Minding Your P's and Q's as Prices Rise

International Cost Estimating and Analysis Association

May 2022

Technomics — Better Decisions Faster

Minding Your P's and Q's as Prices Rise

Alan Karickhoff

Michael Metcalf

Omar Akbik

Brian Flynn

Choices and challenges abound in combining individual prices (P's) and quantities (Q's) of labor and material into one single measure of overall escalation for a project. Popular constructs include the Laspeyres, Paasche, and Fisher.

This research illuminates the issue of which index to use when in the relentless fight against money illusion – the tendency to think in nominal rather than real terms.

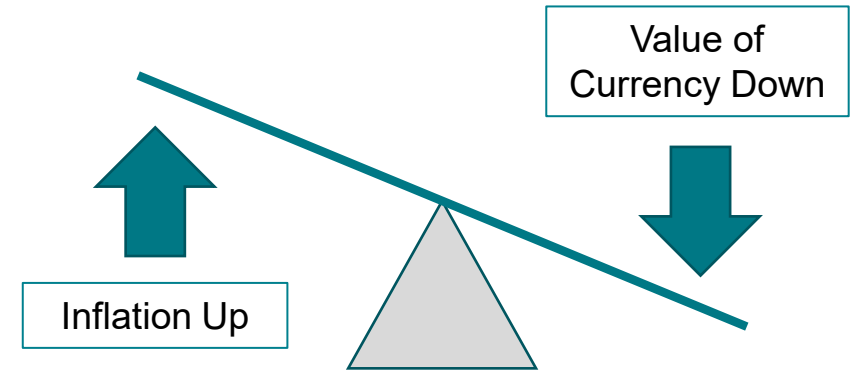Methods are offered for forecasting inflation probability distributions up to three decades out.

