Linking Single Period Arithmetic Attribution Results

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Arithmetic Attribution Definition

The difference between the portfolio and benchmark returns is explained by the sum of a set of attributes.

R=Portfolio Return

$\overline{R}$=Benchmark Return

$a+b+c+\ldots+n$= Attributes

$R-\overline{R}= a+b+c+\ldots+n$

Portfolio return = 21%

Benchmark return = 11%

Allocation = 6%

Selection = 4%

21% - 11% = 6% + 4%

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Challenge: Linking single period attribution results without an unexplained residual.

	Portfolio	Benchmark	Diff.	Allocation	Selection
Period 1	21.00%	11.00%	10.00%	6.00%	4.00%
Period 2	14.00%	9.00%	5.00%	2.00%	3.00%
Total	37.94%	- 20.99%	= **16.95%**		

Naïve Approaches:

Sum	Allocation	Selection	Total
	6.00%	4.00%	
	2.00%	3.00%	
	8.00%	7.00%	**15.00%**

$15.00\% \neq 16.95\%$

Compound	Allocation	Selection	Total
	6.00%	4.00%	
	2.00%	3.00%	
	8.12%	7.12%	**15.24%**

$15.24\% \neq 16.95\%$

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Problem / Solution

Problem : Attributes can't be summed or compounded.

G_{tb} = Original attribute b in time t

$$\sum_t \sum_b G_{tb} \neq R - \overline{R}$$

$$\left[\prod_t \prod_b (1 + G_{tb})\right] - 1 \neq R - \overline{R}$$

Solution : Adjust attributes so they can be summed.

F_{tb} = Adjusted attribute b in time t

$$\sum_t \sum_b F_{tb} = R - \overline{R}$$

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Desirable Linking Algorithm Characteristics

(Cariño 1999)

Generality- The methodology should support any additive single period scheme.

Failing Example: Maribelli-Only links Brinson & Fachler attribution

Familiarity- The interpretation of the multi-period results should be the same as the single period results.

Failing Example: Laker-Cumulative results sacrifice sector level information

No Residuals/Distortions- The methodology should explain exactly the over/under performance without introducing unnecessary distortion.

Failing Examples: Kirievski-Residuals remain.

Campisi-Sign switching.

Algorithms that pass these criteria include:

Frongello, Modified Frongello, Cariño, and Menchero.

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Coefficient Methods

$$F_{tb} = G_{tb}(\text{Scaling Coefficient})$$

$$\sum_t \sum_b F_{tb} = R - \overline{R}$$

Scaling Coefficient Calculations

Cariño(1999)

$$\frac{[\ln(1+R_t)-\ln(1+\overline{R}_t)]/(R_t-\overline{R}_t)}{[\ln(1+R)-\ln(1+\overline{R})]/(R-\overline{R})}$$

Menchero(2001)

$$(1/T)[(R-\overline{R})/((1+R)^{1/T}-(1+\overline{R})^{1/T})] + \frac{(R-\overline{R}-(1/T)[(R-\overline{R})/((1+R)^{1/T}-(1+\overline{R})^{1/T})]\sum_{j=1}^{T}(R_j-\overline{R}_j))(R_t-\overline{R}_t)}{\sum_{j=1}^{T}(R_j-\overline{R}_j)^2}$$

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Coefficient Solutions

	Portfolio	Benchmark	Diff.	Allocation	Selection
Period 1	21.00%	11.00%	10.00%	6.00%	4.00%
Period 2	14.00%	9.00%	5.00%	2.00%	3.00%
Total	37.94%	20.99%	16.95%		

Menchero	Allocation	Selection	Coefficient	Adj. Alloc.	Adj. Selec.
Period 1	6.00%	4.00%	1.1286	6.77%	4.51%
Period 2	2.00%	3.00%	1.1329	2.27%	3.40%
Total				9.04%	7.91%

Cariño	Allocation	Selection	Coefficient	Adj. Alloc.	Adj. Selec.
Period 1	6.00%	4.00%	1.1152	6.69%	4.46%
Period 2	2.00%	3.00%	1.1597	2.32%	3.48%
Total				9.01%	7.94%

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"Andrew, why do we need another algorithm?"

