Quantifying Land Use Regulation and its Determinants – Ease of Residential Development across Swiss Municipalities

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Motivation

Local **land use regulations** affect the amount, location, and architecture of residential development.

Clear positive relationship between land use regulations and inelastic housing supply. Which in turn leads to:

- Higher house prices (Hilber and Vermeulen, 2016; Cosman et al., 2018).
- Spatial misallocation of labor (Hsieh and Moretti, 2019).
- Lower migration response of households (Diamond, 2017).

Land use regulations also foster economic, environmental, and social goals.

- They limit the negative externalities arising from congestion, pollution, and overbuilding.

Research question

Research question: What is the nature of local land use regulatory environments in Switzerland and what determines them?

- We conducted a survey on land use regulation among all Swiss municipalities.
- We construct the **CRED Ease of Residential Development Index (CERDI)** for Switzerland.
- The CERDI provides harmonized information about the local regulatory environment across Swiss municipalities.
- First index about regulatory constraints of land use in Europe.

The paper in a nutshell

1. We analyze determinants of local land use regulation.
   - Most important: Historical building density, natural amenities, socio-demographic factors, and local taxes.
2. We test the validity of the index with regard to local refusal rates and change in approval time.
3. We show that the index captures a significant part of the variation in local housing supply elasticities.
4. Using a Machine Learning (ML) model we predict the CERDI for non-responding municipalities.
   - Vacancy rates is the most important predictor, followed by share employed in industry, and capitalization rates.

Methodology

- Similar to Gyourko et al. (2008) and Gyourko et al. (2019), we construct ten sub-indices, using answers from a comprehensive survey and land use regulation data.

  ▸ Survey

- **Land use regulation process**: Citizens involvement index (CII), Municipality involvement index (MII); Cantonal involvement index (CAII); Organizations involvement index (OII).
- **Rules of regulatory constraints**: Project approval index (PAI); Density restrictions index (DRI); Extensive margin regulation index (EMRI); Open space and affordable housing index (OSAHI); Cost index (CI).

Methodology

- **Outcomes of regulation process and rules**: Outcome index (OI)
- Taking the simple mean, we merge these sub-indices into a single index Y_i, named CERDI.
- This index captures the degree of land use restrictiveness across municipalities.
- We also use principal component analysis to aggregate the ten sub-indices.
- We normalize the aggregate index using standardization, min-max normalisation, and within municipality-type min-max normalisation.

Machine learning model

- The main challenge of predicting the CERDI is selecting the predictors.
- Including too many predictors leads to overfitting.
- In contrast, including too few predictors leads to omitted variable bias.
- To solve this challenge, we use the regularization methods lasso and square-root lasso.
- We use cross-validation for our benchmark model.

▸ ML

Regulatory constraints data

Data	Description	Area share of Switzerland	Source
Crop rotation areas	Areas best suited for agriculture	12.3%	Cantonal offices for spatial development
Forests	Protected forest	27.7%	Arealstatistik Schweiz
Federal inventory of landscapes and natural monuments	Most valuable landscapes for Switzerland	18.9%	Federal Office for the Environment (FOEN)
Regional and national parks	Parks of national importance	12.7%	Federal Office for the Environment (FOEN)
UNESCO cultural sites	Buildings of particular architectural merit, entire towns, and sites created by the emergence of industrialisation	2.8%	Federal Office for the Environment (FOEN)
UNESCO natural sites	Natural sites with outstanding universal value	2.8%	Federal Office for the Environment (FOEN)