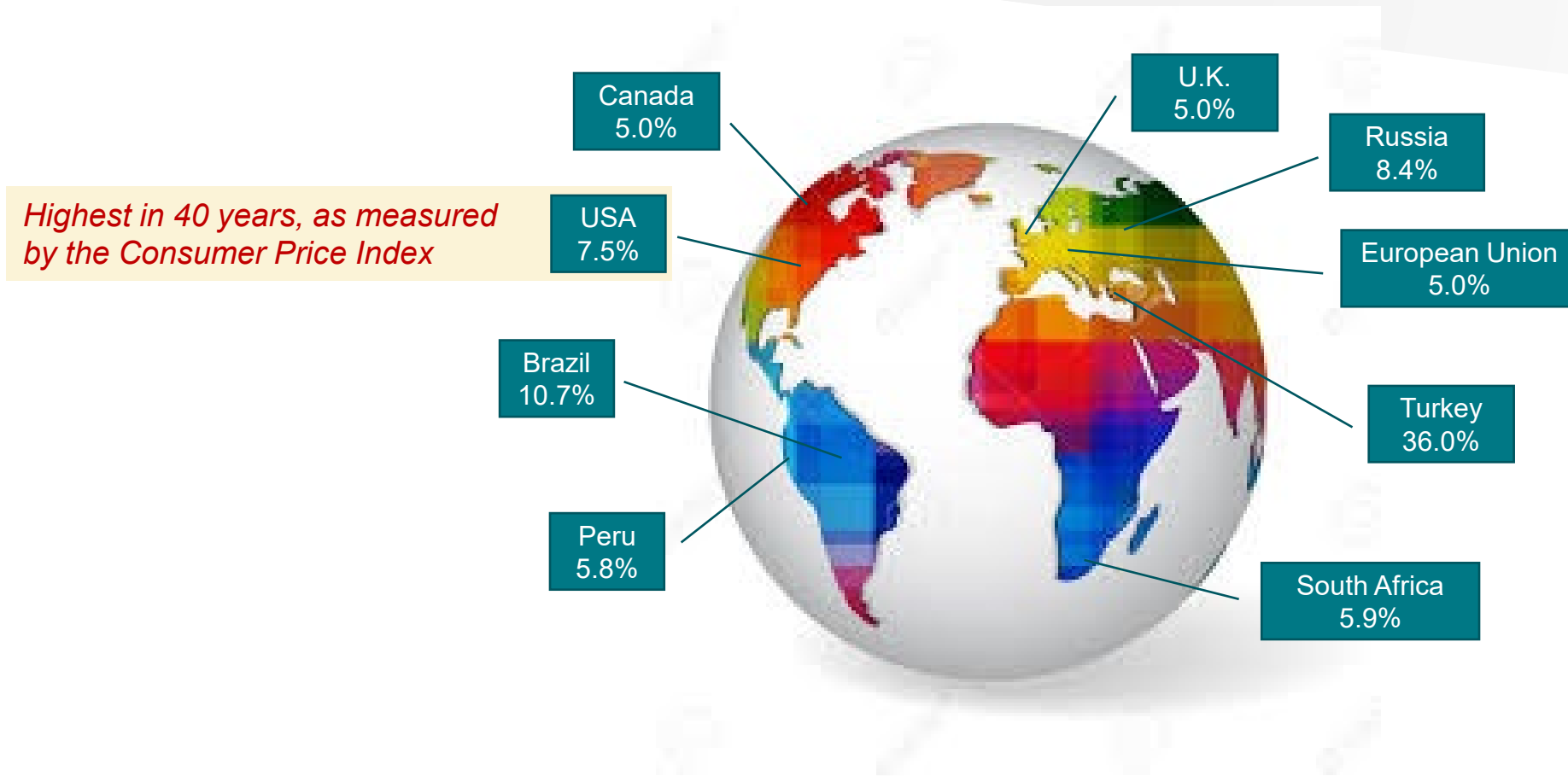Technomics

Prelude – Inflation Devalues Money

Value of Currency Down

Inflation Up

Irving Fisher's Seesaw

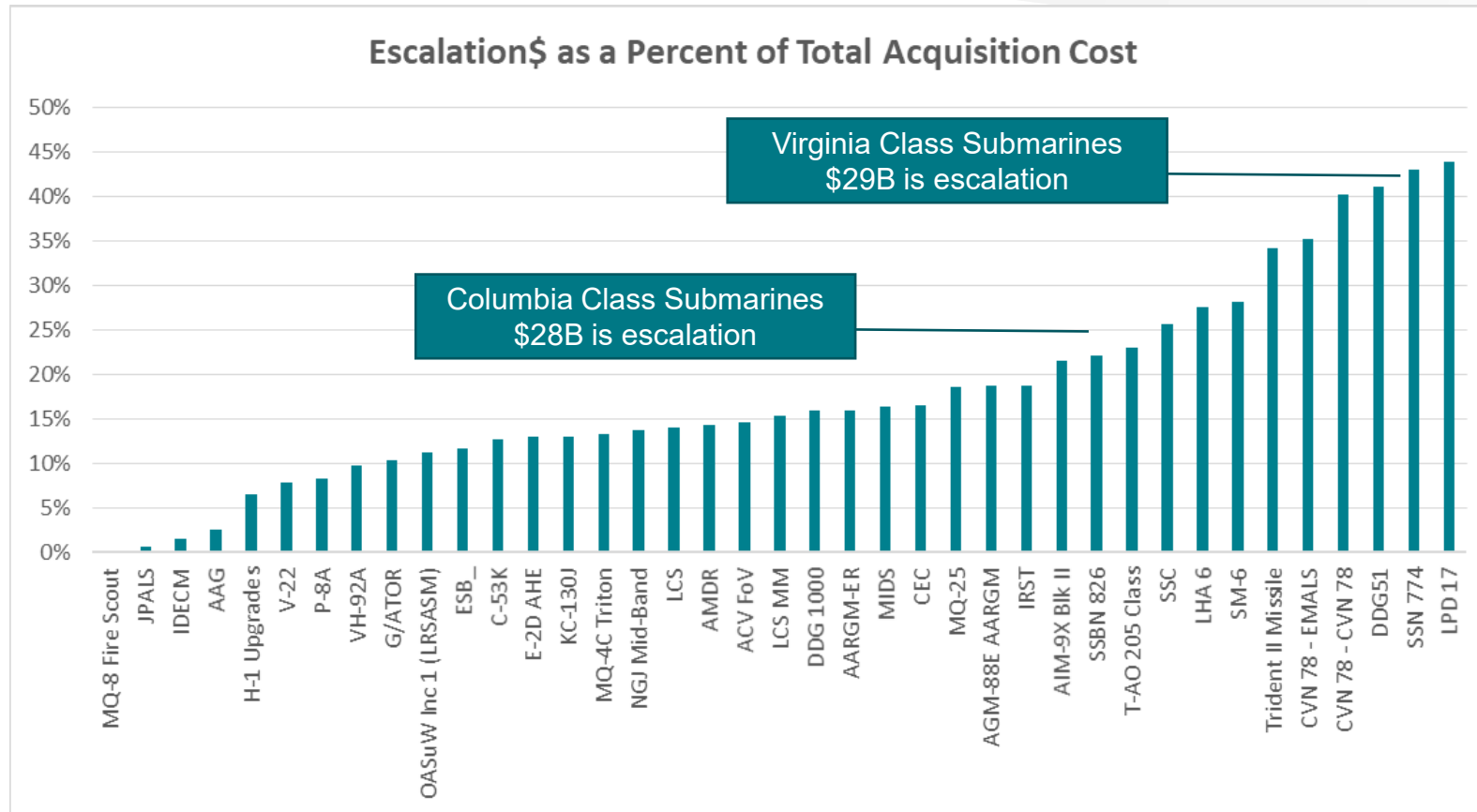Inflation: An increase in the general level of prices in the economy

Prelude – Inflation a Worldwide Phenomenon

Highest in 40 years, as measured by the Consumer Price Index

Canada
5.0%

U.K.
5.0%

Russia
8.4%

USA
7.5%

European Union
5.0%

Brazil
10.7%

Turkey
36.0%

Peru
5.8%

South Africa
5.9%

Current (2021) rates in many developed countries the greatest in decades!

Prelude – The Stakes Are High

Escalation$ as a Percent of Total Acquisition Cost

Virginia Class Submarines
$29B is escalation

Columbia Class Submarines
$28B is escalation

Escalation on average is 17% of acquisition cost for Navy programs

Agenda

Money Illusion
Incomes, investments, debt, and spending are not what they used to be in terms of purchasing power of a currency

The Index Number Problem
How exactly should microeconomic information involving hundreds or even thousands of prices and quantities be aggregated into a smaller number of price and quantity variables?

Index Formulae
Unweighted and weighted index numbers

Practical Considerations
Price relatives, conversions, and implications

Escalation Measurements
Several steps are used to measure escalation for labor, material, select components of overhead, and projects in general

Forecasts
This research offers survey- and market-based measures for the estimation of future probability distributions of inflation

Summary and Conclusions
Our research identifies a clear, groundbreaking path to advance the treatment of inflation in generating life-cycle cost estimates

Technomics

Money Illusion

The cognitive tendency of people and organizations to view their wealth, income, and expenses in *nominal* rather than *real* terms

Examples

- Dow 36,000 was first achieved in November 2021
  - But it's only Dow 22,600 in terms of the purchasing power that prevailed in 1999 when James Glassman made his famous prediction

- Average hourly earnings in the U.S. increased 4% last year
  - In terms of purchasing power, this represents a 3% loss

Examples

- The U.K.'s defense budget has almost doubled from 2000 to 2021, from £28B to £53B
  - But in terms of constant purchasing power, it's increased only 7%, to £30B

- Gas prices in the U.S. today average $3.30 per gallon (thought to be high)
  - But, in constant purchasing power, they're unchanged from 40 years ago.

