Land-Use Restrictions and U.S. Macroeconomic Performance

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Introduction

- **Regional resource reallocation** is central feature of U.S. economy
- 1800s - "Westward Expansion" - population moved to the Midwest and the Great Plains
- 1800s and 1900s - "Urbanization" - moved to Cities
- Mid-late 1900s - moved to California
- CA population share less than 2% in 1900
  - Alabama, Iowa, Kentucky were larger - Kansas about same size
- By 1990, CA population share 12%
Regional Population Shifts Since World War II

- 2010 populations *relative to constant 1950 population share*:
  - Gainers - CA gained 15 million, TX gained 9 million, AZ gained 5 million
  - Decliners - NY lost 11 million, PA lost 9 million, IL, OH, MI lost 4 million
Interpreting Regional Population Shifts

- Reallocations reflect *regional evolutions in productive opportunities and amenities*
  - Population moves from less productive, less desirable locations to more productive, more desirable locations
- Recently, regional population evolutions have slowed substantially
  - Interstate migration rate down 40 percent from previous level
  - CA pop share stopped growing in 1990, despite CA high tech boom
Figure: Employment Shares Across Regions
Interstate Migration Decline, Economic Performance, Housing

- Regional Reallocation Decline roughly coincides with:
  - (1) Decline in U.S. economic performance (Haltiwanger et al (2013))
  - (2) Increase in Housing Prices & Higher House Price Dispersion
    - CA house price premium rose from 28% (1940-1970 ave.) to 262% (1990)
  - (3) Decline in state income convergence (Ganong and Shoag (2014))
    - (3a) Persistent income premia in states with housing price premia

I will draw on joint research with Lee Ohanian (UCLA & FRB Minneapolis) and Ed Prescott (ASU & FRB Minneapolis)

Analysis ties these 3 trends together based on tighter land-use restrictions, and analyzes how land-use regulations have affected U.S. economic performance and regional reallocation of the population
Sand Hill Road Venture Capital IPOs and Private Equity

- Microsoft
- Amazon
- Google
- Facebook
- Twitter
- Tesla
- MetroPCS
- Angies List
- Groupon
- Lyft
- Spotify
- Airbnb
Figure: Sand Hill Road
Model Economy - Overview

- Neoclassical Growth Model with Land & Housing
- Basic model includes consumers who choose how much to work, consume and save, and producers who use labor, land and capital goods to produce output, and houses
- Land is input into housing and production of final goods
- 48 States have the following exogenous attributes
  - Total Factor Productivity (TFP), Amount of Land per state, Land Regulation Policies, & Amenities
- Land regulations raise cost of land and reduce its productivity
- To conduct analysis, need quantitative measures by state for TFP, amount of land, land-use regulations and amenities - but only land acreage is available
Quantifying Land Regulations, Amenities and Productivity

- Use economic model to infer amenities, land regulations, & TFP by state and over time by observing:
  - state housing prices, state acreage, state employment shares, state labor productivity
- Analysis: exogenously change land regulations in model, and assess how GDP, TFP, & location of workers change
- Sensible land deregulation would increase U.S. GDP by more than $130 billion per year ($1.3 trillion over last decade) and generate population relocation, with CA, Middle-Atlantic & NY growing, and Rust Belt and South shrinking
Basic Approach

- For simplicity, there is a representative household that chooses where to locate family members.
- Decision takes into account the TFP, amenity, and land-use regulations of each state.
- At the margin, the household will be indifferent between relocating family members.
- For simplicity, no moving costs - labor and capital are completely mobile.
- All markets are perfectly competitive.
Household Maximization

\[
\max_{\{k_{yjt}, k_{Hjt}, n_{jt}, x_{Hjt}, x_{yjt}, h_{jt}\}, k_{t+1}} \sum_{t=0}^{\infty} \beta^t \left\{ u(c_t, n_t) + \sum_j a_{jt} n_{jt} \right\},
\]