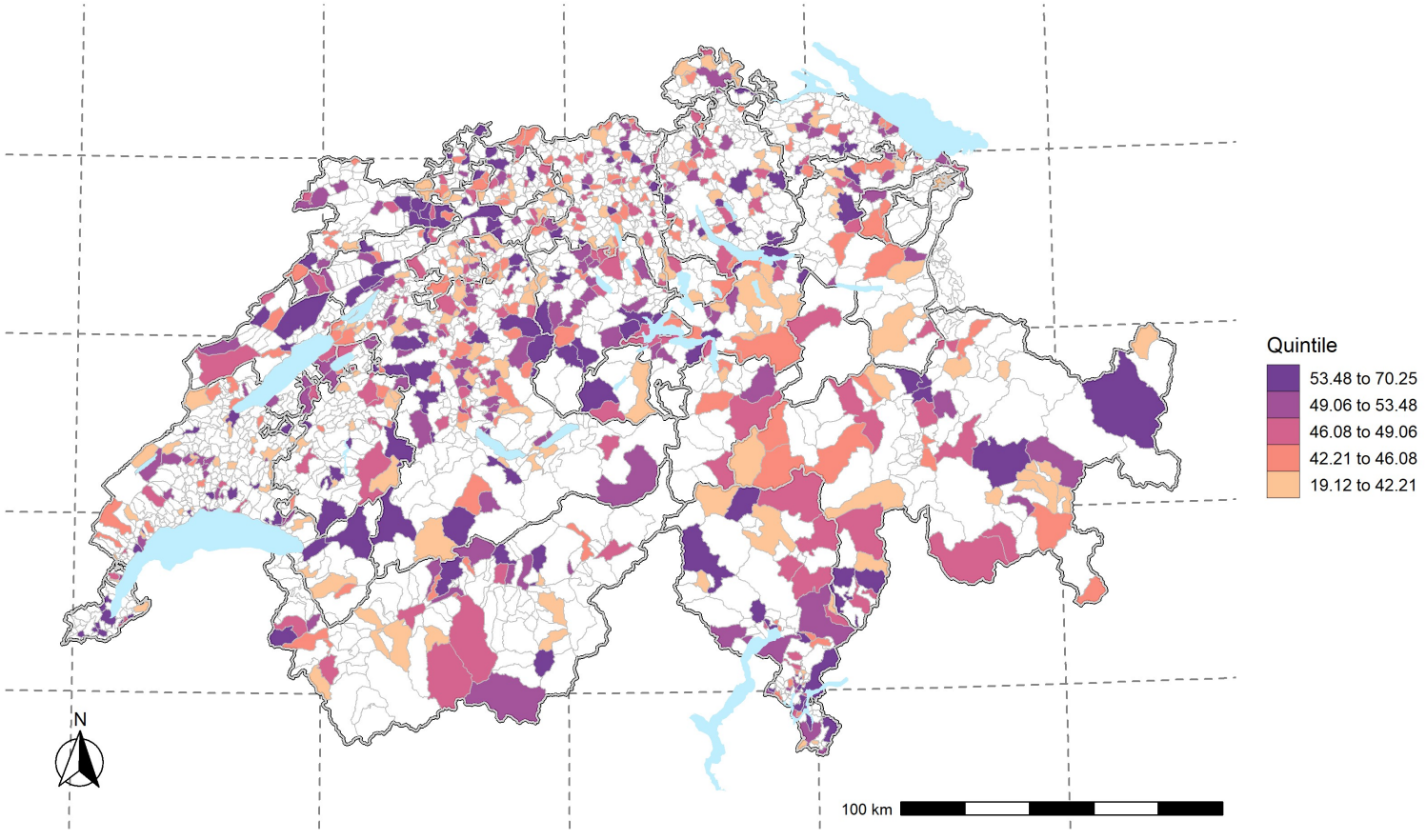
Notes: Regulations on the extensive margin are not mutually exclusive. Overall, these protected areas cover approximately 60 percent of the Swiss territory.

