Flows impact on pension fund managers' abilities. Evidence from UK conventional and SR pension funds.

Abstract

We study the flows impact on manager's abilities of UK conventional and socially responsible (SR) pension funds. We examine two aspects barely documented in pension funds. First, we study the flows influence on timing abilities; specifically, market and style timing; the last aspect, as far as we are aware, has not been studied before. With this purpose we develop multifactorial models, which are corrected with the variable elevation method whether multicollinearity exists. Second, we study separately SR pension funds because they present a special social interest and take into account nonfinancial attributes; therefore these managers may develop different timing abilities and flows may influence in a different way. Our results show different timing abilities between conventional and SR managers; however, both managers consider only flows to improve market timing abilities, but not to develop style timing abilities (perverse timing with respect to other factors does not disappear considering flows).

Keywords: flows, pension funds, Socially Responsible, timing abilities.

JEL codes: G12, G23

1. Introduction.

The worldwide investment in pension funds has experienced significant expansion over the past two decades. With an average annual growth rate of 7.4%, over the period 2009-2012, the total assets invested amounted to more than $21 trillion in 2012 (OECD, 2013). One country with a large pension fund investment is the United Kingdom, exceeded only by the United States, with assets in 2012 worth $2.3 trillion, representing an 11% share of the OECD pension fund market (OECD, 2013).

The important development of these products has encouraged their academic and professional research; nonetheless, for their analysis we should take into account the particular characteristics of these investment products. In first place, although their main purpose is to save for retirement, we must differentiate between pension plans and pension funds. Pension plans are the saving vehicles where individuals (members or sponsors) make contributions, but pension funds are the independent legal entities formed by pension plan contributions; therefore, the contributions of multiples members make up the pension fund assets.

Second, benefits can not be paid at all, or without a significant penalty, unless the beneficiary is older than a legally defined retirement age, or in special circumstances, such as disability, sickness or survivors' benefits. Nevertheless, members are able to move the investment from one fund to another.

Third, pension funds are professionally managed; as a consequence, investors choose a pension plan according to an asset allocation profile (equity, bonds, mixed…) and geographical distribution, but managers decide the investment/disinvestment of the pension fund assets in specific instruments (stocks, bonds, mutual funds…), according to the profile. Moreover, managers are typically compensated as a percentage of assets under management.

In this context, we observe that pension fund assets rely on multiple aspects. First, contributions may come from sponsors or members, may be regular or sporadic, with the same or different amount, or derived from the assets transferred from one fund to another[1]; as a consequence, these factors causes irregular entries.

[1] Additional contributions may come from merger but, following Del Guercio and Tkac (2002), in this analysis we exclude the manager-years where the fund merged with another fund, since the flow measures may be distorted.

On the other hand, outflows are produced by refunds and transfers to other funds. With regard to refunds, these are caused by the occurrence of any of contingencies provided, mainly retirement. Additionally, refunds may also be periodic or one-time (in a single amount). Alternatively, transfers to other funds may be due to different reasons: inappropriate performance, bad results, high fees, changes in the investor profile...

In the last place, asset level also depends on management (good results may produce inflows, but bad results may generate outflows) and tax legislation (tax deductions promote investment, and vice versa).

Accordingly, we observe that pension fund flows are due to several causes, sometimes difficult to identify, mainly because of available data. Nevertheless, we know that flows influence management because the asset level used to offer a picture of management, and manager compensation usually depends on assets under management (Del Guercio and Tkac, 2002); therefore, managers have strong incentives to focus their efforts on developing managerial skills (in order to maintain or attract assets).

In this paper we concentrate on studying the last aspect (i.e., the flows influence on timing abilities) because there are not studies on pension funds, and it has been barely analyzed in mutual funds. Moreover, the behavior of the pension fund investor (individual) requires a detailed study that we will address in future work.

Additionally, we also analyze separately SR pension funds because we consider interesting their study for several reasons. First, whether we consider that pension funds play a social role in the economy, attempting to provide social welfare for the elderly, and SR funds also focus on social welfare (investing in companies that assume a social responsibility and avoiding those perceived to cause health hazards); then, SR pension funds are specially concerned with social welfare, presenting significant economic and social interest. Second, these products take into account nonfinancial attributes, so SR managers may develop different timing abilities, and flows may influence in a different way. Third, although SR pension funds are still developing, the UK is one of the most advanced countries in SRI (about 22% of the UK SR assets that fulfill the Principles for Responsible Investment are subscribed by pension funds, according to Eurosif -2010-).

While investigating the flows influence on manager abilities, our paper makes two main contributions to the existing literature. First, we analyze the flows impact on market timing and style timing; the latter aspect, as far as we are aware, has not been examined before. To this end, we introduce flows in multifactorial timing models, which are corrected with the variable elevation method whether models present multicollinearity problems.

Second, we present the first comparative style timing analysis between conventional and SR pension funds that examines differences between both managers (timing abilities and flows influence on timing skills).

The rest of the paper proceeds as follows. In Section 2, we undertake a literature review. In Section 3, we give a brief description of the UK pension fund market, and we describe the data. Section 4 presents our methodology. Section 5 contains our empirical results, and Section 6 presents our main conclusions.

2. Literature review.

Although extensive research has been conducted on mutual fund flows, relatively little research has been conducted on pension fund flows. Nevertheless, several studies [Edelen (1999), Benson and Humphrey (2008)] argue that flows influence on management behavior.

Management behavior has been traditionally assessed by the abilities of managers to pick stocks that outperform others at the same level of non-diversifiable risk (stock-picking), and the ability to obtain results by changing exposure to the market at the right moment (market timing).

The most widely-used models to capture these abilities are those proposed by Treynor and Mazuy (1966) and Merton and Henriksson (1981). Empirical evidence in mutual and pension funds shows mixed evidence of these abilities. Focusing on pension funds, several authors find positive stock-picking and negative market timing abilities; Coggin et al. (1993) in a USA pension fund sample and, Thomas and Tonks (2001) in UK pension funds. However, Blake et al. (1999) find negative evidence of both abilities in UK pension funds. Other authors find a general absence of these qualities, as Koh et al. (2010) on Singapore pension funds, or Woodward and Brooks (2010) on Australian pension funds.

In UK conventional and SR pension funds, Ferruz et al. (2010) find little positive stock-picking ability in SR pension funds, but negative market timing in conventional and SR funds.

