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Abstract

This study examines the impact of short selling on hedge fund returns from 2010 to 2020. Four different short-selling factors are constructed. Short interest rate (SIR), relative short interest (RSI), days-to-cover (DTC), and shortflow (SF). The findings show that short-selling factors such as short interest rate and shortflow have a significant inverse relationship with US stock returns and only short interest rate significantly and negatively impacts hedge fund returns. We also found that outperforming hedge funds relate positively to days-to-cover relative to the ones that relate negatively. Quantitative characteristics such as net asset value (NAV), minimum investment, and age are found to be significant attributes in influencing the relationship of the hedge funds with the shorting factors. Hedge funds with higher NAV negatively relate with DTC, suggesting that better performing hedge funds may have more expertise in avoiding stocks that are difficult to borrow, including those with a high DTC. Hedge funds that require a higher minimum investment have a negative impact on DTC and SF. These hedge funds typically attract wealthy investors, which gives them better resources to limit their exposure towards heavily shorted stocks, including those with a high DTC and SF. Older hedge funds negatively impact RSI, DTC, and SF, which may indicate either unsuccessful speculation or risk-mitigating hedging strategy.

A qualitative characteristic, such as the country of the hedge fund is also found to be a significant attribute. This is likely because regulatory laws, market conditions, and the geopolitical factors vary between countries, which could lead to differences in hedge fund performance. This paper focuses solely on investigating the impact of short selling on hedge funds only through the speculative shorting perspective.

Keywords: Hedge funds, Short selling, Stocks, Hedge fund characteristics

1 Introduction

The relationship between short selling activities and hedge fund returns has received increased attention in recent years, as short selling has become more prominent in the investment world (Appel, Bulka, & Fos, 2019). Short-selling refers to the selling of borrowed securities with the hope of buying them back at a lower price in the future, which can result in significant losses if the price of the security increases instead of decreasing (Hayes, 2023). It is considered a risky trading activity because the potential losses are not limited, and traders may face margin calls if the stock price rises. In contrast, going long carries less risk because traders cannot receive margin calls.

However, short-selling can also be a very profitable trading strategy if the activity is well-informed. A successful short sale can generate significant returns in a short period of time. This is why hedge funds, which can be known for their aggressive investment strategies, sometimes engage in short-selling. Hedge funds are alternative investment vehicles that use a wide range of investment strategies to achieve their objectives (Fung & Hsieh, 1999). This is why hedge funds, which can be known for their aggressive investment strategies, sometimes engage in short-selling.

Investigating the relationship between short selling and hedge fund returns is challenging due to several reasons. Firstly, it is difficult to isolate the effect of short selling, considering that hedge funds often use a combination of long and short positions (Jiao, Massa, & Zhang, 2016). Secondly, the extent that hedge funds engage in short selling is unclear (Appel et al., 2019). Thirdly, hedge funds are often reluctant to disclose their short positions, making it challenging to obtain accurate data.

Despite these challenges, investigating the relationship between short selling and hedge fund returns is important because it can provide valuable insights into the effectiveness of short selling as a strategy for hedge funds. It can also shed light on the role of short selling in managing risk and generating returns.

Currently, there is still much that is not known about how short selling affects hedge fund returns. For example, it is unclear how much of the returns generated by hedge funds come from short selling versus long positions. Additionally, it is not evident whether short selling is associated with higher or lower hedge fund returns. This paper aims to address the latter. The objective is to determine the role that short selling plays into hedge fund performance and whether it relates positively or negatively with hedge fund returns. Precisely, the central research question that is investigated is: “How does short selling affect hedge fund returns in the period of 2010 to 2020?”

Previous research has demonstrated that short selling exhibits an inverse relationship

with stock returns, and that a high level of short interest corresponds to a more bearish signal in the market (Desai, Ramesh, Thiagarajan, & Balachandran, 2002a). In addition, other studies have shown that informed traders show a greater tendency for short selling, likely due to their higher risk tolerance (Rapach, Ringgenberg, & Zhou, 2016). The evidence available at present strongly supports that there is a correlation between short selling and negative stock returns and that short sellers are informed traders (Senchack & Starks, 1993).

However, within the field of finance, hedge funds are also widely regarded as the most knowledgeable, well informed, and sophisticated institutional traders. As a result, a plausible assumption is that hedge funds engage in informed short selling, potentially endowing shorting activity with the ability to anticipate or signal their future returns, as shown in Massoud et al., (2011).

To represent and check the effects of shorting, four short-selling factors are constructed and returns are regressed on them using the ordinary least squares method. Specifically, the short-selling factors used are: short interest rate (SIR), relative short interest rate (RSI), days-to-cover (DTC), and shortflow (SF). Short interest rate is known to be the most widely used metric of short seller's positions in the literature (Reed, 2013), as also seen in most of the studies mentioned here. Thus, SIR is used as the first metric to measure shorting positions in this study. Relative short interest rate is a constructed metric which captures the change in short interest over a longer term period. This is so that the effects of a long-term short interest rate can be represented. Days-to-cover is the third metric, calculated as the short interest rate over total trading volume. According to Hong et al., (2015), DTC is a better measure than SIR because it accounts for trading costs that vary across stocks. This allows for DTC to capture marginal costs and benefits of the short positions better than SIR. Lastly, shortflow is included as the fourth metric, based on evidence from (Wang, Yan, & Zheng, 2020) showing that it can be a significant predictor of negative stock returns. Shortflow is also a very commonly used short-selling measure.

The existing literature on the relationship between short selling and hedge fund returns is not comprehensive. Most studies have focused on the relationship between short selling factors and stock returns, rather than on how these factors impact hedge fund returns. While some studies have examined the overall relationship between short selling and hedge fund returns, there is a lack of research that fully explores each aspect of short selling by investigating the joint effects of multiple short-selling factors that may influence this relationship. As a result, this research seeks to fill in the gap by exploring the effects of various short-selling factors on hedge fund returns. By incorporating multiple short selling measures, we can capture different aspects and features of short selling, which can ultimately lead to a more nuanced insight of how short selling may affect hedge fund returns.

To inspect the relationship between short selling and hedge fund returns, the relationship between short selling and stock returns is first investigated. That is done by regressing stock returns on the four short-selling factors (SIR, RSI, DTC, and SF) using the ordinary least squares method. The results show that only SIR and SF have a significant negative relationship with stock returns. Secondly, the hedge fund returns are regressed on the four short-selling factors (SIR, RSI, DTC, and SF) using ordinary least squares regressions. The findings show that only SIR is significantly and positively related to hedge fund returns, whereas the other factors turn out insignificant. Next, the cross-section of hedge funds is investigated, to explore whether outperforming hedge funds related differently to the short-selling factors relative to the underperforming ones. This is done through a mean comparison hypothesis testing. Hedge funds with higher returns relate positively to DTC relative to the ones that relate negatively to DTC. The rest of the shorting factors have insignificant results. Lastly, it is also investigated whether hedge fund characteristics affect the performance of hedge funds on the shorting factors. This is also done through a mean comparison hypothesis testing. The findings show that, out of the quantitative characteristics, only net asset value, minimum investment, and age, are found to be significant characteristics that impact the relationship of the hedge funds with some of the short-selling factors. For example, hedge funds with higher NAV relate negatively to DTC, hedge funds with a higher investment requirement relate negatively to DTC, and SF, and older hedge funds relate negatively to RSI, DTC, and SF. Moreover, out of the qualitative characteristics, only the country of the hedge fund is a significant characteristic that impacts the relationship of the hedge funds with the shorting factors.

Therefore, this research also aims to contribute to the existing literature by providing a more comprehensive understanding of the effects of short-selling on hedge funds. The findings of this study will also help hedge funds make more informed decisions and better manage their risk exposures. Furthermore, this research will provide an analysis of short selling by including multiple short-selling factors and considering different aspects of short selling, unlike several previous studies that have focused only on a limited number of shorting factors.

The rest of the paper is organized in the following manner. Section 2 presents and evaluates the existing literature on how short selling affects stocks returns and hedge fund returns. Section 3 provides a detailed overview of the data used in this study, including its sources and sample selection. The rationale behind the sample selection is also explained. Section 4 explains the research methodology, presents the mathematical specifications and the statistical techniques used to test the hypotheses. Section 5 discusses and presents the results of the models mentioned in the methodology. Section 6 concludes the paper by

providing an overall summary of the main findings and providing final remarks regarding potential future research.

2 Literature Review

Short selling is an important aspect of the financial market because it allows investors to profit from a declining market and provides liquidity to the market. Short selling is a strategy in which an investor borrows a security, such as a stock, from a broker and immediately sells it with the expectation that the price will fall. If the price does fall, the investor can purchase the shares back at a lower price and return them to the broker. The difference between the original share price and the repurchase price can be kept as profit by the investor. One of the most consistent findings in academic research is that short sellers tend to be well-informed traders, which means that when they engage in short sales, it often indicates that future returns for the targeted securities are likely to be negative (Reed, 2013). A study by Jank et al., (2017) shows that stocks with secretive short positions demonstrate more negative returns compared to non-secretive positions. This finding suggests that secretive behavior is related to informed trading, and informed traders tend to avoid disclosing their short positions to protect their investment strategy.

Prior research has indicated that some short sellers are better at processing information and generally more well-informed (Senchack & Starks, 1993; Engelberg, Reed, & Ringgenberg, 2012). Short interest and shortflow can be considered as the two most commonly used metrics when investigating the relationship between short-selling and stock returns. Many early studies aimed to determine whether short interest is a bearish indicator, as it is typically associated with negative returns, or a bullish indicator, as short sellers would eventually need to purchase the shares back (Reed, 2013). Numerous studies now show that short interest indicates a bearish market signal because it usually shows negative stock returns (Asquith, Pathak, & Ritter, 2005; Desai, Ramesh, Thiagarajan, & Balachandran, 2002b; Boehme, Danielsen, & Sorescu, 2006). Similarly, the surprise in short interest, which is used to proxy informed short-selling, has been found to negatively impact equity returns (Hanauer, Lesnevski, & Smajlbegovic, 2022). However, there has been no investigation into how short interest, shortflow or any other short-selling factors may impact hedge fund returns.

Hedge funds have gained increasing attention in the financial industry, as they have demonstrated the ability to generate high returns for their investors. They are also characterized by a mostly unregulated structure, adaptable investment approaches, knowledgeable investors, substantial managerial investment, and strong managerial incentives (Ackermann,

McEnally, & Ravenscraft, 1999). As a result, examining hedge funds could provide valuable understanding of the influence of regulations, alternative investment methods, and aligned incentives and performance. Hedge funds are motivated by the potential for high returns and are willing to take on higher risks to achieve them. However, the variability in hedge fund returns has led to a significant amount of academic research aimed at understanding the factors that affect hedge fund returns. Studies have found that hedge fund returns are positively related to the skill and experience of the fund managers. Hedge fund managers seem to also have a notable level of discretion and flexibility with regards to investment strategies, primarily due to their limited regulatory framework. Despite this advantage relative to other investors in the market, hedge funds seem to consistently outperform mutual funds, but they are still unable to consistently beat the market (Ackermann et al., 1999).

Most of the literature focuses on the long positions of hedge funds and thus there is not a lot of information on how short selling affects hedge fund returns. Studies usually explore the longing and shorting of hedge funds separately, however, the study of Jiao et al., (2016) investigates the joint effect of both longing and shorting of hedge funds. They suggest that if short interest and hedge fund holdings move in opposite directions, they are driven by private information. Whereas, when they move in the same directions, they are likely due to hedging incentives. This shows that the directional change of hedge fund holdings and short interest can be an indication of whether hedge fund's short positions are informed or not. Another study that confirms that hedge funds short sell on private information is by Massoud et al., (2011). They provide evidence that short selling can be profitable for hedge funds during the syndicated lending process. Therefore, hedge funds are believed to be well informed in general. However, even though hedge funds can be considered as the most well informed and sophisticated traders, previous literature does not confirm the exceptional expertise of hedge funds (Jank & Smajlbegovic, 2015). At the same time, Liang (1999) demonstrated that hedge funds significantly outperform mutual funds in terms of managerial skills, despite exhibiting greater volatility. Another study has found that some hedge funds manipulate stock prices on specific reporting dates by buying some of their stock holding before market closes (Ben-David, Franzoni, Landier, & Moussawi, 2013). Given that hedge funds engage in short selling using private information and they also have the power to manipulate price, an important question arises is whether hedge funds actually profit from the short selling?

