

# The Illusion of Extrapolating Randomness from Periodic Tables

By

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## Executive Summary

The periodic table of investment returns was first published in 1999. Its purpose was to demonstrate the randomness of returns of various asset classes from one year to the next. The checkerboard pattern shows no obvious pattern of one asset class systematically dominating other asset classes. The order in which the asset classes line up is indeed random. Correlation analysis verifies this: when examining one-year periods there is no statistically significant correlation of rank for consecutive or non-consecutive years. Calculations verify what appears clear to the naked eye: at one-year periods, both the rank relative to other asset classes and the returns of those asset classes follow a random walk.

But periodic tables traditionally show only single year holding periods. When the same tables are constructed for longer holding periods, the randomness of the order of the asset classes in a given period gradually disappears. In fact, patterns in the ranking order of asset classes start to develop at 10-year holding periods and become clear by 20-years. In other words, as the length of the time period increases, the order in which the asset classes line up eventually becomes nonrandom. Furthermore, as the length of the holding period increases, the average correlations become ever stronger, becoming statistically significant after 15 years and rising to as high as 87% for 30-years.

If asset class rankings remained random over longer periods, then time horizons would not affect portfolio decision making. But these results suggest that time is as much a factor as style and size in the portfolio construction process. They challenge the time-diversification fallacy and also suggest that, unlike mean-variance inspired portfolios that do not consider time as a factor, financial planners should consider the anticipated holding period when building investment portfolios that support lifetime financial plans.

## Introduction

Created originally in 1999 by Jay Kloepfer of Callan Associates (Callan, 2018), the periodic table of returns has become one of the most ubiquitous displays for illustrating the randomness of returns.<sup>1</sup> Most advisors agree that it is a very effective graphical exhibit to depict the unpredictability of returns over one-year holding periods. Technically, low and statistically insignificant correlations verify visual judgement: the rankings of the returns of the various asset classes are, indeed, random over one-year periods.

However, financial planners rarely build one-year plans for their clients. Overwhelmingly, they build plans designed for the long term – 20 or 30 years, perhaps even longer. They build lifetime plans, often covering both the accumulation and distribution phases as well as estate planning. Periodic tables based on one year are of little use in this context, except perhaps to demonstrate the folly of focusing on the short term when investing.

This paper presents evidence that the randomness displayed in one-year periodic tables begins to disappear over longer holding periods. That is, longer holding periods have stronger correlations, and these correlations ultimately become statistically significant below the one percent level after 15 years. 2002 Nobel Laureate, Daniel Kahneman, used this same approach to demonstrate the illusion of stock-picking skill (Kahneman, 2011). The implication is that extrapolating the randomness of short-term rankings to the long term is also an illusion. Logicians refer to it as an “unwarranted extrapolation” fallacy (Copi and Cohen, 2005). The fact that correlations in long term investment returns are not random has implications for several areas of financial planning, including the modern portfolio theory versus dedicated portfolio theory debate and the time diversity debate.

The first section of this paper reviews the one-year periodic table and its correlations. The second section begins lengthening the time horizon, highlighting the ever-stronger correlations as the holding period extends to ever longer spans.<sup>2</sup> The third section discusses details of the implications of these results.

# 1. One-Year Periodic Table Correlations – Clearly Random

Exhibit 1 is an example of the periodic table of investment returns found at the Callan website, originators of the concept. The table shows the annual returns of 10 different asset classes over 20 single year periods. A quick glance at the table makes clear that the rankings, the order in which the asset classes line up in a given year, appear to change randomly from year to year. Though there are a couple of streaks, there is no apparent pattern in the checkerboard of colors. The conclusion is that the ranking in one year appears to be uncorrelated with the ranking in any preceding or following years. The implication is that it is best to diversify portfolios because next year's winner is unpredictable. It is like rolling 10-sided dice.

Exhibit 1

Callan Periodic Table of Annual Returns, 10 Asset Classes, 1998-2017

## The Callan Periodic Table of Investment Returns

Annual Returns for Key Indices Ranked in Order of Performance (1998–2017)

1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
S&P 500 Growth	MSCI Emerging Markets	Russell 2000 Value	Russell 2000 Value	Bloomberg Barclays Agg	MSCI Emerging Markets	MSCI Emerging Markets	MSCI Emerging Markets	MSCI Emerging Markets	MSCI Emerging Markets	Bloomberg Barclays Agg	MSCI Emerging Markets	Russell 2000 Growth	Bloomberg Barclays Agg	MSCI Emerging Markets	Russell 2000 Growth	S&P 500 Growth	S&P 500 Growth	Russell 2000 Value	MSCI Emerging Markets
42.16%	66.84%	22.83%	14.92%	10.26%	55.82%	25.55%	34.80%	32.17%	35.38%	-5.24%	78.51%	29.89%	7.84%	18.23%	43.36%	14.89%	5.52%	31.74%	37.28%
S&P 500 Growth	Russell 2000 Growth	Bloomberg Barclays Agg	Bloomberg Barclays High Yield	Bloomberg Barclays High Yield	Russell 2000 Growth	Russell 2000 Value	MSCI World ex USA	MSCI World ex USA	MSCI World ex USA	Bloomberg Barclays High Yield	Bloomberg Barclays High Yield	Russell 2000	Bloomberg Barclays High Yield	Russell 2000 Value	Russell 2000	S&P 500	S&P 500	Russell 2000	S&P 500 Growth
28.58%	43.89%	11.63%	8.43%	-1.37%	48.54%	22.23%	14.47%	25.71%	12.44%	-26.16%	58.21%	26.83%	4.98%	18.95%	38.82%	13.69%	1.38%	21.31%	27.44%
MSCI World ex USA	S&P 500 Growth	S&P 500 Value	Bloomberg Barclays High Yield	MSCI Emerging Markets	Russell 2000	MSCI World ex USA	S&P 500 Value	Russell 2000 Value	S&P 500 Growth	Russell 2000 Value	Russell 2000 Value	S&P 500 Growth	S&P 500 Value	S&P 500 Value	Russell 2000 Value	S&P 500 Value	Bloomberg Barclays Agg	S&P 500 Value	MSCI World ex USA
18.77%	28.24%	6.68%	3.28%	-6.10%	47.25%	28.38%	5.82%	23.48%	9.13%	-38.92%	34.47%	24.59%	4.65%	17.68%	34.32%	12.36%	6.59%	17.49%	24.21%
S&P 500 Value	MSCI World ex USA	Russell 2000	Russell 2000	Russell 2000 Value	Russell 2000 Value	Russell 2000	S&P 500	S&P 500 Value	Russell 2000 Growth	Russell 2000	MSCI World ex USA	MSCI Emerging Markets	S&P 500	MSCI World ex USA	S&P 500 Growth	Bloomberg Barclays Agg	Russell 2000 Growth	Bloomberg Barclays High Yield	Russell 2000 Growth
14.68%	27.32%	-3.02%	2.49%	-11.43%	46.03%	18.33%	4.91%	20.81%	7.65%	-33.79%	33.67%	18.88%	2.11%	16.41%	32.75%	5.97%	-1.38%	17.13%	22.17%
Bloomberg Barclays Agg	Russell 2000	Bloomberg Barclays High Yield	MSCI Emerging Markets	MSCI World ex USA	MSCI World ex USA	S&P 500 Value	Russell 2000 Value	Russell 2000	Bloomberg Barclays Agg	S&P 500 Growth	S&P 500 Growth	Bloomberg Barclays High Yield	S&P 500 Value	Russell 2000	S&P 500	Russell 2000 Growth	MSCI World ex USA	S&P 500	S&P 500
8.67%	21.26%	-3.86%	-2.61%	-15.89%	39.49%	15.71%	4.71%	18.37%	6.87%	-34.92%	31.57%	15.19%	-0.48%	16.35%	32.39%	3.46%	-3.84%	11.96%	21.83%
Bloomberg Barclays High Yield	S&P 500	S&P 500	Russell 2000 Growth	Russell 2000 Value	S&P 500 Value	Russell 2000 Growth	Russell 2000	S&P 500	S&P 500	S&P 500	Russell 2000	S&P 500 Value	S&P 500	Russell 2000 Growth	S&P 500 Value	Russell 2000	S&P 500 Value	Russell 2000 Value	S&P 500 Value
1.87%	21.64%	-9.11%	-0.23%	-30.48%	31.79%	14.31%	4.55%	15.79%	5.49%	-37.60%	27.17%	15.19%	-3.91%	16.00%	31.99%	4.89%	-3.13%	11.32%	15.36%
Russell 2000 Growth	S&P 500 Value	MSCI World ex USA	S&P 500 Value	S&P 500 Value	Bloomberg Barclays High Yield	Bloomberg Barclays High Yield	Russell 2000 Growth	Russell 2000 Value	S&P 500 Value	Russell 2000 Growth	S&P 500 Value	S&P 500	S&P 500	Russell 2000	Bloomberg Barclays High Yield	MSCI World ex USA	Russell 2000 Value	Russell 2000	MSCI Emerging Markets
1.23%	12.73%	-13.37%	-11.71%	-20.85%	28.97%	11.13%	4.15%	13.35%	1.99%	-38.54%	26.47%	15.06%	-4.18%	15.81%	21.82%	4.22%	-4.41%	11.19%	14.65%
Russell 2000	Bloomberg Barclays High Yield	S&P 500 Growth	S&P 500	S&P 500	S&P 500	S&P 500	S&P 500	S&P 500 Growth	Bloomberg Barclays High Yield	Bloomberg Barclays High Yield	S&P 500 Value	S&P 500 Value	S&P 500 Growth	Russell 2000 Value	S&P 500 Growth	Bloomberg Barclays High Yield	Bloomberg Barclays High Yield	Bloomberg Barclays High Yield	S&P 500 Growth
-2.55%	2.39%	-22.08%	-11.89%	-22.10%	28.68%	10.88%	4.00%	11.85%	1.87%	-39.22%	21.17%	15.65%	-5.50%	14.61%	7.44%	2.45%	-4.47%	6.89%	7.84%
Russell 2000 Value	Bloomberg Barclays Agg	Russell 2000 Growth	S&P 500 Growth	S&P 500 Growth	S&P 500 Growth	S&P 500 Growth	Bloomberg Barclays High Yield	S&P 500 Growth	Russell 2000	MSCI World ex USA	Russell 2000 Value	MSCI World ex USA	MSCI World ex USA	Russell 2000 Growth	Bloomberg Barclays Agg	MSCI Emerging Markets	Russell 2000 Value	MSCI World ex USA	Bloomberg Barclays High Yield
6.45%	-0.83%	-22.43%	-12.73%	-23.39%	25.66%	6.13%	2.74%	11.01%	-1.57%	-43.56%	20.58%	8.95%	-12.21%	14.99%	-2.02%	2.19%	-7.47%	2.75%	7.50%
MSCI Emerging Markets	Russell 2000 Value	MSCI Emerging Markets	MSCI World ex USA	Russell 2000 Growth	Bloomberg Barclays Agg	Bloomberg Barclays Agg	Bloomberg Barclays Agg	Bloomberg Barclays Agg	Russell 2000 Value	MSCI Emerging Markets	Bloomberg Barclays Agg	Bloomberg Barclays Agg	MSCI Emerging Markets	Bloomberg Barclays Agg	MSCI Emerging Markets	MSCI World ex USA	MSCI Emerging Markets	Bloomberg Barclays Agg	Bloomberg Barclays Agg
-23.34%	-1.49%	-36.71%	-21.40%	-38.20%	4.16%	4.34%	2.43%	4.33%	-9.78%	-53.33%	5.93%	6.54%	-18.42%	4.21%	-2.60%	-4.32%	-14.82%	2.65%	3.54%

