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CLOSET INDEX FUNDS: A CONTRIBUTION TO THE DEBATE IN EUROPE

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Summary

Since the mid-2000s, the issue of measuring the active nature of management has been of increasing interest in the academic world and among market players. In particular, studies by market regulators have highlighted the possible existence of closet index funds in Europe. Given the financial information issues that it raises, the AMF has mobilised on this subject. The present study aims to contribute to the debate by testing an alternative method to the "active share" method used by certain European regulators, including the European Securities and Markets Authority (ESMA). It draws inspiration from several methods based on market data. This easily implementable method eliminates the need to use a benchmark index and can be applied to comparatively larger samples, thus preventing certain selection biases.

The method is applied to a sample of French funds invested in European equities. The adopted selection criteria are intentionally not very restrictive in order to minimise the risk of false negatives. On the other hand, where a fund is selected, this does not necessarily mean that it is a potential closet index fund: false positives are accepted risks. The proposed method therefore does not make it possible to dispense with an in-depth individual analysis by the regulator. More fundamentally, this second step is all the more necessary given that the applied method is ordinal: it allows the least active funds to be identified among a given population, but in no case does it provide any conclusion as to whether they are closet index funds in absolute terms.

The extension of this research to a larger sample of European funds and a more detailed analysis of the alerts created in this study are already under consideration.

[1] We wish to thank Serge Darolles, Charles-Albert Lehalle and Thierry Roncalli, members of the AMF Scientific Advisory Board, for their comments and suggestions on previous versions of the article. Any errors and omissions that may remain are naturally solely our responsibility.

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1. BACKGROUND AND OBJECTIVES

Since the mid-2000s, measuring the active nature of management has been of increasing interest in the academic world and among market players. In particular, empirical studies have recently highlighted the existence of closet index funds. These are investment funds stating in their regulatory and/or commercial documentation that they are actively managed although they actually track a benchmark index very closely, while charging fees that are greater than the prevailing fees for passive funds and declared as such.

Given the stakes involved in terms of financial information and investor protection, consumer protection associations and financial regulators have begun to take an interest in this issue. In 2014, the Danish market regulator published a study that estimated that the proportion of equity funds domiciled in Denmark and identified as potential closet index funds stood at 30% (nearly 12% in the second analysis)[2]. After an individual assessment of each fund, the Danish regulator was unable to conclude that this practice was proven and decided not to continue its actions. In Sweden, a complaint was lodged at the end of 2014 against Swedbank Robur for abusive sales of closet index funds to investors[3] but the complaint was dismissed in 2015. In Norway, at the end of 2015, the regulator demanded that DNB Bank, also the subject of a class action suit[4], take corrective actions[5]. In the United Kingdom, an initial analysis by the Financial Conduct Authority (FCA)[6] conducted on 23 investment funds presented as active shows that 5 of them in fact had a closet fund profile. More recently, in March 2018, the UK regulator announced that 34 million pounds in compensation has been paid to investors[7].

In connection with these initiatives and actions, the European Securities and Markets Authority (ESMA) set up a working group in 2014 to address the issue of closet index funds. A two-stage study was conducted on a sample of equity funds domiciled in Europe[8]. In the first stage, ESMA carried out a quantitative study to identify funds that could be categorised as closet index funds among a sample of European funds. The results of this first stage were published in February 2016 and estimate the proportion of dubious funds at between 5% and 15% of the market, depending on the criterion applied[9]. In the second stage, the national authorities, including the AMF, carried out a study on funds domiciled in their jurisdiction to determine whether certain funds among those suspected could be considered as closet index funds. After conducting an in-depth quantitative and qualitative analysis, the AMF was unable to confirm that certain funds designated by ESMA's study were actually closet trackers. It should be noted that the aforementioned AMF analysis did not comment on the absence of closet index funds within French management (this was not the aim), but the AMF continued monitoring various funds, including small funds, and in early 2017 incorporated new best practices into its policy on the use of benchmark indices[10].

In this context, the present study aims to contribute to the debate by testing an alternative method to the "active share" method used by certain European regulators, including ESMA. It draws inspiration from several methods based on market data. These methods are easy to implement and require only the daily returns of the funds and the daily returns of market portfolios.

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[2] 22 funds out of 188 analysed. See Finanstilsynet (2016): "Active/passive management in Danish UCITS", 20/04/2016.
[3] Financial Times : 'The future is bleak for closet trackers', December 2014.
[4] A court decision in early 2018 sided with DNB. This decision has been appealed.
[5] Finanstilsynet (2015): "Management of equity funds-Corrective order 14/5784", 2 March.
[6] Financial Conduct Authority (2016): "Meeting investors' expectations Thematic Review TR16/3", April
[7] FCA press release of 14/03/2018, https://www.fca.org.uk/firms/authorised-and-recognised-funds/closet-trackers
[8] The scope of the ESMA study included equity UCITS launched before 2005 but still active in 2014 that transmit data to Morningstar, have more than €50M in assets under management, and charge ongoing fees of more than 0.65%. It should be noted that in the case of the ESMA study, the selection biases are relatively large: survivor bias, bias related to the exclusion of funds that do not report or for which data are not available, in particular.
[9] European Securities and Markets Authority (2016): "Supervisory work on potential closet index tracking", *Public Statement*, 2 February. Several thresholds and indicators were tested by ESMA. For an active Share below 50% and a tracking error below 4%, the proportion of potential closet index funds is 15%. With an active Share below 50% and a tracking error below 3%, this proportion is 7%. Lastly, for an active Share below 50%, a tracking error below 3%, and a R^2 above 95%, the proportion of potential closet trackers falls to 5%.
[10] http://www.amf-france.org/en_US/Reglementation/Dossiers-thematiques/Epargne-et-prestataires/Divers-gestion-d-actifs/Utilisation-des-indices-de-r-f-rence---l-AMF-int-gre-de-nouvelles-bonnes-pratiques-dans-sa-doctrine?langSwitch=true

The method is then tested on a sample of French funds invested in European equities. The adopted selection criteria are intentionally broad in order to minimise the risk of false negatives. On the other hand, the selected funds are not all closet index funds: the risk of false positives is accepted, which requires a second step consisting of a detailed analysis of the activity of the funds in the sample. This second step is all the more necessary given that the applied method is ordinal: it allows the least active funds to be identified among a given population, but in no case does it provide any conclusion as to whether they are closet index funds in absolute terms.

2. MEASURING THE ACTIVE NATURE OF MANAGEMENT: A REVIEW OF ACADEMIC LITERATURE

From the outset, it should be emphasised that while the definition of closet funds seems perfectly intelligible in theory, when it comes to implemention this quickly appears to be highly complex. What does it mean to "track an index"? Is a reference made to a replication of performance or a replication of the composition of the benchmark index? Moreover, which benchmark index should be used? And where should the dividing line between closet index funds and truly active funds be drawn (which threshold should be chosen for the determination of closet index funds)? Should it be fixed, or can it vary over time?

The extreme difficulty of measuring the active nature of a fund in practice is illustrated by the debates prompted by the various methods proposed by academic literature. Initially, fund activity measures were constructed to determine the extent to which the most active funds outperformed the least active funds.

The methods found in the literature can be schematically grouped into two categories: measures based on fund portfolio composition analysis and measures based on analysis of returns (the method used in this study). These two categories can sometimes be combined, which is notably the case in the ESMA 2016 study.

2.1. MEASURES BASED SOLELY ON FUND PORTFOLIO COMPOSITION ANALYSIS

In this type of approach, the deviations of the fund's components are measured relative to a market portfolio or benchmark index. Kacperczyk, Sialm, and Zheng (2005) measure the differences between the sectoral concentration of the funds and the sectoral concentration of the market portfolio. Nevertheless, with regard to the issue of closet index funds, the leading reference in the literature is the article by Cremers and Petajisto (2009). These authors assess the active nature of management by calculating the deviation of the composition of the fund's portfolio relative to the fund's benchmark index. The result is a metric called "active share", which is defined as follows:

$$Active\ share_t = \frac{1}{2}\sum_{i=1}^{N} |w_{fund,i,t} - w_{index,i,t}|$$

where $w_{fund,i,t}$ is the weight of the security i in the fund's portfolio at time t, $w_{index,i,t}$ is the weight of the security i in the composition of the benchmark index at time t, and N is the sum of the securities in the fund's portfolio or in the benchmark index.

The active share varies between 0% and 100%. The higher it is, the more a fund's management will be considered active. More specifically, a high active share is associated with the implementation of a stock-picking strategy.

An illustration of the active share calculation is presented below, in a hypothetical case where the fund's portfolio and the benchmark index are composed of securities that may be different (securities A to H).

Table 1: Illustration of the active share calculation

Securities of portfolio/benchmark index	Weight in portfolio	Weight in index	Difference	Difference (absolute value)
A	40	30	10	10
B	20	10	10	10
C	15	15	0	0
D	0	25	-25	25
E	5	0	5	5
F	10	0	10	10
G	0	5	-5	5
H	10	15	-5	5
Total	**100**	**100**	**0**	**70**
Active Share				**35%**

2.2. MEASURES BASED SOLELY ON THE ANALYSIS OF RETURNS

The measures based on the analysis of returns most commonly used are tracking error (Wermers, 2003 or Müller & Weber, 2014) and R^2 (Amihud & Goyenko, 2013; Müller & Weber, 2014). They can be estimated directly from returns.

