

# 03-economic-mobility-deserts

November 28, 2025

## 1 Economic Mobility Deserts: Identifying Areas of Declining Opportunity

### 1.1 Executive Summary

This notebook identifies **economic mobility deserts** - areas where economic opportunity is declining based on real Census and economic data.

#### 1.1.1 KRL Suite Components Used

- **krl\_data\_connectors.community**: `CensusACSPublicConnector` for demographics, `BEAConnector` for regional income
- **krl\_models**: `LocationQuotientModel`, `ShiftShareModel` for regional economic analysis
- **krl\_policy**: `TreatmentEffectEstimator`, `DifferenceInDifferences` for causal inference
- **krl\_core**: Logging and utilities

#### 1.1.2 Key Intelligence Questions

1. Which states show declining economic opportunity?
2. How do income, poverty, and education levels correlate?
3. What regional economic structures drive opportunity differences?
4. What policy factors correlate with mobility outcomes?

#### 1.1.3 Methodology

Census ACS  
Demographics

BEA Regional  
Income Data

BLS Labor  
Statistics

Opportunity Index  
Construction

Location	Shift-Share	Causal
Quotient	Analysis	Inference

**Estimated Time:** 25-30 minutes

**Difficulty:** Intermediate to Advanced

## 1.2 1. Environment Setup and Data Loading

```
[1]: # Core imports
import os
import sys
import warnings
from datetime import datetime
from pathlib import Path
import importlib

# Add KRL package paths (handles spaces in path correctly)
_krl_base = os.path.expanduser("~/Documents/GitHub/KRL/Private IP")
for _pkg in [
    "krl-open-core/src",
    "krl-data-connectors/src",
    "krl-model-zoo-v2-2.0.0-dev", # Use the dev version with all models
    "krl-causal-policy-toolkit/src"
]:
    _path = os.path.join(_krl_base, _pkg)
    if _path not in sys.path:
        sys.path.insert(0, _path)

# Load environment variables from .env file
from dotenv import load_dotenv
_env_path = os.path.expanduser("~/Documents/GitHub/KRL/krl-tutorials/.env")
load_dotenv(_env_path)

# Force complete reload of KRL modules to pick up any changes
_modules_to_reload = [k for k in sys.modules.keys() if k.
    ↳startswith(('krl_core', 'krl_data_connectors', 'krl_models', 'krl_policy'))]
for _mod in _modules_to_reload:
    del sys.modules[_mod]

import numpy as np
import pandas as pd

# Visualization
import plotly.express as px
import plotly.graph_objects as go
from plotly.subplots import make_subplots
```

```

# =====
# KRL Suite Imports - REAL package imports
# =====

# KRL Data Connectors - Community Tier
from krl_data_connectors.community import (
    CensusACSPublicConnector, # Census demographics
    BEAConnector,             # Bureau of Economic Analysis
    FREDBasicConnector,       # Federal Reserve data
    BLSBasicConnector,        # Labor statistics
)

# KRL Models - Regional Analysis
from krl_models import LocationQuotientModel, ShiftShareModel

# KRL Policy - Causal Inference
from krl_policy import TreatmentEffectEstimator, DifferenceInDifferences

# KRL Core - Utilities
from krl_core import get_logger

warnings.filterwarnings('ignore', category=FutureWarning)

# Initialize logger
logger = get_logger("EconomicMobilityDeserts")

print("=" * 65)
print(" Economic Mobility Deserts Analysis")
print("=" * 65)
print(f" Execution Time: {datetime.now().strftime('%Y-%m-%d %H:%M:%S')}")
print(f" Using KRL Suite (Community Tier + Models + Policy)")
print(f" API Keys: FRED={' ' if os.getenv('FRED_API_KEY') else ' '} | BEA={' ' if os.
    ↪if os.getenv('BEA_API_KEY') else ' '} | Census={' ' if os.
    ↪getenv('CENSUS_API_KEY') else ' '}")
print("=" * 65)

```

```

=====
Economic Mobility Deserts Analysis
=====

Execution Time: 2025-11-28 04:19:47
Using KRL Suite (Community Tier + Models + Policy)
API Keys: FRED=  | BEA=  | Census=
=====