Source: Callan ([www.callan.com](http://www.callan.com))

Exhibit 2 is a larger version of the periodic table. Like Callan, it covers 20 years, 1988-2017. But it uses 18 asset classes that are more diverse than those used by Callan (see Exhibit 3 for a specific listing).<sup>3</sup> The underlying principles and conclusions remain the same: one-year rankings are random. Now it is like rolling 18-sided dice.

Note that what the periodic table is designed to show is the rank order of asset classes, not their absolute returns. A given asset class may be in last place this year by just a tiny fraction or by a large amount. The next year, it may return less than this year but rise to first place because it had the best returns. By the same token, it may rank in first place this year by a tiny or large margin, then achieve an even higher level the next year but drop to last place in the rankings because all others rose enough to beat it. The point is that periodic tables are designed to show randomness of ranks, not levels. This is important because it means that the appropriate statistical correlation to calculate statistical significance must be based on ranks, not levels.

**Exhibit 2**  
**Periodic Table of Annual Returns, 18 Asset Classes, 1998-2017**

1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Lrge Grw	Emrg Mkt	Cmdty	Sm Val	Cmdty	Sm Val	REIT	Emrg Mkt	REIT	Emrg Mkt	LT Gov	Emrg Mkt	Mid Grw	LT Gov	Lrge Val	Mid Val	REIT	Lrge Grw	Sm Val	Emrg Mkt
41.4%	66.5%	31.9%	23.7%	33.6%	31.9%	30.4%	34.0%	34.0%	39.4%	25.9%	78.5%	31.9%	28.2%	30.8%	49.0%	27.2%	5.5%	36.6%	37.3%
Lrge Val	Mid Grw	Mid Core	Sm Core	LT Gov	Emrg Mkt	Emrg Mkt	Cmdty	Emrg Mkt	Cmdty	5-Yr Gov	Mid Grw	Sm Grw	Corp	Sm Val	Sm Grw	LT Gov	REIT	Lrge Val	Lrge Grw
33.2%	47.1%	30.0%	15.7%	17.8%	55.8%	25.6%	24.9%	32.1%	22.1%	13.1%	42.9%	29.6%	17.9%	19.8%	45.2%	23.9%	2.1%	26.9%	29.8%
S&P 500	Sm Grw	Mid Val	REIT	Corp	Sm Grw	Mid Core	Mid Core	Intl Mrkt	Lrge Grw	Corp	Sm Grw	Sm Core	5-Yr Gov	REIT	Sm Val	Corp	5-Yr Gov	Sm Core	Mid Grw
28.6%	46.7%	26.1%	15.5%	16.3%	54.2%	22.8%	16.0%	25.7%	12.9%	8.8%	37.0%	29.3%	9.5%	19.7%	41.6%	17.3%	1.7%	23.4%	26.9%
Intl Mrkt	Cmdty	REIT	Corp	5-Yr Gov	Sm Core	Sm Core	Intl Mrkt	Lrge Val	Intl Mrkt	T-Bills	Mid Core	REIT	REIT	Mid Val	Sm Core	S&P 500	S&P 500	Mid Val	Sm Grw
18.8%	31.8%	25.9%	10.6%	12.9%	48.9%	20.7%	14.5%	25.4%	12.4%	1.6%	37.0%	27.6%	7.3%	19.2%	41.1%	13.7%	1.4%	23.2%	25.5%
LT Gov	Intl Mrkt	Sm Val	Lrge Val	REIT	Mid Val	Intl Mrkt	Mid Val	Sm Val	5-Yr Gov	Sm Core	Mid Val	Sm Val	Lrge Grw	Sm Core	Mid Grw	Lrge Grw	Mid Grw	Mid Core	Intl Mrkt
13.1%	27.9%	7.9%	7.9%	5.2%	47.8%	20.4%	9.8%	24.5%	10.1%	-30.8%	34.9%	26.6%	7.2%	18.5%	37.9%	13.1%	1.3%	22.3%	24.2%
Corp	Lrge Grw	Lrge Val	5-Yr Gov	T-Bills	Mid Core	Sm Val	Sm Val	Lrge Core	LT Gov	Lrge Grw	Intl Mrkt	Mid Core	Lrge Grw	Emrg Mkt	Lrge Val	Lrge Val	T-Bills	Lrge Core	S&P 500
10.8%	23.1%	23.0%	7.6%	1.6%	41.8%	20.2%	8.9%	21.0%	9.9%	-32.6%	33.7%	25.7%	4.4%	18.2%	37.4%	12.1%	0.0%	13.9%	21.8%
5-Yr Gov	Sm Core	LT Gov	Mid Val	Emrg Mkt	Intl Mrkt	Mid Val	Sm Core	Sm Core	Mid Grw	Sm Val	Sm Core	Mid Val	S&P 500	Intl Mrkt	Mid Core	Mid Core	LT Gov	S&P 500	Lrge Val
10.2%	22.8%	21.5%	5.5%	-6.2%	39.4%	19.9%	8.6%	21.0%	9.3%	-32.9%	33.3%	20.7%	2.1%	16.4%	36.3%	11.3%	-0.1%	12.0%	19.6%
Lrge Core	S&P 500	Sm Core	Mid Core	Sm Val	Mid Grw	Cmdty	REIT	Mid Val	Sm Grw	Cmdty	Lrge Grw	Emrg Mkt	Mid Grw	Mid Grw	Lrge Grw	Lrge Core	Lrge Core	Emrg Mkt	Mid Core
10.1%	21.0%	17.7%	5.2%	-9.1%	39.2%	18.2%	8.3%	17.6%	5.5%	-35.0%	31.2%	18.9%	0.9%	16.3%	33.8%	11.1%	-0.4%	11.2%	18.7%
Mid Grw	Mid Val	Corp	T-Bills	Sm Core	REIT	Sm Grw	Lrge Val	S&P 500	S&P 500	Mid Val	Sm Val	Lrge Core	T-Bills	S&P 500	S&P 500	Mid Grw	Corp	Mid Grw	Mid Val
9.1%	10.3%	12.9%	3.8%	-12.1%	38.5%	15.5%	8.0%	15.8%	5.5%	-35.6%	31.1%	18.8%	0.0%	16.0%	32.4%	10.7%	-1.0%	10.1%	15.8%
T-Bills	Sm Val	5-Yr Gov	LT Gov	Mid Core	Lrge Val	Lrge Val	Mid Grw	Mid Grw	T-Bills	S&P 500	REIT	Cmdty	Mid Core	Mid Core	Lrge Core	Mid Val	Mid Core	Cmdty	Sm Core
4.9%	8.8%	12.6%	3.7%	-12.6%	30.2%	15.3%	7.9%	12.2%	4.7%	-37.0%	27.8%	17.6%	-0.9%	15.2%	31.3%	5.7%	-1.1%	9.7%	13.2%
Mid Val	T-Bills	Lrge Core	Sm Grw	Lrge Core	S&P 500	Mid Grw	LT Gov	Mid Core	Corp	REIT	S&P 500	S&P 500	Mid Val	Sm Grw	Intl Mrkt	Sm Grw	Sm Grw	Lrge Grw	Lrge Core
4.8%	4.7%	11.4%	0.8%	-14.0%	28.7%	13.1%	7.8%	12.0%	2.6%	-37.8%	26.5%	15.1%	-4.7%	15.0%	21.0%	5.3%	-3.0%	9.6%	12.7%
Mid Core	Lrge Core	T-Bills	Lrge Core	Intl Mrkt	Lrge Core	Lrge Core	Corp	Lrge Grw	Lrge Val	Mid Grw	Cmdty	Lrge Grw	Sm Core	Lrge Grw	REIT	Sm Val	Intl Mrkt	REIT	Corp
0.3%	4.0%	5.9%	-2.5%	-15.8%	28.1%	13.0%	5.9%	11.4%	2.0%	-37.9%	23.7%	13.2%	-4.9%	14.1%	2.3%	3.9%	-3.0%	9.4%	12.3%
Sm Grw	Mid Core	Mid Grw	Emrg Mkt	Mid Val	Lrge Grw	S&P 500	Lrge Grw	Sm Grw	Mid Core	Lrge Val	Lrge Core	Corp	Sm Grw	Lrge Core	T-Bills	Sm Core	Sm Core	Sm Grw	Sm Val
-2.6%	1.5%	-1.5%	-2.6%	-18.7%	28.0%	10.9%	5.4%	8.9%	1.0%	-38.2%	20.6%	12.4%	-5.6%	12.5%	0.0%	3.8%	-3.3%	7.9%	9.5%
Sm Val	5-Yr Gov	Lrge Grw	Mid Grw	Mid Grw	Cmdty	Lrge Grw	S&P 500	T-Bills	Lrge Core	Sm Grw	Lrge Val	LT Gov	Cmdty	Corp	5-Yr Gov	5-Yr Gov	Lrge Val	Corp	REIT
-2.9%	-1.8%	-7.5%	-4.5%	-21.4%	24.2%	9.1%	4.9%	-4.8%	-0.6%	10.6%	10.1%	10.1%	10.7%	10.7%	-1.1%	3.1%	-7.4%	6.7%	9.3%
Sm Core	Lrge Val	S&P 500	Lrge Grw	Lrge Grw	Corp	Corp	Lrge Core	Corp	Sm Core	Mid Core	Corp	Intl Mrkt	Sm Val	LT Gov	Emrg Mkt	T-Bills	Sm Val	Intl Mrkt	LT Gov
-4.4%	-6.0%	-9.1%	-11.1%	-21.9%	5.3%	8.7%	4.4%	3.2%	-2.5%	-41.0%	3.0%	8.9%	-8.5%	3.3%	-2.6%	0.0%	-9.7%	2.7%	6.2%
REIT	REIT	Intl Mrkt	S&P 500	S&P 500	5-Yr Gov	LT Gov	T-Bills	5-Yr Gov	Mid Val	Lrge Core	T-Bills	5-Yr Gov	Intl Mrkt	5-Yr Gov	Cmdty	Emrg Mkt	Mid Val	5-Yr Gov	Cmdty
-18.8%	-6.5%	-13.4%	-22.1%	-22.1%	2.4%	8.5%	3.0%	3.1%	-5.4%	-42.9%	0.1%	7.1%	-12.2%	2.1%	-5.0%	-2.2%	-9.8%	1.9%	1.7%
Emrg Mkt	Corp	Sm Grw	Intl Mrkt	Sm Grw	LT Gov	5-Yr Gov	5-Yr Gov	LT Gov	Sm Val	Intl Mrkt	5-Yr Gov	Lrge Val	Lrge Val	T-Bills	Corp	Intl Mrkt	Emrg Mkt	LT Gov	5-Yr Gov
-25.3%	-7.4%	-24.8%	-21.4%	-31.9%	1.4%	2.3%	1.4%	1.2%	-11.1%	-43.6%	-2.4%	1.6%	-15.1%	0.1%	-7.1%	-4.3%	-14.9%	1.8%	1.6%
Cmdty	LT Gov	Emrg Mkt	Cmdty	Lrge Val	T-Bills	T-Bills	Sm Grw	Cmdty	REIT	Emrg Mkt	LT Gov	T-Bills	Emrg Mkt	Cmdty	LT Gov	Cmdty	Cmdty	T-Bills	T-Bills
-27.2%	-9.0%	-30.8%	-21.8%	-35.5%	1.0%	1.2%	0.0%	-2.9%	-17.8%	-53.3%	-14.9%	0.1%	-18.4%	-3.3%	-11.4%	-17.9%	-23.4%	0.2%	0.8%

### Exhibit 3

#### 18 Asset Classes Used for Analysis

18 Asset Classes Used for Analysis			
No.	Category	Name in Periodic Tables	Description
1	Equities	Sm Val	Small Cap Value
2	Equities	Sm Neut	Small Cap Neutral (Core, Blend)
3	Equities	Sm Grw	Small Cap Growth
4	Equities	Mid Val	Mid Cap Value
5	Equities	Mid Neut	Mid Cap Neutral (Core, Blend)
6	Equities	Mid Grw	Mid Cap Growth
7	Equities	Lrge Val	Large Cap Value
8	Equities	Lrge Neut	Large Cap Neutral (Core, Blend)
9	Equities	Lrge Grw	Large Cap Growth
10	Equities	S&P 500	S&P 500
11	Equities	Emrg Mkt	Emerging Markets
12	Equities	Intern	Developed International
13	Alternates	Commod	Commodities
14	Alternates	REIT	Real Estate Investment Trust
15	Bonds	T-Bills	30-day Treasury Bills
16	Bonds	5-Yr Gov	Intermediate Term Treasuries
17	Bonds	LT Gov	Long Term Treasuries
18	Bonds	Corp	Long Term Corporate Bonds

Statisticians prefer to rely on calculations to buttress visual conclusions because appearances can be deceiving. If rankings from one year to the next are truly random, correlations of the ranks should be low and not statistically significant. That is, to rule out random variation as the explanation (like getting 51 or 52 heads in 100 flips of a fair coin instead of exactly 50), the correlations would have to have less than a five percent probability of occurring due to random chance. Five percent is the traditional limit used to rule out randomness as the explanation when comparing what we expect the data to show versus what it actually shows.

