# Digital Processes in Real Estate Appraisal – Opportunities for Efficiency and Objectivity

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**Key words**: Real Estate Valuation, Digitalization, Discount Rate, Data Analytics, Big Data

## SUMMARY

In addition to the creative process of the appraiser, i.e. the valuation itself, real estate appraisal also requires cumbersome and time-consuming tasks, whose manual processing is often perceived as a nuisance and which also pose risks to the quality of the valuation. Digitization offers new opportunities for the appraisal profession, which on the one hand allow more efficient ways of working by streamlining the process and at the same time can provide a more reliable and objective basis for the valuation.

In particular, the weak information efficiency of the real estate market can be countered by digital tools that enable the use of Big Data analyses, for example. As essential elements of valuation methods for investment properties, the discount rate and future earnings are critical variables whose determination poses major challenges for appraisers. A digital approach with the aid of Big Data can open up new avenues in valuation and provide relief for the appraiser. Instead of relying on conventional, analogous approaches, the authors choose cause-based approaches to determine these relevant input variables.

The level of the discount rate, i.e. the mathematical return on a real estate investment as the return on the capital invested, is essentially attributable to so-called market factors such as the key interest rate, which permanently determine the development and trends of a market and are therefore referred to as determinants - they determine supply and demand. These market factors include, in particular, macroeconomic as well as sociodemographic factors.
Using regression analyses based on TSCS (Time Series Cross Section) methods, a linear equation, the so-called factor model, was developed to determine the discount rate based on these determinants. The discount rate for the valuation of a property can be determined in a comprehensible way. This makes it possible for the first time to quantify the relationship between the real estate market and the general economic situation at a location and to use it to improve the quality of data on the real estate market.

Besides the discount rate, one of the main input variables for the valuation of a property is the rental income. The rent is not only dependent on the object itself but also on the market that it is located in. The different circumstances and conditions that are present in a certain market can be described and modeled with different parameters. Also, the way that a potential tenant is valuing the property´s characteristics may be dependent on the market conditions. These

effects must be considered when building a model for the rental potential of a specific property.

By describing the effect of neighboring cities on a location as well as the interaction of the value impact of property and location characteristics a rental model was developed that gives deep insight into the composition of value driving factors in the real estate market.

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## 1. INTRODUCTION

In addition to the creative process of the appraiser, i.e. the valuation itself, real estate appraisal also requires cumbersome and time-consuming tasks, whose manual processing is often perceived as a nuisance and which also pose risks to the quality of the valuation.
Laborious data research, whose execution is made significantly more difficult due to the poor information efficiency of the real estate market and the low availability of valid data sources, is one of the core tasks of an appraiser's daily work, along with the determination of individual input variables such as the discount rate or future earnings.
On the one hand, their manual execution has the consequence that the associated time expenditure requires a trade-off between detailed thoroughness and causing long waiting times on the part of the customer and, on the other hand, causes a high susceptibility to errors. Assumptions about input variables of valuation methods can at best reflect the subjective gut feeling of an expert, but never verifiably prove quantitatively complex relationships. Uncertainty about decisions to be made, for which liability still must be assumed, and a high expenditure of time, caused by tedious busywork, cause frustration in the practiced profession. The result is a lack of verifiability and customer dissatisfaction.

Digitization offers new opportunities for appraisers, which on the one hand allow more efficient working methods by streamlining the process and at the same time can provide a more reliable and objective basis for appraisal.

In particular, the weak information efficiency of the real estate market can be addressed by digital tools that enable the use of Big Data analytics, for example.

As essential elements of valuation methods for investment properties, the discount rate and future earnings in particular are critical variables whose determination poses major challenges for appraisers. A digital approach with the aid of Big Data can open up new avenues in valuation and provide relief for the appraiser.

## 2. DISCOUNT RATE MODEL (Mauer 2019)

The discount rate is one of the most important and at the same time most sensitive variables in valuation process. Minor fluctuations in the level of this parameter can lead to significant differences in the value of the property calculated using this method. This applies to all valuation methods that are based on the principle of present value calculation. All the more

reason to focus on its correct determination. Nevertheless, most valuation methods do not provide any or only vague suggestions for determining this parameter, which inevitably leads to the interest rate being estimated in its entirety based on assumtions. Only the German capitalized earnings method prescribes a specific procedure for determining the discount rate. Here, the interest rate is determined retrospectively via back calculation from realized purchase prices of comparable properties and published by the expert committees for property values as a mean value or range in categories differentiated by type of use and location (Moll-Amrein 2009). However, most of the input variables are not known to the expert committees; they are then derived from empirical values and assumptions or even estimated completely (Moll-Amrein 2009), which makes the application of a determination rule superfluous. Furthermore, following a specific calculation rule suggests a supposed accuracy that the underlying database cannot de facto prove.
Despite its undisputed importance for the meaningfulness of the calculated real estate value, the determination of the discount rate in the common valuation methods is based exclusively on subjective moments resulting from assumptions and estimates.

