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That's the Spirit: An Analysis of Investment in Collectible Whisky

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ABSTRACT

This study investigates the financial performance of collectible whisky. By using sales data of over 60,000 individual sales from two of the leading online whisky auction houses over the period 2011 – 2020 a comprehensive hedonic regression is applied to discover price determinants and create a collectible whisky price index in tandem with a repeat sales methodology. This process allows for risk & return measures to be derived. Collectible whisky is found to have a monthly real return ranging from 1.19% to 3.44% while exhibiting high return volatility, especially on the upside. Its investment performance is compared with other common financial assets and whisky is found to outperform equities, real estate, and commodities but underperform relative to fixed income. Diversification opportunities are explored; collectible whisky is uncorrelated with other financial assets. This prompts the creation of an optimised portfolio where collectible whisky receives allocations ranging from 7% to 21% which is consistent with allocations collectibles receive in existing literature. An investor seeking the possibility to realise high gains whilst also wishing to diversify their current portfolio should strongly consider collectible whisky.

Keywords:
Investment Decisions, Alternative Assets, Collectibles, Diversification, Portfolio Choice

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1 Introduction

The world is growing ever thirstier for a bottle of whisky. In the last decade the markets for collectible whisky have experienced an explosion in popularity. Connoisseurs, collectors, and investors alike have crusaded this outcome yet despite this research on the investment performance of whisky remains in its infancy. Given its current state in the economy collectible whisky satisfies the criteria of a collectible. Collectibles have gained the attention of investors and researchers as a result of their potential to realise high gains, their increased accessibility thanks to online auctions, and their resilience to shocks in global financial markets.

The objective of this paper is to pioneer this specific field of study. Specifically, it attempts to answer the following questions: *what is the risk and return profile of collectible whisky as a financial asset, what are the price determinants of collectible whisky, how does investment in collectible whisky perform relative to other common financial assets,* and finally *does collectible whisky investment offer diversification benefits to an investor's portfolio?* To find an answer, data for over 60,000 individual collectible whisky auction sales is retrieved from two of the leading international online UK-based auction houses over the period 2011 – 2020. The paper employs detailed auction data to run a hedonic regression which discovers price determinants and constructs a price index. In tandem with the hedonic regression index, a repeat sales regression approach (Case & Shiller, 1987) is also used to create another price index - from this, risk and return measures can be derived. Under the hedonic approach the monthly real return for collectible whisky is found to be 3.44%, and for the repeat sales model: 1.19%. Collectible whisky outperforms equities, real estate, and commodities but underperforms relative to fixed income over the period of consideration. If returns of collectible whisky is uncorrelated with returns of other financial assets then its introduction into a portfolio could provide diversification benefits, this is found to be the case. Finally, an optimised portfolio is constructed where collectible whisky receives an allocation of 7% under the hedonic model and 21% using the repeat sales model. This is consistent with allocations collectibles have received in previous literature although whisky receives slightly more.

Although investment performance of art and collectibles has been heavily researched collectible whisky is yet to have received the same degree of attention. This paper therefore employs the techniques used in collectibles literature to addresses an obvious gap. By doing this, this paper is able to build on existing alternative assets and collectibles research in the context of finance. This is ever important in this day and age as financial markets have been turbulent, notably having suffered from the 2008 global financial crisis, dwindling growth throughout the 2010s, and the recent Corona crisis pandemic. This has prompted individual and institutional investors to look elsewhere in their investment strategy in the hopes of finding a safe haven for their assets.

The paper is structured as follows: section 2 outlines definitions and perspectives on alternative assets, collectibles, and whisky, section 3 reviews existing literature, section 4 describes the methodology, section 5 discusses the data, section 6 explains the results, and section 7 concludes the findings.