Descriptive statistics

	mean	min	max	sd
Density	434.77	0.86	12810.99	788.18
Density 1919	29.70	0.12	1441.33	60.04
Av. no. of floors	0.69	0.01	4.10	0.44
Dist. lakes	15.99	0.01	103.08	14.38
SE plot	0.27	0.00	0.98	0.18
Ruggedness	0.15	0.00	0.93	0.17
Culture	0.01	0.00	0.30	0.02
Income	36.24	10.75	329.28	13.70
Agriculture	0.24	0.00	2.72	0.28
Industry	0.42	0.00	26.37	0.98
Tax rate s. 80	0.14	0.05	0.19	0.02
Right	0.53	0.00	0.90	0.12
Center	0.24	0.00	0.87	0.13
Left	0.22	0.00	0.58	0.10
House price	8.61	7.22	9.54	0.33
Cap rates	0.04	0.02	0.11	0.01
Own rate	0.51	0.00	0.93	0.11
Vac. rate	0.02	0.00	0.15	0.02
Refusal rate	0.13	0.00	1.00	0.14
Approval durantion	3.05	0.00	5.00	1.10
Price elasticity	0.51	0.25	0.52	0.01
Rent elasticity	3.18	0.65	3.25	0.15

CERDI Index

Figure: Mean Index Y_i for the 715 municipalities that responded to our survey



Determinants of land use regulation

	(1) OLS	(2) OLS	(3) OLS	(4) IV	(5) OLS	(6) OLS	(7) OLS
	Log Mean Index Y_i						
Density	0.021***	0.020***		0.022***	0.019***	0.020***	0.021***
	(0.005)	(0.006)		(0.007)	(0.006)	(0.006)	(0.006)
Density 1919			0.022***				
			(0.008)				
Dist. lakes					-0.003		
					(0.005)		
SE plot						0.067**	
						(0.032)	
Income							-0.019
							(0.026)
Ruggedness	0.082*	0.130**	0.113*	0.141**	0.126**	0.123**	0.128**
	(0.044)	(0.059)	(0.059)	(0.064)	(0.059)	(0.059)	(0.058)
French	0.028*	0.029	0.025	0.031	0.029	0.026	0.029
	(0.017)	(0.029)	(0.029)	(0.029)	(0.028)	(0.028)	(0.029)
Italian	0.055***	0.144**	0.137**	0.145**	0.143**	0.144**	0.142**
	(0.021)	(0.062)	(0.061)	(0.061)	(0.062)	(0.062)	(0.062)
Rhaeto-Romanic	0.014	0.042	0.031	0.042	0.040	0.041	0.038
	(0.049)	(0.058)	(0.057)	(0.057)	(0.059)	(0.059)	(0.059)
Right	-0.082	-0.128	-0.156	-0.113	-0.129	-0.125	-0.128
	(0.078)	(0.095)	(0.098)	(0.102)	(0.095)	(0.095)	(0.096)
Center	-0.003	-0.045	-0.056	-0.029	-0.043	-0.051	-0.044
	(0.076)	(0.105)	(0.110)	(0.107)	(0.106)	(0.106)	(0.106)
Canton FE	No	Yes	Yes	Yes	Yes	Yes	Yes
Obs.	705	705	705	705	705	705	705
R-squared	0.05	0.10	0.10	0.10	0.10	0.11	0.10

Notes: Robust standard errors in parentheses $^{*}p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$. The units of observations are Swiss municipalities. The Mean Index Y_i is based on 715 municipalities.

Housing market

	(1)	(2)	(3)	(4)
	Log Mean Index Y_i			
House price	0.602***			
	(0.205)			
Cap rates		-1.749*		
		(1.055)		
Own rate			-0.175***	
			(0.063)	
Vac. rate				-1.072***
				(0.337)
Density	0.012**	0.016***	0.013**	0.021***
	(0.006)	(0.006)	(0.006)	(0.006)
Ruggedness	0.121**	0.132**	0.101*	0.123**
	(0.059)	(0.063)	(0.058)	(0.059)
French	0.027	0.017	0.029	0.037
	(0.030)	(0.031)	(0.029)	(0.028)
Italian	0.169**	0.112	0.150**	0.136**
	(0.066)	(0.076)	(0.061)	(0.062)
Rhaeto-Romanic	0.046	0.027	0.040	0.041
	(0.056)	(0.061)	(0.058)	(0.057)
Right	-0.171*	-0.143	-0.121	-0.119
	(0.096)	(0.103)	(0.095)	(0.094)
Center	-0.035	-0.020	-0.028	-0.039
	(0.103)	(0.114)	(0.106)	(0.105)
Canton FE	Yes	Yes	Yes	Yes
Obs.	695	663	705	705
R-squared	0.12	0.10	0.11	0.12

Notes: Robust standard errors in parentheses $^{*}p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$. The units of observations are Swiss municipalities. The Mean Index Y_i is based on 715 municipalities.

