

Per capita income vacancy relationship



We are working on Moody's dataset with multiple features and responses for each market. It is quarterly data that means, that every quarter, new record come for each market. It is real estate dataset.

I am currently working with feature name Per_Capita_Income and response vacancy. Help me understand how it works

Excellent — this is an important variable in real estate economics. Let's break it down carefully from **economic logic** → **real estate interpretation** → **statistical behavior** → **feature engineering potential** for your Moody's dataset.

1. Understanding the Feature

Feature: Per_Capita_Income

Definition:

It measures the **average income earned per person** in a market (typically a city or metro area) in a given quarter.

Formally:

$$\text{Per Capita Income} = \frac{\text{Total Income of Residents}}{\text{Total Population}}$$

It reflects **economic prosperity** and **spending power** of people in that region.

2. Relationship to Vacancy Rate (response variable)

a. General Direction (Inverse Relationship)

Typically, **as per capita income increases**, vacancy rates (for apartments, offices, retail, etc.) tend to **decrease** because:

- Higher income → higher **affordability** → more **demand for housing** and commercial space.
- Businesses also expand when local income rises, leading to **higher occupancy in offices and retail properties**.

Higher Per Capita Income \Rightarrow Lower Vacancy Rate

b. Exceptions (Market-Specific or Time-Dependent)

- If income growth is driven by **a few high earners**, not the general population → demand might not rise broadly.
- In overheated markets (e.g., San Francisco, NYC), high income might already correlate with **high property prices**, leading to **some affordability-based vacancies**.

- During **booms**, both income and new construction rise; temporary **oversupply** can increase vacancies despite rising income.

Hence, the **lag** between income and vacancy can matter — vacancy may improve 1–2 quarters *after* income rises.

3. Dynamic Effects in Time Series (Quarterly)

Because your dataset is **quarterly**, you can model **lagged and growth effects**:

Feature Type	Example	Interpretation
Lagged income	<code>Per_Capita_Income_t-1, t-2</code>	Captures delayed demand response
Quarterly change	<code>ΔPCI = PCI_t - PCI_t-1</code>	Measures income momentum
YoY growth	<code>(PCI_t - PCI_t-4) / PCI_t-4</code>	Smooths seasonal noise
Income volatility	<code>Rolling std(PCI, 4q)</code>	Captures income stability and uncertainty

4. How it Works in Each Property Segment

Property Type	Mechanism	Typical Effect
Apartments (Residential)	Rising income → more renters can afford better units or buy homes → short-term vacancy may drop but long-term depend on housing starts	Moderate negative relationship
Offices	Higher income → stronger local businesses and professional jobs → office demand ↑	Strong negative relationship
Retail	Higher consumer income → higher retail sales → store expansions → vacancy ↓	Strong negative relationship
Industrial	Income growth → consumption ↑ → logistics demand ↑	Mild negative relationship

5. Statistical Correlation Check

You can check empirically:

```
python

df.groupby('Market')['Per_Capita_Income'].corr(df['Vacancy'])
```

If most markets show **negative correlation**, that supports the economic expectation.

Also check **lag correlation**:

```
python

for lag in [0,1,2,3,4]:
    corr = df['Per_Capita_Income'].shift(lag).corr(df['Vacancy'])
    print(f"Lag {lag}: {corr}")
```

Often lag 1–2 quarters show strongest effects.

6. Out-of-the-Box Feature Engineering Ideas

Here's how top real estate firms (like CBRE, Moody's, and CoStar) build enhanced income-based features:

1. Income-to-Rent Affordability Ratio

$$\text{Affordability} = \frac{\text{Per Capita Income}}{\text{Average Rent}}$$

High affordability → vacancy ↓.

2. Real Income Growth (Inflation-Adjusted)

$$\text{Real PCI} = \frac{\text{Per Capita Income}}{\text{CPI}}$$

Measures true purchasing power.

3. Income vs. Housing Supply Elasticity

Ratio of income growth to housing completions — helps see if supply matches demand.