In this case, tests based on the venerable Spearman Rank correlation were used, which is readily available online (MacDonald, 2018, Wikipedia, 2018).<sup>4</sup> Without getting too deeply into the technical details, it appropriately calculates the correlation between the ranks of two variables rather than their actual raw data values. Spearman's is considered a more robust tool in than the more commonly seen Pearson correlation coefficient because Pearson's assumes a linear relationship, whereas Spearman's can be linear or nonlinear so long as it is monotonic. Interested readers will find numerous explanations with an online search of "Pearson vs. Spearman." Alternative methods for testing ranks are available with a search for "rank correlations."

With 18 data points for each year, the Spearman Rank correlation would have to be above 46.9 percent to reach a five percent level of significance, above 59.0 percent to reach a one percent level. In the case of the one-year periodic table shown in Exhibit 2 for the most recent 20 years span (1998-2017), there are 19 correlations for 1998, 18 correlations for 1999, 17 correlations for 2000, etc., a combined total of 190 correlations in all (each of size n = 18). This is the same approach used by Kahneman in his study of stock-picking skills (Kahneman, 2011).

The results of these tests are shown in Exhibit 4. For each separate 20-year span, two correlations are shown. The first is for 19 one-year ahead correlations (such as 1998 with 1999, 1999 with 2000, etc.). These correlations show how strongly this year's rank correlates with the following year. The average of these one-year ahead correlations for the 1998-2017 span is 7.0 percent. Historically, the average correlation for all four 20-year spans going back to 1927 is 12.7 percent, with a maximum of 22.5 percent (1938-1957) and a minimum of 5.6 percent (1958-1977). None of these correlations are statistically significant.

To test the possibility of lag effects, 190 correlations were run to calculate "global" averages of all possible lags over the 20-year span (1998 with 1999, 1998 with 2000, etc.). The third column in Exhibit 4 shows that the average correlation for the 1998-2017 span was only 3.5 percent. The average for all four spans was 6.5 percent.

The results lead to the same conclusion: the correlations are likely due to random chance - there is no systematic pattern to the rankings for one-year holding periods with the following year or any year thereafter. These results parallel those found by Kahneman. He also discovered low correlations in studying how well stock pickers did compared to each other in yearly rankings. This led to his conclusion that stock-picking skills were illusory, at least for the group of financial professionals he studied.

On a technical note, rolling overlapping spans were not computed since there might be a few cases where the correlations possibly approach statistical significance, but this could be misleading because one would expect such a result one time out of 20 due to random chance. The takeaway here is that the statistical calculations all verify exactly what the periodic table actually shows: rankings based on one-year holding periods are random.

Exhibit 4

One-year Holding Period Average Correlations

20 Year Span	One Year Ahead Correlations	Global Average Correlations
1998-2017	7.0%	3.5%
1978-97	15.5%	9.2%
1958-77	5.6%	4.5%
1938-57	22.5%	8.7%
Overall Average:	12.7%	6.5%

"Global" = Average of all correlations among all years within span



## 2. Multi-year Periodic Tables – Clearly Nonrandom

The case for randomness in rankings for one-year periodic tables is clear – low, insignificant correlations. But when periodic tables are constructed for longer holding periods, randomness begins to disappear. Exhibit 5 presents the results of compounded annual growth rates (CAGR) over all non-overlapping five-year holding periods back to 1928-1932. For instance, the top ranked entry in 2017 column on the far right indicates Large Cap Growth (“Lrge Grw”) had the highest CAGR (17.8%) for 2013-2017 inclusive.

Although no pattern is obvious to the naked eye in Exhibit 4, a discerning viewer will note that more equities (red and yellow colors) tend to show up in the higher ranks, while fixed income (blue and gray colors) tend to show up in the lower ranks. The average global correlation is 23.2%, stronger but not yet statistically significant. This trend will become more apparent when longer holding periods are considered.