subject to the budget constraint,

\[
c_t + i_t + \sum_j p_{jt} h_{jt} = \sum_j (w_{jt} n_j + q_{jt} x_{jt}) + r_t k_t
\]

\[
k_t = \sum_j k_{jt} = \sum_j k_{yjt} + \sum_j k_{Hjt}, \quad n_t = \sum_j n_{jt}
\]

the housing constraint,

\[
h_{jt} \geq n_{jt}
\]

and the land constraint,

\[
x_{jt} = x_{yjt} + x_{Hjt}.
\]
Maximization problem of competitive output producer:

$$\max_{k_{yjt}, n_{jt}, x_{yjt}} \{ A_{jt} \bar{A}(\tilde{y}_{jt}) \} F(k_{yjt}, n_{jt}, \alpha_{yjt} x_{yjt}) - w_{jt} n_{jt} - r_t k_{yjt} - q_{jt} x_{yjt} \}$$ \hspace{1cm} (1)

Maximization problem of housing producer:

$$\max_{k_{Hjt}, x_{Hjt}} \{ p_{jt} g(\alpha_{Hjt} x_{Hjt}, k_{Hjt}) - r_t k_{Hjt} - q_{jt} x_{Hjt} \}$$

- $\alpha_{Hjt}$ represent policies that affect land use/housing production
- Examples: zoning, environmental rules, building restrictions
- $\alpha_{Hjt}$ is *productivity shifter*, & affects the quantity and price of housing

Resource constraint: $y_t = \sum_j y_{jt} = c_t + i_t$
Quantitative Approach

- Specify CA, NY, TX as individual states, and aggregate other states into 5 regions:
  - Northwest-Mountain states, Rust Belt states, Southern states,
  - Great Plains states, New England-Mid-Atlantic states

- Utility function is standard
  
  \[
  \ln(c_t) - \frac{1}{1 + \frac{1}{\gamma}} \left( \sum_j n_{jt} \right)^{1 + \frac{1}{\gamma}} + a_j n_{jt}
  \]

- Production is Cobb-Douglas with cost share of land in housing 38% and in non-housing production 5%

- Analyze ”steady state” (long-run affects of changes in land-use regulations)
Identifying Model Land Regulations, Amenities, & TFP

Calculate \( \{a_j, A_j, \alpha_{Hj}\} \) as follows:

- Amenities \( (a_j) \) target employment shares (BLS)

- TFP \( (A_j) \) generate regional labor productivity \( (y_j/n_j) \)

- Land-Use Regulations \( (\alpha_{Hj}) \) generate regional house prices
- Assume same distortions to housing and production \( \alpha_{Hj} = \alpha_{yj} = \alpha_j \)
  - Single family home price (Historic Census of Housing & ACS)
  - Urban acreage (USDA & Census Urban land Module)

Formal Identification proof  Data details
Identification of Land Regulation, $\alpha_j$

$$\alpha_j = \frac{(1 - \xi)}{x_j} \left( \frac{n_j}{k_{hj}} \right)^{\frac{\xi}{1-\xi}} [(1 - \xi)n_j + (1 - \theta - \chi) \frac{y_j}{p_j}] \quad (3)$$

- What informs the the land regulation parameters?
- For a given number of acres $x_j$, given number of people $n_j$ (and amenities), given housing capital stock $k_{hj}$, and output in that region $y_j$...
- if prices are higher, $p_j \uparrow$, we infer tighter land-use regulations ($\alpha \downarrow$)
- Lower $\alpha$ means less productive land
2014 Steady State Calibration – No Agglomeration
- Matches calibration targets in all regions, here we show CA, NY, and Texas in 2014:

**Table: Parameter Values and Model vs. Data Moments (CA, NY, and TX)**

<table>
<thead>
<tr>
<th>Parameter Description</th>
<th>Model</th>
<th>Data</th>
<th>Parameter Value</th>
<th>Parameter Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>Labor Productivity in CA ($\frac{YCA}{n_CA}$)</td>
<td>10.380</td>
<td>10.380</td>
<td>$A_{CA,2014}$</td>
<td>4.806</td>
</tr>
<tr>
<td>Employment in CA ($n_CA$)</td>
<td>0.067</td>
<td>0.067</td>
<td>$a_{CA,2014}$</td>
<td>-0.668</td>
</tr>
<tr>
<td>House Prices in CA ($p_CA$)</td>
<td>27.633</td>
<td>27.633</td>
<td>$\alpha_{CA,2014}$</td>
<td>0.005</td>
</tr>
<tr>
<td>Land Per Capita in CA ($x_CA$)</td>
<td>2.084</td>
<td>2.084</td>
<td>$x_{CA,2014}$</td>
<td>2.084</td>
</tr>
<tr>
<td>Labor Productivity in NY</td>
<td>11.824</td>
<td>11.824</td>
<td>$A_{NY,2014}$</td>
<td>5.000</td>
</tr>
<tr>
<td>Employment in NY</td>
<td>0.039</td>
<td>0.039</td>
<td>$a_{NY,2014}$</td>
<td>-0.989</td>
</tr>
<tr>
<td>House Prices in NY</td>
<td>19.417</td>
<td>19.417</td>
<td>$\alpha_{NY,2014}$</td>
<td>0.015</td>
</tr>
<tr>
<td>Land Per Capita in NY</td>
<td>1.037</td>
<td>1.037</td>
<td>$x_{NY,2014}$</td>
<td>1.037</td>
</tr>
<tr>
<td>Labor Productivity in TX</td>
<td>9.943</td>
<td>9.943</td>
<td>$A_{TX,2014}$</td>
<td>4.099</td>
</tr>
<tr>
<td>Employment in TX</td>
<td>0.050</td>
<td>0.050</td>
<td>$a_{TX,2014}$</td>
<td>-0.771</td>
</tr>
<tr>
<td>House Prices in TX</td>
<td>10.230</td>
<td>10.230</td>
<td>$\alpha_{TX,2014}$</td>
<td>0.042</td>
</tr>
<tr>
<td>Land Per Capita in TX</td>
<td>1.874</td>
<td>1.874</td>
<td>$x_{TX,2014}$</td>
<td>1.874</td>
</tr>
</tbody>
</table>


Herkenhoff, Ohanian, Prescott
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Figure: Measures of Land Regulatory Constraints ($\alpha_{Hj}^{1-\xi}$)
Model land regulations are correlated with residential and business regulation indexes in 2014 cross-section.

<table>
<thead>
<tr>
<th>Regulation Indices</th>
<th>Wharton Land Regulation Rank*</th>
<th>Land Regulation Rank*</th>
<th>PRI Business Regulation Rank*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Correlation between Model Land-Use Regulation Rank* and Regulatory Index Rank*</td>
<td>0.82</td>
<td>0.60</td>
<td></td>
</tr>
</tbody>
</table>

*Rank equal to 1 indicates least regulated region, Rank equal to 48 indicates most regulated region.

- Amenities highly correlated with Albuoy (2009) measures
- Aggregate TFP growth follows Fernald et al closely
Counterfactual Experiments

Change land regulations within model and analyze response in economic growth, state population shares, and productivity

- Two experiments:
- (1) roll back land regulations in each state to a previous year
- (2) change state regulations so they move toward Texas regulation level

I pick Texas, because it has the weakest land regulations (Note: TX has country’s weakest zoning laws)

- Deregulate all states halfway to Texas levels in 2014

\[ \alpha'_j = \alpha_j + \frac{1}{2} (\alpha_{TX} - \alpha_j) \]
Figure: Measures of Land Regulatory Constraints ($\alpha_{Hj}^{1-\xi}$)
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Figure: Deregulating CA and NY to their 1980 and 2000 Regulation Levels
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Figure: Deregulating All States to their 1980 and 2000 Regulation Levels
Figure: Deregulating All States to their 1980 and 2000 Regulation Levels
Figure: Log TFP, Deregulate All to their 2000s and 1980s Regulation Levels
Figure: Deregulating All States Halfway to Texas Regulation Levels
Figure: Deregulating All States Halfway to Texas Regulation Levels