External validation

	(1) Refusal rate	(2) Approval duration	(3) Price elasticitiy	(4) Rent elasticitiy
Log Y_i	0.080**	0.934***	-0.026***	-0.073***
	(0.036)	(0.302)	(0.008)	(0.023)
Obs.	689	715	706	706
R-squared	0.01	0.01	0.03	0.03

Notes: Robust standard errors in parentheses $^{*}p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$. The units of observations are Swiss municipalities. The Mean Index Y_i is based on 715 municipalities.

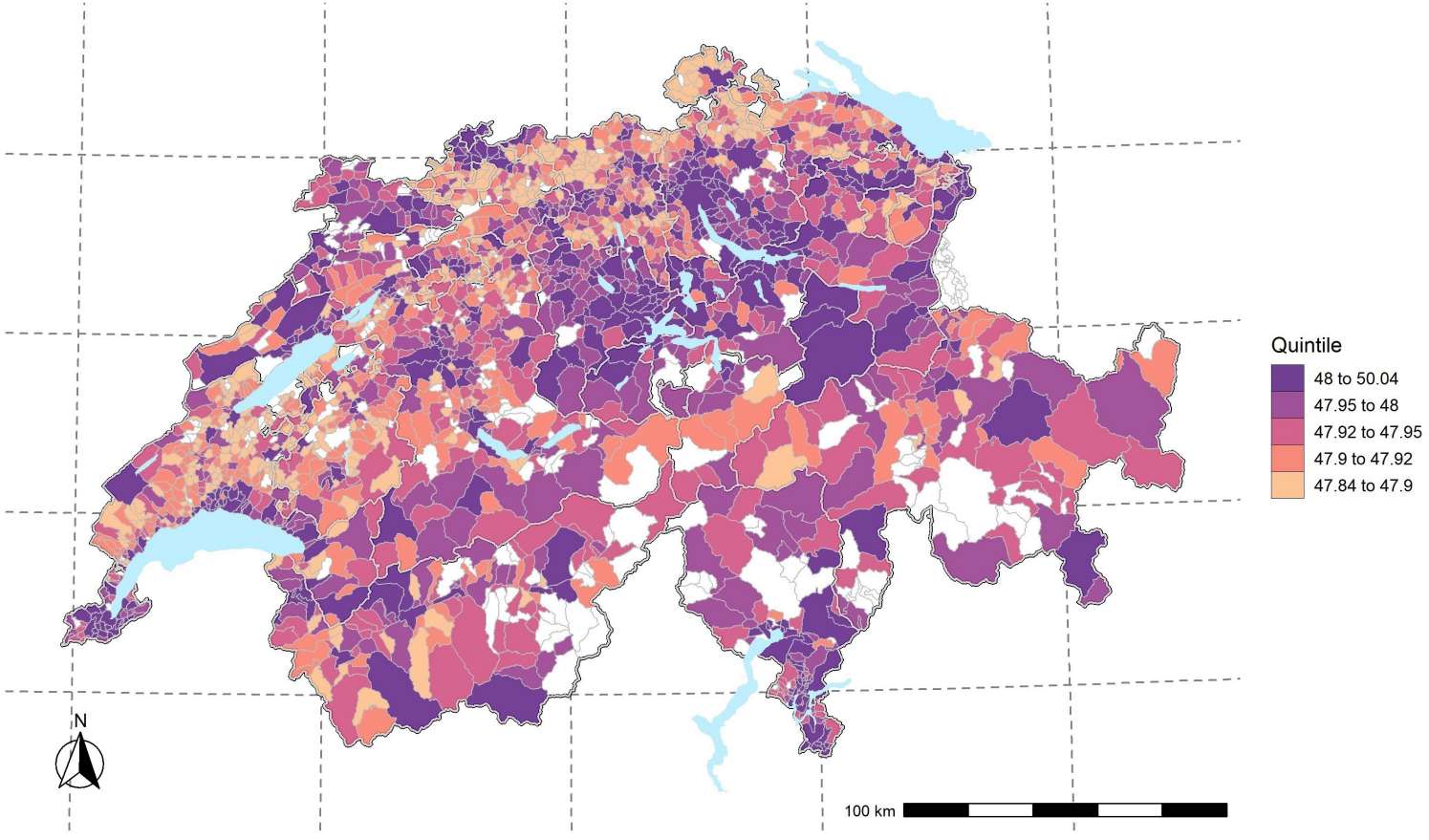
Machine learning: CV Lasso

	(1)	(2)	(3)	(4)	(5)
	Y_i	F_i	Z_i	M_i	T_i
Urban	0.0404	0.0825	0.0404	0.0404	
Av. no. of floors	0.0510	0.1148	0.0510	0.0510	
SE plot	0.0260		0.0260	0.0260	0.0334
Culture	0.0309	0.0338	0.0309	0.0309	
Agriculture		0.0619			
Industry	0.0758	0.0209	0.0758	0.0758	0.0420
Tax rate s. 80	0.0325		0.0325	0.0325	0.0438
Italian	0.0346	0.0506	0.0346	0.0346	0.0468
Rhaeto-Romanic		-0.0095			
Right	-0.0112	-0.0401	-0.0112	-0.0112	
Center		0.0390			
Left					0.0223
House price		0.0204			
Cap rates	-0.0679	-0.0104	-0.0679	-0.0679	-0.0629
Own rate	-0.0526	-0.0018	-0.0526	-0.0526	
Vac. rate	-0.0812	-0.0282	-0.0812	-0.0812	-0.0906
Lambda	26.86	25.69	26.86	26.86	29.98
Observations	661	645	661	661	661

Notes: $^{*}p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$. The units of observations are Swiss municipalities. Y_i = Mean Index, F_i = Factor Analysis Index, Z_i = Standardized Index, M_i = Min-max Index, T_i = Min-max by municipality types (urban, periphery, and rural) Index. The indices are based on 715 municipalities.

CERDI Index

Figure: Predicted Mean Index Y_i



Conclusion