Despite the considerable amount of research on hedge fund returns, there is a lack of research on the impact of short selling activities on hedge fund returns. Short selling, as previously touched upon, is a very risky trading strategy that can also be very profitable for those who are skilled and knowledgeable in its implementation. However, hedge funds can use short selling for different motivations (Wyckoff, 1959). One possibility is for the short

selling to be speculative, which is the high-risk strategy where they sell with the expectation that the price of the security will fall in the future. This is when the investor bets against the market or a certain asset. The second possibility may be using short selling as a hedging strategy where they take short positions to hedge against long positions which limits potential losses. Third can be market making, where hedge funds can act as liquidity providers in the market, buying and selling stocks to keep the market active. Speculative short selling can be an effective way for hedge funds to generate returns in bear markets, which refers to informed trading. Whereas, hedging and market making would refer to uninformed trading because they do not trade on negative information.

Moving on to the effects of short selling on hedge fund returns, the existing literature is limited and scarce. However, a recent study by Jank & Smajlbegovic (2017) revealed that hedge funds outperform other investors in their shorting activities and generate positive returns, and this is mainly attributed to their trading on mispricing factors. Similarly, Liang (1999) briefly discusses the effect of short selling on hedge fund returns. He finds that hedge fund returns from the short-selling strategy have a strong negative correlation with US stock equities. The mixed findings in the studies above provide some information on the performance of hedge funds in short selling activities, but they do not analyze how specific short-selling factors affect hedge fund returns. Each short-selling factor represents a unique aspect of short selling activity and analyzing each factor individually can help provide a more nuanced understanding of how short selling affects hedge funds returns. Thus, this paper will add further precise insight for identifying which factors have the strongest impact and which ones have the weakest impact.

To establish and confirm the existing correlation between short selling and stock returns from prior literature, I hypothesize that the short-selling factors (SIR, RSI, DTC, and SF) have a negative relationship with the cross section of stock returns. To test this hypothesis, I use two common asset pricing approaches. The first one is portfolio sorting and the second one is Fama-Macbeth (1973) regressions. After establishing the relationship between short selling and stock returns, we investigate the relationship between short selling and hedge fund returns. The second hypothesis is that the short-selling factors (SIR, RSI, DTC, and SF) show a positive relationship hedge funds returns. To test this hypothesis, I first create factor-mimicking portfolios on the short-selling factors and then I conduct a time series portfolio regression of the hedge fund returns on the factor-mimicking portfolios. In addition, I delve into the cross-section of hedge funds to see whether outperforming hedge funds relate positively to the short-selling factors. Lastly, I check to what extent do hedge fund characteristics influence the relationship of hedge funds with the shorting factors. Some of the characteristics we will look at are size, age, management fee, and net asset value (NAV),

country, and asset class. The study of Jank & Smajlbabic (2017) shows that diversified, local, industry-experienced, first movers, and active hedge funds outperform the other hedge funds. However, another study shows that hedge funds with high watermarks, fund assets, and the presence of a lockup period are positively related to hedge fund returns whereas the hedge fund's age is negatively related with hedge fund returns (Liang, 1999). To date, there appears to be a gap and no consensus in academic research regarding the potential significance and impact of short selling on hedge fund returns. More research is needed to understand whether the informativeness that hedge funds possess has any predictive power over their performance and returns.

3 Data

To investigate the effects of short selling, I create four short-selling factors that are based on US stock-level short-selling measures in the period 2010 - 2020. As previously mentioned, these four factors are: SIR, RSI, DTC, and SF.

SIR refers to the number of shares held short relative to shares outstanding. The number of shares held short is directly taken from Compustat as short interest on a monthly basis for each CRSP US stock from January 1, 2010 - December 31, 2022. The shares outstanding for each stock are extracted monthly from the CRSP database. RSI refers to the monthly change of short interest relative to its 12-month average. To calculate the first RSI we need the average of short interest rate for the past 12-months. Therefore, all short-selling factors, including RSI, were computed from February 1, 2010 - December 31, 2020. DTC is calculated as the monthly short interest relative to the monthly total trading volume. The monthly total trading volume is taken from the FINRA database. SF is calculated as the monthly short trading volume divided by the monthly total trading volume. The short trading volume is extracted on a monthly basis from the FINRA database. The time period of January 2010 to December 2020 was selected due to multiple factors, including missing data for some short-selling variables prior to January 2010 and the need for a sufficiently long sample period to analyze changes in these variables.

For the same time period, I obtained U.S. stock returns data from the Center for Research in Security Prices (CRSP) database, which consists of 957,555 company returns. After removing the outliers and merging the data, only 200,357 stock returns are used in the final sample.

CRSP is a comprehensive database that includes historical data on all stocks listed on major US exchanges, such as the New York Stock Exchange (NYSE) and the Nasdaq Stock

Market. It is a good representative for short selling activity because it contains data on a broad range of stocks across various sectors and industries (Liberto, 2021). In addition, it is also widely used by academic researchers and institutional investors, who rely on it for their investment analysis and risk management strategies.

To examine the effects of short selling on hedge fund returns, I retrieved 884,789 hedge fund returns from Lipper Hedge Fund Database (TASS) - Wharton Data Services (WRDS) for global hedge funds all over the world. Following the removal of outliers and the merging of the data, only 76,915 hedge fund returns are used in the final sample. Similarly, the hedge fund characteristics such as, assets under management (AUM), net asset value (NAV), minimum investment, maximum leverage, personal capital amount, inception date, performance date, asset class, and country, are also retrieved from TASS. TASS is a reliable source of data on hedge funds, providing performance data, profile data, fund structure and other data about hedge funds (Peng, 2014). It is also a good representative sample of hedge funds because it provides a large, high-quality sample of hedge fund returns and it is also widely used by investors and researchers.

4 Methodology

The goal of this research is to explore the impact of short-selling factors on the returns of hedge funds. The approach involves an initial exploration of the relationship between short-selling factors and US stock returns, followed by an analysis of their impact on hedge fund returns. The first step is to establish whether short-selling factors impact negative stock returns, as previous research has shown (Reed, 2013). That is done through the means of a portfolio sorting and Fama-Macbeth (1973) regressions. This sequential investigation is crucial in determining whether well-informed short selling by hedge funds leads to positive returns for them. To investigate the performance of the short-selling factors on hedge fund returns, first short-selling factor mimicking portfolios are created and then a time series portfolio regression analysis is performed. Lastly, the cross-section of hedge funds is explored to see whether outperforming hedge funds have a different relationship with the shorting factors relative to the underperforming hedge funds. Moreover, hedge fund characteristics are also examined to see whether they impact the relationship that hedge funds have with shorting factors.

To improve the accuracy of the statistical analyses, two techniques are used. The first one is dropping extreme values from the dataset to remove outliers (Adams, Hayunga, Mansi, Reeb, & Verardi, 2019). The second one is log-transforming the variables that have a highly

skewed distribution, such as short-selling factors. By taking the logarithm, extreme values are compressed, and the distribution becomes more normal, which leads to more accurate regression analysis (Ackermann et al., 1999).

4.1 Short-selling factors and US stock returns

To analyze whether short-selling factors negatively impact US stock returns we use two common asset pricing approaches, portfolio sorting and the Fama-Macbeth (1973) regressions. These approaches have been used in multiple research papers to determine the relationship between short selling and stock returns (Boehmer, Jones, & Zhang, 2008; Yan, 2019; Comerton-Forde, Do, Gray, & Manton, 2016; Hong, Li, Ni, Scheinkman, & Yan, 2015; Wang et al., 2020; Engelberg et al., 2012). The standard errors for both approaches are adjusted following Newey and West (1987).

Portfolio sorting is a univariate portfolio analysis that explores whether one independent variable, a short-selling factor in our case, significantly impacts the cross-sectional stock returns (Bali, Engle, & Murray, 2016). It does so by precisely answering the question of whether portfolios with high short-selling firms outperform portfolios with low short-selling firms. A limitation of this approach is that it allows sorting only for one independent variable, hence it cannot control for the effects of any other independent variables.

To conduct this analysis, the cross-sectional distribution of all the short-selling factors is considered. Next, 5 breakpoints will be calculated which will be used to split the sample into portfolios. Then, the average value of the hedge fund returns within each portfolio for each time period is calculated. Lastly, the significance of the difference between the returns of the highest short-selling portfolios (5th quantile) and the returns of the lowest short-selling portfolios (1st quantile) is examined. If the difference is significantly positive, then the analysis suggests that high short-selling portfolios outperform the low short-selling portfolios, implying that short - selling factors significantly impact stock returns.

The second approach, Fama-Macbeth (1973) regression analysis is an alternative approach for examining the relationship between cross-sectional hedge fund returns and the short-selling factors (Bali et al., 2016).

$$Ret_{i,t+1} - Rf_{t+1} = \alpha_{i,t} + \beta_{1,t}SIR_{i,t} + \beta_{2,t}RSI_{i,t} + \beta_{3,t}DTC_{i,t} + \beta_{4,t}SF_{i,t} + \varepsilon_{i,t} \quad (1)$$

In equation 1, $Ret_{i,t+1}$ refers to the future one period ahead, $t + 1$, stock return for each company i , Rf_{t+1} refers to the future one period ahead, $t + 1$, risk-free rate. $\alpha_{i,t}$ is the intercept term, which is the constant value in the regression representing the dependent

variable when all of the independent variables equal zero at time t , for each company i . SIR, RSI, DTC, and SF are the independent variables with a β of their own representing their respective coefficient at time t , for each company i .

The major advantage of the Fama-Macbeth approach is that it can include a large set of independent variables (Bali et al., 2016). Hence, all short-selling factors are included as independent variables into one regression. To conduct this analysis a two-step procedure is required. The first step is to get an intercept and slope coefficients by running a periodic cross-sectional regression of the stock returns on all the short-selling factors. The second step is calculating the average of each regression coefficient across time. A statistically significant average slope coefficient will suggest a significant cross-sectional relation exists between short-selling factors and the stock returns.

4.2 Time series analysis

Stationarity in stock returns is considered a general assumption in asset pricing research (Rosenberg & Ohlson, 1976). Multiple studies have proved the presence of stationarity in stock returns and therefore it can be seen as a general consensus (Perron, 1989; Chaudhuri & Wu, 2003, 2004; Narayan, 2008; Lee, Lee, & Lee, 2010). However, not a lot of research is done about the presence of stationarity in hedge fund returns. Hedge fund returns usually have a different distribution from stock returns. They tend to be highly non-normal, asymmetrically distributed, and highly skewed with fat tails (Lo, 2001). For that reason, stationarity and other statistical properties of hedge fund returns are checked in a similar manner to that of Guirguis (2021). This is done before we conduct the time series portfolio regressions of hedge fund returns with the short-selling factors. Statistical properties of the time series hedge fund portfolio returns are analyzed to make sure that there are no time-specific trends and other time-varying factors that might influence the relationship between the independent variables and the dependent variable (Shumway & Stoffer, 2017). This can lead to more accurate estimates of the regression coefficients and more reliable inference. Furthermore, in a time series regression, the order of observations is important, and modeling the time dependence can help to account for serial correlation in the data. Accounting for serial correlation is important because it affects the standard errors of the regression coefficients, and failing to do so can result in unreliable statistical inferences.

