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An overview of physical and synthetic ETF structures

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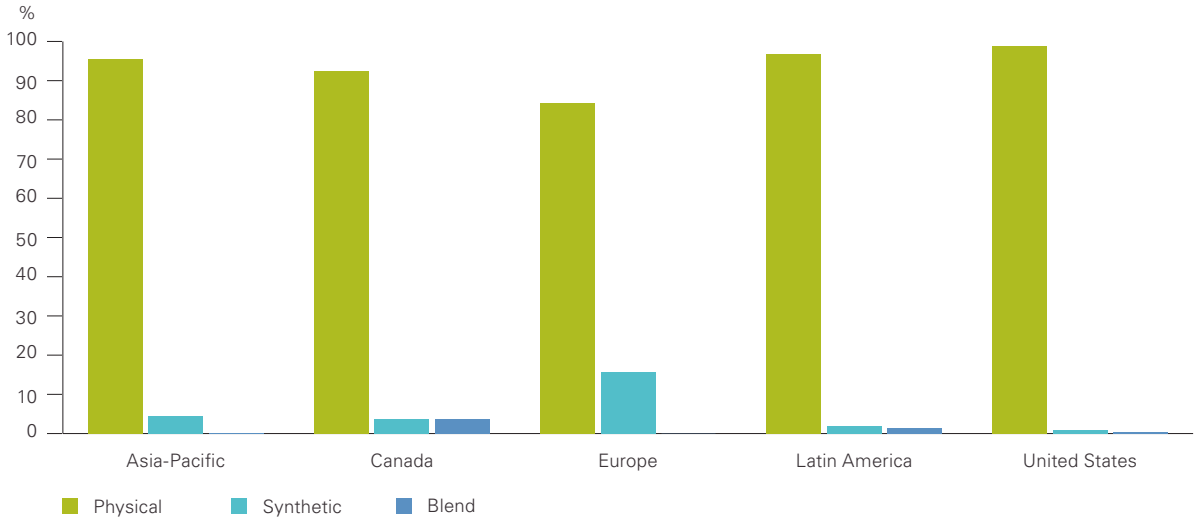
- When selecting an ETF based on replication strategy, investors should consider ownership rights, tracking expectations, asset class exposure and product complexity.
- In this research note, we provide an overview of the global ETF landscape by replication method and assess the risk profiles of synthetic ETFs tracking flagship indices.
- We find that synthetic ETFs may offer more stable tracking error and more efficient access to certain niche market sleeves compared with their physical counterparts. On the other hand, physical ETFs are generally more transparent, straightforward and easy to understand.

Figure 1: Percentage of ETF assets by replication method and region



Source: Vanguard calculations based on Bloomberg data, as at 30 September 2020.

Investors considering ETFs have a choice between funds that use physical replication, and those that use synthetic replication[1]. Physical ETFs aim to fully or partially hold the underlying constituents of an index. Synthetic ETFs use derivatives, namely swaps, to offer exposure to a benchmark.

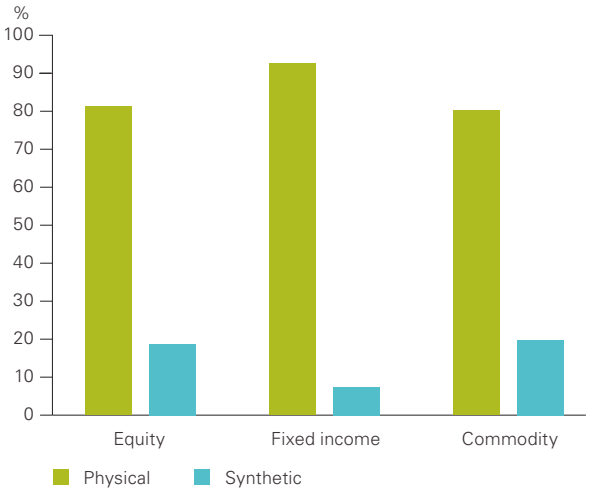
According to ETFGI[2] data, the global ETF industry reached US $6.49 trillion in assets under management (AUM) at the end of September 2020. The lion's share of global ETF assets (US $6.23 trillion) is in physical ETFs. The remaining assets are in synthetic ETFs (US $235.1 billion) and blend[3] ETFs (US $22.2 billion), for the period ending 30 September 2020.

As **Figure 1** shows, the adoption of replication methods varies by region. While synthetic ETFs represent approximately 16% of total ETF assets in Europe, they represent a much smaller percentage of assets in the remaining regions.