Instead of the aforementioned retrograde method of determining the property interest rate, which uses property-specific data from the past to describe the future, a new method is presented below that uses a cause-based determination with the help of digital tools based on Big Data.

### 2.1 Method

In principle, the value of assets is to be determined using transaction prices in an active market. An essential feature of the asset "real estate" is its unique character, characterized by heterogeneous properties such as land characteristics, location or construction method. The comparatively low transaction frequency and strong segmentation of the real estate market differs significantly from that of the stock markets or comparable markets. The real estate market can rarely provide valuation suggestions due to the weak information efficiency and difficult comparability of properties (Hilbers 2001). Instead, an appraiser must act as a kind of simulator of the market, using calculation models to replace the information normally revealed by market events (Francke 2008). If real estate is held as an investment, i.e. if the focus is on generating higher cash returns in the future, the valuation can be based on the present value of its cash flows (CF), which vary in amount and timing.

$$Present\ value = \frac{CF_1}{1+r} + \frac{CF_2}{(1+r)^2} + \cdots + \frac{CF_n}{(1+r)^n}$$

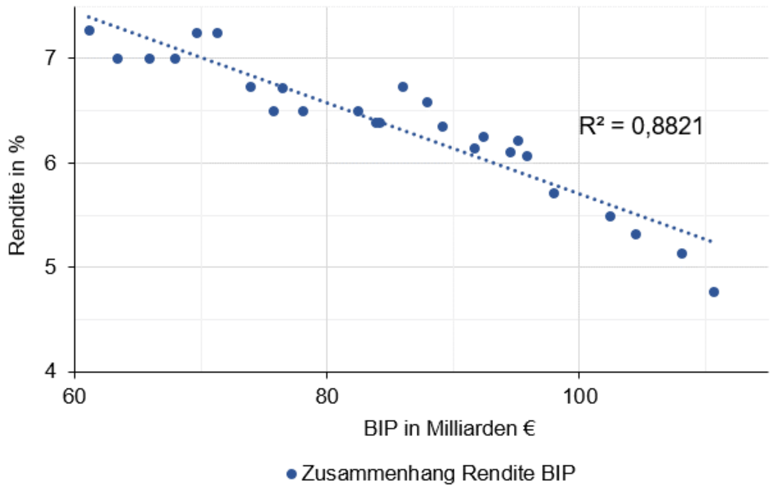
The discount rate r to be used is by no means just a purely mathematical parameter. By representing the return on capital employed, it also reflects the return on the investment (Grundmann 2003). Since it can also include the risk associated with the investment, it reflects in this context the return and risk expectations for the investment. In this context, the discount rate also has important economic significance in addition to its function as a mathematical variable.

The payments generated by the property are subject to a certain degree of uncertainty as to their amount and timing. For example, the rent level may fall, so that the rent payments are reduced at the latest when there is a change of tenant, or unexpected repairs to the roof may become necessary. The risks associated with real estate investment arise on the one hand from general market developments or arise from the property itself and are therefore divided into general systemic risks, i.e. risks dependent on a system (market), and non-systemic risks, i.e. risks specific to the property. The value of a secure (rental) payment is rationally greater than that of an uncertain payment. In this respect, the value of a property is lower, the higher the risk that its future payments will be reduced or even fail. Considering the above formula, the risk can be taken into account in the valuation on the one hand by a discount in the cash flows in the numerator or by a higher interest rate in the denominator. The consideration of risk via the cash flows is referred to as the security equivalence method and via the discount rate as the risk premium method. Both methods lead to the same result when carried out consistently. But how to determine the discount rate to be used?
As with share prices, a parallel development can be observed on the individual real estate sub-markets, e.g. the residential real estate market. This observation can be traced back to so-called market influencing factors, such as the key interest rate, which permanently determine the development and trends of a market and are therefore referred to as determinants - they determine supply and demand (Sailer 2006). Accordingly, the determinants are to be understood as the cause of market developments in the various submarkets and are therefore able to explain the level of returns.
The so-called factor model is a model from the financial industry that describes a return generation process, i.e. it can explain the return of a security based on certain influencing parameters. It is based on the observation that stock prices move in the same direction and assumes a linear relationship between the influencing factors common to all investments of this type and the return. Since the factor model results only from the observation of parallel developments of stock prices and is not based on any specific theory, it is a purely statistical model (Sharpe 1984) (Nowak 1994). Because the developments on the real estate market are also caused by certain influencing parameters, the relationships between returns and these influencing factors can be described in the same way using a factor model. The return r results from the sum of all market influencing factors F, which are weighted with a coefficient β on the basis of their degree of influence, and a constant α.

