A Dynamic Model of Housing Supply

Alvin Murphy

Dept. of Economics, Arizona State University

Weimer School of Advanced Studies in Real Estate and Land Economics

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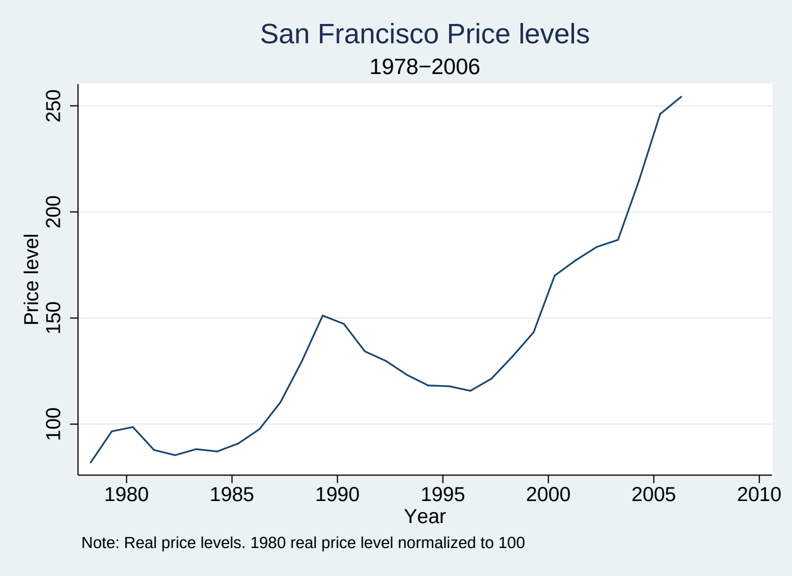
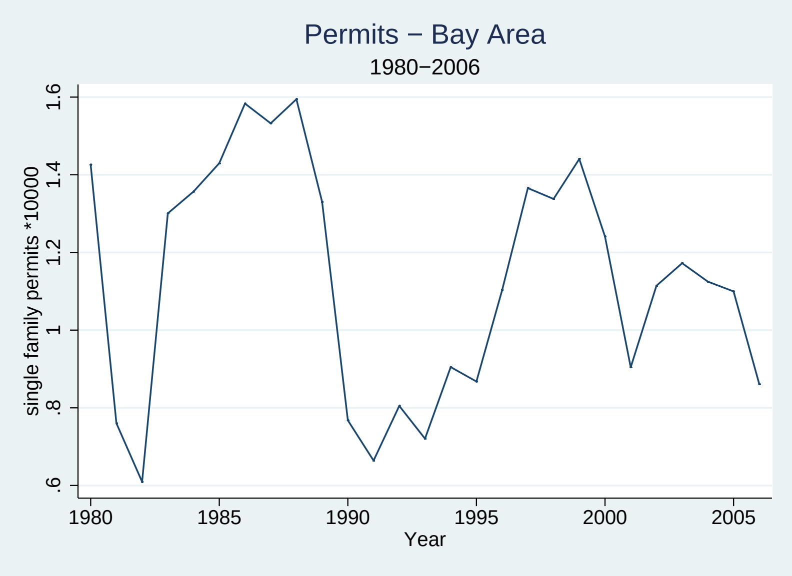
Housing Market Dynamics

- Housing markets typically volatile in both prices and quantities
  - Housing constitutes two-thirds of the average household's asset portfolio
  - Home owners face uninsurable risk and can't diversify
  - 10 million employed in construction sector
- Volatility has potentially large welfare costs

Housing Market Dynamics



Housing Market Dynamics



Microfoundations of Housing Market Dynamics

- Existing literature examines patterns using aggregate data
- Interesting housing patterns across metro areas and through time.

  For example:

  - Predictability of prices: Case and Shiller (1989)
  - Construction volatility: Glaeser and Gyourko (2007)
- A constraint on the current literature has been the lack of micro data.

Microfoundations of Housing Supply

- What underlying factors determine housing supply?

1. Where does new construction occur?
2. When does new construction occur?
   - Given predictable prices, observed construction trends are puzzling.
   - What role does timing and expectations play in construction volatility?
3. How does new construction occur?
   - What explains size of building?

