

# A bond index fund's balancing act: Tracking error and cost

- Fully replicating a bond benchmark can be challenging because of the breadth of the bond market and the limited liquidity in certain market segments. This has created the misconception that bond index funds that don't fully replicate their benchmarks can't track them effectively.
- Successful bond index fund management hinges on aligning a portfolio's key risk factor exposures with those of its benchmark to minimize tracking error and transaction costs.
- Vanguard's global resources, deep investment expertise, and collaborative process are differentiators that support our bond index team's goal of achieving tight benchmark tracking.

## Index fund investing overview

Index funds aim to mirror the returns of a market benchmark. For most market capitalization-weighted equity index funds, this is typically achieved by holding all benchmark securities at their respective weights. However, this approach can be impractical for many bond index funds because of the breadth of the bond market and the limited liquidity in certain bonds. This has led to the misconception that if a bond index fund doesn't fully replicate its benchmark, it can't track it successfully.

## Managing bond index funds: An art and science

Broad bond benchmarks may contain thousands of bonds; for example, the Bloomberg U.S. Aggregate Bond Index contained more than 13,000 securities at year-end 2024. Yet, matching the return of a broad bond benchmark isn't simply a function of holding more bonds.

Many bonds are traded over the counter (that is, trades are negotiated between parties) and not electronically on an exchange. This makes certain bonds either unavailable or prohibitively expensive to trade, creating barriers to fully replicating an index. While owning a subset of a benchmark's bonds can help, doing so naively increases idiosyncratic risk and tracking error relative to a thoughtful, risk-aligned approach. Therefore, bond index fund managers must build a portfolio that aligns its key risk factor exposures with the benchmark while simultaneously minimizing transaction costs.<sup>1</sup>

One tool bond index fund managers use is sampling. Sampling involves selecting and weighting a subset of benchmark bonds in order to have the portfolio's key risk factor exposures align with the benchmark's. However, even skilled sampling doesn't fully eliminate tracking error, as it can overlook correlations among risk factors and is difficult to implement in a portfolio with multiple constraints, such as limits on allowable sector weight deviations and issuer concentration.

Multifactor risk models can help address these limitations by identifying portfolio risk at both the macro and micro level. Optimization models are quantitative tools that find asset combinations to meet a given objective (for instance, minimize tracking error versus a benchmark) within imposed constraints. Integrating skillful sampling with a multifactor risk model and an optimization model enables bond index fund managers to build portfolios that balance expected risks, returns, and transaction costs to minimize tracking error.

## Threading the needle: Risk factor alignment and cost minimization

While aligning the key risk factor exposures of a portfolio with its benchmark helps minimize risk factor-based tracking error, successful bond index fund management also requires minimizing transaction costs. To illustrate the balance between aligning risk exposures and minimizing transaction costs, we estimated the tracking error of two hypothetical portfolios against the Bloomberg U.S. Aggregate Bond Index:

- The "risk-aligned" portfolio matches the benchmark's duration, credit quality, and sector risk factor exposures by sampling bonds from the benchmark and rescaling their weights accordingly.
- The "non-risk-aligned" portfolio has the same number of bonds as the "risk-aligned" portfolio, but the bonds have been randomly selected without regard to matching benchmark risk factor exposures.

We repeated this process monthly for portfolios containing between 5% and 100% of benchmark bonds, running each 500 times, and then calculated the estimated median monthly tracking error. For each risk-aligned portfolio we also estimated monthly round-trip transaction costs.<sup>2</sup>

<sup>1</sup> Key risk factors are typically prioritized in the following order: portfolio duration; key rate durations; sector and credit-quality contributions to duration, sector, industry, and credit-quality weights; portfolio yield; portfolio convexity; and issuer exposure. For brevity, this article focuses on portfolio duration, credit-quality weights, and sector weights given their well-documented impact on bond returns and tracking error. See Fabozzi, Mann, and Fabozzi (2021) for further details.

<sup>2</sup> Round-trip transaction costs represent the total estimated costs to complete a buy and sell transaction. Transaction cost estimates are for illustrative purposes and assume 100% turnover each month. This likely overstates true transaction costs, as most bond index funds and ETFs typically exhibit less than 100% turnover in a month.