4. Relative Income Position

Compare a market's income to the national median:

$$\text{Income Ratio} = \frac{\text{PCI}_{\text{market}}}{\text{PCI}_{\text{US}}}$$

Measures competitiveness of each market.

5. Income Inequality Adjustment

If Gini index or distribution data available, weight PCI by middle-income share — helps detect uneven prosperity.

7. Model Insights

When modeling, this variable can act as:

- **Demand-side driver** for all property types.
- **Early indicator** (leading signal) for vacancy improvements.
- **Interaction variable** with employment or housing supply.

Example interactions:

- `Per_Capita_Income * Employment_Rate`
- `Per_Capita_Income / Median_Rent`
- `ΔPCI * ΔPopulation`

Would you like me to show **how to build engineered features in code (Python)** for this column — including lag, growth, affordability, and relative income? That would make it easier to plug directly into your model pipeline.



Help with out of box features engineering for this column.

Perfect — let's go *deep* into **out-of-box, industry-grade feature engineering** for `Per_Capita_Income` (PCI), specifically tailored for your **quarterly real estate Moody's dataset** and **vacancy as the response**.

Below are **advanced, multi-layered transformations** used by top analytics teams in real estate (Moody's, CBRE, JLL, REIS, CoStar, etc.), going beyond simple lags or growth rates.

Category-wise Breakdown of “Out-of-Box” Features

1. Dynamic Trend & Momentum Features

Feature	Formula / Description	Insight
Quarter-over-Quarter Growth (%)	$(PCI_t - PCI_{t-1}) / PCI_{t-1}$	Captures short-term momentum in income.
Year-over-Year Growth (%)	$(PCI_t - PCI_{t-4}) / PCI_{t-4}$	Removes seasonal noise, key macro trend.
Rolling Income Acceleration	$(QoQ_t - QoQ_{t-1})$	Measures acceleration/deceleration of prosperity.
Rolling Mean Income (4-quarters)	$mean(PCI_{t-3} \rightarrow PCI_t)$	Smoothed income signal, stable economic baseline.
Rolling Std Income (Volatility)	$std(PCI_{t-3} \rightarrow PCI_t)$	Detects instability or uneven income growth.
Z-score Normalized Income (within market)	$(PCI_t - mean_{market}) / std_{market}$	Compares local income to market's historical norm.

2. Relative Income Positioning

Feature	Formula	Interpretation
Market Income vs. National Mean	PCI_{market} / PCI_{US}	High values → strong local economy.
Market Income vs. Region (e.g., South, West)	$PCI_{market} / PCI_{region}$	Detects regional competitiveness.
Income Ranking Percentile	Rank PCI of each market (0-1 scale)	Reflects national market hierarchy.
Relative Change Rank	Rank ΔPCI YoY across markets	Helps identify outperforming metros.

3. Affordability-Driven Features (Demand Elasticity)

Feature	Formula / Proxy	Rationale
Affordability Index	$\text{Per_Capita_Income} / \text{Average_Rent}$	Higher index = stronger tenant affordability.
Housing Cost Share of Income	$\text{Average_Rent} / \text{Per_Capita_Income}$	Measures financial stress level of renters.
Income vs. Home Price Ratio	$\text{Per_Capita_Income} / \text{Median_Home_Price}$	Gauges buy vs rent decision pressure.
Income-to-Debt Ratio Proxy	$\text{Per_Capita_Income} / \text{Mortgage_Rate}$	Indicates affordability sensitivity to interest rates.

These ratios are powerful in explaining **residential vacancy** because they link income and cost directly.

4. Cross-Market Comparative & Relative Dynamics

Feature	Description	Use Case
Relative Income Growth Spread	$\text{PCI_market_growth} - \text{PCI_national_growth}$	Measures local over/under-performance.
Market Divergence Index	$\text{abs}(\text{PCI_market_growth} - \text{PCI_regional_median_growth})$	Volatility in relative income trends.
Convergence Signal	Rolling correlation between market PCI & national PCI	Detects synchronization with macro cycle.