- The local regulatory environment is of crucial importance for land use and housing supply.
- We construct the first harmonized local regulatory environment index for an European country.
- Our results show a large degree of variation in land use regulation.
- We find the historical development, natural amenities, cultural dimensions, and political aspects impact local land use regulation's stringency.
- **Next steps**:
  - Use the CERDI for applications, e.g., analyze the effect of monetary policies on housing contingent on the ease of residential development.
  - Further analyze sub-indices.

Literature

Land use regulation literature focuses on the US:

- Pendall et al. (2006) conduct a survey to discern how metropolitan areas regulate land use.
- Gyourko et al. (2008, 2019) develop a residential land use regulatory index.
- Glaeser and Ward (2009) examine the causes and consequences of land-use regulations in Greater Boston.
- Brueckner and Singh (2018) estimate the elasticity of the land price with respect to floor to area ratio (FAR).

No much literature for other countries:

- Büchler et al. (2019) evaluate the role of geographic and regulatory constraints on the Swiss housing supply elasticity.

Survey

- We conducted an online survey among all municipalities in Switzerland 2020.
- Possibility to answer the survey in the three main Swiss languages (German, French, and Italian).
- In total, we send out the survey three times.
- The survey was personally addressed to the corresponding building secretaries in each municipalities.
- It includes 20 questions and takes an average of 30 minutes to respond.