Exhibit 5

Five-year Holding periods, 1928-32, 1933-37, ... 2013-2017

1932	1937	1942	1947	1952	1957	1962	1967	1972	1977	1982	1987	1992	1997	2002	2007	2012	2017
Corp	Sm Val	Commod	Sm Val	Mid Val	Mid Neut	Lrge Val	Sm Val	Emrg Mkt	Mid Val	Sm Val	Intern	Emrg Mkt	Sm Val	LT Gov	Emrg Mkt	Corp	Lrge Grw
4.5%	29.3%	11.7%	37.3%	22.7%	13.9%	18.2%	28.7%	25.1%	13.4%	28.1%	31.6%	29.8%	24.3%	8.8%	37.0%	10.5%	17.8%
5-Yr Gov	Sm Neut	Lrge Val	Mid Val	Lrge Val	S&P 500	Sm Val	Sm Neut	Intern	Sm Val	Sm Neut	Lrge Val	Mid Val	Lrge Val	Corp	Intern	LT Gov	Mid Neut
3.9%	27.1%	9.4%	29.1%	19.8%	13.6%	17.8%	24.5%	14.5%	13.2%	27.1%	18.6%	20.8%	23.5%	8.3%	22.1%	9.3%	16.8%
LT Gov	Mid Neut	Sm Neut	REIT	S&P 500	Lrge Neut	Mid Val	Mid Val	Lrge Grw	Emrg Mkt	Sm Grw	Emrg Mkt	Lrge Grw	Lrge Neut	5-Yr Gov	Sm Val	Mid Grw	Lrge Val
3.7%	26.4%	9.1%	26.6%	19.4%	13.6%	16.3%	24.3%	8.7%	10.0%	23.5%	18.6%	19.0%	22.4%	8.2%	18.9%	6.5%	16.7%
T-Bills	Sm Grw	Sm Grw	Sm Neut	Lrge Neut	Lrge Grw	Mid Neut	Sm Grw	Mid Val	Commod	Mid Grw	Lrge Neut	Mid Grw	S&P 500	Sm Val	Sm Neut	Sm Neut	Mid Grw
2.5%	24.8%	9.1%	25.8%	17.7%	13.3%	16.3%	23.1%	8.1%	8.1%	21.7%	18.0%	17.8%	20.3%	8.1%	18.2%	6.1%	16.7%
Emrg Mkt	Emrg Mkt	Mid Neut	Lrge Val	Sm Val	Sm Neut	Sm Neut	REIT	Lrge Val	Lrge Neut	Mid Val	Sm Val	Sm Val	Mid Neut	Sm Neut	Mid Neut	Sm Neut	S&P 500
-7.7%	22.0%	8.8%	23.6%	16.9%	11.9%	15.5%	19.7%	7.9%	7.9%	19.5%	17.9%	17.6%	19.9%	7.0%	18.0%	5.7%	15.8%
Lrge Grw	Lrge Val	Mid Grw	Mid Neut	Mid Neut	Mid Grw	Sm Grw	Mid Neut	S&P 500	Lrge Val	Mid Neut	Mid Val	Sm Neut	Sm Neut	Commod	Commod	REIT	Mid Val
-8.2%	21.2%	7.2%	23.4%	16.2%	11.2%	14.8%	18.1%	7.5%	7.2%	18.8%	17.3%	17.5%	19.3%	5.7%	16.8%	5.4%	15.2%
Lrge Val	Mid Grw	Sm Val	Sm Grw	Lrge Grw	Sm Val	Intern	Mid Grw	Sm Val	Lrge Neut	REIT	S&P 500	Sm Val	Lrge Grw	Mid Val	Mid Val	Sm Val	Sm Grw
-12.0%	20.7%	6.8%	21.8%	16.1%	11.0%	14.2%	15.2%	7.5%	7.0%	18.6%	16.5%	17.2%	18.8%	4.6%	16.7%	4.1%	15.0%
S&P 500	REIT	Mid Val	Lrge Neut	Mid Grw	Intern	Mid Grw	Lrge Val	5-Yr Gov	5-Yr Gov	Lrge Val	Sm Neut	S&P 500	Mid Val	T-Bills	REIT	Lrge Grw	Sm Val
-12.5%	19.9%	5.6%	16.4%	14.3%	8.7%	14.0%	13.2%	6.8%	6.4%	14.8%	15.4%	15.9%	18.6%	4.2%	16.6%	3.6%	14.7%
Intern	Lrge Neut	Lrge Grw	Mid Grw	Sm Grw	Mid Val	S&P 500	S&P 500	Commod	Sm Neut	Lrge Neut	Mid Neut	Mid Neut	REIT	Mid Neut	Mid Grw	Mid Val	Sm Neut
-13.6%	18.2%	5.0%	15.8%	13.6%	8.6%	13.3%	12.4%	6.4%	6.4%	14.5%	14.9%	14.7%	17.9%	4.0%	15.8%	3.5%	14.6%
Mid Grw	Intern	S&P 500	S&P 500	Sm Neut	Lrge Val	Lrge Grw	Corp	Corp	S&P 500	Corp	Lrge Neut	Lrge Neut	Mid Grw	Mid Grw	Lrge Val	Mid Neut	Lrge Neut
-18.2%	14.4%	4.6%	14.8%	13.6%	8.2%	11.7%	11.2%	5.9%	6.3%	14.0%	14.1%	13.5%	14.2%	3.5%	15.7%	3.0%	13.3%
Mid Neut	S&P 500	LT Gov	Commod	REIT	Sm Grw	Lrge Neut	Lrge Neut	Mid Neut	T-Bills	Lrge Grw	Lrge Grw	Corp	Commod	REIT	Sm Grw	Sm Grw	REIT
-20.5%	14.3%	4.3%	13.6%	10.0%	7.7%	11.4%	10.1%	5.8%	6.2%	12.4%	14.0%	12.5%	13.2%	3.0%	15.4%	2.9%	9.7%
Sm Neut	Lrge Grw	Lrge Neut	Lrge Grw	Corp	Emrg Mkt	REIT	Emrg Mkt	Sm Neut	LT Gov	Intern	LT Gov	Sm Grw	Intern	Lrge Grw	Lrge Grw	S&P 500	Intern
-20.7%	12.8%	4.0%	11.5%	2.0%	6.6%	10.7%	4.9%	5.5%	5.5%	11.0%	13.0%	12.3%	11.6%	2.2%	13.1%	1.7%	7.5%
Mid Val	Commod	Corp	Emrg Mkt	5-Yr Gov	REIT	Emrg Mkt	T-Bills	T-Bills	Intern	T-Bills	5-Yr Gov	LT Gov	LT Gov	Lrge Val	S&P 500	T-Bills	Corp
-20.8%	12.7%	3.8%	7.9%	1.4%	5.6%	7.8%	3.9%	5.3%	2.1%	10.8%	11.8%	12.1%	10.5%	1.4%	12.8%	0.4%	5.3%
Commod	Mid Val	5-Yr Gov	LT Gov	LT Gov	5-Yr Gov	Corp	5-Yr Gov	LT Gov	REIT	5-Yr Gov	Mid Grw	5-Yr Gov	Sm Grw	Lrge Neut	Lrge Neut	Lrge Neut	Emrg Mkt
-21.1%	12.1%	3.2%	2.5%	1.4%	2.5%	3.6%	2.5%	4.9%	0.3%	9.6%	11.7%	10.3%	9.7%	1.3%	12.7%	-0.3%	4.3%