```

```

[2]: # =====
# Initialize KRL Data Connectors

```

```
# =====

# Initialize all connectors
census = CensusACSPublicConnector()
bea = BEAConnector()
fred = FREDBasicConnector()
bls = BLSBasicConnector()

# Test connections
print(" Testing API Connections...")
print(f" Census: {census.connect()}")
print(f" BEA: {bea.connect()}")
print(f" FRED: {fred.connect()}")
print(f" BLS: {bls.connect()}")

print("\n KRL Suite Packages Loaded:")
print(" • krl_data_connectors: Census, BEA, FRED, BLS")
print(" • krl_models: LocationQuotientModel, ShiftShareModel")
print(" • krl_policy: TreatmentEffectEstimator, DifferenceInDifferences")
```

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```

```

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```

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    Testing API Connections...
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"levelname": "INFO", "taskName": "Task-27"}
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    BEA: None
    Census: True
    BEA: None
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    FRED: True
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{"file": "bls_basic.py", "line": 128, "function": "connect"}, "levelname":
"INFO", "taskName": "Task-27"}
    BLS: True

KRL Suite Packages Loaded:
    • krl_data_connectors: Census, BEA, FRED, BLS
    • krl_models: LocationQuotientModel, ShiftShareModel
    • krl_policy: TreatmentEffectEstimator, DifferenceInDifferences
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"INFO", "taskName": "Task-27"}
    BLS: True

KRL Suite Packages Loaded:
    • krl_data_connectors: Census, BEA, FRED, BLS

```

- krl\_models: LocationQuotientModel, ShiftShareModel
- krl\_policy: TreatmentEffectEstimator, DifferenceInDifferences

## 1.3 2. Data Collection: Multi-Source Economic Indicators

We'll collect data from multiple sources to build a comprehensive opportunity index:

Source	Data	Indicator
Census ACS	Demographics	Income, poverty, education
BEA	Regional Accounts	Personal income by state
BLS	Labor Statistics	Unemployment, earnings
FRED	Economic Data	GDP, housing, inflation

```
[3]: # =====
# Fetch Census Demographics for Opportunity Index
# =====

# Get comprehensive state demographics
demographics_2022 = census.get_demographics_by_state(year=2022)
demographics_2017 = census.get_demographics_by_state(year=2017)

print(" Census ACS Demographics Retrieved:")
print(f"    2022: {len(demographics_2022)} states")
print(f"    2017: {len(demographics_2017)} states")

# Rename columns for clarity
var_names = {
    'B01001_001E': 'population',
    'B01002_001E': 'median_age',
    'B19013_001E': 'median_income',
    'B17001_002E': 'poverty_pop',
    'B02001_002E': 'white_pop',
    'B02001_003E': 'black_pop',
    'B02001_005E': 'asian_pop',
    'B03003_003E': 'hispanic_pop',
}

# Rename and compute derived metrics
for df in [demographics_2017, demographics_2022]:
    for old_name, new_name in var_names.items():
        if old_name in df.columns:
            df.rename(columns={old_name: new_name}, inplace=True)

# Compute rates
if 'poverty_pop' in df.columns and 'population' in df.columns:
    df['poverty_rate'] = (df['poverty_pop'] / df['population']) * 100
```

```
demographics_2022.head()
```

```
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  Census ACS Demographics Retrieved:
    2022: 52 states
    2017: 52 states
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  Census ACS Demographics Retrieved:
    2022: 52 states
    2017: 52 states
```

```
[3]:
```

	NAME	population	median_age	white_pop	black_pop	asian_pop	\
0	Alabama	5028092	39.3	3329012	1326341	69808	
1	Alaska	734821	35.3	450472	23395	47464	
2	Arizona	7172282	38.4	4781702	327077	240642	
3	Arkansas	3018669	38.4	2193348	456693	47413	
4	California	39356104	37.3	18943660	2202587	5949136	



	hispanic_pop	median_income	poverty_pop	state	poverty_rate
0	232407	59609	768897	01	15.292023
1	54890	86370	75227	02	10.237459
2	2297513	72581	916876	04	12.783602
3	243321	56335	475729	05	15.759562
4	15617930	91905	4685272	06	11.904817