Furthermore, active management requires monitoring in detail the portfolio composition, so managers usually focus on particular market segments, generating the management style of a portfolio. As a consequence, managers may develop timing abilities with regard to those styles; that is to say, whether they are able to predict the investment style that will produce the best performance, they will increase the exposure of the fund to the correct style. Nevertheless, style timing studies are less extensive than market timing analyses, especially in pension funds.

With regard to pension funds, Thomas and Tonks (2001) find positive size timing ability in UK pension funds, from 1983-1997. Alda et al. (2011) analyse British and Spanish pension fund managers (from 1999 to 2007), showing stock-picking and book-to-market timing abilities, but perverse timing ability with regard to size and momentum styles.

The study of style timing abilities in SR funds is even more limited. Gregory and Whittaker (2007) find, in UK conventional fund managers, negative market timing, correct timing with respect to the book-to-market factor, and absence of ability in size and momentum factors. However, UK SR mutual funds present negative market and momentum timing, positive book-to-market timing and absence of size timing.

Nonetheless, traditional timing models do not take into account the influence of flows, being able to produce distorted results. Warther (1995), Ferson and Warther (1996) and Edelen (1999) explain that the spurious timing found in many studies [Lee (1999), Fung et al. (2002), Abdel-Kader and Qing (2007), Woodward and Brooks (2010), Elton et al. (2012), and Christensen (2013)] could be solved by including the influence of cash-flows in timing models.

Edelen (1999) and Alda et al. (2014) control the flows effect on market timing in US mutual funds, and provide unbiased market timing coefficients, demonstrating that the tendency of managers to time negatively is attributed to the realized flows at the fund. Accordingly, whether managers consider flows, they may change their behavior to attract more flows, or minimize outflows, developing and improving their abilities.

In the pension fund and SR literature, we find a lack of research into flows affecting on manager abilities, so in this paper we try to fill this gap examining them in conventional and SR pension funds.

3. Pension funds in UK and data.

3.1. Pension fund market in UK.

The UK pension fund market is one of the most developed in the world, with more than $2.3 trillion under management in 2012 (OECD, 2013), exceeded only by the

United States. One reason for this expansion has been the low levels of state pensions until the mid-1990s; however, although state pensions increased from then on, investment in private pensions continues to experience strong growth.

With regard to the investment recovery rules, pension benefits can be taken for retirement (the current and general retirement age is 65 for men and 60 for women); although, under tax rules, the earliest age to recover the investment is 55 years. Nevertheless, many pension scheme rules usually set an age between 60 to 65 years old. The exceptions to this rule are for ill health, death and whether, before 6 April 2006, beneficiaries had the right under the pension scheme to take the pension before age 55.

In addition, the UK is considered one of the leading SR markets, reaching more than £3.9 trillion in SRI, according to Eurosif (2012). With respect to SR pension funds, the UK was the first country to regulate the disclosure of social, environmental, and ethical investment policies of pension funds and charities, in July 2000, by the Amendment to the 1995 Pensions Act. This Amendment requires the trustees of occupational pension funds to disclose in the Statement of Investment Principles ‘‘the extent (if at all) to which social, environmental, and ethical considerations are taken into account in the selection, retention and realization of investments”.

This regulation contributed considerably to the growth of the SR industry, leading to a progressive awareness of their importance and, although the SR practices in pension funds are still emerging, about 22% of the SR assets that fulfill the Principles for Responsible Investment are subscribed by pension funds (mainly occupational pension funds), according to Eurosif (2010).

3.2. Data.

The pension fund data is obtained from Morningstar and contains the monthly returns and monthly TNA (Total Net Assets) of all domestic equity pension funds in the UK, both conventional and SR[2], from January 1994 to December 2013.

We require that the pension funds included in our sample present data for at least 24 months (both returns and TNA), to ensure the consistency of the analyses. Thus, all pension funds that existed for a period of at least 24 months within the time frame

[2] We should clarify that SR mutual funds can be divided considering the strategies followed; for example, social issues, environmental criteria, positive or negative screens... However, the SR pension fund industry is still developing, and pension funds typically report only whether they follow, or not, SRI strategies, without specifying them, so we cannot divide our SR pension funds by these different criteria.

considered have been taken into account, regardless of whether or not they survived until December 2013. Thus, we consider our sample to be free of survivorship bias.

Following the procedure of Del Guercio and Tkac (2002), we exclude the manager-years where the fund merged with another fund, since the flow measures may be distorted. Additionally, similar to Chevalier and Ellison (1997) and Bollen (2007), to include an observation of fund flow, it must be from a fund with at least £10,000,000 of total net assets in two successive months. This eliminates extremely small funds, which may distort the results.

Finally, in order to reduce the effect of outliers, following Barber et al. (2005), Bollen (2007) and Renneboog et al. (2011), we remove the observations of fund flows beyond the 99.5th percentile or below the 0.5th percentile.

After these data adjustments, our sample is restricted to 411 pension funds, specifically, 386 conventional pension funds and 25 SR pension funds.

The risk factors (market excess return, size, book-to-market and momentum) are the UK domestic factors developed by Gregory et al. (2013)[3]. The market excess return is obtained from the FT All-Share Index, as proxy of the market, and the three-month UK Treasury Bill, as proxy of the risk-free asset.

The descriptive statistics of the sample are presented in Table 1, divided into three panels. Panels A and B show the main statistics (mean, standard deviation, minimum and maximum) of monthly flows, return, TNA (Total Net Assets in millions of Pounds) and age (in months) for conventional and SR pension funds, respectively. Panel C presents the same statistics for the market, size, book-to-market and momentum factors.

INSERT TABLE 1

Comparing panels A and B, we observe that monthly return, flows and TNA are higher in conventional funds. This evidence could lead to different results between SR and conventional funds. Additionally, it is remarkable that age, on average, is higher in SR funds. We think that this is a characteristic of our sample, result of the selection process conducted to consider a fund, because some conventional funds reach the maximum and present data for the entire sample. Nevertheless, we should also note that

[3] All these data are obtained from the Xfi Centre for Finance and Investment, University of Exeter: http://business-school.exeter.ac.uk/research/areas/centres/xfi/research/famafrench/disclaimer/

the UK has been a pioneer in the development of SR pension funds, and they are growing particularly since 2000.

With respect to risk factors (panel C), the market excess return, size and book-to-market factors present lower return than conventional and SR funds; however, the momentum factor presents the highest average.

Table 2 shows the correlation coefficients between the pension fund variables and the risk factors. Panel A shows the correlations for conventional funds and panel B for SR pension funds.