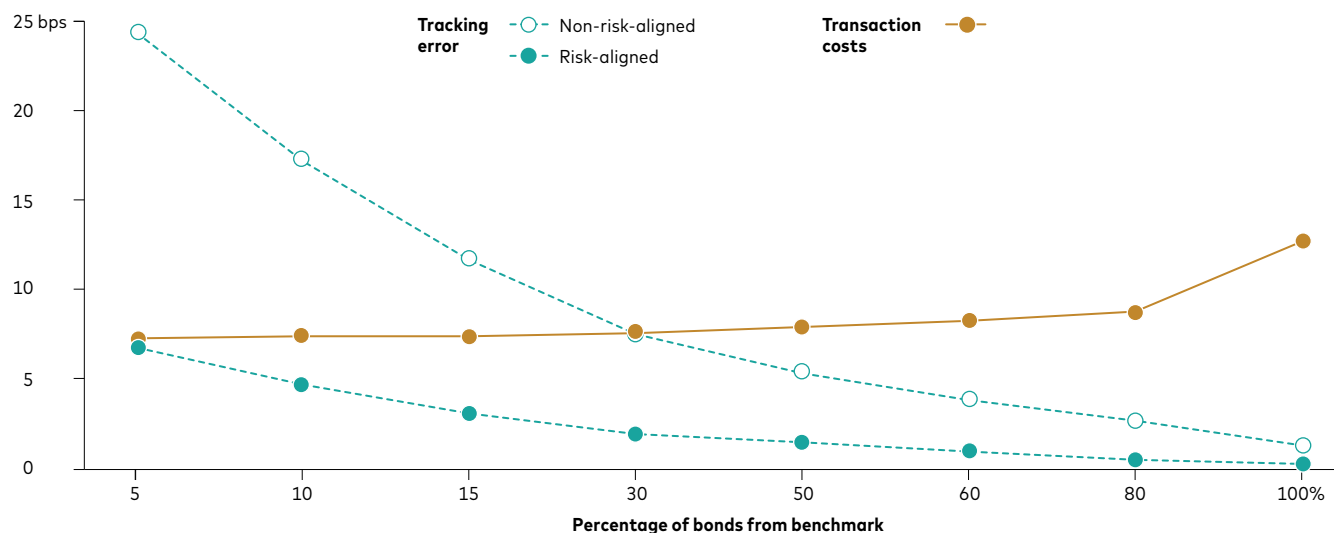
**Figure 1** shows the results. As the percentage of benchmark bonds held increases, the risk-aligned portfolio exhibits lower tracking error at each interval compared with the non-risk-aligned portfolio, with the difference decreasing as the percentage of benchmark bonds held increases. Even portfolios that hold a significant percentage of benchmark bonds can benefit from risk factor alignment. For example, the non-risk-aligned portfolio holding 80% of benchmark bonds has a tracking error roughly five times as high as the risk-aligned portfolio holding 80% of benchmark bonds.

Figure 1 also shows that transaction costs rise as the percentage of benchmark bonds held increases, with a significant jump from 80% to

100%. This reflects that many of these bonds are either unavailable or prohibitively expensive to trade, illustrating why it's often impractical to fully replicate a broad benchmark like the Bloomberg U.S. Aggregate Bond Index.

Aligning a portfolio's risk factor exposures with the benchmark's is paramount since it not only helps minimize risk factor-based tracking error, but also helps lower transaction costs as fund managers can avoid trading the most expensive bonds. Therefore, successful bond index fund management hinges on finding the optimal balance between risk factor alignment and transaction costs.

**FIGURE 1**  
**Risk factor alignment strikes a balance between tracking error and transaction costs**



**Notes:** Each tracking error data point represents the estimated median monthly tracking error across 500 simulations of a portfolio containing a given percentage of the bonds in the benchmark, the Bloomberg U.S. Aggregate Bond Index. The rescaled weights for each portfolio sum to 1. Percentages of bonds included in each portfolio are rounded to the nearest fifth percent and are based on the average number of monthly benchmark constituents. Tracking error is calculated as the standard deviation of monthly excess returns of the portfolio relative to the benchmark across all months in our sample for each of the simulations of a given portfolio size. Each transaction cost data point represents the monthly round-trip cost, quoted in price, to trade an entire portfolio (that is, 100% turnover) that contains a given percentage of the bonds in the benchmark. We estimate portfolio-level transaction costs based on group-level transaction costs across key market sectors (such as Treasuries, mortgages, and corporates) and input from Vanguard's Global Bond Index team. Trades are assumed to be done pro rata across each sector in the benchmark based on average monthly sector weights.