### 1.4 3. Economic Indicators from FRED and BLS

Fetch additional economic context to understand mobility barriers.

```
[4]: # =====
# Fetch National Economic Indicators from FRED & BLS
# =====

# GDP growth (proxy for economic opportunity)
gdp = fred.get_series("GDP", start_date="2015-01-01", end_date="2024-12-31")

# Unemployment rate (labor market tightness)
unemployment = bls.get_unemployment_rate()

# CPI (cost of living pressure)
cpi = fred.get_series("CPIAUCSL", start_date="2015-01-01",
    ↪end_date="2024-12-31")

# Average hourly earnings
earnings = bls.get_series("CES0500000003")

print(" Economic Indicators Retrieved:")
print(f" GDP: {len(gdp)} observations")
print(f" Unemployment: {len(unemployment)} observations")
print(f" CPI: {len(cpi)} observations")
print(f" Earnings: {len(earnings)} observations")

# Compute summary stats
print("\n National Economic Context:")
print(f" GDP Growth (2015-2024): {(gdp['value'].iloc[-1] / gdp['value'].
    ↪iloc[0]) - 1) * 100:.1f}%")
print(f" CPI Growth: {(cpi['value'].iloc[-1] / cpi['value'].iloc[0]) - 1) *
    ↪100:.1f}%")
print(f" Current Unemployment: {unemployment['value'].iloc[-1]:.1f}%")
```

```
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```

```

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"BLSBasicConnector", "message": "Fetching BLS series: CES0500000003", "source":
{"file": "bls_basic.py", "line": 196, "function": "get_series"}, "levelname":
"INFO", "taskName": "Task-33", "series_id": "CES0500000003", "start_year": 2016,
"end_year": 2025}
{"timestamp": "2025-11-28T09:19:50.597616Z", "level": "INFO", "name":
"BLSBasicConnector", "message": "Retrieved 117 observations for CES0500000003",
"source": {"file": "bls_basic.py", "line": 242, "function": "get_series"},
"levelname": "INFO", "taskName": "Task-33", "series_id": "CES0500000003",
"rows": 117}
Economic Indicators Retrieved:
    GDP: 40 observations
    Unemployment: 117 observations
    CPI: 120 observations
    Earnings: 117 observations

National Economic Context:
    GDP Growth (2015-2024): 65.1%
    CPI Growth: 35.3%
    Current Unemployment: 4.4%
{"timestamp": "2025-11-28T09:19:50.597616Z", "level": "INFO", "name":
"BLSBasicConnector", "message": "Retrieved 117 observations for CES0500000003",
"source": {"file": "bls_basic.py", "line": 242, "function": "get_series"},
"levelname": "INFO", "taskName": "Task-33", "series_id": "CES0500000003",
"rows": 117}
Economic Indicators Retrieved:
    GDP: 40 observations
    Unemployment: 117 observations
    CPI: 120 observations
    Earnings: 117 observations

National Economic Context:
    GDP Growth (2015-2024): 65.1%
    CPI Growth: 35.3%
    Current Unemployment: 4.4%

```

```

[5]: # =====
# Calculate Opportunity Change Index by State
# =====

# Merge 2017 and 2022 demographics
df_2017 = demographics_2017.set_index('NAME')
df_2022 = demographics_2022.set_index('NAME')

```

```

# Calculate changes
opportunity_df = pd.DataFrame({
    'state': df_2022.index,
    'income_2017': df_2017['median_income'].values,
    'income_2022': df_2022['median_income'].values,
    'poverty_rate_2017': df_2017['poverty_rate'].values,
    'poverty_rate_2022': df_2022['poverty_rate'].values,
    'population_2022': df_2022['population'].values,
})

# Compute change metrics
opportunity_df['income_growth'] = ((opportunity_df['income_2022'] /
    ↪ opportunity_df['income_2017']) - 1) * 100
opportunity_df['poverty_change'] = opportunity_df['poverty_rate_2022'] -
    ↪ opportunity_df['poverty_rate_2017']

# Opportunity Score: High income growth + declining poverty = better opportunity
opportunity_df['opportunity_score'] = (
    opportunity_df['income_growth'].rank(pct=True) * 0.5 +
    (-opportunity_df['poverty_change']).rank(pct=True) * 0.5
) * 100

opportunity_df = opportunity_df.sort_values('opportunity_score',
    ↪ ascending=False)
opportunity_df['rank'] = range(1, len(opportunity_df) + 1)

print(" Opportunity Score Calculated:")
opportunity_df[['state', 'income_growth', 'poverty_change',
    ↪ 'opportunity_score', 'rank']].head(10)

```

Opportunity Score Calculated:

```

[5]:
      state  income_growth  poverty_change  opportunity_score \
32    New York      311.560051      -31.204451           100.000000
29  New Hampshire      106.180069      -10.147517           96.153846
44      Utah         86.597185       -9.330509           93.269231
11    Hawaii        116.406090       -8.231683           93.269231
21  Massachusetts      97.833173       -6.530596           89.423077
7      Delaware      69.795368       -9.311553           89.423077
23    Minnesota      73.098875       -7.189227           88.461538
45    Vermont       58.454292       -8.977004           83.653846
8  District of Columbia    118.888793       -2.896905           80.769231
1      Alaska       67.572077       -3.945857           78.846154

      rank
32      1

```

29	2
44	3
11	4
21	5
7	6
23	7
45	8
8	9
1	10

## 1.5 4. Regional Economic Analysis with KRL Models

Using `krl_models` for regional economic analysis - specifically the Location Quotient and Shift-Share methods.

```
[6]: # =====
# Demonstrate KRL Model Zoo: Location Quotient
# =====

# Create synthetic regional employment data for demonstration
# In production, this would come from BLS QCEW or CBP data

np.random.seed(42)

# Create sample employment data by region and industry
regions = opportunity_df['state'].head(10).tolist()
industries = ['Manufacturing', 'Services', 'Technology', 'Healthcare', 'Retail']

employment_data = []
for region in regions:
    region_factor = np.random.uniform(0.8, 1.2)
    for industry in industries:
        industry_factor = {'Manufacturing': 0.8, 'Services': 1.0, 'Technology': 1.2,
                           'Healthcare': 1.1, 'Retail': 0.9}[industry]
        employment = int(10000 * region_factor * industry_factor * np.random.
                           uniform(0.7, 1.3))
        employment_data.append({
            'region': region,
            'industry': industry,
            'employment': employment
        })

employment_df = pd.DataFrame(employment_data)

print(" Sample Regional Employment Data:")
print(f" Regions: {len(regions)}")
```

```
print(f"    Industries: {len(industries)}")
employment_df.head(10)
```

Sample Regional Employment Data:

Regions: 10

Industries: 5

```
[6]:
```

	region	industry	employment
0	New York	Manufacturing	9653
1	New York	Services	10820
2	New York	Technology	12072
3	New York	Healthcare	8291
4	New York	Retail	6783
5	New Hampshire	Manufacturing	8032
6	New Hampshire	Services	8731
7	New Hampshire	Technology	11112
8	New Hampshire	Healthcare	6450
9	New Hampshire	Retail	9498

```
[7]: # =====
# Apply Location Quotient Model
# =====

# Initialize and fit Location Quotient Model
lq_model = LocationQuotientModel(
    industry_col='industry',
    employment_col='employment',
    region_col='region'
)

# Fit the model
lq_model.fit(employment_df)

# Get Location Quotient matrix
lq_matrix = lq_model.get_location_quotients()

print(" Location Quotient Matrix (LQ > 1 = Regional Specialization):")
print(lq_matrix.round(2))

# Identify specialized industries for top region
top_region = regions[0]
specialized = lq_model.get_specialized_industries(top_region, threshold=1.1)
print(f"\n {top_region} Specializations (LQ > 1.1):")
for industry, lq in specialized.items():
    print(f"    • {industry}: LQ = {lq:.2f}")
```

Location Quotient Matrix (LQ > 1 = Regional Specialization):

industry	Healthcare	Manufacturing	Retail	Services	Technology
----------	------------	---------------	--------	----------	------------

region					
Alaska	0.88	1.40	1.01	0.89	0.92
Delaware	1.25	0.72	1.08	0.70	1.15
District of Columbia	1.14	0.67	1.04	1.12	0.97
Hawaii	1.02	0.94	1.00	1.21	0.85
Massachusetts	1.16	1.18	0.74	0.88	1.03
Minnesota	0.88	0.79	1.05	1.23	1.02
New Hampshire	0.70	1.11	1.18	1.02	1.03
New York	0.83	1.23	0.77	1.16	1.03
Utah	1.07	0.93	1.15	0.96	0.91
Vermont	0.92	1.19	0.98	0.87	1.06

New York Specializations (LQ > 1.1):

- Manufacturing: LQ = 1.23
- Services: LQ = 1.16

## 1.6 5. Identifying Mobility Deserts

States with low opportunity scores and declining economic conditions are classified as “mobility deserts.”

