CERF Fellow Report Thies Lindenthal

Research findings to Date:

The new research programme is ongoing and has produced several working papers and two (modestly sized) research grants (CDBB, £25K; ZEW SEEK EUR 75K):

Since the last report, I drafted a new working paper jointly with John Clapp, titled *"A New Back Casting Method for Valuing Urban Land: Comparison to Land Residuals".* In this paper, we develop a new method for urban land valuation based on theory which implies that land and structure trade as a bundle until the structure has no economic value. This back casting method first estimates property value, construction costs and residual land value in the year of new construction. Thereafter, the ratio of land to property value changes primarily with structure depreciation; changes in property value are shared by land and structure components. In contrast, land residual methods (land value equals property value minus the depreciated cost to rebuild in the sales year) predicts that the ratio is volatile because it is leveraged by relatively stable replacement costs.

We fit both models to Maricopa County assessor data on houses up to 28 years old during a bust and recovery period (2007–2018) and we evaluate the models for relevance to property tax assessment. Our inability to distinguish from a counterfactual points towards future research focused on sample selection.

The paper has been submitted to the *Journal of Housing Economics*.

My RFS paper on total returns to real estate has been summarised and translated to German and French for a the Swiss journal "Die Volkswirtschaft": https://dievolkswirtschaft.ch/de/2021/07/immobilienanlagen-angebliches-renditewunder-entzaubert/

I spoke at the Korea Planning Association Conference on Smart Cities 2021.

Current working paper

- *"Aesthetic Preferences for Residential Architecture: Finding Ground Truth with Machine Learning Approaches".* With Carolin Schmidt and Wayne Wan.

ML-enabled classifiers are regularly criticized for being “black boxes”: While their predictive power is undisputed, it is difficult to understand why the model arrived at a particular classification. The same can be said for humans classifying photos according to their aesthetic appeal. They can quickly say whether they like a photo or not – but giving justifications for such a choice is often challenging.
Also, human classifiers exhibit inconsistencies and biases, adding to the black box nature of their classifications. This paper first collects binary classifications of house pictures from a large group of participants and then trains personalized ML classifiers for each participant. Predictions from these automated yet personal classification machines shed light on biases and inconsistencies in the participants' assessment of residential real estate's visual appeal.

- *"Towards Accountability in Machine Learning Applications: A System-testing Approach"* With Wayne Xinwei Wan

  A rapidly expanding universe of technology focused startups is trying to change and improve the way real estate markets operate. The undisputed predictive power of machine learning (ML) models often plays a crucial role in the ‘disruption’ of traditional processes. However, an accountability gap prevails: How do the models arrive at their predictions? Do they do what we hope they do – or are corners cut? Training ML models is a software development process at heart. We suggest following the dedicated software testing framework and verifying that the ML model is performing as intended. Illustratively, we augment an off-the-shelf image classifier with a system testing procedure based on local interpretable model-agnostic explanation (LIME) techniques. Analyzing the classifications sheds light on some of the factors that determine the behavior of the system. We show that cross-validation is simply not good enough when operating in regulated environments.

- *"The Odd One Out: Predicting Price Coarseness"* (with Carolin Schmidt, ZEW Manngheim)
  - Presented at ASSA 2020
  - Presented at Weimer School May Session, Homer Hoyt Institute (May 2019, Singer Island, Florida). Conference was on "New data and tools in real estate research"
- *Centre for Digital Built Britain (CDBB)* project *"Machine Learning and AI in the Built Environment"*

- This project improved the foundations for applying tried-and-tested machine learning (ML) approaches to the built environment. This mini project reduced the cost of creating and deploying ML systems by creating versatile and extendable API's, data management infrastructure and mobile apps. A future version of the API's might be commercialised in areas like mortgage origination, insurance claim processing or property tax (non-UK, though) estimation

- Research grant (EUR 75K) from *Strengthening Efficiency and Competitiveness in the European Knowledge Economies* (SEEK) at the ZEW – Leibniz Centre for European Economic Research. Joint application with Carolin Schmidt.
  - Follow-up to the CDBB project to improve ML transfer learning in image recognition, specialised to the the built environment. Real estate research will finally get computer vision models that have been fully retrained with building data instead of general purpose models.
  - The funding will be used to support a new PhD starting under my supervision in September, IT infrastructure and travel.