$$r = \alpha + \beta_1 F_1 + \beta_2 F_2 + \cdots + \beta_p F_p$$

In order for the rate of return, i.e. the discount rate, to be calculated using the factor model, the influencing factors F that are responsible for the development of the real estate market and thus also for the rate of return must be identified. The determinants of the German office and residential real estate markets and the associated key figures were determined using numerous studies and logical-deductive approaches.
Whether they actually have an influence on real estate returns and whether this is linear, as assumed in the factor model, was tested by combining pairs of values from returns and influencing factors of different cities at different points in time in a scatter diagram. The diagram below illustrates such a correlation, which is clearly linear, using the example of

residential property returns and the gross domestic product of the city of Hamburg. A correlation coefficient of 0.88 confirms this relationship and provides information on the strength of the influence.

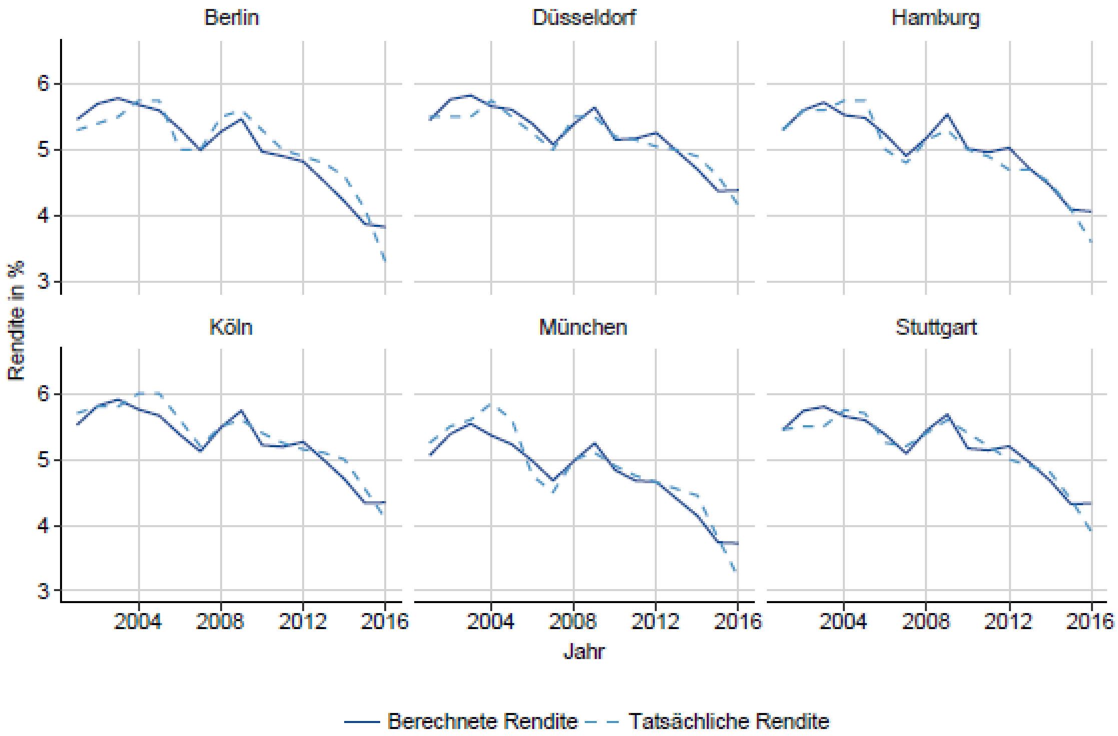



In order to be able to calculate the discount rate in the context of a real estate valuation with the help of the known influencing factors, the parameters α and β must be known, which describe the type and strength of the relationship between influencing factors and return. If GDP alone were the sole factor explaining the return on real estate, the two parameters could be determined using the straight line drawn in the above graph, which best describes the relationship between return and GDP. The parameter α is then the intercept of the straight line and β corresponds to its slope. The same principle is used in the case of multiple influencing factors to calculate the parameters α and β. This corresponds to the method of linear regression. The factor model is then equivalent to a regression equation.