INSERT TABLE 2

The correlations between the market factor and pension fund returns are substantial large and significant, 0.8842 in conventional funds, and 0.8957 in SR pension funds. Similarly, the market factor and the excess pension fund returns are also significantly large (0.8853 and 0.8971 for conventional and SR pension funds). This evidence indicates that we chose an appropriate market index for our samples. The remaining significant correlations, in absolute value, are no greater than 50%, so we do not expect great multicollinearity problems in the models including only these factors.

4. Methodology.

4.1. Traditional timing models.

A variety of models have been used in the financial literature to identify stock-picking and market timing abilities. Two of the most widely used are proposed by Treynor and Mazuy (1966) and Merton and Henriksson (1981).

The Treynor and Mazuy (1966) model (TM henceforth) is expressed as follows:

$$r_{i,t} = \alpha_i + \beta_1 r_{m,t} + \gamma_1 r^2_{m,t} + \varepsilon_{i,t} \qquad (1)$$

Where: $r_{i,t} = R_{i,t} - R_{f,t}$, is the excess return of fund *i* over the risk-free asset *f* during the period *t*; $r_{m,t} = R_{m,t} - R_{f,t}$ is the excess market return over the risk-free asset *f* during the period *t*; α_i represents the stock-picking ability of the manager (a significantly positive alpha indicates correct stock-picking); γ_i determines the market timing skill; specifically, if the gamma is positive and significant, the manager has market timing ability, but if it is negative and significant, the manager's ability is perverse. Finally, $\varepsilon_{i,t}$ is the error term.

The Merton and Henriksson (1981) model (MH henceforth) is as follows:

$$r_{i,t} = \alpha_i + \beta_1 r_{m,t} + \gamma_1 [r_{m,t}]^+ + \varepsilon_{i,t} \qquad (2)$$

Where: $r_{i,t} = R_{i,t} - R_{f,t}$, and $r_{m,t} = R_{m,t} - R_{f,t}$ are the excess returns of the fund *i* and the market over the risk-free asset *f* during the period *t*, respectively; α_i represents the stock-picking ability of the manager; γ_i measures the market timing ability; $[r_{m,t}]^+ = Max[0, r_{m,t}]$ is the payment of an option over the market portfolio with a strike price that is the same as the risk-free asset, and $\varepsilon_{i,t}$ is the error term.

4.2. Style timing models: multifactorial timing versions.

Active management requires a detailed supervision of the portfolio securities, so managers usually focus on specific market segments, resulting in the investment styles of the fund; as a result, managers may develop timing abilities with regard to these styles.

In order to measure style timing abilities, Lu (2005) takes into account the four-factor model of Carhart (1997):

$$r_{i,t} = \alpha_i + \beta_1 r_{m,t} + \beta_2 SMB_t + \beta_3 HML_t + \beta_4 PR1YR_t + \varepsilon_{it} \qquad (3)$$

Where: $r_{i,t}$ is the excess return of fund *i* at time *t* over the risk-free asset; $r_{m,t}$ is the excess return of a representative market index over the risk-free asset; SMB_t is the size factor; HML_t is the book-to-market factor; $PR1YR_t$ is the momentum factor; α_i represents the fund performance, and $\varepsilon_{i,t}$ is the error term.

Therefore, Lu (2005) proposes an extension of the TM model, including the four-factor Carhart model and considering the work of Bollen and Busse (2001). Specifically, Lu (2005) obtains the multifactorial TM version:

$$\begin{aligned} r_{i,t} &= \alpha_i + \beta_1 r_{m,t} + \beta_2 SMB_t + \beta_3 HML_t + \beta_4 PR1YR_t + \\ &\gamma_1 r_{mt}^2 + \gamma_2 SMB_t^2 + \gamma_3 HML_t^2 + \gamma_4 PR1YR_t^2 + \varepsilon_{i,t} \end{aligned} \qquad (4)$$

Where: $r_{i,t}$ is the excess return of fund *i* at time *t* over the risk-free asset; $r_{m,t}$ is the excess return of a representative market index over the risk-free asset; SMB_t is the size factor; HML_t is the book-to-market factor; $PR1YR_t$ is the momentum factor; α_i represents the stock-picking ability; β_1, β_2, β_3 and β_4 measure the sensitivity of the fund to the market, size, book-to-market and momentum styles, respectively. The gamma coefficients (γ_1, $\gamma_{2,}$ $\gamma_{3,}$ γ_4) reflect the timing ability with regard to the market, size, book-to-market and momentum factors. Finally, $\varepsilon_{i,t}$ is the error term.

This model assesses whether a fund manager increases (decreases) the fund risk exposure to a specific factor prior to the factor index increase (decrease). Consequently, if any of the gamma coefficients is positive, it indicates timing ability with regard to this management style; that is to say, managers are increasing the importance of the stocks in that style to increase the performance of the portfolio.

In the same way, the Merton and Henriksson (1981) model can be extended to capture style timing abilities, originating the multifactorial MH model:

$$\begin{aligned} r_{i,t} &= \alpha_i + \beta_1 r_{m,t} + \beta_2 SMB_t + \beta_3 HML_t + \beta_4 PR1YR_t + \\ &\gamma_1 r_{mt}^{+} + \gamma_2 SMB_t^{+} + \gamma_3 HML_t^{+} + \gamma_4 PR1YR_t^{+} + \varepsilon_{i,t} \end{aligned} \quad (5)$$

Where: $r_{i,t}$ is the excess return of fund *i* at time *t* over the risk-free asset; $r_{m,t}$ is the excess return of a representative market index over the risk-free asset; SMB_t is the size factor; HML_t is the book-to-market factor; $PR1YR_t$ is the momentum factor; α_i represents the stock-picking ability; $\beta_{1,}$ $\beta_{2,}$ β_3 and β_4 measure the sensitivity of the fund to the market, size, book-to-market and momentum styles, respectively; γ_1, $\gamma_{2,}$ $\gamma_{3,}$ γ_4 reflect the timing ability with regard to the market, size, book-to-market and momentum factors, respectively. If any of the gamma coefficients is positive, it indicates timing ability with regard to that management style.

4.3. The influence of flows on traditional timing models.

Flows are mainly consequence of investor reactions, so these movements may be accompanied by changes in management behavior; that is to say, managers may take into account the outflows as a cue to improve their abilities, and inflows as a reward for their management.

Nevertheless, traditional and multifactorial timing models do not consider the influence of flows, and may provide biased timing coefficients, as Warther (1995), Ferson and Warther (1996) and Edelen (1999) indicate. These authors explain that the spurious timing found in many studies could be solved by including the flows influence in timing models.