```
[8]: # =====
# Classify States as Opportunity Zones or Mobility Deserts
# =====

def classify_opportunity(score):
    if score >= 75:
        return 'Opportunity Zone'
    elif score >= 50:
        return 'Stable'
    elif score >= 25:
        return 'At Risk'
    else:
        return 'Mobility Desert'

opportunity_df['classification'] = opportunity_df['opportunity_score'].
    ↪apply(classify_opportunity)

# Count by classification
class_counts = opportunity_df['classification'].value_counts()

print(" State Classification by Opportunity Level:")
for classification, count in class_counts.items():
    pct = count / len(opportunity_df) * 100
    print(f" • {classification}: {count} states ({pct:.0f}%)")

# Show mobility deserts
deserts = opportunity_df[opportunity_df['classification'] == 'Mobility Desert']
```

```
print(f"\n Mobility Deserts ({len(deserts)} states):")
for _, row in deserts.iterrows():
    print(f"    • {row['state']}: Income growth {row['income_growth']:.1f}%,  
↳Poverty change {row['poverty_change']:+.1f}pts")
```

State Classification by Opportunity Level:

- At Risk: 18 states (35%)
- Opportunity Zone: 13 states (25%)
- Stable: 12 states (23%)
- Mobility Desert: 9 states (17%)

Mobility Deserts (9 states):

- Montana: Income growth 1.6%, Poverty change +1.3pts
- Louisiana: Income growth 3.1%, Poverty change +3.6pts
- Mississippi: Income growth -7.1%, Poverty change +2.9pts
- Arkansas: Income growth -0.6%, Poverty change +4.1pts
- Florida: Income growth -10.8%, Poverty change +2.7pts
- Ohio: Income growth -9.2%, Poverty change +3.2pts
- New Mexico: Income growth -3.6%, Poverty change +7.1pts
- West Virginia: Income growth -25.6%, Poverty change +5.6pts
- Puerto Rico: Income growth -63.3%, Poverty change +30.6pts

```
[9]: # =====
# Visualization: Opportunity Score Map
# =====

# Add state abbreviations
state_abbrev = {
    'Alabama': 'AL', 'Alaska': 'AK', 'Arizona': 'AZ', 'Arkansas': 'AR',  
↳'California': 'CA',  
    'Colorado': 'CO', 'Connecticut': 'CT', 'Delaware': 'DE', 'Florida': 'FL',  
↳'Georgia': 'GA',  
    'Hawaii': 'HI', 'Idaho': 'ID', 'Illinois': 'IL', 'Indiana': 'IN', 'Iowa':  
↳'IA',  
    'Kansas': 'KS', 'Kentucky': 'KY', 'Louisiana': 'LA', 'Maine': 'ME',  
↳'Maryland': 'MD',  
    'Massachusetts': 'MA', 'Michigan': 'MI', 'Minnesota': 'MN', 'Mississippi':  
↳'MS', 'Missouri': 'MO',  
    'Montana': 'MT', 'Nebraska': 'NE', 'Nevada': 'NV', 'New Hampshire': 'NH',  
↳'New Jersey': 'NJ',  
    'New Mexico': 'NM', 'New York': 'NY', 'North Carolina': 'NC', 'North  
↳Dakota': 'ND', 'Ohio': 'OH',  
    'Oklahoma': 'OK', 'Oregon': 'OR', 'Pennsylvania': 'PA', 'Rhode Island':  
↳'RI', 'South Carolina': 'SC',  
    'South Dakota': 'SD', 'Tennessee': 'TN', 'Texas': 'TX', 'Utah': 'UT',  
↳'Vermont': 'VT',
```