To determine the statistical properties of this time series, I employ a few sophisticated techniques, including the Dickey-Fuller stationarity test, Autocorrelation Function (ACF), Partial Autocorrelation Function (PACF), Autoregressive model (AR), and Moving Average

model (MA), Greene (2012). By utilizing these advanced techniques, we can gain a comprehensive understanding of the dynamics that underlie hedge fund returns and uncover insights about their behavior over time. ACF and PACF are commonly used to analyze time series data, particularly to identify the order of autoregressive (AR) and moving average (MA) models.

To assess the stationarity of the hedge fund portfolios over time, we utilize the Dickey-Fuller test. Specifically, we use this test to determine whether the returns of the hedge fund portfolios follow a random walk or exhibit any trends (Jordanova, 2022). The Dickey-Fuller test is a statistical test used to determine whether a time series is stationary or non-stationary, specifically by testing for the presence of a unit root (Shumway & Stoffer, 2017). To prepare the time series for a Dickey-Fuller test, transformation of the time series is required. The transformation involves differencing the time series one or more times until it becomes stationary. A non-stationary process implies that its statistical properties, such as the mean, variance, and autocovariance structure change over time. A stationary process means that its statistical properties remain constant over time.

After determining the stationarity of the time series we can calculate the ACF. The ACF measures the correlation between a time series and its lagged values. Specifically, it plots the correlation coefficient between the series and its lags at various time lags. This helps to identify the extent to which past values of the series are related to the current value, and to what degree the series is correlated with its own past values. If the ACF decays slowly or has significant spikes, it suggests that the series is autocorrelated and that an AR model might be appropriate.

Next, the PACF is performed. The PACF measures the correlation between a time series and its lagged values after removing the effect of all shorter lags. It provides a measure of the direct relationship between a time series and its own lagged values, controlling for the influence of other lags. If the PACF has significant spikes at a certain lag, it suggests that the series has a significant relationship with its own lag at that particular lag. If the PACF decays slowly, it suggests the presence of a moving average (MA) component.

Additionally, an Autoregressive model with p lags $AR(p)$ is employed to examine whether there is any autocorrelation among the lags of the time series of hedge fund returns (Fernando, 2022).

Moreover, an Moving Average model at q lags $MA(q)$ is also utilized, to evaluate whether there is autocorrelation among the lags of the error term in the time series of the hedge fund returns.

4.3 The effect of short-selling factors on hedge fund returns

Once we have determined the relationship between the short-selling factors and the stock returns, and the statistical properties of the hedge fund returns, the next step is to explore the potential impact of short selling on the hedge funds returns. To do this, we first conduct a time series portfolio approach regression analysis. However, given that our short-selling factors are non-return factors, it is necessary to create mimicking portfolios to facilitate the regression analysis (Fama & French, 1993). A mimicking portfolio is a simulated portfolio that replicates the risk and return characteristics of the short-selling factor. It is noteworthy that mimicking portfolios are created for each short-selling factor individually and the methodology is similar to Chan (1998).

To create the mimicking portfolio, the short-selling factor is split into 10 deciles, ranging from the highest to the lowest. The returns are then matched with the corresponding factor values, and subsequently, a long position is taken in the highest 10th decile, while a short position is taken in the lowest 1st decile. The creation of mimicking portfolios is necessary to estimate the impact of short-selling factors on hedge fund returns accurately. Without this step, it would be impossible to discern the influence of short-selling factors on hedge fund returns.

Next, we conduct a time series portfolio regression, equation 2, between the hedge fund returns and the short-selling mimicking portfolios. This approach loosely follows the calendar time approach of Jank & Smajlbegovic (2017). The time series portfolio regression is conducted by creating a long portfolio of all of the monthly hedge fund returns per each time period. Consequently, we end up with an average hedge fund portfolio return for each time period and short-selling mimicking portfolio factors for each time period. This allows for a time series regression.

$$HfRet_{i,t+1} - R_{f,t+1} = \alpha_{i,t} + \beta_{1,t}SIR_{\text{portf}_{i,t}} + \beta_{2,t}RSI_{\text{portf}_{i,t}} + \beta_{3,t}DTC_{\text{portf}_{i,t}} + \beta_{4,t}SF_{\text{portf}_{i,t}} + \varepsilon_{i,t} \quad (2)$$

In equation 2, $HfRet_{i,t+1}$ is the return of the portfolio for each portfolio i , one period ahead, $t + 1$. $R_{f,t+1}$ refers to the one period ahead risk-free rate. $\alpha_{i,t}$ is the intercept term, representing the dependent variable when all the independent variables equal zero at time t for each portfolio i . SIR_{portf} , RSI_{portf} , DTC_{portf} , and SF_{portf} are the independent variables, the mimicking portfolios of the short-selling factors, with a β of their own representing their respective coefficient at time t for each portfolio i .

4.4 The cross-section of hedge funds and their characteristics

After assessing the statistical distribution of the hedge fund returns and the way they're impacted by the short-selling factors, the cross-section of hedge fund returns is further investigated. Specifically, the outperformance of hedge funds is explored by analyzing whether outperforming hedge funds relate positively or negatively to the shorting factors. The idea is to see whether outperforming hedge funds have a different relationship with the shorting factors relative to the underperforming ones. Before examining this, each hedge fund is regressed individually on each of the short-selling factors from January 2010 - December 2020. Then, only the hedge funds that have a significant relationship with the short-selling factors are selected. Afterwards, those are split into hedge funds that relate positively on the short-selling factors and the ones that relate negatively to the short-selling factors. Finally, a hypothesis test is conducted where the null hypothesis is that the difference between the mean of the hedge fund returns that relate positively to a given short-selling factor and the ones that relate negatively to that short-selling factor is zero. In the case of mean comparison between different characteristics of hedge funds, hypothesis testing can help determine whether there is a significant difference between the means of two or more populations (Wilcox, 2021). This approach is commonly used in finance to analyze differences between groups and make informed investment decisions (Seth, 2021). It allows financial analysts to test specific hypotheses about the population parameters of interest, such as whether the means of two populations are equal or whether a given asset or portfolio outperforms a benchmark index. This analysis is important because it allows us to determine whether whether outperforming hedge funds tend to relate positively or negatively on the short-selling factors.

Lastly, I examine hedge funds characteristics to determine their impact on hedge fund performance. By examining these characteristics, the extent to which they determine the exposure of the hedge funds on the short-selling factors is explored. In other words, whether they impact the hedge fund's relationship with the short-selling factors. The characteristics of hedge funds can be divided into two types: quantitative, which are represented by numerical values, and qualitative, which are represented by textual values. The effect of the quantitative characteristics on hedge funds is checked through a mean comparison hypothesis testing. The null hypothesis is that the mean difference of the characteristic is zero. The characteristics are separated such that one group contains hedge funds that positively relate to a given factor, and the other group contains hedge funds that negatively relate to the same factor. In contrast, for the qualitative characteristics, the percentage of hedge funds that positively relate to each short-selling factor is portrayed in figures.

Diving into the cross-section of hedge funds and their characteristics will provide us valuable additional insight about how outperforming hedge funds are impacted by the shorting

factors and whether their attributes play a role in it.

5 Results and Analysis

In this section, descriptive statistics will be presented first to provide a comprehensive overview of the data. Following this, the results are presented and discussed to draw meaningful insights.

5.1 Descriptive statistics

Table 1 presents the descriptive statistics of the data used in this research paper. The data includes 200,357 observations for each short-selling factor, i.e., SIR, RSI, DTC and SF. The SIR factor has a moderately low average, 0.045, with the smallest amount of variability, 0.059. The percentile of 0.008 and the median percentile of 0.024 show that most of the values of SIR are clustered towards the lower end of a distribution. The RSI has a low average with a higher amount of variability than SIR. The values for SIR are distributed towards zero with a slight skew towards negative values. The DTC factor has the highest average of 3.268 and the highest variability of 13.104. According to the percentiles, the DTC values are skewed towards higher values and in the upper tail of the distribution. The SF average is a slightly negative average with a relatively low variability. The values are distributed around zero with a slight skew towards negative values.

Moving on to the stock returns and the hedge fund returns in Table 1, stock returns have a relatively higher average than hedge funds with a much higher variability of 7.141. Stock returns seem to be clustered around 1 with some extreme values in the upper tail of the distribution. On the contrary, the number of hedge fund observations is 132 due to the time series portfolio approach that is conducted. Moreover, the returns seem to be clustered around zero with a slight skew towards negative values.

Table 1: Descriptive Statistics of Independent and Dependent Variables

	N	Mean	SD	Percentile				
				1 st	25 th	Median	75 th	99 th
SIR	200357	0.045	0.059	0.000	0.008	0.024	0.057	0.275
RSI	200357	0.034	1.497	-0.098	-0.035	-0.004	0.034	0.481
DTC	200357	3.268	13.104	0.018	0.848	1.916	3.775	17.248
SF	200357	-0.001	0.432	-0.676	-0.412	-0.071	0.411	0.675
Stock returns	200357	2.330	7.141	0.790	0.990	1.014	1.561	25.066
Hedge fund returns	132	0.582	1.441	-2.236	-0.059	0.573	1.237	4.299

Note. This table reports the descriptive statistics of the log-transformed independent variables, which are the short-selling factors (SIR, RSI, DTC, SF), and the dependent variables, which are stock returns and hedge fund returns. RSI uses SIR data from 2009-2020 because it uses the annual average of SIR in its calculation. The calculations of the rest of the variables use data from 2010-2020. Percentiles are also shown to depict the distribution of the values in more detail. The hedge fund returns represent the returns of the time series portfolio.

Next, Table 2 presents the correlation between each short-selling factor. The largest correlation coefficient is between SIR and DTC, i.e., 0.173, indicating a positive between those two factors. There is only one negative relationship, which is very weak, -0.001 and is between RSI and SF. The remaining correlation coefficients are very weak, indicating that there is very little linear relationship between the factors.

Table 2: Correlation table of the short-selling factors

	SIR	RSI	DTC	SF
SIR	1			
RSI	0.019	1		
DTC	0.173	0.002	1	
SF	0.005	-0.001	0.001	1

Note. This table reports the correlation coefficients of each log-transformed short-selling factor with itself and the other shorting factors.

5.2 Stock returns and short-selling factors

The first hypothesis states that short-selling factors should reflect the bearish expectations on the stocks meaning they are negatively correlated to future excess stock returns. This suggests that investors have bearish expectations on stock returns when they short the respective stock, hence this should be reflected on the decreasing stock returns. This hypothesis is tested out with portfolio sorting and the Fama-Macbeth (1973) regressions.

The portfolio sorting results show that the average stock returns for each quantile portfolio of every short-selling factor are positive and highly statistically significant at 1% level with the t-statistics ranging from 13.8 to 45.05 and P-values very close to 0. This shows that each of the five portfolios from the various factors produce significant positive excess returns in the 10-year period from 2010-2020. The average return of the difference portfolios for SIR, RSI, DTC, and SF are: -0.406, 0.366, 0.232, and -0.032, respectively (Table 3). However, only the SIR and RSI difference portfolio average returns are significant. The SIR portfolio difference return is significant at 1% level with a t-statistics of -4.53, Table 3. The -0.406 SIR negative difference return suggests that the lowest SIR quantile average return is higher than the highest SIR quantile average return. This indicates that the SIR factor negatively impacts stock return. Specifically, it means that for every percentage increase in the logarithm of the highest SIR quantile, the returns will decrease by -0.406 percent. Heavily shorted firms are found to experience significant negative returns (Desai et al., 2002b). Hence, our result is in line with the financial literature because a high SIR means that a large number of investors believe that the stock is overvalued and are willing to bet against it (Diether, Lee, & Werner, 2008; Senchack & Starks, 1993; Asquith et al., 2005; Boehmer et al., 2008; Engelberg et al., 2012; Desai et al., 2002b). This can create a negative sentiment

around the stock and lead other investors to also sell their shares, driving down the stock price.