Technomics

Solution – Index Numbers

A long-standing challenge in overcoming Money Illusion is the development and application of a metric upon which to measure the changing nature of a currency

Challenges

- When has the value of a currency changed? And by how much?

- What's the means or mechanism by which to measure the change in terms of *real value*?

Index Numbers

- Measure the relative change in price, quantity, value, or other items of interest from one time period

- Use a base year, period, or value, usually denoted as 1.00 or 100
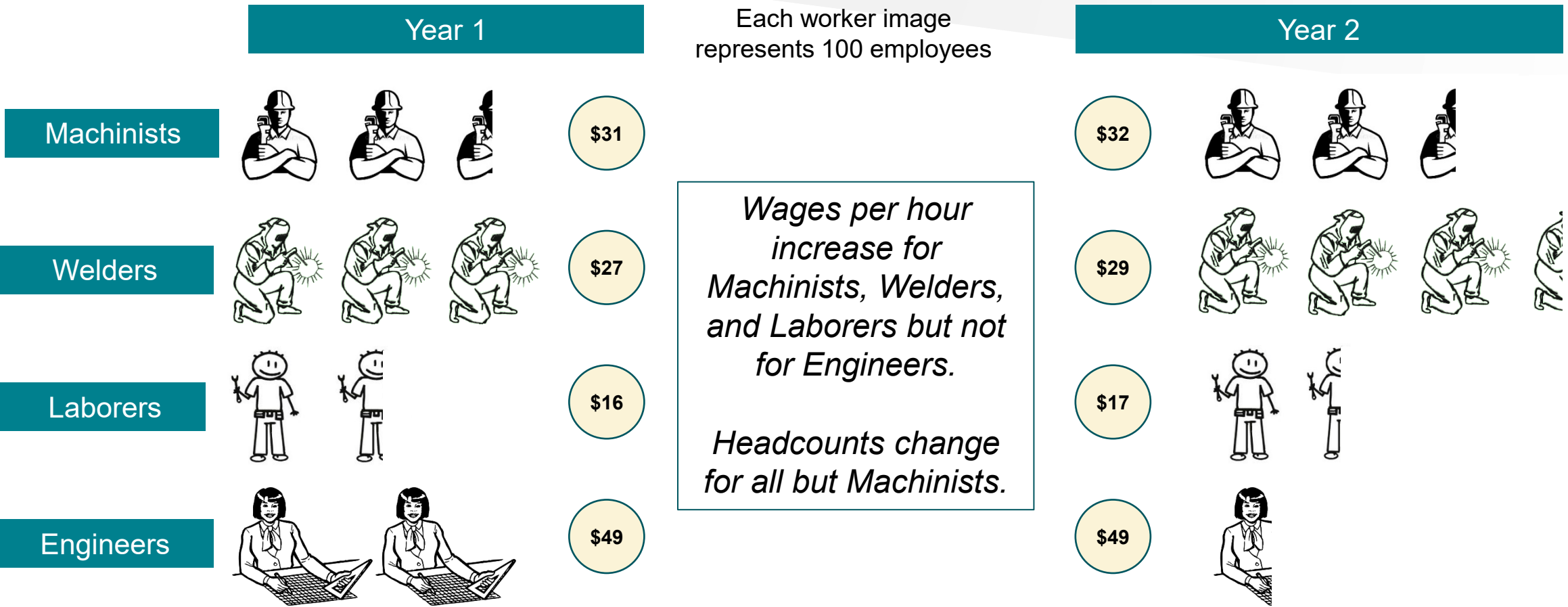
Technomics

The Index Number Problem

BUT, given the solution (use of an index number), there's still a problem:

"How to combine the relative changes in the prices and quantities of various products into

- *A single measure of the relative change of the overall <u>price level</u>, and*

- *A single measure of the relative change of the overall <u>quantity level</u>."*

Organization of Economic Cooperation and Development (OECD)

The Index Number Problem – Shipyard Example

Each worker image represents 100 employees

| | Year 1 | | Year 2 |

Machinists — $31 ... $32

Welders — $27 ... $29

Laborers — $16 ... $17

Engineers — $49 ... $49

Wages per hour increase for Machinists, Welders, and Laborers but not for Engineers.

Headcounts change for all but Machinists.

How do you build an escalation index for labor for the yard?

Solution – Shipyard Example

Low-Level Data → **Market Basket** → **Best-in-Class Index**

Annual Direct Labor Expense
$Job\ Categories = 1\ to\ n$

$Wage = p_i$ $Headcount = q_i$

Individual Job Codes

Welder
Machinist
Laborer
Engineer
Etc.

Laypeyres

$$P_L^{0,t} = \frac{\sum_{i=1}^{n} p_{ti} q_{0i}}{\sum_{i=1}^{n} p_{0i} q_{0i}}$$

Paasche

$$P_P^{0,t} = \frac{\sum_{i=1}^{n} p_{ti} q_{ti}}{\sum_{i=1}^{n} p_{0i} q_{ti}}$$

Laypeyres uses base period headcounts (q_{0i})

Fisher's "Ideal Index"

$$P_F^{0,t} = \sqrt{P_L\, P_P}$$

Paasche uses end period headcounts (q_{ti})

Pure Escalation Index for Labor: Hold headcounts constant but use them as weights, or measures of relative importance within the yard

Technomics

Common Formulas

Index	Formula	Shipyard Example	Explanation
Unweighted Index Numbers			
Dutot	$P_{Dutot}^{0,t} = \dfrac{(\sum_{i=1}^{n} p_{ti})/n}{(\sum_{i=1}^{n} p_{0i})/n}$	$P_{Dutot}^{0,t} = 3.25\%$	Ratio of average prices. Equivalent to the ratio of the sum of prices in the end period and the sum in the base period
Carli	$P_{Carli}^{0,t} = \dfrac{1}{n} \sum_{i=1}^{n} \dfrac{p_{ti}}{p_{0i}}$	$P_{Carli}^{0,t} = 4.22\%$	Arithmetic average of price relatives
Jevons	$P_{Jevons}^{0,t} = \left(\prod_{i=1}^{n} \dfrac{p_{ti}}{p_{0i}} \right)^{(\frac{1}{n})}$	$P_{Jevons}^{0,t} = 4.18\%$	Geometric mean of price relatives
Harmonic	$P_{Harmonic}^{0,t} = \dfrac{n}{\sum_{i=1}^{n} \left(\dfrac{1}{\frac{p_{ti}}{p_{0i}}} \right)}$	$P_{Harmonic}^{0,t} = 4.14\%$	Harmonic mean of price relatives