The tracking error measures the standard deviation of the difference between the fund's return and the benchmark index's return. It is traditionally calculated as follows:

$$Tracking\ error_t = \sigma\left[R_{fund,t} - R_{index,t}\right]$$

where $R_{fund,t}$ is the fund's performance at time t, $R_{index,t}$ is the benchmark index's return at time t, and σ is the standard deviation[11].

A high tracking error can be considered as an indicator of the active nature of the fund.

Similarly, the R^2 is defined as the ratio between the explained variance and the total variance. It can be interpreted as the proportion of the variance in fund performance that can be explained by the variance of the benchmark. The higher R^2 is and the closer it is to 1, the more similar the management style is to indexed management.

[11] This definition of tracking error is similar to that given by the AMF. AMF position/recommendation no. 2011-24 defines ex-post tracking error (ES) as follows:

$$ES = \sqrt{52}\sqrt{\frac{1}{N-1}\sum_{s=1}^{N}(R_s - \bar{R})^2}$$

Where R_s is the tracking difference in week s between the fund's return and the benchmark index's return and $\bar{R}$ is the average of this difference over one year (N = 52 weeks).
In their article, Cremers and Petajisto (2009) adopt a slightly modified definition of tracking error, which first requires the estimation of an initial regression: $R_{fund,t} - R_{f,t} = \alpha_{fund} + \beta_{fund}\left(R_{index,t} - R_{f,t}\right) + \varepsilon_{fund,t}$
where $R_{fund,t}$ is the fund's return at time t, $R_{f,t}$ is the risk-free rate, $R_{index,t}$ is the benchmark index's return at time t, $\varepsilon_{fund,t}$ is the model's residual, and α_{fund} and β_{fund} are the parameters to be estimated.
The tracking error is then defined as follows: $Tracking\ error_t = \sigma\left(\varepsilon_{fund,t}\right)$
where σ is the standard deviation.
In the common approach, any difference in relation to the market index generates a tracking error. This is not the case for the modified version in which the strategies implemented on a long-term basis (for example, an investment in low-*beta* securities) have no impact on the tracking error.

The calculation of these metrics is sometimes refined by using a reference multifactor model. It should be recalled here that this factor-based approach arose from the inability of the Capital Asset Pricing Model (CAPM) to identify the factors influencing returns on securities. In the CAPM model, the market risk premium remunerates investors who hold risky assets rather than risk-free assets, for example by building a diversified portfolio.

For Fama and French (1992), there are other systematic sources of remuneration beyond market *beta*. These factors stem from, for example, the size of the capitalisation of the companies in which the fund invests (investment in large caps vs small caps), their valuation (investment in growth securities vs value securities), and, since Carhart (1997), their trend (or "momentum" premium, resulting from an investment in securities that have outperformed in the past).

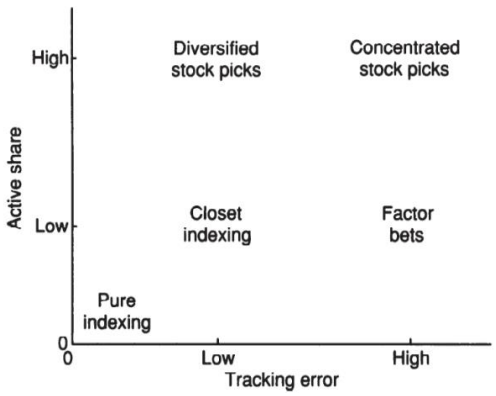
Amihud & Goyenko (2013) propose a measure of activity derived from R^2, obtained by regressing fund returns on returns of influencing factors. R^2 can be interpreted as the proportion of the variance of the fund's return that can be explained by variations in the influencing factors adopted by Fama & French and Carhart. A low R^2 means that the fund has little connection with these factors and will be associated with a stronger fund activity. The measure of activity, called "selectivity" and defined as $1-R^2$, measures the share of fund variance resulting from idiosyncratic risk, i.e., specific characteristics of the fund.

For their part, Herrmann, Rohleder, and Scholz (2016) propose an original activity indicator that seeks to capture shifts in management styles by measuring changes in fund exposure to different market factors. This indicator is defined as the sum of the differences between two consecutive quarters of the coefficients reflecting the exposure to influencing factors. A high indicator value means that the fund shifted its management style between two quarters (for example, reducing large-cap exposure or increasing the weighting of undervalued companies). Conversely, a low activity indicator will mean that the management strategy is stable and may indicate systematic management choices within the fund. Over the long term, a fund with a high activity index may be considered an active fund because a shift in management style may reflect an attempt to beat the benchmark index by the manager.

2.3. MEASURES BASED ON ANALYSIS OF PORTFOLIO COMPOSITION AND FUND RETURNS

The proposed approaches are sometimes combined. This is the case in the study by Cremers and Petajisto (2009), who quantify a fund's activity through two indicators: active share and tracking error.

These measures allow the authors to categorise funds as follows:



Source: Cremers and Petajisto (2009)

Funds following a stock-picking strategy are characterised by significant differences relative to the index composition. Strategies favouring a factor-based approach will have a much lower active share, while generating

high volatility relative to the index. Closet index funds have both a low tracking error and a low active share (between 20% and 60%, according to the authors)[12].

The method used by ESMA (2016) draws heavily from the method implemented by Cremers and Petajisto (2009) and considers a fund to be a closet index fund if, over at least 3 out of 5 years during the study period (2010–2014), the fund has an active share below 60% and a tracking error below 4%. Note here that the choice of the study period is not neutral. The academic literature shows that it is perfectly rational to move closer to the benchmark index and therefore become index-based when the market is bearish[13]. It turns out that over the 5 years analysed by ESMA, the market was bearish for two years (2010 and 2011). This can lead one to consider that a fund is a closet index fund as long as it meets the criteria for a single year.

3. THE CHOSEN METHOD

Unlike ESMA (2016) and Cremers et al. (2016), the choice was made in this study to eliminate the holding-based approach and the active share from the outset in favour of a return-based approach using factor-based models. Indeed, the active share has serious limitations.

3.1. LIMITATIONS OF USING THE NOTION OF "ACTIVE SHARE"…

Although it is attractive because it is synthetic and intelligible, the active share indicator has many limitations, especially when it is applied to European funds.

With regard to the composition of portfolios, unlike in the United States[14], there is no regulatory requirement in Europe for funds to be transparent with respect to the market. The collected data are thus generally provided on a declarative and voluntary basis by the funds to data providers such as Morningstar or Bloomberg. However, the absence of a transparency requirement greatly reduces the size of the analysed samples, while at the same time it introduces a selection bias since only the most transparent funds can be analysed, which harms the representativeness of the studies and biases their results.

The absence of regulatory constraints also does not promote the provision of standardised, regular, precise, and accurate data. Some reports are monthly, while others are quarterly or even less frequent. It is therefore reasonable to question the ability of these data to reflect a fund's level of activity. For example, a fund manager may have active management during a given month and then, as a result of disappointing or pessimistic new information, decide to move closer to the benchmark index to limit losses. In this specific case, biannual data on a fund's composition ("snapshots") will not allow the active nature of the management previously described to be measured (this would require a "film" showing its behaviour over the period). Lastly, these data are only partial, in the sense that off-balance sheet items, particularly derivatives, are generally not taken into account in the portfolio composition.

Beyond the portfolio composition, the issue of the benchmark indices used to measure the active share is also up for debate. In the first place, the choice of the benchmark index used should be considered. At first glance, the index indicated by the manager in its regulatory documentation could play this role, provided that (i) this index is actually indicated and (ii) the choice of the index is consistent with the management style. That is why, far from being limited to an active share measured relative to a benchmark index indicated by the manager, some researchers, like Cremers and Petajisto (2009), test different measurements taken from several indices chosen in

[12] These are the thresholds applied by the authors (Cremers and Petajisto, 2009), but they remain arbitrary at a certain level.
[13] See p.16.
[14] Since 2004, funds registered with the SEC have been subject to a requirement of transparency on the composition of their portfolio. SEC filings are done on a quarterly basis, within 60 days after the end of the quarter, to limit predatory behaviours (See Final rule Shareholder Reports and Quarterly Portfolio Disclosure of Registered Management Investment Companies, 2004).

line with the management objective set out in the regulatory documents. On this subject, it should be pointed out that French equity funds generally reference an index in their legal documentation even if there is no formal regulatory constraint requiring them to do so. The AMF strongly urges management objectives to be set out in precise terms[15].

Moreover, even if the benchmark index is known, its composition is not necessarily known, particularly in the case of proprietary indices, but also for traditional indices. For an investor, having access to the composition of any index generally requires entering into an agreement or even a formal contract with the index producer.

In addition, the calculation of the active share on historical data is done in practice by taking the last known benchmark index, even if it changed during the reference period. An increase in the active share may be misinterpreted as the reinforcement of active management, although it results from a change in the benchmark index.