**Sources:** Vanguard calculations, using data from RIMES, Bloomberg, and MarketAxess® from October 2020 through May 2024.

## The Vanguard bond index fund investing edge

What then, allows bond index fund managers to effectively balance these elements to minimize tracking error? For Vanguard, the answer is global resources, deep investment expertise, and collaboration.

Our bond index portfolio managers leverage global resources across specialized teams, including experienced traders, risk specialists, and credit analysts, each of whom contributes their expertise in an effort to collectively deliver tight benchmark tracking. **Figure 2** shows how these teams collaborate to seek positive investment outcomes by converting fundamental insights into opportunities, applying real-time risk analytics, and achieving efficient trade execution.

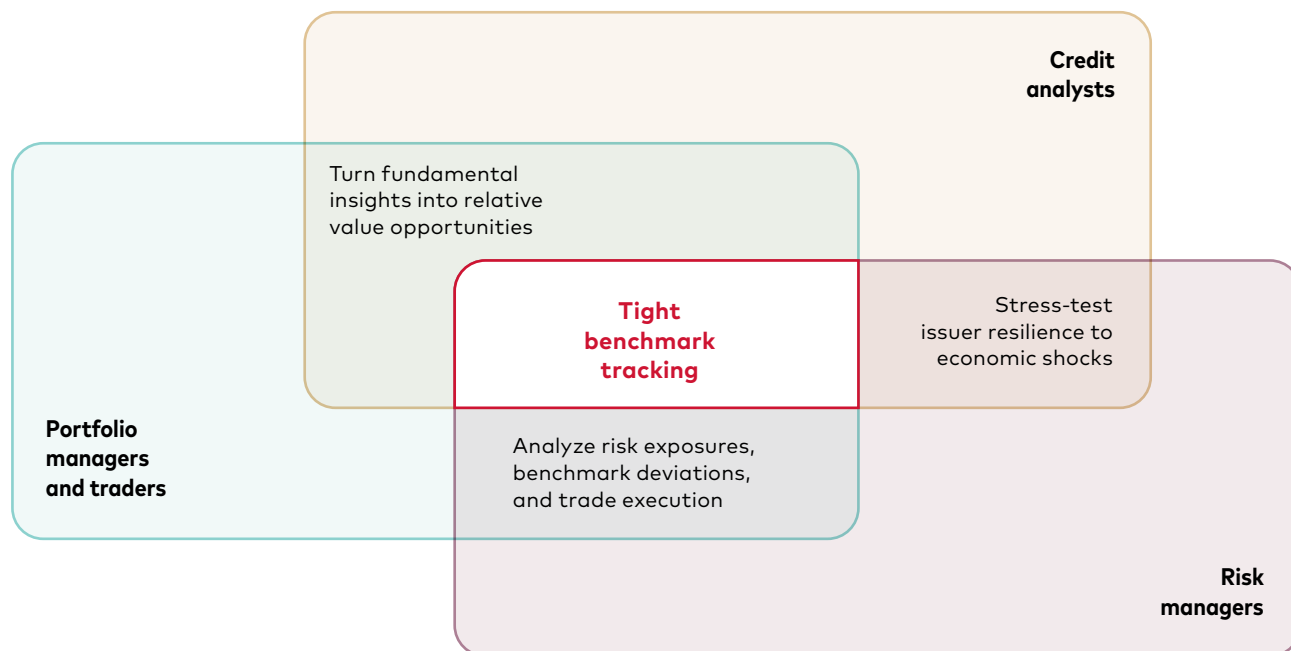
An example of this collaboration generating strong results was the 2023 addition of Ford Motor Company's bonds to the Bloomberg U.S.

Aggregate Bond Index. As Ford's bonds were added to the index, Vanguard's bond index team initially delayed adding their full exposure to our portfolios because increased demand caused them to trade at a premium. Instead, the team allocated to another auto issuer, General Motors, whose bonds were trading at more attractive valuations, to capitalize on the temporary mispricing while still ensuring tight benchmark tracking.

