[Bartik, Gupta, and Mil, “The Costs of Housing Regulation: Evidence from Generative Regulatory Measurement”](https://papers.ssrn.com/sol3/papers.cfm?abstract_id=4627587)

[Github repository for paper](https://github.com/dmilo75/ai-zoning/tree/main)

**Summary:** Develop “generative regulatory measurement”, which uses LLMs to interpret administrative documents. 96% accuracy in binary classification tasks and 0.87 correlation for continuous questions. Establish four descriptive facts about American zoning:

1. Housing regulations are multidimensional, clustered around two main components
2. First component is *value capture*
   1. How municipalities extract economic benefits in areas of high housing demand
3. Second component is *exclusionary zoning*
   1. Results in higher housing costs and socioeconomic exclusion
4. Zoning follows monocentric pattern w/regional variations
   1. Suburban regulations particularly strict in the Northeast

**Introduction**

* Obtain municipal codes for 63% of population covered by local zoning ordinances
* Develop LLM-powered algorithm to estimate housing regulation on full text of these documents
  + Building off Retrieval Augmented Generation (RAG) architecture
* LLM is very accurate:
  + 96% accuracy for binary questions
  + 0.87 correlation for continuous numerical questions

Four descriptive facts about American zoning:

1. Housing regulations are multidimensional
   1. This is in contrast w/prior analysis which tends to sort regulation into “stricter” and “less strict” land use regulation buckets/groupings
2. First component is capturing value in high-demand environment
   1. Allow local governments to extract/redistribute housing surplus
      1. Examples: inclusionary zoning mandates requiring affordable units
   2. Higher in areas with higher amenities
      1. (amenities in terms of consumption, natural amenities, and productive spillovers)
3. Second components are aimed at limiting density and affordable housing options
   1. Strong association between these regulatory measures and indicators of local school performance and social mobility
4. Housing regulation varies within metropolitan areas in ways broadly consistent w/monocentric city model (Alonso, 1964; Muth, 1971)
   1. Denser building is allowed in city centers
   2. Observe substantial sorting of high-income households into expensive suburbs w/minimum size requirements

**Develops model of inter-municipal competition to interpret these facts.**

* Builds off “Tiebout sorting and local goods provision” literature
  + Tiebout, 1956; Epple and Zelenitz, 1981
* Traditional theories of zoning focused on housing sorting across public goods regimes (Fischel, 1987; Brueckner, 1995; Hamilton, 1975)

Four primary contributions to the literature:

* Developing general-purpose approach to measure content of regulatory documents
  + Recent papers using LLMs to collect more detailed data from documents:
    - Dell, 2025; Giesecke, 2023; Lagakos et al., 2025; Jha et al., 2023; Yang, 2023; Bybee, 2023; Hansen and Kazinnik, 2023; Hoffman and Arbel, 2023
* Novel and comprehensive dataset on housing regulation across the United States
  + Paper use references to zoning regulations in court cases (Ganong and Shoag (2017)) or newspaper article mentions of zoning (Stacy et al. (2023))
  + Papers looking at more detailed analysis of regulations at local level:
    - Quigley and Raphael (2005), Ihlanfeldt (2007), Glaeser and Ward (2009), Jackson (2016), and Shanks (2021)

**Construction of National Housing Regulatory Database**

Zoning, broadly, consists of two sets of regulations:

1. Land use regulations
   1. Partitions local land into distinct use classes
2. Bulk regulations
   1. Regulate physical dimensions and density of buildings in different land use classes

* Source text of municipal codes from variety of municipal aggregators:
  + American Legal Publishing, Municode, and Ordinance.com
* 25% of all municipalities, 6% of all townships
* Of the 76% of US population living in municipality/township, we have data for 63% of population

*LLMs*

LLMs have advantages/disadvantages in this setting:

* Advantage is scalability at low cost
  + Additional training, increased accuracy over time as data improves
* Disadvantages include inaccurate measurement and need for manual sourcing of relevant documents

*Processing Municipal Codes Using LLMs*

1. Download sources of municipal codes
   1. Any images of tables are transcribed using Amazon Textract
2. Use “retrieval-augmented generation” (RAG) framework
   1. Combine large pre-trained language model w/external information retrieval, to give LLM ability to “look up” information from vast corpus of text during generation process
   2. Steps for implementing RAG:
      1. Partition each ordinance into small chunks of text
         1. Taking into account hierarchical section structure
      2. Map each chunk of text into a vector representation called embedding
         1. Embeddings are vector representations of text trained to minimize distance between semantically similar content
      3. Vectorize each subsection of ordinance document using OpenAi ‘text-embedding-3-large’ algorithm
3. Prepare set of questions we ask our sample
   1. Begin w/question base already used by the Pioneer Institute
4. Identify most likely relevant information from ordinance to show the LLM
   1. Use cosine similarity, standard measure of vector distance to rank each text chunk by proximity to the question
5. Refine initial ranking of most relevant text produced by cosine similarity and double-check for accuracy
   1. Using cross-encoder reranking model on top 50 chunks of text
6. LLM query itself
   1. Prove two key pieces of info to LLM through API call:
      1. Include 4,000 tokens of relevant text
      2. Provide zoning question

These results aren’t necessarily accurate. 3 distinct strategies improve approach’s accuracy:

1. Prompt chaining
2. Prompt engineering
3. Providing detailed question background information

*Model Validation with Pioneer Data*

* Pioneer dataset serves as excellent starting point for checking model results…although it is a little stale (being current as of 2004)

*Sources of Model Improvements*

**Characterizing Housing Regulations**

*Principal Component Analysis of Housing Regulatory Dataset*

* The average municipality has 14 zoning districts
* Bulk regulations demonstrate significant stringency
  + Lowest minimum lot sizes averaging 10,000 square feet
  + Longest frontage requirements averaging 92 feet
* Process regulations typically involve extended review periods (~ 7 months)
* Multifamily housing is prohibited in 5% of jurisdictions
  + 10% in high-income areas
* 86% of municipalities restrict conversions to multifamily units
* Perform PCA analysis: Housing regulations are *not* well-summarized by a simple unidimensional level of stringency
  + First principal component explains just 13% of overall variation
  + Second principal component explains 11% of the variation
* There is no uniform correlation between zoning questions/policies:
  + For example, minimum lot size and flexible zoning policies show near zero correlation
* Some are surprising:
  + For example, allowing accessory dwelling units is actually positively correlated with the lowest minimum lot size and permit and development caps

Next, focus on economic interpretation of two principal components:

**Value Capture**

* Areas with higher amenities feature higher housing demand
  + Generates surplus that can be captured through regulation
  + See Couture et al. (2024)

**Exclusionary Zoning**

* Highest loading for this principal component is smallest residential minimum lot size
* Municipalities high in this component have substantially fewer housing units affordable to the state median income household, focusing on 3 mechanisms:
  + Exclusionary zoning shifts the entire housing price distribution rightward
  + Exclusionary zoning shifts mass away from left tail, towards median
  + Limits affordability on the rental margin

**Monocentric City Model and Zoning Gradients**

* In this model, there is a productive center, and rents decay as one moves away from this productive center, w/rate of decay governed by transportation costs
  + *Housing regulations may be affecting the rent gradient as one moves away from center*
* Value capture tools predominant in city centers and exclusionary zoning practices intensifying w/distance from urban cores