On the contrary, the RSI portfolio positive difference return of 0.366 is significant at 10% level with a t-statistics of 1.97, Table 3. Since RSI is a measure of how the current short interest rate compares to its historical average over the past 12 months, it takes into account the change in short interest over time and provides a more dynamic view of market sentiment towards a stock. In some cases, an increase in short interest over the past few months may signal that investors are becoming more bearish on a stock and may lead to negative returns in the short term. However, if the short interest rate has been declining over the past 12 months and the current rate is still below its historical average, this may indicate that the market sentiment is becoming more bullish towards the stock, despite the recent increase in short interest. Additionally, there may be other factors that are positively impacting the stock, such as strong earnings growth or positive news announcements, that are outweighing the negative sentiment from short-sellers. In general, it's important to consider multiple factors when analyzing the relationship between short interest rates and stock returns. Moving on to DTC, we see an insignificant portfolio difference return between the lowest DTC quantile average return and the highest DTC quantile average return, Table 3. This contradicts a study by Hong et al. (2015), which argued that DTC is a better predictor of poor stock returns than short interest ratio, as DTC can capture the marginal trading costs of short-selling. However, our findings suggest that DTC is not a significant predictor of negative stock returns. Similarly, SF also turns out to have an insignificant portfolio difference return between the lowest SF quantile average return and the highest SF quantile average return, Table 3. Despite our finding, several studies in the literature suggest otherwise. For instance, Wang et al. (2020) and Comerton-Forde et al. (2016) have found evidence of an inverse relationship between shortflow and future stock returns. Moreover, Yan (2019) also shows that shortflow can be a powerful predictor of negative stock returns and that short sellers may possess private information.

In general, according to the findings of our paper, only SIR and RSI show significant relationships with the stock returns. SIR has a negative relationship and RSI has a positive relationship at a lower significance level from that of SIR. Perhaps, the relationship between short interest and stock returns is not always straightforward, and there could be some variations based on the time horizon being considered. It is possible that in the short term, SIR may affect returns negatively, while in the longer term, RSI may affect returns positively. This is because a high short interest ratio over a longer time period indicates a larger number of borrowed shares that need to be bought back, which increases the probability of unexpected positive news driving up the share price. This could create a problem for the

short sellers who have to buy the shares back, since they'll have to pay a higher price than they initially sold them for.

Table 3: Portfolio Sorting based on each Short-Selling Factor

Reti-Rf	SIR	RSI	DTC	SF
Lowest	2.103*** (27.84)	2.090*** (30.56)	1.951*** (26.51)	2.723*** (22.27)
Portfolio 2	2.892*** (30.54)	2.707*** (18.86)	2.885*** (34.01)	2.722*** (21.98)
Portfolio 3	3.214*** (16.27)	2.654*** (29.11)	2.939*** (19.06)	2.106*** (19.73)
Portfolio 4	2.671*** (15.28)	2.719*** (17.85)	2.637*** (13.18)	2.332*** (27.54)
Highest	1.691*** (53.82)	2.456*** (15.30)	2.182*** (18.08)	2.691*** (19.34)
Highest - Lowest	-0.406*** (-4.53)	0.366* (1.97)	0.232 (1.58)	-0.032 (-0.16)

Note. This table reports the average monthly portfolio returns (in percent) their corresponding t-statistics in parentheses for equal-weighted portfolios. The portfolios are sorted into 5 quantiles according to SIR, RSI, DTC, SF. The lowest portfolio refers to quantile 1 and the highest portfolio refers to quantile 5. The last row reports the average monthly portfolio return (in percent) that goes long in the highest and short in the lowest portfolio. The sample period is January 2010 - December 2020. The t-statistics, p-values, and standard errors are calculated using the Newey and West (1987) adjustment with six lags. Statistical significance: * p_i0.10, **p_i0.05, ***_i0.01.

Fama-Macbeth (1973) regression results regarding the first hypothesis show that SIR impacts excess stock returns negatively with a coefficient of -3.710, a t-statistics of -2.92—and highly significant at 1% level. This means that for one percentage increase in the SIR, the future excess returns will decrease by 3.710 percent. This coefficient indicates a negative statistically cross-sectional relation between SIR and future excess returns. This finding

is similar to the portfolio analysis SIR finding because in both approaches, SIR seems to show a statistically significant negative correlation with future excess returns. As previously mentioned, short sellers who believe that the stock is overvalued and are betting against the stock, may actively sell the stock to drive its price down, creating a self-fulfilling prophecy. As the price drops, more investors may also sell their shares, further driving down the stock price.

The RSI coefficient of -0.023 is negative unlike the positive coefficient in the portfolio analysis but statistically insignificant with a t-statistics of -0.06 . Similarly, the DTC positive coefficient of 0.032 is statistically insignificant with a t-statistics of -1.05 .

However, the negative SF coefficient of -0.170 is statistically significant at 5% level with a t-statistics of -1.99 . This shows that for every percentage increase in the SF factor, the future excess returns will decrease by 0.170 percent. Similarly, to short interest rate, a high shortfall suggests that there is a bearish sentiment among investors and that they believe the stock price will decline. This can lead to a decrease in stock returns, as the negative sentiment can lead to decreased demand for the stock and a decline in its price. However, the difference between the two lies in how they measure this sentiment and the context that they are used in. Short interest rate measures the percentage of a company's outstanding shares that have been sold short, while shortflow measures the actual number of shares that have been sold short. Short interest rate can be affected by changes in the number of outstanding shares, as well as changes in the overall size of the company. For example, if a company issues new shares, the short interest rate may decrease even if the number of shares sold short remains the same. On the other hand, shortflow is not affected by changes in the number of outstanding shares, so it may provide a more accurate measure of the level of bearish sentiment among investors. Additionally, short interest rate can be used to calculate other metrics, such as days to cover, which can give investors an idea of how long it may take for all short positions to be closed out. Shortflow, on the other hand, is not commonly used in this way. In summary, shortflow and short interest rate can indicate a bearish sentiment among investors and potentially predict a decrease in stock returns. However, they measure investor sentiment differently and are used in different contexts.

Finally, the last three Fama-Macbeth regressions (column 5, 6, and 7, Table 4), exploit the advantage of Fama-Macbeth (1973) which is when the specification controls for multiple independent variables. The idea here is to see whether the statistical significance between the future excess returns and the specific short-selling factor remains after controlling for the effects of the other short-selling factors (Bali et al., 2016). The SIR 1% statistical significance is shown throughout all the last three regressions, Table 4. However, the absolute size of the SIR coefficient increases as we add each additional controlling variable in column 5, 6, and 7,

respectively. The SIR coefficient decreases by 1.767 when we add the RSI controlling factor, it decreases by 4.959 when we add RSI and DTC, and it decreases by 4.11 when we include all the short-selling factors. This means that the addition of each short-selling factor, the decreasing effect that SIR has on future excess returns increases, as the significance remains the same at 1% level. Similarly, the 5% significance level also remains for the SF factor in the last regression when we control for all the short-selling factors. Interestingly enough, the SF coefficient also increases in absolute value. Precisely, it decreases by 0.05 percent. The decrease is much smaller than what we see in the SIR factor, however we can confidently say that the inclusion of all of the controlling short-selling factors brings out the negative correlation of SIR and SF with future excess returns more prominently.

Table 4: Fama-Macbeth regressions of the short-selling factors on the stock returns

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
SIR	-3.710***				-5.477***	-8.305***	-7.820***
	(-2.92)				(-4.20)	(-2.99)	(-3.45)
RSI		-0.023			0.534	0.507	0.497
		(-0.06)			(-0.90)	(-0.90)	(-0.91)
DTC			0.032			0.061	0.061
			(-1.05)			(-1.39)	(-1.37)
SF				-0.170**			-0.220**
				(-1.99)			(-2.00)
Constant	2.693***	2.544***	2.475***	2.531***	2.749***	2.731***	2.755***
	(-19.13)	(-17.64)	(-22.00)	(-17.58)	(16.04)	(-19.78)	(-17.92)
R ²	0.002	0.003	0.002	0.003	0.005	0.007	0.009
Adj. R ²	-0.003	-0.002	-0.003	-0.002	-0.005	-0.008	-0.011
N	200357	200357	200357	200357	200357	200357	200357

Note. This table reports the Fama-Macbeth (1973) regressions between each short-selling factor and future excess stock returns. The coefficients are shown with their corresponding t-statistics in parentheses. N refers to the number of observations. The sample period is January 2010 - December 2020. The t-statistics, p-values, and standard errors are calculated using the Newey and West (1987) adjustment with six lags. Statistical significance: * p_i0.10, **p_i0.05, ***p_i0.01.

Overall, the two statistical methodologies of portfolio analysis and Fama-Macbeth (1973) show that SIR has an inverse relationship stock returns at 1% level. RSI shows a significant positive relationship with stock returns only through portfolio sorting at a lower significance level of 10%. Whereas, SF was found to have an inverse relationship with stock returns only through the Fama-Macbeth (1973) regressions at 5% level. From this, we can say that SIR is the most influential factor with future excess returns because its significance remains robust to both asset pricing approaches. RSI would be considered to have a weaker significance and the only positive coefficient compared to SIR and SF thus its relevance could be further

explored. Whereas SF remains significantly robust when controlling for all the short-selling factors in the Fama-Macbeth regression. Thus, SIR and SF are the only two factors that do not reject the null hypothesis. They can be considered as the two main short-selling factors that negatively affect future excess stock returns and this could be the investor expectations playing out into the declining stock returns due to the overall bearish sentiment that might exist in the stock market.

5.3 Time series statistical properties

The Dickey-Fuller stationarity test turns out to reject the null hypothesis at a very high level of t-statistics, i.e., -9.65 , Table 5A, Appendix A. This indicates that the time series does not have a unit root and thus is stationary. However, there can still be other factors that might affect the stationarity of the time series. Rejecting the null hypothesis in the Dickey-Fuller test provides some evidence for stationarity but further investigation and analysis are required to confirm the stationarity of the data. It is important to note that statistical tests like the Dickey-Fuller test, are based on assumptions and have limitations. Therefore, we use other methods and techniques to confirm the stationarity of the data. We perform a visual inspection of the time series plots through an autocorrelation plot and a partial autocorrelation plot.

To further investigate the stationarity of the data, the autocorrelation function (ACF) and partial autocorrelation function (PACF) graphs are plotted to determine if there is any autocorrelation present at different lags, Appendix A, Figure 1A and 2A. In both figures, only the first lag seems to be positively significant for both the ACF and PACF. This indicates a first-order AR and MA process, Table 5. Thus, this degree of autocorrelation can be potentially captured with an AR(1) and MA(1) model.

The AR(1) and MA(1) coefficients in Table 5 are not statistically significant, with z-scores of -1.14 and -1.25 , respectively. This suggests that the residual correlation in the time series may not be significant enough to affect its stationarity. Overall, while the AR and MA coefficients may suggest some residual correlation in the time series, the evidence still supports the conclusion that the time series is stationary.

5.4 Time series portfolio approach on hedge fund returns

After having observed the stationarity, temporal dependence, and trends of our data set, we are ready to explore whether short-selling factors have a positive relationship with hedge fund returns, the second hypothesis. This will be done by discussing the results of the time

series portfolio regression hedge fund returns on mimicking short-selling factor portfolios.

The SIR factor mimicking portfolio in Table 6, column 1, has a negative coefficient of -0.926 with an absolute t-statistics of -1.82 and is statistically significant at 10% level. The low value of 0.036 in this model can be explained by the fact that short selling is only one of several investment strategies employed by hedge funds. While it may play a role in their overall performance, it is not necessarily a dominant factor given that hedge funds tend to focus on long positions. Therefore, the limited impact of short selling on hedge fund returns likely contributes to the low R² value observed in the model. This suggests that SIR has a negative relationship with hedge fund returns, for every percentage increase in the SIR, hedge fund returns will decrease by 0.926 . The drop in value is economically significant because hedge funds usually operate on a scale of billions of dollars which would make a drop of almost 1% in returns a substantial loss. However, the economic significance of the drop in value should still be evaluated based on the specific context and characteristics of the hedge fund in question.