In the United States, synthetic ETFs represent only about 1% of total ETF assets. This is because affiliated transactions, such as those that occur when the ETF sponsor's parent bank also serves as the fund's counterparty, are generally not permitted under US securities laws, notably the Investment Company Act of 1940. In addition, US-listed synthetic ETFs are more likely to have less favourable tax treatments compared with their physical counterparts[4].

There are currently 1,806 ETFs registered for sale in Europe[2]. About 85% of these use physical replication. As **Figure 2** shows, physical replication is most commonly used with equity and fixed income ETFs, whereas synthetic replication predominates among commodity ETFs.

Figure 2: Percentage of Europe-domiciled ETFs by replication method and asset class



Source: Vanguard calculations based on Bloomberg data, as at 30 September 2020.

1 Synthetic replication may also be called derivative replication.

2 *ETFGI Global ETF and ETP industry insights.* September 2020.

3 According to Bloomberg, blend replication represents ETFs that use a combination of derivatives and index members.

4 Dickson, Mance and Rowley. *Understanding synthetic ETFs.* June 2013.

In this research note, we introduce three common approaches to physical replication, namely full, optimised and sampling. We then highlight the differences between two swap structures employed by synthetic ETFs, notably the unfunded and funded model.

We also provide case studies that assess the risk profiles of synthetic ETFs tracking flagship indices, including MSCI World, MSCI Emerging Markets and S&P 500. Ultimately, our aim is to equip investors with the information they need to make the most informed ETF selection decision.

Physical ETFs

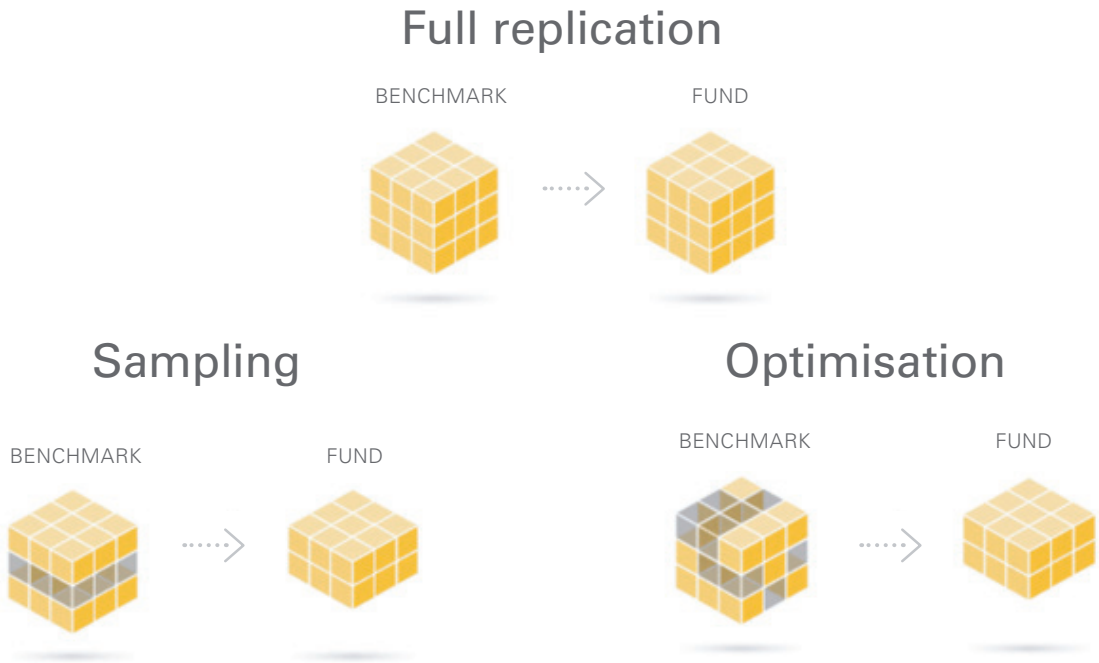
Physical ETFs offer exposure to the performance of an index through full replication, stratified sampling or optimisation (**Figure 3**).

Commodity ETF replication

European commodity ETFs mainly belong to two broad categories:

1. Non-UCITS single commodities ETFs[5] are physically replicated and mostly domiciled in Switzerland. These ETFs offer direct exposure to precious metals—including silver, palladium and gold—which are mostly stored in high-security vaults in Switzerland.
2. Commodity UCITS ETFs track indices constructed using a broad basket of rolling commodity futures. The indices are based on rolling futures contracts rather than on physical assets, as these are more impractical to trade owing to storage and insurance costs. These funds are typically synthetically replicated, using swaps.