5. Temporal / Lag-Interaction Features

Feature	Example	Insight
Lagged PCI	$\text{PCI}_{t-1}, \text{PCI}_{t-2}$	Demand reaction may be delayed.
Lagged Growth Rate	ΔPCI_{t-1}	Captures previous quarter's income push.
Cumulative Growth	$\text{sum}(\Delta \text{PCI}_{\text{last_4q}})$	Long-term income change effect.
Interaction: PCI Lag × Vacancy Lag	$\text{PCI}_{t-1} * \text{Vacancy}_{t-1}$	Tests persistence and feedback effects.

6. Composite Indicators (Macro-Causal Design)

Feature	Formula / Proxy	Economic Interpretation
Income × Employment	$\text{Per_Capita_Income} * \text{Employment_Rate}$	Captures overall wage income mass.
Income × Consumer Spending Index	If available, product of two	Reflects spending power realized in retail.
Real Income (Inflation-Adjusted)	PCI / CPI	Real purchasing power after inflation.
Income Elasticity w.r.t Rent Growth	$\text{corr}(\Delta \text{PCI}, \Delta \text{Rent})$ rolling 4q	Measures how sensitive rent is to income.

7. Cycle & Turning-Point Detection Features

Feature	Method	Insight
Income Cycle Phase (Hilbert transform or detrended)	Extract cycle phase of PCI	Detects turning points before vacancy shifts.
Trend vs. Cycle Ratio	Trend Component / Cycle Component	Quantifies structural vs. temporary movement.
Shock Feature	$\text{abs}(\Delta \text{PCI}_t - \text{mean}(\Delta \text{PCI}_{\text{last_}4q}))$	Detects sudden shocks to income.

8. Behavioral / Elasticity Features (Great for Explainable ML)

Feature	Formula	Meaning
Income Elasticity of Vacancy	$\Delta \text{Vacancy}\% / \Delta \text{PCI}\%$ (rolling estimate)	Measures how sensitive vacancy is to income.
Price Pressure Index	(Income Growth - Rent Growth)	Negative = affordability squeeze.
Vacancy-Adjusted Income Gap	$\text{PCI} / (\text{Vacancy} + \epsilon)$	Shows if high income coexists with low vacancy.

Implementation Blueprint (Python Sketch)

Here's a simple snippet to compute many of these efficiently:

```
python

import pandas as pd

def engineer_pci_features(df):
    df = df.sort_values(['Market', 'Quarter'])
    df['PCI_QoQ_Growth'] = df.groupby('Market')['Per_Capita_Income'].pct_change(1)
    df['PCI_YoY_Growth'] = df.groupby('Market')['Per_Capita_Income'].pct_change(4)
    df['PCI_RollingMean4'] = df.groupby('Market')['Per_Capita_Income'].transform(lambda x:
    x.rolling(4).mean())
    df['PCI_RollingStd4'] = df.groupby('Market')['Per_Capita_Income'].transform(lambda x:
    x.rolling(4).std())
    df['PCI_Acceleration'] = df.groupby('Market')['PCI_QoQ_Growth'].diff(1)
    df['PCI_ZScore'] = df.groupby('Market')['Per_Capita_Income'].transform(lambda x: (x -
    x.mean())/x.std())
    df['Affordability_Index'] = df['Per_Capita_Income'] / df['Average_Rent']
    df['Income_vs_National'] = df['Per_Capita_Income'] / df.groupby('Quarter')
    ['Per_Capita_Income'].transform('mean')
    df['Shock_PCI'] = abs(df['PCI_QoQ_Growth'] - df.groupby('Market')
    ['PCI_QoQ_Growth'].transform(lambda x: x.rolling(4).mean()))
    return df
```

Summary: "Out-of-Box" Insights

Feature Family	Purpose
Growth & Momentum	Detect income cycles driving demand
Affordability & Elasticity	Link income with rent/vacancy pressure
Relative & Comparative	Benchmark local performance
Lagged & Interaction	Capture delayed economic effects

Feature Family	Purpose
Volatility & Shock Detection	Identify instability and turning points

Would you like me to **prioritize the top 10 engineered PCI features** that have the *strongest explanatory power* for **vacancy rate**, based on typical Moody's-like market behavior (apartments/offices/retail)? I can rank and describe those next.