The negative decrease in hedge fund returns suggests that there is a correlation between the SIR short-selling factor and hedge fund returns. Considering that we proved that SIR is negatively related with stock returns through portfolio sorting and Fama-Macbeth (see Table 3, column 1, and Table 4, column 1), we also inferred that short sellers are well-informed traders, however, it seems that even though hedge funds can be well-informed traders on shorting, they might not necessarily profit out of shorting. The reason could be because perhaps hedge funds don't short as much out of speculative reasons but rather for hedging strategies.

The observed decline in hedge fund returns presents evidence that short selling might not be as profitable for hedge funds. Although our previous findings suggest that SIR negatively impacts stock returns and support the idea that short sellers are informed traders, it is important to note that hedge funds, despite being informed traders, may still have limited abilities to generate profits from such shorting activities. This could be because hedge funds are less likely to engage in speculative shorting, and more likely to use shorting as part of their hedging strategies.

According to a study by Asquith et al. (2005), hedge funds are unlikely to generate significant value from short-selling stocks because the only class of stocks that consistently produces negative returns are small-cap stocks with high short interest ratios, which have a relatively small total value. Therefore, even if all hedge funds could short sell these stocks, the value generated would be minimal compared to the estimated total assets under management by the hedge fund industry. However, Massaoud et al. (2011) finds that short-selling of hedge funds make economically significant profits. Hedge fund investors who engage in

short-selling are likely the primary contributors to the SIR short-selling factor. Assuming that these investors accurately predict the declining value of the targeted stock, their short positions should result in profits when the stock price falls, thereby increasing the returns of the hedge fund. However, it's important to note that there are other factors that can influence hedge fund returns, and that short-selling carries risks as well as potential rewards.

The RSI factor mimicking portfolio in Table 6, column 2, has been found to have a negative coefficient of -0.008, with a t-statistic of -0.30 and statistically insignificant. However, in column 6, the regression of both SIR and RSI yields an SIR with a higher coefficient in absolute value and also a higher significance level than in column 1. The SIR coefficient decreases by 0.513 percent relative to the SIR in column 1, making the new SIR coefficient -1.439. The addition of the RSI factor in column 6 seems to increase the SIR coefficient by 0.49 in absolute value, indicating that the SIR factor has a stronger impact on hedge fund returns when the RSI factor is also included in the model. The value of 0.061 is clearly the highest in column 6, where both SIR and RSI are included relative to column 1 and 3, however, it's important to notice that the adjusted value of 0.038 in column 6 is the highest one out of all the models in Table 6, suggesting that this model explains the largest proportion variability of the hedge fund returns. It is not surprising to see that RSI turned out insignificant (column 2 and 6), especially since it was shown that it has a significant positive relation with stock returns in portfolio sorting (see Table 3, column 2) and insignificant in the Fama-Macbeth approach (see Table 4, column 2). The positive relation with stock returns implies that a persistently bearish sentiment in the market and an excessive number of short positions over the long term are unlikely to result in profitable negative stock returns. As a result, RSI may simply not be a reliable indicator that can impact hedge fund returns. It is worth noting that while the RSI factor has the potential to provide insights into how short interest affects hedge fund returns in the long term, it may not be as useful as SIR in explaining hedge fund returns due its statistical insignificance in this model.

The DTC factor mimicking portfolio, Table 6, column 3, also has a negative coefficient of -0.232 with a t-statistics of -0.58 and is statistically insignificant. Moving on to the regression of all three factors together, column 7, RSI and DTC remain insignificant. Whereas, SIR remains significant at the 5% level with a slight increase of the t-statistics by 0.1 in absolute value relative to the t-statistic in column 6. The SIR coefficient decreases even by 0.137 percent relative to the SIR in column 6, making the new SIR coefficient -1.576. The value from column 6 to 7 increases slightly by 0.005, whereas the adjusted decreases by 0.006. It is expected that DTC does not have a significant relation with hedge fund returns because in both approaches of portfolio sorting and Fama-Macbeth, DTC did not have a

significant relation with stock returns either (see Table 3, column 3, and Table 4, column 3).

The SF factor mimicking portfolio, Table 6, column 4, shows a positive coefficient of 0.225 with a t-statistics of -0.63 and statistically insignificant. Finally, the last regression model, column 8, shows that with the inclusion of all factors, the SIR significance level of 5% remains and its coefficient decreases by 0.022, making the new SIR coefficient -1.598. What is worth noting is that SIR remains significant through all of the regressions in Table 6, and increases its significance consecutively from column 1 to column 8. It is evident that the last model in the analysis has the highest value among all models. However, the adjusted R2 value for this model is not the highest, which could be attributed to the insignificance of the short-selling factors, with the exception of SIR.

Overall, based on the regression models presented in Table 6, there is evidence to reject the second hypothesis that short-selling factors have a positive relationship with hedge fund returns. More specifically, the results indicate that the SIR factor actually has an inverse relationship with hedge fund returns, which contradicts our original hypothesis. In addition, the relationship between the other short-selling factors and hedge fund returns cannot be statistically confirmed as they were found to be insignificant in our analysis. The reason for SIR to turn out significant is clear because SIR has a significant relationship with negative stock returns both through portfolio sorting and the Fama-Macbeth procedures. The significant SIR performance was unlike the other short-selling factors because none of the other factors turned out significant in both portfolio sorting and Fama-Macbeth regression. RSI and SF were significantly related to stock returns only in the portfolio sorting and Fama-Macbeth, respectively. For that matter, RSI impacts stock returns positively which indicates that bearish betting of hedge funds on the stocks might not turn out successful. Moreover, even though SF negatively predicts stock returns in Fama-Macbeth regressions, it does not seem to be a significant factor for hedge fund returns.

Another potential explanation as to why SIR turned out to be a significant indicator of hedge fund returns could be the way SIR is calculated. To remind us again, SIR is calculated as shares held short relative to shares outstanding. Perhaps, SIR is the most accurate in representing short selling, even though days-to-cover and shortflow have also been shown in previous studies to predict negative stock returns. Short interest is known as the conventional indicator for arbitrageurs' short selling. As previously mentioned, it is used in multiple studies as a way to represent short selling. Not only that, but it has also been found as the strongest predictor of stock returns (Rapach et al., 2016). However, a working paper by Hong et al., (2015) found that days-to-cover is a stronger predictor of negative stocks returns than short interest ratio. This raises the question of the widely traditional use of short interest when examining short selling in stock returns. Nonetheless, since DTC was

found insignificant in portfolio sorting and the Fama-Macbeth procedure, our findings suggest that SIR is a more powerful measure for short selling and having a stronger relationship with stock returns and hedge fund returns. A plausible reason could be that they capture different aspects of short selling. For example, short interest provides a more comprehensive view and more of a steady level of short interest in a stock, taking into account the total number of shares outstanding. Whereas, days-to-cover measured as short interest relative to total trading volume, can be influenced by large fluctuations in trading volume. Total trading volume, unlike shares outstanding, is a more volatile metric because it represents the actual buying and selling activity in the market which usually varies daily (Nickolas, 2022). Conversely, shares outstanding is a more steady metric that refers to the total number of shares that a company has issued and are available for trading (Chen, 2022). These shares are reported to the Securities and Exchange Commission (SEC) on a quarterly basis, making them very stable and less likely to vary over time. Therefore, according to our findings, SIR seems to be more of a consistent measure of short selling hence it also shows a significant relationship with hedge fund returns. However, the reason why it impacts negative hedge fund returns negatively could be attributed to the fact that most of the short selling that hedge funds do is for hedging strategies rather than speculative. Although, to determine the motivational incentives of hedge funds, the simultaneous change in short interest and hedge fund holdings needs to be observed (Jiao et al., 2016). If they both increase, they are likely to be driven by hedging incentives, otherwise if they go opposite directions, they are likely to be driven by private information. Hence, it cannot be concluded if hedging incentives drive the negative relationship of SIR with hedge fund returns, it still remains a viable possibility.

The other notable findings was that shortflow, the second most commonly used short selling measure, did not significantly predict hedge fund returns. Shortflow had a significant negative relationship only with stock returns in the Fama-Macbeth procedure and not in portfolio sorting. Shortflow, calculated as short trading volume relative to total trading volume, can also be considered as a more volatile metric compared to short interest ratio, which might be a reason why it may not be significantly related to hedge fund returns. Prior studies show mixed evidence whether short sellers are informed about upcoming negative announcements. However, a recent study by Wang et al., (2020) finds that shortflow does not significantly increase before the release of bad news, indicating that short sellers do not derive their predictive power mainly through private information. Therefore, it is possible that hedge funds do not base their trades on private information, which could explain why why in this study, shortflow does not appear to be significantly related to hedge fund returns.

Table 6: Short-Selling Factors and Hedge Fund Returns

Mimicking Portfolio	(1)	(2)	(3)	(4)	(6)	(7)	(8)
SIR	-0.926*				-1.439**	-1.576**	-1.598**
	(-1.82)				(-2.31)	(-2.41)	(-2.44)
RSI		-0.008			-0.029	-0.016	-0.020
		(-0.30)			(-0.97)	(-0.45)	(-0.56)
DTC			-0.232			-0.459	-0.350
			(-0.58)			(-0.71)	(-0.53)
SF				0.225			0.281
				(0.63)			(0.77)
Constant	0.109***	0.410***	0.186***	0.389***	-0.164	-0.012	-0.075
	(15.39)	(3.85)	(2.75)	(3.70)	(-0.61)	(-0.06)	(-0.22)
R^2	0.036	0.001	0.004	0.005	0.061	0.066	0.073
$Adj. R^2$	0.025	-0.011	-0.007	-0.007	0.038	0.032	0.028
N	86	86	86	86	86	86	86

Note. This table reports ordinary least squares regressions between each short-selling mimicking portfolio factor and future excess hedge fund returns. The coefficients are shown with their corresponding t-statistics in parentheses. N refers to the number of observations. The sample period is February 2010 - December 2020. The standard errors are calculated using the Newey and West (1987) correction. Statistical significance: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

5.5 The cross-section of hedge fund returns

In the following section, I delve into the range of diversity in our hedge fund dataset to explore the outperformance of hedge funds, mainly which hedge funds relate positively and which hedge funds relate negatively to each short-selling factor. The mean comparison hypothesis testing includes the null hypothesis that the difference between the mean of

two groups of the hedge fund returns is zero. One group includes hedge fund returns for which those hedge funds are positively related to a given shorting factor, and the other group includes hedge funds that are negatively related to that same factor. The results of this hypothesis testing are shown in Table 7. DTC turns out to be the only factor with a significant t-statistics of -2.01 — at 5% level, Table 7. This means that the null hypothesis is rejected and the mean of the hedge funds returns that relate positively on DTC is significantly higher than the mean of the hedge fund returns that relate negatively on DTC, due to the positive t-statistics. This indicates that hedge funds that relates positively on DTC, perform better than those that show a negative relationship. A higher DTC means that it would take more days for short-sellers to cover their short positions (Hong et al., 2015). This could result from a combination of high short interest and/or low total trading volume. If better performing hedge funds relate positively on DTC, it might indicate that these funds are taking larger short positions in stocks with higher DTC ratios. This could happen due to a few reasons. Better performing hedge funds might have more private information or skills and experience that enable them to identify overvalued stocks more easily and faster, hence they short stocks with a higher DTC. They might also have a higher risk-tolerance which allows them to take on more significant short positions in stocks with higher DTC. The other three short-selling factors, SIR, RSI, and SF turn out to be insignificant (Table 7), meaning that for them the null hypothesis is not rejected. This further implies that there is no significant difference on the mean return between the hedge funds that relate positively and those that relate negatively. Overall, it is intriguing to see that DTC is the only significant factor for which outperforming hedge funds have a positive relationship. Afterall, this may suggest that DTC is a more accurate indicator of low expected stock returns, capturing the marginal cost of an arbitrageur’s short position more effectively than SIR (Hong et al., 2015). This finding applies to all of the hedge funds that were found to have a significant result on all of the short-selling factors.

