Index Replication: Principles and Applications

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Introduction

Index replication is an important tool for portfolio managers seeking returns of indices that are not directly investable. In this paper we present the rationale for index replication without perfectly mimicking the index assets. We also examine how well indices can be replicated by portfolios with compositions that differ, in some cases significantly, from the benchmark index assets. By replicating the exposure to the economic risks and payoffs of a benchmark index, a portfolio with little or no asset overlap with the index can provide investors with a more efficient investable substitute that generates a similar return profile.

Replicating Asset Exposure

The returns to any asset can be decomposed into two components: *systematic* and *idiosyncratic*. The systematic component is driven by factors that are common to other securities, such as sector, macroeconomic, and asset class effects. For example, changes in a factor affecting a specific industry would have similar effects on all firms in that industry. The idiosyncratic components of returns is particular to a single asset, such as the company's competitive position, individual deals and perceived management capabilities, and are not related to industry or other factor trends.

When many assets are bundled together to form an index, the idiosyncratic return components tend to cancel each other out, as winners and loser are both embedded in the index. On the other hand, systematic return components do not cancel each other out because they affect all members of the index. This feature of portfolio diversification is desirable from the point of view of investors because the idiosyncratic components add unnecessary risk to their portfolios. Instead, investors can focus on a few systematic factors. By judicious selection of benchmark indices, an investor can add exposure to beta, small/large cap, value/growth, industry, and other common factors to their portfolio.

To replicate an index, it is not necessary to mimic the idiosyncratic (firm-specific) return components since they cancel each other out. Instead, a replicating portfolio should mimic the systematic exposures: the risks that affect all assets in the benchmark index. This principle is what allows investors to use a subset of assets to measure the performance of a broader asset class and easily get exposure to that class in their portfolio. For example, the S&P 500 is itself, a portfolio that replicates the performance of the whole, value-weighted equity market. Although only 500 equities, out of thousands, are included in the index, it is frequently used as a gauge of the market's performance and as the centerpiece of a fully diversified investment strategy.

Approaches to Replication

The key determinants of whether an asset should be included in a replicating portfolio are the risks and characteristics that it has in common with the benchmark index. Some examples of these characteristics are listed in Table 1. A replicating portfolio can be created by selecting a collection of assets that jointly match these characteristics without regard to whether the selected assets are actually present in the benchmark. It is their systematic exposures, not membership in the benchmark index that makes assets appropriate for inclusion in the portfolio.

Table 1

Asset Characteristics
Market exposure (Beta)
Nation/currency exposure
Firm size
Industry
Growth/value
Momentum
Asset type (stocks, bonds, etc)
Leverage

Example 1: Replicating the S&P 500 with an Overlapping Subset of the S&P

One common approach to index replication involves using a subset of the assets present in the benchmark portfolio. Typically, replicating portfolios will hold the assets that have the largest weights in the benchmark, which are often the most liquid. Asset weights in the replicating portfolio can be determined using techniques of varying sophistication. Even naive approaches can yield good results in many cases; for example, as shown in Figure 1, forming a value-weighted portfolio of the largest 100 stocks in the S&P 500 results in a portfolio that mimics that S&P quite closely, even though no special attention has been paid to matching characteristics of the omitted assets. More sophisticated approaches can yield even better results.

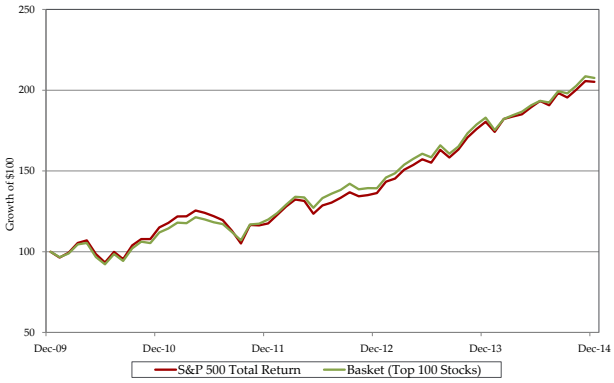

Figure 1: Value-Weighted Portfolio of Largest 100 Stocks vs. S&P 500

Example 2: Replicating an Index with a Non-overlapping Portfolio

Selection of a subset of assets in the benchmark index is one of the most common approaches to index replication, but it is by no means the only approach. Excellent replication can be achieved using completely non-overlapping portfolios. As an illustration, suppose we took the stocks in the Russell 1000 Index, sorted by market capitalization, and numbered them. We form a portfolio of all the odd numbered stocks (equal weighted - yearly rebalanced) and treat it as our target index.

We can then form a tracking index from the even numbered stocks using the same methodology. While there is no overlap between the index and tracking portfolio, the idiosyncratic components of each are diversified away in the aggregation step, resulting in good tracking, as illustrated in Figure 2. Again, more sophisticated methods could be used to improve results further.

