-86788-851-6, RWI - Leibniz-Institut für Wirtschaftsforschung, Essen, DOI: https://doi.org/10.4419/86788851*.

Benjamin, J., Zietz, E., Sirmans, G. (2020). The environment and performance of industrial real estate. *Journal of real estate literature, Vol. 11, No. 3, pp. 279-324.*

Berlemann, M., Freese, J. (2013). Monetary policy and real estate prices: a disaggregated analysis for Switzerland. *International economics and economic policy 10, pp. 469-490. DOI: https://doi.org/10.1007/s10368-012-0222-7.*

Bourassa, S., Hoesli, M., Scognamiglio, D. (2010). Housing finance, prices, and tenure in Switzerland. *Journal of real estate literature, Vol. 18, No. 2, pp. 263-282.*

Chaney, A., Hoesli, M. (2012). Transaction-based and appraisal-based capitalization rate determinants. *Swiss finance institute research paper series No. 12-28*

Collischon, M., Eberl, A. (2020). Let's talk about fixed effects: let's talk about all the good things and the bad things. *Köln Z Soziol 72, pp. 289–299. DOI: https://doi.org/10.1007/s11577-020-00699-8.*

Drechsel, D., Funk, A. (2017). Time-varying and regional dynamics in Swiss housing markets. *Swiss society of economics and statistics, Vol. 153, No. 1, pp. 37-72.*

Égert, B., Mihaljek, D. (2007). Determinants of house prices in central and eastern europe. *BIS working papers, No. 236*.

Federal Office for Housing (2021). Development of the reference index. *Available online: https://www.bwo.admin.ch/bwo/de/home/mietrecht/referenzzinssatz/entwicklung-referenzzinssatz-und-durchschnittszinssatz.html (accessed at June 2021).*

Federal Office for the Environment (2015). Institutionelle Investoren Schweiz: Customer Journey. *Report, Bern, Switzerland.*

Federal Statistical Office (2005). Raumgliederungen der Schweiz. *Neuchâtel, Switzerland, ISBN: 3-303-00301-7.*

Federal Statistical Office (2018). Tax burden 2018 of a single-earner couple with two children and a gross income of 100'000 CHF. *Available online: http://www.estv2.admin.ch/d/dokumentation/zahlen_fakten/karten/2018/kantone/Marie_avec_enfants/R_0100_list.html (accessed on May 2021).*

Federal Statistical Office (2019a). Occupied dwellings or home ownership rate by household type. *Available online: https://www.bfs.admin.ch/bfs/en/home/statistics/construction-housing.assetdetail.20784888.html (accessed at July 2022)*.

Federal Statistical Office (2019b). General overview "buildings" and "apartments" by cantons 2018. *Available online: https://www.bfs.admin.ch/bfs/de/home/statistiken/bau-wohnungswesen.html (accessed on July 2022).*

Federal Statistical Office (2020a). Gross domestic product per resident. *Available online: https://www.bfs.admin.ch/bfs/de/home/statistiken/querschnittsthemen/wohlfahrtsmessung/alle-indikatoren/wirtschaft/reales-bip-pro-kopf.assetdetail.14347461.html (accessed on February 2021).*

Federal Statistical Office (2020b). Vacant apartments per canton. *Available online: https://www.bfs.admin.ch/bfs/de/home/statistiken/bau-wohnungswesen/wohnungen/leerwohnungen.assetdetail.14708711.html (accessed on May 2021).*

Federal Statistical Office (2020c). Construction activity, construction expenditure. *Available online: https://www.bfs.admin.ch/bfs/de/home/statistiken/bau-wohnungswesen/bautaetigkeit.html (accessed on April 2021).*

Federal Statistical Office (2020d). Pension fund statistics 2018. *Neuchâtel, Switzerland, ISBN: 978-3-303-13201-2, Available online: https://www.bfs.admin.ch/asset/de/12527055 (accessed on December 2022).*

Federal Statistical Office (2020e). Swiss consumer prices index. *Available online: https://www.bfs.admin.ch/bfs/en/home/statistics/prices.assetdetail.15284636.html (accessed on June 2021).*

Federal Statistical Office (2020f). Economic structure: companies. *Available online: https://www.bfs.admin.ch/bfs/de/home/statistiken/industrie-dienstleistungen/unternehmen-beschaeftigte/wirtschaftsstruktur-unternehmen.html (accessed on June 2021).*

Federal Statistical Office (2021). Tenants / owners. *Available online: https://www.bfs.admin.ch/bfs/de/home/statistiken/bau-wohnungswesen/wohnungen/wohnverhaeltnisse/mieter-eigentuemer.html (accessed at May 2021).*

Federal Tax Administration (2015). Die Besteuerung der Eigenmietwerte. *Stand der Gesetzgebung: 1. Januar 2015. 3003 Bern, Switzerland.*

Goodmann, L., Mayer, C. (2018). Homeownership and the American dream. *The Journal of economic perspectives, Vol. 32, No. 1, pp. 31-58.*

Gyourko, J. (2009). Understanding commercial real estate: just how different from housing is it? *NBER working paper series, Working Paper 14708*.

Hilber, A.L., Schöni, O. (2016). Housing policies in the United Kingdom, Switzerland, and the United States: lessons learned. *US Department of housing and urban development, Washington, DC, USA, Vol. 18, No. 3, pp. 291-332.*

Hott, C., (2009). Explaining house price fluctuations. *Working papers 2009-05, Swiss National Bank.*

Jordan, T., Ranaldo, A., Söderling, P. (2009). The implementation of SNB monetary policy. *Financial Markets and Portfolio Management, Vol. 23, pp. 349-359, DOI: https://doi.org/10.1007/s11408-009-0118-x*.

Koeniger, W., Lennartz, B., Ramelet, M. (2021). On the transmission of monetary policy to the housing market. *SNB Working Papers.*

Leskinen, N., Vimpari, J., Junnils, S. (2020). Using real estate market fundamentals to determine the correct discount rate for decentralised energy investments. *Sustainable cities and society, Vol. 53, DOI: https://doi.org/10.1016/j.scs.2019.101953*.

Maechler, A., Moser, T. (2020). Monetary policy implementation: how to steer interest rates in negative territory. *Virtual Money Markt Event, Speech*.

Moneypark.ch (2021), Swiss favorite mortgage. *Available online: https://moneypark.ch/presse (accessed on July 2022).*

Schweizerischer Städteverband (SSV) (2020). Statistik der Schweizer Städte 2020. *Bern, Switzerland, ISBN: 978-3-303-00639-9.*

SNB (2005:2010). Monetary policy assessment at year-end. *Press release*. *Available on: https://www.snb.ch/en/the-snb/mandates-goals/monetary-policy/decisions (accessed on November 2022)*

SNB (2011). Monetary policy assessment at year-end. *Press release*. *Available on: https://www.snb.ch/en/the-snb/mandates-goals/monetary-policy/decisions (accessed on November 2022)*

SNB (2011:2015). Monetary policy assessment at year-end. *Press release*. *Available on: https://www.snb.ch/en/the-snb/mandates-goals/monetary-policy/decisions (accessed on November 2022)*

SNB (2016). Monetary policy assessment at year-end. *Press release*. *Available on: https://www.snb.ch/en/the-snb/mandates-goals/monetary-policy/decisions (accessed on November 2022)*

SNB (2019). Monetary policy assessment at year-end. *Press release*. *Available on: https://www.snb.ch/en/the-snb/mandates-goals/monetary-policy/decisions (accessed on November 2022)*

Sutton, G., Hihaljek, D., Subelyte, A. (2017). Interest rates and house prices in the United States and around the world. *BIS Working Papers, No. 665*.

Tripathi, S. (2019). Macroeconomic determinants of housing prices: a cross country level analysis. *MPRA paper No. 98089*.

Wüest Partner AG (2021). Spatial segmentation into market regions. *Available online: https://www.wuest.io/online_services_classic/allgemeine_informationen/raeumliche_gliederung/pdf/regionenkarte.pdf (accessed on November 2021)*.

Appendix

A.1.

Table 4: Summary statistics

Variable	Min.	Max.	Mean	Median	Std. Dev.
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	13353.46	5429.45	5016.81	1742.09
Prices houses (CHF/sqm.)	2618.94	11547.05	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 and location rating rental apartments	1.00	4.90	2.99	3.00	9.43
Market and location rating owner-occupied flats	1.00	4.90	2.99	3.00	9.43
Market and location rating houses	1.00	4.90	2.99	3.00	9.43
Market and location rating office space	1.00	4.90	2.99	3.00	9.43
Market and location rating industrial real estate	1.00	4.90	2.99	3.00	9.42
Market and location 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

Notes: 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. Variables are defined according to Table 1.

A.2.

Table 5: Fixed-effect panel regression – residential housing – building applications

Real estate type:	Rental Apartments		Houses			Owner-Occupied Flats		
Dependent variable:	log of median sqm rental prices		log of median sqm prices			log of median sqm prices		
Model:	(1)	(2)	(1)	(2)	(3)	(1)	(2)	(3)
Market and location rating	0.243***	0.0243***	0.0421***	0.0421***	0.0607***	0.0425***	0.0425***	0.0638***
	(0.0066)	(0.0066)	(0.0095)	(0.0095)	(0.0111)	(0.0114)	(0.0114)	(0.0112)
Investment per resident	0.0265***	0.0265***	0.0071	0.0071	0.0041	0.0263**	0.0262**	0.0226*
	(0.0057)	(0.0057)	(0.0106)	(0.0106)	(0.0124)	(0.0087)	(0.0087)	(0.0109)
Housing stock	0.0021.	0.0021.	0.0054**	0.0054**	0.0049**	0.0058**	0.0058**	0.0048*
	(0.0012)	(0.0012)	(0.0017)	(0.0017)	(0.0017)	(0.0019)	(0.0019)	(0.0020)
Vacancy rate	-0.0035	-0.0035	-0.0386*	-0.0386*	-0.0221	0.0094	0.0094	0.0044
	(0.0041)	(0.0041)	(0.0176)	(0.0176)	(0.0150)	(0.0212)	(0.0213)	(0.0216)
Population growth	-0.0153.	-0.0153.	-0.0137	-0.0137	-0.0048	-0.0599***	-0.0599***	-0.0352*
	(0.0087)	(0.0087)	(0.0155)	(0.0155)	(0.0116)	(0.0171)	(0.0171)	(0.0158)
Building applications	0.0010	0.0010	-0.0004	-0.0004	0.0008	0.0008	0.0008	0.0010
	(0.0006)	(0.0006)	(0.0016)	(0.0016)	(0.0013)	(0.0007)	(0.0007)	(0.0006)
Yields governmental bonds (10 Y)	-0.0038***		-0.0066***			-0.0148***		
	(0.0009)		(0.0011)			(0.0013)		
Variable mortgage rates				-0.0146***			-0.0224***	
				(0.0041)			(0.0046)	
Spread residential		0.0043***						
		(0.0009)						
Fixed mortgage rates (10 Y)					-0.0098***			-0.0176***
					(0.0013)			(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
Adjusted R^2	0.765	0.764	0.850	0.850	0.795	0.895	0.895	0.865
Observations	5936	5936	5936	5936	4664	5936	5936	4664

*Notes: 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 is limited to 56 quarters from 2005 Q1 to 2018 Q4. In Model 3 for houses and owner-occupied flats, the time frame is limited to 44 quarters from 2008 Q1 to 2018 Q4. Variables are defined according to Table 1. Signif. codes: '***' 0.001, '**' 0.01, '*' 0.05, '.' 0.1*

A.3.

Table 6: Fixed-effect panel regression – residential housing – economic structure

Real estate type:	Rental Apartments		Houses			Owner-Occupied Flats		
Dependent variable:	log of median sqm rental prices		log of median sqm prices			log of median sqm prices		
Model:	(1)	(2)	(1)	(2)	(3)	(1)	(2)	(3)
Market and location rating	0.0250***	0.0250***	0.0423***	0.0423***	0.0609***	0.0430***	0.0430***	0.0636***
	(0.0065)	(0.0065)	(0.0094)	(0.0094)	(0.0107)	(0.0113)	(0.0113)	(0.0109)
Investment per resident	0.0280***	0.0280***	0.0071	0.0071	0.0043	0.0277**	0.0277**	0.0240***
	(0.0060)	(0.0060)	(0.0106)	(0.0106)	(0.0123)	(0.0087)	(0.0087)	(0.0011)
Housing stock	0.0021.	0.0021.	0.0055**	0.0055**	0.0049**	0.0059**	0.0059**	0.0049***
	(0.0011)	(0.0011)	(0.0017)	(0.0017)	(0.0017)	(0.0019)	(0.0019)	(0.0020)
Vacancy rate	-0.0023	-0.0023	-0.0384*	-0.0385*	-0.0236	0.0057	0.0055	0.0003
	(0.0042)	(0.0042)	(0.0175)	(0.0175)	(0.0146)	(0.0208)	(0.0209)	(0.0217)
Population growth	-0.0149.	-0.0149.	-0.0135	-0.0136	-0.0037	-0.0589***	-0.0589***	-0.0358***
	(0.0084)	(0.0084)	(0.0157)	(0.0157)	(0.0120)	(0.0167)	(0.0167)	(0.0150)
Economic structure	-0.1654	-0.1648	-0.0261	-0.0252	0.0743	-0.1414	0.1394	0.0366***
	(0.1455)	(0.1454)	(0.1584)	(0.1583)	(0.1866)	(0.2032)	(0.2031)	(0.0248)
Yields governmental bonds (10 Y)	-0.0040***		-0.0065***			-0.0153***		
	(0.0010)		(0.0011)			(0.0013)		
Variable mortgage rates				-0.0146***			-0.0228***	
				(0.0041)			(0.0046)	
Spread residential		0.0043***						
		(0.0009)						
Fixed mortgage rates (10 Y)					-0.0102***			-0.0184***
					(0.0013)			(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
Adjusted R^2	0.766	0.766	0.850	0.850	0.795	0.896	0.895	0.865
Observations	5936	5936	5936	5936	4664	5936	5936	4664

*Notes: 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 is limited to 56 quarters from 2005 Q1 to 2018 Q4. In Model 3 for houses and owner-occupied flats, the time frame is limited to 44 quarters from 2008 Q1 to 2018 Q4. Variables are defined according to Table 1. Signif. codes: '***' 0.001, '**' 0.01, '*' 0.05, '.' 0.1*

A.4.

Table 7: Fixed-effect panel regression – commercial real estate – economic structure

Real estate type:	Office	Industrial Real Estate		Sales Area
Dependent variable:	log of median sqm rental prices	log of median sqm rental price		log of median sqm rental price
Model:	(1)	(1)	(2)	(1)
Market and location 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	-0.4480*	0.1650	0.1639	-0.8011*
	(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
Adjusted R^2	0.584	0.614	0.614	0.543
Observations	5936	5936	5936	5935

*Notes: 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 is limited to 56 quarters from 2005 Q1 to 2018 Q4. Variables are defined according to Table 1. Signif. codes: '***' 0.001, '**' 0.01, '*' 0.05, '.' 0.1*

Chapter III - On the Determinants of Discount Rates in Discounted Cash Flow Valuations: a Counterfactual Analysis*

Abstract: This study addresses the scarcity of empirical findings on the determinants of discount rates in the Discounted Cash Flow (DCF) method, filling a crucial gap in the existing literature and enhancing the understanding of the valuation process from the perspectives of key stakeholders. Leveraging a unique dataset comprising market transactions enriched with expert-based valuation information, the study conducts a comprehensive counterfactual analysis of the fundamental determinants influencing both appraisal-based and transaction-based discount rates. The results reveal that appraisers and investors attribute different levels of importance to object-specific, locational, and macroeconomic variables. A segment-specific analysis further reveals that locational and macroeconomic variables exert a greater influence on discount rates in the residential real estate segment. In contrast, object-specific characteristics hold significantly higher importance in explaining discount rates in the commercial real estate segment.

Keywords

Discount rates, valuation process, Discounted Cash Flow (DCF) Method, real estate fundamentals

*Updated version of the paper published in the *MDPI Journal Real Estate (2024). DOI: https://doi.org/10.3390/realestate1020009*

3.1. Introduction

Market values of income properties are frequently calculated using the Discounted Cash Flow (DCF) method, in which future cash flows are discounted to the present. Expanding upon this approach, the market value of an income property is essentially attributable to two key determinants: a depiction of future cash flows and the discount rate. Whereas cash flows can be derived relatively reliably using detailed rent roll information, object-specific quality criteria, or market data, defining accurate discount rates proves to be more complex. Explanations may include the disparity in discount rates among valuation methodologies, the limited availability of publicly accessible data regarding discount rates, and the divergent weightings assigned to the components of discount rates by the stakeholders involved.

Despite its widespread use in valuing income properties, the existing literature lacks empirical findings on the fundamental determinants of discount rates in the DCF method. This absence underscores the subjective nature of discount rates, implying their susceptibility to uncertainty and potential misjudgment. Furthermore, significant gaps remain in understanding how these fundamental determinants affect discount rates between residential and commercial real estate, as well as how appraisers and investors assign weights to this critical component driving market values of income properties.

This study aims to enhance the understanding of the valuation process in the real estate industry by providing comprehensive insights into the nuanced determinants of discount rates, thereby addressing a significant gap in the existing literature. Leveraging a unique dataset containing detailed property information over fourteen years, the study conducts a comprehensive counterfactual analysis of the fundamental determinants influencing appraisal-based and transaction-based discount rates in the DCF method. While appraisal-based discount rates reflect appraisers' expert knowledge, transaction-based discount rates offer insights into how investors prioritize specific components of the discount rate. Extending the analysis to separately investigate the driving forces of both types of discount rates for specific real estate segments further ensures the validity and robustness of the findings. Additionally, various relative importance measures are utilized to assess the relevance of specific regressors across appraisers, investors, and real estate segments.

The contribution can be summarized as follows. First, by simultaneously analyzing two types of discount rates, the study provides an in-depth examination of their fundamental determinants, offering novel insights into the valuation process and its implications for market trends in real estate markets. Second, by distinguishing between residential and commercial real estate in the empirical analysis, the study offers empirical insights into how the factors

influencing discount rates differ across real estate types. Third, by extending the analysis to explore the divergent weightings assigned to specific components by both appraisers and investors within distinct real estate segments, the study sheds light on how key stakeholders in the real estate industry evaluate and prioritize different factors of discount rates.

The results show that the relevance of regressors crucially depends on the real estate segment considered. Whereas discount rates of residential real estate are best explained by macroeconomic determinants, more weight is attached to object-specific characteristics in the commercial real estate segment. Moreover, the findings indicate that investors prioritize variables associated with market dynamics, while appraisers assign greater significance to a diverse set of variables that characterize a specific real estate asset.

The remainder of this study is organized as follows. The second section presents the theoretical framework and analyzes both appraisal-based and transaction-based discount rates, followed by an examination of guidelines and practices. The third section offers a review of the literature, while the fourth section outlines the methodology. The fifth section elucidates the dataset, and the sixth section summarizes the results.

3.2. Discount rates

Discounting, integral to macroeconomic and asset pricing theories, finds its roots in the derivation of a stochastic discount factor, typically grounded in the consumption-saving tradeoff. Within this context, employing a power utility function, the discount factor (m_{t+1}) signifies the marginal rate of substitution of consumption between at least two periods, expressed as $m_{t+1} = \beta u'(c_{t+1})/u'(c_t)$, where $u(c)$ is a power utility function and β is a subjective discount factor. Expanding upon this theoretical framework leads to the establishment of the law of one price, asserting that assets with identical payoffs share the same price (Cochrane, 1992). A similar inference is derived from Fama (1970), establishing an efficient market model where asset prices incorporate all pertinent information. Consequently, employing a constant discount factor allows the expression of the current asset value as the sum of the present values of all future cash flows.

The discount factor assumes a crucial role by assigning specific weights to future payoffs, cash flows, or dividend streams depending on the considered asset. The intrinsic connection between the discount factor and the time dimension becomes evident when defining the latter as follows:

$$1/(1 + d_i)^t \tag{3.1}$$

Where d_i represents the discount rate of asset i and t indicates time. d_i is also known as the required rate of return, which imparts an economic meaning to the underlying time value of money.

According to Fisher (1930), the nominal discount rate, or the required rate of return more generally, consists of compensation for lost liquidity, inflation, and risk-taking. Therefore, the required rate of return is expressed as follows:

$$d_i = RF_t + I_t + RP_{i,t} \tag{3.2}$$

Where RF_t is the risk-free rate capturing the compensation for lost liquidity, I_t is a compensation for inflation, and RP_i is an asset-specific risk premium for risk-taking (Leskinen et al., 2020).

In the real estate industry, the significance of the discount rate is particularly evident in light of the chosen valuation method. Essentially, the application of a valuation method should produce an accurate estimate of assets' market price while reflecting market fundamentals (Pagourtzi et al, 2003). Given real estate objects' unique characteristics in combination with high transaction costs and, in this regard, incomplete transaction price data, a real estate valuation is an estimate for the likely selling price derived from comparable market evidence (Adams et al., 1999).

This study centers on the commonly used DCF method, employed for calculating the present value of income properties that generate cash flows and are typically owned by commercial investors such as banks, insurance companies, and pension funds:

$$\begin{aligned} PV_{i,t} &= \frac{CF_{i,1}}{(1+d_i)^1} + \frac{CF_{i,2}}{(1+d_i)^2} + \cdots + \frac{CF_{i,n}}{(1+d_i)^n} \\ &= \sum_{t=1}^{n} \frac{CF_{i,t}}{(1+d_i)^t} \end{aligned} \tag{3.3}$$

Where $PV_{i,t}$ is the resulting present value, or market value more generally, of a real estate object i at time t, $CF_{i,t}$ are object-specific cash flows, and the discount rate is represented by d_i. For consistency, the application of the DCF method requires considering both $CF_{i,t}$ and d_i, either in nominal or real terms. In Equation 3.3, $CF_{i,t}$ represents a summary term comprising a set of object-specific incomes and costs. Examples are rental revenues, vacancy costs, or refurbishment costs that can be mapped over time, which allows the entire life cycle of a real estate object to be derived using the DCF method (Gunnelin et al., 2020). In this context, the discount rate yields a rate that reflects the expected required return based on the property's specific risk profile. This approach contrasts with the application of capitalization rates (cap rates), which considers only the initial periodic Net Operating Income (NOI) to derive the

market value of an income property. The absence of a temporal dimension, coupled with the assumption of a fixed growth rate of the NOI, implies that the cap rate converges with the discount rate in the DCF method only when cash flows are nominally constant, thereby imposing a growth rate of zero[26] (Adams et al., 2001).

In order to derive the market value using the DCF method, appraisers require detailed object information to objectivize their valuation. While actual rents together with market rents resulting from property managers' rent rolls allow a precise depiction of incomes, past accounting figures are used as reference values to map vacancy or running costs. Additionally, object data, such as the construction and past refurbishment date, together with refurbishment plans are used to accurately map refurbishment costs. Finally, any appraiser sets a discount rate, the appraisal-based discount rate (d_i^{apr}), which represents an educated estimate of the accurate discount rate for a given real estate object.

Given the limited availability of publicly accessible data regarding discount rates, appraisers often set d_i^{apr} using a benchmark approach or internal methodologies. The former approach considers historical valuations for similar objects, while the latter encompasses internal guidelines, incorporating object-specific characteristics and current market circumstances. In any case, d_i^{apr} is based on appraisers' expert knowledge but may not accurately display the heterogeneous character of a real estate object, current market tendencies, or investors' perception of risk.

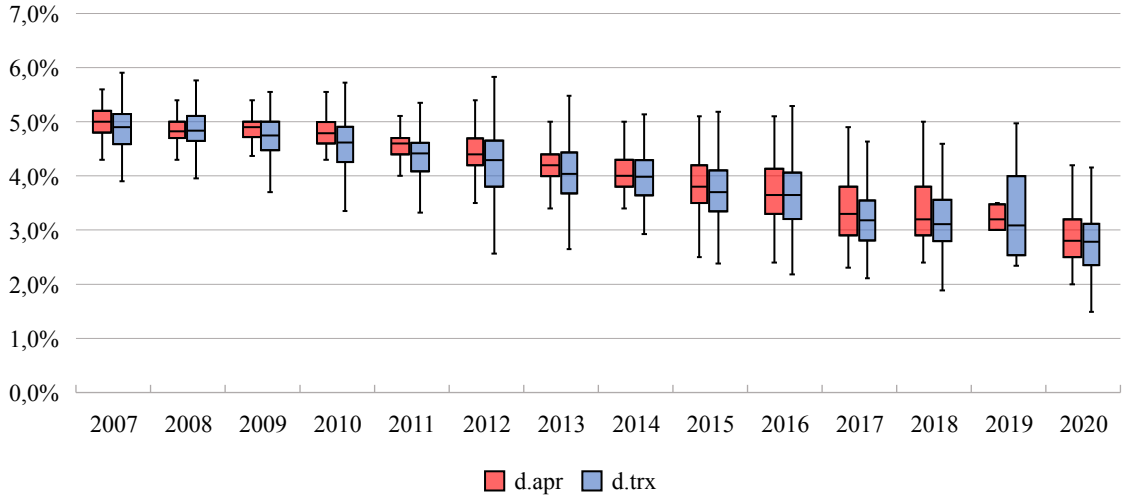
This critical gap is addressed by incorporating transaction-based discount rates (d_i^{trx}), implicitly derived through real market transactions. Specifically, d_i^{trx} is determined when an asset undergoes evaluation using the DCF method and is traded in open market transactions. These discount rates provide valuable insights into investors' sentiment, enhancing the understanding of how their perceived risk is formed, while also reflecting current market dynamics.