The data basis of the study is composed of cross-sectional data and time series, i.e. returns and macroeconomic factors of various German cities over a long period of time. Compared to a pure cross-sectional analysis, this offers the advantage that temporal changes in correlations can be considered and a much larger database is available. This special data structure entails some peculiarities that can distort or even falsify the results of a linear regression. As part of an extensive analysis based on TSCS (time series cross sectional) methods, a regression model was developed that nevertheless leads to consistent estimates of the regression parameters α and β.
An iterative procedure, i.e., the stepwise addition or omission of one of each of the identified influencing factors, made it possible to determine the statistical significance and the influence strength of each influencing factor in interaction with all the others and to conclude which factors are superfluous because their information content is already explained by other factors. Finally, the remaining relevant influencing factors together with their regression parameters, which quantify the type and strength of the correlation, result in the final factor model for the office and residential real estate markets respectively.

### 2.2 Results

The results show that inflation, gross domestic product and population development in the respective location have a significant influence on the returns of both submarkets. While the residential real estate market is also influenced in particular by the interest rate level and the unemployment rate, the DAX is a key figure for alternative investment opportunities in the case of office property returns. Both factor models have a very high coefficient of determination $R^2$, which means that they almost completely describe the level of the return by the influencing factors determined. The following figure illustrates the quality of the regression using the example of office property returns for various cities in Germany by comparing the actual returns with the returns calculated using this factor model.




Factor models can only explain common and not individual developments, which is due to the characteristic of the influencing factors that they are common to all properties in the submarket. Property-specific non-systemic risks can therefore not be taken into account via the factor model. Nevertheless, they are of great importance for real estate valuation because they influence the value.

Contrary to the approach of many other valuation methods, which capture the non-systemic risks via a more or less arbitrary addition or deduction in the discount rate, this approach uses the security equivalence method, in which the non-systemic risks remain located in the cash flows, i.e. where they arise. Like the rents in a rent index, the cash flows of a property are made up of individual parts that are attributable to property characteristics that affect value (e.g. €0.5/sqm/month for the presence of a balcony). A non-systemic risk exists if these shares are not certain and may deviate from their expected value in the future. By decomposing the cash flows into these very micro-sources, those shares that are uncertain can be stochasticized using scatter properties from historical data, i.e., they are subjected to a probability distribution around their expected value. By means of a Monte Carlo simulation, a calculation method that allows to calculate with stochastic instead of deterministic variables, the individual shares can be aggregated back into a single cash flow.

## 3. RENTAL INCOME MODEL (Schlachter 2019)

In addition to the discount rate, one of the main input variables for the valuation of a property is the rental income. The aim is to develop a model for determining the rent depending on the characteristics of the property and its location. In general valuation methods try to simulate the pricing on the market. In the "Vergleichswertverfahren" the valuation is based on direct comparison with existing transactions. In the "Ertragswertverfahren", there is also a type of comparative approach in the form of the discount rate (Liegenschaftszinssatz) that is calculated from the individual transaction contracts.

Within the framework of both methods, a specific spatial sub-market is considered. In addition to the spatial delimitation, a delimitation is made by determining an observation period from which the comparison objects or the discount rate originate. This sometimes leads to a strong limitation of the available comparison objects and there for reduces the reliability of the resulting market value. (Zimmermann 2018).

### 3.1 Method

To overcome these restrictions a market model was created, based on the hedonic price theory to determine the rental income of a property. The input variables for the model are the property and location characteristics.

$$Y = \alpha + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_1 X_2 + \varepsilon$$

The model chosen is not intended to be limited to a spatial sub-market; rather, the respective spatial sub-market and its influence on the rental income is to be represented based on the specific parameters of the location. Beside the location parameters that are present at the specific location, the influence of surrounding areas should be considered as well.

Locations and Cities have interdependencies. For example, a structurally strong metropolitan region has a dominant influence on the surrounding areas. This influence must be considered to develop a precise market model. This is done with the potential model as part of the regression analysis.