In particular, Edelen (1999) add a third regressor ($F_{i,t}\tilde{X}_{m,t}$) in traditional TM and MH market timing models to link the fund's market-timing performance and the fund flow[4]:

$$r_{i,t} = \alpha_i + \beta_1 r_{m,t} + \gamma_1 \tilde{X}_{m,t} + \gamma_2 F_{i,t} \tilde{X}_{m,t} + \varepsilon_{it} \qquad (6)$$

Where: $r_{i,t}$ is the excess return of fund *i* at time *t*; $r_{m,t}$ is the excess return of the market at time *t*; $\tilde{X}_{m,t}$ is the market timing regressor, either $r_{m,t}^2$ in the TM model or $[r_{m,t}]^+ = \max(0, r_{m,t})$ in the MH model; $F_{i,t}$ is the Sirri and Tufano (1998) fund flow measure; γ_1 captures the market timing ability, and γ_2 captures the effect of net flows on market timing ability. Thus, γ_1 measures the true market timing ability of the manager.

With respect to the fund flow measure ($F_{i,t}$), we apply the one proposed by Sirri and Tufano (1998), which reflects the net growth in fund assets beyond asset appreciation:

$$F_{i,t} = \frac{TNA_{i,t} - TNA_{i,t-1}(1 + R_{i,t})}{TNA_{i,t-1}} \qquad (7)$$

Where: $F_{i,t}$ is the fund flow and reflects the percentage growth of fund *i* at time *t* in excess of the growth that would have occurred if there were no new inflows and all dividends had been reinvested. $TNA_{i,t}$ and $TNA_{i,t-1}$ are the total net assets for fund *i* at the end of time *t* and *t-1*. $R_{i,t}$ is the fund's return at time *t*. This measure assumes that all flows occur at the end of the period, in our case, the month.

Edelen (1999) also develops an alternative model, including lagged flow, instead of concurrent flow, due to reverse causality problems, as fund returns also affect flows. Therefore, introducing the lagged flow we avoid endogeneity problems between concurrent returns and concurrent flows (model 8).

$$r_{i,t} = \alpha_i + \beta_1 r_{m,t} + \gamma_1 \tilde{X}_{m,t} + \gamma_2 F_{i,t-1} \tilde{X}_{m,t} + \varepsilon_{i,t} \qquad (8)$$

Where: $r_{i,t}$ is the excess return of fund *i*; r_{mt} is the excess return of the market; $\tilde{X}_{mt}$ is the market timing regressor, either $r_{m,t}^2$ in the TM model or $[r_{m,t}]^+ = \max(0, r_{m,t})$

[4] We do not introduce the flow-trading response coefficient used in Edelen (1999), since the purpose of including it is to prevent inflows crossing with outflows within a cash accumulation period. We avoid this problem by using net flows, and we also believe that flows remaining in cash must be taken into account, since they modify the proportion of funds exposed to the market (beta), and thus affect market timing in accordance with the Bollen and Busse (2001) hypothesis.

in the MH model); $F_{i,t-1}$ is the lagged flow; γ_1 captures the market timing ability, and γ_2 captures the effect of net flows on market timing ability.

4.4. Flows influence on multifactorial timing models.

Models (7) and (8) capture the influence of flows on market timing abilities. Nonetheless, since managers are also able to develop timing abilities with regard to different styles, we propose two models considering the flows influence on style timing abilities.

Following the methodology applied by Edelen (1999) in TM and MH models, we include several regressors in the multifactorial versions of TM and MH (models 4 and 5) to link style-timing and flow. Specifically, model (9) measures the style timing abilities and the flows influence on timing with regard to the market, size, book-to-market and momentum factors.

$$\begin{aligned} r_{i,t} &= \alpha_i + \beta_1 r_{m,t} + \beta_2 SMB_t + \beta_3 HML_t + \beta_4 PR1YR_t + \gamma_1 \tilde{X}_{m,t} + \gamma_2 SM\tilde{B}_t + \\ &+ \gamma_3 HM\tilde{L}_t + \gamma_4 PR1Y\tilde{R}_t + \gamma_5 F_{i,t-1}\tilde{X}_{mt} + \gamma_6 F_{i,t-1} SM\tilde{B}_t + \gamma_7 F_{i,t-1} HM\tilde{L}_t + \gamma_8 F_{it,-1} PR1Y\tilde{R}_t + \varepsilon_{it} \end{aligned} \quad (9)$$

Where: $r_{i,t}$ is the excess return of fund *i*; $r_{m,t}$ is the excess return of the market; $\tilde{X}_{m,t}, SM\tilde{B}_t, HM\tilde{L}_t$ *and* $PR1Y\tilde{R}_t$ are the style timing factors - either $r_{m,t}^2$, SMB_t^2, HML_t^2 and $PR1YR_t^2$ in the TM version, or $[r_{m,t}]^+ = \max(0, r_{m,t})$, $[SMB_t]^+ = \max(0, SMB_t)$, $[HML_t]^+ = \max(0, HML_t)$ and $[PR1YR_t]^+ = \max(0, PR1YR_t)$ in the MH version; F_{it-1} is the lagged flow, included to avoid endogeneity problems between concurrent flows and returns; γ_1, γ_2, γ_3 and γ_4 capture the timing abilities with regard to market, size, book-to-market and momentum factors; γ_5, γ_6, γ_7 and γ_8 are the interactive terms that consider the influence of flows in timing abilities.

4.5. Multicollinearity issues.

We should note that some of the proposed models, specially both versions of model (9), present a great number of variables, which may originate multicollinearity problems. To avoid this phenomenon influencing our results, we study its existence and correct the affected models through the method of the variable elevation, proposed by Soto et al. (2000).

In order to determine the existence of multicollinearity and the causative variable/s, we apply a principal component analysis. Specifically, we compute the determinant of the correlation matrix of the variables estimated in each model, the eigenvalues of the covariance matrix, the condition indices and the variance inflation factors (VIF).

When some or all independent variables are highly correlated, the determinant will be near zero. Belsley et al. (1980) indicate the multicollinearity level with the condition index (η), which is the square root of the ratio of the largest eigenvalue to the corresponding eigenvalue. Particularly, whether $\eta < 5$, multicollinearity may be ignored; whether $5<\eta<10$, the index shows weak multicollinearity; whether $10<\eta<30$, multicollinearity is moderate; whether $30<\eta<100$, the index indicates strong evidence, and when $\eta>100$, multicollinearity is very strong.

With regard to the variance inflation factor (VIF), it measures the increase of the variance of an estimated coefficient due to collinearity.

$$VIF_i = \frac{1}{1 - R_i^2} \qquad (10)$$

Where: R_i^2 is the coefficient of determination obtained by regressing the i^{th} predictor on the remaining predictors.