Figure 10 displays the development of appraisal-based and transaction-based discount rates in Switzerland between 2007 and 2020. During this time frame, median transaction-based discount rates decreased by 2.1 percentage points, i.e., from 4.9% in 2007 to 2.8% in 2020. The same trend can also be observed in appraisal-based discount rates, which declined from 5.1% in 2007 to 2.8% in 2020.

---

[26] To see this, one can rewrite the present value of a given real estate object as $PV_i = CF_{i,t=0} \sum_{t=1}^{n} \frac{(1+g)^t}{(1+d)^t}$ or equivalently as $PV_i = \frac{CF_{i,t=1}}{d-g}$, where g is a constant annual growth rate. From the last expression, it follows that only if $g = 0$, the application of discount rates from the DCF method or cap rates result in the same present value ($d = d_i^{cap} = d_i$).

Figure 10: Development of discount rates



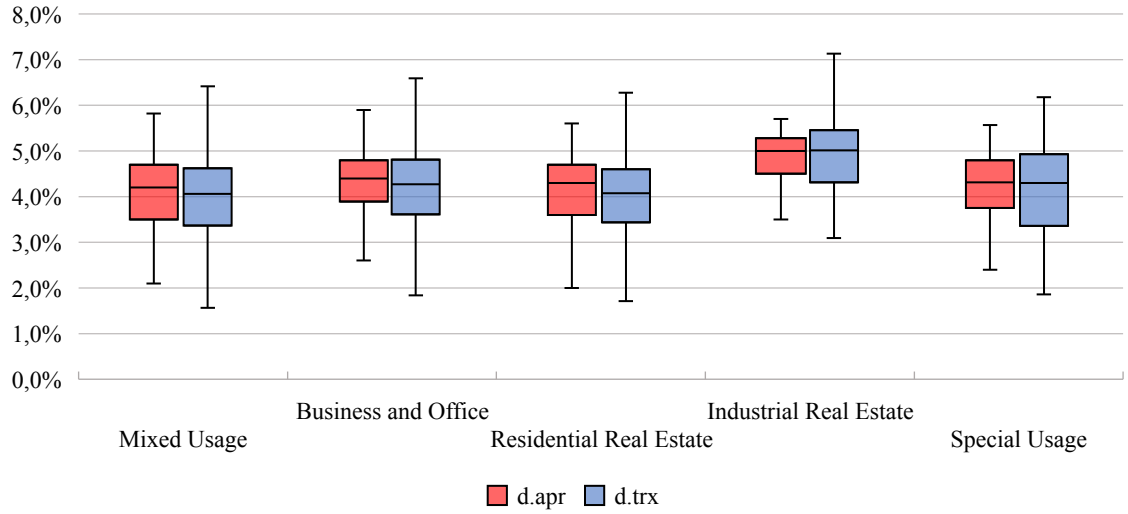
Notes: Box plots visualize the distribution of transaction-based (d.trx) and appraisal-based (d.apr) discount rates (source: Wüest Partner AG) in Switzerland between 2007 and 2020. The displayed span of values extends from the 10th to the 90th percentile. Within the plot, the box ranges from the 30th to the 70th percentile, and the horizontal line within the box denotes the median (50th percentile).

The disparity between appraisal-based and transaction-based discount rates is a noteworthy trend, which can be attributed to multiple factors. First, appraisers may overestimate the risk-premium as a component of discount rates. In fact, Chaney and Hoesli (2012) found that appraisers tend to overvalue economic risks and object-specific characteristics. Second, during a time of constantly declining interest rates, discount rates react with a time lag to changes in the interest rate environment. Between 2007 and 2020, yields on Swiss governmental bonds with 10-year maturity declined from 2.45% in January 2007 to -0.68% in January 2020. The literature in this regard speaks about *appraisal smoothing*, which states that appraisers attach more weight to past-related rather than present-related information, and numerous studies found empirical evidence for this phenomenon (Geltner et al., 2003; Cho et al., 2013; Cheng et al., 2011). And third, increased willingness to pay of commercial real estate investors in light of the overall decline in interest rates between 2007 and 2020 resulted in an increased demand for real estate assets. Evidence for the latter is found in the balance sheet of Swiss pension funds, whose total share of real estate assets increased from 13.2% (79.7 billion Swiss Francs) in 2007 to 17.1% (140.1 billion Swiss francs) in 2020 (Federal Statistical Office, 2007:2020).

A differentiated picture emerges from Figure 11, which displays appraisal-based and transaction-based discount rates between 2007 and 2020 across different real estate types consisting of business and office properties, industrial real estate, special usage, mixed usage,

and residential real estate[27]. Whereas the highest median discount rates are observed in industrial real estate, the lowest discount rates are found in mixed usages.

Figure 11: Type-specific discount rates



Notes: Box plots visualize the distribution of transaction-based (d.trx) and appraisal-based (d.apr) discount rates (source: Wüest Partner AG) in Switzerland between 2007 and 2020 across different real estate types. Displayed real estate types consist of business and office properties, industrial real estate, special usage, mixed usage, and residential real estate. The displayed span of values extends from the 10th to the 90th percentile. Within the plot, the box ranges from the 30th to the 70th percentile, and the horizontal line within the box denotes the median (50th percentile).

Different discount rates across real estate types argue in favor of a varying risk premium across real estate types. The residential real estate segment, in particular, benefits from structural circumstances, such as low homeownership rates in Switzerland. In 2020, approximately 57.8% of Swiss residents rented their homes (Federal Statistical Office, 2022), creating sustained demand in the residential real estate segment. This high demand is reflected in consistently low vacancy rates, which ranged from 1.7% in 2020 to 1.1% in 2007 (Federal Statistical Office, 2022b). Furthermore, variations in transaction-based discount rates between real estate types may also be explained by segment-specific regulations and uncertainty about future cash flows. Swiss residential rental contracts can generally be terminated within three or six months, which implies that the income generated from this particular usage moves very closely to market rents. Rental contracts for all other usages, in contrast, run for a fixed maturity. The latter poses additional risks because tenants in these usages are often as important as market movements (Sivitanides et al., 2001).

[27] Objects are generally classified as residential real estate if the rental income from residential usages exceeds 80%. The same logic is applied to classify industrial real estate or business and office properties, with the latter type being determined by the proportion of office and business rental incomes. Mixed-usage properties combine residential usage with industrial, commercial, or office usages. Special usages are those which, on the one hand, cannot be classified into the types already mentioned or, on the other hand, contain a significant proportion of storage usage.

As a complex valuation method that requires a substantial amount of detailed data, the DCF method necessitates the formulation of guidelines for assessing the components of the discount rate in real estate valuations. According to the Royal Institution of Chartered Surveyors (2010, subsequently RICS), the risk premium is categorized into market risks and object-specific risks. Market risks encompass factors such as illiquidity risks due to prolonged transaction durations, unavailability of financial resources, and the non-performance of market rental expectations, as well as locational, economic, and legislative risks. On the other hand, object-specific risks pertain to tenant defaults, re-letting uncertainties, ownership and management costs, and variations in lease structures, including lease breaks (RICS, 2010, p. 9).

Guidelines also exist for the risk-free rate as a component of discount rates, aiming to portray a secure and maturity-equivalent return on the capital market. More specifically, the risk-free rate is intended to reflect a feasible return at the valuation date that aligns with the investment's duration (Bienert and Funk, 2007, p. 359). Real estate valuation, being a point-in-time assessment, requires a valuation date-specific risk-free rate. While empirical evidence for determining the precise risk-free rate in real estate valuations is limited, opting for a valuation date-specific risk-free rate allows for consideration of current market conditions and developments in the interest rate environment (Haase, 2014).

Furthermore, accounting standards offer some direction on discount rates in real estate valuations, albeit vaguely. For example, according to the International Financial Reporting Standards (IFRS), discount rates under the DCF approach should be presented as pre-tax and not adjusted for risks that have already been factored into future cash flows (PWC, 2023, p. 40). Although accounting standards do not explicitly dictate the elements of discount rates, they are implicitly influenced by the disclosure of market values in financial statements. While the Generally Accepted Accounting Principles (GAAP) standard in the United States (US) mandates the presentation of income property values using a historical cost model, the IFRS standard permits the disclosure of values based on fair value, with any resulting gains or losses accounted for in the income statement (PWC, 2016, p. 97). Consequently, variations in the market values of income properties, potentially influenced by changes in discount rates, can be leveraged to secure external capital, which, in turn, may be reinvested in new income properties.

3.3. Review of literature

The existing literature offers a broad variety of approaches to analyze the determinants of discount rates in the real estate industry. A frequently discussed question refers to the practicality of Sharpe's (1964) Capital Asset Pricing Model (CAPM) to derive the discount rate

for various asset classes[28]. An example is given by Jud and Winkler (1995), who focused on cap rates for offices, warehousing/distribution, retail, and apartments from 21 Metropolitan Statistical Area (MSA) in the US. The authors found that cap rates are robustly associated with capital market returns, but respond with significant adjustment lags. Using the CAPM to derive the discount rate of a given real estate object, either through a direct or indirect approach, is confounded by the specific character of real estate objects. For example, the persisting heterogeneity among real estate objects renders it difficult to find adequate benchmark returns for an investor's specific portfolio. Furthermore, the non-existence of chronological information for alternative real estate types impedes a valid estimation of asset betas. High transaction costs, long transaction durations, specific fiscal aspects, asymmetric information, risk-averse preferences of market participants, and homogeneous beliefs about return distributions are further arguments against a meaningful application of the CAPM to determine the discount rate of real estate objects (Breidenbach et al., 2006).

Given these arguments, the vast majority of studies in the relevant literature pursued the strategy to directly estimate assets' discount rates, including versatile explanatory factors. Among those discount rates, cap rates are by far the most frequently analyzed type. For example, Chuangdumrongsomsuk and Fuerst (2017) analyzed the determinants of transaction-based office cap rates in New York City, Chicago, and Los Angeles between 2000 and 2013. The authors concluded that office cap rates are mainly driven by local and object-specific variables. Equivalently, MacDonald and Dermisi (2008) focused on transaction-based cap rates for office buildings in Chicago between 1996 and 2007 and detected a robust association with object-specific variables and market forces, such as local vacancy rates and changes in financial sector employment.

A notable study that addressed a wider geographical range was conducted by Sivitanidou and Sivitanides (1999). The authors assessed the relevance of local-fixed and time-variant components of transaction-based office cap rates between 1985 and 1995 across 18 MSAs in the US. The authors found that office cap rates are significantly influenced by population growth and the risk-free rate, with the location of a property emerging as one of the strongest predictors of cap rates. Similarly, Chichernea et al. (2008) analyzed the factors driving geographical cross-sectional variation of cap rates for multifamily properties across 34 MSAs in the US. The authors did not report a significant relationship between variables characterizing aggregated demand and average excess cap rates. However, the authors detected a robust and

[28] Applying the CAPM to determine assets' discount rate either follows the direct or the indirect approach. Whereas the direct approach hinges on an adequate approximation of market returns, the indirect approach builds upon asset returns using publicly available returns of similar asset classes.

significant relevance of supply determinants, such as the regulation restrictiveness provided by Malpezzi (1996). The significance of supply determinants is supported by a broad part of the real estate literature and suggests an inefficient pricing mechanism across real estate markets at a given point in time (Maier and Herath, 2010).

Chervachidze and Wheaton (2010) conducted a study to explore whether standard explanatory factors for cap rates could be expanded by incorporating additional macroeconomic determinants. Specifically, they examined whether a measure of the general corporate risk premium and the growth rate of debt relative to the Gross Domestic Product (GDP) offered additional explanatory power for cap rates. Using a dataset of quarterly appraisal-based cap rates for commercial real estate across 30 MSAs in the US from 1980 to 2009, they found that their refined model provided significantly greater predictive power than the baseline model across all commercial real estate subgroups. Similarly, Larriva and Linnemann (2022) discovered compelling indications of fund flows predicting transaction-based cap rates within the office and multifamily sector. Using a Vector Error Correction Model (VECM) on a dataset of quarterly observations from 1993 to 2020, the authors concluded that their refined model outperformed standard predictors suggested by the relevant literature. Specifically, they found that incorporating cash flow, unemployment rates, and historical cap rates resulted in more accurate cap rate estimates compared to models based on risk premiums, return expectations, and past cap rates.

A recent study by Letdin et al. (2023) analyzed approximately 8’000 single-tenant retail property transactions from 2005 to 2019 in the US. Their main emphasis involved the analysis of the risk linked to tenant attributes while controlling for object-specific characteristics, deal and lease characteristics, local characteristics, and macroeconomic indicators. Using Least Absolute Shrinkage and Selection Operator (LASSO) regression techniques to adequately select the relevant predictors, the authors concluded that tenant credit-worthiness indicators, the ownership structure, and default risks are some of the primary drivers of cap rates.

When examining the geographical focus of the aforementioned studies, a considerable number of them concentrated on the US and its subregions. Despite being relatively less common, some studies have focused on the European continent. For instance, MacAllister and Nanda (2016) addressed the question of whether foreign real estate investments are a driving force of cap rates. In focusing on the office market capturing 28 European cities from 15 countries between 1999 and 2013, the authors analyzed transaction-based cap rates from around 9000 office sales by means of a two-step estimation procedure. Although the results hardly

depend on the country considered, the authors identified persistent effects stemming from foreign real estate investments on cap rates.

While the majority of existing studies have concentrated on cap rates, there are also a few studies that examined the determinants of discount rates in DCF valuations. Gunnelin et al. (2004) analyzed the main determinants of appraisal-based discount rates in the DCF procedure, capturing approximately 600 appraisal-based office valuations in the three largest cities of Sweden in 2000. They found that discount rates for office properties in rural areas are about 75 basis points higher than those in central locations. Furthermore, the authors observed a significant connection between lower discount rates and properties with higher market rents, while higher discount rates were associated with properties exhibiting a higher long-run vacancy rate.

The existing literature offers compelling insights into the fundamental determinants and mechanisms underlying either appraisal-based or transaction-based cap rates, utilizing a variety of explanatory factors. However, most studies have concentrated on a single real estate type, leaving a significant gap in understanding the practicality of fundamental determinants across different asset classes. This gap gains in relevance as even within studies focusing on similar asset classes, multifaceted representations of object-specific, locational, and macroeconomic variables can be observed (Chuangdumrongsomusk and Fuerst, 2017; MacAllister and Nanda, 2016; MacDonald and Dermisi, 2008; Sivitandou and Sivitanides, 1999). While this observation is certainly also attributable to differing research questions being examined or varying datasets used, the question about the generalizability of the fundamental determinants of discount rates, or cap rates in this regard, has insufficiently received attention in the existing literature. The almost exclusive focus on transaction-based cap rates further raises questions about the decision-making of appraisers. Although they are obliged to provide an objective assessment of a given property, few empirical findings exist regarding how these critical stakeholders prioritize the fundamental determinants of discount rates and how the weight assigned to these factors varies among asset classes. Furthermore, empirical findings on the fundamental factors influencing discount rates in DCF methods are scarce, prompting the question of the extent to which the driving forces of cap rates may be applied in this valuation method. Building on this, this study seeks to address these gaps by offering an in-depth analysis of the fundamental drivers of both appraisal-based and transaction-based discount rates across diverse real estate types.

3.4. Methodology

The study applies a direct estimation approach, guided by theory and intuition, to estimate and compare the determinants of appraisal-based and transaction-based discount rates, utilizing their functional benefits in relation to object-specific, locational, and macroeconomic variables:

$$d_i = f(object, locational, macroeconomic) \tag{3.4}$$

This functional advantage is at the expense of heterogeneous discount rates across time, real estate types, and locations. To address these concerns, the methodology is based on theoretically and empirically grounded determinants of appraisal-based (d_i^{apr}) and transaction-based (d_i^{trx}) discount rates. The baseline estimation equation is summarized as follows:

$$d_{i,t}^{j} = \alpha_0 + \beta_i \cdot RF_t + \gamma_i \cdot I_t + \delta_i \cdot RP_{i,t} + \varepsilon_i \cdot \psi_{i,t} + \vartheta_{i,t} \tag{3.5}$$

Where $d_{i,t}^{j}$ are discount rates j, represented by appraisal-based and transaction-based discount rates, for asset i at a given date t. α_0 is a constant, RF_t is a risk-free rate, I_t represents inflation, $RP_{i,t}$ is a vector of variables characterizing the risk premium, $\psi_{i,t}$ is a vector of control variables, and $\vartheta_{i,t}$ is an error term.

Since the underlying dataset (Section 3.5) contains real estate transactions throughout Switzerland over a period of fourteen years (2007 to 2020), some object-specific variables display a large variation. To diminish the influence of such variations, the baseline estimation equation will be constructed using robust regression techniques. Robust regressions are a fitting estimation technique to deal with heteroskedasticity or if any other fundamental assumptions, such as the normal distribution of the residuals, are unfulfilled by the data (Susanti et al., 2014). A commonly applied robust regression method is the M-estimation, which is a maximum likelihood estimation technique. The M-estimation minimizes the objective function $\rho(\vartheta_{i,t}) = \rho(y_{i,t} - x_{i,t}'b)$, where ρ summarizes the contribution of each residual to the objective function. Defining $\varphi = \rho'$ as the influence curve, differentiating the objective function with respect to b, and setting the partial derivative to 0 results in $\varphi(y_i - x_i'b)x_i' = 0$, where the weight function is defined as $w(\vartheta) = \varphi(\vartheta)/\vartheta$ with $w_i = w(\vartheta_i)$. These equations are solved with iteratively reweighted least-squares (Fox and Weisberg, 2010). The subsequent estimation procedure applies Huber's (1981) M-estimations, which utilizes a weight function that assigns a weight of 1 to observations with small residuals while decreasing the weight as the residuals increase.

To control for the unobserved heterogeneity affecting either appraisal-based or transaction-based discount rates, dummy variables reflecting the respective real estate type, quarter, year, and region (Swiss cantons) are included. These variables are captured by $\psi_{i,t}$ in the estimation equation. Regional dummy variables account for non-varying market-specific effects and prove

to be relevant because, as an immovable asset bound to a specific location, income properties are directly affected by their location. In Switzerland specifically, local variations between discount rates may arise from the federal system, which specifies that the federal state and the 26 cantons are fiscal jurisdictions. These cantons may delegate some authority to their municipalities, resulting in a very heterogenous regulatory landscape affecting Swiss real estate markets (Basten et al., 2017). For instance, significant inter-cantonal differences exist in the tax obligations incurred during the acquisition of a real estate asset, as well as the tax burdens associated with the ownership of such an asset. Including year and quarter dummy variables accounts for the seasonality in discount rates, as observed in Figure 10, while the inclusion of type-specific dummy variables accommodates variations in discount rates among real estate types (Figure 11).

Multifaceted Relative Importance (RI) measures are applied to deepen the understanding of how appraisers and investors weigh specific determinants of discount rates. The RI refers to an individual regressor's contribution to a multiple regression model. While the end goal is to divide the overall R^2 into relative weights for each regressor, respective results either sum up to the respective R^2 or to 1.0 when weights are proportions (Braun et al., 2019). In the subsequent analysis, proportions of the RI will be displayed, considering several RI measures. The first RI measure, *last*, which is also called "usefulness" by Darlington (1968), is a type of metric that computes the fraction of the total variability in the response variable that is accounted for by each predictor variable when it is added to the model last[29]. The second RI measure, *first*, calculates the proportion of variance in the response variable that is explained by each predictor variable when it is added to the model first. This metric quantifies the amount of variability in the response variable that is accounted for by each predictor variable when no other variables have been included in the model. The third measure, *betasq*, calculates the squared standardized beta coefficients for each predictor variable, which represent the strength and direction of the linear relationship between the predictor variable and the response variable, standardized by their standard deviation (Grömping, 2006). The fourth measure, *car*, is the correlation-adjusted marginal correlation (CAR-Score) by Zuber and Strimmer (2011). This measure approximates the importance on the basis of a canonical ordering of grouped correlated predictors. Finally, the decomposition by Genizi (1993), *genizi*, focuses on orthogonal compatibility and is based on a specially constructed orthonormal basis for the space of all predictors (Firth, 1998). In order to make the RI across all variables comparable, proportional scaling on all RI measures considered is applied.

[29] This metric is identical to the alteration in R^2 that arises from the inclusion of each predictor variable last.

To assess the validity of the findings, the estimation approach, encompassing robust regression techniques and various RI measures, is applied to both a full-sample analysis and a segment-specific analysis. The segment-specific analysis delves deeper into the determinants of discount rates for different real estate types, encompassing residential and commercial real estate buildings. By disaggregating the data, the study aims to identify unique factors driving discount rates within distinct real estate types, providing a nuanced understanding of the critical role of object-specific, locational, and macroeconomic variables in shaping appraisal-based and transaction-based discount rates.

3.5. Data and variable description

The subsequent analysis utilizes a unique dataset containing detailed information on the transaction processes of income properties in Switzerland from 2007 to 2020. When a commercial investor wishes to buy or sell an income property, it is evaluated by an independent appraisal firm. After the transaction, the details are transmitted back to the appraiser, allowing refinement of the original valuation and the implicit derivation of transaction-based discount rates. The present dataset bundles detailed information throughout the appraisal and transaction process, containing detailed information reflecting appraisers' expert knowledge enriched with transaction details. As every income property in the dataset has undergone both appraisal and market transactions, a robust foundation for conducting a counterfactual analysis of the determinants of appraisal-based and transaction-based discount rates is established.

Table 8 summarizes the variables for the subsequent analysis, while corresponding summary statistics are attached in Table 14 of Appendix B.1. Various macroeconomic and locational variables are taken into account that influence discount rates. To approximate a secure and maturity-equivalent return on the capital market, the risk-free rate is modeled using yields on government bonds with a 20-year maturity. This extended governmental bond maturity is selected based on the assumption that longer bond maturities and their associated higher interest rates more accurately capture investors' return expectations, particularly during periods of expansionary monetary policy with declining interest rates. The quarterly level of inflation is used to represent the compensation for inflation, as established in Equation 3.2. This approach aligns with the available information for appraisers and investors, providing a practical method to account for the compensation demanded by investors and offering insight into how appraisers address inflation. Next, the estimation procedure accounts for real GDP growth rates, as the fundamental relationship between economic growth and changes in rental incomes shapes market participants' expectations regarding future cash flows. Among the macroeconomic variables affecting discount rates, the study incorporates a variable indicating

the absolute difference between quarterly growth rates of the Swiss Market Index (SMI) and yields on government bonds with a 20-year maturity (Spread). This variable serves as a measure of the economy-wide risk appetite as it compares returns on the stock market with those of risk-free bonds.

Table 8: Variable description

Variable *Variable name*	**Description**	**Classification**	**Source**
Appraisal-based discount rate $d_{i,t}^{apr}$	Discount rates, according to appraisers' expert knowledge.	Dependent variable	Wüest Partner AG
Transaction-based discount rate $d_{i,t}^{trx}$	Transaction-based discount rates, implicitly derived through market transactions.	Dependent variable	Wüest Partner AG
Macro-location rating *Macro_R*	Standardized property type-specific rating for each municipality in Switzerland (1=worst, 5=best).	Risk premium	Wüest Partner AG
Micro-location rating *Micro_R*	Standardized property type-specific rating for the specific location of a real estate object within a given municipality (1=worst, 5=best).	Risk premium	Wüest Partner AG
Object quality rating *Object_R*	Standardized rating reflecting the quality of a particular real estate object (1=worst, 5=best).	Risk premium	Wüest Partner AG
Age *Age*	Years between the date of complete refurbishment and the valuation date. In the absence of complete refurbishment, years between the construction year and the valuation date.	Risk premium	Wüest Partner AG
Effective area *Eff_area*	Approximation for the object-specific size. Reflects the total effective area from all usages contained in a real estate object.	Risk premium	Wüest Partner AG
Object-specific vacancy rate *Vac_P*	Object-specific vacancy rate.	Risk premium	Wüest Partner AG
Municipality-specific vacancy rate *Vac_M*	Vacancy rate for a given municipality.	Risk premium	Federal Statistical Office
Contract duration *Contract_dur*	Average contract durations of commercial usages within a given object.	Risk premium	Wüest Partner AG
Inflation rate *Inflation*	Quarterly inflation according to the Swiss consumer price index.	Inflation	Federal Statistical Office
Real GDP growth *GDP_growth*	Real yearly GDP growth rate.	Risk premium	Federal Statistical Office
Yields on governmental bonds *Govb_20Y*	Yields on governmental bonds with 20-year maturity.	Risk-free rate	Swiss National Bank
Population growth *Pop_growth*	Calculated as: $Pop\_growth = (P_t - P_{t-1})/ P_{t-1}$. Where P_t is the number of residents at year t in a given Swiss municipality.	Risk premium	Federal Statistical Office
Spread *Spread*	Difference between quarterly growth rate of the SMI and contemporaneous yields on governmental bonds with 20-year maturity.	Risk premium	Swiss National Bank

Notes: Variables for the subsequent analysis. The first column lists the variable and its name as used in the empirical analysis. The second column provides additional information about each variable. The third column classifies the variables according to the components of discount rates, as summarized in Equation 3.2. The last column indicates the source of each variable.