- Annual TFP Growth Rate, Percentage Point Change (2000 to 2014)
- Annual Output Growth Rate, Percentage Point Change (2000 to 2014)

Deregulate 25% to TX:
- TFP Growth Rate: 0.35
- Output Growth Rate: 0.45

Deregulate 50% to Texas:
- TFP Growth Rate: 0.60
- Output Growth Rate: 0.70
**Summary Table of Experiments**

Table shows relative gains in variables across experiments \(\times^{2014,\text{counterfactual}}\) \(\times^{2014,\text{baseline}}\)

Largest gains come from moving toward Texas-level regulations

<table>
<thead>
<tr>
<th></th>
<th>(1) Baseline</th>
<th>(2) Dereg. CA to 2000</th>
<th>(3) Dereg. CA to 1980</th>
<th>(4) Dereg. CA &amp; NY to 2000</th>
<th>(5) Dereg. CA &amp; NY to 1980</th>
<th>(6) Dereg. All to 2000</th>
<th>(7) Dereg. All to 1980</th>
<th>(8) Dereg. 25% to TX</th>
<th>(9) Dereg. 50% to TX</th>
</tr>
</thead>
<tbody>
<tr>
<td>Relative Consumption</td>
<td>1.000</td>
<td>1.007</td>
<td>1.013</td>
<td>1.014</td>
<td>1.045</td>
<td>1.033</td>
<td>1.090</td>
<td>1.071</td>
<td>1.119</td>
</tr>
<tr>
<td>Relative Output</td>
<td>1.000</td>
<td>1.007</td>
<td>1.015</td>
<td>1.013</td>
<td>1.037</td>
<td>1.029</td>
<td>1.072</td>
<td>1.062</td>
<td>1.101</td>
</tr>
<tr>
<td>Relative TFP</td>
<td>1.000</td>
<td>1.007</td>
<td>1.014</td>
<td>1.016</td>
<td>1.050</td>
<td>1.030</td>
<td>1.069</td>
<td>1.054</td>
<td>1.085</td>
</tr>
<tr>
<td>Relative Labor Productivity</td>
<td>1.000</td>
<td>1.011</td>
<td>1.021</td>
<td>1.023</td>
<td>1.073</td>
<td>1.044</td>
<td>1.100</td>
<td>1.079</td>
<td>1.124</td>
</tr>
<tr>
<td>Relative Investment</td>
<td>1.000</td>
<td>1.008</td>
<td>1.015</td>
<td>1.012</td>
<td>1.032</td>
<td>1.026</td>
<td>1.060</td>
<td>1.057</td>
<td>1.089</td>
</tr>
<tr>
<td>Relative Labor</td>
<td>1.000</td>
<td>0.997</td>
<td>0.994</td>
<td>0.990</td>
<td>0.967</td>
<td>0.986</td>
<td>0.974</td>
<td>0.984</td>
<td>0.979</td>
</tr>
</tbody>
</table>

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Summary and Conclusions

- Land-use regulations have tightened over time, particularly in NY, CA.

- Land regulations are an important factor for labor reallocation across regions - highly productive states (NY, CA) have very expensive housing.

- Deregulating existing urban land in each state from 2014 regulation levels back to 1980 levels would increase US GDP and productivity by about 6 percent.

- Deregulating existing urban land in each state from 2014 regulation levels back to 1980 levels would permanently increase US GDP and productivity by about 7 percent.

- Land deregulation reduces housing costs and costs of producing output, and leads people to relocate from low productivity states to high productivity states.

- Biggest winners are CA, NY, and the Mid-Atlantic.
Appendix
Agglomeration

Increasing returns of 3%, $\lambda = .03$.