Index	Formula	Shipyard Example	Explanation
Weighted Index Numbers			
Laspeyres	$P_{L}^{0,t} = \dfrac{\sum_{i=1}^{n} p_{ti} q_{0i}}{\sum_{i=1}^{n} p_{0i} q_{0i}}$	$P_{L}^{0,t} = 3.60\%$	Weighted by base-period quantities. Popular in EPA clauses and national statistics
Paasche	$P_{P}^{0,t} = \dfrac{\sum_{i=1}^{n} p_{ti} q_{ti}}{\sum_{i=1}^{n} p_{0i} q_{ti}}$	$P_{P}^{0,t} = 4.73\%$	Weighted by end-period quantities. Less intuitive than the Laspeyres index.
Fisher	$P_{F}^{0,t} = \sqrt{P_L P_P}$	$P_{F}^{0,t} = 4.16\%$	An "ideal" index which captures the phenomenon of weights changing over time

Technomics

Practical Considerations

- Escalation indices often formulated as weighted *price relatives*

Material Index for Class Standard Equipment (CSE) on Destroyers

$$Material_{CSE}^{0,t} = \left(\frac{p_t^{Engines}}{p_0^{Engines}}\right)w_1 + \left(\frac{p_t^{Propellers}}{p_0^{Propellers}}\right)w_2 + \cdots + \left(\frac{p_t^{Item\#61}}{p_0^{Item\#61}}\right)w_{61}$$

Economic Price Adjustment (EPA) Clause for Ship Construction

$$EPA_{Labor}^{0,t} = \left(\frac{p_t^{USA}}{p_0^{USA}}\right)w_{USA} + \left(\frac{p_t^{France}}{p_0^{France}}\right)w_{France} + \cdots + \left(\frac{p_t^{Germany}}{p_0^{Germany}}\right)w_{Germany}$$

A *price relative* is the ratio of prices of an item between two time periods

The weights are relative expenditures, or percentages of the total

Technomics

Practical Considerations

- Such formulas (that use base-period weights) are Laspeyres indices in disguise

$$P_L^{0,t} \equiv \frac{\sum_{i=1}^{n} p_{ti} q_{0i}}{\sum_{i=1}^{n} p_{0i} q_{0i}} = \frac{\sum_{i=1}^{n} p_{ti} q_{0i}(p_{0i}/p_{0i})}{\sum_{i=1}^{n} p_{0i} q_{0i}}$$

$$P_L^{0,t} = \frac{\sum_{i=1}^{n} p_{0i} q_{0i}(p_{ti}/p_{0i})}{\sum_{i=1}^{n} p_{0i} q_{0i}} = \sum_{i=1}^{n} w_{0i}\left(\frac{p_{ti}}{p_{0i}}\right), where \quad w_{0i} = \frac{v_{0i}}{\sum_{i=1}^{n} v_{0i}} = \frac{p_{0i} q_{0i}}{\sum_{i=1}^{n} p_{0i} q_{0i}}, and \; where$$

$$v_{0i} = the\; value\; (price\; x\; quantity = expenditure)\; of\; an\; item\; in\; the\; base\; period.$$

The Paasche Price Index is a *current-period* harmonic mean of price relatives

Technomics

Escalation Measurement

Several steps are used to measure escalation for labor, material, select components of overhead, and projects in general, and to generate probabilistic forecasts

- Overview
- Data Collection
- Data Aggregation
- Linkage to the CPI-U

Technomics
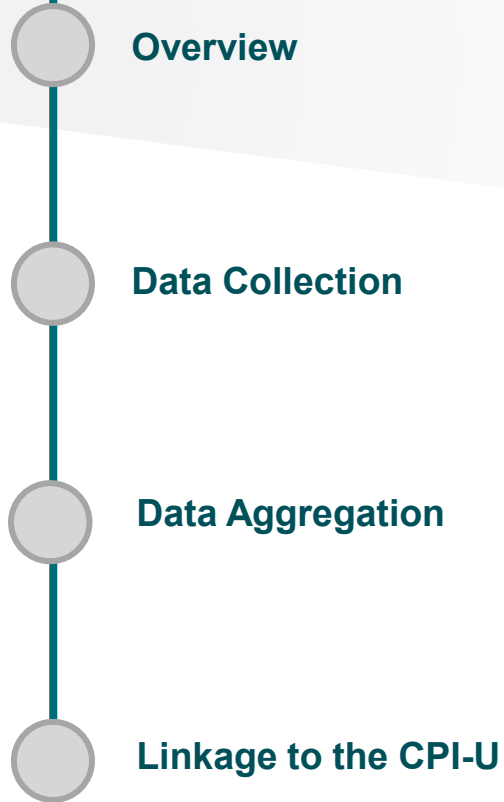
Escalation Measurement – Overview

- Develop unique indices for a basket of items
  - Extensive data collection effort

- Leverage the linkage between core inflation and unique escalation
  - Use a Compound Annual Growth Rate (CAGR) as a metric
  - Compute deltas between unique escalation and macro inflation

- Deflate historical escalation indices using the Consumer Price Index (CPI)

- Leverage market-implied forecasts of macro inflation to generate point and probabilistic estimates of escalation