On a municipality level, yearly population growth rates and vacancy rates are accounted for to capture appraisers' and investors' expectations of rental growth in response to altered local conditions. The risk premium associated with a specific income property is determined by a set of variables unique to that object. This includes the object-specific vacancy rate, derived from detailed rent roll information. To account for locational characteristics influencing discount

rates, the real estate type-specific micro- location and macro-location ratings are included. Whereas the macro-location rating is a standardized assessment that reflects the quality of a municipality as a whole, the micro-location rating specifies the precise location of an income property within a particular municipality[30].

With the inclusion of the object-specific quality rating in the empirical analysis, a standardized assessment for evaluating the market value of an income property is accounted for. In alignment with the majority of analogous empirical studies, the age of a given income property is factored into the analysis. Specifically, the study considers a simplified economic age by taking into account the date of a complete refurbishment[31]. The effective area, a variable reflecting the size of a given object, is associated with a group of object-specific risk premiums, quantifying exposure to a specific location while accounting for diversification factors. The study also assesses the significance of average rental contract durations. The inclusion of persistent contract durations offers insights into object-specific risks associated with reletting or the planning for future incomes. The significance of average contract durations depends on the composition of usages within a particular object. Since residential housing contracts in Switzerland can generally be terminated within three months, average contract durations relate to commercial real estate, which is subject to a fixed maturity.

Overall, the underlying dataset encompasses a diverse range of fundamental drivers that characterize discount rates derived from the DCF method between 2007 and 2020. A crucial feature of this dataset lies in the incorporation of expert-based knowledge along with a limited set of additional sources. The use of a restricted number of sources standardizes the dataset, facilitating comparisons of specific variables across different real estate types.

3.6. Empirical results

The subsequent discussion of empirical findings first presents the results from applying the estimation approach to the full sample (Section 3.6.1), which contains income properties from various real estate types that have been part of market transactions between 2007 and 2020. Thereafter, the empirical investigation centers on a segment-specific analysis (Section 3.6.2), considering residential and commercial real estate objects separately. Section 3.6.3 discusses the results when applying multifaceted RI measures to the findings presented in the previous sections.

[30] The macro-location rating accounts for fundamental location-specific elements such as the municipality type, tax burden, labor market conditions, and price developments

[31] A complete refurbishment refers to a comprehensive renovation of the interior as well as the exterior of a given object

3.6.1. Full-sample analysis

Table 9 displays the results when analyzing the determinants of appraisal-based (Model 1) and transaction-based (Model 2) discount rates for the full sample. The micro-location rating, the macro-location rating, and the object-specific rating are all inversely connected with appraisal-based and transaction-based discount rates. Whereas a one-unit increase in the macro-location rating has the potential to decrease both types of discount rates by approximately 3%, notable differences are observed in the context of the micro-location and the object-specific quality rating. Appraisers appear to place greater emphasis on the precise location of a given property than investors, which becomes apparent considering that a one-unit increase in the micro-location rating decreases appraisal-based discount rates by approximately 0.8% more than transaction-based discount rates. Regarding the object-specific quality rating, differences become even larger. A one-unit increase in the object-specific quality ratings decreases appraisal-based discount rates by approximately 3.9% and transaction-based discount rates by 2.3%.

Object-specific vacancy rates enter with a positive sign into the estimation equation for both types of discount rates, suggesting that appraisers and investors perceive persistent vacancy rates as an additional risk. The effective area displays a heightened sensitivity to transaction-based discount rates, underscoring investors' heightened consideration of property size in their asset diversification and investment decisions. Interestingly, while the object-specific age shows the expected sign, its lack of significance suggests that age plays a subordinated role in determining discount rates in the DCF method. This observation may inherently be tied to the DCF method, which explicitly accounts for depreciation over time, or routine maintenance and renovations already factored into the object-specific quality rating.

In the group of locational and macroeconomic determinants, several results are noteworthy. The risk-free rate enters the estimation equation with a positive coefficient, indicating a significant association between discount rates and changes in the interest rate environment. Notably, transaction-based discount rates exhibit a considerably larger interest rate sensitivity compared to appraisal-based discount rates. The analysis reveals that a 1 percentage point (pp) increase in long-term interest rates corresponds to an approximately 3% rise in appraisal-based discount rates, and a 5% increase in transaction-based discount rates. This heightened sensitivity in transaction-based discount rates is attributed to their market-driven nature, leading to greater responsiveness to immediate market conditions and short-term fluctuations in interest rates.

Table 9: Full-sample analysis

	Dependent variable:	log of $d_{i,t}^{apr}$	log of $d_{i,t}^{trx}$
	Model:	(1)	(2)
	Constant	1.418***	1.230***
		(0.037)	(0.059)
Object-specific variables	Macro_R	-0.032***	-0.031***
		(0.003)	(0.005)
	Micro_R	-0.042***	-0.034***
		(0.003)	(0.005)
	Object_R	-0.039***	-0.023***
		(0.004)	(0.006)
	Age	0.00004	0.00004
		(0.0001)	(0.0002)
	Vac_P	0.001***	0.0005***
		(0.0001)	(0.0002)
	log(Eff_area)	0.018***	0.024***
		(0.002)	(0.003)
Macroeconomic and locational variables	Govb_20Y	0.029***	0.052***
		(0.010)	(0.016)
	Pop_growth	0.108	0.418**
		(0.131)	(0.208)
	Inflation	-0.015***	-0.006
		(0.006)	(0.009)
	GDP_growth	0.047***	0.041***
		(0.009)	(0.014)
	Vac_M	0.006***	0.008***
		(0.002)	(0.003)
	Spread	0.001	0.003***
		(0.001)	(0.001)
	Type dummies	Yes	Yes
	Quarter dummies	Yes	Yes
	Year dummies	Yes	Yes
	Local dummies	Yes	Yes
	Observations	2297	2297
	Residual std. error	0.071	0.104

*Notes: Models 1 and 2 are based on robust regression techniques using M-estimation according to Huber (1981) for the full sample. Standard errors are presented in brackets. Real estate type, quarter, year and local dummies are included and each model. Local dummies are equivalent to cantonal dummies. Definition of variables according to Table 8. Signif. codes: '***' 0.001, '**' 0.01, '*' 0.05, '.' 0.1.*

Population growth, akin to the risk-free rate, appears to exert mixed effects on discount rates. The pronounced impact on transaction-based discount rates likely reflects investors' heightened attention to local real estate market dynamics. Moreover, population growth can signal future shifts in market demand that are more relevant to investors than to appraisers, potentially leading the latter to underestimate local market dynamics. This disparity in perception among market participants also raises questions about inflation's role in discount rates. Appraisers traditionally integrate broader economic conditions, including inflation, into real estate valuations. In contrast, investors, with potential shorter investment horizons, prioritize current market conditions, where inflation's influence on investment decisions is comparatively diminished. Additionally, in a declining inflationary environment, transaction-

based metrics may exhibit reduced sensitivity to inflationary changes, especially if factors such as shifts in interest rates or changing investor expectations counteract inflation's impact.

The coefficient associated with real GDP growth rates indicates that overall economic development in Switzerland positively influences discount rates. This finding supports the interpretation that a stronger economy enhances expectations of rental growth, thereby affecting discount rates accordingly. The significance of macroeconomic factors in discount rate determination is underscored by the substantial impact of the economy-wide risk premium (Spread), particularly notable in transaction-based discount rates. Similarly, the local vacancy rate shows a direct connection with discount rates, with a more pronounced effect observed in transaction-based discount rates.

3.6.2. Segment-specific analysis

In order to further analyze the influence of specific variables on discount rates and to critically assess the presented coefficients from the full-sample analysis, Table 10 summarizes the results when applying the same empirical strategy separately for residential and commercial real estate. The residential real estate segment exclusively encompasses residential buildings, whereas the commercial real estate segment contains a diverse range of real estate types, including business and office spaces, industrial real estate, and objects with mixed or special usages. All real estate types that are grouped to the commercial real estate segment contain a significant share of commercial usages. Variables are defined identically as in the full-sample analysis from Table 9.

Turning to the results for residential real estate detailed in Models 1 and 2 of Table 10. The micro-location and macro-location ratings are both inversely connected to discount rates, though appraisal-based discount rates show a stronger sensitivity to variations in these ratings. Notable disparities are observed specifically for the object-specific quality rating, which significantly impacts appraisal-based discount rates but has a negligible effect on transaction-based discount rates. The results further reveal that the object-specific age plays a minor role in explaining discount rates for the residential real estate segment. The same holds true for the object-specific vacancy rate, which does not significantly affect both types of discount rates. The object-specific vacancy rate may be a weak predictor of discount rates in the residential real estate segment arising from local circumstances, such as the relatively high tenant occupancy rates and the resulting low vacancy risks. Conversely, the size of residential real estate properties exhibits a significant positive association with discount rates, with transaction-based discount rates demonstrating greater sensitivity compared to appraisal-based discount rates.

Examining the macroeconomic determinants of discount rates in the residential real estate segment reveals a particularly notable effect of the risk-free rate. An increase in long-term interest rates by 1 pp raises appraisal-based discount rates by approximately 2.2% and transaction-based discount rates by 5.7%. The considerably higher sensitivity of transaction-based discount rates to the long-term interest rates may be traced back to the Swiss regulatory environment, which states that residential rents are tied to the reference index[32]. Consequently, the interest rate environment plays a decisive role for income streams derived from residential real estate objects, which increases in relevance for investors and transaction-based discount rates.

As already observed in the full-sample analysis (Table 9), the impact of inflation on appraisal-based discount rates is statistically significant, whereas transaction-based discount rates show no significant connection with inflation. This result may be interpreted as evidence that appraisers tend to take a more comprehensive and forward-looking approach, whereas investors demonstrate greater responsiveness to short-term market dynamics. This picture is strengthened by the direct connection between GDP growth rates and appraisal-based discount rates. Notably, investors place a heightened emphasis on the local vacancy rate compared to appraisers. Explanations include that current vacancy rates have a direct impact on investors' beliefs about future rental incomes, making them more sensitive to fluctuations in the communal vacancy rate.

Consider the determinants of discount rates in the commercial real estate segment, as summarized in Models 3 and 4 of Table 10. Several object-specific variables gain in significance and magnitude in the commercial real estate segment for both types of discount rates. Object-specific variables such as the micro- and macro-location rating, as well as the object-specific quality rating, exhibit sensitivities that are more than double those observed in the residential real estate segment (Models 1 and 2 of Table 10). Similarly, the significantly higher sensitivity of transaction-based discount rates compared to appraisal-based discount rates for commercial real estate suggests that investors prioritize object-specific characteristics more heavily. This can be attributed to the market's immediate responsiveness to nuanced object-specific factors, reflecting investors' perception of the impactful role of such characteristics in shaping the perceived value and performance of commercial real estate objects.

[32] The reference index is a weighted average of mortgage interest rates in Switzerland. It is published quarterly and implies that tenants and owners have the right to enforce rent adjustments accordingly. If the reference index increases, owners can enforce an increase in rents, and vice versa for a decreasing reference index

Table 10: Segment-specific analysis

	Segment:	Residential real estate		Commercial real estate	
	Dependent variable:	log of $d_{i,t}^{apr}$	log of $d_{i,t}^{trx}$	log of $d_{i,t}^{apr}$	log of $d_{i,t}^{trx}$
	Model:	(1)	(2)	(3)	(4)
	Constant	1.250***	0.994***	1.791***	1.842***
		(0.041)	(0.069)	(0.066)	(0.104)
Object-specific variables	Macro_R	-0.026***	-0.018***	-0.060***	-0.079***
		(0.003)	(0.006)	(0.007)	(0.011)
	Micro_R	-0.022***	-0.014**	-0.065***	-0.063***
		(0.003)	(0.006)	(0.005)	(0.008)
	Object_R	-0.020***	0.005	-0.049***	-0.053***
		(0.004)	(0.007)	(0.007)	(0.011)
	Age	0.00004	0.00001	-0.0004**	-0.0004
		(0.0001)	(0.0002)	(0.0002)	(0.0003)
	Vac_P	0.0001	-0.00002	0.001***	0.001***
		(0.0001)	(0.0002)	(0.0002)	(0.0004)
	log(Eff_area)	0.013***	0.019***	0.020***	0.028***
		(0.002)	(0.004)	(0.003)	(0.005)
	Contract_dur			-0.004***	-0.003**
				(0.001)	(0.001)
Macroeconomic and locational variables	Govb_20Y	0.022*	0.057***	0.020	0.020
		(0.011)	(0.019)	(0.018)	(0.028)
	Pop_growth	0.170	0.085	0.395	1.092**
		(0.133)	(0.221)	(0.275)	(0.433)
	Inflation	-0.019***	-0.005	-0.011	-0.002
		(0.007)	(0.011)	(0.010)	(0.016)
	GDP_growth	0.033***	0.019	0.052***	0.076***
		(0.010)	(0.017)	(0.013)	(0.021)
	Vac_M	0.003*	0.007**	0.013***	0.013**
		(0.002)	(0.003)	(0.004)	(0.006)
	Spread	0.001	0.002*	0.0003	0.003*
		(0.001)	(0.001)	(0.001)	(0.002)
	Type dummies	No	No	Yes	Yes
	Quarter dummies	Yes	Yes	Yes	Yes
	Year dummies	Yes	Yes	Yes	Yes
	Local dummies	Yes	Yes	Yes	Yes
	Observations	1259	1259	860	860
	Residual std. error	0.054	0.088	0.065	0.102

*Notes: Models 1 to 4 are based on robust regression techniques using M-estimation according to Huber (1981). Standard errors are presented in brackets. Models 1 and 2 pertain to residential real estate properties, while Models 3 and 4 focus on real estate properties with commercial usages. Real estate type, quarter, year, and local dummies are included as per model specifications. Local dummies are equivalent to cantonal dummies. Definition of variables according to Table 8. Signif. codes: '***' 0.001, '**' 0.01, '*' 0.05, '.' 0.1.*

Rental contract durations play a pivotal role in commercial real estate as they serve as critical indicators of future expected rental incomes. To evaluate this segment-specific characteristic, Models 3 and 4 in Table 10 include the duration of tenant contracts (Contract_dur) for income properties with commercial usages. The estimated coefficients indicate that longer contract durations are associated with lower appraisal-based and transaction-based discount rates. Notably, appraisal-based discount rates demonstrate a higher sensitivity to persistent contract durations. This heightened sensitivity can be attributed to appraisers' meticulous consideration of contract durations, acknowledging that stable or

extended durations significantly impact overall cash flow stability and predictability, thus placing greater emphasis on this variable in the DCF method.

Compared to residential real estate, the significance and relevance of macroeconomic variables have shifted for commercial real estate objects. Specifically, the sensitivity of the risk-free rate in elucidating discount rates for commercial real estate has waned, potentially reflecting investors' heterogeneous return expectations for commercial properties and appraisers' difficulty in finding adequate benchmark returns within this particular segment. In contrast, population and GDP growth have increased importance for both types of discount rates, with transaction-based discount rates displaying heightened sensitivities in comparison to appraisal-based discount rates. As these variables serve as indicators for future cash flow developments, it can be concluded that investors, in particular, place emphasis on local circumstances when making investment decisions. This emphasis on local factors is further underscored by the relevance of local vacancy rates, which contribute to an increase in both types of discount rates.

3.6.3. Relative importance

To gain deeper insights into the determinants influencing discount rates, this section utilizes RI measures to analyze and compare the fundamental drivers of appraisal-based and transaction-based discount rates. While each RI measure has its unique attributes, the focus is on the average (avg) RI across all measures for variables grouped into object-specific, locational, and macroeconomic categories. Figure 12 in Appendix B.2 also visualizes the RI of the full set of variables. While the RI of these variables, particularly the dummy variables, is displayed for completeness, they are not the primary focus of the interpretation.

First discussed are the findings presented in Table 11, which provides an overview of the RI values derived from the full-sample analysis. The average RI of object-specific variables is slightly higher for appraisal-based discount rates at 13.0% compared to 12.1% for transaction-based discount rates. Among these variables, the micro- and macro-location ratings, along with property size, exhibit the highest average RI. The micro-location rating has high relevance for appraisal-based discount rates, whereas property size plays a significant role in transaction-based discount rates. These findings suggest that appraisers prioritize quality criteria in determining risk premiums, while investors focus more on property size and associated cluster risks. This distinction is also highlighted by the disparity in the RI for the object-specific quality rating, which holds greater importance for appraisal-based discount rates (2.6%) than for transaction-based discount rates (0.9%).

Table 11: Relative importance – full-sample

	Discount rate:	$d_{i,t}^{apr}$						$d_{i,t}^{trx}$					
	RI measure:	*last*	*first*	*betasq*	*genizi*	*car*	*avg*	*last*	*first*	*betasq*	*genizi*	*car*	*avg*
Object-specific variables	Macro_R	4.77%	2.37%	1.26%	2.40%	2.70%	2.70%	4.65%	2.00%	2.35%	2.39%	2.70%	2.82%
	Micro_R	9.62%	3.55%	1.52%	3.57%	3.67%	4.38%	5.38%	2.42%	1.62%	2.38%	2.40%	2.84%
	Object_R	6.18%	1.23%	1.26%	2.16%	2.23%	2.61%	1.97%	0.27%	0.77%	0.85%	0.64%	0.90%
	Age	0.01%	0.96%	0.00%	0.75%	0.48%	0.44%	0.11%	1.52%	0.04%	0.98%	0.86%	0.70%
	Vac_P	1.89%	0.60%	0.24%	0.72%	0.70%	0.83%	0.86%	0.46%	0.21%	0.51%	0.48%	0.50%
	log(Eff_area)	4.93%	0.92%	0.81%	1.88%	1.85%	2.08%	9.11%	2.17%	2.87%	3.69%	3.86%	4.34%
Macroeconomic and locational variables	Govb_20Y	0.26%	35.17%	1.53%	19.68%	33.58%	18.04%	1.16%	33.79%	13.20%	19.81%	34.02%	20.40%
	Pop_growth	0.06%	0.71%	0.01%	0.42%	0.30%	0.30%	0.86%	1.27%	0.24%	0.93%	0.84%	0.83%
	Inflation	0.21%	7.23%	0.33%	5.14%	1.57%	2.90%	0.04%	7.75%	0.12%	5.54%	2.29%	3.15%
	GDP_growth	0.93%	4.33%	9.31%	8.32%	8.93%	6.36%	0.82%	3.81%	15.67%	6.89%	7.17%	6.87%
	Vac_M	0.48%	0.34%	0.09%	0.38%	0.22%	0.30%	0.36%	0.30%	0.13%	0.38%	0.22%	0.28%
	Spread	0.12%	4.44%	0.04%	2.87%	2.00%	1.90%	0.92%	5.50%	0.53%	3.69%	2.98%	2.73%

Notes: Proportions of RI measures, as elaborated in Section 3.4, are displayed. The last column (avg) indicates the average RI across all the measures considered. Model 1 ($d_{i,t}^{apr}$) and Model 2 ($d_{i,t}^{trx}$) for the full-sample analysis (see Table 9) serve as the foundation for the displayed RI values. Definition of variables according to Table 8.

Table 11 further reveals that object-specific age and vacancy rates show modest relevance in relation to discount rates. We conjecture that because discount rates in the DCF method do not explicitly account for risks already incorporated into cash flows, the relevance of age and vacancy rates is diminished. Additionally, differences in appraisers' perspectives and investors' perceptions of risks may further diminish the importance of these variables. The largest relevance is attached to macroeconomic variables, which in total contribute 29.8% (appraisal-based) and 34.2% (transaction-based) to the explained variance in discount rates across all considered RI measures. The risk-free rate is by far the most relevant determinant, amounting to an average RI of 18.0% for appraisal-based and 20.4% for transaction-based discount rates. GDP growth rates are also a particularly relevant determinant of discount rates, representing 6.4% (appraisal-based) and 6.9% (transaction-based) of the average RI across all real estate types.

The results from Table 11 indicate disparities in the attribution of relevance between appraisers and investors concerning object-specific, locational, and macroeconomic variables in the full-sample analysis. To further examine this observation, RI measures are applied separately to the residential and commercial real estate segment. Table 12 summarizes the results obtained through the analysis of RI measures for residential real estate objects. Respective RI values demonstrate a pattern that aligns closely with the previously discussed findings in Table 11. While the micro-location rating undergoes a notable decline in relevance, the overall results indicate that object-specific characteristics collectively account for

approximately 8.6% (appraisal-based) or 6.1% (transaction-based) of the average RI across all measures considered in the residential real estate segment.

Table 12: Relative importance – residential real estate

	Discount rate:	$d_{i,t}^{apr}$						$d_{i,t}^{trx}$					
	RI measure:	*last*	*first*	*betasq*	*genizi*	*car*	*avg*	*last*	*first*	*betasq*	*genizi*	*car*	*avg*
Object-specific variables	Macro_R	5.71%	3.39%	0.60%	2.81%	3.21%	3.14%	2.35%	2.73%	0.30%	2.18%	2.43%	2.00%
	Micro_R	4.17%	2.08%	0.23%	1.54%	1.50%	1.90%	0.89%	1.12%	0.06%	0.65%	0.58%	0.66%
	Object_R	2.69%	1.32%	0.20%	1.58%	1.54%	1.47%	0.01%	0.31%	0.00%	0.45%	0.20%	0.19%
	Age	0.01%	0.89%	0.00%	0.64%	0.42%	0.39%	0.14%	1.43%	0.01%	0.93%	0.88%	0.68%
	Vac_P	0.04%	0.01%	0.00%	0.07%	0.00%	0.03%	0.13%	0.01%	0.01%	0.07%	0.00%	0.04%
	log(Eff_area)	6.00%	0.19%	0.33%	0.81%	0.77%	1.62%	8.16%	0.60%	0.54%	1.61%	1.63%	2.51%
Macroeconomic and locational variables	Govb_20Y	0.01%	36.97%	0.02%	21.86%	37.27%	19.23%	0.73%	36.64%	2.01%	23.37%	40.25%	20.60%
	Pop_growth	0.10%	0.37%	0.01%	0.28%	0.18%	0.19%	0.31%	0.81%	0.02%	0.58%	0.48%	0.44%
	Inflation	0.27%	7.59%	0.16%	5.78%	1.87%	3.13%	0.00%	9.41%	0.00%	7.00%	3.39%	3.96%
	GDP_growth	1.31%	3.61%	5.08%	8.44%	8.44%	5.38%	0.04%	3.99%	0.19%	7.32%	7.18%	3.75%
	Vac_M	0.20%	0.42%	0.01%	0.31%	0.16%	0.22%	0.85%	0.38%	0.07%	0.37%	0.25%	0.38%
	Spread	0.11%	4.45%	0.01%	3.33%	2.36%	2.05%	0.10%	5.21%	0.02%	3.80%	2.61%	2.35%

Notes: Proportions of RI measures, as elaborated in Section 3.4, are displayed. The last column (avg) indicates the average RI across all the measures considered. Model 1 ($d_{i,t}^{apr}$) and Model 2 ($d_{i,t}^{trx}$) for the residential real estate segment (see Table 10) serve as the foundation for the displayed RI values. Definition of variables according to Table 8.

The reduced significance of object-specific variables in explaining discount rates for residential real estate objects can be attributed to structural factors in Switzerland. Investments in residential real estate benefit from strong demand, supported by high tenant occupancy rates and consequently low vacancy risks. While residential real estate investments are generally perceived as low risk, the interpretation of object-specific variables varies notably between appraisers and investors. Appraisers prioritize micro-location and macro-location ratings, crucial for assessing the intrinsic value of residential properties within a broader market context. In contrast, investors place less emphasis on these ratings, potentially influenced by the historically low vacancy rates during the period under consideration. The lower risk of tenant turnover is also reflected in the diminished importance given to the object-specific quality rating, which conversely holds greater relevance for appraisers.

The predominant portion of the RI for residential discount rates (Table 12) is ascribed to macroeconomic variables, collectively contributing 30.2% in appraisal-based and 31.5% in transaction-based discount rates. Within this category, the risk-free rate stands out as the most critical determinant for both types of discount rates, with an average RI of approximately 20%. Given the perception of residential real estate as low risk, variations in discount rates are closely linked to the risk-free rate, a fundamental benchmark in the capital market. This significance is

amplified by Switzerland's regulatory framework, where rental payments are tied to the reference index, making interest rate fluctuations crucial for future rental incomes.