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Survey construction

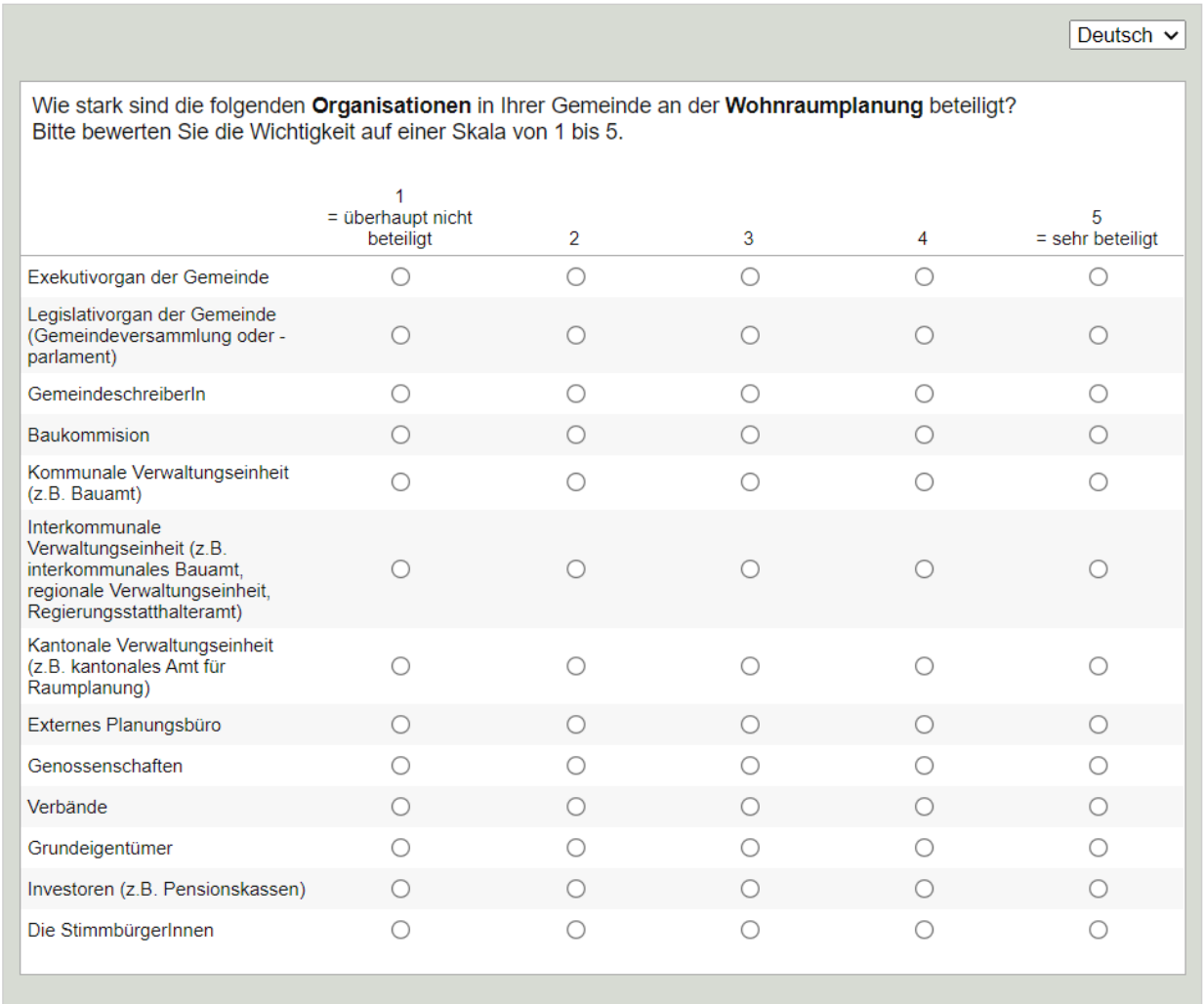
To construct the survey, we counted with the help of:

- EspaceSuisse (Association for spatial planning)
- Federal Office for Spatial Development (ARE)
- The Swiss Federal Institute for Forest, Snow and Landscape Research (WSL)
- Swiss Association of Municipalities
- Swiss Conference of Building Secretaries (SBK)
- Prof. Jean-David Gerber (University Bern) and Prof. David Kaufmann (ETH)
- Municipalities Bern and Medel

$\Longrightarrow$ Create a survey that applies to all municipalities and captures the most crucial aspects and the heterogeneity of local land use regulations. Back

Example survey question

Figure: Question 1



Deutsch

Wie stark sind die folgenden **Organisationen** in Ihrer Gemeinde an der **Wohnraumplanung** beteiligt?
Bitte bewerten Sie die Wichtigkeit auf einer Skala von 1 bis 5.