Escalation Measurement – Data Collection
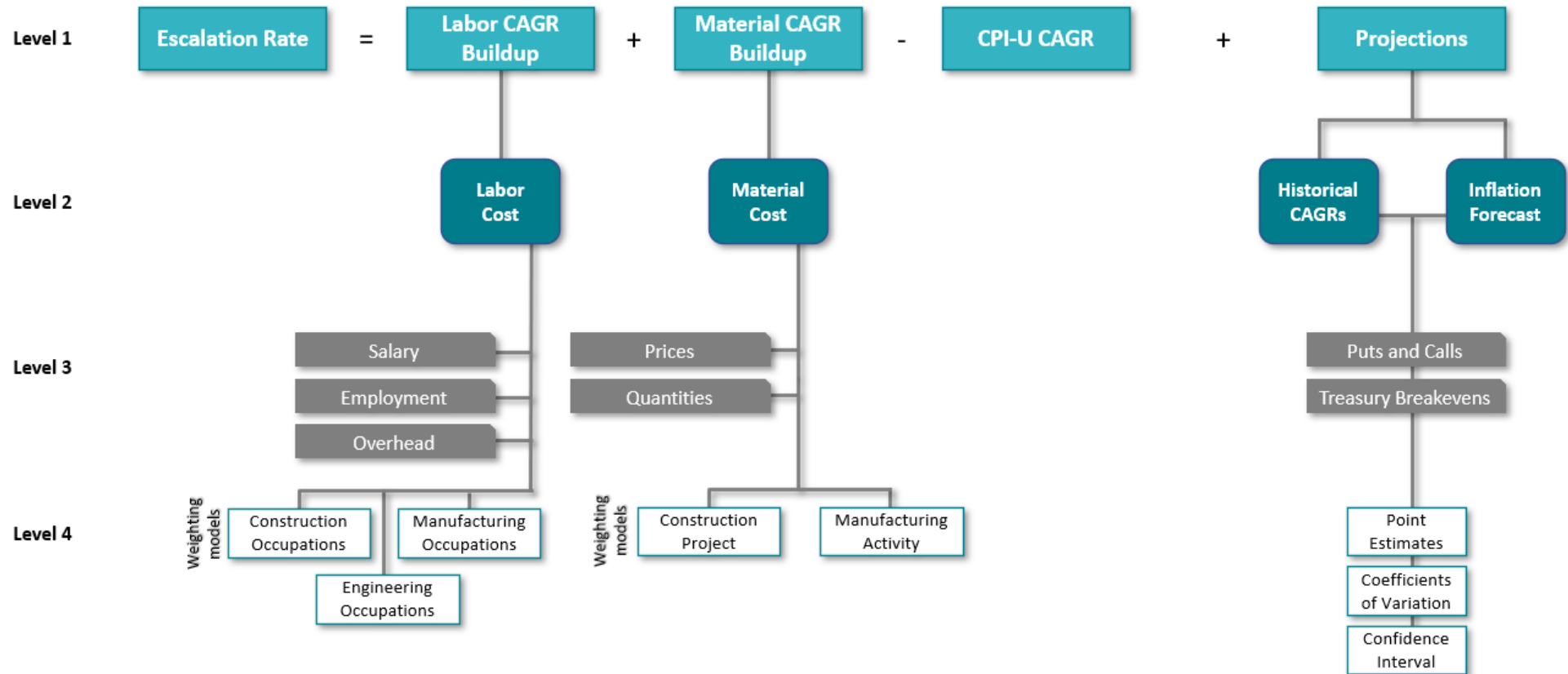
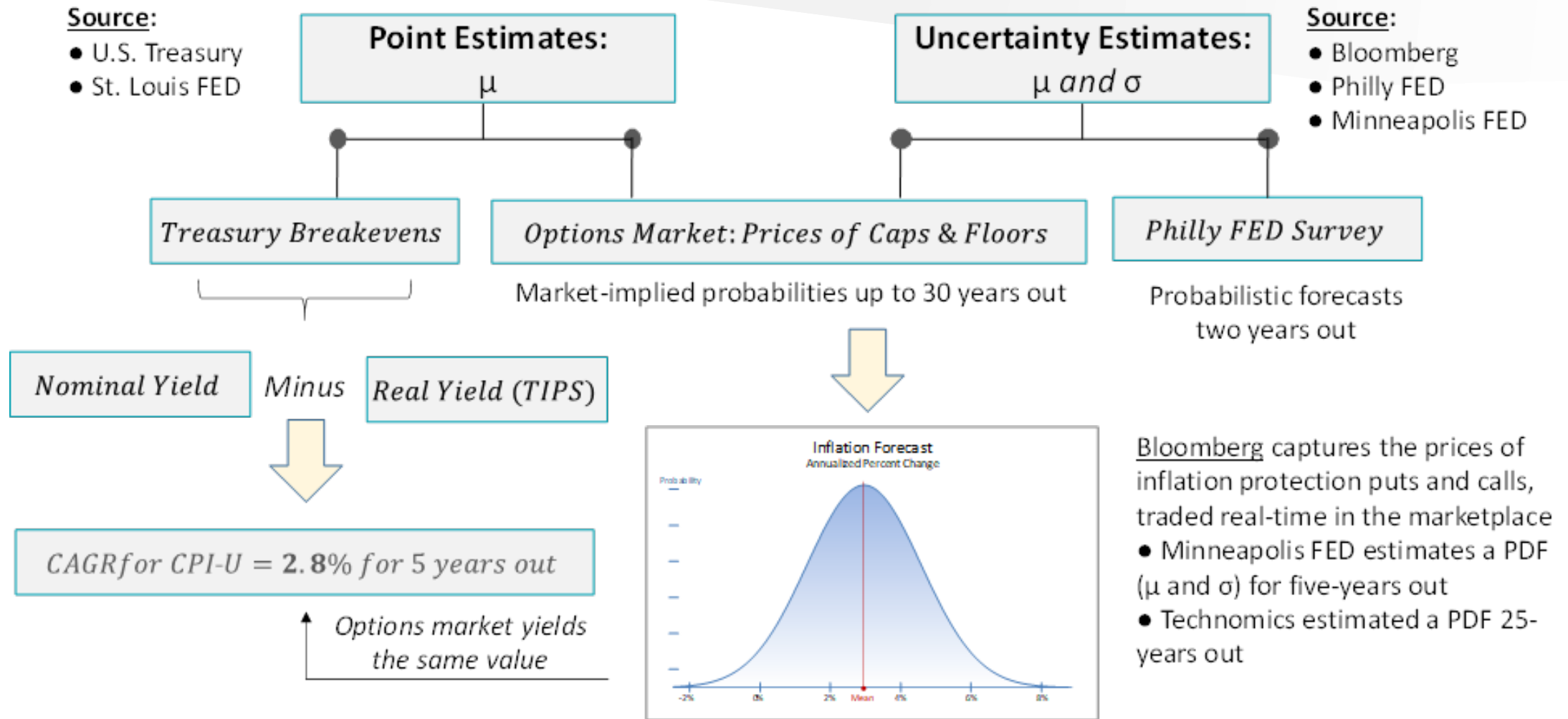Strong results depend upon an extensive data-collection effort