A VIF of one means that there is no correlation among the i^{th} predictor and the remaining predictor variables and the variance of the estimated coefficient is not inflated. Kleinbaum et al. (1988) indicate that, in general, values less than five are acceptable, but there are serious multicollinearity when the VIF excesses ten, requiring correction.

After detecting the problem and identifying the causative variables, we try to solve the multicollinearity problem with the method of variable elevation, proposed by Soto et al. (2000), and described in detail in the Appendix.

This method is applied when the option to remove variables does not seem appropriate because we are interested in their permanence; subsequently, it develops modified variables. Specifically, after detecting the main exogenous variable/s causing multicollinearity, and from a geometric interpretation, the causative variable is the closest to the hyperplane generated by the others, in a Euclidean sense. As a result, increasing the angle formed by this variable with the hyperplane of the other variables, the collinearity decreases, although the original data vector (X_i) and the modified data vector (X_i^*) are the same.

This methodology pursues to calculate the λ value (result of the angle increase), and the modified variable (X_1^*), which is the real variable (X_1) plus λ times the residuals (e_1) obtained from the variable regression over the other explanatory variables (See Appendix for more details):

$$X_1^* = X_1 + \lambda e_1 \qquad (11)$$

5. Results.

In this section we examine the timing abilities and the flows influence on timing abilities of UK domestic equity pension funds (both conventional and SR managers).

The model regressions are cross-sectional, and the coefficients are estimated with the Least Absolute Deviations (LAD) method. We apply the LAD estimation because Stambaugh (1986), and Mankiew and Shapiro (1986) show that OLS estimations may produce biased estimators in finite samples. On the other hand, the LAD estimation overcomes this problem by minimizing the sum of absolute errors, rather than the sum of squared errors. Additionally, LAD results are robust to the presence of outliers, a common feature in flows data.

Furthermore, we analyze the existence of multicollinearity in each of the estimated models by their determinants, eigenvalues, condition indices and VIF. With regard to VIF, although it is usually employed in OLS method, we also consider its use in the LAD estimation because this method is also based on the errors, and the VIF can also measure how much the variance of an estimated coefficient is increased due to collinearity. After the preliminary analysis of multicollinearity, we will correct the affected models with the method of variable elevation (described in the methodology and the Appendix).

5.1. Results of traditional and multifactorial timing models.

The results of traditional and multifactorial timing models are collected in Table 3. This table is divided into five panels (A, B, C, D and E) and reflects the results of models (1) to (5) for conventional and SR pension funds.

INSERT TABLE 3

Before examining these results, we should mention that the multicollinearity analysis of these models does not show multicollinearity problems (nonzero determinants, condition indices without multicollinearity problems and FIV smaller than five in all conventional and SR variables)[5]; therefore, we do not modify the models described in the methodology.

Panels A and B show the results of traditional TM and MH timing models, respectively. Panel A shows that all managers present positive stock-picking abilities (α coefficients are positive and significant) but perverse timing abilities (γ_1 coefficients are significantly negative), although the TM model displays absence of timing for SR funds (panel A). These results are in line with Coggin et al. (1993), in a USA pension funds, and Thomas and Tonks (2001), in UK pension funds.

Panel C shows the results of the four-factor Carhart model. We observe that none of the managers are able to develop performance (α coefficients are not significant). Additionally, conventional and SR mangers invest in small cap values (β_2 are significantly positive) and follow momentum strategies (β_4 coefficient are significantly positive). Nonetheless, conventional managers invest in value stocks, but SR managers invest in growth stocks (β_3 are significantly positive and negative, respectively).

Panels D and E display the results of the multifactorial timing versions (models 4 and 5). In spite of presenting similar styles and positive stock-picking abilities, managers develop different style timing abilities. On the one hand, conventional managers present perverse timing with regard to the market and book-to-market factors (significantly negative γ_1 and γ_3), positive size timing (γ_2), and absence of timing with regard to the momentum factor (γ_4).

On the other hand, SR managers develop positive market timing, negative timing with regard to book-to-market and momentum factors, and with respect to size timing, panel D shows positive ability, but panel E shows absence of timing.

We observe contradictory market timing results between traditional models (panels A and B) and multifactorial models (panels D and E) in SR funds. Budiono and Martens (2009) explain these results as the fact that the study of a single style timing skill (e.g. market timing) leads to overestimating the loading on the selected characteristic, and a negative bias towards other characteristics. Consequently, we believe that the multifactorial models provide a better timing analysis.

[5] These results are not reported in this paper, but they are available from the authors upon request.

Overall, we observe that conventional and SR managers follow some investment styles and try to develop timing abilities with regard to them; however, they are not able to time correctly all of them; in particular, conventional managers only time correctly size strategies and SR managers time correctly the market. These results are consistent with previous studies, which find poor timing abilities with regard to some factors [Chan et al. (2002), Swinkels and Tjong-a-Tjoe (2007) or Gregory and Whitaker (2007)].

5.2. Flows influence on traditional and multifactorial timing models.

In this section we examine whether the poor timing results found are attributed to the realized flow at the fund; specifically, we study whether managers are influenced by flows with the models (8) and (9).

Table 4 shows the results of the model (8) for the TM version (panel A) and the MH version (panel B).

INSERT TABLE 4

The multicollinearity study does not detect problems in the two versions of model (8): nonzero determinants, condition indices and FIV less than five, in all variables[6]; as a consequence, we apply the proposed model.

Concerning conventional managers, the negative market timing previously found can be attributed to the realized flow. With the flow interactive term, market timing coefficients are now insignificant (but positive), while the interactive flow terms are negative. The result is in line with Edelen (1999), whom finds generally insignificant positive market timing coefficients, demonstrating that flows influence on market timing abilities and a fund's beta covaries negatively with market returns only to the extent that the fund experiences flow.

We confirm that perverse market timing disappears when we introduce flows effect in SR funds. Market timing becomes positive, in contrast to the traditional model results (absence in the TM model and negative timing in MH model). Therefore, negative market timing can be completely attributed to the realized flow at the fund.

In the last place, we estimate the TM and MH versions of model (9) to examine the flows influence on style timing skills.

[6] These results are not reported in this paper, but are available upon request.

The multicollinearity analysis does not show problems with conventional pension fund data; however, we detect multicollinearity problems for SR pension funds in both model versions. Specifically, the determinants of the correlation matrices are 0.000015 for the TM version, and 0.0000004 for the MH version.