Lastly, very independently of the accessibility and the quality of the data, the amount of the active share is highly dependent on the type of benchmark index: the narrower and more concentrated the benchmark index, the more difficult it will be for the manager to demonstrate a high active share.

3.2. …LEAD TO THE CHOICE OF THE RETURN-BASED APPROACH

While the regulator, unlike data providers, has complete, quality data on the composition of portfolios, the active share disadvantages described above explain why it was not applied in this study. On the contrary, methods based on market data were favoured. These more easily applied methods require only the daily returns of funds and the daily returns of market portfolios. In particular, they eliminate the need to use a benchmark index. It is thus possible to obtain the necessary data within a very short time frame, on a daily frequency, and to have a more complete sample, which is preferable, particularly from a supervision perspective.

The activity measure used here relies on three metrics based on returns: style-shifting activity (SSA) developed by Herrmann, Rohleder, and Scholz (2016), tracking error, and R^2. These three metrics result from the use of factor analysis applied to equity portfolio management. Economic research shows that fund performance depends on exposure to risk factors common to equity markets. Consequently, if a fund's performance is compared with these risk factors for a given market and date, it is possible to determine what influences the fund's performance on that date and what strategy it follows: does the fund favour small caps or large caps? Does the fund focus more on growth stocks or value stocks? Estimation over several periods allows changes in the fund's management styles over time to be analysed.

The calculation of fund activity indicators is done in several steps.

3.2.1. Factors influencing fund's returns (four-factor model)

The academic literature identifies many factors influencing fund performance (more than 300). The four traditional factors set forth by Fama & French and Carhart are incorporated here given the scope of the studied funds (funds invested in European equities). The four factors are:

(i) The return on the market in question R_M, from which the risk-free rate R_F is subtracted (Jensen 1968).

(ii) *Small minus Big* (SMB), which is the difference on a given market between the daily average returns of small-cap companies and the average daily returns of large-cap companies (Fama & French 1992). This factor therefore measures whether the fund favours small-cap or large-cap securities.

(iii) *High minus Low* (HML), which is the difference on the market in question between the daily average returns of companies that have a high book-to-market ratio and the average daily returns of companies that

[15] See the AMF Position/Recommendation no. 2011-05 (A guide to the monitoring of collective investment schemes).

have a low book-to-market ratio (Fama & French 1992). This factor aims to determine whether the fund favours growth securities or value securities.

(iv) *Momentum* (MOM), which is the difference on the market in question between the average daily returns of the best-performing companies over 11 months (with a one-month delay) and the average daily returns of the worst-performing companies over these 11 months (Carhart 1997). This factor can therefore be used to determine whether the fund favours securities that have recently outperformed or underperformed.

The four-factor model consists of a regression of the fund's return on these four factors. The results of the estimates make it possible to calculate three metrics: style-shifting activity (SSA) by Herrmann *et al.* (2016), tracking error, and R^2. However, the calculation of the three metrics requires two separate estimates. A first quarterly estimate provides the style-shifting activity (SSA), and a second half-yearly estimate is used to calculate the tracking error and the R^2. These two estimates are necessary to be able to associate a corresponding tracking error and R^2 with each activity indicator. The activity indicator is calculated as the difference in strategy of a fund between two quarters (see below). It is therefore an indicator that measures the change in activity of a fund over the half-year period. It then seems logical to associate this activity indicator with a tracking error and an R^2 calculated over a half-year period.

3.2.2 Calculation of the Style Shifting Activity (SSA) by Hermann et al. (2016) by a quarterly regression

Factors influencing a fund's return are first measured quarterly (moving quarters on a monthly basis). The estimated model can be written as:

$$r_{i,d,q,t} - R_{F\,d,q,t} = \alpha_{i,q,t} + \sum_{k=1}^{4} b_{i,q,t}^{k} f_{d,q,t}^{k} + e_{i,d,q,t}$$

where $r_{i,d,q,t}$ is the gross return of the fund i, on day d, in quarter q, in half-year period t, $R_{F\,d,q,t}$ is the risk-free rate on day d, in quarter q, in half-year period t, $f_{d,q,t}^{k}$ are the 4 factors common to all the funds, $\alpha_{i,q,t}$ and $b_{i,q,t}^{k}$ are the parameters to be estimated by the ordinary least squares (OLS) method, and $e_{i,d,q,t}$ is the residual following the estimation[16].

The estimated parameters $b_{i,q,t}^{1}, b_{i,q,t,}^{2}, b_{i,q,t}^{3}, b_{i,q,t}^{4}$ therefore represent the exposure of the fund i to the four factors during the quarter q. The parameters therefore allow the investment strategy adopted by the fund (for example, slantedtowards small caps or towards undervalued securities, etc.) to be identified.

The four-factor model can therefore be rewritten as follows:

$$r_{i,d,q,t} - R_{F\,d,q,t} = \alpha_{i,q,t} + b_{i,q,t}^{1}\left(R_{M\,d,q,t} - R_{F\,d,q,t}\right) + b_{i,q,t}^{2}\,SMB_{d,q,t} + b_{i,q,t}^{3}\,HML_{d,q,t} + b_{i,q,t}^{4}\,MOM_{d,q,t} + e_{i,d,q,t}$$

The SSA or style-shifting activity measures changes over time in the fund's exposure to the various selected factors. It is defined as the sum of the differences between two consecutive quarters of the four coefficients estimated by regression (relative to the four factors used in the model) and can be written as follows:

$$Activity = \sum_{k=1}^{4} \left| b_{i,q,t}^{k} - b_{i,q-1,t}^{k} \right|$$

A high value of the activity variable thus means that the fund has changed its exposure to the various factors (by decreasing or increasing it) and therefore its management style between two quarters. For this study, we will focus on funds that for the activity indicator display a low value, which may indicate management choices according to a methodology applied systematically within the fund and may cast doubt on the active nature of the management. For example, a low activity indicator may mean that a fund closely tracks a benchmark index that reflects one of the four factors.

[16] For a detailed presentation of the model, refer to the Appendix.

Two dimensions of the activity are captured here:

- voluntary modification of an exposure to the factors (reducing large-cap exposure, increasing the weighting of undervalued companies, etc.) or
- intentional non-adjustment to variations in the factors, such as in the case of a buy-and-hold strategy where the fund does not change the composition of its portfolio. In this case, the exposure to the various factors will then be modified from one quarter to the next; the explanatory power of each factor taken independently (i.e., the value of $b^1_{i,q,t}, b^2_{i,q,t,}, b^3_{i,q,t}, b^4_{i,q,t}$) will vary, and the fund will be considered active by definition.

It should also be noted that a fund changing the composition of its portfolio to replicate the change in composition of its index will be considered as a passive fund with this method. The first factor of the model represents the performance of the market on which the fund invests[17]. If the fund changes the composition of its portfolio to copy its benchmark index, then the explanatory power of the first factor will be constant, the parameter $b^1_{i,q,t}$ will not be modified from one quarter to another, and the fund will therefore not be considered as an actively managed fund over this period.

One limitation of this approach is that if a manager does not change its factor exposure, it will sometimes be incorrectly considered as passive. However, it is conceivable that a manager will be positioned on a particular factor for a long period (for example, on the "value" factor before the financial crisis and then on another factor later).

3.2.3 Calculation of the tracking terror and R^2 by a half-yearly regression

Factors influencing a fund's return are this time calculated biannually (moving half-year periods on a monthly basis) to obtain metrics consistent with the activity indicator, from the following regression:

$$r_{i,d,t} - R_{Fd,t} = \alpha_{i,t} + \sum_{k=1}^{4} b^k_{i,t} f^k_{d,t} + e_{i,d,t}$$

where $r_{i,d,t}$ is the gross return of the fund i, on day d, in half-year period t, $R_{Fd,t}$ is the risk free rate on day d, in half-year period t, $f^k_{d,t}$ are the four factors common to all the funds, $\alpha_{i,t}$ and $b^k_{i,t}$ are the parameters to be estimated by the OLS method, and $e_{i,d,t}$ is the residual following the estimation[18].

- Tracking error

The calculation of the tracking error requires prior the estimation of the residual. Note that the parameters ($\alpha_{i,t}$ and $b^k_{i,t}$) are estimated on a biannual basis from daily data ($r_{i,d,t}$ and $f^k_{d,t}$). The residual is then calculated on a daily basis with fixed parameters estimated by fund and by half-year period, such as:

$$e_{i,d,t} = r_{i,d,t} - \alpha_{i,t} - \sum_{k=1}^{4} b^k_{i,t} f^k_{d,t}$$

Tracking error is defined as:

$$Tracking\ error_{i,t} = \sigma(e_{i,d,t})$$

where σ is the standard deviation and $e_{i,d,t}$ is the error term of the estimated equation. The approach adopted here for the calculation of the tracking error differs from the standard calculation[19]. Nevertheless, it was

[17] It is for this reason that the sample is restricted to equity funds invested in European securities, as the factor representative of the market's performance must be unique. All the funds in the sample must therefore have the same geographic investment universe.
[18] For a more detailed presentation of the model, refer to the appendix.
[19] It should be noted that under the notion of tracking error, often used by the academic literature, different definitions and calculation methods hide in reality. Three distinct calculation methods are thus presented in this study: the traditional methodology of comparing the performance of a fund with that of its index, the method used by Cremers and Petajisto, and the method used by Herrmann, Rohleder, and Scholz. This last definition is the one used in the study. See p.6

favoured because it does not require the determination of a benchmark index and is more immune to the bias from constant factor bets[20].