	Math Used	Approach
Menchero & Cariño	Lagrange Calculus & Natural Logarithms Graduate Level	Mathematics used to stretch known attributes until the unexplained voids are filled.
Andrew's Complaint	1. Unintuitive 2. Confusing 3. No Critical Review 4. Unnecessary	1. Arbitrary 2. Fails to answer the question, "Where do the voids (residuals) come from?"
Andrew's Solution	Algebra High School Level	Identify the causes of these voids and attribute the voids to those causes.

Frongello Method is Based on Sound Assumptions

Adding $\overline{R}$ to both sides of our attribution definition,

$$R - \overline{R} = a + b + c + \ldots + n$$

we arrive at a definition of portfolio return.

$$R = \overline{R} + a + b + c + \ldots + n$$

Portfolio return = 21%

Benchmark return = 11%

Allocation = 6%

Selection = 4%

21%=11%+6%+4%

Frongello Dollar Example

	Port.	Bench.	Diff.	Alloc.	Select.
Period 1	21.00%	11.00%	10.00%	6.00%	4.00%
Period 2	14.00%	9.00%	5.00%	2.00%	3.00%
Total	37.94%	20.99%	16.95%		

Start Value for Portfolio and Benchmark=$100

Expectations:

Portfolio Dollar return = $100*37.94% = $37.94

Benchmark Dollar return = $100*20.99% = $20.99

Difference = $37.94-$20.99 = $16.95

The $16.95 difference comes from allocation and selection.

Frongello Example – First Adjustment

	Portfolio Return			Benchmark Return
	Bench.	Alloc.	Select.	Bench.
Period 1	11.00%	6.00%	4.00%	11.00%
Period 2	9.00%	2.00%	3.00%	9.00%

	Portfolio					Benchmark		
	Beg MV	Bench	Alloc.	Select.	End MV	Beg MV	Bench	End MV
Period 1	$100.00	$11.00	$6.00	$4.00	**$121.00**	$100.00	$11.00	**$111.00**
Period 2	**$121.00**	$10.89	$2.42	$3.63	$137.94	**$111.00**	$9.99	$120.99

Portfolio dollar return = $137.94-$100.00=$37.94

Benchmark dollar return = $120.99-$100.00=$20.99

We are expecting $37.94 and $20.99.

How much of the $16.95 difference comes from Allocation and Selection?

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Frongello Example – Second Adjustment

	Portfolio Return			Benchmark Return
	Bench.	Alloc.	Select.	Bench.
Period 1	11.00%	6.00%	4.00%	11.00%
Period 2	9.00%	2.00%	3.00%	9.00%

	Portfolio					Benchmark		
	Beg MV	Bench	Alloc.	Select.	End MV	Beg MV	Bench	End MV
Period 1	$100.00	$11.00	**$6.00**	**$4.00**	$121.00	$100.00	$11.00	$111.00
Period 2	$121.00	$10.89	**$2.42**	**$3.63**	$137.94	$111.00	$9.99	$120.99

Looking for $16.95 of outperformance

Total Allocation=$6.00+$2.42=$8.42

Total Selection=$4.00+$3.63=$7.63

$8.42+$7.63=$16.05

Allocation & Selection explain only $16.05 out of $16.95

Where is this additional $.90 coming from?