Table 13: Relative importance – commercial real estate

	Discount rate:	$d_{i,t}^{apr}$						$d_{i,t}^{trx}$					
	RI measure:	*last*	*first*	*betasq*	*genizi*	*car*	*avg*	*last*	*first*	*betasq*	*genizi*	*car*	*avg*
Object-specific variables	Macro_R	9.78%	4.61%	2.95%	5.13%	5.96%	5.69%	11.95%	5.98%	4.44%	7.24%	8.45%	7.61%
	Micro_R	25.12%	8.58%	4.55%	9.80%	10.28%	11.67%	14.78%	8.32%	3.29%	8.77%	9.15%	8.86%
	Object_R	8.44%	1.44%	2.09%	2.77%	2.97%	3.54%	4.09%	0.72%	1.25%	1.70%	1.73%	1.90%
	Age	0.89%	1.30%	0.20%	1.51%	1.19%	1.02%	0.49%	1.29%	0.13%	1.25%	1.02%	0.84%
	Vac_P	1.54%	0.97%	0.24%	0.78%	0.75%	0.86%	2.00%	1.48%	0.38%	1.31%	1.29%	1.29%
	log(Eff_area)	4.91%	1.01%	0.93%	1.70%	1.57%	2.02%	7.81%	1.94%	1.82%	3.04%	3.06%	3.54%
	Contract_dur	3.45%	0.22%	0.63%	0.82%	0.67%	1.16%	1.89%	0.01%	0.42%	0.41%	0.26%	0.60%
Macroeconomic and locational variables	Govb_20Y	0.18%	29.40%	1.44%	16.25%	27.88%	15.03%	0.13%	27.12%	1.21%	14.23%	24.02%	13.34%
	Pop_growth	0.30%	1.89%	0.06%	1.17%	1.01%	0.89%	1.15%	2.54%	0.27%	1.80%	1.70%	1.49%
	Inflation	0.09%	7.11%	0.17%	4.47%	1.57%	2.68%	0.01%	6.29%	0.02%	4.07%	1.75%	2.43%
	GDP_growth	1.41%	4.98%	14.48%	8.10%	9.22%	7.64%	2.77%	3.14%	34.89%	6.67%	7.04%	10.90%
	Vac_M	2.11%	0.46%	0.51%	0.93%	0.62%	0.93%	1.57%	0.67%	0.47%	1.22%	0.83%	0.95%
	Spread	0.03%	3.55%	0.01%	2.13%	1.40%	1.42%	0.79%	4.50%	0.34%	2.88%	2.51%	2.20%

Notes: Proportions of Relative Importance (RI) measures, as elaborated in Section 3.4, are presented. The last column (avg) indicates the average RI across all measures considered. Model 3 ($d_{i,t}^{apr}$) and Model 4 ($d_{i,t}^{trx}$) for the commercial real estate segment (see Table 10) serve as the foundation for the displayed RI values. Definition of variables according to Table 8.

When examining the RI of specific determinants for the commercial real estate segment (Table 13), a different pattern emerges. Notably, the average relevance of object-specific characteristics is estimated to be 26.0% for appraisal-based discount rates and 24.6% for transaction-based discount rates. Among these characteristics, local quality ratings, specifically the micro-location and macro-location ratings, are important for both types of discount rates. This heightened importance in the commercial real estate segment can be attributed to businesses prioritizing strategic locations to attract customers or clients. The success of commercial real estate often hinges on factors such as the proximity to business centers, accessibility, and the economic vitality of the region, which are effectively captured by these locational ratings. Diving deeper, the results reveal that the micro-location rating is the most relevant predictor of both types of discount rates, with appraisers attaching an even greater weight to this rating. Investors, in particular, prioritize the macro-location rating more than appraisers, reflecting their commitment to thorough and systematic market analysis when making investment decisions.

Table 13 reveals significant divergences in RI values between appraisal-based and transaction-based discount rates for commercial real estate, particularly concerning the object-specific quality rating and size. Appraisers emphasize the object-specific quality rating,

meticulously analyzing unique property characteristics to ensure a thorough and transparent appraisal. In contrast, the heightened relevance of property size for transaction-based discount rates reflects the increased risk premium demanded by investors. Investors' focus on size may be driven by diversification considerations and income potentials, as larger properties offer greater rental income opportunities but also introduce higher associated reletting risks.

Table 13 shows a significant decline in the relevance of the risk-free rate, which is 15.0% for appraisal-based and 13.3% for transaction-based discount rates. While not significant in the estimation equations for commercial discount rates (Table 10), the risk-free rate remains the most relevant determinant, underscoring its role as a secure, maturity-equivalent return. Interestingly, GDP growth rates have gained importance in explaining discount rates for the commercial real estate segment. This increased relevance underscores the vital connection between commercial tenants, whose economic performance is closely tied to GDP growth, and the valuation of commercial properties. Thus, both appraisers and investors consider GDP growth rates crucial for determining discount rates, reflecting future income potentials and risks. Despite the shift in relevance between macroeconomic variables, their overall importance for discount rates in the commercial real estate segment remains substantial, averaging 28.6% for appraisal-based and 31.3% for transaction-based discount rates.

3.7. Conclusion

This study delves into the determinants of discount rates, a critical factor elucidating the market values of income properties. Despite their significance, there exists a notable dearth of empirical research on the factors influencing discount rates within the application of the DCF method. Building on this, the study conducts a comprehensive counterfactual analysis of the driving forces behind both appraisal-based and transaction-based discount rates. By employing the estimation approach across the full sample and separately for residential and commercial real estate, the empirical investigation provides insights into the determinants influencing the decision-making process of key stakeholders in the real estate industry. This study not only deepens our understanding of the factors influencing discount rates but also contributes to the broader body of knowledge surrounding income properties' market valuation.

The full-sample analysis reveals that both types of discount rates are significantly associated with object-specific, locational, and macroeconomic variables. Appraisal-based discount rates exhibit heightened sensitivity to the micro-location and the object-specific quality rating, reflecting appraisers' adherence to professional standards. In contrast, investors prioritize object-specific vacancy rates and size, with the latter having the highest RI among object-specific variables, highlighting their emphasis on investment decisions and asset

diversification. Additionally, macroeconomic variables indicate that transaction-based discount rates are more responsive to interest rate fluctuations, reflecting investors' market-driven perception, whereas appraisers focus more on standardized object-specific characteristics.

Conducting the analysis across residential and commercial real estate segments revealed a lack of homogeneity in the impact of specific variables. In the residential segment, object-specific variables exhibit relatively low RI values of 8.6% for appraisal-based and 6.1% for transaction-based discount rates. This observation may be attributed to structural conditions in Switzerland, such as a high proportion of tenants in the population, leading to a perceived low risk in residential real estate investments. Macroeconomic variables dominate in the residential segment, accounting for a RI of 30.2% in appraisal-based and 31.5% in transaction-based discount rates. Among these, the risk-free rate emerges as a crucial determinant, with an average RI of approximately 20%. The significance of the risk-free rate is tied to Switzerland's regulatory framework, where rental payments are linked to the reference index, making interest rate fluctuations pivotal for future rental incomes from residential real estate.

In the commercial real estate segment, the analysis underscores the growing importance of object-specific variables, particularly the micro- and macro-location ratings, as well as the object-specific quality rating. Their sensitivity is more than twice as high as in the residential segment, with transaction-based discount rates displaying a notably greater sensitivity compared to appraisal-based discount rates. This heightened sensitivity in transaction-based discount rates reflects investors' immediate response to nuanced object-specific factors. It emphasizes how investors recognize the influential role of these characteristics in shaping perceived value and performance. On average, object-specific characteristics contribute 26.0% to appraisal-based and 24.6% to transaction-based discount rates in terms of average RI values. The shift in relevance of macroeconomic variables does not substantially impact their overall contribution: 28.6% for appraisal-based and 31.3% for transaction-based discount rates in the commercial real estate segment.

This study illuminates crucial factors influencing the decision-making processes of appraisers and investors. Appraisers, mandated to derive objective valuations during the appraisal process and estimate likely selling prices for income properties, often face the challenge of incorporating the heterogeneous risk perceptions of commercial real estate investors and capturing market sentiment accurately. The findings of this study advocate for the application of segment-specific methodologies when determining discount rates in the DCF method. For residential real estate, while object-specific and locational variables remain crucial, greater emphasis should be placed on fundamental macroeconomic determinants. Conversely,

in the context of commercial real estate, standardized and widely accepted object-specific and locational variables may carry more weight, with macroeconomic variables playing a smaller yet still significant role. Additionally, the results question the applicability of commonly used determinants of discount rates in the literature, such as population growth and the age of the property.

Moving forward, it is essential for future research to expand upon the driving forces behind discount rates, deepening our understanding of the underlying rationale of the key stakeholders involved in the real estate industry. As of today, there is a limited availability of publicly accessible data regarding discount rates for the DCF method. Future research could benefit from incorporating datasets from multiple appraisal firms to enhance the generalizability of findings, capturing a broader spectrum of appraisers' and investors' perspectives and methodologies in real estate valuation. Especially in light of the recent increase in interest rates, extended knowledge about the determinants of discount rates will remain a topic of great interest for real estate practitioners and policymakers.

Abbreviations

Abbreviation	Meaning
CAPM	Capital Asset Pricing Model
DCF	Discounted Cash Flow
GAAP	Generally Accepted Accounting Principles
GDP	Gross Domestic Product
IFRS	International Financial Regulation Standards
LASSO	Least Absolute Shrinkage and Selection Operator
MSA	Metropolitan Statistical Area
PP	Percentage Points
RI	Relative Importance
RICS	Royal Institution of Chartered Surveyors
SMI	Swiss Market Index
US	United States
VECM	Vector Error Correction Model

References

Pagourtzi, E., Assimakopoulos, V., Hatzichristos, T. and French, N. (2003). Real estate appraisal: a review of valuation methods. *Journal of property investment and finance, 21, pp. 383-401.*

Adams, A., Booth, P. M., MacGregor, B. D. (1999). Property investment appraisal. *British actuarial journal, 5, pp. 955-982.*

Adams, A.F., Jackson, J.D., Cook, J.P. (2001). Capital market theory and real estate valuation: a case study in choosing an "appropriate" discount rate. *Journal of forensic economics, Vol. 14, No. 2, pp. 119-133.*

Basten, C., Von Ehrlich, M., Lassmann, A. (2017). Income taxes, sorting and the costs of housing: evidence from municipal boundaries in Switzerland. *The economic journal, Vol. 127, No. 601, pp. 653-687.*

Bienert, S., Funk, M. (2007). Immobilienbewertung Osterreich. *ÖVI Immobilienakademie, Wien, Austria.*

Braun, M.T., Converse, P.D., Oswald, F.L. (2019). The accuracy of dominance analysis as a metric to assess relative importance: the joint impact of sampling error variance and measurement unreliability. *Journal of applied psychology, Vol. 104, No. 4, pp. 593-602.*

Breidenbach, M., Mueller, G., Schulte, K. (2006). Determining real estate betas for markets and property types to set better investment hurdle rates. *Journal of real estate portfolio management, Vol. 12, No. 1, pp. 73-80.*

Chaney, A., Hoesli, M. (2012). Transaction-based and appraisal-based capitalization rate determinants. *Swiss finance institute research paper series, No. 12-28*.

Chervachidze, S., Wheaton, W. (2010). What determined the great cap rate compression of 2000-2007, and the dramatic reversal during the 2008-2009 financial crisis? *The journal of real estate finance and economics, Vol. 46, No. 2, pp. 208-231.*

Chichernea, D., Miller, N., Fisher, J., Sklarz, M., White, B. (2008). A cross-sectional analysis of cap rates by MSA. *The journal of real estate research, Vol. 30, No. 3, pp. 249-292.*

Cho, Y., Hwang, S., Lee, Y. (2013). The dynamics of appraisal smoothing. *Real estate economics. Vol. 42, No. 2, pp. 497-529.*

Cheng, P., Lin, Z., Liu, Y. (2011). Heterogeneous information and appraisal smoothing. *Journal of real estate research. Vol. 33, No. 4, pp. 443-470.*

Chuangdumrongsomsuk, M., Fuerst, F. (2017). Determinants of cap rates in U.S. office markets. *Journal of real estate literature, Vol. 25, No. 2, pp. 267-282.*

Cochrane, J.H., Hansen, P.H. (1992). Asset pricing explorations for macroeconomics. *NBER macroeconomics annual, Vol 7, pp. 115-165.*

Darlington, R.B. (1968). Multiple regression in psychological research and practice. *Psychological bulletin, Vol. 69, No. 3, pp. 161-182.*

Fama, E. (1970). Efficient capital markets: a review of theory and empirical work. *Journal of finance, Vol. 25, pp. 383-420.*

Federal Statistical Office (2007:2020). Pension fund statistics - Key figures 2016-2020 / 2007-2013. *Available online: https://www.bfs.admin.ch/bfs/en/home/news/whats-new.gnpdetail.2022-0085.html (accessed on June 2023).*

Federal Statistical Office (2022). Tenants / owners. *Available online: https://www.bfs.admin.ch/bfs/en/home/statistics/construction-housing/dwellings/housing-conditions/tenants-owners.html (accessed on March 2024).*

Federal Statistical Office (2022b). Vacant apartments. Development. *Available online: https://www.bfs.admin.ch/bfs/de/home/statistiken/bau-wohnungswesen/wohnungen/leerwohnungen.assetdetail.27565789.html (accessed on March 2024).*

Fox. J., Weisberg, S. (2010). Robust regression in R. *An appendix to an R companion to applied regression, 2nd ed.; McMaster University: Hamilton, ON, Canada.*

Firth, D. (1998). Relative importance of explanatory variables: an annotated bibliography. *Conference on statistical issues in the social sciences, Stockholm, Nuffield College: Oxford, UK, 1998, Available online: http://warwick.ac.uk/dfirth/papers/Stockholm1998.pdf (accessed on July 2023).*

Fisher, I. (1930). The theory of interest, as determined by impatience to spend income and opportunity to invest. *The macmillan company, New York.*

Geltner, D., MacGregor, B. D., Schwann, G. M. (2003). Appraisal smoothing and price discovery in real estate markets. *Urban studies, Vol. 40, No 5/6, pp. 1047-1064.*

Genizi, A. (1993). Decomposition of R2 in multiple regression with correlated regressors. *Statistica sinica, Vol. 3, No. 2, pp. 407-420.*

Grömping, U. (2006). Relative importance for linear regression in R: the package relaimpo. *Journal of statistical software, Vol. 17, No. 1, pp. 1-27.*

Gunnelin, A., Hendershott, P., Hoesli, M., Söderberg, B. (2004). Determinants of cross-sectional variation in discount rates, growth rates and exit cap rates. *Real estate economics, Vol. 32, No. 3, pp. 217-237.*

Haase, R. (2014). Immobilienbewertung: Eine kapitalmarktorientierte Ableitung des Basiszinssatzes. *Swiss real estate journal, No. 8, pp. 4-12.*

Huber, P. J. (1981). Robust statistics. *Wiley: Hoboken, NJ, USA.*

Maier, G., Herath, S. (2010). Efficiency of the real estate market: a meta-analysis. *17th Annual European real estate society conference in Milan, Italy.*

Jud, G., Winkler, D. (1995). The capitalization rates of commercial properties and market returns. *Journal of real estate research, Vol. 10, No. 5, pp. 509-518.*

Larriva, M., Linnemann, P. (2022). The determinants of capitalization rates: evidence from the U.S. real rstate market. *Journal of property investment and finance, Vol. 40, No. 2, pp. 119-169.*

Leskinen, N., Vimpari, J., Junnils, S. (2020). Using real estate market fundamentals to determine the correct discount rate for decentralised energy investments. *Sustainable cities and society, Vol. 53, DOI: https://doi.org/10.1016/j.scs.2019.101953.*

Letdin, M., Sirmans, G.S., Smersh, G., Zhou, T. (2023). The role of tenant characteristics in retail cap rate variation. *Journal of real estate finance and economics, DOI: https://doi.org/10.1007/s11146-023-09958-9.*

MacAllister, P., Nanda, A. (2016). Do foreign buyers compress office real estate cap rates? *The journal of real estate research, Vol. 38, No. 4, pp. 569-594.*

MacDonald, J., Dermisi, S. (2008). Capitalization rates, discount rates, net operating income: the case of downtown Chicago office buildings. *The journal of real estate portfolio management, Vol. 14, No. 4, pp. 363-374.*

Malpezzi, S. (1996). Housing prices, externalities, and regulation in U.S. metropolitan areas. *Journal of housing research, Vol. 7, No. 2, pp. 209-241.*

PWC (2016). IFRS and US GAAP: similarities and differences. *Available online: https://www.pwc.ch/en/publications/2016/pwc-ifrs-us-gaap-similarities-and-differences-2016.pdf (accessed on September 2023).*

PWC (2023). Applying IFRS for the real estate industry. *Available online: https://www.pwc.ch/en/publications/2023/Applying%20IFRS%20for%20the%20real%20estate%20industry.pdf (accessed on September 2023).*

Royal Institution of Chartered Surveyors (2010). Discounted cash flow for commercial property investments. *RICS guidance note, Royal Institution of Chartered Surveyors: London, UK.*

Sharpe, W.F. (1964). Capital asset prices: a theory of market equilibrium under conditions of risk. *The journal of finance, Vol. 19, No. 3, pp. 425-442.*

Sivitanides, P., Southard, J., Torto, R., Wheaton, W. (2001). The determinants of appraisal-based capitalization rates. *Real estate finance, Vol. 18, pp. 27-38.*

Sivitanidou, R., Sivitanides, P. (1999). Office capitalization rates: real estate and capital market influences. *The journal of real estate finance and economics, Vol. 18, No. 3, pp. 297-322.*

Susanti, Y., Pratiwi, H., Sulistijowati H., S., Liana, T. (2014). M-estimation, S-estimation, and MM-estimation in robust regression. *International journal of pure and applied mathematics, Vol. 91, No. 3, pp. 349-360.*

Zuber, V., Strimmer, K. (2011). High-dimensional regression and variable selection using CAR scores. *Statistical applications in genetics and molecular biology, Vol. 10, No. 1.*

Appendix

B.1.

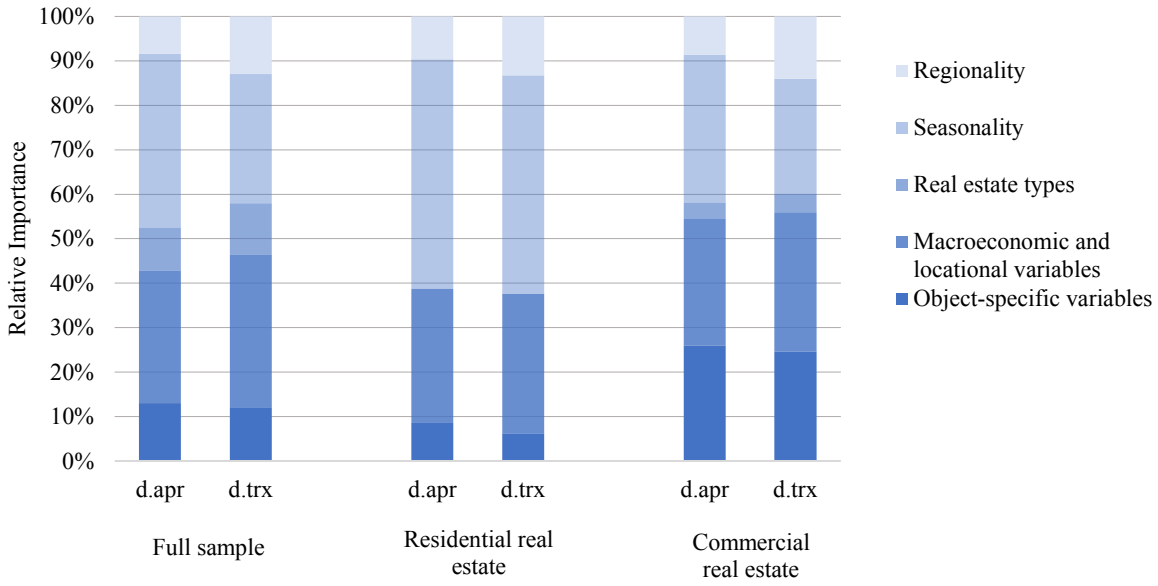
Table 14: Summary statistics

Variable Variable name	**Min.**	**Max.**	**Mean**	**Median**	**Std. Dev.**
Transaction-based discount rate $d_{i,t}^{trx}$	1.49	8.35	4.12	4.19	0.85
Appraisal-based discount rate $d_{i,t}^{apr}$	2.00	6.90	4.23	4.40	0.73
Macro location rating Macro_R	1.15	5.00	4.21	4.38	0.73
Micro location rating Micro_R	1.40	5.00	3.60	3.60	0.62
Object quality rating Object_R	1.57	5.00	3.42	3.37	0.55
Age Age	0.00	100.00	30.09	27.00	20.86
Effective area Eff_area	60.00	73383.00	3876.67	2085.00	5684.84
Object-specific vacancy rate Vac_P	0.00	100.00	7.31	0.78	16.54
Yields on governmental bonds Govb_20Y	-0.41	3.42	1.42	1.33	1.11
Population growth Pop_growth	-0.03	0.16	0.01	0.01	0.01
Inflation rate Inflation	-1.37	2.97	0.14	-0.03	0.96
Real GDP growth GDP_growth	-3.27	3.12	0.53	0.94	1.63
Vacancy rate Vac_M	0.00	12.10	1.06	0.62	1.22
Spread Spread	0.11	19.69	4.15	2.90	4.32
Average contract duration Contract_dur	0.04	25.76	5.00	3.73	4.11

Notes: All displayed values represent the full sample of real estate objects from 2007 to 2020, except for average contract duration (Contract_dur), which applies exclusively to the commercial real estate segment. Definition of variables according to Table 8.

B.2.

Figure 12: Relative importance – full set of variables



Notes: Average proportions of Relative Importance (RI) for appraisal-based (d.apr) and transaction-based discount rates (d.trx) across the RI measures last, first, betasq, genizi, and car, as elaborated in Section 3.4. The displayed RI values correspond to Model 1 (d.apr) and Model 2 (d.trx) for the full sample in Table 9, Model 1 (d.apr) and Model 2 (d.trx) for residential real estate (Table 10), and Model 3 (d.apr) and Model 4 (d.trx) for commercial real estate (Table 10). The average RI is grouped into object-specific, macroeconomic, and locational variables, as well as dummy variables. The dummy variables include regionality (regional dummies), seasonality (time and quarter dummies), and real estate types (real estate type dummies). For models focused on residential real estate, real estate type dummies are not displayed as the estimations in this segment only include residential real estate objects.

Chapter IV - ESG Ratings and Real Estate Key Metrics: a Case Study*

Abstract: This study examines whether and through which channels ESG ratings influence key metrics in the real estate industry. Focusing on Switzerland as a case study and concentrating on commercial real estate investors and their income properties, we utilize unique datasets and employ an OLS post-LASSO estimation procedure to identify and quantify the associations between ESG ratings and four key metrics: appraisal-based and transaction-based discount rates, rental incomes, and vacancy rates. Our results demonstrate that ESG ratings maintain a significant association with all four key metrics even after undergoing robustness checks. When dissecting the total ESG rating into its components, the environmental rating stands out as the most significant. While largely dependent on the specific metric being analyzed, the association of social and governance ratings tends to be less pronounced. Delving deeper into individual ESG rating levels, our findings suggest potential signaling effects, as properties with higher ESG ratings demonstrate heightened sensitivity to both types of discount rates and vacancy rates. Overall, our findings deepen the understanding of the association between ESG ratings and real estate markets, illuminating the intersection of sustainability and financial relevance.

Keywords

Real estate finance, sustainability, real estate fundamentals

*Updated version of the paper published in the *MDPI Journal Real Estate (2024). DOI: https://doi.org/10.3390/realestate1030014*

4.1. Introduction

In 2004, a report by the United Nations (2004) marked the origins of Environmental, Social, and Governance (ESG) ratings, launching them to the forefront of discussions surrounding assets sustainability characteristics. Since then, ESG ratings have emerged as indispensable tools for investors and stakeholders within the real estate industry, complementing conventional financial metrics. Real estate, distinguished by its tangible and immovable nature, occupies a unique position within this paradigm. Delving deeper, the sector contends with fundamental questions regarding the essence of ESG ratings, recognizing their adaptation toward a comprehensive approach to sustainability.

Fueled by growing intra-industry interest in the association between ESG ratings and financial performance, the real estate sector has embraced this topic. Recent literature offers preliminary insights into the connection between ESG ratings and Real Estate Investment Trusts (REITs), marking a pivotal step toward understanding how sustainability metrics intersect with property investments. At the object-level, however, the association between ESG ratings and key performance metrics remains largely unexplored, prompting critical questions about their applicability and significance. Central to this inquiry is the underlying mechanism by which sustainability attributes translate into the financial performance of real estate assets, alongside the appropriate methodologies for evaluating these potential associations. The ambiguity surrounding ESG ratings is further highlighted by the complex and diverse regulatory landscape governing sustainability at both the international and national levels. While the European Union (EU) has taken a major step with the EU Taxonomy, establishing a regulated framework for measuring sustainability attributes, ESG rating methodologies remain predominantly in the hands of independent agencies, with no direct oversight from governmental or international regulatory bodies.