Figure 3. Physical replication



Source: Vanguard.

5 Article 53 of the UCITS directive states that single constituents cannot exceed 20% of total index weight. As such, UCITS commodity ETFs do not offer exposure to a single commodity.

Fully replicating ETFs attempt to track the performance of the target index by investing in all, or a substantial part, of their assets in the stocks that make up the index, holding each stock in approximately the same proportion as its weighting in the index. This replication method is often chosen for ETFs that offer exposure to plain vanilla cap-weighted benchmarks that track widely accessible developed-market equities, such as the S&P 500.

Meanwhile, ETFs that adopt a sampling approach only hold a subset of the parent index's securities. This method aims to match the risk and return profile of the index that the fund seeks to track, and is typically used for ETFs that offer exposure to broad fixed income indices.

ETFs that track large, global equity benchmarks often use an optimisation process. Similarly, optimised funds also hold only a portion of the benchmark's constituents. This process is often chosen when full replication—because of the scale of the target benchmark—is deemed impractical and not cost effective. But instead of using a sampling technique, the subset is constructed by running an optimisation minimising the ex-ante tracking error versus the parent benchmark[6].

Sampling and optimisation techniques are commonly used for ETFs that track indices with a large number of holdings or with less-liquid securities. For regulatory reasons, it may not always be possible to physically hold all of the securities in the index. In these instances, full replication can be challenging and expensive.

Sampling and optimisation techniques are frequently used with fixed income index funds. Compared with equity indices, fixed income benchmarks typically contain a broader basket of securities. For example, the Bloomberg Barclays Global Aggregate Index currently holds 26,264 bonds. By comparison, the MSCI World Index is composed of 1,607 stocks[7]. Additionally, many bonds in fixed income indices may be illiquid or difficult to access. This is because many investors tend to hold bonds until maturity.

For these reasons, ETF providers use optimisation and sampling to match the underlying indices' characteristics, such as issuer, yield and term. Skilled portfolio managers are able to minimise tracking error while reducing transaction costs, lowering turnover and maintaining liquidity. Not surprisingly, ETFs that use sampling and optimisation techniques may suffer from higher tracking error[8] compared with their fully replicating counterparts.

At Vanguard, our preference is to fully replicate the indices we track wherever possible; however, in certain circumstances, full replication may not be practical or cost effective.

All told, physically replicating ETFs tend to be transparent and straightforward. They only use derivatives—namely futures—to equitise cash. Additionally, physical ETFs have no, or limited, counterparty risk. For physical funds, counterparty risk only exists if the ETF engages in securities lending.

Key questions for physical replication:

1) How broad is the desired exposure?
2) Are there difficult-to-access securities, markets (emerging or frontier) or assets (e.g., commodities)?
3) Are there regulatory or legal restrictions which may make physical holdings less attractive (capital controls, repatriation restrictions)?
4) Which physical replication technique does the ETF use?
5) Does the issuer have the capabilities to effectively replicate the exposure physically (a sophisticated or global trading capability, a track record of offering index products, sufficient broker relationships)?
6) Does the issuer understand the local market trading and regulatory practices?
7) Does the ETF participate in securities lending?

6 While a fund's prospectus may state that it uses optimised or sampling techniques, a manager may fully replicate the strategy. The reverse is not permitted.

7 Index member data for Bloomberg Barclays Global Aggregate Index and the MSCI World as per Bloomberg. Data as at 30 September 2020.

8 Tracking error is the annualised standard deviation of excess returns versus the benchmark index.

Securities lending

Securities lending refers to the temporary transfer ('lending') of a security by one party to another in exchange for collateral, including cash, shares and bonds, for a fee.

While swap ETFs can also lend securities, it is uncommon in practice because the securities in the reference basket do not usually generate high fees.

To mitigate the risk of default, borrowers also post collateral of equal or greater market value than the loaned security. Borrowers and lenders are often connected via agents, such as banks, which collect a portion of the lending proceeds.

Securities lending revenue can offset a fraction of the ETF's ongoing charge, which can reduce the total cost of ownership and improve the fund's tracking performance.

Unlike most lenders, Vanguard does not take a percentage of lending revenue. Instead, all securities lending revenue, net of programme costs, is credited to Vanguard funds.