Frongello Example – Second Adjustment

	Portfolio Return			Benchmark Return
	Bench.	Alloc.	Select.	Bench.
Period 1	11.00%	6.00%	4.00%	11.00%
Period 2	9.00%	2.00%	3.00%	9.00%

	Portfolio					Benchmark		
	Beg MV	Bench	Alloc.	Select.	End MV	Beg MV	Bench	End MV
Period 1	$100.00	$11.00	$6.00	$4.00	$121.00	$100.00	$11.00	$111.00
Period 2	$121.00	**$10.89**	$2.42	$3.63	$137.94	$111.00	**$9.99**	$120.99

In period 2, the portfolio earned $.90 more at the benchmark rate of return.

How?

Because the portfolio base is $10 larger than the benchmark base.

$10*9%=$.90

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Frongello Example – Second Adjustment

	Portfolio Return			Benchmark Return
	Bench.	Alloc.	Select.	Bench.
Period 1	11.00%	6.00%	4.00%	11.00%
Period 2	9.00%	2.00%	3.00%	9.00%

	Portfolio					Benchmark		
	Beg MV	Bench	Alloc.	Select.	End MV	Beg MV	Bench	End MV
Period 1	$100.00	$11.00	**$6.00**	**$4.00**	$121.00	$100.00	$11.00	$111.00
Period 2	**$121.00**	$10.89	$2.42	$3.63	$137.94	**$111.00**	$9.99	$120.99

The extra $10 comes from allocation ($6) and selection ($4) in period 1.

The additional $.90 comes from these attributes earning the benchmark rate.

($6+$4)*9%=$.54+$.36

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Frongello Example – Both Adjustments

	Portfolio Return			Benchmark Return
	Bench.	Alloc.	Select.	Bench.
Period 1	11.00%	6.00%	4.00%	11.00%
Period 2	9.00%	2.00%	3.00%	9.00%

	Portfolio					Benchmark		
	Beg MV	Bench	Alloc.	Select.	End MV	Beg MV	Bench	End MV
Period 1	$100.00	$11.00	$6.00	$4.00	$121.00	$100.00	$11.00	$111.00
Period 2	$121.00	**$9.99**	**$2.96**	**$3.99**	$137.94	$111.00	$9.99	$120.99

Reallocate the $.90 from the benchmark return to the attributes.

Allocation = $6 + $2.42 + $.54 = $8.96

Selection = $4 + $3.63 + $.36 = $7.99

$8.96+ $7.99 = $16.95

Finally, we have attributed the exact amount we are trying to explain!

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Frongello Adjustments Recap

Before we added attributes, we made two adjustments.

Adjustment 1:
Scale the current attribute by the
total portfolio return through the prior period.

Adjustment 2:
Multiply the prior attributes by the
current benchmark return.

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Percent Example

	Portfolio	Benchmark	Diff.	Allocation	Selection
Period 1	21.00%	11.00%	10.00%	6.00%	4.00%
Period 2	14.00%	9.00%	5.00%	2.00%	3.00%
Total	37.94%	20.99%	**16.95%**		

Frongello Solution:

	Allocation	Selection
Period 1	6.00%	4.00%
Period 2 (Adj. 1)	2% x 1.21 = 2.42%	3% x 1.21 = 3.63%
Period 2 (Adj. 2)	6% x 9% = .54%	4% x 9% = .36%
Total	**8.96%**	**7.99%**

Furthermore:

- Treat the 2 period result as a single period, and link on a third, etc.

Frongello - Multiple Period Example

	Port.	Bench.	Diff.	Alloc.	Select.	Adj. Alloc.	Adj. Selec.
Period 1	21.00%	11.00%	10.00%	6.00%	4.00%	6.00%	**4.00%**
Period 2	14.00%	9.00%	5.00%	2.00%	3.00%	2.96%	**3.99%**
Period 3	20.00%	12.00%	8.00%	1.00%	7.00%	2.45%	**10.61%**
Period 4	17.00%	10.00%	7.00%	5.00%	2.00%	9.42%	**5.17%**
Total	93.67%	49.06%	44.61%			20.83%	23.78%