The residual or error term of the model captures all the elements that have an impact on the fund's performance but are not represented by one of the four factors. It represents the unexplained part of the model. This residual may group together other factors that have an impact on the fund's performance, such as a sector factor (favouring one sector over another) or a liquidity factor (giving more importance to liquid securities). When the standard deviation of this residual is low, this means that the elements (other than those already present in the model) influencing the fund's performance vary little from one quarter to another. A low tracking error can thus be interpreted as a constant exposure of the fund to factors not present in the model. Like the activity indicator, a low tracking error value may indicate systematic management choices within the fund, casting doubt on the active nature of the management.

- R^2

R^2 is obtained through the same regression as tracking error. It is used to measure the portion of the variance of $r_{i,d,t}$ explained by the model (and therefore incidentally the model's relevance). A high R^2 means that a significant portion of the variance of the fund's return is explained by the returns on the factors. However, these factors can be easily tracked through indices. A high R^2 thus means that a significant portion of the return can be replicated by holding the indices reflecting the factors. A high R^2 indicates a low differentiation of the fund relative to the factors.

These three metrics make it possible to assess two aspects of the closet-index characteristics of a fund. Firstly, the activity indicator and the tracking error measure the evolution of the exposure to the various factors (present in the model or not), thus making it possible to highlight the systematic nature of the fund management choices. With the R^2, it is possible to measure the portion of the return that can be explained by the factors and therefore know in what proportion the fund tracks these factors.

These three indicators therefore indicate, depending on their level, whether a fund is likely to be an active fund or a passive fund. The table below summarises the expected characteristics of each fund category.

Table 2: Expected level of the three indicators by fund type

	SSA	Tracking error	R^2
Passive funds	Low	Low	High
Active funds	High	High	Low

[20] Consider a fund that keeps its exposure to the various factors constant but whose portfolio composition moves away from that of its benchmark index. In this case, the variation between two quarters of the estimated parameters b^1,b^2,b^3, and b^4 will be zero, and the variation of the residual will be small, as the explanatory power of the parameters b^1,b^2,b^3, and b^4 will remain substantially the same. The standard deviation of the residual , calculated over a half-year period, will therefore also be low. On the other hand, as the composition of its portfolio and therefore the performance of the fund moves away from that of its benchmark index, the traditional measure of tracking error will be high. The definition used here seeks to capture the variation in exposure to unobserved factors.

4. EMPIRICAL ANALYSIS

4.1. PRESENTATION OF THE SAMPLE

The initial database comes from an extraction of 2,436 equity funds domiciled in France and referenced in Lipper (Thomson Reuters) during the 2006–2015 period. Only primary funds are used (i.e., the most important share class of the funds in terms of assets under management when it has more than one)[21]. In addition, the sample includes both funds that are still active at the end of 2015 and funds that disappeared during the study period, so that the results of the analysis are not affected by survivor bias[22].

The data necessary to calculate the indicators pertain to the 2006–2016 period[23] and come from the Lipper database and AMF internal data.

Secondly, the following were eliminated:

- funds whose daily performance figures are not available for at least two consecutive half-year periods during the 2006–2016 period;
- funds for which it is clearly stated in the prospectus or the Key Investor Information Document (KIID) that the management objective is replication of a benchmark index;
- formula funds;
- feeder funds;
- funds with no data on ongoing charges[24]; and
- funds that do not have Europe or a European country as an investable universe.

The final sample thus consists of 792 funds.

4.2. CONSTRUCTION OF ACTIVITY INDICATORS

The method used to identify potential closet index funds involves several steps. The first two steps calculate the three measures necessary for the study: style-shifting activity, tracking error, and R^2.

4.2.1 Estimation of style-shifting activity

For each of the 792 funds, a first quarterly regression is run. “Quarter” refers to moving three-month periods on a monthly basis, so that our study period (January 2006 – December 2016) is composed of 130 quarters. This regression makes it possible to obtain the parameters[25] $b^1_{i,q,t}, b^2_{i,q,t,}, b^3_{i,q,t}, b^4_{i,q,t}$ in order to then calculate the activity indicator (the style-shifting activity being calculated as the difference in the estimated parameters between two consecutive quarters[26]; it therefore reflects a fund’s behaviour over a half-year period). This step provides 66,620 observations on the activity indicator.

[21] This is equivalent to keeping the primary fund or the share class charging the highest fees, since we use for the study the gross performance, common to all the share classes of the same fund.
[22] It is reasonable to think that the funds that disappeared prematurely are funds that fail to attract or retain their investors because of insufficient performance. A sample composed exclusively of active funds would create a bias, because it would only keep the best-performing funds. This bias, known as survivor bias, is corrected by keeping funds that are still active and funds that have disappeared in the sample.
[23] We thus have the returns on funds (and factors) for the 2006–2016 period. However, the fund selection criteria require the fund to have been active between 2006 and 2015. This eliminates from the outset funds created during 2016 and whose data will be insufficient to carry out the estimates.
[24] The fund performance figures provided by Lipper are performance net of fees. The model estimated here requires fund performance gross of fees. It is therefore necessary to obtain the data on fees in order to calculate the data gross of fees.
[25] The four factors whose parameters we seek to estimate are retrieved directly from Kenneth French’s website, where they are calculated for Europe. However, two modifications have been made. On the one hand, as the factors are in dollars, they have been converted into euros. On the other hand, the risk-free rate (1-month interest rate on US government bonds) was replaced with the 3-month interest rate on German sovereign bonds.
[26] For example, the style-shifting activity for the first half of 2015 is the difference in the estimated parameters between the quarter from April to June 2015 and the quarter from January to March 2015.

4.2.2 Estimation of tracking error and R^2

For each of the funds in the sample, a second half-yearly regression is run, this time to calculate the tracking error and the R^2, which will be consistent with the style-shifting activity, defined as a difference between two consecutive quarters. "Half-year period" refers to moving six-month periods on a monthly basis, so that our study period (January 2006 – December 2016) is composed of 127 half-year periods. This regression makes it possible to estimate the parameters $\alpha_{i,t}$ and $b_{i,t}^{k}$ and the coefficient of determination of the model (R^2) and then calculate the residual of the model $e_{i,d,t}$. The tracking error is obtained by calculating the half-yearly standard deviation of the residual. This step also provides 66,620 observations for each indicator.

Once these three measurements are obtained for all the funds and all the periods, the following steps, operating by successive eliminations, reduce the list to a sample containing the least active funds. It should be remembered here that the funds included on the final list are only the least active funds and cannot in themselves be regarded as closet index funds.

4.3. IDENTIFICATION OF THE SAMPLE POTENTIALLY CONTAINING CLOSET INDEX FUNDS

4.3.1 Identification of the least active funds within the sample

A fund is considered to be sparsely active when it has either a low value for the style-shifting activity or the tracking error or a high value for the R^2 at least once during the study period. To identify them, the deciles for the style-shifting activity, the tracking error, and the R^2 are calculated for each half-year period included in the study. For the style-shifting activity and the tracking error, the first decile of each half-year period will be used, while for the R^2, the last decile of each half-year period will be kept.

Only funds with either a style-shifting activity or a tracking error below the first decile or an R^2 above the last decile, at least once during the period under review (i.e., the funds considered as the least active during at least one half-year period) are kept, i.e., 750 funds (95% of the sample) representing a total of 65,933 observations (of which 16,782 observations indicate a relatively low level of activity during the period).

- *Complementaries indicators*

It appears that the selected activity indicators are quite complementary. In fact, in the vast majority of cases (nearly 85%), the funds considered to be sparsely active are so considered due to a single indicator with a distribution balanced between the three metrics.