REIT	Corp	Emrg Mkt	Corp	T-Bills	LT Gov	5-Yr Gov	Intern	Mid Grw	S&P 500	Emrg Mkt	REIT	REIT	Corp	S&P 500	LT Gov	Emrg Mkt	LT Gov
-22.2%	8.6%	2.3%	2.2%	1.3%	2.2%	3.4%	1.1%	4.6%	-0.2%	9.4%	10.2%	6.6%	9.2%	-0.6%	5.7%	-0.9%	3.5%
Lrge Neut	LT Gov	REIT	5-Yr Gov	Emrg Mkt	Corp	LT Gov	Corp	REIT	Sm Grw	LT Gov	T-Bills	T-Bills	Emrg Mkt	Intern	Corp	Intern	5-Yr Gov
-22.7%	4.5%	2.0%	1.7%	0.4%	2.1%	2.4%	0.3%	4.3%	-0.4%	6.0%	7.6%	6.3%	7.6%	-2.7%	5.1%	-3.4%	1.4%
Sm Grw	5-Yr Gov	Intern	T-Bills	Intern	T-Bills	T-Bills	LT Gov	Lrge Neut	Lrge Grw	Corp	Sm Grw	Intern	5-Yr Gov	Emrg Mkt	5-Yr Gov	Commod	T-Bills
-24.1%	4.4%	1.1%	0.4%	-0.6%	2.0%	2.4%	-0.1%	3.0%	-2.7%	5.6%	3.3%	1.4%	6.4%	-4.7%	3.8%	-3.5%	0.2%
Sm Val	T-Bills	T-Bills	Intern	Commod	Commod	Commod	Commod	Sm Grw	Mid Grw	Commod	Commod	Commod	T-Bills	Sm Grw	T-Bills	Lrge Val	Commod
-24.2%	0.2%	0.1%	-7.0%	-4.6%	-0.8%	0.0%	-0.6%	-0.1%	-5.3%	3.3%	-0.3%	-2.7%	4.6%	-5.9%	2.9%	-5.1%	-7.8%

Exhibit 6 covers non-overlapping 15-year holding periods back through 1928. The dominance of small cap and mid cap US equities in the reddish colors now become readily apparent except for the span covering the Great Depression. Likewise, the lower performance of the blue colored fixed income securities becomes apparent. The global correlation rises to 46.4%, very close to 5 percent statistical significance. Note that the table no longer has 20 columns because only six independent, non-overlapping spans are available.

### Exhibit 6

#### 15-year Holding Periods, 1928-1942, 1943-1957, ..., 2003-2017

1942	1957	1972	1987	2002	2017
Corp 5.6%	Sm Val 21.2%	Sm Val 17.6%	Sm Val 19.6%	Sm Val 16.3%	Mid Grw 12.9%
Lrge Val 5.3%	Mid Val 19.8%	Mid Val 16.0%	Mid Val 16.7%	Sm Neut 14.5%	Sm Neut 12.8%
Emrg Mkt 4.8%	Mid Neut 17.8%	Sm Neut 14.9%	Sm Neut 16.0%	Mid Val 14.4%	Mid Neut 12.4%
LT Gov 4.2%	Lrge Val 17.0%	Mid Neut 13.3%	Intern 14.3%	Lrge Val 13.8%	Sm Val 12.4%
5-Yr Gov 3.9%	Sm Neut 16.9%	Lrge Val 13.0%	Mid Neut 13.8%	Lrge Grw 13.1%	Emrg Mkt 12.3%
Sm Neut 3.2%	S&P 500 15.9%	Emrg Mkt 12.3%	Lrge Val 13.4%	Mid Neut 12.7%	Mid Val 11.7%
Mid Neut 3.0%	Lrge Neut 15.9%	Sm Grw 12.1%	Lrge Neut 13.1%	Lrge Neut 12.1%	Lrge Grw 11.4%
Lrge Grw 2.8%	Sm Grw 14.2%	REIT 11.4%	Emrg Mkt 12.6%	Mid Grw 11.7%	Sm Grw 10.9%
Mid Grw 1.9%	Mid Grw 13.8%	Mid Grw 11.2%	S&P 500 9.9%	S&P 500 11.5%	REIT 10.5%
Sm Val 1.5%	REIT 13.7%	S&P 500 11.1%	REIT 9.5%	LT Gov 10.5%	S&P 500 9.9%
S&P 500 1.5%	Lrge Grw 13.6%	Lrge Grw 10.5%	5-Yr Gov 9.2%	Emrg Mkt 10.0%	Lrge Val 8.6%
Sm Grw 1.1%	Emrg Mkt 4.9%	Intern 9.8%	Mid Grw 8.8%	Corp 10.0%	Lrge Neut 8.4%
T-Bills 0.9%	Commod 2.4%	Lrge Neut 8.1%	Corp 8.6%	REIT 9.0%	Intern 8.2%
Intern 0.0%	Corp 2.1%	5-Yr Gov 4.2%	Sm Grw 8.3%	5-Yr Gov 8.3%	Corp 6.9%
Commod -0.2%	LT Gov 2.0%	T-Bills 3.9%	T-Bills 8.2%	Commod 5.2%	LT Gov 6.1%
REIT -1.7%	5-Yr Gov 1.9%	Corp 3.2%	LT Gov 8.1%	Sm Grw 5.1%	5-Yr Gov 3.6%
Lrge Neut -1.7%	T-Bills 1.2%	LT Gov 2.4%	Lrge Grw 7.6%	T-Bills 5.0%	Commod 1.3%
Mid Val -2.1%	Intern 0.1%	Commod 1.9%	Commod 3.6%	Intern 3.2%	T-Bills 1.2%



Extending the length to 30 years, the correlations among the three non-overlapping time spans rise well above what is needed for statistical significance at the one percent level (Exhibit 7). The most recent span, 1988-2017, has a 74.6% correlation with 1958-87, and an 87.0% correlation with earliest span, 1928-57. This was the highest correlation and implies that 1988-2017 was more similar to 1928-57 than to 1958-87. The middle span itself, 1958-87, has a 69.5% correlation with 1928-57. The overall average for all three is 77.0%.