Selection Illustrated

	Current Attribute	Port Ret Thru n-1	Current Bench Ret	Sum Prior Adj Attributes	Frongello Adjusted Attribute*
Period 1	4.00%	0.00%	11.00%	0.00%	**4.00%**
Period 2	3.00%	21.00%	9.00%	4.00%	**3.99%**
Period 3	7.00%	37.94%	12.00%	7.99%	**10.61%**
Period 4	2.00%	65.53%	10.00%	18.60%	**5.17%**

* = Curr Attribute x (1+Port Ret Thru n-1) + Curr Bench Ret x Sum Prior Adj Attributes

- The formula reduces to the Frongello algorithm

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Frongello Adjusted Attributes

$$F_{tb} = G_{tb} \prod_{j=1}^{t-1} (1 + R_j) + \overline{R}_t \sum_{j=1}^{t-1} F_{jb}$$

Intuitive interpretation:

Each **original attribute** is scaled by the **portfolio total return through the prior period** and the **current period return of the benchmark** compounds with the **total return due to that attribute through the prior period**.

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Differentiating Characteristics

(Mirabelli 2000)

Non A-Causal - The linking methodology should not be dependent on future events when scaling single period results.

(Frongello 2002)

Sincerity - The method should reflect the reality of fundamental financial principles. Beware of mathematical rhetoric.

Intuitive - The method should preferably use mathematics friendly to a wide audience.

Order Dependence - The ordering of periods will affect cumulative attribution results when defining the portfolio investment base by total return. By definition accurate, despite some protests.

Return Sensitive – Periods of low returns will require higher scaling than periods of high returns, and vice versa.

A-Causality - Frongello vs. Menchero

The Frongello method is not dependent on future returns.
Prior period scaling does not change when adding periods.

Frongello	Port.	Bench.	Diff.	Alloc.	Select.
Period 1	21.00%	11.00%	10.00%	**6.00%**	**4.00%**
Period 2	14.00%	9.00%	5.00%	**2.96%**	**3.99%**
Total	37.94%	20.99%	16.95%	8.96%	7.99%

Frongello	Port.	Bench.	Diff.	Alloc.	Select.
Period 1	21.00%	11.00%	10.00%	**6.00%**	**4.00%**
Period 2	14.00%	9.00%	5.00%	**2.96%**	**3.99%**
Period 3	20.00%	12.00%	8.00%	2.45%	10.61%
Total	65.53%	35.51%	30.02%	11.41%	18.60%

The Menchero scaling coefficient is dependent on future returns.
Prior period scaling does change when adding periods.

Menchero	Port.	Bench.	Diff.	Alloc.	Select.
Period 1	21.00%	11.00%	10.00%	**6.77%**	**4.51%**
Period 2	14.00%	9.00%	5.00%	**2.27%**	**3.40%**
Total	37.94%	20.99%	16.95%	9.04%	7.91%

Menchero	Port.	Bench.	Diff.	Alloc.	Select.
Period 1	21.00%	11.00%	10.00%	**7.82%**	**5.22%**
Period 2	14.00%	9.00%	5.00%	**2.61%**	**3.92%**
Period 3	20.00%	12.00%	8.00%	1.31%	9.14%
Total	65.53%	35.51%	30.02%	11.74%	18.28%

Sincerity - Frongello vs. Cariño

A model should attribute the contribution to excess return in the period in which it occurs.

	Port.	Bench.	Cum. Port	Cum. Bench.	Cum. Diff.	Cont. Cum. Diff.
Period 1	21.00%	11.00%	21.00%	11.00%	10.00%	**10.00%**
Period 2	14.00%	9.00%	37.94%	20.99%	16.95%	**6.95%**
Period 3	20.00%	12.00%	65.53%	35.51%	30.02%	**13.07%**

Frongello Method:

Contribution to excess return is attributed to the period in which it occurs.