In September 2023, Vanguard's credit research team upgraded its internal rating of Ford and signaled that rating agencies would likely follow, triggering the potential for Ford to be added to the benchmark. Vanguard's credit research team had favorable outlooks for both GM, which was already in the benchmark, and Ford.

FIGURE 2

### Vanguard's collaborative ecosystem brings together world-class expertise



Source: Vanguard.

In October 2023, Vanguard traders observed sufficient liquidity in both GM and Ford bonds with the desired risk characteristics but noticed credit spreads on Ford's bonds had decreased by 20 to 40 basis points following the announcement of their addition to the index. (A basis point is one-hundredth of a percentage point.) This resulted in the decision to be initially underweight to Ford and overweight to GM based on relative valuations, with the goal of aligning their weights to the benchmark once the valuations of Ford's bonds normalized.

Vanguard risk managers provided insights into expected tracking error for various overweight and underweight scenarios of Ford and GM, helping our portfolio managers appropriately size the risk exposure and understand the potential transaction costs. This strategy enabled Vanguard's bond index team to effectively balance capturing positive value for our funds, minimizing cost, and closely tracking the benchmark.

## **Harnessing the power of Vanguard bond index funds**

The breadth of the bond market and the limited liquidity in certain bonds can make it challenging to fully replicate broad bond benchmarks. However, bond index fund managers can still mirror the returns of a benchmark without full replication by creating portfolios that align risk factor exposures with the benchmark and minimize transaction costs.

At Vanguard, our global resources, deep investment expertise, and collaborative process are differentiators that support our bond index team's objective of producing tight benchmark tracking.

## **References**

Fabozzi, Frank J., 2016. *Bond Markets, Analysis, and Strategies*, Ninth Edition. Pearson Education, Inc.

Fabozzi, Frank J., Steven V. Mann, and Francesco Fabozzi, 2021. *The Handbook of Fixed Income Securities*, Ninth Edition. McGraw Hill.

Lawrence, Stephen, Andrew J. Patterson, and Marvin Ertl, 2024. *Considerations for Index Fund Investing*. The Vanguard Group.

Markowitz, Harry, 1952. *Portfolio Selection*. The Journal of Finance 7(1): 77–91.

## Authors



Erich Pingel,  
CFP®, CFA



Stephen Lawrence,  
Ph.D.



Josh Barrickman,  
CFA



Rachel Baxter,  
CFA

*Acknowledgments: We would like to thank Jim Rowley for his helpful comments and feedback. Special acknowledgments go to Alexcia Mazahreh, Gaurav Malhotra, Justin Copeland, and Ross Walter for their helpful discussion and analytical support regarding bond transaction costs.*

## Connect with Vanguard®

[vanguard.com](https://vanguard.com)

**For more information about Vanguard funds, visit [vanguard.com](https://vanguard.com) to obtain a prospectus or, if available, a summary prospectus. Investment objectives, risks, charges, expenses, and other important information are contained in the prospectus; read and consider it carefully before investing.**

CFA® is a registered trademark owned by CFA Institute.

Certified Financial Planner Board of Standards Inc. owns the certification marks CFP® and Certified Financial Planner™ in the U.S., which it awards to individuals who successfully complete CFP Board's initial and ongoing certification requirements.

© 2025 MarketAxess Holdings Inc. Underlying data © 2025 FINRA.  
All data is provided as is, with no warranties.

# Vanguard®

© 2025 The Vanguard Group, Inc.  
All rights reserved. Vanguard Marketing  
Corporation, Distributor.

ISGBIFB 032025

## Important Information

VIGM, S.A. de C.V. Asesor en Inversiones Independiente ("Vanguard Mexico") registration number: 30119-001-(14831)-19/09/2018. The registration of Vanguard Mexico before the Comisión Nacional Bancaria y de Valores ("CNBV") as an Asesor en Inversiones Independiente is not a certification of Vanguard Mexico's compliance with regulation applicable to Advisory Investment Services (Servicios de Inversión Asesorados) nor a certification on the accuracy of the information provided herein. The supervision scope of the CNBV is limited to Advisory Investment Services only and not all services provided by Vanguard Mexico.