Increases gains from deregulating NY and CA alone by 30-40%

<table>
<thead>
<tr>
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<th>(1) Baseline</th>
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<th>(3) Dereg. CA to 1980</th>
<th>(4) Dereg. CA &amp; NY to 2000 &amp; to NY</th>
<th>(5) Dereg. CA &amp; NY to 1980 &amp; to NY</th>
<th>(6) Dereg. All to 2000 to</th>
<th>(7) Dereg. All to 1980 to</th>
<th>(8) Dereg. 25% to TX to</th>
<th>(9) Dereg. 50% to TX to</th>
</tr>
</thead>
<tbody>
<tr>
<td>Relative Consumption</td>
<td>1.000</td>
<td>1.007</td>
<td>1.015</td>
<td>1.017</td>
<td>1.063</td>
<td>1.040</td>
<td>1.112</td>
<td>1.082</td>
<td>1.144</td>
</tr>
<tr>
<td>Relative Output</td>
<td>1.000</td>
<td>1.010</td>
<td>1.021</td>
<td>1.017</td>
<td>1.059</td>
<td>1.040</td>
<td>1.102</td>
<td>1.086</td>
<td>1.142</td>
</tr>
<tr>
<td>Relative TFP</td>
<td>1.000</td>
<td>1.010</td>
<td>1.020</td>
<td>1.023</td>
<td>1.087</td>
<td>1.043</td>
<td>1.106</td>
<td>1.080</td>
<td>1.127</td>
</tr>
<tr>
<td>Relative Labor Productivity</td>
<td>1.000</td>
<td>1.015</td>
<td>1.032</td>
<td>1.035</td>
<td>1.131</td>
<td>1.066</td>
<td>1.160</td>
<td>1.123</td>
<td>1.195</td>
</tr>
<tr>
<td>Relative Investment</td>
<td>1.000</td>
<td>1.011</td>
<td>1.024</td>
<td>1.018</td>
<td>1.057</td>
<td>1.040</td>
<td>1.096</td>
<td>1.089</td>
<td>1.141</td>
</tr>
<tr>
<td>Relative Labor</td>
<td>1.000</td>
<td>0.995</td>
<td>0.989</td>
<td>0.983</td>
<td>0.936</td>
<td>0.976</td>
<td>0.950</td>
<td>0.967</td>
<td>0.956</td>
</tr>
<tr>
<td>Cons. Equiv. Welfare Gain (percentage points)</td>
<td>0</td>
<td>0.746</td>
<td>1.558</td>
<td>1.322</td>
<td>4.559</td>
<td>3.399</td>
<td>9.396</td>
<td>7.672</td>
<td>13.125</td>
</tr>
</tbody>
</table>
Table below illustrates output gains from deregulation, holding one or more inputs fixed.

Table: Decomposition of Output Gains from Deregulation

<table>
<thead>
<tr>
<th>All Inputs Vary</th>
<th>Deregulate All to 2000</th>
<th>Deregulate All to 1980</th>
<th>Deregulate 25% to TX</th>
<th>Deregulate 50% to Texas</th>
</tr>
</thead>
<tbody>
<tr>
<td>All Inputs Vary</td>
<td>1.029</td>
<td>1.072</td>
<td>1.062</td>
<td>1.101</td>
</tr>
<tr>
<td>Only Land Regulation Changes, ((x,k,n)) are fixed</td>
<td>1.006</td>
<td>1.017</td>
<td>1.014</td>
<td>1.023</td>
</tr>
<tr>
<td>Land regulation and (x) change, ((k,n)) fixed</td>
<td>1.008</td>
<td>1.022</td>
<td>1.019</td>
<td>1.030</td>
</tr>
<tr>
<td>Land regulation and ((x,k)) change, (n) fixed</td>
<td>1.009</td>
<td>1.026</td>
<td>1.021</td>
<td>1.035</td>
</tr>
<tr>
<td>Land regulation and ((x,n)) change, (k) fixed</td>
<td>1.012</td>
<td>1.031</td>
<td>1.028</td>
<td>1.044</td>
</tr>
</tbody>
</table>
Alternate Land Share of Final Goods Sector

**Table:** 3% Land Share of Final Goods Sector. Variables expressed relative to baseline values $x_{2014, baseline}$. Welfare expressed as fraction of lifetime consumption.