	1 = überhaupt nicht beteiligt	2	3	4	5 = sehr beteiligt
Exekutivorgan der Gemeinde	○	○	○	○	○
Legislativorgan der Gemeinde (Gemeindeversammlung oder -parlament)	○	○	○	○	○
GemeindeschreiberIn	○	○	○	○	○
Baukommision	○	○	○	○	○
Kommunale Verwaltungseinheit (z.B. Bauamt)	○	○	○	○	○
Interkommunale Verwaltungseinheit (z.B. interkommunales Bauamt, regionale Verwaltungseinheit, Regierungsstatthalteramt)	○	○	○	○	○
Kantonale Verwaltungseinheit (z.B. kantonales Amt für Raumplanung)	○	○	○	○	○
Externes Planungsbüro	○	○	○	○	○
Genossenschaften	○	○	○	○	○
Verbände	○	○	○	○	○
Grundeigentümer	○	○	○	○	○
Investoren (z.B. Pensionskassen)	○	○	○	○	○
Die StimmbürgerInnen	○	○	○	○	○

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Survey questions

The survey includes questions on:

- **Land use regulation process**, e.g., who/how involved are organizations/stakeholders in affecting residential spatial planning?
- **Rules of regulatory constraints**, e.g., what are the density restrictions or what are the costs of getting a building permit?
- **Outcomes of regulation process and rules**, e.g., how long does it take to get a building permit?

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Machine learning model

The lasso estimator (Frank and Friedman, 1993; Tibshirani, 1996):

$$\hat{\beta}_{lasso}(\lambda) = \text{arg min} \frac{1}{n} \sum_{i=1}^{n} \left(y_i - \boldsymbol{x}' \boldsymbol{\beta} \right)^2 + \frac{\lambda}{n} \sum_{j=1}^{p} \psi_j |\beta_j|, \quad (1)$$

The square-root lasso (Belloni et al., 2011, 2014):

$$\hat{\beta}_{\sqrt{lasso}}(\lambda) = \text{arg min} \sqrt{\frac{1}{n} \sum_{i=1}^{n} \left(y_i - \boldsymbol{x}' \boldsymbol{\beta} \right)^2} + \frac{\lambda}{n} \sum_{j=1}^{p} \psi_j |\beta_j|, \quad (2)$$

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Advantages of ML model

- Reduces the variance, limiting the model complexity, but at the cost of introducing some bias.
- We use cross-validation to select the optimal λ.

Advantages of ML model:

1. Better predictions with high dimensional data.
2. Sparser model that is more straightforward and easy to interpret.
3. Ranks the determinants by their relative importance for predicting the land use regulation index.

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Correlation indices

	fi	CII	MII	CAII	OII	PAI	DRI	EMRI	OSAHI	CI	OI
Y_i	1.00										
CII	0.57***	1.00									
MII	0.55***	0.42***	1.00								
CAII	0.09**	0.10***	0.16***	1.00							
OII	0.55***	0.41***	0.33***	0.08**	1.00						
PAI	0.58***	0.22***	0.32***	0.14***	0.45***	1.00					
DRI	0.46***	0.05	0.18***	-0.17***	0.02	0.16***	1.00				
EMRI	0.23***	0.04	-0.09**	-0.05	-0.02	0.03	0.02	1.00			
OSAHI	0.36***	0.13***	0.08**	-0.16***	0.21***	0.08**	0.14***	-0.08**	1.00		
CI	0.47***	0.18***	0.11***	-0.00	0.16***	0.18***	0.20***	-0.06*	0.17***	1.00	
OI	0.43***	0.16***	0.15***	0.10***	0.10***	0.22***	0.20***	-0.11***	-0.01	0.27***	1.00

Notes: $^{*}p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$. The indices are based on 715 municipalities. Land use regulation process: Citizens involvement index (CII), Municipality involvement index (MII); Cantonal involvement index (CAII); Organizations involvement index (OII). Rules of regulatory constraints: Project approval index (PAI); Density restrictions index (DRI); Extensive margin regulation index (EMRI); Open space and affordable housing index (OSAHI); Cost index (CI). Outcomes of regulation process and rules: Outcome index (OI).