This material is solely for informational purposes and does not constitute an offer or solicitation to sell or a solicitation of an offer to buy any security, nor shall any such securities be offered or sold to any person, in any jurisdiction in which an offer, solicitation, purchase or sale would be unlawful under the securities law of that jurisdiction. Reliance upon information in this material is at the sole discretion of the recipient.

Securities information provided in this document must be reviewed together with the offering information of each of the securities which may be found on Vanguard's website: <https://www.vanguardmexico.com/institutional/products/en/list/overview> or [www.vanguard.com](https://www.vanguard.com)

Vanguard Mexico may recommend products of The Vanguard Group Inc. and its affiliates and such affiliates and their clients may maintain positions in the securities recommended by Vanguard Mexico.

ETFs can be bought and sold only through a broker and cannot be redeemed with the issuing fund other than in very large aggregations. Investing in ETFs entails stockbroker commission and a bid-offer spread which should be considered fully before investing. The market price of ETF Shares may be more or less than net asset value.

All investments are subject to risk, including the possible loss of the money you invest. Investments in bond funds are subject to interest rate, credit, and inflation risk. Governmental backing of securities applies only to the underlying securities and does not prevent share-price fluctuations. High-yield bonds generally have medium- and lower-range credit quality ratings and are therefore subject to a higher level of credit risk than bonds with higher credit quality ratings.

**There is no guarantee that any forecasts made will come to pass. Past performance is no guarantee of future results.**

Prices of mid- and small-cap stocks often fluctuate more than those of large-company stocks. Funds that concentrate on a relatively narrow market sector face the risk of higher share-price volatility. Stocks of companies are subject to national and regional political and economic risks and to the risk of currency fluctuations, these risks are especially high in emerging markets. Changes in exchange rates may have an adverse effect on the value, price or income of a fund.

The information contained in this material derived from third-party sources is deemed reliable, however Vanguard Mexico and The Vanguard Group Inc. are not responsible and do not guarantee the completeness or accuracy of such information.

This document should not be considered as an investment recommendation, a recommendation can only be provided by Vanguard Mexico upon completion of the relevant profiling and legal processes.

This document is for educational purposes only and does not take into consideration your background and specific circumstances nor any other investment profiling circumstances that could be material for taking an investment decision. We recommend getting professional advice based on your individual circumstances before taking an investment decision.

These materials are intended for institutional and sophisticated investors use only and not for public distribution.

Materials are provided only for the recipient's exclusive use and shall not be distributed to any other individual or entity. Broker-dealers, advisers, and other intermediaries must determine whether their clients are eligible for investment in the products discussed herein.

The information contained herein does not constitute an offer or solicitation and may not be treated as such in any jurisdiction where such an offer or solicitation is against the law, or to anyone for whom it is unlawful to make such an offer or solicitation, or if the person making the offer or solicitation is not qualified to do so.

THESE MATERIALS ARE PROVIDED FOR THE EXCLUSIVE USE OF RECIPIENT AND CONTAIN HIGHLY CONFIDENTIAL INFORMATION, WHICH SHALL NOT BE REPRODUCED OR TRANSMITTED TO ANY THIRD PARTIES WITHOUT VANGUARD'S PRIOR WRITTEN CONSENT. THE CONTENTS OF THESE MATERIALS SHALL NOT BE UNDERSTOOD AS AN OFFER OR SOLICITATION TO BUY OR SELL SECURITIES IN BRAZIL AND VANGUARD IS NOT MAKING ANY REPRESENTATION WITH RESPECT TO THE ELIGIBILITY OF ANY RECIPIENT OF THESE MATERIALS TO ACQUIRE THE INTERESTS IN THE SECURITIES DESCRIBED HEREIN UNDER THE LAWS OF BRAZIL. SUCH SECURITIES HAVE NOT BEEN REGISTERED IN BRAZIL AND NONE OF THE INTERESTS IN SUCH SECURITIES MAY BE OFFERED, SOLD, OR DELIVERED, DIRECTLY OR INDIRECTLY, IN BRAZIL OR TO ANY RESIDENT OF BRAZIL EXCEPT PURSUANT TO THE APPLICABLE LAWS AND REGULATIONS OF BRAZIL.