Frongello	Port.	Bench.	Diff.	Adj. Alloc.	Adj. Select.	Cont. Cum. Attr.
Period 1	21.00%	11.00%	10.00%	6.00%	4.00%	**10.00%**
Period 2	14.00%	9.00%	5.00%	2.96%	3.99%	**6.95%**
Period 3	20.00%	12.00%	8.00%	2.45%	10.61%	**13.07%**
Total	65.53%	35.51%	30.02%	11.41%	18.60%	

Cariño Method:

Contribution to excess return is **not** attributed to the period in which it occurs.

Cariño	Port.	Bench.	Diff.	Adj. Alloc.	Adj. Select.	Cont. Cum. Attr.
Period 1	21.00%	11.00%	10.00%	7.76%	5.18%	**12.94%**
Period 2	14.00%	9.00%	5.00%	2.69%	4.04%	**6.73%**
Period 3	20.00%	12.00%	8.00%	1.29%	9.06%	**10.35%**
Total	65.53%	35.51%	30.02%	11.75%	18.27%	

Return Sensitivity – Cariño vs. Menchero

Cariño	Port	Bench	Diff.	Alloc	Selec	**Coef**	Adj. Alloc	Adj. Selec
Period 1	21.00%	11.00%	10.00%	6.00%	4.00%	**1.17**	**6.99%**	4.66%
Period 2	14.00%	9.00%	5.00%	2.00%	3.00%	**1.21**	2.42%	3.64%
Period 3	8.00%	1.00%	7.00%	1.00%	6.00%	**1.29**	1.29%	**7.76%**
Total	48.98%	22.20%	26.78%				10.71%	16.06%

Menchero	Port	Bench	Diff.	Alloc	Selec	**Coef**	Adj. Alloc	Adj. Selec
Period 1	21.00%	11.00%	10.00%	6.00%	4.00%	**1.22**	**7.29%**	4.86%
Period 2	14.00%	9.00%	5.00%	2.00%	3.00%	**1.22**	2.44%	3.66%
Period 3	8.00%	1.00%	7.00%	1.00%	6.00%	**1.22**	1.22%	**7.31%**
Total	48.98%	22.20%	26.78%				10.95%	15.83%

Notice that the Cariño scaling coefficients vary with the level of return while the Menchero coefficients do not.

Attributes are a component of total return and they compound with the growth occurring in other periods.

Therefore, an attribute in a lower return period should be scaled more than a comparable attribute in a higher return period.

Frongello methods agree with Cariño method on this issue.

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Order Dependence - Frongello

BEFORE	Port.	Bench.	Diff.	Alloc.	Select.	Adj. Alloc.	Adj. Selec.
Period 1	21.00%	11.00%	10.00%	6.00%	4.00%	6.00%	4.00%
Period 2	14.00%	9.00%	5.00%	2.00%	3.00%	2.96%	3.99%
Period 3	8.00%	1.00%	7.00%	1.00%	6.00%	1.47%	8.36%
Total	48.98%	22.20%	26.78%			**10.43%**	**16.35%**

AFTER	Port.	Bench.	Diff.	Alloc.	Select.	Adj. Alloc.	Adj. Selec.
Period 1	8.00%	1.00%	7.00%	1.00%	6.00%	1.00%	6.00%
Period 2	14.00%	9.00%	5.00%	2.00%	3.00%	2.25%	3.78%
Period 3	21.00%	11.00%	10.00%	6.00%	4.00%	7.74%	6.00%
Total	48.98%	22.20%	26.78%			**10.99%**	**15.78%**

Reversing the periods produces a different result!

Don’t read this page unless you are a fanatic!!