Sorry I was asking can you look for some more top notch features engineering which top real estate industry use

Excellent — you're already thinking like an institutional analyst 🙌.

Let's now go **beyond the conventional "growth and ratio" transforms** into the **top-tier, research-grade feature engineering** used by *Moody's, CBRE, JLL, CoStar, and Real Capital Analytics* for variables like **Per Capita Income (PCI)** when modeling **vacancy, absorption, and rent**.

Below are the **high-impact, industry-level PCI features** grouped by advanced concept areas.

🧠 1. Macro-Micro Fusion Features

(combining local income data with broader economic context)

Feature	Description	Why It's Top-Tier
Income Differential vs. National Median	$PCI_{market} - PCI_{national_median}$	Used by Moody's REIS to benchmark local affordability and wage competitiveness.
Income Divergence Index	$(PCI_{market} / PCI_{region_avg}) - 1$	Highlights whether a metro is overheating or lagging within its region.
Income Synchronization Index	Rolling correlation of market PCI with national PCI over 8 qtrs	Detects how tightly a market's cycle follows national macro trends (key for cyclic risk modeling).
Income Beta (Macro Sensitivity)	Regression β of market PCI vs national PCI over rolling window	Measures exposure of local income to national shocks.

🧩 2. Structural Affordability and Stress Indicators

Feature	Formula / Proxy	Insight
Disposable Income per Housing Unit	$PCI * Population / Housing_Units$	Moody's & CoStar use this to gauge market absorption power.
Rent Burden Ratio (Adjusted)	$(Average_Rent * 12) / (PCI * 0.6)$	Uses 60% of income to represent disposable segment; identifies affordability stress.
Consumer Leverage Proxy	$PCI / (Credit_Delinquency_Index + 1)$	High values mean financially healthy tenants → lower vacancy risk.

Feature	Formula / Proxy	Insight
Income Adequacy to Replacement Cost	$PCI / Construction_Cost_Index$	If low, new supply unlikely → stabilizes vacancy.

3. Urban Economics-Inspired Ratios

Feature	Description	Interpretation
Agglomeration Advantage Proxy	$PCI * Population_Density$	Captures urban productivity — richer, denser markets tend to have low vacancy.
Economic Intensity Index	$(Employment_Rate * PCI)$	Proxy for total wage bill capacity driving space absorption.
Spatial Income Gradient	$\log(PCI_core / PCI_suburb)$	(If sub-market data available) — identifies migration or affordability shift trends.
Income Diversification Ratio	$(Service_Sector_Income / Manufacturing_Sector_Income)$	Higher ratio → more stable demand base.

4. Cycle and Turning-Point Features


Feature	Method	Used For
Filtered Trend Component	Apply Hodrick–Prescott or Baxter–King filter to PCI	Removes noise to isolate long-term prosperity trend.
Cycle Phase Indicator	Hilbert transform → phase angle of PCI cycle	Leading indicator of turning points in vacancy.
Income Shock Index	`	$\Delta PCI - \text{rolling_mean}(\Delta PCI)$
Cycle-to-Trend Ratio	$\text{cycle_component} / \text{trend_component}$	Quantifies cyclical deviation strength.

5. Income-to-Market Dynamics (Cross-Elasticities)

Feature	Formula	Insight
Income–Rent Elasticity Proxy	Rolling regression slope of $\log(Rent)$ on $\log(PCI)$	Core metric used by Moody's to estimate affordability limits.
Income–Vacancy Elasticity	Rolling regression slope of $Vacancy$ on PCI	Measures sensitivity of space absorption to income shifts.
Income–Supply Gap Index	$(\Delta PCI - \Delta Construction_Employment)$	Highlights when demand (income) outpaces new supply.
Income–Population Growth Imbalance	$(\Delta PCI / \Delta Population)$	Detects whether rising income comes from wage growth or migration.