THIS DOCUMENT WAS SENT BY VANGUARD SPECIFICALLY TO ITS RECIPIENT AND CONTAINS HIGHLY CONFIDENTIAL INFORMATION, WHICH SHALL NOT BE REPRODUCED OR TRANSMITTED TO ANY THIRD PARTIES WITHOUT VANGUARD'S PRIOR AND WRITTEN CONSENT. THE CONTENTS OF THIS MESSAGE SHALL NOT BE UNDERSTOOD AS AN OFFER OR SOLICITATION TO BUY OR SELL SECURITIES IN BRAZIL.

This document is provided at the request of and for the exclusive use of the recipient and does not constitute, and is not intended to constitute, a public offer in the Republic of Colombia, or an unlawful promotion of financial/capital market products. The offer of the financial products described herein is addressed to fewer than one hundred specifically identified investors. The financial products described herein may not be promoted or marketed in Colombia or to Colombian residents, unless such promotion and marketing is made in compliance with Decree 2555/2010 and other applicable rules and regulations related to the promotion of foreign financial/capital market products in Colombia.

The financial products described herein are not and will not be registered before the Colombian National Registry of Securities and Issuers (Registro Nacional de Valores y Emisores - RNVE) maintained by the Colombian Financial Superintendency, or before the Colombian Stock Exchange. Accordingly, the distribution of any documentation in regard to the financial products described here in will not constitute a public offering of securities in Colombia.

The financial products described herein may not be offered, sold or negotiated in Colombia, except under circumstances which do not constitute a public offering of securities under applicable Colombian securities laws and regulations; provided that, any authorized person of a firm authorized to offer foreign securities in Colombia must abide by the terms of Decree 2555/2010 to offer such products privately to its Colombian clients.

The distribution of this material and the offering of securities may be restricted in certain jurisdictions. The information contained in this material is for general guidance only, and it is the responsibility of any person or persons in possession of this material and wishing to make application for securities to inform themselves of, and to observe, all applicable laws and regulations of any relevant jurisdiction. Prospective applicants for securities should inform themselves of any applicable legal requirements, exchange control regulations and applicable taxes in the countries of their respective citizenship, residence or domicile.

This document and its content should not be considered as an offer, if it were the case the offer of the securities described herein would be made in accordance with general rule No. 336 of the Financial Market Commission (Comisión para el Mercado Financiero). The securities described herein are not registered under Securities Market Law, nor in the Securities Registry nor in the Foreign Securities Registry of the Chilean Financial Market Commission, and therefore such securities are not subject to its oversight. Since such securities are not registered in Chile, the issuer is not obligated to provide public information in Chile regarding the securities. The securities shall not be subject to public offering unless they are duly registered in the corresponding Securities Registry in Chile. The issuer of the securities is not registered in the Registries maintained by the Chilean Financial Market Commission, therefore it is not subject to the supervision of the Chilean Financial Market Commission or the obligations of continuous information.



*El presente documento y su contenido no deberá considerarse como una oferta, en su caso la oferta de los valores aquí descritos se realizaría conforme a la norma de carácter general No. 336 de la Comisión para el Mercado Financiero. Los valores aquí descritos, al ser valores no inscritos bajo la Ley de Mercado de Valores en el Registro de Valores o en el Registro de Valores extranjeros que lleva la Comisión para el Mercado Financiero, no están sujetos a la fiscalización de ésta. Por tratarse de valores no inscritos, no existe la obligación por parte del emisor de entregar en Chile información pública respecto de esos valores. Los valores no podrán ser objeto de oferta pública mientras no sean inscritos en el Registro de Valores correspondiente. El emisor de los valores no se encuentra inscrito en los Registros que mantiene la Comisión para el Mercado Financiero, por lo que no se encuentra sometido a la fiscalización de la Comisión para el Mercado financiero ni a las obligaciones de información continua.*

The securities described herein have not been registered under the Peruvian Securities Market Law (Decreto Supremo No 093-2002-EF) or before the Superintendencia del Mercado de Valores (the "SMV"). There will be no public offering of the securities in Peru and the securities may only be offered or sold to institutional investors (as defined in Appendix I of the Institutional Investors Market Regulation) in Peru by means of a private placement. The securities offered and sold in Peru may not be sold or transferred to any person other than an institutional investor unless such securities have been registered with the Registro Público del Mercado de Valores kept by the SMV. The SMV has not reviewed the information provided to the investor. This material is for the exclusive use of institutional investors in Peru and is not for public distribution.