If you define investment base by	and compound past attributes by	the cross product of Selection earned over Allocation will be assigned to	Use the following formula:
Portfolio Total Return	Index Total Return	Selection	Frongello Linking Algorithm $F_{tb} = G_{tb}\prod_{j=1}^{t-1}(1+R_j) + \overline{R}_t\sum_{j=1}^{t-1}F_{jb}$
Index Total Return	Portfolio Total Return	Allocation	Reversed Frongello Linking Algorithm $F_{tb} = G_{tb}\prod_{j=1}^{t-1}(1+\overline{R}_j) + R_t\sum_{j=1}^{t-1}F_{jb}$
Average Total Return	Average Total Return	Half Selection & Half Allocation	Modified Frongello Linking Algorithm $F_{tb} = G_{tb}.5[\prod_{j=1}^{t-1}(1+R_j) + \prod_{j=1}^{t-1}(1+\overline{R}_j)] + .5(R_t+\overline{R}_t)\sum_{j=1}^{t-1}F_{jb}$

Frongello

Frongello	Port	Bench	Diff.	Alloc	Selec	Adj. Alloc	Adj. Selec
Period 1	21.00%	11.00%	10.00%	6.00%	4.00%	6.00%	4.00%
Period 2	14.00%	9.00%	5.00%	2.00%	3.00%	2.96%	3.99%
Total	48.98%	22.20%	26.78%			8.96%	7.99%

$$F_{tb} = G_{tb}\prod_{j=1}^{t-1}(1+R_j) + \overline{R}_t\sum_{j=1}^{t-1}F_{jb}$$

Modified Frongello

M. Frongello	Port	Bench	Diff.	Alloc	Selec	Adj. Alloc	Adj. Selec
Period 1	21.00%	11.00%	10.00%	6.00%	4.00%	6.00%	4.00%
Period 2	14.00%	9.00%	5.00%	2.00%	3.00%	3.01%	3.94%
Total	48.98%	22.20%	26.78%			9.01%	7.94%

$$F_{tb} = G_{tb}.5[\prod_{j=1}^{t-1}(1+R_j) + \prod_{j=1}^{t-1}(1+\overline{R}_j)] + .5(R_t + \overline{R}_t)\sum_{j=1}^{t-1}F_{jb}$$

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Modified Frongello - Multiple Period Example

	Port.	Bench.	Diff.	Alloc.	Select.	Adj. Alloc.	Adj. Selec.
Period 1	21.00%	11.00%	10.00%	6.00%	4.00%	6.00%	**4.00%**
Period 2	14.00%	9.00%	5.00%	2.00%	3.00%	3.01%	**3.94%**
Period 3	20.00%	12.00%	8.00%	1.00%	7.00%	2.74%	**10.33%**
Period 4	17.00%	10.00%	7.00%	5.00%	2.00%	9.11%	**5.48%**
Total	93.67%	49.06%	44.61%			20.86%	23.75%

Selection Illustrated					
	Current Attribute	Avg. Cum. Ret Thru n-1	Current Avg. Ret	Sum Prior Adj Attributes	Mod - Frongello Adjusted Attribute*
Period 1	4.00%	0.00%	16.00%	0.00%	**4.00%**
Period 2	3.00%	16.00%	11.50%	4.00%	**3.94%**
Period 3	7.00%	29.47%	16.00%	7.94%	**10.33%**
Period 4	2.00%	50.52%	13.50%	18.27%	**5.48%**

= Curr Attribute x [(1+Port Ret Thru n-1) + (1+Bench Ret Thru n-1)]/2 +

[Curr Port Ret + Curr Bench Ret]/2 x Sum Prior Adj Attributes

- The formula reduces to the Modified Frongello algorithm

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Do these methods provide different answers?