6. Spatial and Peer-Benchmark Features

Feature	Description	Insight
Neighbor Income Diffusion	Average PCI of adjacent markets (weighted by distance)	Captures spillover of prosperity across metros.
Relative Competitiveness Score	$(PCI_{market} - \text{mean}(PCI_{neighbors})) / \text{std}(PCI_{neighbors})$	Used in regional cluster modeling to predict migration and vacancy pressure.
Income Gravity Index	$\sum (PCI_j / \text{distance}_{ij}^2)$	Quantifies pull from nearby wealthy markets.
Migration-Potential Proxy	$(PCI_{neighbors_growth} - PCI_{market_growth})$	Predicts relocation flow pressure.



7. Derived Behavioral & Expectation Indicators

Feature	Description	Why It Matters
Consumer Confidence Proxy	Lagged Δ PCI smoothed over 2 quarters	Higher perceived income growth → stronger retail & office demand.
Income-Expectation Spread	Difference between current PCI and its 1-year forecast (from ARIMA/trend)	Used by investment teams to spot optimism/pessimism.
Income Momentum Oscillator (IMO)	$(PCI_t - PCI_{t-4}) / (PCI_{t-4})$ detrended	Identifies inflection points faster than growth rate.



8. Machine-Learning-Friendly Transformations

Technique	Example	Purpose
Polynomial & Interaction Terms	$PCI^2, PCI * \text{Employment_Rate}, \Delta PCI * \text{Population_Growth}$	Capture nonlinear affordability and demand effects.
Market-Level Embeddings	Use PCA or Autoencoder on income-related variables	Compress correlated macro signals.
Temporal Decay Feature	Exponentially weighted moving average of PCI growth	Gives more weight to recent economic shifts.
Income Shock Frequency Count	Count of quarters where	ΔPCI



Summary — “Top-Notch” PCI Feature Themes

Category	Example Use	Why Industry Uses It
Macro-Micro Fusion	Income β , Synchronization	For cyclical risk modeling
Affordability & Stress	Rent-Burden, Disposable Income	To forecast demand limits
Urban Economics	Agglomeration, Density	To measure structural resilience
Cycle Detection	HP-filter trend, phase angle	To time peaks/troughs
Cross-Elasticities	Income–Vacancy regression	To estimate sensitivities
Spatial Spillovers	Neighbor diffusion	For regional contagion modeling

Would you like me to now give you a **Python feature-engineering template** that implements 15–20 of these “institutional-grade” PCI features automatically (with placeholders for variables like rent, population, etc.) so you can plug it directly into your Moody’s pipeline?



So me some more features engineering with Per_Capita_Income.

Perfect — you’re really thinking like a *quantitative real estate strategist* now 🙌.

You already explored lag, growth, affordability, macro, and elasticity features — so let’s now go even deeper into **premium-grade, research-style feature engineering** for Per_Capita_Income (PCI) used in advanced **real estate econometrics and machine-learning pipelines**.

Below are **fresh and creative features** divided into **8 expert-level categories** — these are the kind of transforms you’d find in models from Moody’s, Oxford Economics, and Blackstone Real Estate Intelligence teams.



1. Non-Linear Income Dynamics

Feature	Formula / Description	Why It’s Powerful
Income Growth Volatility Index	Rolling 4-quarter std of ΔPCI	Measures income stability; stable income → lower vacancy risk.
Skewness of Income Growth (rolling)	Rolling 8-quarter skewness	Detects asymmetric prosperity — a few high earners can mask weak middle-income segments.
Income Acceleration Ratio	$\Delta(\Delta\text{PCI}_t)$	ΔPCI_{t-1}
Income Saturation Ratio	$\text{PCI}_t / \max(\text{PCI_history_market})$	How close a market is to its historical income peak → used to detect maturity vs. growth phase.
Curvature in Income Trend	2nd derivative of rolling 4q mean	Signals turning points before vacancy changes.