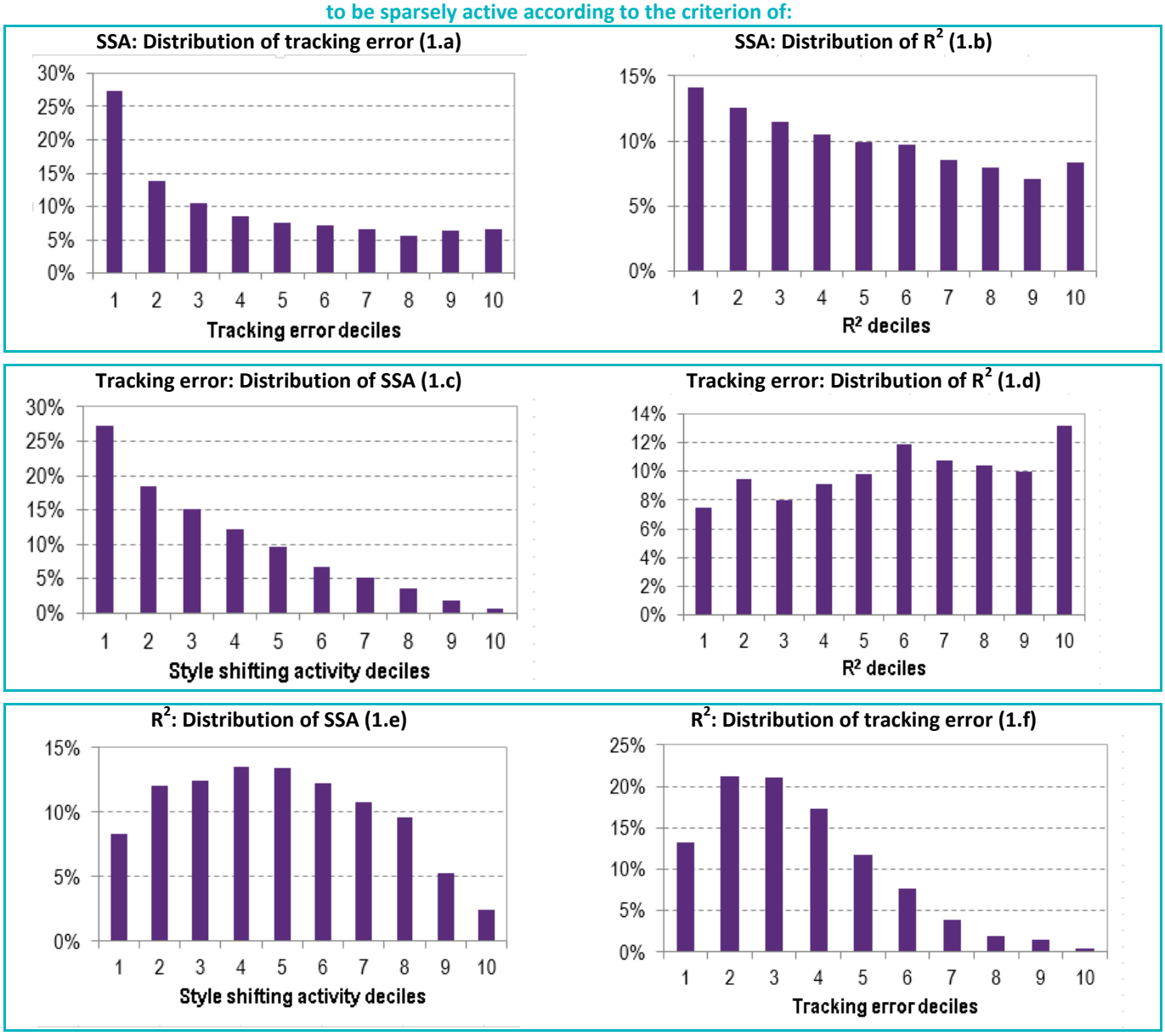
Table 3: Number of times when the funds are considered to be sparsely active due to:

	Number of observations	Percentage
One indicator	**13,893**	**83%**
SSA	4,419	26%
TE	4,108	24%
R^2	5,366	32%
Two indicators	2,734	16%
Three indicators	155	1%
Total	16,782	100%

- *Analysis of relationships between indicators*

When a fund is considered to be sparsely active according to one of the indicators during the study period, the distribution of the other two indicators is analysed (figure 1). It thus appears that a low SSA is generally associated with a low tracking error and vice versa (figures 1.a and 1.c), which indicates a certain convergence between the style-shifting activity and the tracking error. However, when a fund isconsidered to be sparsely active due to an R^2 above the last decile, the style-shifting activity or the tracking error is not necessarily below the first decile (figures 1.e and 1.f). Conversely, when the style-shifting activity or the tracking error is below the first decile, the distribution of the R^2 is not necessarily concentrated around the last deciles, especially for the style-shifting activity. The style-shifting activity and the tracking error, to a lesser extent, therefore seem to be complementary indicators to the R^2.

Figure 1: Distribution of the indicators when the funds areconsidered to be sparsely active according to the criterion of:



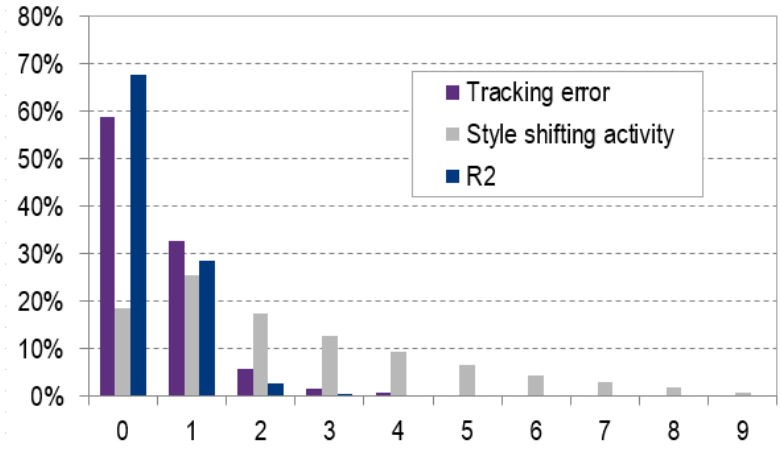
Sources: Lipper, AMF.

Note (figure 1A): in 27% of cases, a SSA below the first decile is associated with a tracking error below the first decile. In half of the cases, it is associated with a tracking error below the 3rd decile.

- *Analysis of the stability of the indicators over time*

The analysis of the evolution of the distribution of the activity indicators throughout the study period gives indications about their stability over time. Here, it appears that in most cases, the "jumps" in the distribution, when they exist, are small (figure 2).

Figure 2: Magnitude of inter-decile changes in activity indicators over time



Sources: Lipper, AMF.

4.3.2. Consideration of market trends

For the 750 funds still in the running, the degree of activity should not be calculated when the markets are strongly bearish (more than 10% decline in the Eurostoxx 50 dividends reinvested for the reference half-year period)[27]. The academic literature shows that it is perfectly rational to move closer to the benchmark index and therefore become index-based when the market is bearish, as the fund's underperformance in a generalised bearish phase is more sanctioned[28]. Out of the 127 analysed periods, the markets were bearish 23 times in this scenario. This condition amounts to eliminating 7 funds and keeping 743.

4.3.3. Consideration of the persistence of the sparsely active nature of the management

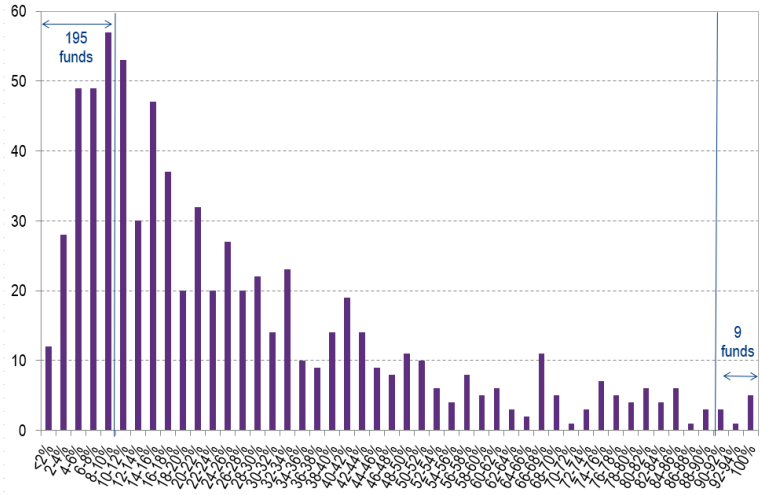
Even so, a criterion in absolute terms (number of times when the fund is sparsely active) seems misleading for qualifying a fund as a potential closet index fund. It is not equivalent for a fund to be sparsely active five times if it is present for only five half-year periods or if it is present over the entire study period (127 half-year periods). A criterion measuring the persistence of low activity over time seems more relevant for discriminating funds.

When this notion of persistence is taken into account, it appears that the vast majority of the funds in our sample cannot be considered as sparsely active, and when they are, this is not systematically the case: more than half of the funds in the sample are sparsely active less than 20% of their time in the sample (figure 3). Conversely, five funds in the sample have relatively little active behaviour in all the periods.

[27] Thus, our style-shifting activity measuring, for example, whether fund F_i changed its strategy between the 1st and 2nd calendar quarters of year N will only be used if the market did not fall by more than 10% over the 1st half of that year.

[28] Gottesman, Morey, and Rosenberg (2013) show that when the market is bullish, there is a strong link between outperformance and future inflows. However, this relationship disappears when the markets are bearish and the outperformance or underperformance of the funds does not significantly influence future inflows. Active funds are therefore encouraged to adopt a passive behaviour when the markets are bearish since outperformance is not rewarded.

Figure *3*: Number of sparsely active half-year periods relative to the number of half-year periods in the sample, excluding periods of significant market declines



Sources: Lipper, AMF.