Recent Frongello Study

Periods=120 (Monthly, Sep 93 – Aug 03)
Trials = 10,000
Index= Lehman Brothers Aggregate
Portfolio = Index carve outs (100 randomly selected issues)
Scheme = Duration, Allocation, Selection by sector buckets

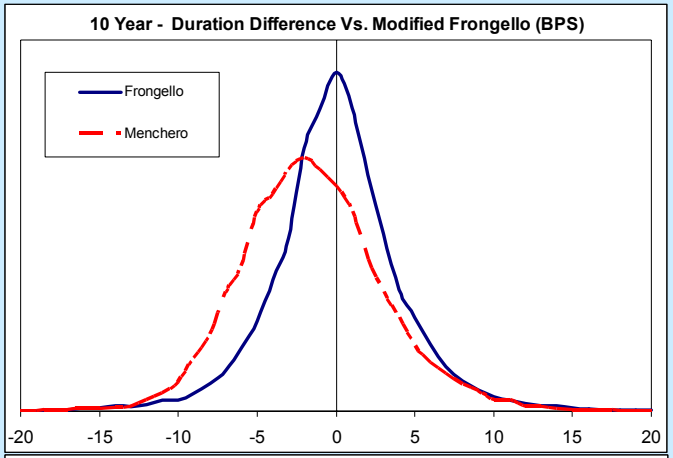
Results

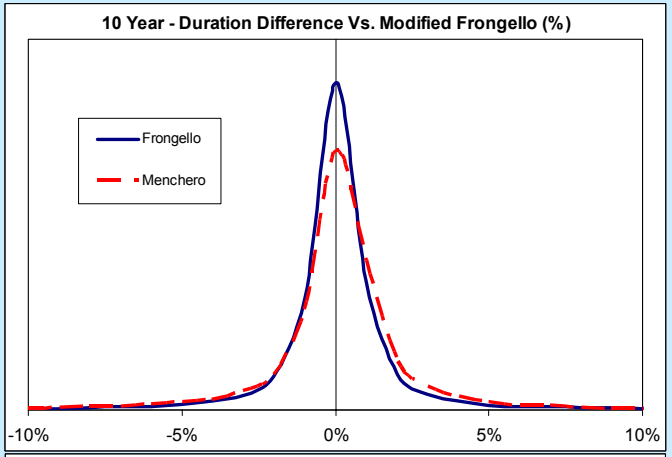
Cariño and Modified Frongello linked results are almost identical.
Maximum BPS difference in linked results never more than 1/3 of a BP for any attribute.
Roughly 97% of the time the linked attributes differ by less than .1%.

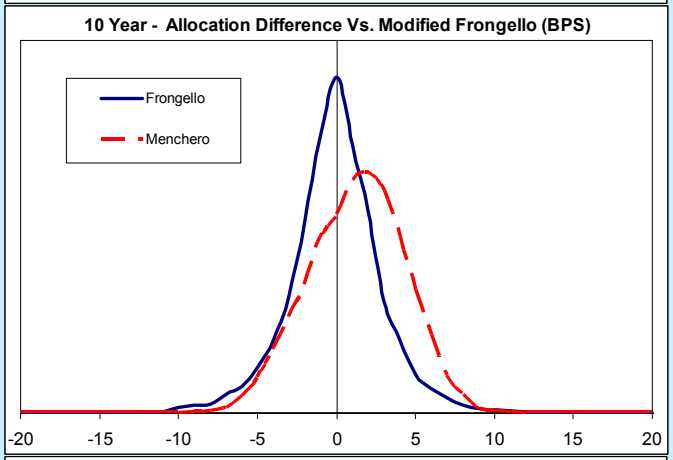
Frongello and Menchero provide very close approximations to Modified Frongello & Cariño.