**Exhibit 7**  
**30-Year Holding Periods, 1928-57, 1958-87, 1988-2017**

1957	1987	2017
Lrge Val 11.0%	Sm Val 18.6%	Sm Val 14.4%
Sm Val 11.0%	Mid Val 16.4%	Sm Neut 13.7%
Mid Neut 10.1%	Sm Neut 15.4%	Mid Val 13.0%
Sm Neut 9.9%	Mid Neut 13.5%	Mid Neut 12.5%
S&P 500 8.5%	Lrge Val 13.2%	Mid Grw 12.3%
Mid Val 8.3%	Emrg Mkt 12.4%	Lrge Grw 12.2%
Lrge Grw 8.1%	Intern 12.0%	Lrge Val 11.2%
Mid Grw 7.7%	Lrge Neut 10.6%	Emrg Mkt 11.1%
Sm Grw 7.5%	S&P 500 10.5%	S&P 500 10.7%
Lrge Neut 6.7%	REIT 10.4%	Lrge Neut 10.2%
REIT 5.8%	Sm Grw 10.2%	REIT 9.7%
Emrg Mkt 4.9%	Mid Grw 10.0%	Corp 8.4%
Corp 3.8%	Lrge Grw 9.1%	LT Gov 8.3%
LT Gov 3.1%	5-Yr Gov 6.7%	Sm Grw 7.9%
5-Yr Gov 2.9%	T-Bills 6.0%	5-Yr Gov 5.9%
Commod 1.1%	Corp 5.9%	Intern 5.7%
T-Bills 1.1%	LT Gov 5.2%	Commod 3.2%
Intern 0.1%	Commod 2.8%	T-Bills 3.1%

Correlations:	1988-2017	1958-87
1958-87	74.6%	
1928-57	87.0%	69.5%
<b>Overall Average:</b>		<b>77.0%</b>

This dominance is much clearer when overlapping intervals are plotted. In Exhibit 8, the right-most column lists the returns for the 30-year span ending in 2017, where Small Value achieved an average per year of 14.4 percent annualized return over 1988-2017, higher than any other asset class during that same 30-year span. The second from right column shows that it led again over the 30-year span, 1987-2016 at 13.7 percent per year. This is not surprising, since this span has 29 of the same 30 data points as the 1988-2017 span. All the other columns tell a similar story, also not surprising, given that these are overlapping intervals.