Other working papers (not directly related to CERF project)

- *"Exogenous Demand Shocks and Liquidity of Turkish Residential Real Estate"*, with Tuğba Güneş
- *"Local market power in residential property markets"*, with Joseph Ooi
- *"500 Years of Housing Rents, Quality and Affordability"*, with P. Eichholtz and M. Korevaar (submitted for review) https://www.researchgate.net/publication/328278380_500_Years_of_Urban_Rents_Housing_Quality_and_Affordability

Links to your research outputs:

- Piet Eichholtz, Matthijs Korevaar, Thies Lindenthal, Ronan Tallec, (2021) "The Total Return to Residential Real Estate", *The Review of Financial Studies*, https://doi.org/10.1093/rfs/hhab042

- Clapp, J., Cohen, J. and T. Lindenthal (2021). "Are Estimates of Rapid Growth in Urban Land Values an Artifact of the Land Residual Model?". *Journal of Real*

Estate Finance and Economics. https://link.springer.com/article/10.1007/s11146-021-09834-4

- Lindenthal, T. and E. Johnson (2021). "Machine Learning, Architectural Styles and Property Values". *Journal of Real Estate Finance and Economics*. https://link.springer.com/article/10.1007/s11146-021-09845-1

- Working Paper "500 Years of Housing Rents, Quality and Affordability" (with Matthijs Korevaar, and Piet Eichholtz) https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3418495

- *"Machine Learning and AI in the Built Environment",* Final report. https://www.cdbb.cam.ac.uk/Downloads/ResearchBridgeheadDownloads/CDBBMiniProjectFinalReportThiesLindenthal_edited.pdf

- *"The Odd One Out: Predicting Price Coarseness"* https://www.dropbox.com/s/apzo3r4uvqxnxk7/The%20Odd%20One%20Out.pdf?dl=0

Publications generated during the CERF fellowship(s)

- Piet Eichholtz, Matthijs Korevaar, Thies Lindenthal, Ronan Tallec, (2021) "The Total Return to Residential Real Estate", *The Review of Financial Studies*
- Clapp, J., Cohen, J. and T. Lindenthal (2021). "Are Estimates of Rapid Growth in Urban Land Values an Artifact of the Land Residual Model?" *Journal of Real Estate Finance and Economics*.
- Lindenthal, T. and E. Johnson (2021). "Machine Learning, Architectural Styles and Property Values". *Journal of Real Estate Finance and Economics*.
- Lindenthal, T. "Beauty in the Eye of the Home-Owner: Aesthetic Zoning and Residential Property Values" (2017). *Real Estate Economics*.
- Lindenthal, T., Eichholtz P. and D. Geltner (2017). "Land Assembly in Amsterdam, 1832-2015". *Regional Science and Urban Economics*.
- Lindenthal, T. (2017). "Estimating Supply Elasticities for Residential Real Estate in the UK", in: Huang, B., Cao K. and E. Silva (Eds.) *Comprehensive Geographic Information Systems: Socio-economic applications*. Elsevier.

Seminars, conference presentations (since Aug. 2016)

- Panelist at Korea Planning Association Conference on Smart Cities: “Big Data & Machine Learning: Applications in Real Estate Research”, 9.9.2021
- Panelist at J*oint AsRES/GCREC/AREUEA International Conference 2021*, presenting “Application of AI and Big Data in Real Estate and Urban Studies”
- UCL conference: "The Case of Affordable Housing: a global perspective on financing and institutional ownership", presented *“500 Years of Urban Rents, Housing Quality and Affordability”*
- Weimer School May Session, Homer Hoyt Institute (May 2019, Singer Island, Florida), presented *"The Odd One Out: Predicting Price Coarseness"*
- Weimer School Session, Homer Hoyt Institute (Jan 2019, Singer Island, Florida). Presented “*Machine Learning, Building Vintage and Propery Values*”
- ASSA/American Real Estate and Urban Economics Association (AREUEA) Annual Meeting, Chicago (Jan. 2019). Presented “*Machine Learning, Building Vintage and Propery Values*”
- Urban Economics Asssociation, Annual Meeting (NYC, Oct. 2018). Paper “*Machine Learning, Building Vintage and Propery Values*”
- ReCapNet conference. Presented “Local market power in residential property markets”. (Nov 2018, Mannheim)
- Participated in CERF Cavalcade (23.5.2018) with “Unique Assets, Quality Uncertainty and Noisy Prices”
- ASSA/American Real Estate and Urban Economics Association (AREUEA) Annual Meeting, Chicago (Jan. 2017). Presented research paper titled “Beauty in the Eye of the Home-Owner: Aesthetic Zoning and Residential Property Values”

Press releases and other academic activities

- I am the initiator of the Virtual Real Estate Seminar (https://seminar.re), the largest real estate seminar, as far as I know. In recent sessions, we had up to 140 participants.
- I am co-organiser of the *Cambridge/NUS/Florida Real Estate Finance and Investment Symposium* which was held at the University of Cambridge, on Sep. 26-27th, 2019. This symposium is linked to a special issue at the *Journal of Real Estate Finance and Economics*. I am an editor for this special issue.