Note: 195 of the 743 funds are among the least active for less than 10% of their time in the sample. However, nine funds are among the least active for more than 90% of their time in the sample. The more funds there are on the right side of this chart, the more likely they are to be considered as closet index funds.

4.3.4. Definition of potential closet index funds

The threshold from which a fund will be considered as a potential closet index fund is determined using the Jenks natural breaks classification method. This method makes it possible, on a discrete sample, to minimise intra-class variance (i.e., establish the most uniform classes possible) and maximise inter-class variance (i.e., establish classes that are as different from each other as possible).

Given the asymmetric nature of the distribution of the persistence data, the appropriate number of classes is calculated by applying Scott's formula, which takes into account, in addition to the sample size, the dispersion parameters:

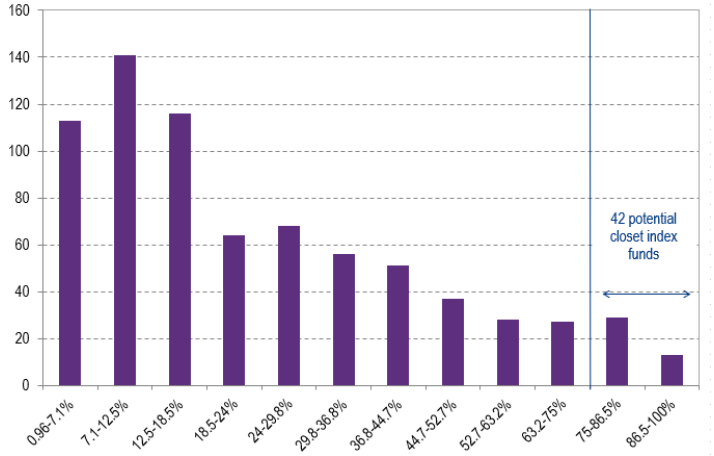
$$k = \frac{b - a}{3{,}5 \times \sigma \times \mathrm{n}^{\left(-\frac{1}{3}\right)}}$$

where k is the number of classes, b is the maximum value taken by the persistence variable, a is the minimum value taken by the persistence variable, σ is the standard deviation of the persistence variable for the entire sample, and n is the sample size.

For our sample, the number of data classes obtained by Scott's formula is equal to 12. For these 12 classes, 13 thresholds are therefore obtained. The graphical analysis (figure 4) results in the selection of the last two classes of the distribution.

A potential closet index fund will thus be defined as a fund that is sparsely active in a relatively systematic manner (75% of the time in the sample).

Figure 4: Number of sparsely active half-year periods relative to the number of half-year periods in the sample according to the Jenks optimization method, excluding periods of significant market declines



Sources: Lipper, AMF.

4.4. ROBUSTNESS TESTS

A criticism traditionally made against the Fama-French factors lies in the fact that they are calculated on all the securities available on the European market. Certain securities included in the calculation of the factors are therefore illiquid and undesired by asset managers, which may make the Fama-French factors unrealistic for an investor. This is likely to pose difficulties for the SMB factor, as the Small Cap factor could be considered as non-investable. In order to better reflect a manager's investable universe, other estimates were made by incorporating factors calculated from widely used indices.

Secondly, unlisted index funds with a European geographical focus were added to the sample to verify that these funds are correctly identified as passive by the models.

4.4.1. Test of alternative factors

Two models were tested: the first based on STOXX factors and the second using MSCI factors.

The factors reconstructed from STOXX indices are calculated as follows:

- Market return: the Euro Stoxx 50 index, from which the 3-month German sovereign yield is subtracted
- *Small minus Big*, which is the difference in return between the STOXX Europe Small Cap index and the STOXX Europe Large Cap index
- *High minus Low*, which is the difference in return between the STOXX Europe Value index and the STOXX Europe Growth index
- *Momentum*, which is the difference between the STOXX Europe Momentum index and the Euro Stoxx 50 index.

The factors reconstructed from MSCI indices are calculated as follows:

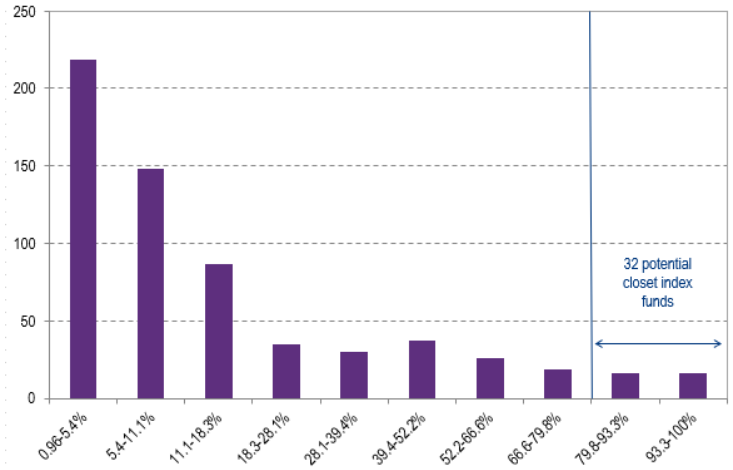
- Market return: the MSCI Europe index, from which the 3-month German sovereign yield is subtracted
- *Small minus Big*, which is the difference in return between the MSCI Europe Small Cap index and the MSCI Europe Large Cap index
- *High minus Low*, which is the difference in return between the MSCI Europe Value index and the MSCI Europe Growth index
- *Momentum*, which is the difference between the MSCI Europe Momentum index and the MSCI Europe index

All the indices are calculated net of dividends reinvested.

Similar to the model using the Fama-French factors, the Jenks method is also applied to those using the STOXX and MSCI factors to determine the thresholds at which a fund will be considered as a potential closet index fund:

- For the model using the STOXX factors, differents filters applied led to the selection of 633 funds. A fund will be considered as a potential closet index funds if it is among the least active managed funds for more than 79.8% of its presence in the sample. The model thus identifies 32 potential closet index funds.

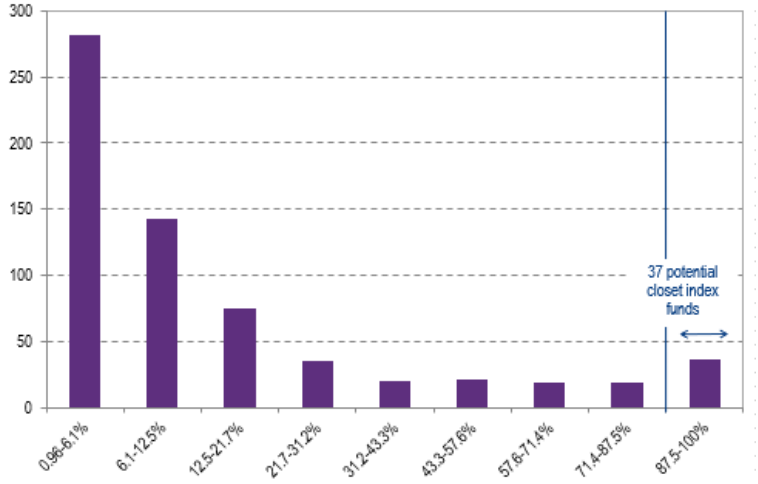
Figure 5: Number of sparsely active half-year periods calculated with the model using the STOXX factors relative to the number of half-year periods in the sample, excluding periods of significant market declines



Sources: Lipper, AMF.

- With regard to the model using the MSCI factors, differents filters applied led to the selection of 653 funds. A fund will be considered as a potential closet index funds if it isamong the least active managed funds for more than 87.5% of their time in the sample. The model thus identifies 37 potential closet index funds.

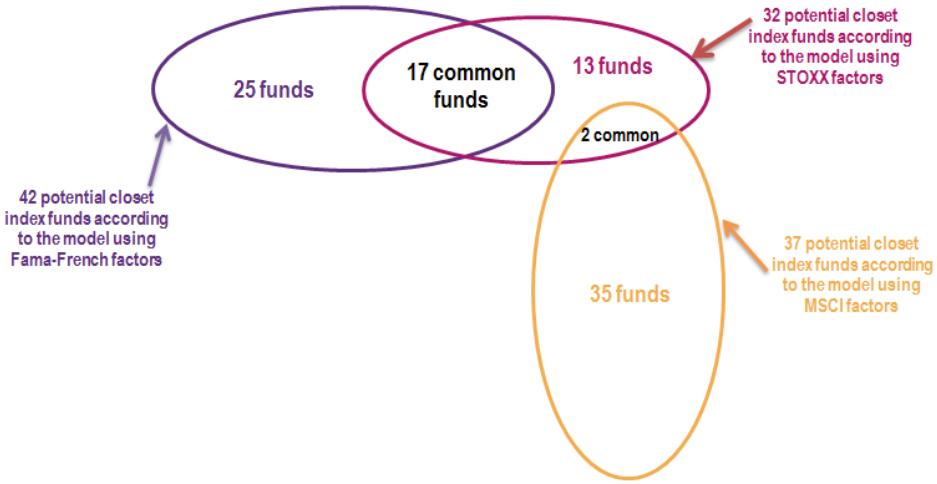
Figure 6: Number of sparsely active half-year periods calculated with the model using the MSCI factors relative to the number of half-year periods in the sample, excluding periods of significant market declines



Sources: Lipper, AMF.