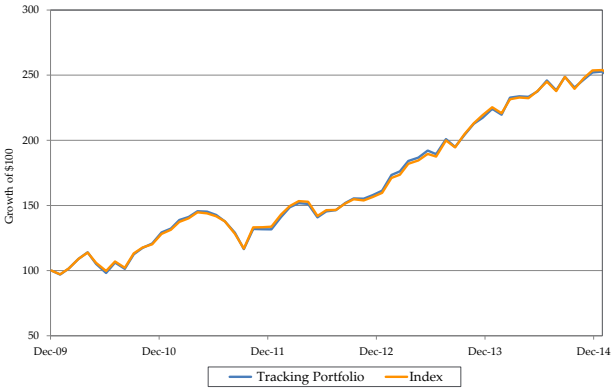

Figure 2: Non-Overlapping Tracking Portfolio and Index

Example 3: Replicating a Large Cap Index with Smaller Cap Firms

In Examples 1 and 2, the assets in the replicating portfolio were very similar to those in the benchmark index. However, it is also possible to replicate a benchmark using assets that are dissimilar from the benchmark assets. For example, we can use a simple strategy to replicate the S&P 500 Index using only equities from the Russell 1000 that are not in the S&P 500 (and are therefore much smaller, on average). We start by measuring the weight of the 10 GICS sectors in the S&P 500. We use stocks from the Russell 1000 that are not in the S&P 500 to form 10 market-cap weighted sub-portfolios, one for each sector. We then weight the sub-portfolios based on the GICS weights from the S&P 500. Since the smaller stocks have a higher beta, the resulting portfolio is then de-levered to match the beta of the S&P 500. Although there are many more sophisticated approaches to replication, this simple method,

which matches only GICS sector weights and beta, tracks the S&P reasonably well, as illustrated in Figure 3.

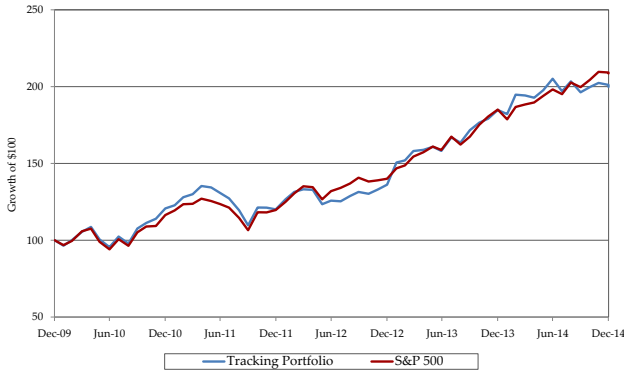

Figure 3: Replicating the S&P 500 with Tracking Portfolios

Application: Replicating PE/VC Returns

Venture capital (VC) backed firms are primarily privately held and thus are not included in the most common equity benchmarks. Nevertheless, VC-backed firms participate in similar economic activities and have exposure to the same systematic risks as their public counterparts. When VC-backed firms are aggregated to remove idiosyncratic effects, the major drivers of their returns are similar to those of their public counterparts.

One way to see that VC-backed firms are driven by the same factors as public firms is to look at the timing of successful VC exits. These exits are typically in the form of IPOs or acquisitions. Both IPOs and acquisitions tend to happen in waves and these waves correspond to times of positive performance in associated industries[1,2,3]. In effect, the same factors that drive the performance of public companies make possible successful exits from the VC stage. Moreover, the acquisition of VC-backed firms by public counterparts suggests that the acquiring firms are engaged in a similar business, with similar risks and rewards.

Company Returns: Private vs. Public

As seen in the logarithmic chart in Figure 4, the performance of Fibrogen, a successful VC-backed private company in the healthcare services sector, shows striking similarities to the that of Stryker (ticker: SYK), a publicly traded healthcare company. Although both Fibrogen and Stryker have a few noticeable idiosyncratic movements, the overall similarity of their return patterns demonstrates the power of systematic factors in determining overall returns.

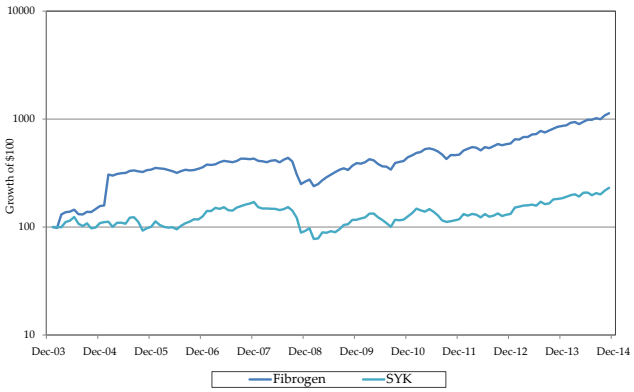

Figure 4: Fibrogen, a Venture Capital Company vs. Public Equities

Sector Returns: Private vs. Public

Certain firm characteristics (management, funding, and business stage) of venture-backed firms as a group may differ significantly from those of publicly traded equivalents. However, when startup firms are aggregated, the idiosyncratic movements cancel each other out and the index performance is ultimately driven by systematic characteristics. This can be seen in Figure 5, where the performance of the privately held VC-backed healthcare services sector largely mimics VHT, the public market equivalent ETF. Neither index is designed to track the other, but the two tend to move together because the similarity of the underlying drivers of their returns.