Key questions for securities lending:

1) How much of the gross revenues from securities lending are allocated to the ETF? And how much is passed onto the fund?
2) What is the ETF provider's approach to securities lending?
3) What is the provider's approach to borrower selection?
4) Does the provider offer a form of borrower default indemnification?[9]
5) What is the % of the ETF out on loan?
6) Is there a maximum % on loan?
7) What type of collateral is accepted?

Synthetic ETFs

Unlike physical ETFs, which hold an index's underlying securities, synthetic ETFs capture the return of an index using swaps. More specifically, a swap counterparty pledges to deliver the performance of an index for a variable spread, which is paid by the ETF. The two main approaches synthetic ETFs adopt are the unfunded model and the fully funded model.

Unfunded model

Under the unfunded model, the ETF enters into a total return swap agreement with a single counterparty or multiple counterparties[9]. Under this arrangement, the ETF uses investors' cash to buy a reference, also known as a substitute basket. This basket is often purchased from the swap counterparty and is typically ring-fenced as part of a tri-party—or in some cases, quad-party—agreement, whereby the assets are held separately from those of the asset manager or swap counterparty, for the purposes of risk control and asset segregation.

In return, the swap provider pledges to provide the performance of the chosen index to the ETF. Meanwhile, the ETF provides the return of the reference basket to the swap provider (**Figure 4**).

In the unfunded structure, the reference basket may contain securities which are not associated with the underlying index. As such, if the counterparty defaults, the investor will no longer maintain exposure to the desired index.

Compared with physical funds, synthetic ETFs that follow the unfunded model are exposed to a higher level of counterparty risk. This risk can be measured as the difference between the ETF's net asset value (NAV) and the reference basket's value. According to the UCITS directive, this difference—often called the valuation gap—cannot be greater than 10% of the ETF's NAV[10].

Swaps are marked-to-market on a daily basis. If exposure to the swap counterparty exceeds 10% of the fund's NAV, the swap is reset. In this instance, the counterparty transfers additional securities to the reference basket. Swap reset mechanisms vary from product to product and are usually triggered at a predetermined level as part of the counterparty swap agreement. The contract details are not always made publicly available.

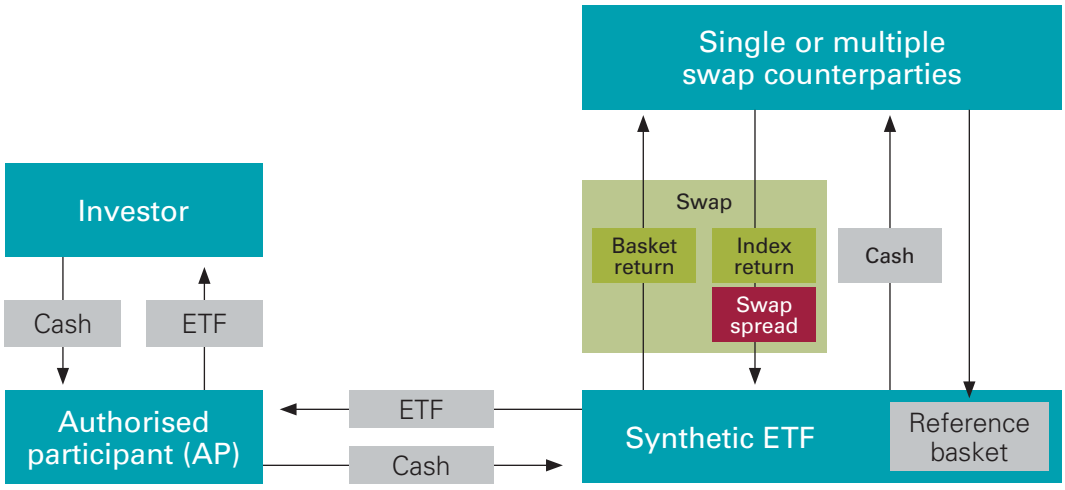
9 A multiple-counterparty model mitigates counterparty risk.

10 Synthetic ETF providers may apply more stringent criteria than what is required under the UCITS directive.

Additionally, the securities in the reference basket, which are often chosen and purchased by the swap counterparty, may not be as liquid as the underlying index. With that in mind, investors holding synthetic ETFs are encouraged to check the securities in the reference basket on ETF providers' websites.

Comparing reference baskets between synthetic ETFs that follow the unfunded model requires additional due diligence. As such, investors are encouraged not only to assess the quality of the basket, but also to ensure that its asset allocation is in line with their investment mandates' risk and return profiles.