<table>
<thead>
<tr>
<th></th>
<th>(1) Baseline</th>
<th>(2) Dereg. CA to 2000</th>
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<th>(8) Dereg. 25% to TX</th>
<th>(9) Dereg. 50% to Texas</th>
</tr>
</thead>
<tbody>
<tr>
<td>Relative Consumption</td>
<td>1</td>
<td>1.0055</td>
<td>1.0113</td>
<td>1.0117</td>
<td>1.0376</td>
<td>1.0269</td>
<td>1.0731</td>
<td>1.0517</td>
<td>1.0873</td>
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<tr>
<td>Relative Output</td>
<td>1</td>
<td>1.0062</td>
<td>1.0127</td>
<td>1.0105</td>
<td>1.0298</td>
<td>1.0228</td>
<td>1.0547</td>
<td>1.0448</td>
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<tr>
<td>Relative Measured Solow Residual</td>
<td>1</td>
<td>1.0062</td>
<td>1.0126</td>
<td>1.014</td>
<td>1.0448</td>
<td>1.0256</td>
<td>1.0578</td>
<td>1.0416</td>
<td>1.0656</td>
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<tr>
<td>Relative Labor Productivity</td>
<td>1</td>
<td>1.0095</td>
<td>1.0193</td>
<td>1.0208</td>
<td>1.0657</td>
<td>1.0375</td>
<td>1.0828</td>
<td>1.0612</td>
<td>1.0959</td>
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<tr>
<td>Relative Investment</td>
<td>1</td>
<td>1.0067</td>
<td>1.0135</td>
<td>1.0098</td>
<td>1.0256</td>
<td>1.0205</td>
<td>1.0448</td>
<td>1.0411</td>
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<td>Relative Labor</td>
<td>1</td>
<td>0.99677</td>
<td>0.99351</td>
<td>0.98989</td>
<td>0.96628</td>
<td>0.98585</td>
<td>0.97405</td>
<td>0.98461</td>
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<tr>
<td>Cons. Equiv. Welfare Gain (percentage points)</td>
<td>0</td>
<td>0.51806</td>
<td>1.0602</td>
<td>0.86953</td>
<td>2.5339</td>
<td>2.1297</td>
<td>5.6513</td>
<td>4.4179</td>
<td>7.3592</td>
</tr>
</tbody>
</table>
Table: Undistorted Final Goods Sector: $\alpha_{yj} = 1 \quad \forall j$. Variables expressed relative to baseline values $x_{2014,\text{baseline}}$. Welfare expressed as fraction of lifetime consumption.

<table>
<thead>
<tr>
<th></th>
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<tbody>
<tr>
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<td>1</td>
<td>1.0031</td>
<td>1.0058</td>
<td>1.0058</td>
<td>1.014</td>
<td>1.0128</td>
<td>1.0297</td>
<td>1.0268</td>
<td>1.041</td>
</tr>
<tr>
<td>Relative Output</td>
<td>1</td>
<td>1.0022</td>
<td>1.0039</td>
<td>1.0032</td>
<td>1.0065</td>
<td>1.0062</td>
<td>1.011</td>
<td>1.012</td>
<td>1.0166</td>
</tr>
<tr>
<td>Relative Measured Solow Residual</td>
<td>1</td>
<td>1.0023</td>
<td>1.0041</td>
<td>1.0048</td>
<td>1.0115</td>
<td>1.0081</td>
<td>1.0139</td>
<td>1.0117</td>
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<tr>
<td>Relative Labor Productivity</td>
<td>1</td>
<td>1.0031</td>
<td>1.0056</td>
<td>1.0064</td>
<td>1.0149</td>
<td>1.0102</td>
<td>1.0151</td>
<td>1.0131</td>
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<td>Relative Investment</td>
<td>1</td>
<td>1.0016</td>
<td>1.0027</td>
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<td>1.002</td>
<td>1.0022</td>
<td>0.99958</td>
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<td>0.99835</td>
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<td>0.99597</td>
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<tr>
<td>Cons. Equiv. Welfare Gain (percentage points)</td>
<td>0</td>
<td>0.23878</td>
<td>0.43543</td>
<td>0.35922</td>
<td>0.78829</td>
<td>0.81617</td>
<td>1.8182</td>
<td>1.8203</td>
<td>2.723</td>
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</table>