Overview

- New Construction
  - Large Scale Developments
  - Small Scale Infill Construction
- What determines the rate of small scale infill construction?
  - Includes vacant and “under-utilized” parcels.
  - Excludes greenfield developments and all large housing developments.
- Covers approx 55% of construction in Bay Area (1988-2004)

Overview

- Estimate the parameters of the profit function using a dynamic model.
- Parcel owners choose the optimal period to develop their parcel
- They also choose the type/size of construction.
- Parcel owners take into account future prices and costs

Preview of Results

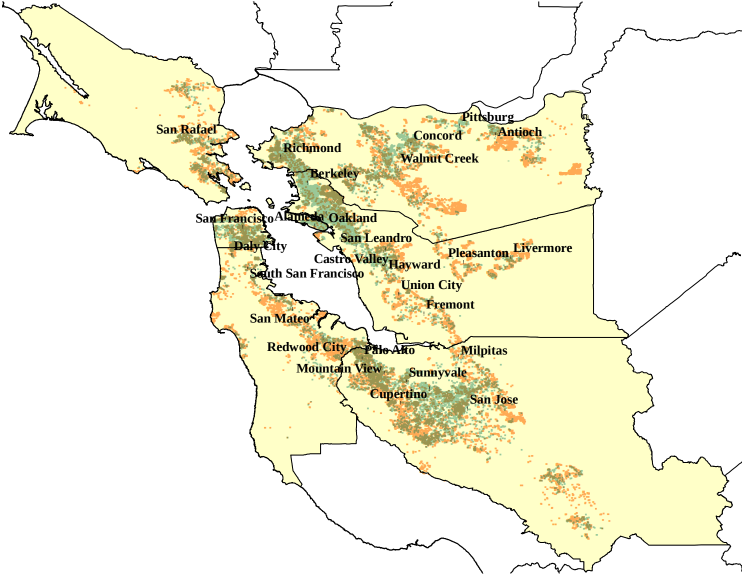
- Price appreciation caused by increase in value of buildable parcel
- Build big when return on size high
- Don't build that much more when prices high
- Costs are pro-cyclical
  - Explains puzzling building patterns
  - Cost trends combined with forward looking behavior dampen volatility
- Strong evidence that build decision is when-and-not-if.

Data

- Data is formed from two primary sources
  - Dataquick dataset is a transactions dataset that provides information on every house that sold in Bay Area between 1988 and 2004
  - California Statewide Infill Study provides a geo-coded parcel inventory
- Data from six core counties of Bay Area between 1988 and 2004.
- Observe characteristics parcels that were vacant/underutilized in 1988.
- Observe when, where, and how any parcel gets developed.