Figure 4. The unfunded swap model



Source: Vanguard.

Case study: Substitute basket for MSCI World

In practice, the reference basket often exhibits a different risk and return profile to the underlying index that the synthetic ETF is seeking to track.

While most synthetic ETF providers publish constituent data for the reference basket on a daily basis on their public websites, historical holding data is not as easily accessible. For this reason, it is difficult to analyse how the composition of the basket varies over time compared with the underlying index.

Looking at snapshot data, we can see that on 31 May 2019, the country allocation for the reference basket of a synthetic MSCI World UCITS product differed significantly from its underlying index on 30 September 2020. As **Figure 5** shows, the largest deviation was in France, which only represented 3.25% of the MSCI World Index but comprised almost 18% of the reference basket's total weight.

At the sector level, the largest differences were in communication services and health care, which the reference basket was overweight by 6.12 percentage points and underweight by 3.94 percentage points, respectively (**Figure 6**). Additionally, the reference basket was underweight in financials by 2.61 percentage points and in real estate by 2.37 percentage points relative to the index.

With 39.72% of the weight in the top-ten holdings, the reference basket is also concentrated at the stock level. By comparison, the corresponding figure for MSCI World is 17.33%. The number of stocks in the reference basket is also lower at 354 compared with 1,607 for MSCI World. On aggregate, these differences contribute to an ex-ante tracking error of 4.62%. As a result, the reference basket will have a very different risk and return profile to the benchmark the ETF is intended to track, which must be managed by the swap counterparty.

11 In the event of a borrower default, the asset manager guarantees to cover the shortfall.

Figure 5. Country weights of the reference basket versus MSCI World

Country	Reference basket (%)	MSCI World (%)	Active exposure (%)
France	17.95	3.25	14.70
Germany	4.50	2.93	1.57
Switzerland	1.79	3.17	–1.37
Canada	1.27	3.09	–1.82
United Kingdom	0.00	4.05	–4.05
United States	59.04	66.50	–7.45

Source: FactSet data for the GICS country classification, as at 30 September 2020.

Figure 6. Sector weights of the reference basket versus MSCI World

Sector	Reference basket (%)	MSCI World (%)	Active exposure (%)
Communication services	14.97	8.85	6.12
Consumer discretionary	14.07	11.83	2.24
Energy	4.20	2.48	1.72
Information technology	23.60	22.10	1.49
Consumer staples	9.45	8.22	1.23
Other	0.24	0.01	0.23
Industrials	9.61	10.38	–0.77
Utilities	2.21	3.25	–1.04
Materials	2.16	4.47	–2.31
Real estate	0.42	2.80	–2.37
Financials	9.26	11.86	–2.61
Health care	9.82	13.75	–3.94

Source: FactSet data for the GICS sector classification, as at 30 September 2020.

Figure 7. Key characteristics

	MSCI World	Reference basket
Number of stocks	1,607	354
Weight in top 10 holdings (%)	17.33	39.72
Ex-ante tracking error (%)		4.62

Source. FactSet data, as at 30 September 2020.

Fully funded model

Under the fully funded model, the ETF transfers investors' cash to the counterparty, which in return provides the performance of the underlying index. To mitigate risk, the counterparty posts collateral with an independent third party, such as a custodian.

The collateral can either be held in the ETF's name (transfer of title) or in the name of the counterparty but pledged in favour of the ETF (pledge agreement). If the counterparty defaults, the custodian transfers assets from the segregated account to the ETF's custody account under the transfer of title arrangement. Meanwhile, under the pledge agreement, collateral is posted to a pledged account in the name of the counterparty. As such, the ETF doesn't have direct access to the assets.

Synthetic ETF investors should always check the composition of the collateral baskets. This information may or may not be shared on ETF providers' websites. According to UCITS rules, the collateral basket must comply with liquidity and diversification requirements. Additionally, synthetic ETF providers often mitigate counterparty risk exposure via full or over collateralisation.

As in the case of the reference basket, the composition of the collateral pool differs from that of the underlying index. During periods of increased market distress, trading securities in the collateral basket can also be challenging, especially if the underlying market is closed.