**Exhibit 8**  
**Rolling Overlapping 30-year Spans**

1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Sm Val	Sm Val	Sm Val	Sm Val	Sm Val	Sm Val	Sm Val	Sm Val	Sm Val	Sm Val	Sm Val	Sm Val	Sm Val	Sm Val	Sm Val	Sm Val	Sm Val	Sm Val	Sm Val	Sm Val
16.2%	17.7%	18.3%	18.6%	18.0%	21.2%	22.8%	21.3%	20.2%	18.9%	16.6%	16.3%	16.5%	15.5%	14.9%	14.7%	14.5%	13.1%	13.7%	14.4%
Mid Val	Mid Val	Mid Val	Mid Val	Mid Val	Sm Neut	Sm Neut	Sm Neut	Sm Neut	Sm Neut	Sm Neut	Sm Neut	Sm Neut	Sm Neut	Sm Neut	Sm Neut	Sm Neut	Sm Neut	Sm Neut	Sm Neut
15.2%	16.6%	17.3%	16.8%	15.5%	18.3%	20.3%	18.8%	18.0%	17.3%	15.1%	15.0%	14.9%	14.3%	13.8%	13.8%	13.9%	12.6%	13.0%	13.7%
Lrge Val	Emrg Mkt	Sm Neut	Sm Neut	Sm Neut	Mid Val	Mid Val	Mid Val	Mid Val	Mid Val	Mid Val	Mid Val	Mid Val	Mid Val	Emrg Mkt	Mid Val	Mid Val	Mid Val	Mid Val	Mid Val
15.1%	15.7%	16.2%	16.0%	15.2%	17.5%	19.2%	17.6%	16.6%	16.1%	14.0%	14.2%	14.5%	13.9%	13.5%	13.8%	13.7%	12.2%	12.4%	13.0%
Emrg Mkt	Lrge Val	Lrge Val	Lrge Val	Lrge Val	Mid Neut	Mid Neut	Mid Neut	Lrge Val	Emrg Mkt	Lrge Val	Lrge Val	Mid Neut	Mid Neut	Mid Val	Emrg Mkt	Mid Neut	Mid Neut	Mid Neut	Mid Neut
14.4%	15.6%	16.0%	15.8%	13.6%	15.4%	17.2%	16.1%	15.1%	15.4%	13.2%	13.2%	12.9%	12.5%	13.4%	12.7%	12.8%	11.7%	11.9%	12.5%
Sm Neut	Sm Neut	Mid Neut	Mid Neut	Mid Neut	Lrge Val	Lrge Val	Lrge Val	Mid Neut	Lrge Val	Mid Neut	Emrg Mkt	Lrge Val	Emrg Mkt	Mid Neut	Mid Neut	Mid Grw	Lrge Grw	Lrge Grw	Mid Grw
13.5%	15.2%	14.4%	14.0%	13.2%	14.6%	16.8%	15.6%	15.1%	15.1%	12.6%	12.9%	12.5%	11.9%	12.2%	12.4%	12.6%	11.7%	11.5%	12.3%
Mid Neut	S&P 500	Lrge Neut	Lrge Neut	Lrge Neut	Lrge Neut	Mid Grw	Emrg Mkt	Emrg Mkt	Mid Neut	Emrg Mkt	Mid Neut	Emrg Mkt	Lrge Grw	Lrge Grw	Lrge Grw	Lrge Grw	Mid Grw	Mid Grw	Lrge Grw
12.8%	13.7%	13.9%	13.7%	12.6%	13.7%	15.2%	14.5%	15.0%	14.9%	11.9%	12.9%	12.4%	11.8%	11.6%	12.2%	12.6%	11.6%	11.5%	12.2%
Lrge Neut	Lrge Neut	Emrg Mkt	Emrg Mkt	Emrg Mkt	Mid Grw	Lrge Neut	Mid Grw	Mid Grw	Mid Grw	Mid Grw	Mid Grw	Mid Grw	Mid Grw	Mid Grw	Mid Grw	Emrg Mkt	Emrg Mkt	Emrg Mkt	Lrge Val
12.8%	13.7%	13.8%	12.5%	11.3%	13.1%	15.2%	14.2%	13.7%	14.0%	11.9%	11.9%	11.5%	11.6%	11.5%	12.0%	12.2%	10.7%	10.7%	11.2%
S&P 500	Mid Neut	S&P 500	S&P 500	S&P 500	Emrg Mkt	REIT	Lrge Neut	Lrge Neut	Lrge Neut	Lrge Grw	Lrge Grw	Lrge Grw	Lrge Val	Lrge Val	Lrge Val	Lrge Val	S&P 500	Lrge Val	Emrg Mkt
12.7%	13.6%	13.2%	12.2%	10.7%	12.5%	14.7%	13.9%	13.5%	13.6%	11.4%	11.9%	11.3%	11.5%	11.5%	11.7%	11.5%	10.4%	10.4%	11.1%
Lrge Grw	Lrge Grw	Lrge Grw	Lrge Grw	Lrge Grw	S&P 500	Emrg Mkt	REIT	REIT	Lrge Grw	Lrge Neut	S&P 500	S&P 500	Lrge Neut	Lrge Neut	Lrge Neut	S&P 500	Lrge Val	S&P 500	S&P 500
12.6%	13.3%	13.1%	11.9%	10.3%	12.2%	13.8%	13.8%	13.4%	13.1%	11.3%	11.2%	10.7%	11.1%	11.0%	11.2%	11.3%	10.2%	10.2%	10.7%
Intern	Intern	Mid Grw	Mid Grw	Mid Grw	Lrge Grw	S&P 500	S&P 500	S&P 500	S&P 500	S&P 500	Lrge Neut	Lrge Neut	LT Gov	S&P 500	S&P 500	Lrge Neut	Lrge Neut	Lrge Neut	Lrge Neut
11.5%	12.3%	12.5%	11.4%	10.2%	12.1%	13.7%	12.7%	12.5%	13.0%	11.0%	11.1%	10.5%	11.0%	10.8%	11.1%	11.3%	10.1%	9.9%	10.2%
Mid Grw	Mid Grw	Intern	Intern	LT Gov	REIT	Lrge Grw	Lrge Grw	Lrge Grw	REIT	REIT	REIT	REIT	S&P 500	Corp	LT Gov	LT Gov	REIT	REIT	REIT
10.3%	12.1%	12.4%	10.4%	9.3%	11.6%	13.4%	12.5%	12.2%	12.0%	10.3%	10.2%	10.2%	11.0%	9.9%	9.4%	9.7%	9.3%	9.0%	9.7%
Corp	Corp	LT Gov	REIT	Corp	Sm Grw	Sm Grw	Intern	Intern	Intern	LT Gov	LT Gov	Corp	Corp	LT Gov	Corp	REIT	LT Gov	Corp	Corp
9.1%	9.2%	9.2%	9.4%	9.3%	10.4%	12.4%	11.2%	12.0%	11.9%	10.2%	9.7%	10.2%	10.8%	9.9%	9.4%	9.4%	8.7%	8.0%	8.4%
LT Gov	Sm Grw	REIT	Corp	REIT	Intern	Intern	Sm Grw	Sm Grw	LT Gov	Corp	Corp	LT Gov	REIT	REIT	Intern	Corp	Corp	LT Gov	LT Gov
9.1%	9.0%	9.2%	9.0%	9.2%	10.3%	11.8%	10.6%	9.8%	9.3%	9.4%	9.6%	10.2%	10.2%	9.8%	9.2%	9.4%	8.4%	8.0%	8.3%
5-Yr Gov	LT Gov	Corp	LT Gov	5-Yr Gov	Corp	Corp	Corp	Corp	Sm Grw	Intern	Intern	Intern	Intern	Intern	REIT	Intern	Intern	Sm Grw	Sm Grw
8.7%	8.9%	9.0%	8.9%	8.8%	9.4%	9.8%	9.6%	9.0%	9.3%	8.8%	9.5%	9.1%	8.7%	9.3%	9.1%	9.0%	7.4%	6.6%	7.9%
REIT	5-Yr Gov	Sm Grw	5-Yr Gov	Intern	LT Gov	LT Gov	LT Gov	LT Gov	Corp	5-Yr Gov	5-Yr Gov	5-Yr Gov	5-Yr Gov	5-Yr Gov	5-Yr Gov	Sm Grw	Sm Grw	5-Yr Gov	5-Yr Gov
7.7%	8.7%	8.9%	8.5%	8.6%	9.4%	9.5%	9.5%	9.0%	9.1%	8.6%	8.4%	8.5%	8.5%	7.7%	7.4%	7.5%	6.4%	6.0%	5.9%
T-Bills	REIT	5-Yr Gov	Sm Grw	Sm Grw	5-Yr Gov	5-Yr Gov	5-Yr Gov	5-Yr Gov	5-Yr Gov	Sm Grw	Sm Grw	Sm Grw	Sm Grw	Sm Grw	Sm Grw	5-Yr Gov	5-Yr Gov	Intern	Intern
6.8%	8.4%	8.5%	8.1%	6.7%	8.7%	8.6%	8.3%	8.0%	8.3%	6.9%	6.6%	6.0%	6.2%	6.0%	6.7%	7.0%	6.4%	5.7%	5.7%
Sm Grw	T-Bills	T-Bills	T-Bills	T-Bills	T-Bills	T-Bills	T-Bills	T-Bills	T-Bills	T-Bills	T-Bills	T-Bills	T-Bills	Commod	T-Bills	T-Bills	T-Bills	Commod	Commod
6.6%	6.7%	6.7%	6.7%	6.6%	6.4%	6.1%	6.1%	6.0%	6.0%	5.8%	5.5%	5.1%	4.6%	4.6%	4.0%	3.7%	3.4%	3.5%	3.2%
Commod	Commod	Commod	Commod	Commod	Commod	Commod	Commod	Commod	Commod	Commod	Commod	Commod	Commod	T-Bills	Commod	Commod	Commod	T-Bills	T-Bills
3.4%	4.2%	5.3%	4.4%	4.4%	3.8%	4.3%	5.4%	5.0%	5.8%	3.8%	3.8%	4.1%	4.4%	4.3%	3.9%	3.6%	2.9%	3.2%	3.1%

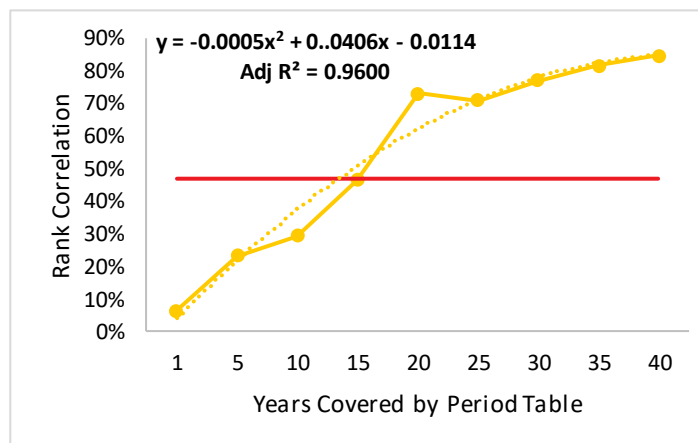
Exhibit 9 summarizes the results for all non-overlapping time spans tested, 1 to 40 years. A simple **linear** regression of correlation against years of time span yielded a positive coefficient statistically significant well below one percent and an Adjusted R Squared of 89.3 percent. Due to the slight concavity that is evident, a **quadratic** equation was fitted to the scatterplot. The Adjusted R-Squared increased to 96%. Both variables, years and years squared were statistically significant at or very near the 1% level (.0004 and .0119 respectively). The crossover point between random and non-random, to the extent that statistical

significance can draw that line, appears to occur at about 15 years. Prior to that horizon, the correlations are not statistically significant at the 5% level; after that horizon, they are. And they become more so, the longer the horizon becomes.

### Exhibit 9

#### Rank Correlations for 1- to 40-year Holding Periods

Years of Periodic Table	Average Correlation
1	6.5%
5	23.2%
10	29.4%
15	46.4%
20	73.2%
25	71.1%
30	77.0%
35	81.6%
40	84.7%



### 3. Implications

These results strongly support the conclusion that returns become non-random for longer holding periods. This has implications for planning, the time diversity debate, and the debate between modern portfolio theory and dedicated portfolio theory.

Financial planners should welcome the implication from this analysis. It verifies most planners' intuition that long term investing is more predictable than short term investing in the sense that the correlations are higher for longer spans of time. Further, these results suggest that high allocations to equities are, in fact, warranted because they outrank fixed income in terms of expected long-term returns. Finally, planning for longer horizons is the right thing to do not only from a client's lifetime perspective as a human being but also from an investment standpoint. End clients will be better off the longer the time horizon in the financial plan. This assumes, of course, they buy and hold their investments, and ignore active management policies designed for short term investing.

Regarding time diversity, this debate has continued unsettled for decades. It started with Paul Samuelson, an economist so brilliant that few had the courage to challenge him (Samuelson, 1969). His original paper was followed by additional work (Samuelson, 1971, 1989, 1990, 1994), which, by the time of his last publication on the matter, had spawned a stream of research into his contentions. He claimed that terminal wealth was independent of the holding period under some conditions, including the assumption that the decision maker's criterion does not include his/her current wealth and that Bernoulli was right about expected utility theory.