Screen Shot
Counties and Tracts

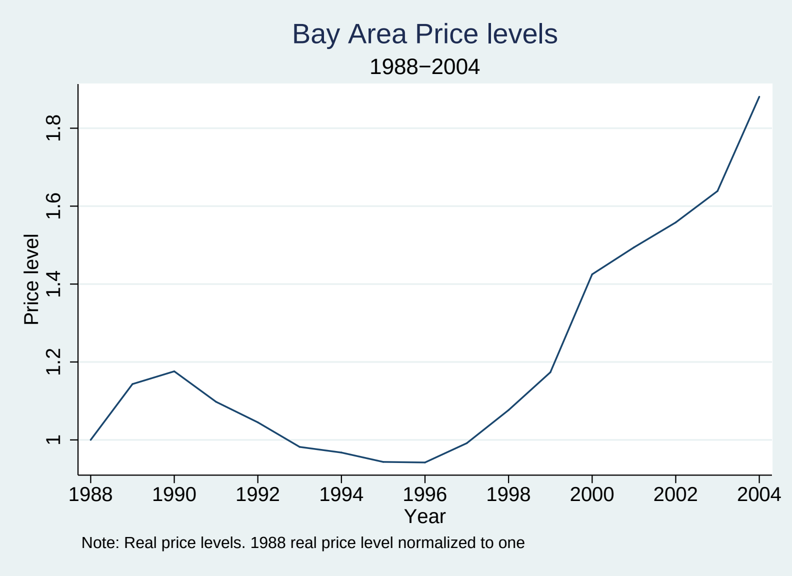
Bay Area: Parcels 1988



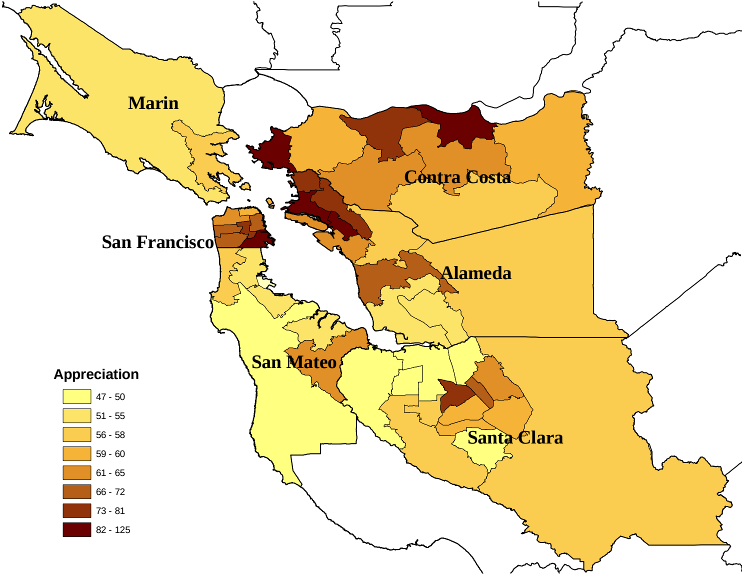
Motivation for Dynamic Approach – Descriptive Analysis

- Agents take into account expectations about future prices and costs
- In the Bay Area there were significant changes in the housing prices between 1988 and 2004.
- Large cross section variation in price appreciation.

Bay Area Price Levels



Appreciation Rates by PUMA: 1990-2004



Model Overview

- Parcel owners make a sequence of decisions that maximize the discounted sum of expected per-period profits.
- Parcel owners make two decisions in each period
    1. Build or don't build a residential unit
    2. If build, choose how much housing services to provide.
- Building ends the process $\Rightarrow$ optimal stopping problem
- 3 outcomes: 2 choices plus sales prices
- Parcel owners have (rational) expectations about future prices and costs

Model - Notation

- x_{njt} can be divided into two components:
    1. parcel level variables, x_{nt}
    2. tract level variables, x_{jt}.
- Ω_t is the information set at time t
- The discrete decision variable is $d_{nt} \in \{0, 1\}$
- h is the level of housing services
- $\pi_d(x_{njt}, h_{nt}) + \epsilon_{dnt}$ is the per period profit function

Model – Per-period Profits

- Sales price

$$P_{nt} = \rho_{jt} h_{nt}^{\gamma_{1jt}} x_n^{\gamma_{2jt}} e^{\nu_{nt}}$$

- Variable costs that vary with the level of housing services provided

$$VC_{nt} = (\alpha_{0jt} x_n^{\alpha_1} e^{\eta_{nt}}) \cdot h_{nt}$$

- Fixed costs associated with any construction

$$FC_{nt} = \delta_{ct}$$

Model - Decision Two: Housing Services

- If a parcel owner decides to build, that period becomes the terminal period and lifetime expected profits become the per-period profits

$$\pi_{1nt} = \underbrace{\rho_{jt} h_{nt}^{\gamma_{1jt}} x_n^{\gamma_{2jt}} e^{.5\sigma_\nu^2}}_{Expected\ Price} - \Big(\underbrace{(\alpha_{0jt} x_n^{\alpha_1} e^{\eta_{nt}}) \cdot h_{nt}}_{Variable\ Costs} + \underbrace{\delta_{ct}}_{Fixed\ Costs} \Big) + \epsilon_{nt}$$

- Conditional on building, a parcel owner chooses h to maximize profits.
- First order condition yields the optimal housing services, h^*:

$$h_{nt}^* = \left(\frac{\gamma_{1jt} \rho_{jt} x_n^{\gamma_{2jt}} e^{.5\sigma_\nu^2}}{\alpha_{0jt} x_n^{\alpha_1} e^{\eta_{nt}}} \right)^{\frac{1}{1-\gamma_{1jt}}}$$

Model - Decision One: Build Decision

- Determinants of parcel owner's decision are:
  - unobserved shocks in period t, $\epsilon_{nt} \sim$ i.i.d. Type 1 Extreme Value
  - observed variables affecting per-period profits in period t, x_{nt}
  - Any variables that predict future values of x, which I denote by Ω_{nt}.
- $\pi_0(x)$ is normalized to zero $\Rightarrow$ $v_0(\Omega)$ is simply the continuation value
- Absorbing decision $\Rightarrow$ $v_1(\Omega)$ is simply per period profits

$$\begin{aligned} v_0(\Omega) &= \sigma_\epsilon \beta \Big(\int log[exp(v_0(\Omega')/\sigma_\epsilon) + exp(\pi_1(x')/\sigma_\epsilon)] q(\Omega'|\Omega) d\Omega' \Big) \\ v_1(x) &= \pi_1(x) \end{aligned}$$