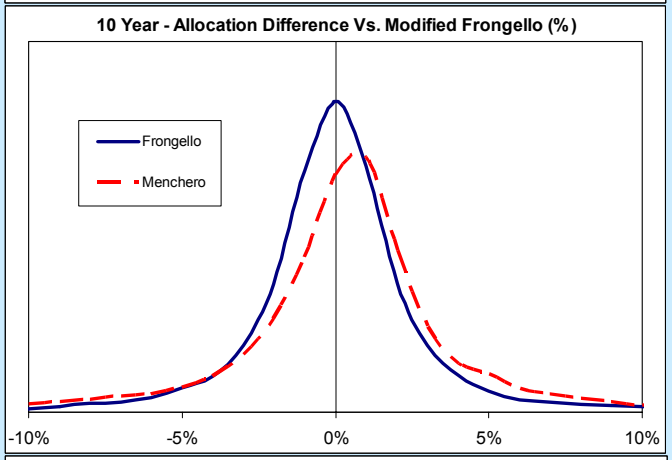
Conclusion

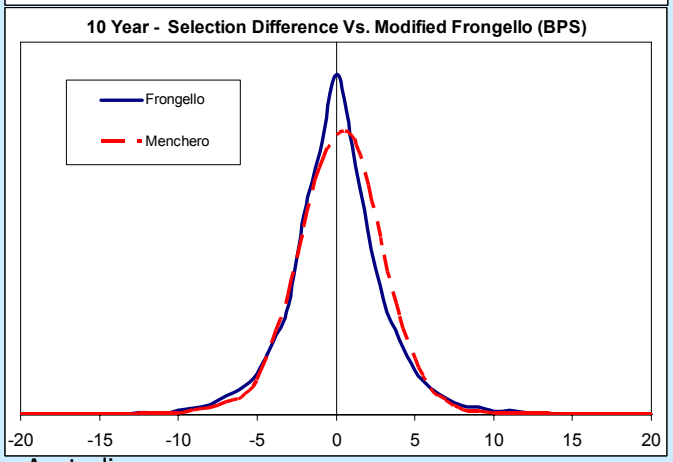
The linked results are *mathematically* different between the methods,
but these differences are not *materially* different.

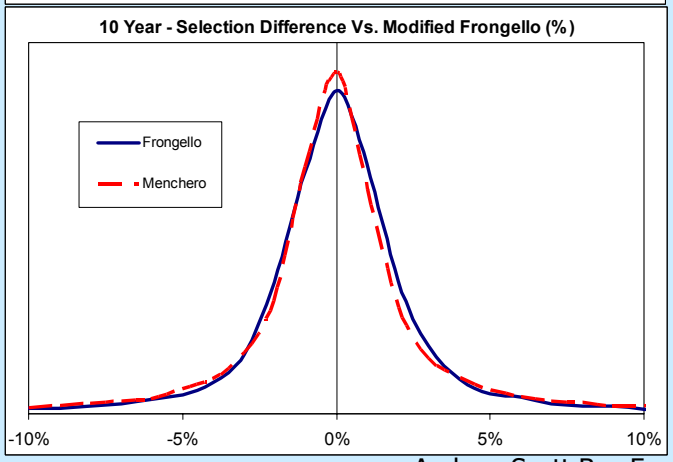

10 Year - Duration Difference Vs. Modified Frongello (BPS)
Frongello
Menchero
-20
-15
-10
-5
0
5
10
15
20


10 Year - Duration Difference Vs. Modified Frongello (%)
Frongello
Menchero
-10%
-5%
0%
5%
10%

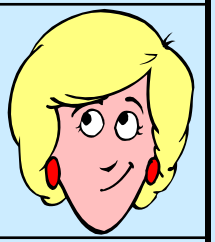

10 Year - Allocation Difference Vs. Modified Frongello (BPS)
Frongello
Menchero
-20
-15
-10
-5
0
5
10
15
20


10 Year - Allocation Difference Vs. Modified Frongello (%)
Frongello
Menchero
-10%
-5%
0%
5%
10%


10 Year - Selection Difference Vs. Modified Frongello (BPS)
Frongello
Menchero
-20
-15
-10
-5
0
5
10
15
20


10 Year - Selection Difference Vs. Modified Frongello (%)
Frongello
Menchero
-10%
-5%
0%
5%
10%

Linking method comparison

	Non A-Causal	Intuitive	Non Order Dependent	Sincerity	Return Sensitive	Suitable for Absolute Attribution	Agreement Among Methods
Modified Frongello							
Frongello							
Cariño							
Menchero							

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Questions?