Table 7: The effect of hedge fund outperformance with respect to the short-selling factors

Returns	SIR	RSI	DTC	SF
(1)	(0.79)	(-1.08)	(2.01)**	(-1.33)

Note. This table shows the t-statistics of the following null hypothesis: there is no significant difference between the mean return of hedge funds that positively relate to a given shorting factor and the mean return of hedge funds that negatively relate to the same factor. The data sample consists of only hedge funds that relate significantly to each short-selling factor. Statistical significance: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

5.6 Hedge fund characteristics

In this final section, I analyze the characteristics of hedge funds in order to assess their influence on the hedge funds' performance. Through this analysis, I investigate how these characteristics influence the relationship of hedge funds with the short-selling factors. To assess the impact of quantitative characteristics on the relationship that hedge funds have with the shorting factors, a hypothesis testing for a mean comparison is applied (Table 8). Whereas, for the qualitative characteristics, I display the percentages of hedge funds that relate positively to each short-selling factor (Appendix B).

The quantitative hedge fund characteristics include: assets under management (AUM), net asset value (NAV), minimum investment, maximum leverage, personal capital amount, and age. AUM refers to the total amount of assets that a hedge fund manages on behalf of its clients (Chen, 2022). AUM is often used as a metric for size. For instance, a study by Edelman et al., (2013) showed that larger hedge funds have more assets under management relative to smaller hedge funds, according to the "Hedge Fund 100" list. Another study by Getmansky (2012) also uses AUM as a proxy for size. Hence, it is one of the most commonly used metrics to proxy the size of hedge funds and it often indicates the success of the hedge funds. The impact of size on short selling can vary. Larger funds may have advantages such as easier access to collateral, lower costs, and better risk management when shorting (Jank & Smajlbegovic, 2015). These benefits can enable them to engage in short selling more effectively.

NAV, however, refers to the difference between total assets and liabilities of a hedge fund divided by total shares outstanding (Chen, 2022). NAV is commonly used as a performance indicator and risk monitoring tool for hedge funds to mitigate adverse events, according to the European Central Bank (2022). It is possible that changes in NAV could affect the hedge fund's decision to engage in short selling. For example, a higher NAV usually means that the fund has generated greater returns than the losses it has incurred in its investments. Thus, funds with higher NAV may have a larger capital, more resources and experienced personnel to engage in short selling.

Minimum investment is usually set by hedge fund managers and is the minimum subscription amount that an investor is required to invest in order to participate in a hedge fund (Ross, 2021). A higher minimum investment may indicate that the hedge fund is targeting wealthy and more sophisticated investors who have substantial amounts of financial resources and are willing to take more risk. A lower minimum investment may indicate that the fund is targeting a broader range of investors, including those who may not have as much wealth or investment experience.

Maximum leverage refers to the percentage amount of leverage that they can borrow

relative to the hedge fund's wealth (Barth, Hammond, & Monin, 2020). In general, hedge funds leverage their investments by borrowing money to increase investment exposure as well as risk (SEC, n.d.). The maximum leverage of a hedge fund can vary depending on the strategy and the risk management practices of the hedge fund. Hedge funds that employ higher leverage in their portfolios may have a higher desire for risk, which could lead them to engage in short selling.

Personal Capital amount refers to the amount of capital that the principal of the hedge fund has invested into the fund. The personal amount of capital invested by the principal of the hedge fund may increase the total capital available to the fund, which could potentially increase the amount of short selling that the fund can undertake. However, this would also mainly depend on the investment strategy of the fund and its risk appetite.

Lastly, age will be calculated by subtracting inception date from the performance date as computed in a study by Jank & Smajlbegovic (2017), in contrast, however, I use the performance end date instead of position date due to the data availability constraint on TASS - WRDS. Inception date refers to the time the fund launched and began its operations. Performance end date refers to the last date on which the performance of a hedge fund is measured. Research on the age of a hedge fund has shown mixed evidence on whether younger hedge funds perform better in short sales or not (Jank & Smajlbegovic, 2015). Despite the extensive research on the quantitative characteristics mentioned, it remains crucial to investigate whether each specific characteristic influences the hedge fund's coefficient on each short-selling factor.

Finally, I conduct the hypothesis testing similarly like in section 5.4, where only the hedge funds that have a significant relationship with the short-selling factors are considered. The null hypothesis is that the mean difference of the characteristic is zero. The characteristics are separated such that one group contains hedge funds that positively relate to a given factor, and the other group contains hedge funds that negatively relate to the same factor.

The results of the hypothesis testing on the quantitative characteristics are shown in Table 8. AUM, the size characteristic, remains statistically insignificant across all of the short-selling factors (Table 8, row 1). In other words, the size of the hedge fund turns out to not be important in influencing whether the hedge fund relates positively or negatively to each of the short-selling factors. Moving on to NAV, only DTC is statistically significant at 5% level. This implies that the mean of the hedge funds' NAV's that relate positively to DTC is statistically different from the mean of the hedge fund returns that relate negatively to DTC. Moreover, the mean of the NAV's that have a negative relationship with DTC, is higher than the mean of the NAV's with a positive DTC relationship, due to the negative t-statistics of -2.12 , (Table 8, row 2). This indicates that hedge funds that relate neg-

atively to DTC, have higher net asset values than those that relate positively. This can be attributed to a few different reasons. A higher net asset value indicates that the hedge fund has better financial performance and that there's lower likelihood for a default event (ECB, 2007). Such hedge funds may be more advanced in their risk management and limit their exposure to stocks with high DTC. A high DTC can indicate more difficulty in borrowing stock for short-selling which can lead to increased transaction costs or not being able to close the short positions in a timely manner (Hong et al., 2015). Better performing hedge funds, such as those with a higher NAV, are more skilled at avoiding such stocks. At the same time, it can also be the case that these hedge funds are either unsuccessful at speculative shorting or that their primary focus for shorting is hedging.

Moreover, DTC turns out to be even more statistically significant, at 1% level, for minimum investment (Table 8, row 3). The observation implies that the mean of the minimum investment for hedge funds that relate negatively to DTC is statistically different and higher than the mean of those that relate positively, due to the negative t-statistics of -2.48 . A higher minimum investment requirement for hedge funds allows them to target only wealthy investors with a certain level of financial resources (Ackermann et al., 1999). The idea is so that they can be selective with their investments and ensure exclusivity to their clients. Because these hedge funds deal with greater amounts of capital, and take on higher risk, they tend to be more sophisticated and earn higher returns in general. For the same reason mentioned above, such outperforming hedge funds may be better at limiting their exposure towards high DTC stocks. Minimum investment seems to also play a role for the shortflow as well. Similarly, the mean of minimum investment for hedge funds that relate negatively to SF is statistically different and higher than the mean of those that relate positively with a negative t-statistics of -2.15 (Table 8, row 3). This finding suggests that minimum investment is an important characteristic when considering the exposure of hedge funds to shortflow. Hedge funds with higher minimum investment requirements may also be more cautious and able to avoid stocks that are heavily shorted, hence the negative relationship with SF. Maximum leverage and personal capital amount do not seem to be statistically significant, thus they appear to not be relevant characteristics when considering the hedge fund's exposure to short selling. At last, the age of the fund shows to be a significant characteristic for three short-selling factors, RSI, DTC, and SF. The null hypothesis is rejected, meaning that the mean of the age of the hedge funds that relate negatively is statistically different and higher than the mean of those that relate positively for all of the three short-selling factors. This is supported by the negative and statistically significant t-statistics of -2.07 , -1.67 , and -2.73 for each factor respectively, as shown in Table 8, row 6.

The implication is that older hedge funds relate negatively to RSI, DTC, and SF. It

is likely that older hedge funds have more experience and an established reputation which can lead to them generating higher returns and also avoiding heavily shorted stocks. Yet, the majority of studies in the literature show that younger hedge funds outperform older ones generally due to their innovative investments and better education. Jones (2006) found that younger and smaller hedge funds offer better performance than larger and older ones. Another study by Pástor et al., (2015), discovered that younger hedge funds tend to perform better because they are more equipped and skilled, possibly due to better education and proficiency in using modern technology. Jank & Smjalebgovic (2017) provide evidence that suggests that younger hedge funds may perform better due to their ability to trade on mispricing factors, but the effect is weak and not statistically significant. Nevertheless, the findings of this paper demonstrate that hedge funds that relate negatively to RSI, DTC, and SF, tend to be older. The negative relationship with the shorting factors implies that either their speculative shorting activity is unsuccessful or their primary motive for shorting is hedging. On the one hand, their unsuccessful speculation could be due to a variety of reasons, such as market-inefficiencies, poor-decision making, or inadequate analysis. On the other hand, the negative relationship could be caused by their hedging strategy which is not intended to maximize returns but rather mitigate risk. That means that during unfavorable market conditions, hedge funds would encounter smaller losses due to the risk minimization, however during favorable market conditions, the short positions may partially offset the gains made in long positions, leading to reduced overall profits. It is beyond the scope of this paper to determine which one of these hedge fund strategies could lead to the negative relationship. However, that can be a topic to be explored in further research.

Table 8: The significance of hedge fund characteristics on hedge fund performance

	SIR	RSI	DTC	SF
(1) AUM	(-0.01)	(-0.78)	(-1.34)	(-0.48)
(2) NAV	(0.31)	(0.23)	(-2.12)**	(-1.40)
(3) Min. Investment	(-0.94)	(-0.08)	(-2.48)***	(-2.15)**
(4) Max. Leverage	(-0.86)	(0.62)	(1.12)	(-0.10)
(5) Personal Capital Amount	(1.58)	(-0.24)	(0.62)	(0.41)
(6) Age	(0.97)	(-2.07)**	(-1.67)*	(-2.73)***

Note. This table shows the t-statistics on the following null hypotheses: there is no significant mean difference between the group of hedge funds that positively relate to a given short-selling factor and the group that negatively relates to the same factor, within each characteristic. The data sample consists of only hedge funds that have a significant relationship with each short-selling factor. AUM refers to assets under management. NAV refers to net asset value. Statistical significance: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Moving on to how qualitative characteristics affect the relationship of the hedge funds with the shorting factors, two important qualitative characteristics are included, asset class and country. Investing in different asset classes is important for hedge funds as it allows for diversification, reduces risk, and enhances returns. It provides hedge funds with the flexibility to implement dynamic trading strategies and take advantage of market opportunities across various markets (Fung & Hsieh, 1999). The asset class is important for shorting for hedge funds because it can impact volatility, liquidity, short interest, and the impact of macroeconomic factors on short selling performance. Additionally, it helps in better risk management by balancing the portfolio's risk exposure according to the fund's objectives and risk tolerance. The hedge funds in the data sample invest in various asset classes, including equity, fixed income, commodity, currency, property & other, sector focus, investment approach, geographic focus, and investment focus. These different types of asset classes will be investigated further. Similarly, just like asset class, country is also a very important characteristic for hedge funds. The country in which a hedge fund is shorting can impact its performance due to variations in regulatory environment, market structure, economic conditions, and political and geopolitical risks. Hedge fund managers must consider these factors when shorting stocks in different countries. Our data covers hedge funds from 48 countries, but only the ones that represent at least five hedge funds are considered. These countries include the Cayman Islands, Hong Kong, Ireland, Isle of Man, United Kingdom,

United States, Luxembourg, Singapore, Switzerland, and Bermuda.