To model this effect the interaction between two locations must be modeled first. The gravitational model was developed by representatives of "social physics" who wanted to transfer scientific laws to human action. It represents an analogy to Isaac Newton's law of gravitation (Mösgen 2008). When transferring the gravitational model, the attractive force between two locations results from the weighting factor K multiplied by the product of the masses of locations i and j divided by the squared distance of locations $d_{ij}$

$$I_{ij} = K \frac{M_I M_J}{{d_{ij}}^2}$$

In its base form the potential of a location is calculated by the sum of all single interaction effects from the gravitation model.

$$P_i = \sum_{j=1}^{n} \frac{M_j}{d_{ij}}$$

As with the gravitational model, the potential model was detached from the physically model. In the general form of the potential model, the mass $M_j$ is replaced by the attractiveness function $f(A_j)$ and the influence of distance by the resistance function $f(d_{ij})$. The distance or a quantity of time that reflects the time it takes to overcome a distance can be used in the resistance function. The modified formula for the potential of a location is shown in formula below.

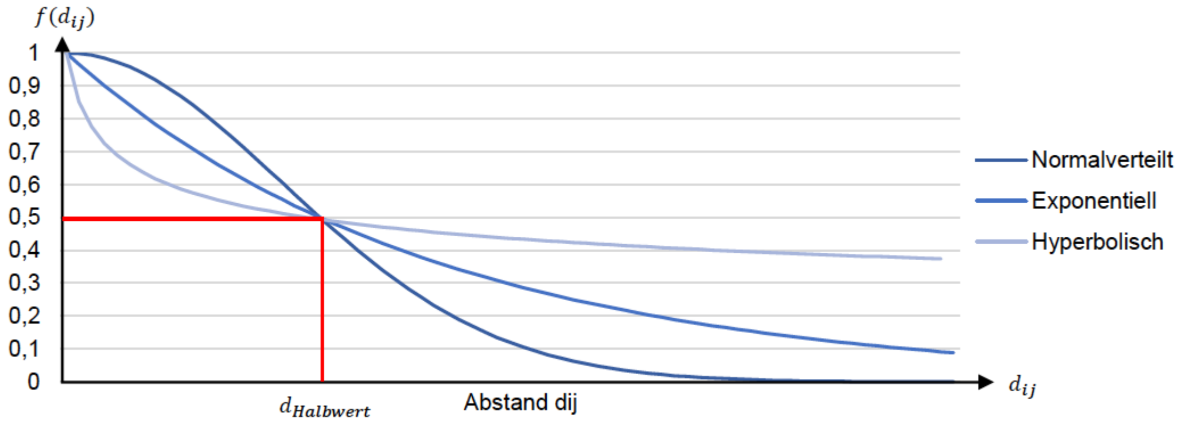
$$P_i = \sum_{j=1}^{n} g(A_j) * f(d_{ij})$$

Population figures, employment figures or the gross domestic product can be used as an attractiveness function for a location (Meinke 1971). In the case represented in this paper the GDP per inhabitant is multiplied by the total amount of inhabitants in a specific location.

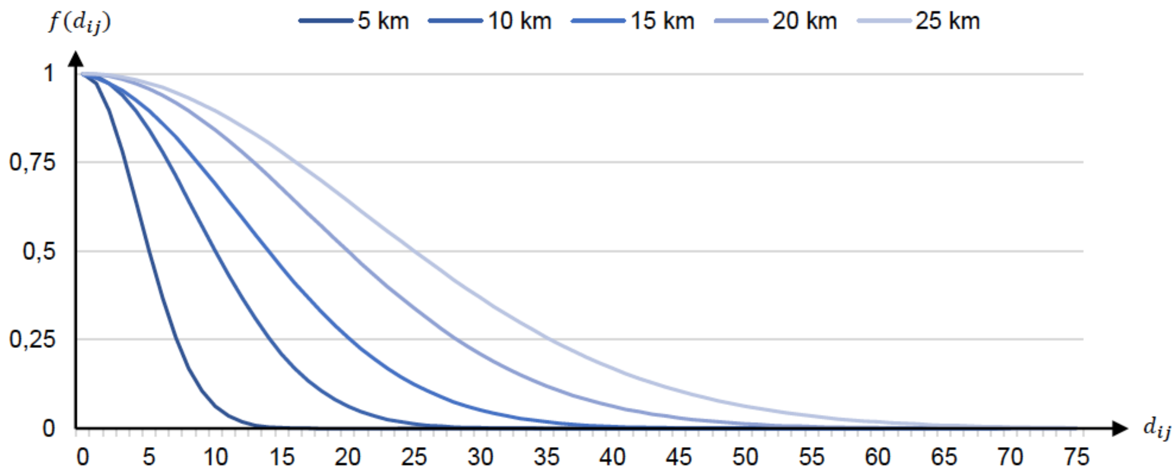
$$g(A_j) = Bevölkerungszahl_j * BIP - Pro - Kopf_j$$