```

    'Virginia': 'VA', 'Washington': 'WA', 'West Virginia': 'WV', 'Wisconsin': 'WI',
    'Wyoming': 'WY',
    'District of Columbia': 'DC', 'Puerto Rico': 'PR'
}

opportunity_df['state_abbrev'] = opportunity_df['state'].map(state_abbrev)

fig = px.choropleth(
    opportunity_df,
    locations='state_abbrev',
    locationmode='USA-states',
    color='opportunity_score',
    scope='usa',
    color_continuous_scale='RdYlGn',
    hover_name='state',
    hover_data={'income_growth': ':.1f', 'poverty_change': ':.1f',
    'opportunity_score': ':.0f'},
    title='Economic Opportunity Score by State (2017-2022)',
)

fig.update_layout(height=500)
fig.show()

```

## 1.7 6. Causal Analysis with KRL Policy Toolkit

Using `krl_policy` for causal inference to understand policy impacts on mobility.

### 1.7.1 Performance Optimization Note

The `TreatmentEffectEstimator` has been optimized with parallel processing for maximum precision:

Feature	Benefit	Configuration
<b>High Bootstrap Count</b>	Stable CI endpoints, minimal p-value jitter	<code>n_bootstrap=2000</code>
<b>Parallel Processing</b>	Near-instant computation across all cores	<code>n_jobs=-1</code>
<b>Progress Tracking</b>	Real-time iteration monitoring	Automatic via <code>tqdm</code>

**Bootstrap Accuracy Hierarchy:** - **B = 200-400:** Minimal viability (tails wobble, CI jitter) - **B = 800-1200:** Stability zone (endpoints stop drifting) - **B = 2000: High-fidelity inference** (stable p-values, tight CIs) ← **This notebook** - **B > 5000:** Asymptotic luxury (diminishing returns)

**Why B=2000?** Bootstrap error declines at  $O(1/\sqrt{B})$ . With parallel processing removing runtime penalty, B=2000 delivers maximum practical precision before diminishing returns dominate.

See [TREATMENT\\_EFFECT\\_OPTIMIZATION.md](#) for technical details.

```
[10]: # =====
# Demonstrate KRL Policy: Treatment Effect Estimation
# =====

# Create sample data for policy evaluation
# Simulate: States that implemented workforce programs vs. control states

np.random.seed(42)
n_states = len(opportunity_df)

# Assign treatment (workforce program) to states with lower opportunity
opportunity_df['treatment'] = (opportunity_df['opportunity_score'] < 50).
    ↳astype(int)

# Outcome: Simulated employment growth
opportunity_df['outcome'] = (
    opportunity_df['income_growth'] * 0.3 +
    opportunity_df['treatment'] * 5 + # Treatment effect
    np.random.normal(0, 3, n_states)
)

print(" Policy Evaluation Dataset:")
print(f" Treatment group (workforce program): {opportunity_df['treatment'].
    ↳sum()} states")
print(f" Control group: {(1 - opportunity_df['treatment']).sum()} states")
print(f"\n Mean outcome (treated):↳
    ↳{opportunity_df[opportunity_df['treatment']==1]['outcome'].mean():.2f}")
print(f" Mean outcome (control):↳
    ↳{opportunity_df[opportunity_df['treatment']==0]['outcome'].mean():.2f}")
```

```
Policy Evaluation Dataset:
Treatment group (workforce program): 27 states
Control group: 25 states

Mean outcome (treated): 5.72
Mean outcome (control): 20.42
```

```
[11]: # =====
# Apply Treatment Effect Estimator - HIGH-PRECISION VERSION
# =====

print(" High-Precision Configuration:")
print(" • Bootstrap Iterations: 2000 (maximum stability)")
print(" • Parallel Processing: All CPU cores")
print(" • Adaptive Bootstrap: Disabled (using full iteration count)")
print(" • Progress Tracking: Real-time via tqdm\n")
```

```

# Prepare data for treatment effect estimation
te_data = opportunity_df[['income_2017', 'poverty_rate_2017', 'treatment', 'outcome']].copy()
te_data = te_data.fillna(0)

# Initialize Treatment Effect Estimator for maximum precision
te_estimator = TreatmentEffectEstimator(
    method='doubly_robust',
    treatment_col='treatment',
    outcome_col='outcome',
    n_bootstrap=2000,          # High iteration count for stable CI endpoints
    adaptive_bootstrap=False, # Use full 2000 iterations
    n_jobs=-1,                # Parallel across all CPU cores
    random_state=42
)

print(" Fitting doubly robust estimator with 2000 bootstrap iterations...")
print(" (Parallel processing makes this fast despite high iteration count)\n")

import time
start_time = time.time()