The first four figures in Appendix B show how each asset class affects the relationship of the hedge funds with each of the short-selling factors (Figure 1B, Figure 2B, Figure 3B, and Figure 4B). Specifically, each figure shows the percentage of hedge funds that relate positively with the given short-selling factor. For example, in Figure 1B, out of all the hedge funds that invest in one particular asset class, around 80% relate positively to SIR. This trend is seen across all of the asset classes on average on SIR in any particular way. However, it is worth noting that the majority of hedge funds across various asset classes generate positive returns from short-selling activities, suggesting that asset class does not necessarily have an adverse impact on hedge funds' short-selling performance.

In Figure 2B, out of all the hedge funds that invest within each asset class, only 40% of them relate positively to RSI. Similarly, this trend is also seen across all of the asset classes on average. This indicates that asset class does not seem to influence the relationship of hedge funds with RSI either. However, the majority of hedge funds, i.e. 60%, within each asset class relate negatively to RSI. Since the outcome is consistent across all asset classes, it is unclear whether asset class is the sole reason for the negative performance, suggesting that there may be other factors contributing to this outcome.

Figure 3B, shows that out of all the hedge funds that invest in each asset class, around 20% of them relate positively to DTC. Again, the same trend is shown across all the asset classes on average, indicating that asset class is not a significant characteristic in affecting the relationship of the hedge funds with DTC. However, what is significant is that the majority of hedge funds, around 80%, out of each asset class, relate negatively to DTC. The same observation occurs for Figure 4B, where the majority of hedge funds, around 80%, within each asset class, also relate negatively to SF. Overall, asset class does not seem to be an important characteristic to affect the relationship of any of the four short-selling factors. Nonetheless, the relationship of the majority within each asset class differs. It is only positive for SIR and negative for the rest of the factors. However, it's difficult to draw further conclusions as there may be other factors, such as hedge funds' specific strategies, that could have a more significant impact on the relationship with the short-selling factors.

Moving on, Figure 5B, 6B, 7B, and 8B show how the country affects the relationship of hedge funds, Appendix B. Figure 5B displays the proportion of hedge funds that exhibit a positive relation to SIR, categorized by their respective countries of origin. Out of all the hedge funds from the Cayman Islands, Isle of Man, Ireland, United Kingdom, and United States around 80% of each country on average relate positively to SIR. Whereas, out of all the hedge funds from Hong Kong, only 55% of them relate positively to SIR, making Hong Kong the country with the lowest positive relation to SIR. The rest of the countries relate positively

at around 80% on average. This outcome could be a result of the differences in short-selling restrictions and legislative laws between Hong Kong and the rest of the countries. A study by Jain (2012) shows that short-selling restrictions in a country reduce borrowing in that country by 45%. Figure 6B shows the percentage of hedge funds that relate positively to RSI per each country. It generally displays more variability among countries than Figure 5B. The highest percentage of hedge funds that relate positively to RSI are from Luxembourg, i.e. around 75%. Whereas, the lowest percentage of hedge funds that relate positively to RSI are from the Cayman Islands, i.e. around 35%. Overall, this figure portrays it better that country is a significant characteristic that affects the relationship of hedge funds with RSI. Figure 7B, shows the percentage of hedge funds that relate positively to DTC, per country. The figure shows that the percentage of hedge funds that relate positively per country is very low, around 20%. Moreover, Figure 7B portrays the least variability among countries, making country a less significant factor for DTC.

Lastly, Figure 8B, shows the percentage of hedge funds that relate positively to SF per country. It portrays more variability among countries than Figure 7B, however the hedge funds of the majority of countries seem to relate negatively to SF, just like in Figure 7B.

To summarize, asset class did not turn out to be a significant characteristic in determining the relationship of hedge funds with the short-selling factors due to the invariability of the hedge funds' relationship with the shorting factors within each asset class. However, country as the second characteristic showed more variability, suggesting that it affects the relationship that hedge funds have with short selling more than asset class. Specifically, the country seemed to show the most variability with regards to RSI, indicating that it could be an important factor that impacts the short selling performance of hedge funds. Although exploring the reasons behind this is beyond the intended focus of this paper, it is worth noting that different legislation laws and rules regarding short-selling in each country may be potential factors.

6 Conclusion

The central question of this study was “How does short selling affect hedge fund returns in the period of 2010 to 2020”? To explore this question, it is first hypothesized that the short-selling factors, SIR, RSI, DTC and SF, have a negative relationship with US stock returns. This hypothesis was not rejected only for the SIR factor as SIR was found to significantly impact stock returns negatively both through portfolio sorting and the Fama-Macbeth (1973) regressions. Whereas, SF does not reject the hypothesis testing only through the Fama-Macbeth approach (1973) and not through portfolio sorting. The other two factors

were found insignificant. Perhaps, the consistent negative relationship of SIR and SF with stock returns that was found across multiple studies, is the reason why these are the two most shorting metrics used in the literature (Reed, 2013; Wang et al., 2020; Boehmer et al., 2008; Diether et al., 2008).

Moving on to the second hypothesis which states that the short-selling factors have a positive relationship with hedge fund returns, a time series analysis is first performed on the hedge fund portfolio time series. The time series analysis showed that the hedge fund portfolio time series is stationary with insignificant residual autocorrelation that seems to not impact the stationarity of the time series. This analysis is important to ensure accuracy and reliability of the time series regression results. Regarding the second hypothesis, the SIR factor was found to have a significant negative relation with hedge fund returns, contrary to the null hypothesis. The rest of the factors, RSI, DTC, and SF, are statistically insignificant. Thus, the second hypothesis was rejected by all of the shorting factors because none of them showed a significant positive relationship with fund returns. The significance of short interest rate might be attributed to its ability to impact stock returns negatively through both portfolio sorting and Fama-Macbeth (1973) procedure, as well as its consistency as a short-selling measure compared to the more volatile metrics like days-to-cover and shortflow. The negative correlation between short interest rate and hedge fund returns could potentially stem from hedge funds engaging in short selling primarily for hedging strategies rather than speculative purposes (Wyckoff, 1959). It is important to note, however, that the exact motivations behind hedge fund short selling cannot be definitively determined without further analysis. Specifically, to fully understand the motivations behind the short interest rate and hedge funds, the simultaneous change in short interest rate and hedge fund holdings should be considered, as suggested by Jiao et al (2016).

Lastly, the cross-section of hedge funds is investigated to further explore how hedge fund characteristics impact the relationship of hedge funds with the shorting factors. Initially, the focus is on which hedge funds relate positively and negatively to each factor. The results revealed that outperforming hedge funds relate positively to DTC relative to the ones that relate negatively to DTC. The other shorting factors were found to be insignificant. Although this cross-sectional analysis applies only to hedge funds that significantly relate to all of the short-selling factors, it may suggest that after all DTC might capture the marginal cost of short selling better than short interest rate, as Hong et al. (2016) suggests. Secondly, it is further investigated how quantitative and qualitative characteristics impact the relationship of hedge funds with the shorting factors. In general, a performance indicator, such as NAV, minimum investment and age are found to be significant characteristics that show the relationship of the hedge funds with some of the shorting factors. Hedge funds

with higher NAV relate negatively to DTC. Better performing hedge funds might be more skilled at avoiding stocks that are more difficult to borrow, such as those with a high DTC. Hedge funds with a higher investment minimum requirement relate negatively to DTC, and SF. Such hedge funds are usually more sophisticated in the sense that they tend to target wealthier investors, thus they might be better at limiting their exposure towards stocks that are heavily shorted, such as those with a high DTC and SF.

Older hedge funds relate negatively to RSI, DTC, and SF. Although literature suggests that younger hedge funds tend to outperform older ones due to their innovative investments and better education (Jones, 2009), we found that older hedge funds tend to relate negatively to RSI, DTC, and SF, which may indicate unsuccessful speculation or a primarily risk-mitigating hedging strategy. Additionally, out of the qualitative characteristics, only the country of a hedge fund seemed to have an impactful significance on the relationship that shorting factors have with hedge funds. Perhaps, various legislative laws, market structure, and geopolitical environment may affect investment decisions and therefore the performance of hedge funds (Jain, Jain, McInish, & McKenzie, 2013).

A key limitation of this study is that it primarily focuses on investigating the impact of short selling on hedge fund returns solely through the speculative shorting perspective. It is well-established that hedge funds engage in short selling for a variety of reasons, with hedging being a predominant motivation (Wyckoff, 1959). Consequently, the scope of this research is limited to offer an empirical analysis of short selling on hedge funds. This is mainly because the study does not delve into the different motivations behind short selling, such as the proportions attributed to speculative shorting, hedging, market making, and other ones. Further research can focus on dissecting the shorting activities to determine the different motivations and their implications on hedge fund returns.

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Appendix

Appendix A: Time series analysis

Table 5: Time series analysis tests for the hedge fund portfolio returns

	Dickey-Fuller	AR(1)	MA(1)
Coefficient		-0.093	0.060
	(-9.65)***	(-1.14)	(-1.25)

Note. This table reports the t-statistics of the Dickey-Fuller test and the z-scores of the AR(1) and MA(1) models in parentheses. Statistical significance: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

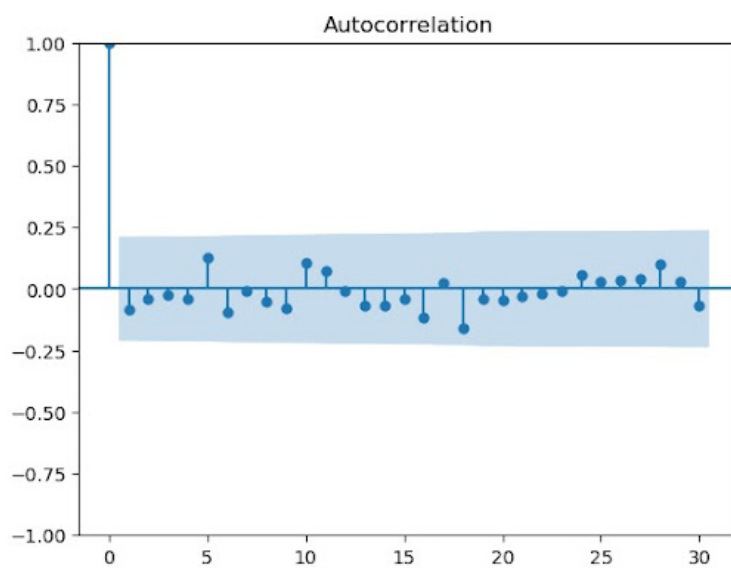


Figure 1: ACF of the time series hedge fund portfolio returns

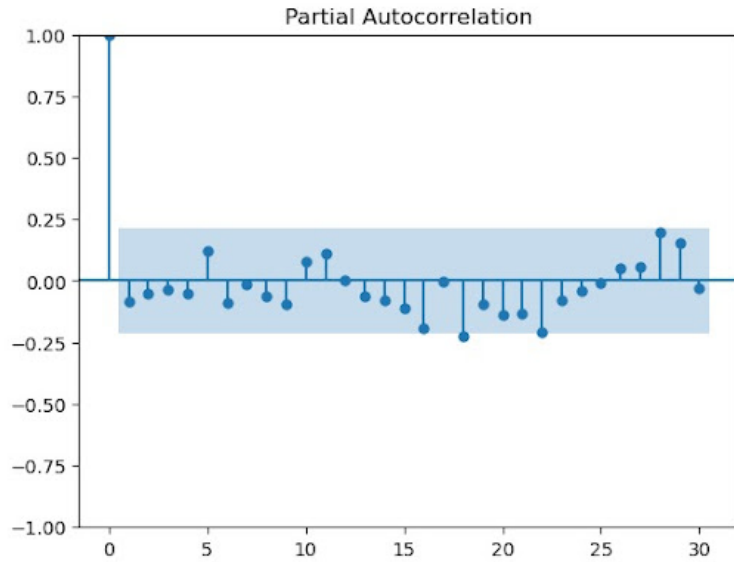


Figure 2: PACF of the time series hedge fund portfolio returns

Appendix B: Qualitative characteristics

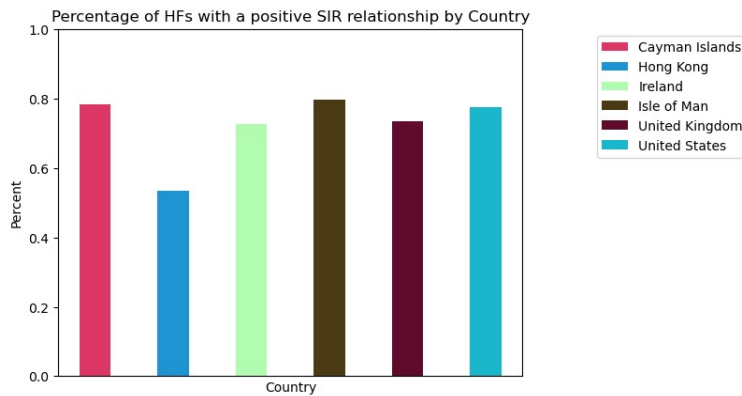


Figure 3: Hedge funds' positive SIR coefficient per asset class

Note This figure shows the percentage of hedge funds per asset class that positively relate to SIR. Each column represents the following asset class respectively: equity, fixed income, commodity, currency, property & other, sector focus, investment approach, geographic focus, and investment focus. The data sample consists of only hedge funds that have a significant relationship with each short-selling factor.