The resistance function describes the effect that distance has on the attractiveness function. The distance can be incorporated into the model in the form of spatial distance or the time or cost of covering a corresponding distance (Handy 2001). The resistance function can be divided into the following three basic forms which have different behaviors in dependence of distance:

- Hyperbolic resistance function
- Exponential resistance function
- Gaussian resistance function



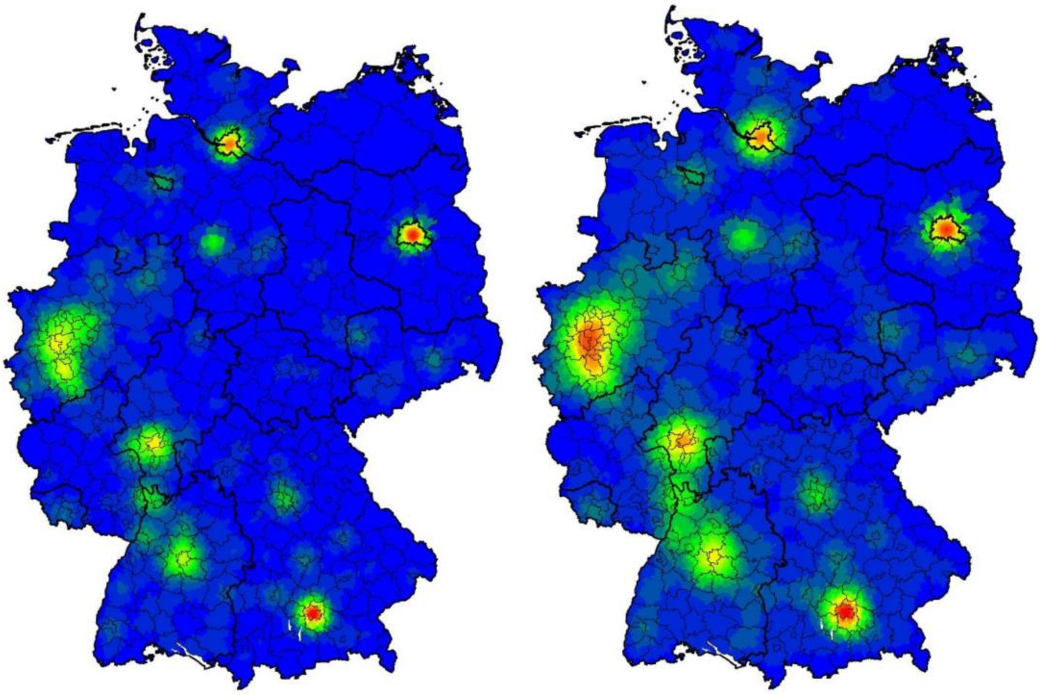

In this paper the Gaussian resistance function is used to model the influence based on the distance. The expanse of the influence will be described based on the distance where the factor from the resistance function is exactly 0.5.




In the context of this paper the potential of location i is calculated according to the following formula as the product of the population of location j, the gross domestic product per inhabitant of location j and the value of the resistance function for locations i and j summed up over all locations J.

$$P_i = \sum_{j=1}^{J} B_j * BIP_j * e^{{d_{ij}}^2 \frac{\ln 0{,}5}{{d_{Halbwert}}^2}}$$

The following figure shows the result of the potential calculated for every zip code region in Germany for a half-value distance of 10 and 15 km.