# Estimate Average Treatment Effect
te_estimator.fit(
    data=te_data,
    treatment_col='treatment',
    outcome_col='outcome',
    covariate_cols=['income_2017', 'poverty_rate_2017']
)

elapsed = time.time() - start_time

print(f"\n Estimation complete in {elapsed:.2f} seconds")
print("\n Treatment Effect Estimation (Doubly Robust):")
print(f" Average Treatment Effect (ATE): {te_estimator.effect_:.2f}")
print(f" Standard Error: {te_estimator.std_error_:.2f}")
print(f" 95% CI: [{te_estimator.ci_[0]:.2f}, {te_estimator.ci_[1]:.2f}]")
print(f" P-value: {te_estimator.p_value_:.4f}")

if te_estimator.p_value_ < 0.05:
    print("\n Statistically significant treatment effect detected")
else:
    print("\n Treatment effect not statistically significant")

print("\n Why B=2000?")
print(" • Bootstrap error declines at  $O(1/\sqrt{B})$ ")

```

```
print("    • B=2000 ensures stable CI endpoints and p-values")
print("    • Parallel processing removes runtime penalty")
print("    • Beyond 2000, diminishing returns dominate")
```

High-Precision Configuration:

- Bootstrap Iterations: 2000 (maximum stability)
- Parallel Processing: All CPU cores
- Adaptive Bootstrap: Disabled (using full iteration count)
- Progress Tracking: Real-time via tqdm

Fitting doubly robust estimator with 2000 bootstrap iterations...  
(Parallel processing makes this fast despite high iteration count)

```
{"timestamp": "2025-11-28T09:19:51.527937Z", "level": "INFO", "name":
"krl_policy.estimators.treatment_effect", "message": "Fitted doubly_robust:
ATE=-4.2258 (SE=2.7366, p=0.1226)", "source": {"file": "treatment_effect.py",
"line": 284, "function": "fit"}, "levelname": "INFO", "taskName": "Task-54"}
```

Estimation complete in 0.01 seconds

Treatment Effect Estimation (Doubly Robust):

Average Treatment Effect (ATE): -4.23

Standard Error: 2.74

95% CI: [-9.59, 1.14]

P-value: 0.1226

Treatment effect not statistically significant

Why B=2000?

- Bootstrap error declines at  $O(1/\sqrt{B})$
- B=2000 ensures stable CI endpoints and p-values
- Parallel processing removes runtime penalty
- Beyond 2000, diminishing returns dominate

## 1.8 7. Visualization Dashboard

```
[12]: # =====
# Dashboard: Economic Mobility Indicators
# =====

fig = make_subplots(
    rows=2, cols=2,
    subplot_titles=(
        'Opportunity Score Distribution',
        'Income Growth vs Poverty Change',
        'Classification by State Count',
        'Top/Bottom States by Opportunity'
    ),
```

```

        specs=[{"type": "histogram"}, {"type": "scatter"}],
                [{"type": "pie"}, {"type": "bar"}]]
    )

    # Histogram of opportunity scores
    fig.add_trace(
        go.Histogram(x=opportunity_df['opportunity_score'], nbinsx=20,
            ↪marker_color='#0077BB'),
            row=1, col=1
    )

    # Scatter: Income growth vs poverty change
    fig.add_trace(
        go.Scatter(
            x=opportunity_df['income_growth'],
            y=opportunity_df['poverty_change'],
            mode='markers',
            marker=dict(color=opportunity_df['opportunity_score'],
            ↪colorscale='RdYlGn', size=10),
            text=opportunity_df['state'],
            hovertemplate='%{text}<br>Income: %{x:.1f}%<br>Poverty: %{y:.1f}pts'
        ),
            row=1, col=2
    )

    # Pie: Classification counts
    class_counts = opportunity_df['classification'].value_counts()
    fig.add_trace(
        go.Pie(labels=class_counts.index, values=class_counts.values,
            marker=dict(colors=['#009988', '#EE7733', '#CC3311', '#0077BB'])),
            row=2, col=1
    )

    # Bar: Top/bottom states
    top_5 = opportunity_df.head(5)
    bottom_5 = opportunity_df.tail(5)
    combined = pd.concat([top_5, bottom_5])

    fig.add_trace(
        go.Bar(x=combined['state'], y=combined['opportunity_score'],
            marker_color=['#009988']*5 + ['#CC3311']*5),
            row=2, col=2
    )

    fig.update_layout(height=700, showlegend=False, title_text='Economic Mobility
    ↪Analysis Dashboard')
    fig.show()

```

## 1.9 8. Key Insights & Policy Implications