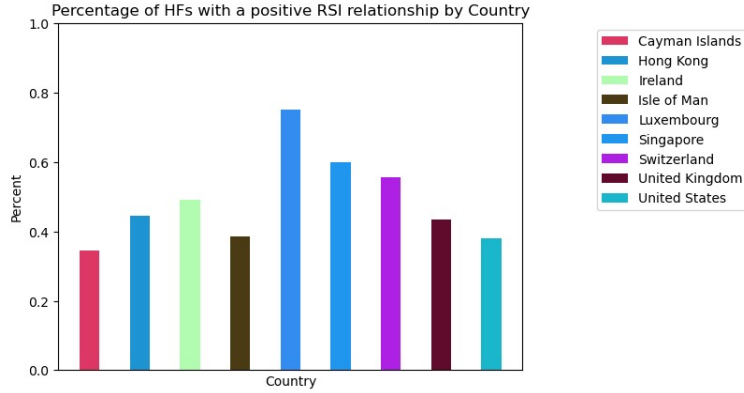


Figure 4: Hedge funds' positive RSI coefficient per asset class

Note This figure shows the percentage of hedge funds per asset class that positively relate to RSI. Each column represents the following asset class respectively: equity, fixed income, commodity, currency, property & other, sector focus, investment approach, geographic focus, and investment focus. The data sample consists of only hedge funds that have a significant relationship with each short-selling factor.

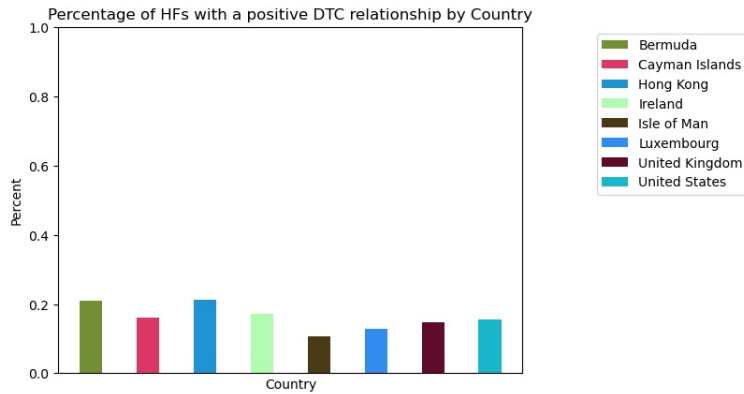


Figure 5: Hedge funds' positive DTC coefficient per asset class

Note This figure shows the percentage of hedge funds per asset class that positively relate to DTC. Each column represents the following asset class respectively: equity, fixed income, commodity, currency, property & other, sector focus, investment approach, geographic focus, and investment focus. The data sample consists of only hedge funds that have a significant relationship with each short-selling factor.

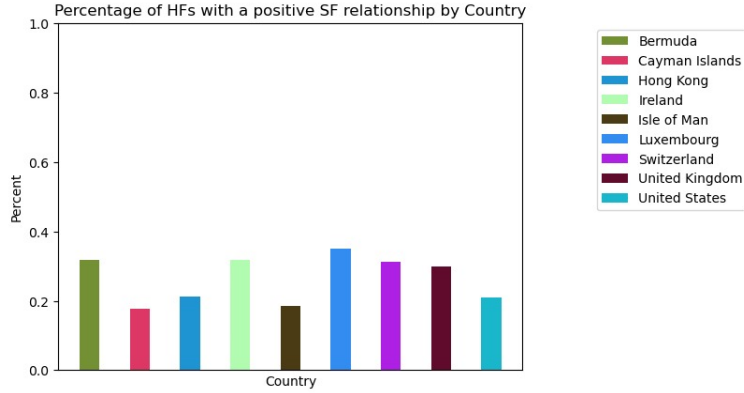


Figure 6: Hedge funds' positive SF coefficient per asset class

Note This figure shows the percentage of hedge funds per asset class that positively relate to SF. Each column represents the following asset class respectively: equity, fixed income, commodity, currency, property & other, sector focus, investment approach, geographic focus, and investment focus. The data sample consists of only hedge funds that have a significant relationship with each short-selling factor.

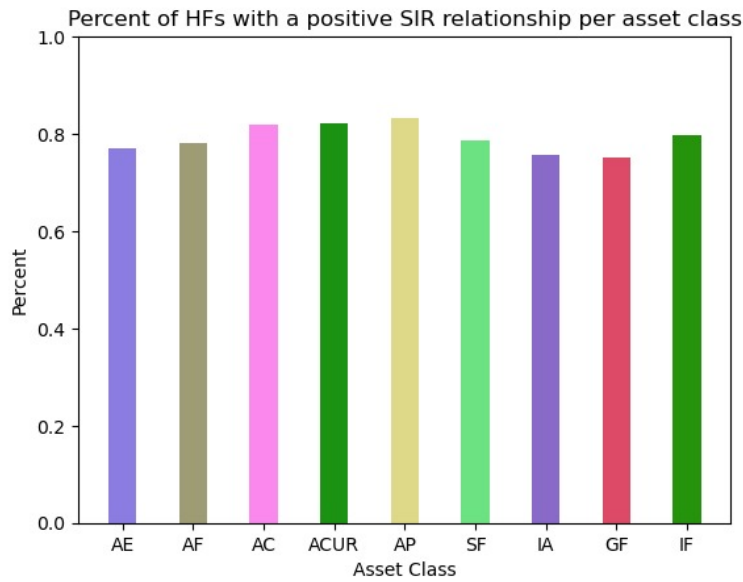


Figure 7: Hedge funds' relation to SIR per country

Note This figure shows the percentage of hedge funds per country that positively relate to SIR. The data sample consists of only hedge funds that have a significant relationship with each short-selling factor.

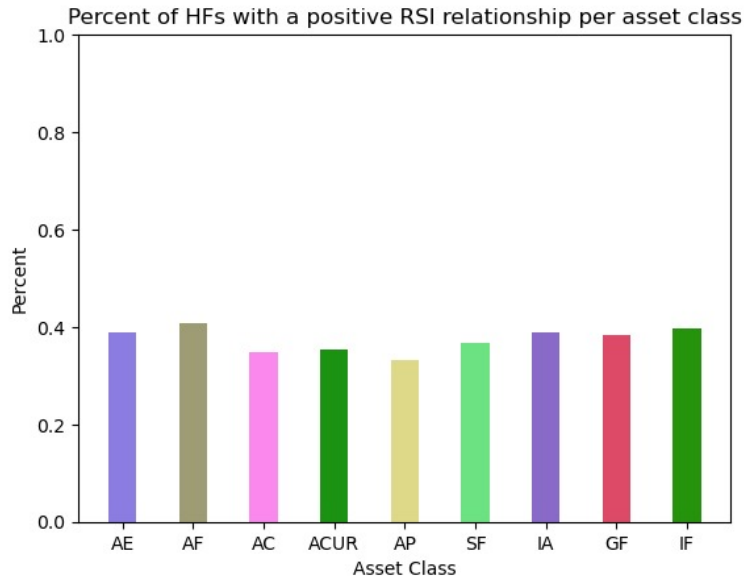


Figure 8: Hedge funds' relation to RSI per country

Note This figure shows the percentage of hedge funds per country that positively relate to RSI. The data sample consists of only hedge funds that have a significant relationship with each short-selling factor.

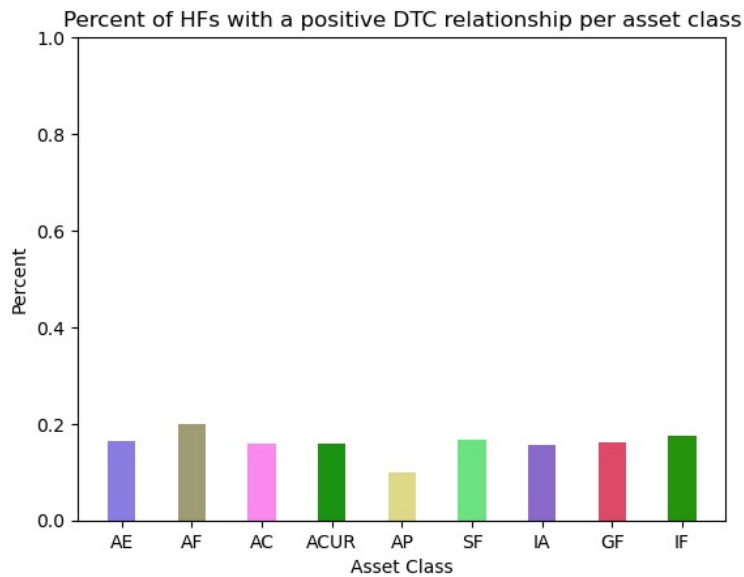


Figure 9: Hedge funds' relation to DTC per country

Note This figure shows the percentage of hedge funds per country that positively relate to DTC. The data sample consists of only hedge funds that have a significant relationship with each short-selling factor.

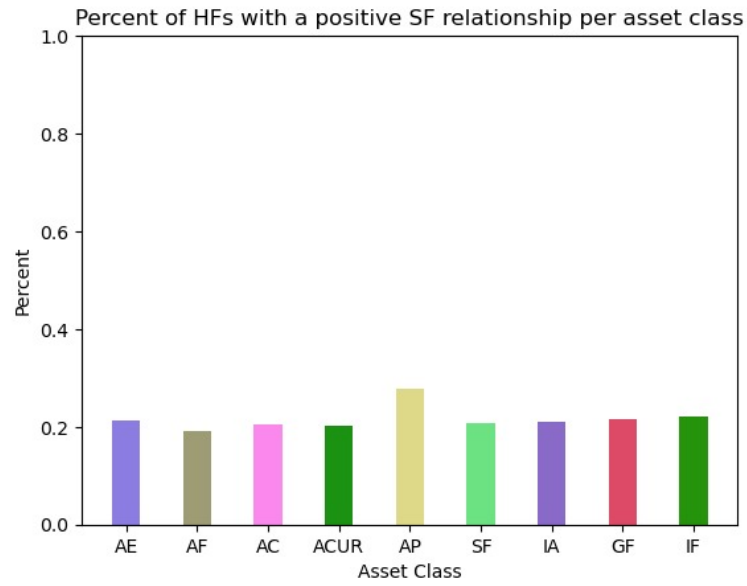


Figure 10: Hedge funds' relation to SF per country

Note This figure shows the percentage of hedge funds per country that positively relate to SF. The data sample consists of only hedge funds that have a significant relationship with each short-selling factor.