We then study the variables causing multicollinearity. The condition indices only detect collinearity in the last variable ($F_{it,-1}PR1Y\tilde{R}_t$), being strong (53.71) in the TM version and moderate (20.60) in the MH version. The FIV is only higher than five (5.41) in the last variable of the TM version.

Given these evidences, we apply the method of variable elevation to modify this variable, $F_{it,-1}PR1Y\tilde{R}_t$, and correct both versions of model (9), although only for SR funds.

The results of model (9) for conventional funds and SR funds are displayed in table 5. The TM and MH versions for SR funds show the results with the corrected variable[7].

INSERT TABLE 5

With regard to conventional funds, market timing coefficients confirm the flows influence, being not significant and significantly positive in panels A and B, respectively. Additionally, timing with regard to size factor is still positive, and momentum timing coefficients are also insignificant, as in Table 3 (panels D and E). However, book-to-market timing is still negative, and the flow terms are not significant.

These findings show that market beta covaries negatively with market returns only when the fund experiences flow; however, the book-to-market beta covaries negatively independently of fund flow; that is to say, managers use flows only to improve market timing abilities.

Regarding SR pension funds, results remain practically the same as in the multifactorial models (4) and (5). Market timing is positive, the size timing is positive in the TM version but not significant in the MH version, and the book-to-market timing is perverse. The most substantial change is in the momentum timing coefficient of MH version, changing into positive; however, perverse momentum timing continues in the TM version.

[7] We also perform the model with the original variable for SR funds. Timing results are the same than in the new model, but the interactive flow variables (the variables with the flows influence) are not significant; therefore, we consider that the model with the modified variable improves the fitting model.

Therefore, although perverse momentum timing disappears in one model, SR managers only improve the market timing abilities considering flows, as their conventional counterparts.

On the whole, flow influences mainly on market timing abilities because perverse timing with respect to other factors does not disappear when the flow effect is considered. Therefore, managers develop the rest of style timing abilities independently of fund flows.

In this way, managers can use this information to increase their performance, trying to improve those timing abilities with negative results.

6. Conclusions.

We provide new evidence on pension fund manager behavior by examining the flow influence on timing abilities of UK conventional and SR domestic equity pension fund managers. In doing so, we make two main contributions to the financial literature.

First, whereas prior research has mainly focused on mutual funds flows, pension fund flows have rarely been investigated; nevertheless, it is an interesting topic of study.

Although pension fund investors cannot disinvest until retirement (except under certain circumstances), they are able to move the investment from one fund to another; consequently, these movements can have an important impact on managerial skills. Specifically, flows influence on managers because the asset level used to offer a management picture, and their compensation usually depends on assets under management.

Our study is the first to analyze this aspect in pension funds. In particular, we examine the flow influence on several style timing abilities. To this purpose we develop multifactorial timing models that incorporate interactive flow terms, and we compare them with traditional style timing models. Additionally, we evaluate the existence of multicollinearity problems and we correct the affected models through the method of the variable elevation.

Second, we present the first comparative style timing analysis between conventional and SR pension funds. Additionally, as SR pension funds are particularly concerned with social welfare, we examine the existence of differences between both managers.

Our results show that both sets of managers present poor timing abilities, although timing abilities are different.

On the one hand, conventional managers time correctly the market and size factors, present negative book-to-market timing and absence of momentum timing. Initially, we also find negative market timing, but it was attributed to the realized flow. Nevertheless, perverse book-to-market timing does not disappear considering flows, so managers do not take into account the fund flows to time this style.

Regarding to SR pension funds, managers present positive timing with regard to market and size factors, but perverse timing with regard to book-to-market and momentum factors, independently of flows.

On the whole, we observe that flows influence mainly on market timing abilities, but managers develop the rest of style timing abilities independently of fund flows (perverse timing with respect to other factors does not disappear when the flow effect is considered).

The limited timing abilities and scarce use of flows found may be useful to managers in order to increase their performance trying to improve the timing abilities in those styles with negative abilities.

The absence of results in the flows influence could be analyzed in more detail considering the determinants of flows; nonetheless, the data available in this study is not suitable for disentangling this study, which should consider many and different factors, as we describe at the beginning of this work. As a consequence, a further topic of research may be this interesting aspect.

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Table 1: Summary statistics

	Mean	Std. Dev.	Minimum	Maximum
Panel A: Conventional pension funds (386 funds)				
Monthly returns	0.0077	0.0458	-0.2954	0.2541
Monthly flows	0.0202	0.1260	-0.2852	2.3595
Monthly Total Net Assets	19.30	129	10	3120
Age (months)	59.466	43.858	24	240
Panel B: SR pension funds (25 funds)				
Monthly returns	0.0067	0.0461	-0.1887	0.1648
Monthly flows	0.0199	0.1200	-0.2305	1.6838
Monthly Total Net Assets	14.70	26.1	10	113
Age (months)	66.8190	45.56	24	175
Panel C: Risk factors				
rm	0.0036	0.0407	-0.1361	0.0990
SMB	0.0022	0.0333	-0.1148	0.1561
HML	0.0016	0.0358	-0.1856	0.1233
PR1YR	0.0085	0.0486	-0.2740	0.1377

Table 1 is divided into three panels. Panel A and B shows the summary statistics (mean, standard deviation, minimum and maximum) of monthly flows, return, total net assets (in millions of Pounds Sterling) and age (in months) for conventional and SR pension funds, respectively. Panel C shows the same statistics (mean, standard deviation, minimum and maximum) for the Carhart risk factors: market excess return (rm), size (SMB), book-to-market (HML) and momentum (PR1YR).