Trade-off between tracking error and transparency

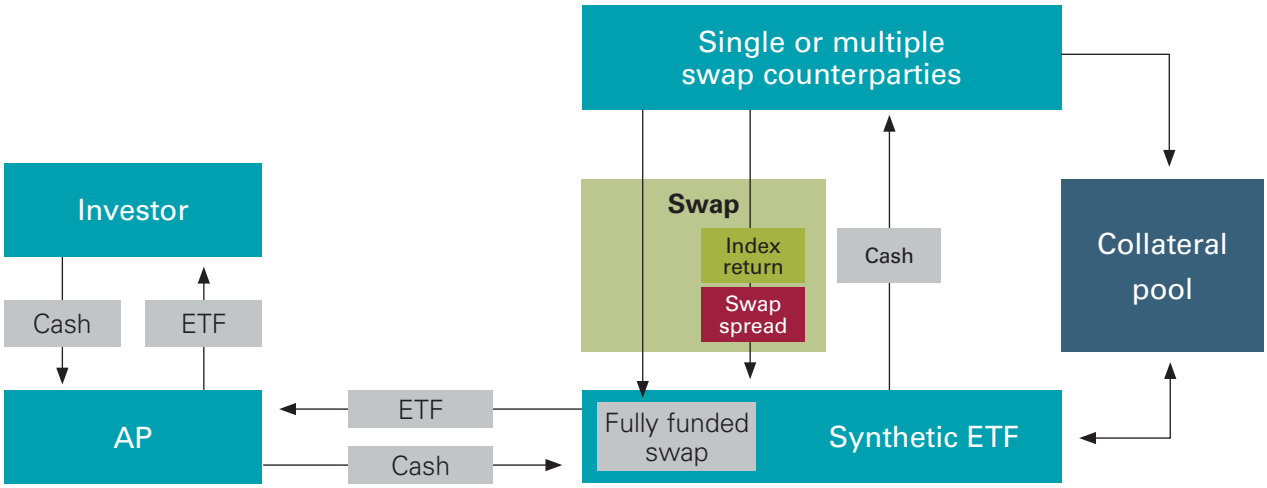
Generally, synthetic ETFs tend to experience lower tracking error compared with their physical peers. This outperformance can typically be seen in less-liquid sleeves of the market, such as emerging market equities, where physically replicated ETFs are more likely to use sampling or optimisation techniques.

While synthetic ETFs tend to offer lower tracking error[12] compared wih their physical counterparts, they are also less transparent when it comes to tracking difference[13].

For synthetic ETFs, the main sources of tracking difference (fund return less index return) are the ongoing charge and swap spread. The ongoing charge has a negative impact on an ETF's tracking difference, while the swap spread may contribute either positively or negatively.

Overall, it is difficult to conduct accurate tracking difference attribution on synthetic ETFs. While ongoing charge data are publicly available, swap spread details are less widely shared. To increase synthetic ETF transparency, swap providers could become more forthcoming with information on swap costs and resets.

Figure 8. The fully funded model



Source: Vanguard.

12 Tracking error is the annualised standard deviation of excess returns versus the benchmark index.
13 Synthetic ETFs under the Microscope: A Global Study. Morningstar ETF Research. May 2012.

Case study: Emerging market equity ETFs

Synthetic replication is commonly used in the emerging markets equity space. This is because emerging market stocks tend to be less liquid and harder to access compared with their developed-market peers.

For this reason, physical emerging market equity ETFs often employ sampling techniques. In fact, almost all physical UCITS ETFs that track the MSCI Emerging Markets Index currently use sampling.

One drawback of sampling is that by deviating from full replication, an ETF's tracking error increases. By comparison, synthetic ETFs offer minimal tracking error. This is because the performance of a synthetic ETF relative to the benchmark is stable, as it's dictated by the swap spread and expense ratio[14].

According to **Figure 9**, UCITS ETFs tracking the MSCI Emerging Markets Index have experienced a higher tracking error compared with their synthetic counterparts for the three years ending 30 September 2020.

While tracking error for synthetic MSCI Emerging Markets UCITS ETFs has been lower compared with physical funds, tracking difference has been higher in absolute terms over the examined period.

Figure 10 shows that the three-year average tracking error for synthetic ETFs was 0.69%, lower than the 1.21% for physical funds. Meanwhile, the average three-year tracking difference for synthetic funds was –0.65%, which was wider than the –0.39% for physical ETFs.

Currently, the asset-weighted ongoing charges for MSCI Emerging Markets UCITS physical and synthetic ETFs are similar at 0.21% and 0.25% respectively[15]. As such, swap spreads have been the main contributor to the higher tracking difference experienced by synthetic emerging market equity ETFs over the past three years. Over longer investment horizons, tracking difference can have a more significant impact on performance than tracking error.