2. Spatial & Regional Context Features

Feature	Formula / Idea	Insight
Income Spillover Index	Weighted average PCI of nearby markets using inverse-distance weights	Captures regional demand diffusion.
Income Gradient (Urban vs. Suburban)	$\text{PCI_central_business_district} / \text{PCI_suburban}$	If suburban PCI rises faster, may indicate migration → temporary vacancies downtown.
Regional Dispersion Index	Std of PCI across all markets within a region	High dispersion = regional inequality → unbalanced demand.
Neighbor PCI Gap	$\text{PCI_market} - \text{mean}(\text{PCI_neighbors})$	Indicates relative prosperity (competitiveness).

3. Income-Consumption Interaction Features

Feature	Formula	Interpretation
Income-to-Retail-Sales Ratio	$\text{PCI} / \text{Retail_Sales_per_Capita}$	High ratio may mean under-consumption potential (retail vacancy risk).
Real Disposable Income	PCI / CPI	True purchasing power; inflation-adjusted prosperity.
Income Velocity Proxy	$\text{Retail_Sales} / \text{PCI}$	Speed of money circulation; stronger retail markets = lower retail vacancy.
Savings Propensity Proxy	$1 - (\text{Retail_Sales} / \text{PCI})$	Captures conservative spending behavior → stable but slower space absorption.

4. Supply-Demand Balance Signals

Feature	Formula	Why It's Useful
Income-Supply Pressure Ratio	$(\Delta \text{PCI}) / (\Delta \text{Construction_Employment or } \Delta \text{Housing_Completions})$	Shows whether demand (income) growth keeps up with supply expansion.
PCI / Units_Under_Construction		If income rises but new supply rises faster, vacancy risk increases.
Income-Permit Ratio	$(\text{PCI Growth}) / (\text{Building_Permits Growth})$	Leading signal for overbuilding.
Absorption Elasticity Proxy	$\text{corr}(\Delta \text{PCI}, \text{Net_Absorption, rolling}=4)$	Measures responsiveness of demand to income.

5. Temporal Interaction Features (Multi-lag Design)

Feature	Example	Purpose
Lag1, Lag2, Lag4	$\text{PCI}_{t-1}, \text{PCI}_{t-2}, \text{PCI}_{t-4}$	Capture delayed income effects on vacancy.
Lag Difference Spread	$\text{PCI}_{t-1} - \text{PCI}_{t-4}$	Detects mid-term acceleration.
Cumulative Income Growth (past 1 year)	$\text{sum}(\Delta \text{PCI}_{t-4 \rightarrow t-1})$	Represents sustained prosperity momentum.
Lag Interaction	$(\text{PCI}_{t-1} * \text{Employment}_{t-1})$	Measures combined delayed impact of income + jobs.

6. Market Cycle Positioning Features

Feature	Description	Insight
PCI Cycle Strength	Ratio of cyclical to trend component from HP filter	Distinguishes structural vs cyclical growth.
PCI Momentum Score	$\text{EMA}(\Delta \text{PCI})$ over 4q normalized 0-1	Indicates positive or negative income regime.

Feature	Description	Insight
PCI Turning Point Probability	Derived from Markov regime-switch model on PCI	Used by institutional forecasters to time vacancy reversals.
PCI Trend Duration	Count of consecutive quarters with positive Δ PCI	Shows run-length of expansion phase.

7. Income Distribution & Segmentation Features

(If you have data on income tiers, or can use proxies like affordability)

Feature	Formula / Concept	Why It's Cutting-Edge
Middle-Income Share Proxy	$(PCI / Median_Income)$ if available	Strong predictor of stable housing demand.
Gini-Adjusted PCI	$PCI * (1 - Gini_Index)$	Real demand power after accounting for inequality.
Income Inequality Slope	$(Top10\%_Income - Bottom50\%_Income) / PCI$	Highlights polarization → affects vacancy patterns.
Weighted PCI by Population Segment	Weighted avg across income brackets	Captures true income distribution impact.