Table 2: Correlation matrices

Panel A: Correlation matrix of conventional pension fund variables and risk factors

	R_{it}	r_{it}	F_{it}	F_{it-1}	rm_t	SMB_t	HML_t	$PR1YR_t$
R_{it}	1							
r_{it}	0.9993***	1						
F_{it}	-0.0376***	-0.039***	1					
F_{it-1}	-0.0079	-0.0093	0.2524***	1				
rm_t	0.8842***	0.8853***	-0.0329***	0.0012	1			
SMB_t	0.3097***	0.314***	-0.0354***	-0.0269***	0.1102***	1		
HML_t	0.42***	0.4182***	-0.0223***	0.0025	0.1218***	-0.1374***	1	
$PR1YR_t$	-0.2924***	-0.2933***	-0.0062	-0.0149*	-0.2227***	-0.1287***	-0.5437***	1

Panel B: Correlation matrix of SR pension fund variables and risk factors

	R_{it}	r_{it}	F_{it}	F_{it-1}	rm_t	SMB_t	HML_t	$PR1YR_t$
R_{it}	1							
r_{it}	0.9993***	1						
F_{it}	-0.004	-0.0052	1					
F_{it-1}	0.0583*	0.057*	0.2911***	1				
rm_t	0.8957***	0.8971***	0.035	0.052	1			
SMB_t	0.3841***	0.3867***	0.028	0.1331***	0.1102***	1		
HML_t	0.238***	0.2352***	0.0694**	0.0815**	0.1218***	-0.1374***	1	
$PR1YR_t$	-0.2868***	-0.2876***	-0.1327***	-0.1785***	-0.2227***	-0.1287***	-0.5437***	1

Table 2 is divided into two panels. Panel A shows the correlation matrix between the conventional pension fund variables [pension fund returns (R_{it}), excess pension fund return (r_{it}), flows (F_{it}) and lagged flows ($F_{it,-1}$)] and the risk factors [market excess return (rm), size factor (SMB), book-to-market factor (HML) and momentum factor (PR1YR)]. Panel B presents the same correlations as Panel A for SR pension fund variables and Carhart risk factors.

*,**,*** indicate significance at the 10%, 5% and 1% level, respectively.

Table 3: Results of TM, MH, Carhart and style timing models.

	α	β_1	β_2	β_3	β_4	γ_1	γ_2	γ_3	γ_4	$\bar{R}^2$
Panel A: Model (1)										
Conventional funds	0.0020***	0.9297***				-0.6380***				0.552
	(0.000)	(0.000)				(0.000)				
SR funds	0.0026***	0.9103***				-0.1977				0.556
	(0.000)	(0.000)				(0.181)				
Panel B: Model (2)										
Conventional funds	0.0028***	0.9939***				-0.1186***				0.552
	(0.000)	(0.000)				(0.000)				
SR funds	0.0034***	0.9454***				-0.0631**				0.556
	(0.000)	(0.000)				(0.032)				
Panel C: Model (3)										
Conventional funds	-0.0001	0.9293***	0.1852***	0.0139***	0.0416***					0.569
	(0.562)	(0.000)	(0.000)	(0.001)	(0.000)					
SR funds	0.0004	0.9263***	0.3276***	-0.0216*	0.0358***					0.620
	(0.250)	(0.000)	(0.000)	(0.090)	(0.000)					
Panel D: Model (4)										
Conventional funds	0.0005***	0.9246***	0.1802***	0.0167***	0.0437***	-0.5443***	0.4405***	-0.1888***	0.0042	0.570
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.877)	
SR funds	0.0009**	0.9464***	0.3553***	-0.0323***	0.0057	0.4224***	0.4635***	-0.2514**	-0.6664***	0.628
	(0.013)	(0.000)	(0.000)	(0.001)	(0.419)	(0.000)	(0.006)	(0.020)	(0.000)	
Panel E: Model (5)										
Conventional funds	0.0011***	0.9691***	0.1532***	0.0536***	0.0325***	-0.0861***	0.0641***	-0.0739***	0.0164	0.570
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.121)	
SR funds	0.0026***	0.8973***	0.3437***	-0.0040	0.1125***	0.0745***	0.0069	-0.0600*	-0.1921***	0.629
	(0.000)	(0.000)	(0.000)	(0.838)	(0.000)	(0.002)	(0.820)	(0.058)	(0.000)	

Table 3 is divided into five panels (A, B, C, D and E) and presents the results of the LAD cross-sectional regressions of models (1) to (5) for conventional and SR pension funds. Each panel shows the estimates for the following parameters: α, which represents stock-picking ability, except in panel C, which represents fund performance; β_1, β_2, β_3 and β_4 measure the sensitivity of the fund to the market, size, book-to-market and momentum factors, respectively; γ_1, γ_2, γ_3 and γ_4 represent the timing abilities with respect to market, size, book-to-market and momentum factors, respectively. P-values are reported in parentheses. The last column shows the adjusted R-squared coefficient ($\bar{R}^2$). *, **,*** indicate significance at the 10%, 5% and 1% level, respectively.

Table 4: Flows influence on traditional timing models

	α	β_1	γ_1	γ_2	$\bar{R}^2$
Panel A: Model (8) with TM version					
Conventional funds	0.0026***	0.9254***	0.5166	-0.5566**	0.555
	(0.000)	(0.000)	(0.244)	(0.019)	
SR funds	0.0016**	0.8794***	0.1050*	1.2995**	0.569
	(0.026)	(0.000)	(0.068)	(0.014)	
Panel B: Model (8) with MH version					
Conventional funds	0.0029***	0.9607***	0.0690	-0.0049	0.554
	(0.000)	(0.000)	(0.100)	(0.861)	
SR funds	0.0013	0.8522***	0.0431**	-0.1272**	0.570
	(0.268)	(0.000)	(0.041)	(0.041)	

Table 4 is divided into two panels. Panel A presents the results of the LAD cross-sectional regression of model (8) with the TM version, for conventional and SR pension funds. Panel B presents the same information as panel A for the MH version. Each panel shows the estimates for the following parameters: α, which represents stock-picking ability; β_1, which measures the sensitivity of the funds to market return; γ_1, which reflects market timing ability, and γ_2 is the interactive term that introduces the effect of flows on market timing. P-values are reported in parentheses. The last column shows the adjusted R-squared coefficient ($\bar{R}^2$).

*,**,*** indicate significance at the 10%, 5% and 1% level, respectively.

Table 5: Flows influence on multifactorial timing models

	α	β_1	β_2	β_3	β_4	γ_1	γ_2	γ_3	γ_4	γ_5	γ_6	γ_7	γ_8	$\overline{R}^2$
Panel A: Model (9) with TM version														
Conv. funds	0.0001	0.9295***	0.2224***	-0.0033	0.0566***	-0.1033	0.8570***	-0.8367***	-0.1555	-0.9429**	1.0138	0.0292	-0.3110	0.575
	(0.675)	(0.000)	(0.000)	(0.696)	(0.000)	(0.130)	(0.000)	(0.000)	(0.105)	(0.021)	(0.119)	(0.964)	(0.115)	
SR funds	-0.0085***	0.9809***	0.6344***	-0.0773*	0.1667***	1.9147***	2.5387***	-3.0240***	-1.0522***	-3.2305***	0.8052	7.4126	-0.3313	0.719
	(0.000)	(0.000)	(0.000)	(0.056)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.001)	(0.279)	(0.139)	(0.176)	
Panel B: Model (9) with MH version														
Conv. funds	0.0004	0.9094***	0.2044***	0.1009***	0.0495***	0.0313***	0.0575***	-0.2122***	0.0125	-0.0222	-0.0010	-0.0266	-0.0302	0.576
	(0.104)	(0.000)	(0.000)	(0.000)	(0.000)	(0.003)	(0.000)	(0.000)	(0.153)	(0.545)	(0.980)	(0.671)	(0.169)	
SR funds	-0.0017**	0.7423***	0.3346***	-0.0004	-0.0892***	0.3780***	0.3405	-0.155*	0.0015***	-0.6657***	0.7563**	3.1001**	-0.0001***	0.719
	(0.031)	(0.000)	(0.000)	(0.991)	(0.000)	(0.000)	(0.262)	(0.068)	(0.000)	(0.005)	(0.015)	(0.029)	(0.001)	