The financial products described herein may be offered or sold in Bermuda only in compliance with the provisions of the Investment Business Act 2003 of Bermuda. Additionally, non-Bermudian persons may not carry on or engage in any trade or business in Bermuda unless such persons are authorized to do so under applicable Bermuda legislation. Engaging in the activity of offering or marketing the financial products described herein in Bermuda to persons in Bermuda may be deemed to be carrying on business in Bermuda.

Vanguard Mexico does not intend, and is not licensed or registered, to conduct business in, from or within the Cayman Islands, and the interests in the financial products described herein shall not be offered to members of the public in the Cayman Islands.

The financial products described herein have not been and will not be registered with the Securities Commission of The Bahamas. The financial products described herein are offered to persons who are non-resident or otherwise deemed non-resident for Bahamian Exchange Control purposes. The financial products described herein are not intended for persons (natural persons or legal entities) for which an offer or purchase would contravene the laws of their state (on account of nationality or domicile/registered office of the person concerned or for other reasons). Further, the offer constitutes an exempt distribution for the purposes of the Securities Industry Act, 2011 and the Securities Industry Regulations, 2012 of the Commonwealth of The Bahamas.

This document is not, and is not intended as, a public offer or advertisement of, or solicitation in respect of, securities, investments, or other investment business in the British Virgin Islands ("BVI"), and is not an offer to sell, or a solicitation or invitation to make offers to purchase or subscribe for, any securities, other investments, or services constituting investment business in BVI. Neither the securities mentioned in this document nor any prospectus or other document relating to them have been or are intended to be registered or filed with the Financial Services Commission of BVI or any department thereof.

This document is not intended to be distributed to individuals that are members of the public in the BVI or otherwise to individuals in the BVI. The funds are only available to, and any invitation or offer to subscribe, purchase, or otherwise acquire such funds will be made only to, persons outside the BVI, with the exception of persons resident in the BVI solely by virtue of being a company incorporated in the BVI or persons who are not considered to be "members of the public" under the Securities and Investment Business Act, 2010 ("SIBA").

Any person who receives this document in the BVI (other than a person who is not considered a member of the public in the BVI for purposes of SIBA, or a person resident in the BVI solely by virtue of being a company incorporated in the BVI and this document is received at its registered office in the BVI) should not act or rely on this document or any of its contents.

Vanguard represents and agrees that it has not offered or sold, and will not offer or sell, any ETFs or Mutual Funds to the public in Uruguay, except in circumstances which do not constitute a public offering or distribution under Uruguayan laws and regulations. Neither Vanguard ETFs or Mutual Funds nor issuer are or will be registered with the Superintendency of Financial Services of the Central Bank of Uruguay to be publicly offered in Uruguay.

Bloomberg® and Bloomberg Indexes mentioned herein are service marks of Bloomberg Finance LP and its affiliates, including Bloomberg Index Services Limited ("BISL"), the administrator of the index (collectively, "Bloomberg") and have been licensed for use for certain purposes by Vanguard. Bloomberg is not affiliated with Vanguard and Bloomberg does not approve, endorse, review, or recommend the Financial Products included in this document. Bloomberg does not guarantee the timeliness, accurateness or completeness of any data or information related to the Financial Products included in this document.

Vanguard Mexico is not responsible for and does not prepare, edit, or endorse the content, advertising, products, or other materials on or available from any website owned or operated by a third party that may be linked to this email/document via hyperlink. The fact that Vanguard Mexico has provided a link to a third party's website does not constitute an implicit or explicit endorsement, authorization, sponsorship, or affiliation by Vanguard with respect to such website, its content, its owners, providers, or services. You shall use any such third-party content at your own risk and Vanguard Mexico is not liable for any loss or damage that you may suffer by using third party websites or any content, advertising, products, or other materials in connection therewith.

**Connect with Vanguard®**

**Vanguard®**

© 2025 The Vanguard Group, Inc.  
All rights reserved.