Escalation Measurement – Data Aggregation
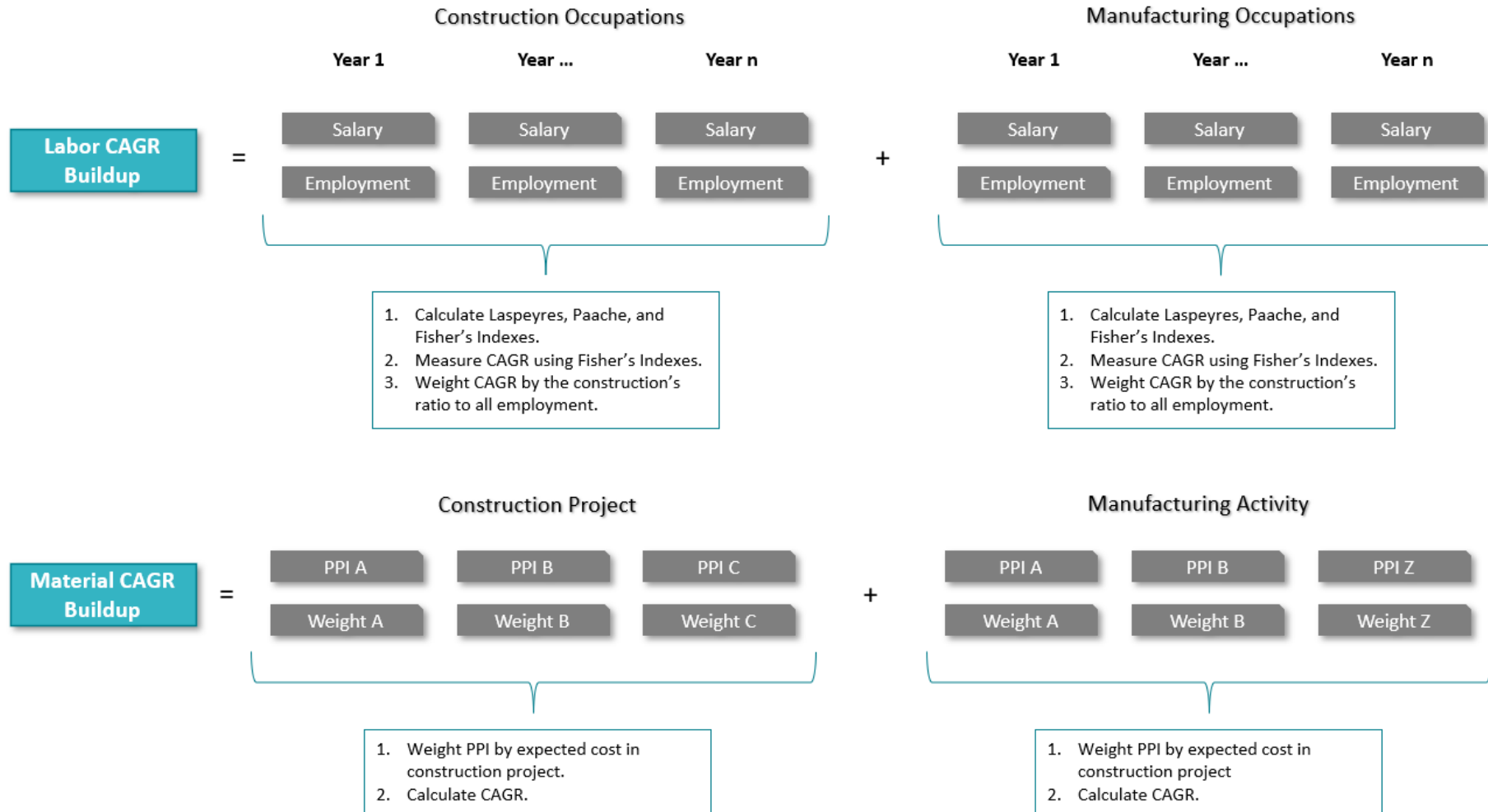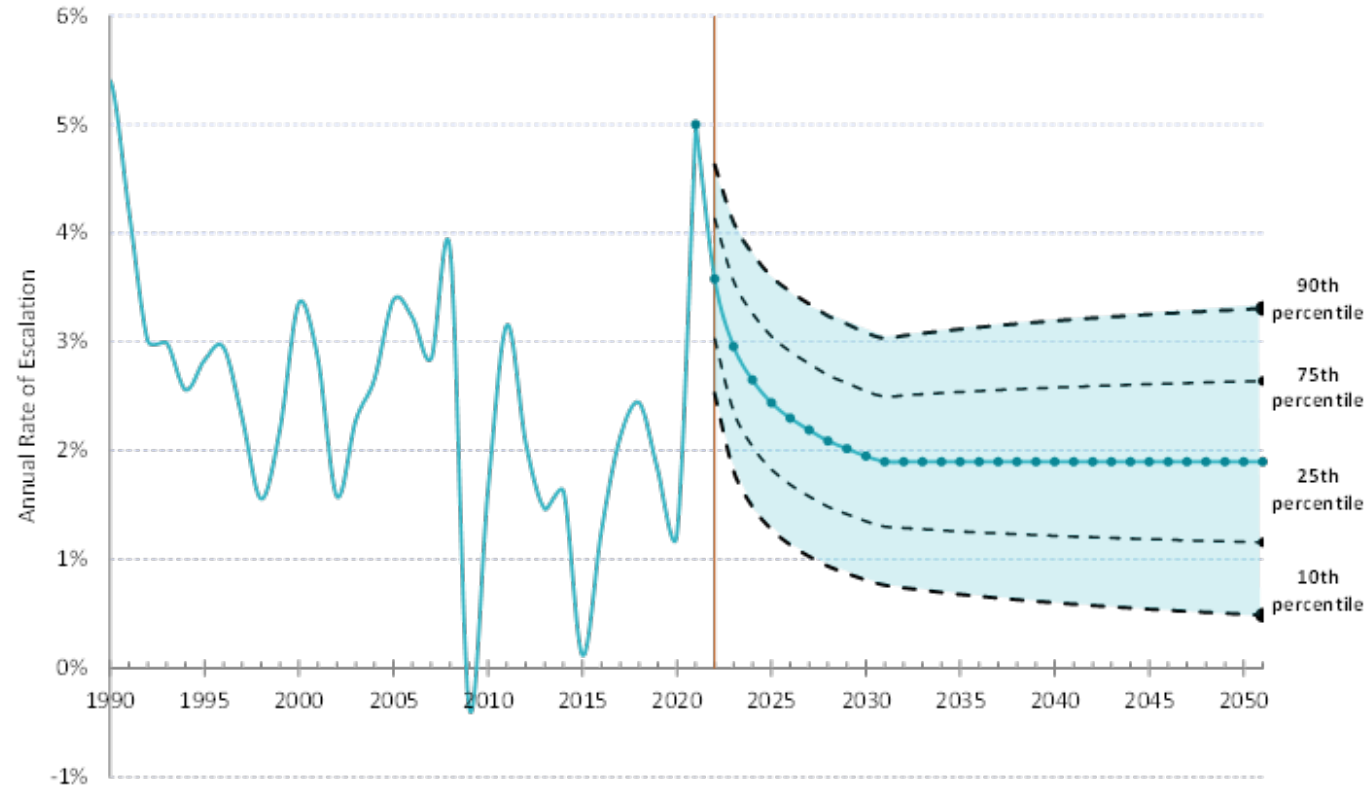
Escalation Measurement – Linkage to the CPI-U