Using the results of the three models (standard Fama-French model and Fama-French model with factors from the STOXX and MSCI indices), 92 potential closet index funds are obtained, of which 65 were still being run at the end of the study period. The comparison of the results shows that the model using the Fama-French factors and the model using the factors derived from the STOXX indices are relatively convergent, as 17 funds are identified by the two models. Conversely, the model using the factors calculated from the MSCI indices would appear complementary to the other two, as only 2 funds are also identified by one of the other two models. This is largely explained by the methods for construction of the factors, which are quite similar for the Fama-French and Stoxx factors.

Figure 7: Number of funds identified by each model



However, each model seems relevant for flagging potential closet index funds. The model using Fama-French factors seems more likely to identify potential closet index funds among funds focusing on small caps as well as Socially Responsible Investment funds, while the model using factors derived from STOXX indices seems to better flag potential closet index funds having the Euro Stoxx 50 or the MSCI EMU as the benchmark, and the model based on MSCI indices primarily captures funds having the MSCI Europe or the Stoxx Europe 600 as the benchmark index.

4.4.2. Addition of index funds (ETFs excluded) to the sample

In order to test the relevance of the method used, index funds with a European geographical focus were added to the sample to verify that these funds are correctly flagged as passive. The three models using three different sources of factors (Fama-French, STOXX, and MSCI) were tested.

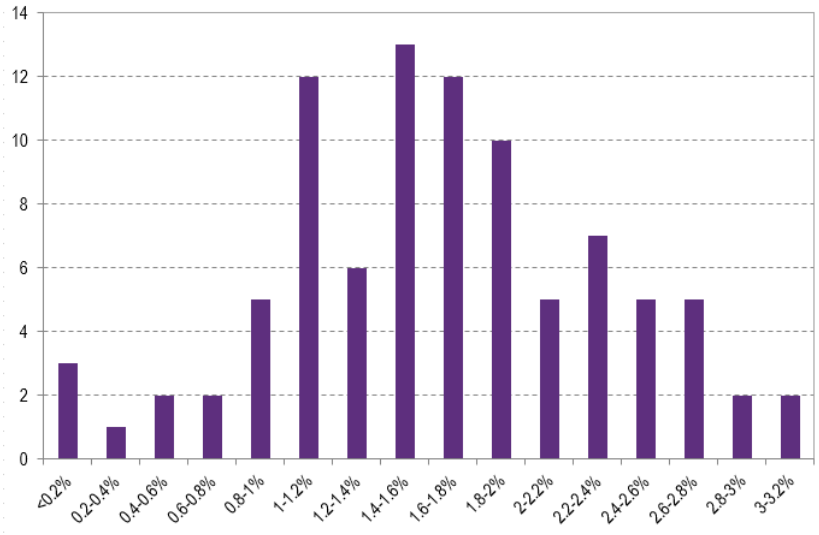
The results show that none of the three models consider index funds as passive if they are focused on a particular country or sector. On the other hand, all the index funds having a European benchmark index without a sector focus are identified as passive by at least one of the models.

The three models therefore seem relevant for flagging potential closet index funds that have a European focus. However, the identification of funds focused on a particular country or a sector requires a more specific model.

4.5. RESULTS

The choice was made to retain the results of the three estimates. We thus identify 92 primary funds, of which 65 were still being run at the end of 2016. Among the funds, two distinct categories stand out, depending on the levels of ongoing cherges posted, which vary between 0.10% and 3.12%, with an average of around 1.65%.

Figure 8: Distribution of 92 potential closet index funds according to the level of their ongoing charges



Sources: Lipper, AMF.

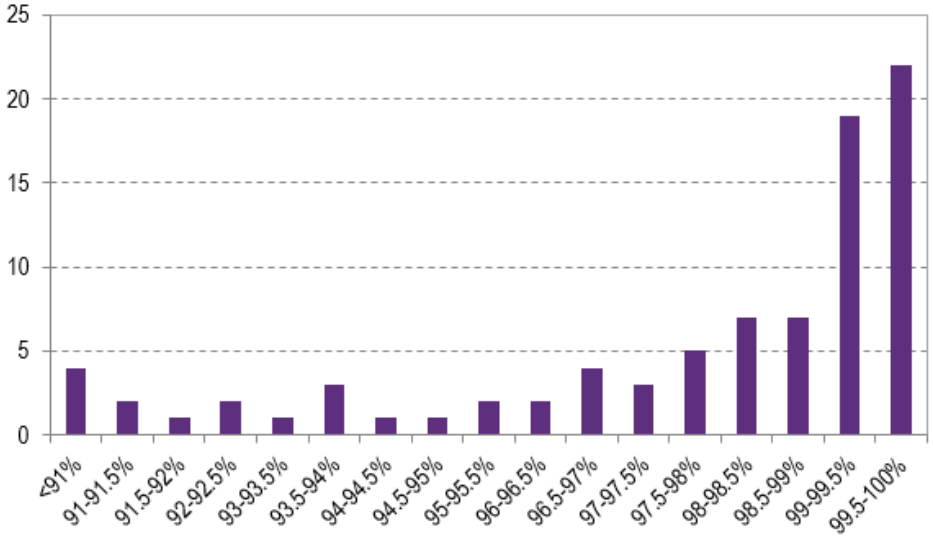
Funds with fees similar to those for indexed management cannot be considered as potential closet index funds insofar as the expense to the saver in terms of fees paid is low or almost zero. However, as regards financial information, the content of the prospectus may not reflect the reality of the implemented management policy. Six funds thus have ongoing fees below 0.6%[29]. Sometimes these are actually funds intended for institutional investors.

Of the 92 flagged funds, only the 86 funds with ongoing charges of 0.6% or more are retained for the presentation of the results below.

For almost half of the funds, the correlation with the benchmark index mentioned in the prospectus is above 99% (figure 9).

[29] As a reminder, ESMA excluded funds with ongoing charges below 0.65% from its study.

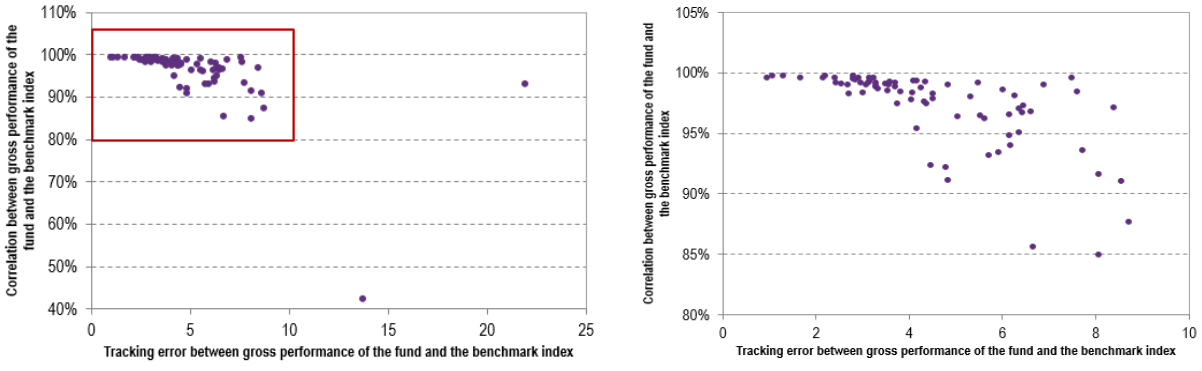
Figure 9: Distribution of correlations of 86 potential closet index funds with their benchmark indices



Sources: Lipper, AMF.

In some cases, this high correlation is combined with a low tracking error (Figure 10). In nearly 40% of cases, the funds present a correlation between gross performances and the benchmark index above 99% and a tracking error below 4%. In one quarter of the cases, the tracking error is less than 3%.

Figure 10: Correlations and tracking errors between gross performances of funds and of their benchmark indices (2006-September 2017)



Sources: Lipper, AMF.

It should be remembered that the selected criteria and thresholds are intentionally broad in order to minimise the risk of non-detection of closet index funds at "risk" of capturing false positives. Among the funds ultimately identified are funds for which the regulatory documentation and/or management reports indicate a management that is more or less active but still in line with the stated management objective. Further analysis is therefore necessary to confirm or refute whether these funds are closet index funds.

5. CONCLUSION

This study aims to test a method of detecting closet index funds based exclusively on market data. This choice has substantial advantages. In particular, this method can be easily implemented. The necessary data can also be collected within very short timeframes and at high frequencies. Above all, the method allows the largest possible study samples to be maintained, which limits the risks of selection bias. In particular, it eliminates the need to use a benchmark index, unlike methodologies based on the active share indicator.