Amid the dynamic landscape of sustainability matters, this study examines whether and through which channels ESG ratings influence key metrics in the real estate industry. Focusing on Switzerland as a case study, we leverage the country's regulatory enforcement of sustainability standards and concentrate on commercial real estate investors and their income properties. We utilize unique datasets comprising approximately 6'300 expert-based Discounted Cash Flow (DCF) valuations and around 850 real market transactions in Switzerland spanning from 2019 to 2022. From these datasets, we analyze the association between ESG ratings and four key metrics derived from a conceptual framework: appraisal-based and transaction-based discount rates, rental income, and vacancy rates. The evaluation of these metrics is conducted through an ESG rating, approved by Global Real Estate

Sustainability Benchmark (GRESB) and acknowledged for its objectivity and meticulous quantification consistently applied across Swiss locations. Using an Ordinary Least Squares (OLS) post Least Absolute Shrinkage and Selection Operator (LASSO) estimation procedure, we seek to identify and quantify the association between ESG ratings and key real estate metrics, employing a flexible and adaptive approach to explore the extent to which sustainability ratings intersect with real estate markets.

To bridge the current gaps in the literature, our contribution can be summarized as follows. First, by disentangling total ESG ratings into their individual sub-ratings, we offer a detailed examination of the fundamental characteristics and complexities of such ratings, thereby exploring the intersection between broad sustainability coverage and targeted financial relevance. Second, leveraging appraisal and transaction processes, we enhance the understanding of the association between ESG ratings and four key metrics for income properties, contributing to the identification of influencing channels. Third, we offer new insights into a relatively unexplored type of ESG rating, advancing the field by critically assessing its relevance and practical application within the real estate industry.

The remainder of this study is organized as follows. The second section discusses the definition of ESG ratings, their emergence, and regulation. The third section provides a review of the relevant literature, followed by a discussion in the fourth section on the potential channels through which ESG ratings may influence real estate assets. The fifth section presents the data, and the sixth section outlines the methodology. In the seventh section, we present the empirical results, with a discussion in the eighth section.

4.2. Definition, emergence, and regulation of ESG ratings

The fundamental concept underlying ESG ratings is associated with Socially Responsible Investments (SRI), an investment approach that weights social or environmental concerns similarly as financial rewards (Richardson, 2009). In contrast to older analytical frameworks, such as Environment Health and Safety (EHS) and Corporate Social Responsibility (CSR), ESG aims to quantify specific components through the perspective of risk or opportunity and represents an analytical framework to quantify the degree to which an industry, an asset or a portfolio is operating in a sustainable manner. Building on this, an ESG rating includes specific measurable components concerning the environment (E), society (S) and governance (G), which have become key indicators for management competence, non-financial performance, and risk management in the financial industry (Kiernan, 2007).

On a global scale, the emergence of ESG ratings is linked to economic crises, extreme weather events, or even wars. A prominent example is the economic crisis in 2008, which

affected the public and private sectors and put investors' investment decisions, social impacts, and respective governance practices to the fore (Billio et al., 2020). ESG ratings also gained prominence through a key initiative by the European Commission. In July 2018, the Commission established the Technical Expert Group (TEG) on sustainable finance, composed of experts from academia, industry, and finance, to develop a unified classification system for sustainable economic activities (Lucarelli et al., 2020). The resulting EU Taxonomy aims to create a standardized and transparent framework for determining the environmental sustainability of economic activities, guided by six environmental objectives[33]. The EU Taxonomy targets industries categorized under the Nomenclature of Economic Activities (NACE) system, focusing on sectors responsible for approximately 93.5% of the EU's greenhouse gas emissions. Companies meeting the Taxonomy's technical screening criteria are required to disclose the proportion of their economic activities, such as turnover and capital expenditure, that align with the framework. Additionally, financial intermediaries investing in these firms must report the percentage of their investments that comply with the Taxonomy. This regulatory framework was enacted into law in late 2020, with compliance requirements for market participants coming into force in December 2021 (TEG European Commission, 2020).

Several initiatives have been implemented to enhance the transparency, accuracy, and consistency of ESG ratings. For example, the European Securities and Markets Authority (ESMA) has issued guidelines for ESG rating providers, detailing best practices for ESG rating methodologies and disclosure requirements (ESMA, 2021). Additionally, organizations, such as the Global Reporting Initiative (GRI), Sustainability Accounting Standards Board (SASB), and Task Force on Climate-related Financial Disclosures (TCFD), have developed frameworks for companies to report their ESG performance (GRI and SASB, 2021). Overall, the determination of specific submatrices within an ESG framework hinges on the principle of materiality, with the alignment of these submatrices to financial materiality being a pivotal requirement to substantiate their relevance in evaluations conducted by investors and stakeholders in the real estate industry. Of course, the alignment necessitates ongoing adjustments to address emergent global challenges effectively (Escrig-Olmedo et al., 2019), which also contributes to a multitude of indicators across ESG ratings furnished by different providers. As pointed out by Berg et al. (2022), different indicators across ESG ratings also imply that they may not inherently be comparable. In fact, differences between ESG ratings

[33] The six environmental objects are: (1) climate change mitigation, (2) climate change adaptation, (3) sustainable use and protection of water and marine resources, (4) transition to a circular economy, (5) pollution prevention and control, and (6) protection and restoration of biodiversity and ecosystems

may arise through different definitions of ESG ratings across providers, such as the inclusion of alternative sub-ratings and different weighting approaches (Tsang et al., 2023). Furthermore, the difficulty in comparing ESG ratings is compounded by the lack of transparency in methodologies, data sources, and weighting systems used by different providers (Abhayawansa and Tyagi, 2021).

4.2.1. Regulation of sustainability matters in Switzerland

Although Switzerland is not part of the EU and therefore not bound to the EU Taxonomy, a number of significant initiatives and regulations pertaining to sustainability have been undertaken. Early instances include the implementation of the federal energy law in 1999, emphasizing energy efficiency and renewable energies, as well as the introduction of the federal CO2 law, aiming to diminish greenhouse gas emissions in accordance with international reduction commitments (Eberwein et al., 2015). In 2013, the Swiss Sustainable Construction Standard (SNBS) was introduced, which evaluates the sustainability of buildings based on numerous criteria, such as energy, materials, ecology, and quality. In 2018, the Swiss parliament approved a revision of the Energy Law, which includes measures to promote energy efficiency in buildings. The revised law mandates that building owners disclose their buildings' energy performance when selling or renting them, and introduces financial incentives for energy-efficient renovations (Federal Council, 2017).

A pivotal action was undertaken in 2019 when the Swiss parliament approved the Swiss Climate Policy 2050, a strategy designed to achieve carbon neutrality by 2050 through the reduction of greenhouse gas emissions in Switzerland. The policy includes measures to promote energy-efficient buildings, such as stricter building codes, increased subsidies for energy-efficient renovations, and incentives for building owners to invest in renewable energy sources (Federal Council, 2019). Recently, the Federal Council adopted the executive order on climate reporting for large Swiss companies, which came into force on January 1, 2024. Public companies, banks, and insurance companies that employ at least 500 people and have a balance sheet total of at least 20 million Swiss francs, or revenues of more than 40 million Swiss francs, are required to report publicly on climate issues (Federal Council, 2022).

Compliance with regulations and initiatives enacted by the Swiss Parliament and Federal Council is monitored by the Swiss Financial Market Supervisory Authority (FINMA), which defines guidelines that obligate financial institutions to consider ESG factors in their investment processes and to transparently communicate their ESG policies and practices to stakeholders. Similarly, pension funds in Switzerland are mandated by the federal act on Occupational Retirements, Survivors' and Disability Pensions (BVG) to take ESG considerations into

account when making investments. Pension funds are required to provide regular updates on the ESG performance of their portfolios and to furnish detailed information on ESG aspects of their investments. Therefore, regulations in Switzerland serve to force financial institutions and pension funds to consider ESG factors in their investment processes, and to promote transparency in their ESG policies and practices (FINMA, 2021).

As part of the financial industry, the real estate industry in Switzerland is directly affected by the enacted regulatory framework and initiatives. However, the real estate industry possesses distinct characteristics, which differentiate it from other industries. Accounting for about one quarter of total greenhouse gas emissions (Federal Office for the Environment, 2022), largely due to heating and cooling systems, sustainability aspects have become paramount in the real estate industry. Furthermore, as tangible assets bound to a specific location, real estate properties may also be affected by a wide range of locational characteristics, such as the socioeconomic structure, environmental hazards, or climate change risks. In addition, real estate investments are often of a long-term nature and their consequences on their location and environment can persist beyond the investment duration.

Recognizing the critical importance of location quality in assessing sustainability, ESG providers have shifted towards establishing ratings that focus on location-based indicators. The guiding principle behind these ESG ratings is a quantitative assessment of sustainability aspects for specific locations based on objective data. These ratings aim to identify areas with high sustainability potential, assess the resilience of income properties to environmental risks, evaluate social impact considerations, and ensure alignment with industry standards. However, the assessment of these location-based ESG ratings remains largely uncharted territory. This includes investigating potential channels through which location-based ESG ratings may be associated with key metrics of income properties, as well as performing a disaggregated analysis to uncover the underlying mechanisms by breaking down the total rating into its individual sub-ratings.

4.3. Review of literature

As ESG-related studies gained cross-industry interest, a significant portion of the literature, particularly in the real estate industry, has focused on the connection between sustainability ratings and REITs. Focusing on REITs in the United States (US) between 2000 and 2011, Eichholtz et al. (2012) identified a positive association between the share of Leadership in Energy and Environmental Design (LEED) and Energy Star-certified buildings and operating performance measures, such as the return on assets, return on equity, and the ratio of operational to total revenue. Similarly, Fuerst (2015) analyzed the association between sustainability

benchmarking ratings provided by the GRESB and the financial performance of REITs. Using a dataset of 442 detailed GRESB ratings for REITs in the US, Asia, and Europe between 2011 and 2014, the study concluded that investing in sustainability enhances operational performance while reducing risk exposure and stock volatility.

Among the various sustainability ratings available, ESG ratings have become a focal point in real estate literature. Brounen and Marcato (2018), for instance, analyzed the performance of US REITs from 2011 to 2018, evaluating the relevance of ESG ratings from GRESB, Thomson Reuters, and KLD MSCI within an asset pricing framework. Their results indicated performance premiums associated with Reuters and KLD ratings, while GRESB ratings were correlated with lower REIT returns. Moreover, the study revealed that sub-ratings for social and governance factors positively influenced returns, whereas environmental ratings were linked to diminished returns. In a later study, Aroul et al. (2022) confirmed the positive relationship between ESG ratings and REIT performance. Examining publicly traded US REITs from 2019 to 2020, they demonstrated that REITs with higher ESG ratings operated more efficiently and exhibited enhanced operational performance.

A second strand of the literature centered on an object-level analysis, examining the association between sustainability ratings and various key metrics. A prevalent approach in this literature involves investigating real estate prices using hedonic pricing methods, thereby exploring the underlying pricing mechanisms (Bruegge et al., 2016; Fuerst and Shimizu, 2016; Addae-Dapaah and Wilkinson, 2020). The range of analyzed key metrics and their association with eco-labels is notably multifaceted, encompassing factors such as occupancy rates (Fuerst and McAllister, 2009; Holtermans and Kok, 2017), rental rates (Fuerst and Dalton, 2019), and capitalization rates (cap rates) (McGrath, 2013). These studies commonly focus on eco-labels such as LEED certification, Energy Star-certified buildings, or Energy Performance Certificates (EPCs).

Given the critical role of ESG ratings in complementing standard financial metrics, it is somewhat surprising that the prevalent literature offers very few results about the association between ESG ratings and real estate key metrics on an object-level. This also counts for Switzerland, where research, including Feige et al. (2013), or Kempf and Syz (2022), has concentrated on the association between rental prices and sustainability attributes or MINERGIE-certified residential properties. A somewhat broader approach was taken by Marty and Meins (2017), who assessed potential rent premiums in Switzerland based on Economic Sustainable Indicators (ESI). They found that above-average premiums are paid for factors related to “location and mobility”, such as good public transportation connections or short

distances to the city center or recreational areas, and particularly for factors related to "health and comfort"[34]. Similarly, Meins et al. (2010) examined the feasibility and practicality of ESI indicators in Switzerland to improve the transparency of the DCF method for assessing property risk, particularly in determining the discount rate.

Overall, the exploration of whether and how ESG ratings may be associated with key metrics for income properties is a frontier largely unexplored, leaving a significant gap in the current understanding of sustainable finance. Leveraging comprehensive appraisal and transaction data, we meticulously analyze the association between ESG ratings and four key metrics. Moreover, by deconstructing the overall ESG ratings into their individual sub-ratings, we shed light on the intricate interplay between broad sustainability coverage and targeted financial relevance, providing a more granular understanding of how ESG factors may drive financial performance in real estate markets.

4.4. Identifying influencing channels

The association of ESG ratings with key metrics is intricately intertwined with the regulatory landscape, compelling commercial real estate investors to report sustainability ratings for their assets. Centering on commercial real estate investors and their income properties, we explore potential channels through which ESG ratings influence key metrics, considering their connection to financial materiality and thereby substantiating their relevance for key stakeholders in real estate markets.

Our estimation approach leverages the evaluation of these assets, particularly through the income approach, where market values are typically assessed by discounting future cash flows to the present. In Switzerland, the DCF method is frequently applied to evaluate the market value of income properties:

$$PV_{i,t} = \sum_{t=1}^{n} \frac{CF_{i,t}}{(1 + d_i)^t} \tag{4.1}$$

Where $PV_{i,t}$ is the resulting present value, or market value more generally, of a real estate object i at time t, $CF_{i,t}$ are object-specific cash flows, and the discount rate is represented by d_i (Gunnelin et al., 2004). Consequently, the market value of an income property is essentially driven by cash flows and the discount rate, which forms the cornerstone in the related literature exploring the connection between eco-labels. Specifically, cash flows and discount rates

[34] ESI represents a sustainability rating, encompassing object- and location-based indicators across five following groups: flexibility and polyvalence, energy and water dependency, location and mobility, safety and security, health and comfort.

encompass a variety of components acquired through appraisal and transaction processes, offering a robust foundation for critically assessing their association with ESG ratings.

To objectively evaluate the market value of an income property, appraisers require detailed information about actual incomes and costs, as summarized in object-specific cash flows in the DCF framework. Among these, actual rental incomes and vacancy rates are particularly suitable for analyzing their association with ESG ratings, given their direct linkage to real estate markets and their reflection of market participants' immediate responses to location-specific criteria. Rental incomes, in this regard, may be associated with ESG ratings through real estate owners or investors in this regard, passing on the quality of a given location on local rental prices, which is capitalized by agents' willingness to pay through hedonic mechanisms (Feige et al., 2013). Alternatively, ESG ratings may also affect object-specific cash flows via a demand-side effect induced through the increased quality of a given location, potentially influencing vacancy rates (Fuerst and McAllister, 2011). In addition to these potential effects arising from object-specific cash flows, an association with ESG ratings may also be mediated through the discount rate (McGrath, 2013). The discount rate reflects the probability with which the expected rental income will be realized and corresponds to the return that a given investor can expect under normal market conditions. The discount rate is generally composed of a risk-free rate (RF_t), capturing the compensation for lost liquidity, a compensation for inflation (I_t), and an object-specific risk premium for risk-taking ($RP_{i,t}$) (Leskinen et al., 2020):

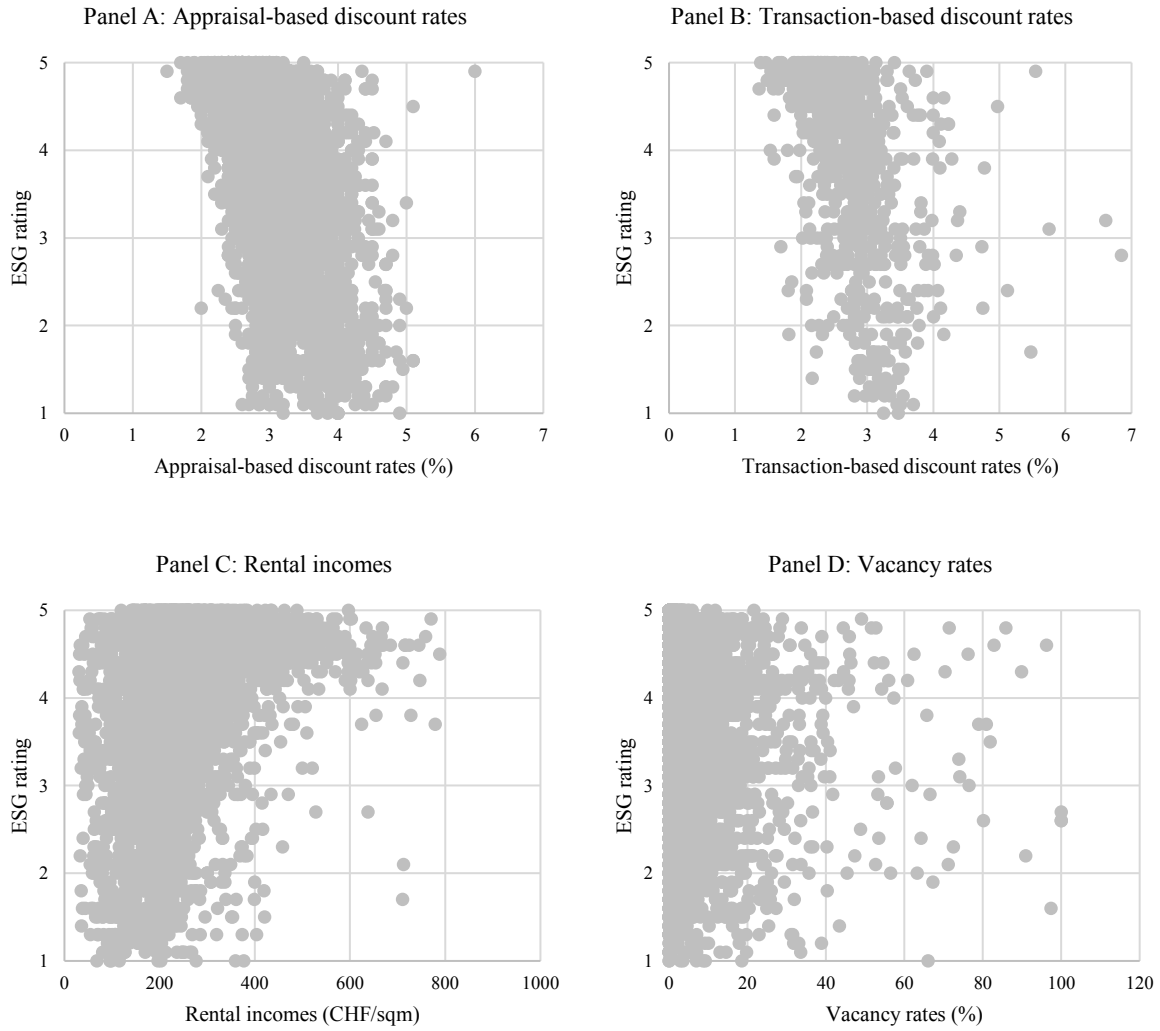
$$d_i = RF_t + I_t + RP_{i,t} \tag{4.2}$$

The risk premium stands out as particularly intriguing, acknowledging that the real estate literature commonly agrees on its association with object- and location-specific characteristics (Chuangdumrongsomsuk and Fuerst, 2017; Chaney and Hoesli, 2012). If ESG ratings are perceived to be associated with lower risks, higher future cash flows, and improved sustainability, they can lead to lower discount rates. Conversely, if ESG ratings are perceived to be associated with higher risks, lower future cash flows and reduced sustainability, they can increase discount rates (Galema and Gerritsen, 2022).

Throughout this study, we will analyze appraisal-based (d_i^{apr}) and transaction-based (d_i^{trx}) discount rates. Whereas appraisal-based discount rates are determined by appraisers using the DCF method in real estate valuations, transaction-based discount rates are implicitly derived from market transactions and reflect investors' perception of risks at a given point in time. While appraisal-based discount rates facilitate the examination of whether appraisers consider ESG-related indicators when determining discount rates, the analysis of transaction-based

discount rates enables us to infer whether investors prioritize these indicators when making investment decisions, eventually through a mark-up in the object-specific risk premium.

Figure 13: ESG ratings across real estate metrics



Notes: Displayed are total ESG ratings (vertical axis) against appraisal-based discount rates in Panel A, transaction-based discount rates in Panel B, rental incomes in Swiss Francs (CHF) per square meter (sqm) in Panel C, and against vacancy rates (%) in Panel D. All objects have been evaluated or traded between 2019 and 2022. Source: Wüest Partner AG.

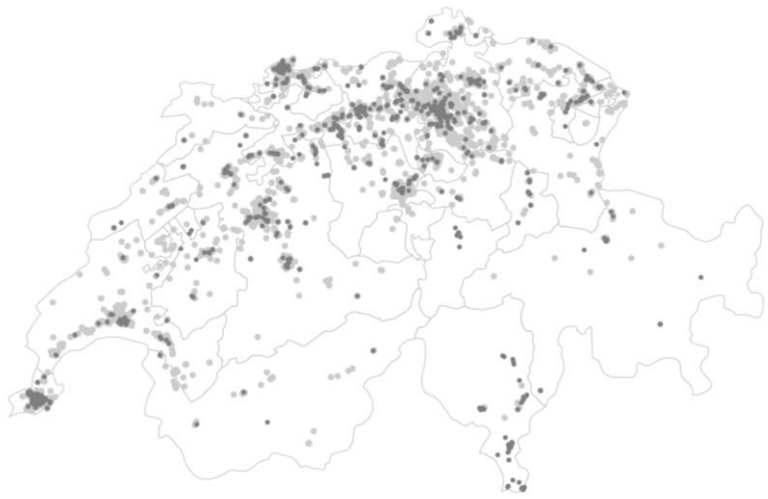
Figure 13 illustrates the association between ESG ratings (Section 4.5.1) and selected key metrics. In Panel A, an inverse association is evident between appraisal-based discount rates and ESG ratings. Income properties with higher ESG ratings, particularly between 4 and 5, are associated with lower discount rates compared to those with ratings between 1 and 2. A similar inverse association is observed for transaction-based discount rates in Panel B. Panel C shows a direct association between total ESG ratings and rental income per square meter (sqm), with the highest rental incomes per sqm linked to increased ESG ratings. Panel D presents the association between ESG ratings and vacancy rates, revealing a less pronounced pattern.

Furthermore, Figure 13 also highlights the presence of potential signaling effects, as previously discussed by Fuerst et al. (2016), suggesting that the association between ESG ratings and the considered key metrics might not be linear. Income properties with high ESG ratings (between 4 and 5) are notably associated with lower discount rates, whereas properties with lower ESG ratings (between 1 and 2) tend to have higher discount rates. A similar trend is observed in rental incomes, though it is less pronounced for vacancy rates. These considerations prompt a closer examination of the association across various ESG rating levels for each key metric, a topic explored in detail in Section 4.7.3.

4.5. Data

In the context of this study, the relevance of sustainability criteria influencing Swiss real estate markets can be traced back to the year 2019 when the Swiss parliament approved the Swiss Climate Policy 2050. Subsequently, sustainability criteria gained in importance among commercial real estate investors, and its increase in significance further accelerated with the Federal Council's recent adoption of the executive order on climate reporting for Swiss companies, effective from the start of 2024. Building on this, the empirical part of this study analyzes the time frame between 2019 and 2022 using two unique datasets – a dataset capturing expert-based valuations and a dataset containing real market transactions. The geographical distribution of the real estate objects analyzed is displayed in Figure 14.

Figure 14: Geographical distribution



Notes: Geographical distribution of 6'261 expert-based real estate valuations (light gray) and 836 transactions of real estate objects (dark gray). All real estate objects displayed have been evaluated or traded between 2019 and 2022. The boundaries displayed refer to Swiss cantonal layers. Source: Wüest Partner AG.

To assess the association between ESG ratings and appraisal-based discount rates, rental incomes, and vacancy rates, we use a dataset capturing approximately 6'300 expert-based DCF

valuations of commercial investors' income properties. The effectiveness of the DCF methodology stems from the combination of appraisers' knowledge and detailed, high-quality data, including rent rolls, which provide comprehensive information on actual rental incomes and vacancy rates. The second dataset contains roughly 850 income properties that have been sold in market transactions. For each income property from the second dataset, an expert-based DCF valuation exists together with transaction data providing information about transaction-based discount rates.

4.5.1. ESG rating

Both datasets have been enriched with an ESG rating, as outlined in Table 15. Similar to most ESG ratings in the real estate industry, the ESG rating considered consists of multiple indicators grouped under the three core pillars, emphasizing the need for transparency in their disclosure (Kempeneer et al., 2021). Environmental indicators encompass a wide array of indicators related to climate change and associated risks, as well as multifaceted indicators of greenery, land sealing, and mobility aspects. Social indicators address aspects directly linked to society, including health and well-being, safety and natural hazards, socioeconomic structure, building stock, and recreational areas. In contrast, governance indicators focus on aspects related to subordinate developments, such as current trends in local real estate markets, initiatives toward renewable energy, and spatial planning efforts. Further information about the ESG rating considered is provided in Appendix C.1 (Table 20).

The considered ESG rating aims to provide a comprehensive assessment of sustainability for any given location in Switzerland, incorporating distinctive data beyond the conventional characteristics typically used to describe a location[35]. It includes indicators based on expert classifications, such as raster data for natural hazards and air pollutants, as well as benchmark-based indicators. From these indicators, an overall ESG rating, along with sub-ratings for the E, S, and G pillars, is calculated on a scale from 1 to 5, with 5 representing the highest value. These ratings are subsequently compared and reclassified using precalculated ESG ratings for 2 million Swiss buildings, yielding the total ESG rating and sub-ratings for each pillar.