8. Composite & Interaction Features

Feature	Description	Economic Interpretation
PCI × Employment Rate	Combined strength of prosperity & job availability.	
PCI × Population Growth	Expanding population with rising income → boom market.	
PCI / Rent Index	Affordability ratio, dynamic version of rent burden.	
PCI × Consumer_Confidence_Index	Sentiment-adjusted purchasing power.	
Δ PCI × Interest_Rate	Income-interest interaction → affordability stress test.	
PCI / Household_Debt_Per_Capita	Measures real disposable liquidity.	
Income-Vacancy Interaction	$\Delta PCI * \Delta Vacancy_t-1$	Captures feedback between demand and space absorption.

9. Advanced Statistical / ML Feature Patterns

Technique	Example	Use
Fourier or Wavelet Features	Extract frequency components of PCI cycles	Identifies periodic income oscillations driving demand.
Nonlinear Transformations	$\log(PCI)$, $1/PCI$, \sqrt{PCI}	Stabilize variance and capture nonlinear impact.

Technique	Example	Use
Polynomial Expansion	PCI^2, PCI^3	Useful when vacancy responds asymmetrically to income.
Principal Component of PCI & Related Features	PCA on [PCI, Employment, Retail Sales, Rent]	Summarizes macro demand factor.
Income Shock Dummy	1 if `	ΔPCI

10. Real Estate-Specific PCI Features

(rarely discussed but extremely impactful)

Feature	Description	Purpose
Wage-Driven Demand Index	$\Delta PCI / \Delta \text{Average_Rent}$	Shows if wage growth outpaces cost growth.
Affordability Momentum	$\Delta (PCI / \text{Rent_Index})$	Tracks affordability trend over time.
Income-to-Vacancy Gap	$(PCI / (\text{Vacancy} + \epsilon))$	Simple but effective ratio to measure prosperity vs empty space.
Income Growth vs Construction Cost Growth	$\Delta PCI - \Delta \text{Construction_Cost_Index}$	If negative, income isn't keeping up → risk of overbuild.
Income Resilience Index	$\text{rolling_sum}(\min(\Delta PCI, 0)) / \Delta PCI$	ΔPCI

Example Python Implementation (modular)

Here's a scalable pattern you can adapt:

```
python

def advanced_pci_features(df):
    df = df.sort_values(['Market', 'Quarter'])
    g = df.groupby('Market')

    df['PCI_QoQ'] = g['Per_Capita_Income'].pct_change(1)
    df['PCI_YoY'] = g['Per_Capita_Income'].pct_change(4)
    df['PCI_Volatility_4q'] = g['PCI_QoQ'].rolling(4).std().reset_index(level=0, drop=True)
    df['PCI_Acceleration'] = g['PCI_QoQ'].diff()
    df['PCI_Saturation'] = df['Per_Capita_Income'] / g['Per_Capita_Income'].transform('max')
    df['PCI_Zscore'] = g['Per_Capita_Income'].transform(lambda x: (x - x.mean()) / x.std())
    df['Affordability'] = df['Per_Capita_Income'] / df['Average_Rent']
    df['Real_PCI'] = df['Per_Capita_Income'] / df['CPI']
    df['Income_Rent_Elasticity'] = df['PCI_QoQ'] / (df['Rent_QoQ'] + 1e-6)
    df['Income_Supply_Ratio'] = df['PCI_QoQ'] / (df['Construction_Employment_QoQ'] + 1e-6)
    df['Income_Vacancy_Gap'] = df['Per_Capita_Income'] / (df['Vacancy'] + 1e-6)
    df['PCI_Cycle_Strength'] = df['PCI_YoY'] / (abs(df['PCI_Volatility_4q']) + 1e-6)
    return df
```

Key Idea Summary

Concept	Why It Matters
Income stability	Stable income markets have consistent occupancy.
Affordability ratios	Link income and housing/rent dynamics.

Concept	Why It Matters
Spatial context	Prosperity spillovers explain cross-market effects.
Supply-demand balance	Real driver of vacancy patterns.
Cycle detection	Anticipates turning points in vacancy.
Behavioral effects	Income sentiment and inequality influence demand.

Would you like me to now **rank** the *top 15 most predictive PCI-derived features for vacancy*, based on real empirical studies and institutional modeling practices (so you know where to focus first)?