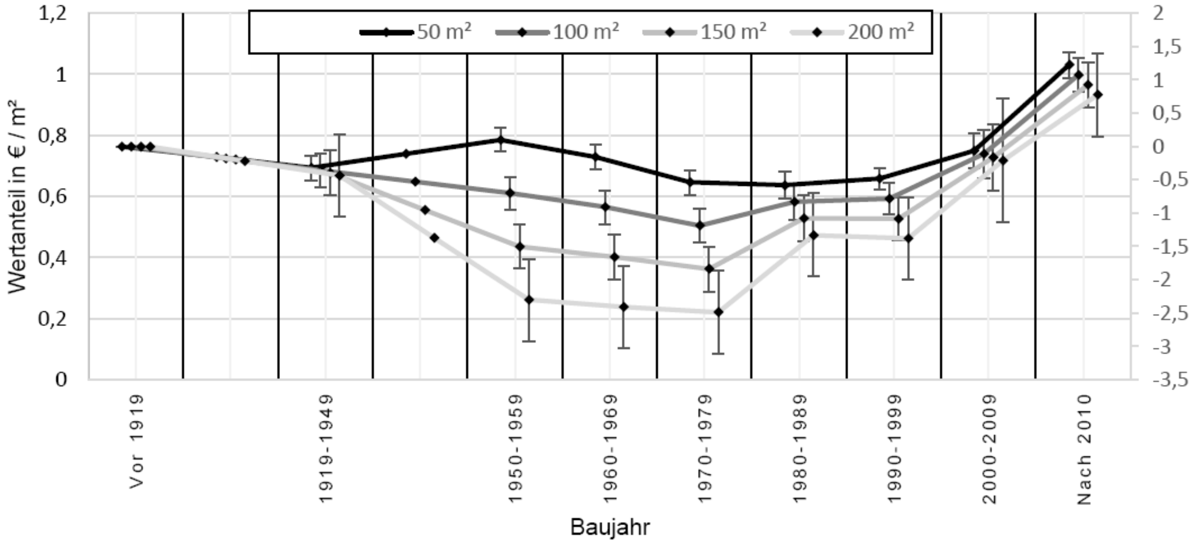
Besides the characteristics of the property itself and other location parameters the potential will be included in the regression model. As seen in the formular below the interactive terms Property characteristics (OE) and Locations characteristics (SE) will be included.

$$Wert = \alpha + \sum_{k=1}^{K} \beta_k OE_k + \sum_{j=1}^{J} \beta_{K+j} SE_j + \sum_{i=1}^{K} \sum_{l=1}^{K} \beta_{K+J+il} (OE_i * OE_l)$$
$$+ \sum_{o=1}^{J} \sum_{p=1}^{J} \beta_{K+J+KK+op} (SE_o * SE_p) + \sum_{m=1}^{J} \sum_{n=1}^{K} \beta_{K+J+KK+JJ+mn} (OE_n * SE_m) + \varepsilon$$

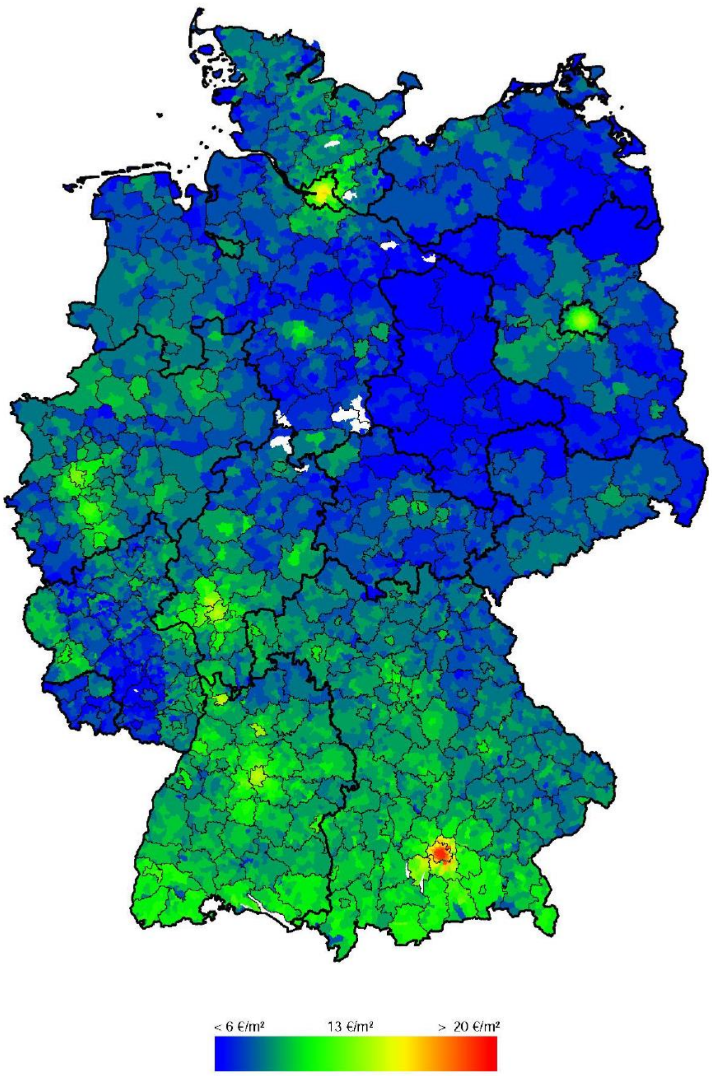
$mit$
$OE: Objekteigenschaft$
$SE: Standorteigenschaft$
$\alpha: Regressionskonstante$
$\beta: Regressionskoeffizient$
$\varepsilon: Störterm$