As a data-driven assessment, this ESG rating enhances objectivity by resisting influence from stakeholders involved in the appraisal or transaction process, unlike object-specific ESG ratings, which may be more prone to such biases. This objectivity improves comparability across different locations and has led to the rating's approval by GRESB. Although this study does not delve into the inclusion of specific indicators, the ESG rating provides a robust

[35] Compared to the EU Taxonomy, which adopts a broader, regulatory approach, the considered ESG rating is more granular and specifically adapted to the real estate sector.

foundation for evaluating its association with key real estate metrics, incorporating a diverse set of factors commonly associated with sustainability in the real estate industry.

Table 15: ESG rating description

ESG sub-rating	Criteria	Indicators
Environment indicators (E)	Climate change and risks	Heat days in 2020, difference in heat days between 2060 and 2020, cooling degree days in 2020, difference in cooling degree days between 2060 and 2020.
	Greenery and sealing	Proportion of shrubs, proportion and diversity of greening, surface sealing.
	Mobility	Public transport quality class, car sharing locations, future public transport infrastructure, public e-car charging stations.
	Resource utilization	Population density.
Social indicators (S)	Health and well-being	Road noise during the day, road noise at night, railway noise during the day, railway noise at night, aircraft noise, long-term air pollution index, radon.
	Safety and natural hazards	Hail, flood, fall, landslide, storm, debris flow, avalanche, earthquake, surface runoff.
	Socioeconomic structure	Diversity of household sizes, diversity of age structure, diversity of socio-economic milieus, diversity of income, price range distribution.
	Building stock	Diversity of building categories, mix of dwelling sizes, diversity of building ages.
	Recreational areas	Recreational and green areas, public meeting places, e.g. fire pits and playgrounds.
Governance indicators (G)	Real estate market	Supply ratio, vacancy rates.
	Renewable energy	Energy city label, utilization of solar potentials.
	Spatial planning	Building permits, conversion shares in building permits, densification potential.

Notes: The table specifies each sub-rating, respective criteria and indicators entering the ESG rating. More detailed information, including the sources and weightings contributing to the ESG rating, is provided in Appendix C.1 (Table 20). Source: Wüest Partner AG.

4.5.2. Variable description

In the subsequent empirical analysis, we examine the association between ESG ratings, including their sub-ratings, and four key metrics: appraisal-based and transaction-based discount rates, rental incomes, and vacancy rates. Our estimation procedure incorporates various control variables, acknowledging that our outcome variables are conventionally influenced by a multitude of additional factors. Table 16 summarizes the relevant variables, while summary statistics for both datasets are attached in Appendix C.2 (Table 21 and 22).

Considering first appraisal-based and transaction-based discount rates. As outlined in Equation 4.2, from a theoretical standpoint, discount rates encompass a risk-free rate, an inflation compensation, and a risk premium. To approximate the risk-free rate, we incorporate yields from government bonds with a 20-year maturity. We have opted for this extended maturity period under the presumption that longer government bond maturities and the associated higher interest rates more accurately reflect investors' return expectations in a low-interest-rate environment. We consider the yearly inflation rate to represent the compensation for inflation. Including the yearly inflation rate corresponds with the accessible data available

to appraisers and investors, offering a pragmatic approach to assess the direct effects of inflation on future cash flows.

Table 16: Variable description

Variable name Description	**Source**
ESG rating Total ESG rating (Min = 1, Max = 5)	Wüest Partner AG
E-rating Rating for the environment (E) (Min = 1, Max = 5)	Wüest Partner AG
S-Rating Rating for the society (S) (Min = 1, Max = 5)	Wüest Partner AG
G-Rating Rating for the governance (G) (Min = 1, Max = 5)	Wüest Partner AG
$\boldsymbol{d_i^{apr}}$ Appraisal-based discount rate	Wüest Partner AG
$\boldsymbol{d_i^{trx}}$ Transaction-based discount rate	Wüest Partner AG
Rental_I_sqm Effective rental income in Swiss Francs (CHF) derived from rent rolls divided by the total effective area	Wüest Partner AG
Vacancy_R Object-specific vacancy rate derived from rent rolls	Wüest Partner AG
Age Difference between the construction year of a given object and the valuation date	Wüest Partner AG
LogSqm Logarithm of the total effective area, measured in sqm	Wüest Partner AG
Micro_L Rating for the location of a given object within a given municipality (Min = 1, Max = 5)	Wüest Partner AG
Macro_L Locational rating characterizing the municipality of a given object (Min = 1, Max = 5)	Wüest Partner AG
Object_R Standardized rating characterizing the overall quality of a given object (Min = 1, Max = 5)	Wüest Partner AG
Standard_R Standardized rating characterizing the standard of a given object (Min = 1, Max = 5)	Wüest Partner AG
Condtion_R Standardized rating characterizing the condition of a given object (Min = 1, Max = 5)	Wüest Partner AG
IR_20 Yields on governmental bonds with 20-year maturity	Swiss National Bank
Inflation Yearly inflation according to the consumer price index	Federal Statistical Office

Notes: Variable names, descriptions and sources for the subsequent empirical analysis. In both datasets used, the variables are defined identically.

Besides macroeconomic variables affecting both appraisal-based and transaction-based discount rates, we approximate the risk premium using an array of locational and object-specific variables. To account for locational characteristics, we include the macro- and micro-location rating. Whereas the macro-location rating is a standardized assessment that reflects the quality of a municipality as a whole, the micro-location rating specifies the precise location of an income property within a particular municipality. The macro-location rating classifies the municipality, capturing fundamental elements, such as the municipality type, tax burden, and price developments. Both the macro- and micro-location rating are tied to the specific type of a

given income property, encompassing condensed information about locational characteristics that traditionally affect key metrics. To control for the overall quality of a given object, we incorporate the object-specific quality rating, which is a standardized rating defined by any appraiser during the assessment of a given object. Besides these standardized ratings, we control for the object-specific age and the size (LogSqm), which are variables that traditionally drive discount rates (Letdin et al., 2023).

In our empirical investigation to analyze the role of ESG ratings on rental incomes, we control for variables that are generally applied in hedonic estimation procedures (Djurdjevic et al., 2008). We incorporate both the macro-location and micro-location rating to consider local quality criteria that influence rental prices. Because rental prices are primarily influenced by distinct quality criteria, we consider the overall condition and the standard of a given object. Considering the standard and condition of an object provides a more detailed and granular understanding of the rental object's attributes, allowing for accurate price differentiation between objects. We additionally incorporate the specific age and size of a given object to more effectively account for variations in rental incomes across different locations.

Concerning vacancy rates, we incorporate the macro-location and micro-location rating to control for local characteristics that influence local vacancy rates. We also consider the object-specific quality rating to accommodate differing tenant preferences among locations, which can impact vacancy rates. Controlling for the object-specific age and size follows a similar approach.

Across all key metrics under consideration, we include dummy variables controlling for seasonality, regionality, and real estate type-specific differentials. Seasonality is addressed with the inclusion of year dummy variables, accounting for significant events between 2019 and 2022, such as the emergence of the COVID-19 pandemic in 2020 and changes in monetary policy, including increasing target interest rates in 2022. Real estate type dummy variables control for variations in key metrics inherently tied to specific property categories due to structural circumstances. Examples include the persistent rent control system in Switzerland, allowing property owners or tenants to adjust rental incomes according to the reference index or the Consumer Price Index (CPI) (Hilber and Schöni, 2016), the historically high share of Swiss tenants resulting in low vacancy rates in the residential real estate segment, and the risk premium asked by commercial investors for this particular segment[36]. Regional dummy variables, including those for the 26 cantons, accommodate Switzerland's spatial political structure. This incorporation addresses the pronounced heterogeneity within Switzerland's

[36] The reference index is a weighted average of mortgage interest rates in Switzerland.

regulatory landscape, arising from the Swiss federalist system, which grants each canton the authority to establish distinct locally binding regulations (Basten et al., 2017). As a result, the key metrics considered exhibit significant fluctuations across Swiss regions.

4.6. Methodology

In order to test and estimate the connection between ESG ratings and real estate key metrics, we employ an OLS post-LASSO estimation methodology (Belloni and Chernozhukov, 2013), wherein we use LASSO for variable selection and subsequently employ OLS to quantify the connection between ESG ratings, their corresponding sub-ratings, and predefined key metrics. In light of the dataset outlined in Section 4.5, the employment of the LASSO estimation technique in our analysis serves a dual purpose. Firstly, it facilitates a meticulous evaluation of these established drivers, and secondly, it systematically examines the association of ESG ratings, including their sub-ratings, with the designated outcome variables. This hybrid approach integrates a priori variable selection based on intuition and theory with a data-driven model, offering a robust framework for investigating the association between ESG ratings and the predefined outcome variables.

Our baseline estimation equation is summarized as follows:

$$Y_{i,t} = \alpha_0 + \gamma_i \cdot ESG_{i,t} + \delta_i \cdot \psi_{i,t} + \vartheta_{i,t} \tag{4.3}$$

Where $Y_{i,t}$ denotes the key metrics for asset i at a given date t, encompassing appraisal-based and transaction-based discount rates, along with rental incomes and vacancy rates. $ESG_{i,t}$ reflects either the total ESG rating or sub-ratings for the pillars $E_{i,t}$, $S_{i,t}$, and $G_{i,t}$. $\psi_{i,t}$ summarizes control variables, and $\vartheta_{i,t}$ is an error term.

The LASSO method extends OLS estimation by augmenting the model with a penalty term on the sum of the absolute coefficients. This penalty term facilitates variable selection by setting many potential explanatory variables to have zero coefficients (Tibshirani, 1996). In particular, applying a linear LASSO solves the following absolute value function:

$$\hat{\beta} = \underset{\beta}{argmin}\left(\frac{1}{n}\sum_{i=1}^{n}(Y_i - X_i\beta')^2 + \lambda\sum_{j=1}^{p}|\beta_j|\right) \tag{4.4}$$

Where $\beta = [\alpha_0, \gamma_1, \gamma_2, \dots, \delta_1, \delta_2, \dots]$, X_i represents p potential covariates in the dataset of n observations, and Y_i is the outcome variable. In Equation 4.4, λ represents the LASSO penalty term ($\lambda > 0$), which belongs to the tuning parameters in our estimation procedure (Letdin et al., 2023). All variables have been standardized according to the z-score normalization. The optimal value of the regularization parameter λ was determined using 10-fold cross-validation, extracted from the fitted LASSO model. In fact, applying k = 10 in k-fold cross validation can

be seen as common practice in the empirical literature (Marcot and Hanea, 2021). To enhance the robustness of our findings, we conduct a thorough examination using alternative variable selection methods (Section 4.7.4). This evaluation assesses the consistency of selected variables across various cross-validation settings, contributing to the reliability of our results.

Upon identifying the pertinent regressors selected through the LASSO estimation procedure (l), we incorporated them into an OLS:

$$Y_{i,t} = \alpha_0 + \gamma_i \cdot ESG_{i,t}^{l} + \delta_i \cdot \psi_{i,t}^{l} + \vartheta_{i,t} \tag{4.5}$$

A list of all variables incorporated in our estimation procedure is attached in Appendix C.3 (Table 23). While our estimation approach employs a comprehensive OLS post-LASSO regression model with cross-validation to explore the associations between ESG ratings and key metrics of income properties, it is crucial to acknowledge the inherent challenges in attributing causal relationships in this study. In fact, the country-wide obligation for commercial real estate investors to report such ratings, along with the distinctives of ESG ratings as outlined in Section 4.5, forms essential components within the framework for assessing their connection to income properties' key metrics. However, with the emergence of sustainability criteria and ESG ratings, they face opposition from traditionally heterogeneous perceptions among market participants in real estate markets. For instance, there might be a scenario where an association between vacancy rates and rental incomes with ESG ratings only emerges for particular "green" tenants who either choose to locate themselves in sustainable areas or are willing to pay a rent premium. Additionally, appraisers and investors may implicitly incorporate factors contained in ESG ratings, predating the formal conceptualization and regulation of these ratings. This underlines the importance to control for a multitude of empirically grounded variables that collectively influence the key metrics under consideration, all of which are assessed through LASSO, to mitigate omitted variables bias and achieve conditional exogeneity.

4.7. Empirical results

The results are organized according to the key metrics under consideration. Section 4.7.1 presents the findings related to appraisal-based and transaction-based discount rates, while Section 4.7.2 focuses on rental incomes and vacancy rates. In Section 4.7.3, we extend the empirical analysis by exploring the association between key metrics across different rating levels. Section 4.7.4 provides a robustness check through the assessment of alternative model specifications.

4.7.1. Appraisal-based and transaction-based discount rates

Considering first the findings presented in Table 17, which summarizes the results from the OLS post-LASSO estimation procedure for appraisal-based and transaction-based discount rates. In Model 1, the total ESG rating is selected by LASSO and significantly contributes to the equation for appraisal-based discount rates. This suggesting that sustainability characteristics, on an aggregated level, are positively associated with appraisal-based discount rates. The results indicate that a one-unit increase in the total ESG rating is associated with an approximate 3.2% decrease in appraisal-based discount rates. To achieve a nuanced understanding of the association between ESG ratings and appraisal-based discount rates, Model 2 applies our OLS post-LASSO estimation procedure to the sub-ratings of the total ESG rating, specifically focusing on the environment (E-rating), society (S-rating), and governance (G-rating). Apparently, all sub-ratings have been selected by LASSO and display a significant inverse connection with appraisal-based discount rates. Among those ratings, appraisal-based discount rates appear to be particularly sensitive to changes in the E-rating, whereas the S-rating and G-rating exhibit comparatively smaller sensitivities. These results suggest that environmental factors may have a more significant influence on appraisal-based discount rates, while social and governance factors likely play a subordinated role.

The relevance of environmental factors in explaining appraisal-based discount rates is supported by the significant association with the micro- and the macro-location rating. In Models 1 and 2, both locational quality criteria enter significantly into the estimation equations. Similarly, the object-specific quality rating displays a notable sensitivity to appraisal-based discount rates, suggesting that a considerable share in the variation of appraisal-based discount rates hinges on the object quality itself. The age is characterized by a counterintuitive estimate, as one would expect the risk premium to increase with the age of a given real estate object. Explanations may be found in the DCF method, wherein depreciation is explicitly accounted for over time, stable income that is independent of object characteristics is considered, and routine maintenance and renovations are already factored into the object-specific quality rating. Conversely, appraisal-based discount rates appear to increase with the size of an object, indicating an increasing risk premium associated with relatively sizable real estate objects.

The risk-free rate enters the estimation equations in Models 1 and 2 with a counterintuitive sign. Throughout the period under consideration, interest rates predominantly remained in the negative territory, particularly in 2021, before experiencing a subsequent increase in 2022. Average discount rates, in contrast, consistently decreased during the same time frame. Due to the conventional time lag in the responsiveness of discount rates to changes in the interest rate

environment, the influence of interest rates on discount rates may have become attenuated during the period under investigation. The same holds true for inflation, which has a minor and insignificant effect on appraisal-based discount rates.

Table 17: ESG ratings – appraisal-based and transaction-based discount rates

Dependent variable:	log of d_i^{apr}	log of d_i^{apr}	log of d_i^{trx}	log of d_i^{trx}
Model:	(1)	(2)	(3)	(4)
Constant	1.558***	1.553***	1.333***	1.318***
	(0.018)	(0.019)	(0.070)	(0.072)
Macro_L	-0.056***	-0.050***	-0.031***	-0.014
	(0.003)	(0.003)	(0.011)	(0.013)
Micro_L	-0.032***	-0.031***	-0.042***	-0.038***
	(0.002)	(0.002)	(0.010)	(0.010)
Quality_R	-0.041***	-0.042***		
	(0.003)	(0.003)		
Age	-0.0004***	-0.0003***	-0.001***	-0.001***
	(0.00003)	(0.00003)	(0.0001)	(0.0001)
LogSqm	0.022***	0.021***	0.016**	0.012*
	(0.001)	(0.001)	(0.007)	(0.007)
IR_20	-0.045***	-0.045***	-0.039***	-0.040***
	(0.004)	(0.004)	(0.013)	(0.013)
Inflation	0.002	0.002		
	(0.002)	(0.002)		
ESG rating	-0.032***		-0.042***	
	(0.002)		(0.007)	
E-rating		-0.024***		-0.053***
		(0.002)		(0.007)
S-rating		-0.004**		
		(0.002)		
G-rating		-0.011***		-0.006
		(0.002)		(0.007)
Regional dummies	Yes	Yes	Yes	Yes
Year dummies	Yes	Yes	Yes	Yes
Type dummies	Yes	Yes	Yes	Yes
Observations	6166	6166	836	836
Adjusted R^2	0.593	0.598	0.435	0.45
Residual std. error	0.094	0.093	0.159	0.156

*Notes: The results displayed are derived from an OLS post-LASSO estimation procedure, in which we employ LASSO for variable selection and OLS for quantification. In the LASSO variable selection procedure, the optimal value of the regularization parameter λ was determined using 10-fold cross-validation. The optimal value of λ is 0.0020 in Model 1, 0.0012 in Model 2, 0.0103 in Model 3 and 0.0010 in Model 4. Year, type, and regional dummies are included in each model. The time frame under consideration refers to the years from 2019 to 2022. Variables are defined according to Table 16. Signif. codes: '***' 0.001, '**' 0.01, '*' 0.05, '.' 0.1*

In Models 3 and 4, we examine the association between transaction-based discount rates and ESG ratings. Compared to appraisal-based discount rates, transaction-based discount rates

reflect investors' perceptions, providing information on whether ESG ratings may be reflected in the risk premium of a given real estate object. In Model 3, the total ESG rating emerges as a relevant predictor for transaction-based discount rates, having been selected by LASSO, and revealing an inverse association between the two variables. Notably, transaction-based discount rates exhibit a more pronounced sensitivity to variations in the total ESG rating compared to appraisal-based discount rates. A one-unit increase in the ESG rating is associated with a decrease in transaction-based discount rates of approximately 4.2%. Furthermore, in Model 4, we include ESG sub-ratings in our OLS post-LASSO estimation, revealing that the predominant association of the total ESG rating observed in Model 3 primarily stems from the E-rating. The relevance of the S-rating is not retained by LASSO, resulting in its attenuation as a regressor in the model, while the G-rating does not significantly enter the estimation equation. This observation highlights a significant limitation of relying solely on associations resulting from aggregated ratings, which may obscure important variations within the data and potentially serve as a foundation for aggregation errors.

Overall, the association of ESG ratings with transaction-based discount rates mirrors the pattern observed with appraisal-based discount rates, with environmental ratings serving as the primary driver of the aggregated association detected. In contrast to appraisal-based discount rates, transaction-based discount rates exhibit a lower sensitivity to variations in the macro-location rating. Nonetheless, it is noteworthy that the micro-location rating displays an increased degree of responsiveness in relation to transaction-based discount rates, suggesting that investors place a heightened emphasis on the precise geographical location of a particular real estate object compared to the overall rating of a given municipality. Different weightings between appraisers and investors also become apparent considering the object-specific quality rating or inflation, which have been excluded by LASSO from the estimation equation for transaction-based discount rates.

4.7.2. Rental incomes and vacancy rates

Table 18 summarizes the results of applying our empirical strategy to analyze the association between ESG ratings, rental incomes, and vacancy rates. Examining first the results for rental incomes, as displayed in Models 5 and 6. Model 5 reveals that the total ESG rating is directly associated with rental incomes. Notably, a one-unit increase in the ESG rating is linked to an average increase of approximately 6.3% in rental incomes. In Model 6, we further decompose the association of the total ESG rating into its individual sub-ratings. Similar to appraisal-based discount rates (Table 17), all sub-ratings are selected by LASSO. A substantial portion of the association between the total ESG rating and rental incomes is primarily mediated

through the E-rating. Rental incomes display a relatively small sensitivity to changes in the G-rating, which becomes even smaller for the S-rating. While the finding that rental income associations are primarily mediated through environmental factors is well-documented in prior studies (Marty and Meins, 2017; Meins et al., 2010), we hypothesize that the reduced sensitivity of social and governance aspects may result from varying perceptions of these attributes among market participants.

Table 18: ESG ratings – rental incomes and vacancy rates

Dependent variable:	log of Rental_I_sqm	log of Rental_I_sqm	log of Vacancy_R	log of Vacancy_R
Model:	(5)	(6)	(7)	(8)
Constant	4.441***	4.374***	8.859***	8.966***
	(0.061)	(0.061)	(1.655)	(1.703)
Macro_L	0.075***	0.069***	-0.746**	-0.694**
	(0.011)	(0.011)	(0.295)	(0.277)
Micro_L	0.094***	0.089***	-0.521***	-0.481***
	(0.007)	(0.007)	(0.183)	(0.184)
Standard_R	0.090***	0.091***		
	(0.010)	(0.010)		
Condition_R	0.076***	0.081***		
	(0.007)	(0.007)		
Quality_R			0.547**	0.518**
			(0.237)	(0.237)
Age	-0.0004***		-0.003	-0.003
	(0.0001)		(0.003)	(0.003)
LogSqm	-0.069***	-0.063***	0.366***	0.341***
	(0.005)	(0.005)	(0.126)	(0.126)
ESG rating	0.063***		-0.809***	
	(0.007)		(0.185)	
E-rating		0.043***		-0.797***
		(0.006)		(0.146)
S-rating		0.009*		-0.149
		(0.006)		(0.149)
G-rating		0.017***		
		(0.006)		
Regional dummies	Yes	Yes	Yes	Yes
Year dummies	Yes	Yes	Yes	Yes
Type dummies	Yes	Yes	Yes	Yes
Observations	6261	6261	6166	6166
Adjusted R^2	0.256	0.256	0.058	0.060
Residual std. error	0.317	0.317	8.284	8.277

*Notes: The results displayed are derived from an OLS post-LASSO estimation procedure, in which we employ LASSO for variable selection and OLS for quantification. In the LASSO variable selection procedure, the optimal value of the regularization parameter λ was determined using 10-fold cross-validation. The optimal value of λ is 0.3901 in Model 5, 0.3238 in Model 6, 0.0483 in Model 7, and 0.0412 in Model 8. Year, type, and regional dummies are included in each model. Variables are defined according to Table 16. Signif. codes: '***' 0.001, '**' 0.01, '*' 0.05, '.' 0.1.*

The responsiveness of rental incomes to various influencing factors becomes evident through the remaining LASSO-selected variables in Models 5 and 6. While the significant association with both micro- and macro-location ratings unveils rental incomes' sensitivity to locational characteristics, tenants' willingness to pay for unique object-specific attributes is illustrated by the direct association with the standard and condition rating. Interestingly, the object-specific age is not a significant variable in the estimation equation, while rental incomes inversely correlate with the object-specific size. This suggests that older properties tend to command lower rents and indicates a decreasing rent premium for larger properties.

In Models 7 and 8, we analyze the association between ESG ratings and vacancy rates. Our OLS post-LASSO estimation procedure selects the total ESG rating as a relevant variable for object-specific vacancy rates (Model 7). A one-unit increase in the total ESG rating is associated with an approximate 0.8 percentage point decrease in average vacancy rates. In Model 8, we break down the total ESG rating and asses the relevance of ESG sub-ratings to vacancy rates. We find that the E-rating remains the most influential predictor among all ESG sub-ratings, whereas the S-rating exhibits an insignificant estimate, and the G-rating has not been selected by LASSO. We conjecture that this observation may be attributed to the underlying mechanisms governing real estate markets, where location attractiveness – largely influenced by the quality-related factors encompassed in the E-rating – exerts a positive demand-side effect, thereby influencing vacancy rates.