Swap spreads are calculated by counterparties using a number of assumptions, including stock-borrowing income, rebalance risk, hedging costs and interest rate differentials between the 3-month LIBOR and the overnight rate. Depending on how closely these assumptions match the index, the swap spread can either reduce or increase the ETF's tracking difference. While the swap spread contributes to the overall return of a synthetic ETF, it is not transparent to investors and can be difficult to predict.

Figure 9. Three-year annualised tracking error and tracking difference for Europe-domiciled ETFs tracking MSCI Emerging Markets Index by replication method.

Physical	Tracking error	Tracking difference
ETF 1	0.38%	-0.33%
ETF 2	1.57%	-0.30%
ETF 3	0.43%	-0.17%
ETF 4	1.84%	-0.55%
ETF 5	1.84%	-0.59%
Average	**1.21%**	**-0.39%**

Synthetic	Tracking error	Tracking difference
ETF 1	0.89%	-0.44%
ETF 2	1.76%	-0.44%
ETF 3	0.11%	-0.54%
ETF 4	0.11%	-0.45%
ETF 5	0.85%	-0.77%
ETF 6	0.03%	-0.80%
ETF 7	0.56%	-1.02%
ETF 8	1.20%	-0.77%
Average	**0.69%**	**-0.65%**

Source: Vanguard calculations using data from Bloomberg. Data cover the period 30 September 2017 through 30 September 2020.

14 Changing of either swap terms or costs over time is likely to increase the relative amount of tracking error.

15 Vanguard calculations using data from Bloomberg. Data as at 30 September 2020.

Figure 10. Average annualised tracking error and tracking difference for Europe-domiciled physical and synthetic ETFs tracking MSCI Emerging Markets Index

Source: Vanguard calculations using data from Bloomberg. Data cover the period 30 September 2017 through 30 September 2020.

Case study: S&P 500

Synthetic replication is also widely used for UCITS ETFs tracking the S&P 500 Index. This is because synthetic ETFs offer a tax advantage over their physical peers.

Under the current US Internal Revenue Service (IRS) regulations in section 871(m), certain equity-linked instruments, including synthetic S&P 500 ETFs, are exempt from withholding taxes[16]. As such, synthetic ETFs receive 100% of the dividends paid by the stocks in the S&P 500.

Meanwhile, physically replicated S&P 500 ETFs domiciled in Ireland pay an annual withholding tax of 15% because of the double-tax treaty between Ireland and the United States.

By comparison, the S&P 500 Net Total Return Index assumes a 30% withholding tax on dividends. Given the index's higher tax rate, most—if not all—S&P 500 synthetic and physical ETFs outperform the benchmark.

In each of the past six years, the best-performing synthetic ETF outperformed the best-performing physical ETF[17]. Depending on the year, outperformance fluctuated significantly, ranging from a minimum of 0.02 percentage points in 2014 to a maximum of 0.30 percentage points in 2019.

We deconstructed the relative performance difference into three components, namely the dividend tax advantage, ongoing charges figure (OCF) differential and residual.

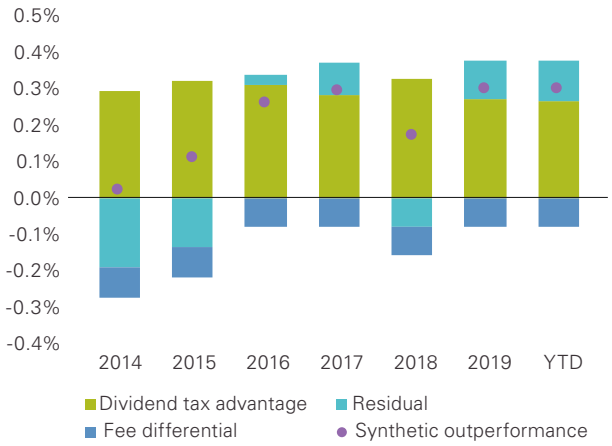
By taking 15% of the S&P 500's annual dividend yield, we approximated the impact of the tax exemption on performance. This resulted in a contribution of about 30 bps per annum, assuming that the swap provider passed the entire benefit of the tax advantage to the fund, which may not have been the case.

Over the examined period, the OCF differential (synthetic ETF OCF less physical ETF OCF) was 8 bps

16 871(m) Qualified Indices Data. Exchange Data International.