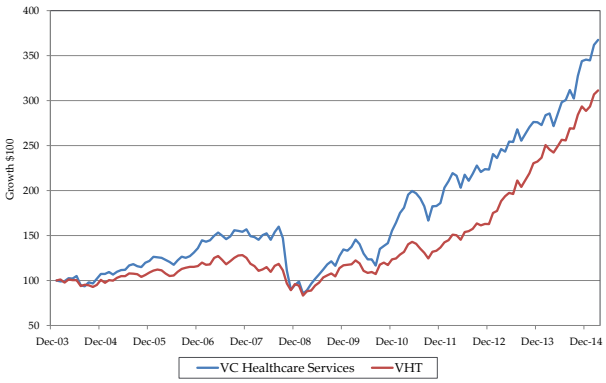

Figure 5: VC-backed Healthcare Services Sector vs. VHT

Figure 6: Thomson Reuters Venture Capital Research Index vs. Thomson Reuters Venture Capital Index

VC and PE: Private vs. Public

The Thomson Reuters Venture Capital Research Index (the "*Research* Index") aggregates the performance of privately held VC-backed firms in all economic sectors. The Thomson Reuters Venture Capital Index (the "VC Index") is a portfolio that seeks to replicate the Research Index by matching the underlying exposures through investments in publicly traded securities. While none of the assets in the VC Index are in the *Research* Index, the replication methodology leads to a strong tracking relationship, as seen in Figure 6.

It should be noted that venture capital returns are driven largely by sector exposure, but are not completely replicable with a naive or static portfolio. For example, venture-backed firms have a nonlinearity to their payoffs (either they end up worth nothing or dramatically outperform). Because this characteristic is common to venture-backed firms, it is not wholly removed by diversification. Replicating private company returns requires access to detailed, non-public data about the characteristics and performance of the private companies in the *Research* Index. Moreover, because of the nonlinearity of VC returns, constructing a replicating portfolio in public equities requires a sophisticated methodology that employs dynamic market exposure, time-varying weighting, and other techniques.

Replicating the performance of an index of firms owned by private equity (PE) buyout funds (Thomson Reuters Private Equity Buyout *Research* Index) requires similar sophisticated techniques and data. The resulting tracking portfolio, the Thomson Reuters Private Equity Buyout Index, generates a strong tracking relationship similar to its VC counterpart, as we see in Figure 7.

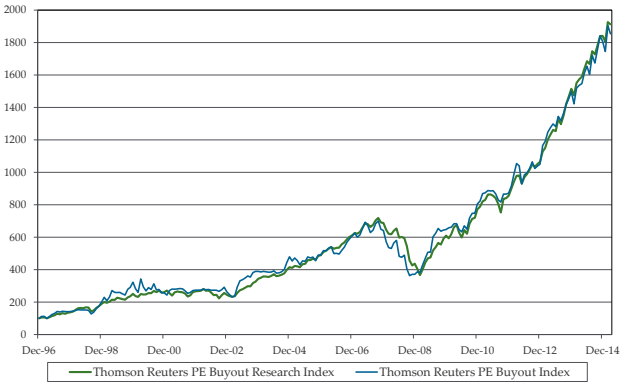

Figure 7: Thomson Reuters Private Equity Research Index vs. Thomson Reuters Private Equity Buyout Index

Conclusion

Benchmark index replication is a valuable technique that provides efficient investment access to a wide range of factor returns. While the simplest replicating portfolios invest in a subset of assets in the index, this is not necessarily the most desirable approach when costs or availability of

the benchmark index assets are an issue. Instead, investable portfolios can be created from assets that may not be in the original benchmark, but which capture the relevant aspects of the benchmark index returns: the exposures of the benchmark to systematic economic factors.

Replicating portfolios can be created with varying levels of sophistication, depending on the characteristics of the benchmark portfolio and the factors that are replicated. For simpler benchmark indices, matching a few characteristics (beta or industry exposure) can yield good tracking. For more complex benchmark indices, such as a private equity or venture capital, more sophisticated methods and data are required to achieve good tracking. While the sophistication of the factor identification and replication methodology varies by benchmark, the underlying principles of replication are always the same.

References

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