Regarding Bernoulli, Kahneman and Tversky's Prospect Theory (Kahneman and Tversky, 1979, Kahneman, 2011) challenges Bernoulli's expected utility theory, which continues to serve as the foundation for much of economic theory. Prospect Theory demonstrates that Bernoulli's assumptions rely on decision-making without a reference point (or that all decision-makers have the same reference point), which, in turn, leads to absurd conclusions that violate rational behavior. Richard Thaler, the 2017 Nobel prize-winner in Economics, continues Kahneman and Tversky's work in behavioral economics (Thaler, 2015).

Regarding Samuelson, Prospect Theory also challenges his conclusions, at least indirectly. It suggests that risk, in fact, does decrease as the holding period lengthens. It decreases because it is less difficult to predict what is likely to be the best investment (small value stocks) over longer holding periods. The one-year periodic chart masks this reality.

Regarding the debate between modern portfolio theory and dedicated portfolio theory, the implication is that the lack of any time element in MPT hinders its usefulness to those who do not, as Kahneman says, have "theory induced blindness" (Kahneman, 2011). This blindness is a condition, according to Kahneman, that means "...once you have accepted a theory and used it as a tool in your thinking, it is extraordinarily difficult to notice its flaws." This seems to explain much of the blind allegiance to modern portfolio theory. Dedicated portfolio theory, on the other hand, incorporates time directly into its formulation. This is best seen in its application to retirees. They generally want to have a steady, predictable, and secure stream of income from their retirement portfolios and have at least some awareness of the probability that it will last the rest of their lives.

If everyone had sufficient funds and predict with certainty their future spending when they retired, they could purchase Treasury bonds maturing in each year to match their desired income for the next, say, 30 years and hold each bond to maturity. With TIPS, they could even insure against inflation. They could then sit back and allow the funds to roll in like a paycheck every year.

Unfortunately, most people are not in such an envious position because they do not have enough money, especially now, thanks to the low yields on bonds. Nor would it be particularly efficient to do so. Beyond about 15 years, even the worst performance of the S&P 500 index is better than the best performance of

Treasury and other types of investment grade bonds. dedicated portfolio theory suggests that clients and their advisors should determine an acceptable level of probability that the money will last the projected life time covered in the plan, such as an 80% probability that the money will provide a sufficient income stream for living expenses over the next 30 years.

Once the probability is set, the next step is to determine a time horizon for an “Income Portfolio” to provide the initial stream of income, usually 5 to 10 years, that will consist of a ladder of bonds whose coupons and redemptions will supply the necessary cash (referred to as a “cash matching” portfolio in most college finance texts). The rest of the portfolio can be dedicated to growth. This portion, the “Growth Portfolio” can be allocated to equities or other faster growing investments. The path that the total portfolio must follow over the entire 30 years can be plotted to monitor progress. This is called the “Critical Path” and is a better benchmark for progress than the S&P 500 or some other external standard that is unrelated to an individual’s personal situation.

Each year, as the shortest term bond matures to supply the following year’s living expenses, that bond will need to be replaced to maintain the initial time horizon for the Income Portfolio. Assuming the total portfolio is on target (on or above its Critical Path), enough of the Growth Portfolio is liquidated to replenish the Income Portfolio and maintain its time horizon. This process will repeat itself, year after year, so long as the original financial plan is unchanged.

If the total portfolio lies below its Critical Path when a bond matures out of the Income Portfolio, the replenishment can wait another year. In fact, replenishment could wait up to the entire length of the initial time horizon for the Income Portfolio. For example, each year covered by the bonds in the Income Portfolio typically requires about 5 percent of the total portfolio. So an 8-year Income Portfolio would require about 40 percent of the total portfolio and result in a classic 60/40 asset allocation. Thus, at the extreme, the client could wait the market out for up to 8 years.

There are many more nuances to dedicated portfolio theory, but, as this short explanation hopefully makes clear, it appears to be very good strategy to pursue, especially for retirees, because it takes into consideration the work of recent Nobel prize winners in terms of human behavior and the allocation of investments over time.

#### **4. Conclusion**

The one-year periodic table is an excellent visual for demonstrating the folly of trying to predict which asset class will perform the best in any given year. Statistical analysis verifies that there is no statistically significant correlation between the rank of any asset class in one year and its rank in the next year.

However, this is not true as the time horizon for the holding period begins to lengthen. Once the holding period reaches 15 years or more, the correlations become statistically significant. That means predictability become viable. It thus refutes the fallacy of the unwarranted extrapolation of randomness over one-year holding periods to holding periods of 15 years or more. Because most personal financial plans are for lifetimes extending longer than 15 years, one-year periodic tables should be a little use to financial planners, except to demonstrate that listening to the financial pundits prognosticating on the media about “where to put your money this year” is unwise. It verifies something advisors have been saying for years.

## Appendix A - Data Sources:

### DATA SOURCES AND DESCRIPTION

MSCI data copyright MSCI, all rights reserved. The MSCI All Country World Index is a free float adjusted market capitalization index comprised of developed and emerging markets countries designed to capture the characteristics of a global equity market portfolio. The MSCI World ex USA Index is a free float adjusted market capitalization index comprised of developed countries designed to capture the characteristics of the developed equity markets globally excluding the United States. The MSCI Emerging Markets Index is a free float adjusted market capitalization index comprised of emerging markets countries designed to capture the characteristics of the emerging equity markets globally. MSCI Value & Growth Indexes categorize value and growth securities using eight historical and forward-looking variables. MSCI Small Cap Indexes cover all investable small cap securities with a market capitalization below that of the companies in the MSCI Standard Indexes, targeting approximately 14% of each market's free-float adjusted market capitalization.

Center for Research in Security Prices (CRSP®) data provided by the Center for Research in Security Prices, University of Chicago. CRSP indices are segmented by deciles 1 thorough 10, with 1 being the largest. Decile breakpoints are based on NYSE market capitalization (plus AMEX equivalents since July 1962 and NASDAQ equivalents since 1973). Value and growth indices are determined by book-to-market ratios where decile breakpoints for value are the three deciles with the highest book-to-market ratios and growth are the three deciles with the lowest book-to-market ratios.

The S&P 500 is a trademark of Standard & Poor's Index Services Group. The S&P 500 Index includes 500 of the top companies in leading industries in the U.S. economy. Focusing on the large-cap segment of the market, the S&P 500 covers approximately 80% of available U.S. market cap.

Russell data copyright © Russell Investment Group, all rights reserved. The Russell ranks US common stocks by market capitalization at each reconstitution period (May 31). The Russell 3000 is the broadest index and is comprised of the 3,000 largest US stocks. The Russell 1000 is considered the large cap index and contains the 1,000 largest US stocks. The Russell 2000 measures the small-cap segment of the US stocks market and is comprised of the US stocks 1,001-3,000 as measured by market capitalization. Russell assigns companies to value and growth style indices based on price-to-book ratios and I/B/E/S forecast medium-term growth.

Dow Jones® data provided by Dow Jones Indexes. The Dow Jones U.S. Select REIT Index is a float adjusted market capitalization index consisting of publicly traded U.S. real estate securities.

Bloomberg indices are trademarks or service marks of Bloomberg Finance, L.P. The Bloomberg Commodity Total Return Index, formerly the DJ-UBS Commodity Index, is a broadly diversified index that tracks the commodities markets through commodity futures contracts.

US bonds, bills, and inflation data © Stocks, Bonds, Bills, and Inflation Yearbook™, Ibbotson Associates, Chicago (annually updated work by Roger G. Ibbotson and Rex A. Sinquefeld).

Dimensional Fund Advisors data available at [www.dimensionalfund.com](http://www.dimensionalfund.com).



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<sup>3</sup> The data came from several sources, including the Center for Research in Security Prices (CRSP). See reference on data sources.

<sup>4</sup> Technically inclined readers will note that other rank correlation measures are available, such as Kendall's Tau, Mann-Whitney U-Test, plus others, depending on the assumptions regarding the underlying distributions and other considerations. The Spearman test was used here due to its common usage and also due to the small sample size for each correlation (18 data points), based on the work of Xu, Hou, and Zou (Xu, Hou, and Zou, 2013).