- ## Health Care
  - 100 to 150 basis points over the last decade, using BLS's "Employer Cost of Employee Compensation – Heath Care" as a gauge

- ## Labor Rates
  - Defense wage-rate increases for selected occupations can sometimes run roughly 50 to 100 basis points above core inflation, based on data from the prime contractors

- ## Material Items
  - High-end construction projects can run up to 100 basis points above the CPI-U, on average

Technomics

Forecasts

Source:
- U.S. Treasury
- St. Louis FED

Point Estimates:
μ

Uncertainty Estimates:
μ *and* σ

Source:
- Bloomberg
- Philly FED
- Minneapolis FED

Treasury Breakevens

Options Market: Prices of Caps & Floors

Philly FED Survey

Market-implied probabilities up to 30 years out

Probabilistic forecasts two years out

Nominal Yield Minus *Real Yield (TIPS)*

*CAGR for CPI-U = **2.8%** for 5 years out*

Options market yields the same value

Inflation Forecast
Annualized Percent Change

Probability

-2%   0%   2%   Mean   4%   6%   8%

Bloomberg captures the prices of inflation protection puts and calls, traded real-time in the marketplace
- Minneapolis FED estimates a PDF (μ and σ) for five-years out
- Technomics estimated a PDF 25-years out

Technomics

Forecasts

Probabilistic Estimates of CPI-U Inflation

Forecasts

Probabilistic Estimates of Escalation
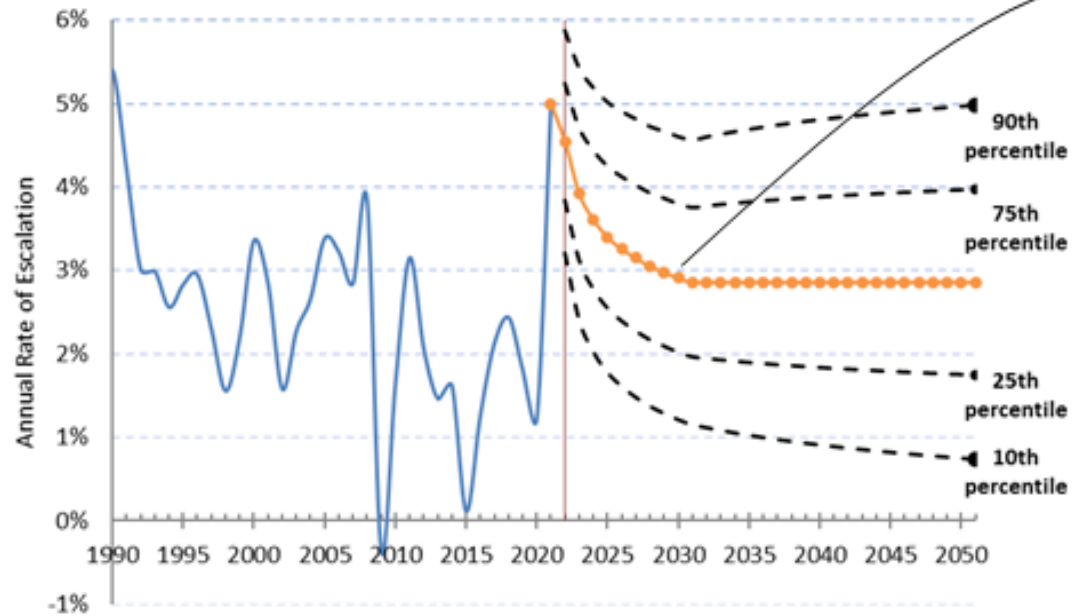
Cross-Cut of Forecast in 2031