Estimation Overview

- There are three outcomes associated with the model.
  - The binary decision to build or not in each period.
  - The housing service provision decision made conditional on building.
  - Sales price of properties that sell.
- Model is estimated in 3 stages

Estimation Overview

1. Using observed sales, estimate price equation (for each tract and year)
2. Using observed construction size and Step 1 estimates, estimate housing service equation
3. Using observed timing of development, and Step 1 & 2 estimates, estimate remaining fixed cost parameters.

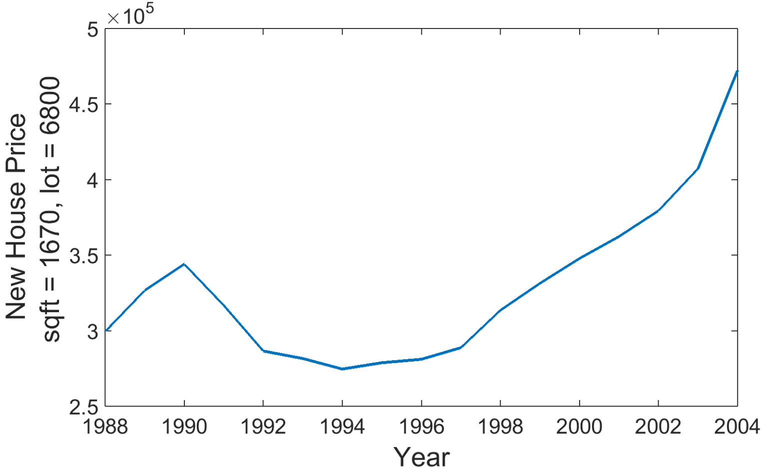
Estimation - Price Parameters

- Use all previous sales to estimate the following regression equation separately for each tract/year combination.

$$log(P_{nt}) = log(\rho_{jt}) + \gamma_{1jt} log(h_{nt}) + \gamma_{2jt} log(x_n) + \gamma_{3jt} old + \nu_{nt}$$