Herkenhoff, Ohanian, Prescott

Regulations and The Tarnishing of the Golden State p. 39
Covariance between amenities and regulation

Using model data from 1950 - 2014 we estimate the following relationship between amenities and state regulations:

\[
a_{jt} = -1.323 \alpha_{jt} + \hat{\gamma} X_{jt} + \hat{u}_{jt}
\]

(4)

\[(0.262)\]

(5)

The point estimate on \( \alpha_{jt} \) is significant at the 1 percent level.

<table>
<thead>
<tr>
<th>Relative Consumption</th>
<th>1</th>
<th>1.0065</th>
<th>1.0128</th>
<th>1.0132</th>
<th>1.0377</th>
<th>1.031</th>
<th>1.079</th>
<th>1.0662</th>
<th>1.1082</th>
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<tbody>
<tr>
<td>Relative Output</td>
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<td>1.007</td>
<td>1.0137</td>
<td>1.0117</td>
<td>1.0296</td>
<td>1.0263</td>
<td>1.0606</td>
<td>1.0566</td>
<td>1.0884</td>
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<tr>
<td>Cons. Equiv. Welfare</td>
<td>0</td>
<td>0.60642</td>
<td>1.1871</td>
<td>1.0143</td>
<td>2.6187</td>
<td>2.49</td>
<td>6.1022</td>
<td>5.6173</td>
<td>8.9873</td>
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</table>
Data

- State population and Employment: U.S. Census and BLS
- No official long-run state CPI
- Turner, Tamura, Mulholland, & Baier (2007) construct this to 2000
  - Extension of Berry, Fording, and Hanson (2000), who use historic ‘family budget sets’ from BLS
- After 2000, we project their series onto regional CPIs ($R^2$ of .99 for 30 years of overlap), extrapolate to 2014.
- Real state GDP: Deflate nominal state output from BEA using constructed deflators

Back to calibration
Data

- Land constraints: Literature uses Wharton Land Regulation Index & Saiz MSA Supply Elasticities
  - Atemporal, do not measure usable land, unitless index, not designed for this type of model

- Our approach: feed in actual urban land acreage, infer regulations using market prices
  - State urban land from USDA Economic Research Services (ERS) 1945-1997
  - Extend ERS data using 2010 Census Urban Acreage estimates

- Historic single-family house price data from US Census of Housing (1940-2000)
- Extend with same criteria to 2014 American Community Survey
Formal Identification Proof

- Have share parameters, \( r, n_j, y_j, p_j, \) and \( x_j \)
- Solve for \( k_{hj} \): Use first order condition for \( k_{hj} \) in housing, \( \frac{r k_{hj}}{p_j h_j} = \xi \), and the fact that the stand-in household sets \( h_j = n_j \).
- Solve for \( k_{yj} \): Use first order condition for \( k_{yj} \) in final goods, \( \frac{r k_{yj}}{y_j} = \theta \)
- Solve for \( w_j \): Use first order condition for \( n_j \) in final goods, \( \frac{w_j n_j}{y_j} = \chi \)
- Solve for \( c \): Finals goods resource constraint yields \( c \) and \( y \), \( \sum_j (k_{yj} + k_{hj}) = k, y = \sum y_j \), and in steady state \( i = \delta k, c = y - i \).
- Solve for amenities \( a_j \) using the labor leisure condition:

\[
- \frac{u_{njt}}{u_{ct}} = w_{jt} - p_{jt} + \frac{a_{jt}}{u_{ct}}
\]

