

# Modeling: Predicting Food Affordability

Seungwon (Sydney) Lee      Demi Leng      Darlane Zhang  
Hannah Chung

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## 1 RQ1: Which socioeconomic and geographic factors most strongly predict food affordability in California?

### 1.1 Approach

To identify which socioeconomic and geographic factors most strongly predict food affordability in California, we focus on a small set of interpretable predictors:

- **Socioeconomic:** median\_income
- **Geographic:** region\_name
- **Demographic:** race\_eth\_name

**Why filter to geotype == "PL"?** We restrict the analysis to place-level observations to keep the unit of analysis consistent (cities/towns/CDPs) and avoid mixing geographic levels that may have different variance structures.

**Modeling choice:** We compare a baseline (mean-only) model to Ridge regression models using 1-, 2-, and 3-feature subsets. Ridge is a linear model that remains interpretable while stabilizing estimates when one-hot encoding categorical predictors.

**Important note on leakage / interpretability:** We intentionally did not usecost\_yr as a predictor here because affordability\_ratio is conceptually tied to cost and income. Including variables that directly define the outcome can inflate predictive performance without answering “which contextual factors matter most.”

```
import numpy as np
import pandas as pd
```

```

from pathlib import Path
import matplotlib.pyplot as plt

from sklearn.model_selection import train_test_split
from sklearn.dummy import DummyRegressor
from sklearn.metrics import mean_absolute_error, r2_score
from utils.model_utils import rmse, make_ridge_model, eval_model_rq1

RANDOM_STATE = 159
np.random.seed(RANDOM_STATE)

DATA_PATH = Path("./data/food_affordability.csv")
OUT_DIR = Path("./outputs"); OUT_DIR.mkdir(exist_ok=True)
FIG_DIR = Path("./figures"); FIG_DIR.mkdir(exist_ok=True)

df = pd.read_csv(DATA_PATH)

drop_cols = [
    "version", "ind_definition", "ind_id", "reportyear",
    "LL95_affordability_ratio", "UL95_affordability_ratio",
    "se_food_afford", "rse_food_afford",
    "county_name", "county_fips", "region_code",
    "ave_fam_size"
]
df = df.drop(columns=drop_cols, errors="ignore")

df.shape
(14365, 11)

TARGET = "affordability_ratio"
FULL_FEATURES = ["region_name", "race_eth_name", "median_income"]

# Filter to Place -level only
df_pl = df[df["geotype"] == "PL"].copy()

# Keep only rows where target and all full features exist
df_pl = df_pl.dropna(subset=[TARGET] + FULL_FEATURES).copy()

print("Rows after PL filter + dropna:", df_pl.shape[0])
df_pl[FULL_FEATURES + [TARGET]].head()

Rows after PL filter + dropna: 3003

```

	region_name	race_eth_name	median_income	affordability_ratio
539	Bay Area	Total	102750.0	0.057327
554	Southern California	White	12500.0	0.647035
557	Southern California	Total	12500.0	0.647035
560	Southern California	AfricanAm	17310.0	0.543686
561	Southern California	Latino	14933.0	0.630229

```

# one consistent split for fair comparison across models
X = df_pl[FULL_FEATURES].copy()
y = df_pl[TARGET].copy()

X_train, X_test, y_train, y_test = train_test_split(
    X, y, test_size=0.2, random_state=RANDOM_STATE
)

X_train.shape, X_test.shape
((2402, 3), (601, 3))

import itertools

features = FULL_FEATURES # ["region_name", "race_eth_name", "median_income"]
results = []

# Baseline model
dummy = DummyRegressor(strategy="mean")
dummy.fit(X_train, y_train)
pred_dummy = dummy.predict(X_test)
results.append({
    "model": "Dummy(mean)",
    "features": "",
    "RMSE": rmse(y_test, pred_dummy),
    "MAE": mean_absolute_error(y_test, pred_dummy),
    "R2": r2_score(y_test, pred_dummy),
})

# Models using 1 feature, 2 features, and all 3 features
for k in [1, 2, 3]:
    for subset in itertools.combinations(features, k):
        subset = list(subset)
        name = f"Ridge(log1p y) | {''.join(subset)}"
```

```

model = make_ridge_model(subset, X_train)

out = eval_model_rq1(
    name,
    model,
    X_train[subset], X_test[subset],
    y_train, y_test
)
out["features"] = ", ".join(subset)
results.append(out)

metrics_rq1 = pd.DataFrame(results).sort_values("RMSE")
metrics_rq1

```

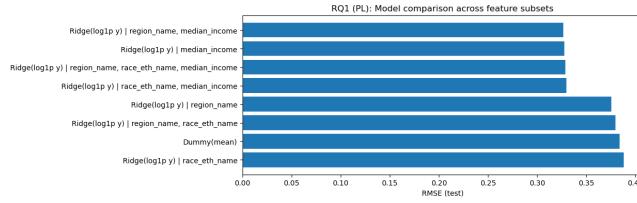
	model	features	RMSE	MAE	R2
5	Ridge(log1p region_name0.326686 y)   re- me- gion_name, dian_income me- dian_income		0.144770	0.270545	
3	Ridge(log1p median_income0.327603 y)   me- dian_income		0.149809	0.266445	
7	Ridge(log1p region_name0.328525 y)   re- race_eth_name, gion_name, me- race_eth_nadian_income m...		0.145994	0.262311	
6	Ridge(log1p race_eth_na0.329761 y)   me- race_eth_nadian_income me- dian_income		0.150958	0.256749	
1	Ridge(log1p region_name0.375812 y)   re- gion_name		0.184413	0.034665	
4	Ridge(log1p region_name0.379931 y)   re- race_eth_name gion_name, race_eth_name		0.183159	0.013385	
0	Dummy(mean)	0.383904	0.219424	-0.007358	
2	Ridge(log1p race_eth_na0.388153 y)   race_eth_name		0.197312	-0.029778	

```

metrics_rq1.to_csv(OUT_DIR / "rq1_pl_subset_models_metrics.csv", index=False)

plt.figure(figsize=(10, 4))
plt.barh(metrics_rq1["model"][:, -1], metrics_rq1["RMSE"][:, -1])
plt.xlabel("RMSE (test)")
plt.title("RQ1 (PL): Model comparison across feature subsets")
plt.savefig(FIG_DIR / "rq1_pl_subset_models_rmse.png", dpi=150, bbox_inches="tight")
plt.show()

```



Across the tested feature subsets, models that include **median income** perform best. The top-performing specification uses **region\_name + median\_income**, achieving  $\text{RMSE} \approx 0.3267$  and  $R^2 \approx 0.2705$  on the test set. Using **median\_income** alone is nearly as good ( $\text{RMSE} \approx 0.3276$ ,  $R^2 \approx 0.2664$ ), suggesting that income is the dominant predictor in this setup.

Adding **race\_eth\_name** does **not** improve performance here (the 3-feature model has slightly worse RMSE/R<sup>2</sup> than the best 2-feature model). Meanwhile, **region\_name** alone performs much worse (**R<sup>2</sup> near 0.03**), indicating that regional labels by themselves explain little unless income is included.

Overall, these results indicate that **median income** is the strongest predictor of food affordability, with **region** contributing a small additional gain beyond income in this place-level sample.