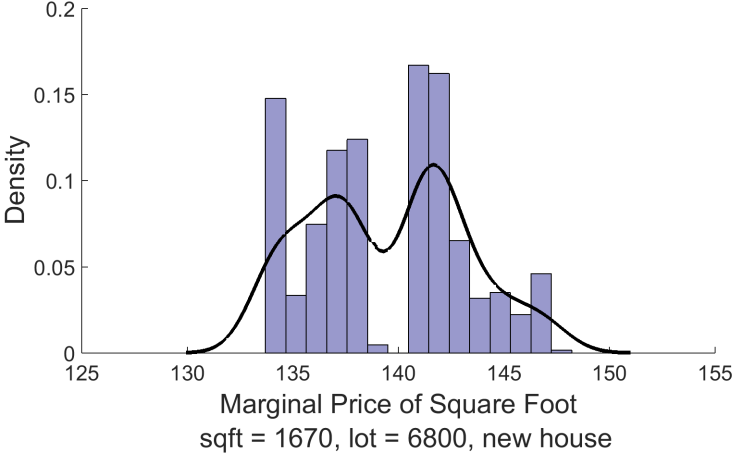
Results - Hedonic Price Regressions

Figure: Price of Typical House by Year



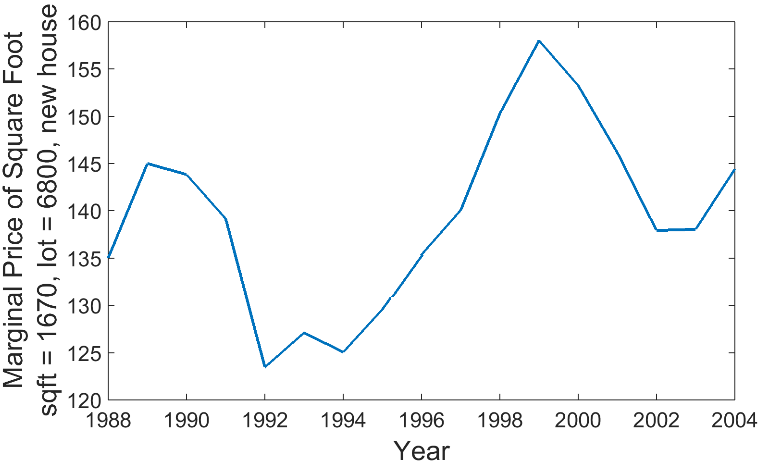
Results - Hedonic Price Regressions

Figure: Distribution of the Marginal Price of Square Foot in a Typical House



Results - Hedonic Price Regressions

Figure: Time Trend of the Marginal Price of Square Foot in a Typical House



Estimation - Variable Cost Parameters

$$VC_{nt} = (\alpha_{0jt} x_n^{\alpha_1} e^{\eta_{nt}}) \cdot h_{nt}$$

$$h^*_{nt} = \left(\frac{\gamma_{1jt} \rho_{jt} x_n^{\gamma_{2jt}} e^{.5\sigma_\nu^2}}{\alpha_{0jt} x_n^{\alpha_1} e^{\eta_{nt}}} \right)^{\frac{1}{1-\gamma_{1jt}}}$$

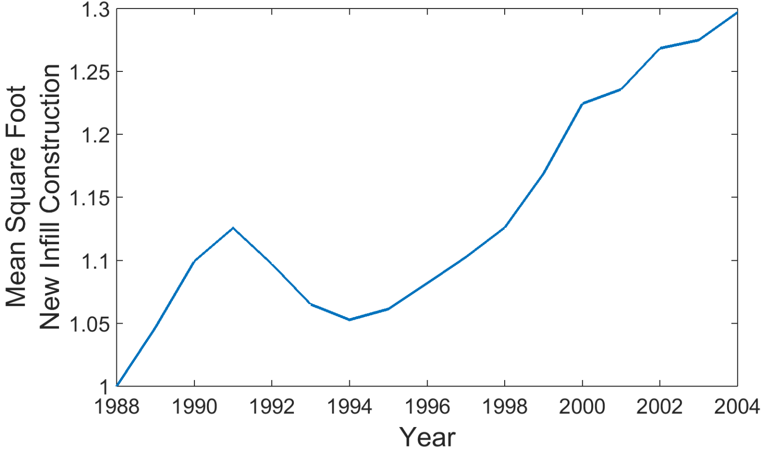
$$(\gamma_{1jt} - 1) log(h_{nt}) + log(\gamma_{1jt}) + log(\rho_{jt}) + \gamma_{2jt} log(x_n) + .5\sigma_\nu^2 =$$

$$log(\alpha_{0jt}) + \alpha_1 log(x_n) + \eta_{nt}$$

- Estimating by least squares yields estimates of α_{0jt}, α_1
- Compare with RS Means cost data

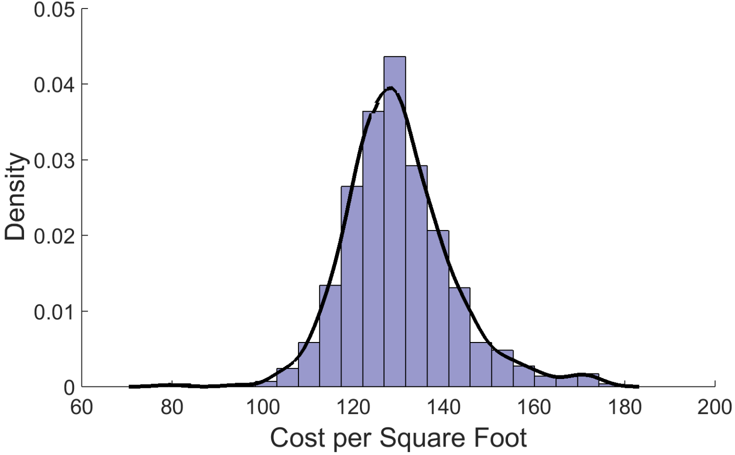
Estimation - Variable Costs - Identification