```
[13]: # =====
# Key Insights Summary
# =====

print("=" * 65)
print(" KEY INSIGHTS: Economic Mobility Deserts Analysis")
print("=" * 65)

print(f"\n Geographic Scope: 50 States + DC")
print(f" Analysis Period: 2017-2022")

print(f"\n NATIONAL TRENDS:")
print(f"     • Avg Income Growth: {opportunity_df['income_growth'].mean():.1f}%")
print(f"     • Avg Poverty Change: {opportunity_df['poverty_change'].mean():+.2f}_pts")
print(f"     • States Improving: {(opportunity_df['opportunity_score'] >= 50).sum()}")
print(f"     • States Declining: {(opportunity_df['opportunity_score'] < 50).sum()}")

print(f"\n TOP 5 OPPORTUNITY STATES:")
for _, row in opportunity_df.head(5).iterrows():
    print(f"     {row['rank']}. {row['state']}: Score {row['opportunity_score']:.0f}")

print(f"\n MOBILITY DESERTS:")
for _, row in opportunity_df.tail(5).iterrows():
    print(f"     {row['rank']}. {row['state']}: Score {row['opportunity_score']:.0f}")

print("\n" + "=" * 65)
print(" POLICY RECOMMENDATIONS")
print("=" * 65)
print("""
1. TARGETED INTERVENTIONS: Focus workforce programs on
   mobility desert states showing declining opportunity.

2. EARLY WARNING: Use Location Quotient analysis to
   identify regions losing key industries.

3. CAUSAL EVALUATION: Apply Difference-in-Differences
   to measure policy effectiveness over time.

4. GRANULAR ANALYSIS: Upgrade to Professional tier for
   county/tract-level mobility desert identification.
```

## =====

### KEY INSIGHTS: Economic Mobility Deserts Analysis

## =====

Geographic Scope: 50 States + DC  
 Analysis Period: 2017-2022

#### NATIONAL TRENDS:

- Avg Income Growth: 36.1%
- Avg Poverty Change: -1.69 pts
- States Improving: 25
- States Declining: 27

#### TOP 5 OPPORTUNITY STATES:

1. New York: Score 100
2. New Hampshire: Score 96
3. Utah: Score 93
4. Hawaii: Score 93
5. Massachusetts: Score 89

#### MOBILITY DESERTS:

48. Florida: Score 11
49. Ohio: Score 10
50. New Mexico: Score 9
51. West Virginia: Score 5
52. Puerto Rico: Score 2

## =====

### POLICY RECOMMENDATIONS

## =====

1. TARGETED INTERVENTIONS: Focus workforce programs on mobility desert states showing declining opportunity.
2. EARLY WARNING: Use Location Quotient analysis to identify regions losing key industries.
3. CAUSAL EVALUATION: Apply Difference-in-Differences to measure policy effectiveness over time.
4. GRANULAR ANALYSIS: Upgrade to Professional tier for county/tract-level mobility desert identification.

## 1.10 9. Data Provenance & Next Steps

### 1.10.1 Data Sources Used

Source	Package	Data
Census ACS	CensusACSPublicConnector	State demographics
FRED	FREDBasicConnector	GDP, CPI
BLS	BLSBasicConnector	Unemployment, earnings

### 1.10.2 KRL Suite Components Demonstrated

Package	Component	Use Case
krl_models	LocationQuotientModel	Regional industry specialization
krl_policy	TreatmentEffectEstimator	Policy impact evaluation

### 1.10.3 Next Steps

- [04-environmental-justice-health.ipynb](#): Environmental burden analysis
- [10-urban-resilience-dashboard.ipynb](#): Complete integration workflow

### 1.10.4 Professional Tier Features

```
from krl_data_connectors.professional import LODESConnector
from krl_policy import SyntheticControlMethod

# Tract-level job access data
lodes = LODESConnector(license_key="YOUR_KEY")
job_access = lodes.get_rac(state="CA", year=2021)

# Synthetic control for policy evaluation
scm = SyntheticControlMethod()
scm.fit(panel_data, treated_unit="California", treatment_time=2018)
```

---

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*This notebook is part of the Khipu Socioeconomic Analysis Suite public showcase.*