Summary

Probabilistic Estimates of CPI-U Inflation
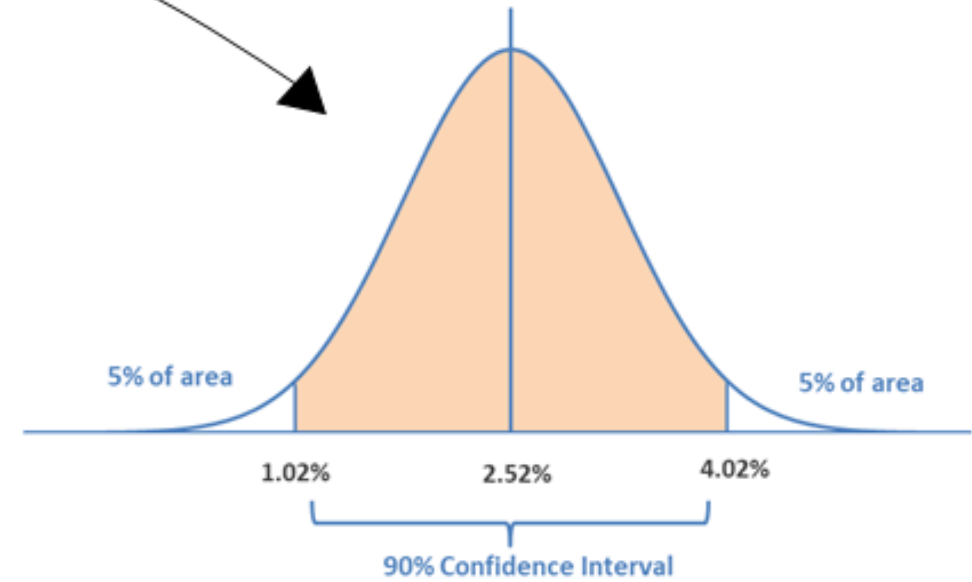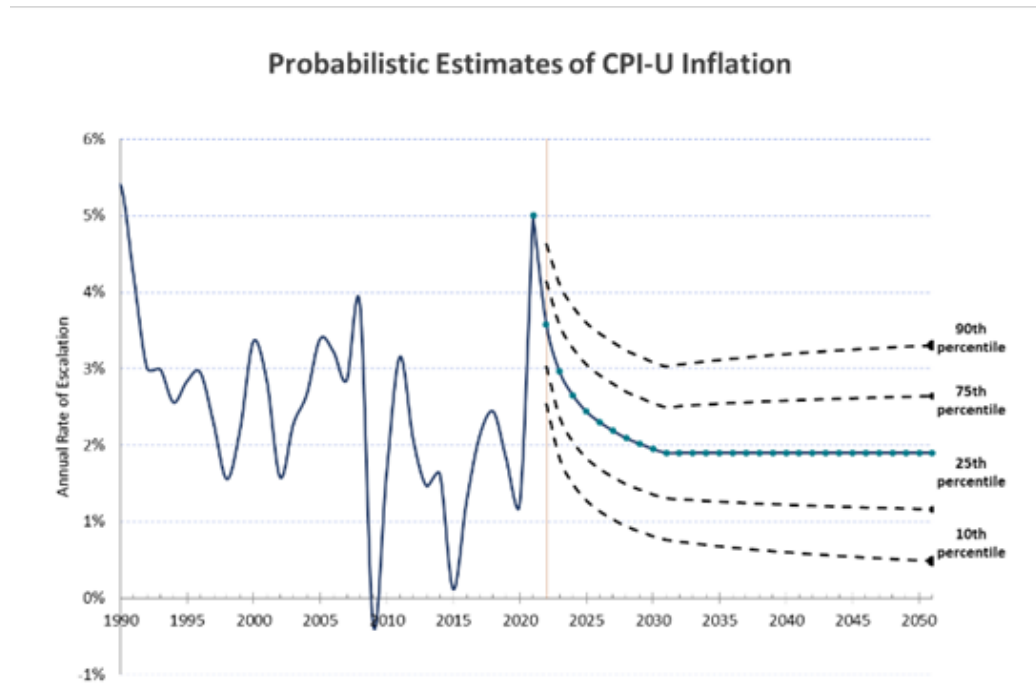
Historical Data:

- Collected historic national CPI-U indexes and calculated Compound Annual Growth Rate (CAGR)
- Calculated a delta between historical escalation to general inflation (Consumer Price Index – Urban Workers [CPI-U]) for 2011-2021

	CPI-U CAGR	Average Delta
10-Yr (2011 – 2021)	1.82%	+.50%
5-Yr (2016 – 2021)	2.34%	N/A

Projections:

- Applied market-based models to calculate point estimates for CPI-U inflation out 30 years
- Also produced probability distributions of projected inflation rates
- Used the historical deltas to forecast composite escalation (labor, materials and overhead)

Conclusions

- Measurement of escalation
  - Challenging
  - Use of government-prescribed indices risky
  - Definitive indices require a strong investment in data collection

- Escalation is a significant percentage of a program or project's nominal cost
  - The percentage will increase as inflation rises

- Probabilistic estimates of inflation can and do change
  - CVs increase with volatility in the economy

- Point predictions of the inflation rate change with macroeconomic currents
  - They are high today

- Treasury "Breakevens" are a valuable measure of inflation

- Inflation derivatives yields PDFs
  - Market based
  - Reflect views of those with "skin in the game"

Accurately measuring escalation and modeling the risk and uncertainty of projections supports better decision making

Technomics