Shorrocks-Shapley decomposition

	(1)	(2)	(3)	(4)
	Y_i	Z_i	M_i	T_i
Index	Relative importance			
CII	0.1291	0.1374	0.1295	0.1414
MII	0.1188	0.1265	0.1192	0.1286
CAII	0.0063	0.0067	0.0063	0.0181
OII	0.1127	0.1200	0.1130	0.0671
PAI	0.1328	0.1414	0.1332	0.1255
DRI	0.1145	0.1219	0.1149	0.0807
EMRI	0.0781	0.0832	0.0783	0.0907
OSAHI	0.0693	0.0738	0.0695	0.0514
CI	0.0899	0.0957	0.0901	0.0820
OI	0.0876	0.0933	0.0879	0.1252

Notes: Y_i = Mean Index, Z_i = Standardized Index, M_i = Min-max Index, T_i = Min-max by municipality types (urban, periphery, and rural) Index. The indices are based on 715 municipalities. Land use regulation process: Citizens involvement index (CII), Municipality involvement index (MII); Cantonal involvement index (CAII); Organizations involvement index (OII). Rules of regulatory constraints: Project approval index (PAI); Density restrictions index (DRI); Extensive margin regulation index (EMRI); Open space and affordable housing index (OSAHI); Cost index (CI). Outcomes of regulation process and rules: Outcome index (OI)

References I

Belloni, A., Chernozhukov, V., and Wang, L. (2011). Square-root lasso: Pivotal recovery of sparse signals via conic programming. *Biometrika*, 98:791–806.

Belloni, A., Chernozhukov, V., and Wang, L. (2014). Pivotal estimation via square-root lasso in nonparametric regression. *Annals of Statistics*, 42:757–788.

Brueckner, J. K. and Singh, R. (2018). Stringency of land-use regulation: Building heights in us cities. *CESifo Working Paper Series No. 6978*.

Büchler, S., von Ehrlich, M., and Schöni, O. (2019). The amplifying effect of capitalization rates on housing supply. *mimeo*.

Cosman, J., Davidoff, T., and Williams, J. (2018). Housing appreciation and marginal land supply in monocentric cities with topography. *mimeo*.

Diamond, R. (2017). Housing supply elasticity and rent extraction by state and local governments. *American Economic Journal: Economic Policy*, 9(1):74–111.

References II

Frank, L. E. and Friedman, J. H. (1993). A statistical view of some chemometrics regression tools. *Technometrics*, 35(2):109–135.

Glaeser, E. L. and Ward, B. (2009). The causes and consequences of land use regulation: Evidence from greater boston. *Journal of Urban Economics*, 65:265–278.

Gyourko, J., Hartley, J., and Krimmel, J. (2019). The local residential land use regulatory environment across u.s. housing markets: Evidence from a new wharton index. *NBER Working Paper No. 26573*.

Gyourko, J., Saiz, A., and Summers, A. (2008). A new measure of the local regulatory environment for housing markets: The wharton residential land use regulatory index. *Urban Studies*, 45(3):693â€“729.

Hilber, C. A. and Vermeulen, W. (2016). The impact of supply constraints on house prices in england. *Economic Journal*, 126(591):358–405.

References III

Hsieh, C.-T. and Moretti, E. (2019). Housing constraints and spatial misallocation. *American Economic Journal: Macroeconmics*, 11(2):1–39.

Pendall, R., Puentes, R., and Martin, J. (2006). From traditional to reformed: A review of the land use regulations in the nationâ€™s 50 largest metropolitan areas. *The Brookings Institution*.

Tibshirani, R. (1996). Regression shrinkage and selection via the lasso. *Journal of the Royal Statistical Society. Series B (Methodological)*, 58(1):267–288.