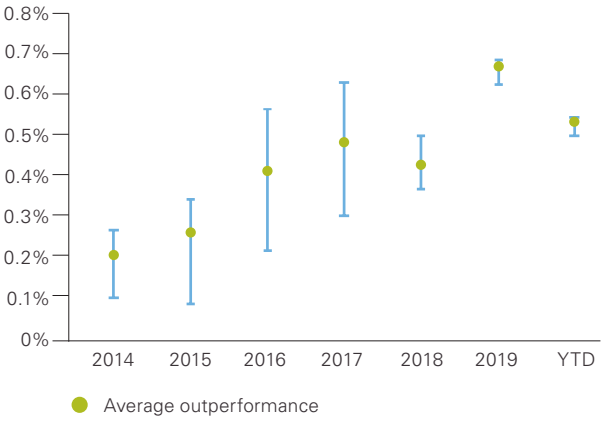
17 Data cover the period 31 December 2013 through 30 September 2020.

Figure 11. Synthetic vs. physical ETFs outperformance breakdown



Source: Vanguard calculations using data from Bloomberg. Data cover the period 31 December 2014 through 30 September 2020.

Figure 12. Range of tracking differences for synthetic ETFs versus the S&P 500 net total return index



Source: Vanguard calculations using data from Bloomberg. Data cover the period 31 December 2014 through 30 September 2020.

per year. Since the OCF differential and the tax advantage have remained stable over the past six years, performance fluctuations can only be explained by the residual, which includes swap provider costs and revenues.

As **Figure 11** shows, the positive contribution of the dividend tax advantage was largely offset by the negative impact of the OCF differential and swap fee in 2014 and 2015. Meanwhile, the effect of the OCF differential and swap fee was offset by additional sources of revenue from the beginning of 2016 through to the end of September 2020.

Given the opaque nature of swap spreads, it is difficult to explain the large fluctuations in relative performance. Years with stronger outperformance could be explained by the synthetic ETF provider negotiating better swap spreads, generating revenue from securities lending, leverage, earning a cross-currency premium or simply passing on more revenue to the fund.

We also examined tracking difference patterns in synthetic and physical S&P 500 UCITS ETFs. While the average tracking difference range for physical S&P 500 ETFs was only 4 bps, it reached a maximum of 35 bps for synthetic funds.

According to **Figure 12**, the average tracking difference range for synthetic S&P 500 UCITS ETFs, as measured by the vertical bars, has generally been wide over the past six years. Unlike their more homogeneous physical peers, synthetic S&P 500 UCITS ETFs behave very differently. All told, it is difficult to accurately assess the true risk and return profile of these funds.

Conclusion

When selecting an ETF based on replication strategy, investors need to consider a number of factors, including ownership, tracking expectations, asset class and level of product complexity.

Physical ETFs directly own all or a subset of the securities that constitute the index. Meanwhile, investors holding synthetic ETFs only have ownership rights to the underlying collateral pools or reference baskets, which may or may not align with their overarching risk and return profiles.

Synthetic ETFs generally tend to offer lower tracking error compared with their physical peers. This is because swap counterparties guarantee the return of the underlying index. In the case of physical ETFs, tracking error may be higher due to sampling or optimisation techniques, transaction costs, rebalancing and corporate actions.

Tracking difference, on the other hand, may be higher or lower for synthetic ETFs. Since swap providers are not always forthcoming about costs, accurately deconstructing a synthetic ETF's tracking difference can also be challenging.

Accessing certain markets via physical replication can be expensive and inefficient. In these instances, synthetic replication may be an appropriate solution, especially for investors seeking exposure to less liquid or more niche sleeves of the market.

Finally, physical ETFs are reasonably transparent, straightforward and easy to understand, while synthetic ETFs are more complex and opaque.

Key questions for synthetic replication:

1) Is the swap exposure to a single counterparty, or is it diversified across several counterparties?
2) Is the value chain—namely fund promoter, market maker, swap counterparty and custodian—transparent? Are there any potential conflicts of interest?
3) What is the current and historic swap spread? How often do swap spreads change and how are changes communicated to investors?
4) What are the rules that determine the quality and liquidity of the reference basket?
5) If the swap counterparty defaults, what is the process and expected time frame to appoint a new counterparty?
6) What is the quality of the collateral basket and is the asset allocation in line with the investor's risk profile?
7) For fully funded swap structures, how easy is it to gain access to the collateral in case of counterparty default?
8) How often is the swap reset and what is the target level for the collateral or reference basket?
9) Are the constituents of the reference basket or collateral holdings publicly available?
10) Is the level of counterparty risk published on the provider's website?

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