Figure: Time Trend of Mean Square Foot



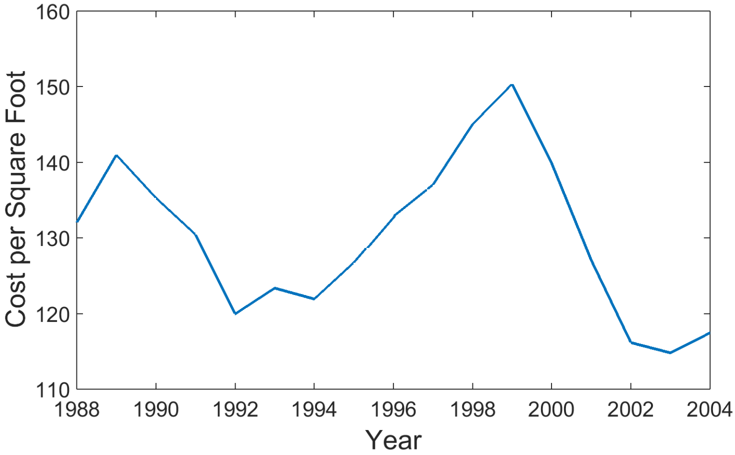
Results - Variable Costs

Figure: Distribution of the Cost per Square Foot in a Typical House



Results - Variable Costs

Figure: Time Trend of the Cost per Square Foot in a Typical House



Estimation - Dynamic Discrete Choice

- Hotz and Miller (1993), Arcidiacono and Miller (2011)
- Letting “hats” on variables denote their estimates from the first step, I can rewrite the choice specific value functions as:

$$
\begin{aligned}
v_0(\Omega;\delta) &= \beta\Big(\int \big(\pi_1(x') - log[\widehat{P_1}(\Omega')]\big)\widehat{q}(\Omega'|\Omega)d\Omega'\Big) \\
v_1(x;\delta) &= \pi_1(x)
\end{aligned}
$$

- Parcel owner will choose to build if $v_1(x;\theta) + \epsilon_{1nt} > v_0(\Omega;\theta) + \epsilon_{nt}$
- Given the distribution of ϵ, this is a binary logit model
- I estimate δ using maximum likelihood

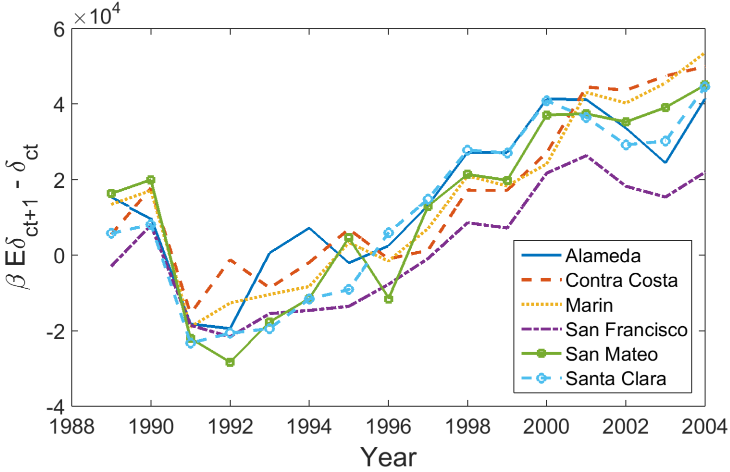
Results - Fixed Costs

$$FC_{nt} = \delta_{ct}$$

- Estimate county-by-year dummies.
- Actually estimate $(\beta E_t \delta_{ct+1} - \delta_{ct})$
- Roughly interpreted as expected growth in the latent fixed costs

Results – Expected Fixed Cost Growth by County

Figure: Time Trend of Expected Fixed Cost Growth by County



Dynamic Behavior

- Charles Smith, San Francisco Chronicle, Dec 19, 2007

"Last, you might consider the potential effect on construction and design costs as the housing market continues deflating. However modest the price deflation may be in Marin County, contractors are becoming less and less busy as the housing frenzy abates. That means prices for materials and labor are already falling, and may well continue to fall for months."

Implications of Dynamic Behavior

- Without cost considerations, model underpredicts construction during the boom of the late 1990s
- Rising costs discourage parcel owners from only building at peak
- Cost trends and forward looking behavior dampen volatility
- Fully dynamic model necessary to understand the primitives that drive observed aggregate trends
- A static model yields fixed cost estimates in excess of $2 million
  - Evidence that parcel owners choosing when and not if to build

Conclusion

- Combine dynamic discrete choice and static continuous choice problems.
  - a very large state space.
  - fine geographic levels.
  - time varying parameters
- Use model to explain where and when construction occurs
  - quantities
  - timing & volatility

Appendix

Bay Area: Counties and Tracts

Back to Data

Pilot California Infill Parcel Locator

▸ Back to Data