Table 5 is divided into two panels. Panel A presents the results of the LAD cross-sectional regression of model (9) with the multifactorial TM version, for conventional and SR pension funds. Panel B presents the same information as panel A for the multifactorial MH version. Each panel shows the estimates for the following parameters: α, which represents stock-picking ability; β_1, β_2, β_3 and β_4, which measure the sensitivity of the fund to the market, size, book-to-market and momentum factors, respectively; γ_1, γ_2, γ_3 and γ_4, which represent timing ability with respect to market, size, book-to-market and momentum factors, respectively; γ_5, γ_6, γ_7 and γ_8, which represent the interactive terms that introduce the flows effect on timing abilities with respect to market, size, book-to-market and momentum factors, respectively. P-values are reported in parentheses. The last column shows the adjusted R-squared coefficient ($\overline{R}^2$).

*,**,*** indicate significance at the 10%, 5% and 1% level, respectively.

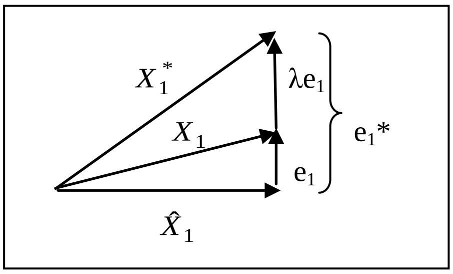
Appendix

Method of variable elevation

Soto et al. (2000) propose the method of variable elevation to modify the exogenous variables causing multicollinearity, instead of removing variables, because their permanence is interesting.

After the detection of the main exogenous variable/s causing multicollinearity, the method establishes, from a geometric interpretation, that the variable causing multicollinearity (X_1) is the closest to the hyperplane generated by the others $\{X_2, X_3, ..., X_p\}$ in an Euclidean sense. As a result, increasing the angle formed by the variable with the hyperplane of the others (figure 1), collinearity decreases, although the original data vector (X_1) and the corrected data vector (X_1^*) are the same. Consequently, from a vector point of view, this method tries to calculate the λ value, as figure 1 shows [see Soto et al. (2000) for further detail].

Figure 1: Vector representation of the relationship between original (X_1), estimated ($\hat{X}_1$) and modified (X_1*) variables.



Source: Soto et al. (2000)

Therefore, the original variable (X_1) and the modified variable (X_1^*) are:

$$X_1 = \hat{X}_1 + e_1 \quad \text{(A.1.)}$$

$$X_1^* = \hat{X}_1 + (\lambda_1 + 1)e_1 = X_1 + \lambda_1 e_1 \quad \text{(A.2.)}$$

Or according the vector magnitudes, and applying the Pythagorean theorem:

$$X_1^2 = \hat{X}_1^2 + e_1^2 \quad \text{(A.3.)}$$

$$X_1^{*2} = \hat{X}_1^2 + e_1^{*2} = \hat{X}_1^2 + (\lambda_1 + 1)^2 e_1^2 = \hat{X}_1^2 + \beta_1^2 e_1^2 \text{, where: } \beta_1 = \lambda_1 + 1 \text{ and } \lambda_1 \geq 0 \quad \text{(A.4.)}$$

The transformation of X_1 into X_1^* aims to decrease the VIF (variance inflation factor) because X_1 is highly collinear with others, so the fitting regression of X_1 on the remaining variables will be good, the coefficient of determination (R^2) will be close to one and the VIF will be large. Specifically, whether $VIF_1 = \frac{1}{1 - R_1^2}$ and $R_1^2 = \frac{\hat{X}_1^2}{X_1^2} = 1 - \frac{e_1^2}{X_1^2}$ → $1 - R_1^2 = \frac{e_1^2}{X_1^2}$

and $\frac{1}{1 - R_1^2} = \frac{X_1^2}{e_1^2}$

Supposing that we accepted a $VIF_1^* = F_1^*$ for the new variable, and considering expressions (A.3.) and (A.4.), we realize that:

$$X_1^{*2} = X_1^2 + (\beta_1^2 - 1)e_1^2 \qquad \text{(A.5.)}$$

$$\frac{1}{1 - R_1^{*2}} = \frac{X_1^{*2}}{e_1^{*2}} = \frac{X_1^{*2}}{\beta_1^2 e_1^{*2}} = \frac{X_1^2 + (\beta_1^2 - 1)e_1^2}{\beta_1^2 e_1^2} < FIV_1^* = F_1^* \qquad \text{(A.6.)}$$

Where: $e_1^* = \beta_1 e_1; \beta_1 \geq 1$

Consequently:

$$X_1^2 + (\beta_1^2 - 1)e_1^2 < F_1 \beta_1^2 e_1^2; \rightarrow X_1^2 - e_1^2 < F_1 \beta_1^2 e_1^2 - \beta_1^2 e_1^2 \rightarrow X_1^2 - e_1^2 < (F_1 - 1)\beta_1^2 e_1^2 \rightarrow$$

$$\frac{X_1^2 - e_1^2}{e_1^2 (F_1 - 1)} < \beta_1^2 \rightarrow \beta_1 \geq +\sqrt{\frac{X_1^2 - e_1^2}{e_1^2 (F_1 - 1)}} \qquad \text{(A.7.)}$$

Ideally, $F_1=1$; i.e., no variance inflation with respect to least squares, but it represents a major change in the data of the studied variable; therefore, several authors take VIF <5 acceptable.

The estimated variable ($\hat{X}_1$) and the residuals (e_1) are obtained from the regression of the variable (X_1) over the remaining explanatory variables. And the modified variable (X_1^*) is the real variable (X_1) plus λ times its residuals (e_1):

$$X_1^* = X_1 + \lambda e_1 \qquad \text{(A.8.)}$$