The proposed method is to measure the degree of relative activity within a given fund population and its persistence over time based on three indicators: tracking error, R^2, and SSA, an original activity indicator created by Herrmann, Rohleder, and Scholz (2016) that seeks to capture shifts in management styles by measuring changes in fund exposures to various market factors between two quarters. These indicators are obtained by estimating the traditional four-factor model by Fama-French and Carhart. These three metrics make it possible to assess two aspects of the closet index nature of a fund. Firstly, the activity indicator and the tracking error measure the evolution of the exposure to the various factors (present in the model or not), thus making it possible to highlight the systematic nature of the fund management choices. With the R^2, it is possible to measure the portion of the return that can be explained by the factors and therefore know in what proportion the fund tracks these factors. It should be noted that a limitation of the style-shifting activity is undoubtedly that it considers a fund whose factor exposure does not vary over time to be passive. However, it is conceivable that a manager will be positioned on a particular factor for a long period.

The method is applied to a sample of nearly 800 French funds invested in European equities. The results show that the activity indicators used are relatively complementary: in the vast majority of cases, the funds considered as the least active in the population are so considered due to a single indicator with a distribution balanced between the three metrics. In addition, the analysis of the evolution of the distribution of the activity indicators throughout the study period demonstrates their stability over time. Here, it appears that in most cases, the "jumps" in the distribution, when they exist, are slight.

In order to test the robustness of the method, additional estimates are made using sources of factors alternative to those of Fama and French, namely factors derived from the STOXX and MSCI indices. The comparison of the results shows that the results are sensitive to the factors used: when the factor construction methods are rather similar, the models are relatively convergent. Conversely, when they differ, the models are rather complementary. In addition, unlisted index funds with a European geographical focus were added to the sample to verify that these funds are correctly identified as passive by the models. The results show that this is the case for index funds that have a European benchmark index without any sector focus. However, none of the three models can identify closet index funds if they are focused on a particular country or sector. Identifying country-specific or sector-specific funds therefore requires a more specific model, which is seen as a limitation of the proposed method.

This study is thus intended to fuel the current discussions at the European level. This work is expected to continue, particularly by analysing the alerts created in this study in more detail and by extending this research to a larger sample of European funds.

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Appendix: Presentation of the four-factor model

The four-factor model (for the quarterly regression) is as follows:

$$r_{i,d,q,t} - R_{F\,d,q,t} = \alpha_{i,q,t} + b^1_{i,q,t}\left(R_{M\,d,q,t} - R_{F\,d,q,t}\right) + b^2_{i,q,t}\,SMB_{d,q,t} + b^3_{i,q,t}\,HML_{d,q,t} + b^4_{i,q,t}\,MOM_{d,q,t} + e_{i,d,q,t}$$

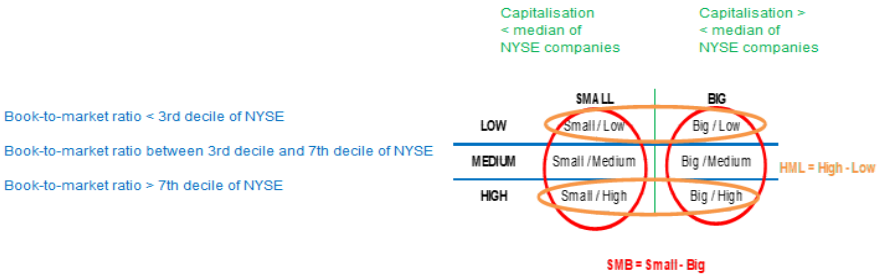
where $r_{i,d,q,t}$ is the gross return of the fund i, on day d, in quarter q, in half-year period t, $R_{F\,d,q,t}$ is the risk-free rate on day d, in quarter q, in half-year period t, $\alpha_{i,q,t}, b^1_{i,q,t}, b^2_{i,q,t}, b^3_{i,q,t}$ and $b^4_{i,q,t}$ are the parameters to be estimated by the ordinary least squares (OLS) method, and $e_{i,d,q,t}$ is the residual following the estimation.

The four factors used are:

i. The return on the market in question R_M, from which the risk-free rate R_F is subtracted (Jensen 1968).
ii. *Small minus Big* (SMB), which is the difference on a given market between the daily average returns of small-cap companies and the average daily returns of large-cap companies (Fama & French 1992).
iii. *High minus Low* (HML), which is the difference on the market in question between the daily average returns of companies that have a high book-to-market ratio and the average daily returns of companies that have a low book-to-market ratio (Fama & French 1992).
iv. *Momentum* (MOM), which is the difference on the market in question between the average daily returns of the best-performing companies over 11 months and the average daily returns of the worst-performing companies over these 11 months (Carhart 1997).

The estimated parameters $b^1_{i,q,t}, b^2_{i,q,t,}, b^3_{i,q,t}, b^4_{i,q,t}$ therefore represent the exposure of the fund i to the four factors during quarter q.

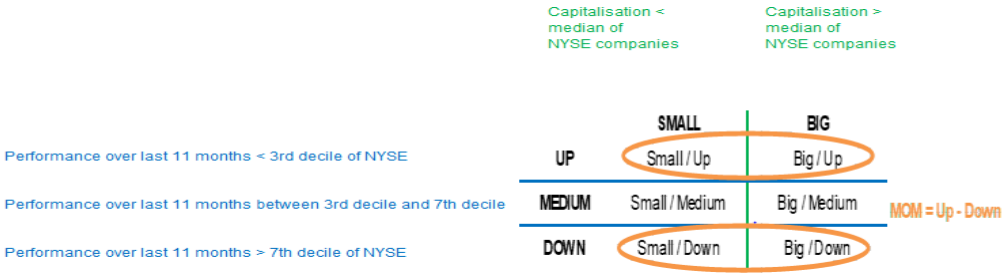
The original method used by Fama & French and Carhart focuses on the US market and uses all companies listed on NYSE, Amex, and NASDAQ. Every June, companies listed on the NYSE are sorted by their capitalisation (share price multiplied by the number of shares), and the median is calculated. This median is then used to separate all companies listed on NYSE, Amex, and NASDAQ into two groups: one whose companies have a capitalisation below the median and one whose companies have a capitalisation above the median. Using the same principle, in June, companies listed on NYSE are sorted by book-to-market ratio, and the 3rd decile and 7th decile thresholds are calculated. All companies listed on NYSE, Amex, and NASDAQ are then separated into three groups: one comprising companies with a book-to-market ratio below the 3rd decile of NYSE, one grouping together companies with a book-to-market ratio between the 3rd decile and the 7th decile, and the last including companies whose book-to-market ratio is above the 7th decile of NYSE. Intersecting these two criteria results in two groups according to capitalisation and three groups according to the book-to-market ratio, i.e., six portfolios (see diagram below).



For each of the six portfolios, the average return of the companies in this group is calculated for each day. By calculating the average return of the three small portfolios and the three big portfolios, the small minus big (SMB) factor is obtained as the daily difference of the average return of the small portfolio and the average

return of the big portfolio. Using the same principle, the high minus low factor is calculated as the daily difference between average returns of the high portfolio and average returns of the low portfolio.

The third factor, momentum, is calculated using the same principle, by intersecting the capitalisation criterion and a new criterion related to 11-month performance with a one-month delay[30]. The median capitalisation is still calculated on the median of the capitalisations of companies listed on NYSE, but this time on a daily basis. The second criterion requires sorting the companies listed on NYSE every day according to the 11-month performance with a one-month delay. As such, the sorting at 1 January 2016 uses the performances of each security between January 2015 and November 2015. Two thresholds are then calculated: one corresponding to the 3rd decile and the second corresponding to the 7th decile. As before, all companies listed on NYSE, Amex, and NASDAQ are divided into six portfolios (see diagram below).



The momentum factor (MOM) is calculated as the daily difference between average returns of the up portfolio and average returns of the down portfolio.

Lastly, the factor reflecting market performance R_M is obtained by a capitalisation-weighted average of the performance of all companies listed on NYSE, Amex, and NASDAQ in this period. The risk-free rate R_F is the 1-month interest rate on US government bonds.

All the returns used for this method are calculated dividends reinvested.

These factors are then reproduced for different geographical areas, including Europe, and the methodology used differs somewhat. Every year, the securities of the European market[31] are sorted according to their capitalisation and according to their book-to-market ratio, but the thresholds are not calculated on a specific market, as is the case for the US, but on the entire market. Small-cap companies are those whose capitalisation is below the first decile. The thresholds for the book-to-market ratio remain the same (the Low group has a book-to-market ratio of below the 3rd decile, the Medium group has a book-to-market ratio between the 3rd decile and the 7th decile, and the High group has a book-to-market ratio above the 7th decile). However, they are calculated only on companies that have a high capitalisation.

Six other portfolios are obtained from capitalisation and past performance. The securities of the European market are sorted every day according to their capitalisation, and the 1st decile is used to constitute the two groups: small vs big. The securities in the second category are used to calculate the past performance thresholds. The 11-month performance levels with a one-month delay are calculated, and the 3rd and 7th decile of the big securities will serve as thresholds.

[30] For example, the 11-month performance with a one-month delay at 1 January 2015 is the performance between 1 January 2014 and 30 November 2014.
[31] The European market includes here: Austria, Belgium, Switzerland, Germany, Denmark, Spain, Finland, France, Great Britain, Greece, Ireland, Italy, the Netherlands, Norway, Portugal, and Sweden.