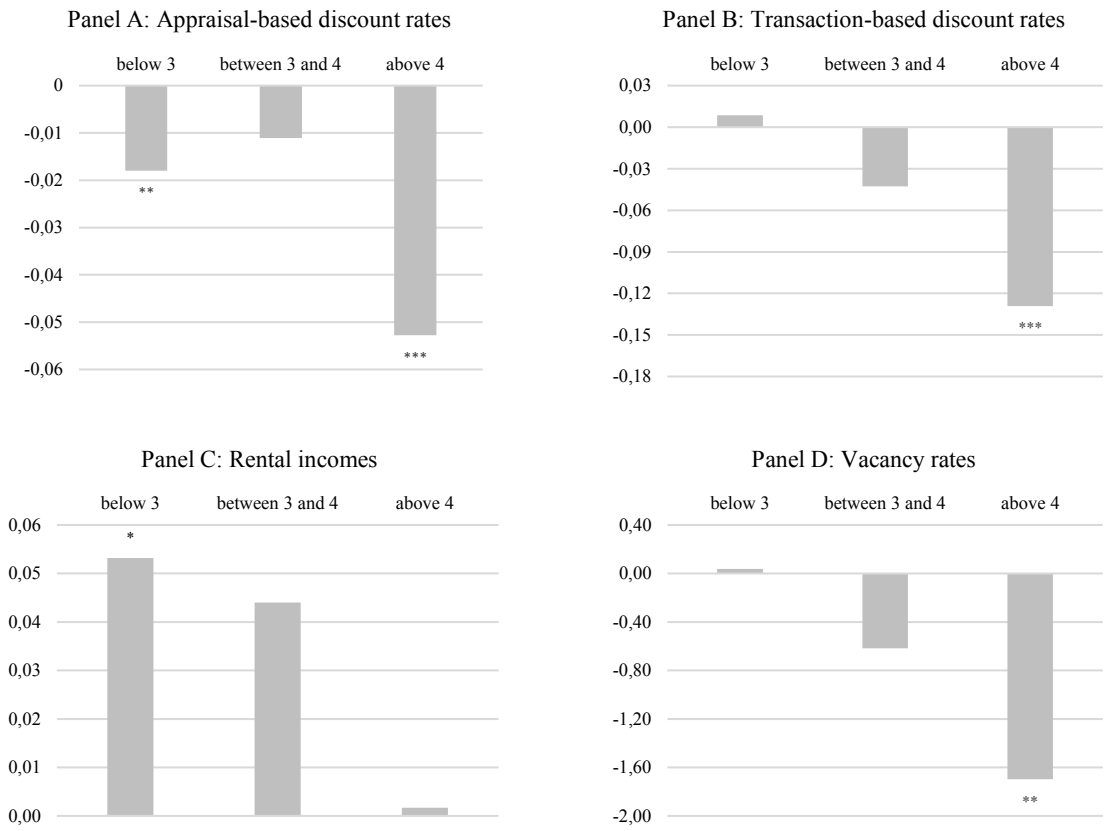
The significance of locational quality criteria also becomes evident in the estimation equations for vacancy rates. An increase in both the micro and macro-location ratings is associated with a decrease in vacancy rates. Furthermore, our results suggest nuanced interplays among object-specific variables in explaining vacancy rates. Surprisingly, the object-specific quality rating enters into the estimation equations for vacancy rates with a positive sign, which suggests that even high-quality objects may experience vacancies. Conversely, our results reveal that vacancy rates are not consistently affected by the object-specific age but tend to increase with the size of a given real estate object.

4.7.3. Exploring ESG rating levels

Our prior analyses have shed light on the connection between ESG ratings and the pertinent metrics, operating under the assumption of a linear association. Yet, beyond this linear perspective, ESG ratings may implicitly signal value, implying that their connection with outcome variables could differ across varying rating levels. To further explore potential signaling effects of both high and low ESG ratings, Figure 15 summarizes the results from our

established estimation procedure, illustrating the association between various ESG rating levels (e.g., below 3, between 3 and 4, and above 4) and the previously discussed real estate key metrics.

Figure 15: ESG rating levels analysis



*Notes: The coefficients displayed correspond to total ESG ratings across different levels, e.g., below 3 (ESG ratings < 3), between 3 and 4 (ESG ratings ≥ 3 and < 4), as well as above 4 (ESG ratings ≥ 4). The coefficients are the results of the same OLS post-LASSO estimation procedure as displayed in Table 17 (Models 1 and 3 for appraisal- and transaction-based discount rates) and in Table 18 (Models 5 and 7 for rental incomes and vacancy rates). Signif. codes: '***' 0.001, '**' 0.01, '*' 0.05, '.' 0.1*

In Panel A, the analysis reveals a pronounced sensitivity between ESG ratings and appraisal-based discount rates, with the most substantial association observed in the upper bound, particularly for ESG ratings exceeding 4. Intermediate and low ratings (below 4) do not exhibit a significant association with appraisal-based discount rates. A similar pattern emerges in Panel B for transaction-based discount rates, highlighting that the primary association is particularly pronounced in properties with ESG ratings above 4. Since the existing Swiss regulatory framework imposes obligations on commercial real estate investors, the inclusion of risk discounts in discount rates is likely indicative of a future-proofing effect for sustainable investments, as previously reported by Kempf and Syz (2022), which may reveal an implicit risk discount for strategic investment decisions towards sustainable locations.

Applying the same approach to rental incomes (Panel C) suggests that particularly low levels of ESG ratings are associated with increasing rental incomes. We speculate that this might suggest that rental incomes in the upper bound of the ESG rating already account for locational sustainability characteristics. As a result, the association between higher ESG ratings and rental incomes appears marginal, limiting the potential for additional mark-ups on rental prices, especially given the constraints of Switzerland's rent control system.

Panel D highlights a notable sensitivity of vacancy rates to higher ESG ratings (above 4), providing evidence of a higher signaling effect for heightened ESG ratings. We posit that this increased sensitivity is likely attributed to properties with higher ESG ratings attracting greater demand, potentially leading to a reduction in vacancy rates. Thus, tenants sorting themselves around sustainable locations may be inherently linked to the fundamental mechanisms composing real estate markets, where local quality characteristics are transmitted through object-specific cash flows via a demand-side effect.

4.7.4. Assessing model specifications

In order to further test the obtained results, we apply additional selection methods to assess the validity of LASSO-selected variables, as displayed in Table 19. We first perform a robustness check using Elastic Net regression, which is a regularization technique that combines the penalties of both Ridge regression and LASSO. Specifically, Elastic Net penalizes the absolute size of regression coefficients (LASSO penalty) and the squared size of coefficients (Ridge penalty). This combination allows Elastic Net to select variables like LASSO while also handling multicollinearity more effectively, akin to Ridge regression (Zou and Hastie, 2005).

Next, we employ the Adaptive LASSO as an additional variable selection method. The Adaptive LASSO extends the conventional LASSO methodology by incorporating data-driven weights for each predictor variable during the regularization process. In contrast to standard LASSO regression, which uniformly penalizes all predictors, the Adaptive LASSO assigns unique weights to each predictor based on their estimated coefficients derived from an initial model. This adaptive approach employs cross-validation to iteratively fit the model, enabling the determination of adaptive weights by varying the regularization parameter λ (Zou, 2006).

While LASSO's stronger regularization generally leads to a more stringent variable selection process – resulting in fewer non-zero coefficients and a sparser model – both the Elastic Net and Adaptive LASSO methods offer distinct advantages in managing collinearity and highlighting variable importance. As illustrated in Table 19, Elastic Net and Adaptive LASSO produce comparable variable selection outcomes. Despite differences in the selection

methods, the qualitative consistency of the results reaffirms the reliability of the selected variables.

Table 19: Assessing variable selection

Dependent variable:	log of d_i^{apr}				log of d_i^{trx}				log of Rental_I_sqm				Vacancy_R			
Model:	(1)		(2)		(3)		(4)		(5)		(6)		(7)		(8)	
Method	EN	AL	EN	AL	EN	AL	EN	AL	EN	AL	EN	AL	EN	AL	EN	AL
Macro_L	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Micro_L	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Quality_R	Y	Y	Y	Y	N	N	N	N					Y	Y	Y	Y
Standard_R									Y	Y	Y	Y				
Condition_R									Y	Y	Y	Y				
Age	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	N	Y	Y	Y	Y
LogSqm	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
IR_20	Y	Y	Y	Y	Y	Y	Y	Y								
Inflation	Y	Y	Y	Y	N	N	N	N								
ESG rating	Y	Y			Y	Y			Y	Y			Y	Y		
E-rating			Y	Y			Y	Y			Y	Y			Y	Y
S-rating			Y	Y			N	N			Y	Y			Y	Y
G-rating			Y	Y			Y	Y			Y	Y			N	N

Notes: Selected variables (Y =Yes, N=No) by Elastic Net (EN) and Adaptive Lasso (AL) using 10-fold cross validation to determine the optimal regularization parameter λ. With the exception of applied selection methods, selected variables are the results of the same estimation procedure as displayed in Table 17 (Models 1 and 2 for appraisal-based discount rates, Models 3 and 4 for transaction-based discount rates) and in Table 18 (Models 5 and 6 for rental incomes, Models 7 and 8 for vacancy rates). The variables are defined according to Table 16.

4.8. Discussion

The question of whether, and through which channels, ESG ratings may be associated with key metrics in the real estate industry is intrinsically linked to the fundamental dynamics governing real estate markets. The integration of sustainability concerns into financial decision-making processes, particularly in real estate, requires an understanding of both regulatory frameworks and market forces that convert non-financial attributes, such as environmental, social, and governance considerations, into measurable financial outcomes. This study, although focused on Switzerland, offers insights with broad relevance, as the underlying principles transcend national boundaries and can inform global investigations into the intersection of sustainability ratings and financial performance across various markets.

Recent developments in Switzerland serve as a case study to demonstrate how sustainability factors, such as ESG ratings, are progressively embedded into financial practices. The study's conceptual framework, detailed in Section 4.4, offers a robust and adaptable foundation that accommodates the complex interactions between ESG ratings and income properties' key metrics. This framework is not limited to the Swiss real estate industry but can be reutilized for

diverse regulatory environments and real estate markets, allowing for a more comprehensive understanding of how ESG ratings influence financial performance internationally. By capturing these interactions, the framework establishes a foundation for future research, enabling scholars and practitioners to explore the intricate mechanisms through which sustainability is integrated into the financial relevance of real estate and beyond.

An important feature of this study is its methodological approach, which integrates theoretical insights with a data-driven model. The combination of variable selection methods, such as the LASSO technique, with subsequent OLS estimation, proves effective in addressing the inherent complexity and ambiguity found in ESG ratings. This methodology allows us to navigate the uncertainties surrounding sustainability ratings with their inconsistent regulatory frameworks, while still delivering reliable preliminary results about their relevance and practical application within the real estate industry.

However, a critical limitation of this research – and indeed, any study attempting to assess ESG ratings with financial metrics – is the availability of granular data. In addition to ESG ratings and real estate metrics, a range of object-level control variables must be accessible to mitigate omitted variable bias and ensure conditional exogeneity. Without access to detailed, high-quality data on these variables, any analysis risks oversimplifying the association between sustainability ratings and real estate key metrics.

4.9. Conclusion

In an era increasingly dedicated to sustainability, our study has endeavored to assess the intricate association between sustainability and real estate assets. Drawing insights from the Swiss regulatory framework, we leveraged appraisal and transaction processes to identify key metrics potentially associated with ESG ratings, including appraisal-based and transaction-based discount rates, rental incomes, and vacancy rates. Guided by comprehensive datasets featuring 6’300 expert-based valuations and around 850 real market transactions, we applied an OLS post-LASSO estimation procedure to identify and quantify the association between ESG ratings and real estate key metrics.

At an aggregated level, our results indicate that the total ESG rating is significantly associated with the key metrics considered. Our results argue in favor of a robust connection between ESG ratings and all key metrics considered. Specifically, we observed a sensitivity of 3.2% in appraisal-based discount rates and 4.2% in transaction-based discount rates in response to a one-unit change in the total ESG rating. We also identified a direct connection between ESG ratings and rental incomes. A one-unit increase in the total ESG rating has the potential to

increase average rental incomes by approximately 6.3%. Similarly, the total ESG rating is significantly connected to object-specific vacancy rates, resulting in a reduction of 0.8 percentage points in response to a one-unit increase in the total ESG rating.

Dissecting the total ESG rating into its sub-ratings reveals that the overall association is primarily mediated through the environmental sub-rating. Among all key metrics considered, this sub-rating demonstrates the highest sensitivity and establishes the most significant associations. Notably, the relevance of the social and governance sub-ratings varies substantially across the key metrics under consideration. While LASSO identifies all ESG sub-ratings in the context of appraisal-based discount rates, indicating that appraisers consider a diverse range of factors when evaluating a real estate object, transaction-based discount rates are predominantly influenced by the environmental sub-rating. Conversely, in the case of rental incomes, robust associations are mainly evident for the environmental and the governance sub-rating, while for vacancy rates, the environmental sub-rating is the sole sub-rating selected by LASSO and characterized by a significant association. These results question the intersection between broad sustainability coverage and targeted financial relevance, suggesting that both perspectives do not necessarily align and vary depending on the key metric being considered.

In our further exploration of potential signaling effects at different levels of total ESG ratings, we observed that high ESG ratings, particularly those exceeding 4, exhibit an increased sensitivity in the context of appraisal-based and transaction-based discount rates, as well as in vacancy rates. However, for rental incomes, we did not observe a consistent association between higher ESG ratings and increased rental levels. The detection of potential signaling effects for specific key metrics highlights that an association with sustainability attributes may not be linear, further underscoring the varied perceptions of sustainability attributes among market participants.

Several parallels can be drawn when comparing our results to the existing literature, especially regarding the sign and magnitude of previously documented findings. Among the few empirical findings about the connection between sustainability ratings and discount rates, our results validate their inverse connection to the risk premium, as reported by McGrath (2013). Furthermore, our results align with a broader body of evidence on rent premiums, supporting findings from both international studies (Fuerst and Dalton, 2019) and national investigations (Feige et al., 2013; Marty and Meins, 2017; Kempf and Syz, 2022). While there is a limited benchmark for vacancy rates, our study advances this area by reporting a consistent inverse association between ESG ratings and vacancy rates, mirroring the observations of Fuerst and McAllister (2009) and Holtermans and Kok (2017).

Building on our findings and anticipating upcoming regulatory efforts to incorporate and report sustainability ratings, we advocate for their standardization. Specifically, we emphasize the development of transparent frameworks, together with unified methodologies for measuring financial relevance alongside adequate sustainability indicators, to foster transparency and the effective management of sustainability issues. Thus, we encourage policymakers to develop comprehensive guidelines on the scope of sustainability ratings and their practical application in object valuations and investment decisions. Consequently, future research should further explore the fundamental mechanisms through which sustainability ratings may be associated with real estate markets, thereby deepening our understanding of this critical issue.

Abbreviations

Abbreviation	Meaning
ARE	Federal Office for Spatial Development
AL	Adaptive Least Absolut Shrinkage and Selection Operator
BFS	Federal Statistical Office
BAKOM	Federal Office of Communications
BAFU	Federal Office for the Environment
BAV	Federal Office of Transport
BFE	Federal Office of Energy
BVG	Occupational Retirements, Survivor's and Disability Pensions
CHF	Swiss Francs
CPI	Consumer Price Index
CSR	Corporate Social Responsibility
DCF	Discounted Cash Flow
EHS	Environment Health and Safety
EPC	Energy Performance Certificate
ESG	Environment, Society, and Governance
ESI	Economic Sustainable Indicator
EU	European Union
FINMA	Swiss Financial Market Supervisory Authority
GRESB	Global Real Estate Sustainability Benchmark
GRI	Global Reporting Initiative
GWR	Federal Register of Buildings and Dwellings
LASSO	Least Absolut Shrinkage and Selection Operator
LEED	Leadership in Energy and Environmental Design
LFI	National Forest Inventory
OLS	Ordinary Least Squares
SASB	Sustainability Accounting Standards Board
SNBS	Swiss Sustainable Construction Standard
Sqm	Square meter
SRI	Socially Responsible Investments
TCFD	Task Force on Climate-related Financial Disclosures
UK	United Kingdom
UN	United Nations

References

Abhayawansa, S., Tyagi, S. (2021). Sustainable investing: the black box of environmental, social, and governance (ESG) ratings. *The journal of wealth management, Vol. 24, No. 1, pp. 49-54, DOI: https://doi.org/10.3905/jwm.2021.1.130.*

Addae-Dapaah, K., Wilkinson, J. (2020). Green premium: what is the implied prognosis for sustainability? *Journal of sustainable real estate, Vol. 12, No. 1,* pp. 16-33. *DOI: https://doi.org/10.1080/19498276.2021.1915663.*

Aroul, R., Sebherwal, S., Villupuram, S. (2022). ESG, operational efficiency and operational performance: evidence from real estate investment trusts. *Mangerial finance, Vol. 48, No. 8, pp. 1206-1220.*

Basten, C., Von Ehrlich, M., Lassmann, A. (2017). Income taxes, sorting and the costs of housing: evidence from municipal boundaries in Switzerland. *The economic journal, Vol. 127, No. 601, pp. 653-687.*

Belloni, A., Chernozhukov, V. (2013). Least squares after model selection in high-dimensional sparse models. *International statistical institute (ISI) and the Bernoulli society for mathematical statistics and probability, Vol. 19, No. 2, pp. 521-547.*

Berger, F., Kölbel, J., Rigobon, R. (2022). Aggregate confusion: the divergence of ESG ratings. *Review of finance, Vol. 26, No. 6, pp. 1315-1344, DOI: https://doi.org/10.1093/rof/rfac033.*

Billio, M., Costola, M., Hristova, I., Latino, C. (2020). Inside the ESG ratings: (dis)agreement and performance. *Corporate social responsibility and environmental management, Vol. 28, No. 5, pp. 1426-1445.*

Brounen, D., Marcato, G. (2018). Sustainable insights in public real estate performance: ESG scores and effects in REIT markets. *Berkeley lab.: Berkeley, CA, USA.*

Bruegge, C., Carrión-Flores, C., Pop, J. (2016). Does the housing market value energy efficient homes? Evidence from the energy star program. *Regional science and urban economics, Vol. 57, pp. 63-76, DOI: https://doi.org/10.1016/j.regsciurbeco.2015.12.001.*

Chaney, A., Hoesli, M. (2012). Transaction-based and appraisal-based capitalization rate determinants. *Swiss finance institute research paper series No. 12-28.*

Chuangdumrongsomsuk, M., Fuerst, F. (2017). Determinants of cap rates in U.S. office markets. *Journal of real estate literature, Vol. 25. No. 2, pp. 265-282, DOI: https://doi.org/10.1080/10835547.2017.12090458.*

Djurdjevic, D., Eugster, C., Haase, R. (2008). Estimation of hedonic models using a multilevel approach: an application for the Swiss rental market. *Swiss journal of economics and statistics, Vol. 144, No. 4, pp. 679-701.*

Eberwein, G., Lobsiger, E., Eschenauer, U., Jetel, M., Carabias-Hütter, V. (2015). Subtask 2 - Switzerland: the 2000 watt society. *DOI: https://doi.org/10.13140/RG.2.2.20290.17609.*

Eichholtz, P., Kok, N., Yonder, E. (2012). Portfolio greeness and the financial performance of REITs. *Journal of international money and finance, Vol. 31, No. 7, pp. 1911-1929, DOI: https://doi.org/10.1016/j.jimonfin.2012.05.014.*

Escrig-Olmedo, E., Fernandez-Izquierdo, M., Ferrero-Ferrero, I., Rivera-Lirio, J., Muñoz-Torres, M. (2019). Rating the raters: evaluating how ESG rating agencies integrate sustainability principles. *Sustainability, Vol. 11, pp. 915.*

ESMA (2021). ESG ratings: Status and key issues ahead. *ESMA report on trends, risks and vulnerabilities, No. 1, pp. 105-115, Available online: https://www.esma.europa.eu/sites/default/files/trv_2021_1-esg_ratings_status_and_key_issues_ahead.pdf (accessed on November 2023).*

Federal Council (2017). Federal Council brings totally revised Energy Act into force in 2018. *Available online: https://www.admin.ch/gov/de/start/dokumentation/medienmitteilungen.msg-id-68637.html (accessed on December 2023).*

Federal Council (2019). Climate protection: Federal Council adopts Switzerland's long-term climate strategy. *Available online: https://www.admin.ch/gov/en/start/documentation/media-releases.msg-id-82140.html (accessed on February 2024).*

Federal Council (2022). Federal Council brings ordinance on mandatory climate disclosures for large companies into force as of 1 January 2024. *Available online: https://www.admin.ch/gov/en/start/documentation/media-releases.msg-id-91859.html (accessed on March 2024).*

Federal Office for the Environment (2022). Greenhouse gas emissions from buildings. *Available online: https://www.bafu.admin.ch/bafu/en/home/topics/climate/state/data/greenhouse-gas-inventory/buildings.html (accessed on April 2024).*

Feige, A., Mcallister, P., Wallbaum, H. (2013). Rental price and sustainability ratings: which sustainability criteria are really paying back? *Construction management and economics, Vol. 31, No. 4, pp. 322-334, DOI: https://doi.org/10.1080/01446193.2013.769686.*

FINMA (2021). Preventing and combating greenwashing. *FINMA Guidance. Bern, Switzerland.*

Fuerst, F. (2015). The financial rewards of sustainability: a global performance study of real estate investment trusts. *Available online SSRN: https://ssrn.com/abstract=2619434 or DOI: http://dx.doi.org/10.2139/ssrn.2619434 (accessed on March 2024).*

Fuerst, F., Dalton, B. (2019). Gibt es einen wissenschaftlichen Konsensus zur Wirtschaftlichkeit nachhaltiger Immobilien? *Z Immobilienökonomie, Vol. 5, pp. 173-191.*

Fuerst, F., McAllister, P. (2009). An investigation of the effect of eco-labeling on office occupancy rates. *The journal of sustainable real estate, Vol. 1, No. 1, pp. 49-64.*

Fuerst, F., McAllister, P. (2011). The impact of energy performance certificates on the rental and capital values of commercial property assets. *Energy policy, Vol. 39, No. 10, pp. 6608-6614.*

Fuerst, F., Oikarinen, E., Harjunen, O. (2016). Green signalling effects in the market for energy-efficient residential buildings. *Applied energy, Vol. 180, No. 15, pp. 560-571.*

Fuerst, F., Shimizu, C. (2016). Green luxury goods? The economics of eco-labels in the Japanese housing market. *Journal of the Japanese and international economies, Vol. 39, pp. 108-122, DOI: https://doi.org/10.1016/j.jjie.2016.01.003.*

Galema, R., Gerritsen, D. (2022). ESG rating score revisions and stock returns. *Available online SSRN: https://ssrn.com/abstract=4218969 or DOI: http://doi.org/10.2139/ssrn.4218969.*

GRI and SASB. (2021). A practical guide to sustainability reporting using GRI and SASB standards. *Report, available online: https://www.globalreporting.org/media/mlkjpn1i/gri-sasb-joint-publication-april-2021.pdf (accessed on March 2024).*

Gunnelin, A., Hendershott, P., Hoesli, M., Söderberg, B. (2004). Determinants of cross-sectional variation in discount rates, growth rates and exit cap rates. *Real estate economics, Vol. 32, No. 3, pp. 217-237.*

Hilber, A.L., Schöni, O. (2016). Housing policies in the United Kingdow, Switzerland, and the United States: lessons learned. *US Department of housing and urban development, Washington, DC, USA, Vol. 18, No. 3, pp. 291-332.*

Holtermans, R., Kok, N. (2017). On the value of environmental certification in the commercial real estate market. *Real estate economics, Vol. 47, No. 3, pp. 685-722*

Kempeneer, S., Peeters, M., Compernolle, T. (2021). Bringing the user back in the building: an analysis of ESG in real estate and a behavioral framework to guide future research. *Sustainability, Vol. 13, No. 6, DOI: https://doi.org/10.3390/su13063239.*

Kempf, C., Syz, J. (2022). Why pay for sustainable housing? Decomposing the green premium of the residential property market in the canton of Zurich, Switzerland. *SN business & economics, Vol. 2, No. 170, DOI: https://doi.org/10.1007/s43546-022-00346-8.*

Kiernan, M. (2007). Universal owners and ESG: leaving money on the table? *Corporate governance: An international review, Vol. 15, pp. 478-485.*

Leskinen, N., Vimpari, J., Junnils, S. (2020). Using real estate market fundamentals to determine the correct discount rate for decentralised energy investments. *Sustainable cities and society. Vol. 53, DOI: https://doi.org/10.1016/j.scs.2019.101953.*

Letdin, M., Sirmans, G., Smersh, G., Zhou, T. (2023). The role of tenant characteristics in retail cap rate variation. *Journal of real estate finance and economics, DOI: https://doi.org/10.1007/s11146-023-09958-9.*

Lucarelli, C., Mazzoli, C., Rancan, M., Severini, S. (2020). Classification of sustainable activities: EU taxonomy and scientific literature. *Sustainability, Vol. 12, No. 16, DOI: https://doi.org/10.3390/su12166460.*

Marcot, B., Hanea, A. (2021). What is an optimal value of k in k-fold cross-validation in discrete Bayesian network analysis? *Computational statistics, Vol. 36, pp. 2009-2031, DOI: https://doi.org/10.1007/s00180-020-00999-9.*

Marty, R., Meins, E. (2017). Der Schweizer Mietimmobilienmarkt belohnt andere Nachhaltigkeitsmerkmale als Energieeffizienz. *Swiss Real Estate Journal, Vol. 15, pp. 47-54.*

McGrath, K. (2013). The effects of eco-certification on office properties: a cap rates-based analysis. *Journal of property research, Vol. 30, No. 4, pp. 345-365, DOI: https://doi.org/10.1080/09599916.2012.762034.*

Meins, E., Wallbaum, H., Hardziewski, R., Feige, A. (2010). Sustainability and property valuation: a risk-based approach. *Building research and information, Vol. 38, No. 3,* pp. 280-300, *DOI: https://doi.org/10.1080/09613211003693879.*

Richardson, B. (2009). Keeping ethical investment ethical: regulatory issues for investing for sustainability. *Journal of business ethics, Vol. 87, pp. 555-572.*

TEG European Commission (2020). Taxonomy report: technical annex. *TEG European Commission, Brussels, Belgium.*

Tibshirani, R. (1996). Regression shrinkage and selection via the lasso. *The journal of the royal statistical society, Vol. 58, No. 1, pp. 267-288.*

Tsang, A., Frost, T., Cao, H. (2023). Environmental, social, and governance (ESG) disclosure: a literature review. *The British accounting review, Vol. 55, No. 1, DOI: https://doi.org/10.1016/j.bar.2022.101149.*

United Nations (2004). Who cares wins: connecting financial markets to a changing world. *Available online: https://www.unepfi.org/fileadmin/events/2004/stocks/who_cares_wins_global_compact_2004.pdf (accessed on February 2024).*

Zou, H. (2006). The adaptive lasso and its oracle properties. *Journal of the American statistical association, Vol. 101, No. 476, pp. 1418-1429.*

Zou, H., Hastie, T. (2005). Regularization and variable selection via the elastic net. *Journal of the royal statistical society. Series B (statistical methodology), Vol. 67, No. 2, pp. 301-320.*

Appendix

C.1.