### 3.2 Results

After the quantification of the model with data from real estate advertisements the interaction of different value drivers can be further investigated. In the following example the construction year and the living space have an interacting term in the rent prediction model. Regarding the construction year, a non-linear relationship can be observed. The living space is also valued differently for the years of construction 1950 to 1999. For all categories, the values of larger apartments are below those of smaller apartments. There is a significant difference for the construction years from 1950 to 1999. Regardless of the living space, the most recent rental apartments have the highest value share.




Irrespective of the information inefficiency that prevails on the real estate market, it is possible to develop a model for determining the rental income depending on the property and location characteristics. By quantifying the influence of the location characteristics, in particular the economic and socio-demographic factors, conclusions can be drawn about the influence of these factors on the real estate market. By modeling the value driving forces the rental potential for a specific property can be predicted for every possible location as seen in the final figure.


< 6 €/m²
13 €/m²
> 20 €/m²

## REFERENCES

Francke, H., 2008, Immobilien als Vermögensgüter und Besonderheiten von Immobilieninvestitionen, In: Immobilienökonomie - Band IV: Volkswirtschaftliche Grundlagen, p. 30, München, Karl-Werner Schulte.

Grundmann, W.; Luderer, B., Formelsammlung Finanzmathematik, Versicherungsmathematik, Wertpapieranalyse, p. 46, Stuttgart, Leipzig, Wiesbaden, Teubner

Hilbers, P.; Lei, Q.; Zacho, L., 2001, Real Estate Market Developments and Financial Sector Soundness, In: IMF Working Paper, Volume 129-2001, p. 9.

Immobilienwertermittlungsverordnung. ImmoWertV in der Fassung vom 14.07.2021. Fundstelle: BGBl. I, p. 2805.

Mauer, C., 2019, Diskontierung von Zahlungsströmen bei der Immobilienbewertung unter besonderer Berücksichtigung der systemischen Risiken, München, Verlag Dr. Hut

Moll-Amrein, M. 2009, Der Liegenschaftszinssatz in der Immobilienwertermittlung und seine institutionelle Implementierung – Ein deutscher Sonderweg, p. 149, 230–235, Wiesbaden, Immobilien-Zeitung.

Nowak, T., Faktormodelle in der Kapitalmarkttheorie, p. 15, Köln.

Sailer, E., 2006, Der Boden in der Volkswirtschaft, In: Spezielle Betriebswirtschaftslehre der Immobilienwirtschaft, 5. Aufl., p.117, Hamburg, Egon Murfeld.

Schlachter, M. 2019, Einfluss von Objekt- und Standorteigenschaften auf den Wert von Wohnimmobilien, München.

Sharpe, W., Factor models, CAPMs, and the APT, In: The Journal of Portfolio Management, Volume 11-1984, p. 21.

Zimmermann, J.; Mauer, C.; Schlachter, M., 2018, Bewertung von Immobilien unter Anwendung allgemeiner finanzmarktorientierter Verfahren. Teil II. Der Immobilienbewerter – Zeitschrift für die Bewertungspraxis, Heft 1-2018, p. 10-16, Köln.

## BIOGRAPHICAL NOTES

Dr. Christina Mauer and Dr. Maximilian Schlachter started their research on real estate valuation during their PhD at Technical University Munich in 2015. During that time, they published several papers about valuation methods and their difficulties in renowned journals. Dr. Mauer then worked as a fund manager for a large international real estate fund while Dr. Schlachter worked as a Senior Data Scientist at one of the largest real estate data providers in

Germany. Both were confronted with the practical problems of the valuation industry during this time and therefore decided to found their company, einwert, to create new solutions based on digital tools.

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