- Solve for effective units of land \( \alpha_{hj}x_{hj} \): Use definition of production function, \( h_j = (k_{hj})^\xi (\alpha_{hj} x_{hj})^{1-\xi} \), and solve for

\[
\alpha_{hj} x_{hj} = \left( \frac{n_j}{(k_{hj})^\xi} \right)^{(1/(1-\xi))}
\]
Formal Identification Proof

- Solve for land price $q_j$: Use land share in housing, $\frac{q_j x_{hj}}{p_j n_j} = 1 - \xi$, and land share in final goods, $\frac{q_j x_{yj}}{y_j} = 1 - \theta - \chi$. Rearrange and add these equations, and use $x_j = x_{hj} + x_{yj}$:

$$q_j x_{hj} + q_j x_{yj} = (1 - \xi)p_j n_j + (1 - \theta - \chi) y_j$$

Thus

$$q_j = \frac{1}{x_j} [(1 - \xi)p_j n_j + (1 - \theta - \chi) y_j]$$

- Recover $x_{hj}$ and $x_{yj}$: $x_{hj} = \frac{(1-\xi)p_j n_j}{q_j}$, and land share in final goods, $x_{yj} = \frac{(1-\theta-\chi) y_j}{q_j}$

- Solve for $\alpha_{hj}$ using $x_{hj}$ and the expression for effective units of land, $\alpha_{hj} x_{hj} = \left( \frac{n_j}{(k_{hj})^\xi} \right) \left( \frac{1}{(1-\xi)} \right)$, and substitute in the definition of $q_j$

$$\alpha_{hj} = \frac{(1 - \xi)}{x_j} \left( \frac{n_j}{k_{hj}} \right)^\xi \left[(1 - \xi)n_j + (1 - \theta - \chi) \frac{y_j}{p_j} \right]$$
Formal Identification Proof

- Impose $\alpha_j = \alpha_{hj} = \alpha_{yj}$. This allows us to identify TFP.
- Now using $(x_{hj}, x_{yj}, \alpha_{yj})$ and $n_j, k_j, y_j$, we can recover total factor productivity $A_j$:

$$y_j = A_j k_{yj}^\theta n_j^\chi (\alpha_{yj} x_{yj})^{1-\theta-\chi}$$
**Figure:** Labor Productivity Across Regions ($\frac{y_j}{n_j}$)
Figure: Total Factor Productivity Across Regions

[Graph showing total factor productivity across different regions from 1950 to 2014.]
Testing the Model Fit for TFP

We aggregate model state TFP to the national level and compare to actual TFP. It is very close.

Table: Comparison of aggregated Model TFP to Actual

<table>
<thead>
<tr>
<th></th>
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<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Model TFP Growth Rate</td>
<td>1.75</td>
<td>1.76</td>
<td>0.33</td>
<td>0.89</td>
<td>1.77</td>
<td>0.91</td>
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<tr>
<td>Actual TFP Growth Rate</td>
<td>2.12</td>
<td>1.81</td>
<td>0.86</td>
<td>0.50</td>
<td>1.12</td>
<td>0.87</td>
</tr>
</tbody>
</table>
Figure: Measures of Regional Amenities \((a_j)\)

- Amenities highly correlated with Albuoy (2009) measures
What are amenities $a_j$ capturing?

Our amenities generally align with quality of life indices, as well as changes over time.

<table>
<thead>
<tr>
<th>Table: Comparison of Model’s Amenities to Quality of Life Indices</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quality of Life Indices</td>
</tr>
<tr>
<td>Albouy Rank*</td>
</tr>
<tr>
<td>---------------------------------------------------------------</td>
</tr>
<tr>
<td>Correlation between Model Amenity Rank* and Quality of Life Index Rank*</td>
</tr>
</tbody>
</table>

*Rank equal to 1 indicates best place to live, Rank equal to 48 indicates worst place to live.