Table 20: Detailed ESG rating description

ESG Sub-Rating	Criteria (Weight)	Indicator	Radius	Source
Environment Indicators (E)	Climate change and risks (12)	Heat days in 2020 (RCP45)	Point	National Centre for Climate Services
		Difference in heat days between 2060 and 2020 (RCP45)	Point	National Centre for Climate Services
		Cooling degree days in 2020 (RCP45)	Point	National Centre for Climate Services
		Difference in cooling degree days between 2060 and 2020 (RCP45)	Point	National Centre for Climate Services
	Greenery and sealing (12.5)	Proportion greening	50 m	LFI
		Diversity greening	50 m	LFI
		Surface sealing	50 m	Copernicus
	Mobility (12.5)	Public transport quality class	Point	ARE
		Car sharing locations	2000 m	BAV, BAKOM, Wüest Partner
		Future public transport infrastructure	Municipality	Wüest Partner
		Public e-car charging stations	4000 m	BFE
	Resource utilization (10.5)	Population density	300 m	BFS
		Employment density	300 m	BFS
Social Indicators (S)	Health and well-being (12.5)	Road noise during the day	Point	BFS
		Road noise at night	Point	BFS
		Railway noise during the day	Point	BFS
		Railway noise at night	Point	BFS
		Aircraft noise	Point	Wüest Partner
		Long-term air pollution index	Point	Meteotest
		Radon	Point	BAG, Wüest Partner
	Safety and natural hazards (12.5)	Mudslide	Point (50 m buffer)	BAFU, Geotest AG, Wüest Partner
		Hail	Point	MeteoSchweiz, Wüest Partner
		Flood	Point (50 m buffer)	BAFU, Geotest AG, Wüest Partner
		Fall	Point (50 m buffer)	BAFU, Geotest AG, Wüest Partner
		Landslide	Point (50 m buffer)	BAFU, Wüest Partner
		Storm	Point	BAFU, Wüest Partner
		Debris flow	Point (50 m buffer)	BAFU, Geotest AG, Wüest Partner
		Avalanche	Point (50 m buffer)	BAFU, Geotest AG, Wüest Partner
		Earthquake	Point	BAFU, Geotest AG, Wüest Partner
		Surface runoff	Point (50 m buffer)	BAFU, Geotest AG, Wüest Partner
	Socioeconomic structure (9)	Diversity of household sizes	300 m	BFS STATPOP, Wüest Partner
		Diversity of age structure	300 m	BFS STATPOP, Wüest Partner
		Diversity of socio-economic milieus	300 m	Microm, Wüest Partner
		Diversity of income	300 m	Wüest Partner
		Price range distribution	Municipality	Wüest Partner
	Building stock (7.5)	Diversity of building categories	300 m	GWR, Wüest Partner
		Mix of dwelling sizes	300 m	GWR, Wüest Partner
		Diversity of building ages	300 m	GWR, Wüest Partner
	Recreational areas (6)	Recreational and green areas	Municipality	BFS
		Public meeting places	1000 m	BAV, BAKOM, Wüest Partner
Governance Indicators (G)	Real estate market (2)	Supply ratio	Municipality	Wüest Partner
		Vacancy rates	Municipality	Wüest Partner
	Renewable energy (1.5)	Energy city label	Municipality	Energiestadtlabel
		Utilization of solar potentials	Municipality	Energyreporter geoimpact AG
	Spatial planning (1.5)	Building permits, densification potential	Municipality	Wüest Partner
		Densification potential population	Municipality	Wüest Partner
		Densification potential employees	Municipality	Wüest Partner
		Conversion shares in building permits	Municipality	Wüest Partner

Notes: The table summarizes each sub-rating of the total ESG rating, along with their respective criteria, weights, information about indicators, and sources. Weightings for each sub-rating take into account Swiss specific characteristics. For example, environmental and social indicators receive relatively high weights compared to governance indicators. This is mainly due to the persistent heterogeneity across Swiss regions, through which urban regions would receive a consistently better rating for the governance. The column "radius" characterizes the spital scale at which the respective indicator is measured. "Point" refers to the process of verifying the property's coordinates against the corresponding raster value. "Point (50m buffer)" entails pre-buffering the raster, selecting the point where the property's coordinates intersect with the raster. Distances are measured in meters (m), while spatial political ranges ("Municipality") represent the range within which the respective indicator is recorded. RCP45 represents the scenario RCP 4.5, which predicts a global warming of 2.6 degrees Celsius by the year 2060. Abbreviations used: BFS = Federal Statistical Office, LFI = National Forest Inventory, ARE = Federal Office for Spatial Development, BAV = Federal Office of Transport, BAKOM = Federal Office of Communications, BFE = Federal Office of Energy, BAFU = Federal Office for the Environment, GWR = Federal Register of Buildings and Dwellings.

C.2.

Table 21: Summary statistics – valuations dataset

Variable Variable name	**Min.**	**Max.**	**Mean**	**Median**	**Std. Dev.**
Appraisal-based discount rate d_i^{apr}	1.50	6.00	2.99	2.95	0.45
Rental income per sqm Rental_I_sqm	30.48	788.36	230.70	216.49	86.67
Object-specific vacancy rate Vacancy_R	0.00	100.00	4.33	1.45	8.55
Macro-location rating Macro_L	1.18	5.00	4.37	4.53	0.62
Micro-location rating Micro_L	1.00	5.00	3.58	3.50	0.62
Object quality rating Quality_R	1.18	5.00	3.42	3.40	0.49
Standard rating Standard_R	1.30	5.00	3.36	3.30	0.53
Condition rating Condition_R	1.00	5.00	3.50	3.40	0.75
Age Age	1.00	822.00	52.21	48.00	42.64
Square meter Sqm	130.00	97425.00	4209.61	2418.75	5996.55
Yields on governmental bonds IR_20	-0.41	1.20	0.15	-0.06	0.52
Inflation Inflation	-0.70	2.80	1.16	0.60	1.38
Total ESG rating ESG rating	1.00	5.00	3.89	4.10	0.91
Rating for the environment E-rating	1.00	5.00	3.61	3.80	1.04
Rating for the society S-rating	1.10	5.00	3.66	3.70	0.90
Rating for the governance G-rating	1.00	5.00	3.70	4.00	1.00

Notes: Summary statistics reflect variations across expert-based DCF valuations between 2019 and 2022. The dataset is used in the empirical investigation to analyze the association between ESG ratings and appraisal-based discount rates, rental incomes, and vacancy rates. Variables are defined according to Table 16.

Table 22: Summary statistics – transactions dataset

Variable Variable name	**Min.**	**Max.**	**Mean**	**Median**	**Std. Dev.**
Transaction-based discount rates d_i^{trx}	1.36	6.85	2.74	2.71	0.61
Macro-location rating Macro_L	1.20	5.00	4.20	4.40	0.82
Micro-location rating Micro_L	1.80	5.00	3.68	3.60	0.63
Object quality rating Quality_R	2.30	4.88	3.39	3.32	0.47
Age Age	0.00	599.00	58.88	51.00	47.90
Square meter Sqm	77.00	73383.00	3060.90	1731.30	5054.85
Yields on governmental bonds IR_20	-0.41	1.20	0.23	0.06	0.57
Inflation Inflation	-0.70	2.80	1.13	0.60	1.48
Total ESG rating ESG rating	1.00	5.00	3.85	4.20	1.04
Rating for the environment E-rating	1.00	5.00	3.48	3.60	1.15
Rating for the society S-rating	1.30	5.00	3.68	3.80	0.92
Rating for the governance G-rating	1.00	5.00	3.55	3.70	1.11

Notes: Summary statistics reflect variations across market transactions between 2019 and 2022. The dataset is used in the empirical investigation to analyze the association between ESG ratings and transaction-based discount rates. Variables are defined according to Table 16.

C.3.

Table 23: Variable classification

Variable Name	Description	Classification
ESG rating	Total ESG rating (Min = 1, Max = 5)	Continuous
E-rating	Rating for the environment (E) (Min = 1, Max = 5)	Continuous
S-rating	Rating for the society (S) (Min = 1, Max = 5)	Continuous
G-rating	Rrating for the governance (G) (Min = 1, Max = 5)	Continuous
d_i^{apr}	Appraisal-based discount rate	Continuous
d_i^{trx}	Transaction-based discount rate	Continuous
Rental_I_sqm	Effective rental income in Swiss Francs (CHF) derived from rent roll divided by the total effective area	Continuous
Vacancy_R	Vacancy rate derived from rent rolls	Continuous
Age	Difference between the construction year of a given object and the valuation date	Continuous
LogSqm	Logarithm of the total effective area, measured in sqm	Continuous
Micro_L	Rating for the location of a given object within a given municipality (Min = 1, Max = 5)	Continuous
Macro_L	Locational rating characterizing the municipality of a given object municipality (Min = 1, Max = 5)	Continuous
Object_R	Standardized rating characterizing the overall quality of given object (Min = 1, Max = 5)	Continuous
Standard_R	Standardized rating characterizing the standard of a given object (Min = 1, Max = 5)	Continuous
Condtion_R	Standardized rating characterizing the condition of a given object (Min = 1, Max = 5)	Continuous
IR_20	Yields on governmental bonds with 20-year maturity	Continuous
Inflation	Inflation according to the consumer price index	Continuous
YD_19	Year dummy for the year 2019	Dummy
YD_20	Year dummy for the year 2020	Dummy
YD_21	Year dummy for the year 2021	Dummy
YD_22	Year dummy for the year 2022	Dummy
Type_D1	Real estate type dummy for residential real estate properties	Dummy
Type_D2	Real estate type dummy for mixed usages (residential, industrial, or office purposes)	Dummy
Type_D3	Real estate type dummy for industrial real estate properties	Dummy
Type_D4	Real estate type dummy for special usages	Dummy
CT_D1	Regional type dummy for canton Zurich	Dummy
CT_D2	Regional type dummy for canton Berne	Dummy
CT_D3	Regional type dummy for canton Lucerne	Dummy
CT_D4	Regional type dummy for canton Uri	Dummy
CT_D5	Regional type dummy for canton Schwyz	Dummy
CT_D6	Regional type dummy for canton Obwalden	Dummy
CT_D7	Regional type dummy for canton Nidwalden	Dummy
CT_D8	Regional type dummy for canton Glarus	Dummy
CT_D9	Regional type dummy for canton Zug	Dummy
CT_D10	Regional type dummy for canton Fribourg	Dummy
CT_D11	Regional type dummy for canton Solothurn	Dummy
CT_D12	Regional type dummy for canton Basel-City	Dummy
CT_D13	Regional type dummy for canton Basel-Country	Dummy
CT_D14	Regional type dummy for canton Schaffhausen	Dummy
CT_D15	Regional type dummy for canton Appenzell Ausserrhoden	Dummy
CT_D16	Regional type dummy for canton Appenzell Innerrhoden	Dummy
CT_D17	Regional type dummy for canton St.Gallen	Dummy
CT_D18	Regional type dummy for canton Grison	Dummy
CT_D19	Regional type dummy for canton Aargau	Dummy
CT_D20	Regional type dummy for canton Thurgau	Dummy
CT_D21	Regional type dummy for canton Ticino	Dummy
CT_D22	Regional type dummy for canton Vaud	Dummy
CT_D23	Regional type dummy for canton Valais	Dummy
CT_D24	Regional type dummy for canton Neuchâtel	Dummy
CT_D25	Regional type dummy for canton Geneva	Dummy
CT_D26	Regional type dummy for canton Jura	Dummy

Notes: The table specifies the variables (variable names, descriptions, and classification) for expert-based DCF valuations and market transactions between 2019 and 2022 applied in the OLS post-LASSO regression approach, as discussed in Section 4.6. Variables are specified according to Table 16 and are defined identically in both datasets used for the empirical analysis. More detailed information about the ESG rating can be found in Appendix C.1 (Table 20).

Chapter V: Conclusion

Amidst the ever-evolving landscape of real estate markets, new questions constantly arise, shaping the trajectory of research in the real estate industry. Yet, despite this dynamism, certain pivotal questions have been given insufficient attention. First, there is a lack of empirical evidence regarding the differentiation of interest rate sensitivities across various interest rate types, locations and various real estate types, notably within commercial real estate segments. Second, although discount rates are extensively applied in DCF valuations across Switzerland, their subjective nature introduces the possibility of miscalculation, thereby increasing the risk of suboptimal valuation outcomes and inefficiencies in financial assessment practices. Third, there is a limited theoretical and empirical evidence concerning the relevance and practicality of sustainability ratings, particularly within the context of Switzerland.

In this dissertation, we addressed three emerging questions in the real estate industry and endeavored to offer answers by integrating sound theoretical knowledge, high-quality data, suitable estimation approaches, and an extensive understanding of Swiss real estate markets. The first study delved into the fundamental relationship between interest rates and real estate prices, while the second study investigated the influential factors behind a largely unexplored determinant of real estate assets' market value – the discount rate. Our third study delved into the pressing issue of sustainability and its potential association with specific key metrics of real estate assets. The collective contribution of all three studies involves a comprehensive analysis of the significance of real estate fundamentals, valuation methodologies, and shifts in regulatory frameworks.

5.1. Interest rates and real estate prices

The first study offered an examination of the intricate connection between interest rates and real estate prices. To illuminate this complex linkage, we analyzed price movements of six distinct real estate types, attributing these fluctuations to four representative interest rate representatives: variable and fixed mortgage rates, yields on government bonds, and a newly introduced metric known as the *spread*, which gauges the attractiveness of investing in real estate assets. To isolate the impact of interest rates on these price dynamics, we employed a panel fixed-effect regression model tailored to a specific regional type.

Our findings not only emphasize the significance of the fundamental connection between interest rates and real estate prices, but also demonstrate that the importance of this relationship largely hinges on the type of real estate being examined. Residential real estate prices, particularly those prices of owner-occupied flats and houses, exhibit a heightened sensitivity to

changes in mortgage interest rates. Specifically, a 1 percentage point decrease in variable mortgage rates corresponds to a 1.5% increase in median house prices and a 2.3% increase in prices for owner-occupied flats. Similarly, a 1 percentage point reduction in fixed mortgage rates leads to a 1.0% increase in median house prices and a 1.8% increase in median prices of owner-occupied flats. Residential rental prices, on the contrary, demonstrate lower sensitivity to changes in interest rates, such as yields on government bonds. This can be attributed to the influence of the Swiss rental control system, where rental prices are tied to the reference index. Surprisingly, our findings suggest a direct connection between residential rental prices and the *spread*. This raises the possibility that residential rental prices may exhibit less flexibility in downward adjustments compared to upward shifts.

In the relatively unexplored commercial real estate sector, particularly within the Swiss context, conclusive effects were solely discerned in rental prices for office space. Our findings indicate that office rental prices increase by approximately 0.4% in response to a 1 percentage point decline in government bonds, suggesting a comparable sensitivity to interest rates as observed in rental apartment prices. However, insignificant or counterintuitive effects were observed in rental prices for sales areas and industrial real estate. We posit that prices within the commercial real estate segment may be more influenced by factors related to aggregate demand rather than changes in interest rates, with the monetary policy stance potentially offsetting the expected impact of interest rates.

Through a spatial analysis of interest rate effects across Swiss monitoring regions and various real estate types, we found that real estate prices in the residential housing segment are particularly sensitive to interest rates in the most densely populated areas of Switzerland, such as Geneva and Zurich. This heightened sensitivity suggests that these regions may possess an inelastic housing supply, leading to more pronounced price effects in response to changes in interest rates. A similar result was obtained for office rental prices in the region of Geneva. However, within the group of industrial real estate and sales area, we encountered inconsistent results with significant variations between regions. These findings underline our presumption that observed interest rate effects are largely dependent on the specific real estate segment under consideration.

In conclusion, our findings underscore the pivotal role that interest rates play in driving real estate price dynamics, particularly through the diverse channels by which they impact various real estate types. The heterogeneity in interest rate sensitivities across different real estate types and regions presents a significant challenge to the Swiss federal system, potentially leading to a fragmented regulatory landscape. This highlights the need for policymakers to deepen their

understanding of how interest rates shape real estate markets and adapt regional policies accordingly. This understanding becomes even more crucial when considering the multitude of other fundamental factors that collectively shape real estate dynamics, further reinforcing the need for informed and region-specific policy interventions to ensure market stability.

5.2. Determinants of discount rates

The second study focused on a particular component that contains much explanatory power for price developments of income properties – the discount rate. In fact, the discount rate is, besides a depiction of cash flows, the dominant factor driving real estate prices of income properties. While highly pertinent for elucidating changes in market values of income properties, the discount rate in the DCF method is inherently subjective, primarily due to the absence of publicly available data sources and vague guidelines about this particular component. Moreover, under specific accounting standards in Switzerland, market value growth resulting from fluctuations in discount rates can yield book gains, which can then be utilized to leverage external capital. Therefore, an expanded understanding of the fundamental drivers of discount rates is not only crucial for real estate practitioners but also for mortgage lenders and institutions concerned with financial stability.

Using a unique dataset compromising expert-based valuations together with market transactions, we analyzed the determinants of appraisal-based and transaction-based discount rates. Whereas the former provides insights into how appraisers weight specific determinants of discount rates, the latter allows derivations about the perceived risk of investors at a given point in time. By conducting a comprehensive counterfactual analysis of both types of discount rates, we illuminate the fundamental forces shaping this essential component. To address the persistent heterogeneity in the dataset, we applied robust regression techniques.

Our full-sample analysis uncovered a nuanced landscape of both similarities and distinctions in the fundamental determinants shaping appraisal-based and transaction-based discount rates. Notably, appraisal-based and transaction-based discount rates display heightened sensitivity to locational variables, such as the micro- and macro-location rating, indicating appraisers' commitment to professional standards or investors' strategic emphasis on asset diversification. However, transaction-based discount rates react more responsive to fluctuations in interest rates, reflecting investors' perception driven by market dynamics.

Analyzing the residential and commercial real estate segments separately revealed a significant shift in the relevance among fundamental determinants of discount rates. Regarding residential real estate, object-specific characteristics contribute around 8.6% (appraisal-based) or 6.1% (transaction-based) to the average relative importance across all considered measures.

The primary drivers of relative importance in this segment are macroeconomic variables, accounting for 30.2% (appraisal-based) and 31.5% (transaction-based) of the discount rates. In the commercial real estate segment, object-specific characteristics have an average relative importance of 26.0% (appraisal-based) and 24.6% (transaction-based), while macroeconomic variables contribute approximately 28.6% (appraisal-based) and 31.3% (transaction-based) to the explained variance in discount rates. Thus, we find that macroeconomic variables best explain discount rates of residential real estate properties. Conversely, object-specific variables emerge as the primary explanatory factors for discount rates of commercial real estate.

Overall, the findings of this study advocate for the use of type-specific methodologies when determining discount rates in the DCF method. For residential real estate, greater emphasis should be placed on fundamental macroeconomic factors, while for commercial real estate, object-specific and locational variables may carry greater weight. Furthermore, it is essential for regulatory authorities to closely scrutinize the discount rates used in the financial statements of commercial real estate investors, and to establish unified guidelines on how appraisal firms should derive this critical component.

5.3. ESG ratings and real estate key metrics

The third study builds upon the growing focus on sustainability matters during recent years, thereby exploring the association between ESG ratings and the real estate industry. As inherent immovable and physical assets, real estate objects are particularly susceptible to locational sustainability attributes, a momentum bolstered by the Federal Council's recent adoption of the executive order on climate reporting for sizable Swiss companies. Amid concrete regulation about the coverage range of ESG ratings and insufficient guidelines about underlying methodologies, their relevance and practicability for the real estate industry remains an uncharted territory, especially at an individual object-level.

Aiming to provide comprehensive insights into the foundational origins of ESG ratings, we provided an in-depth description of their definition, emergence, and regulatory frameworks. Focusing on a relatively unexplored type of ESG ratings, we detailed the underlying indicators, their weightings, and the methodologies applied, revealing new perspectives on the diverse indicators that real estate professionals associate with the broader topic of sustainability. By integrating appraisal and transaction processes, we identified four critical metrics potentially associated to the specified ESG rating: appraisal-based and transaction-based discount rates, rental incomes, and vacancy rates. To explore the potential connections between these key metrics and ESG ratings, we employed an OLS post-LASSO estimation procedure, conducting our analysis at both aggregated and disaggregated levels.

At an aggregated level, our analysis unveiled significant associations between the total ESG rating and the considered key metrics. Acknowledging that ESG ratings may implicitly signal value, we investigated potential signaling effects. We found that higher ESG ratings, particularly those above 4, are more sensitive in relation to both types of discount rates, and vacancy rates. Possible explanations include an implicit risk discount for investments in sustainable locations, which may stem from their enhanced locational quality, or the operation of fundamental mechanisms in real estate markets that transmit heightened local quality characteristics into object-specific cash flows.

To gain a deeper understanding of the underlying mechanisms, we conducted a disaggregated analysis of the sub-ratings across the three pillars: environment, society, and governance. Our findings indicate that sustainability characteristics are predominantly mediated through environmental factors. The significance of social and governance ratings varied with the specific key metrics assessed. Through the estimation procedure, all three sub-ratings were relevant for appraisal-based discount rates and rental incomes, while the social rating was excluded from transaction-based discount rates, and the governance rating was found to be irrelevant for vacancy rates.

The distinctiveness of the association between ESG ratings – or sustainability ratings more broadly – and key metrics in the real estate industry is expected to become increasingly significant in the near future. While our findings offer preliminary evidence of a potential association with financial materiality at an aggregated level, they also indicate that the relevance of underlying sub-ratings largely depends on the specific metrics being examined. This highlights that broad sustainability coverage may not always intersect with financial relevance in the Swiss real estate industry. As regulatory initiatives for sustainability reporting continue to evolve, we strongly advocate for the standardization of ESG ratings. Developing transparent frameworks that incorporate both comprehensive sustainability aspects and financial considerations is essential. Furthermore, we encourage real estate professionals to rigorously analyze the foundations of ESG ratings, paying close attention to the methodologies and indicators that underpin these assessments.

5.4. Future research

The real estate industry, with its heterogeneous and immovable physical assets, presents interesting opportunities for future research. The sector's substantial economic impact, driven by both private and commercial investments, underscores the importance of targeted studies. Research priorities, however, will likely differ across real estate types and will be shaped by the unique dynamics of national and regional markets. As the industry continues to evolve

amidst shifting regulatory frameworks and financial developments, it is critical for future research to address these changes, providing insights that enable policymakers to respond effectively and ensure market stability.

Building on the studies presented in this dissertation, several questions emerge for future research. One critical area is the impact of macroeconomic factors on real estate markets, specifically the sensitivity of real estate prices to interest rate fluctuations. In the commercial real estate segment, empirical findings on interest rate sensitivity are notably scarce, underscoring the opportunity to further investigate and elucidate the pricing mechanisms in this segment. Additionally, on a global scale, the influence of different types of interest rates on various real estate categories remains largely unexplored. While the distinctiveness of interest rate types is influenced by country-specific regulations, we encourage future research to delve into these promising areas. Gaining a deeper understanding of these dynamics is crucial for recognizing the broader impact of monetary policy on real estate markets.

In the pursuit of enhancing the precision and reliability of real estate valuation practices, we underscore the necessity for future research into the determinants of discount rates. As of today, existing guidelines and regulations surrounding discount rates exhibit a degree of ambiguity, leaving room for potential misinterpretation and subjective judgment. Thus, future investigations should address this vital research domain and provide hands-on recommendations for regulatory agencies in order to improve and refine existing guidelines. While contingent upon data accessibility, the development and refinement of sophisticated models concerning discount rates are poised to enhance the accuracy of real estate valuations. Building on this, a quantitative assessment of theoretically founded determinants of discount rates, along with various estimation methods, represents a valuable approach for future research to calibrate the weight attached to discount rate determinants, but also to identify further factors that may help explain the level and development of this crucial component.

Within the current field of tension, the question of the relevance of sustainability ratings for real estate assets is of great significance in the industry. This strand of literature is expected to attract increasing attention, and further empirical research will be necessary to deepen our understanding of this pivotal topic. Especially in today's context, empirical findings regarding the relevance of sustainability ratings are crucial for providing a suitable basis for regulatory agencies to regulate and standardize how these ratings should be incorporated into financial statements and real estate valuations. Thus, future research should continue to analyze the financial materiality of various sustainability ratings on key metrics of real estate assets,

disclosing the methodologies used to calculate these ratings and critically assessing their validity.