2 Definitions and Perspective

2.1 Alternative Assets

An alternative asset or alternative investment is a broad term; it is considered to be anything that is not simply a long position in a traditional financial investment. Otherwise put, it is an investment that isn't in fixed-income, publicly traded equities, or cash (Chambers et al., 2015). This provides a lot of possibilities for what an alternative asset could be. They can be divided into two categories: those that are tangible, and those that are intangible. Tangible alternative assets include commodities, art, wine, precious metals, antiques, cars, stamps, and so on. Intangible alternative assets include but are not limited to: investment in private equity, mutual funds, hedge funds, or financial derivatives. Contrary to what the name suggests, some alternative assets play such a prominent role in today's investors' portfolios that they no longer strike one as being 'alternative'. This is especially the case for commodities, real estate, and financial derivatives. Individual investors and institutions engage in an investment from a desire to earn future returns that exceed the value of their initial outlay and recompense the time interval of the investment period. Alternative assets attract investors since they provide a set of qualities that are not commonly found in traditional assets such as the ability to generate excess returns through long term, high risk, or illiquid investments, realising diversification benefits through low correlation with other assets, inflation-hedging benefits, and the ability to scale through large investment sums (World Economic Forum, 2015).

This paper considers a type of alternative asset that is not as commonly found in investor portfolios as others - collectibles. The literature surrounding popular alternative assets is extensive, whereas for certain collectibles this remains to be fully explored.

2.2 Collectibles

Belk (1995) defines the nature of collecting as: "*the process of actively, selectively, and passionately acquiring and possessing things removed from ordinary use".* Almost always, the price that is paid for such collectibles exceeds the intrinsic value of the item. Collectors rarely acquire these items so that they can be put to their proper use, but rather they are kept in a state of preservation. Some build collections with the intention to sell in the future and realise a profit, others intend to keep them as family heirlooms, while in some cases their use is postponed until a significant life event – for example, opening a vintage bottle of wine at a wedding. Because of this, someone who considers themselves a collector might not necessarily consider themselves an investor despite collectible items falling under a branch of alternative assets. Beyond intrinsic value rarity plays a huge role in determining the collectability of an item (explaining why many collectibles are old items), as does popularity: either of the item itself or of the producer. A limited-edition Mercedes-Benz will fetch a high resale price because of its rarity, and because people value Mercedes.

In the finance literature, many have investigated the opportunities that collectibles present in generating excess risk-adjusted return as well as for diversification benefits (Burton & Jacobsen, 1999; Mei and Moses, 2002; Campbell, Koedijk, & de Roon, 2009; Dimson & Spaenjers, 2014). The term *'emotional assets'* was coined by Campbell et al. (2009), they found that investors are willing to forego financial return in exchange to invest in items that they value for personal reasons. This provides evidence that investors incorporate both their own and societal values into the portfolio management process.

A bottle of whisky is considered to be collectible provided that it satisfies the following conditions. First, it must be produced in limited quantity and its production constrained to a finite period. The distillery must no longer have the capacity to produce more bottles of that particular type. Second, it must have a certain degree of appreciation by the market such that collectors are willing to trade it. Provenance is important; a bottle from an unheard-of distillery could indeed be rare, yet the lack of reputation may disqualify it from being collectible.

2.3 Collectible Whiskey

Whiskey is a spirit that is produced from a variety of grains. Those most commonly used are barley, corn, rye, and wheat. It is first distilled, and then aged in wooden casks before it is bottled[1]. The time spent in cask is therefore referred-to as the whiskey's *age*. Age varies amongst different whiskies, each type generally having minimum aging requirements. *Vintage*, however, refers to the year in which the whiskey was distilled. While there are a multitude of factors that impact the taste of a whiskey, those most influential are the grain from which it is made and the barrel in which it is aged. The alcoholic content (ABV) of whiskey is typically at least 40%. There are many types of whiskey: Single Malt, Scotch, Irish, Bourbon, Japanese, and Blended to name a few. Each are distilled using varying ingredients and techniques. Blended whiskey is as the name implies; it is composed of a mixture of whiskey types. Notably, bottles of Single Malt tend to be most sought-after since they take longest to produce, and inferior Single Malts tend to be relegated into blended whiskey. Single Malts are so distinguishing that some collectors track only the performance of these[2]. A benefit of acquiring whiskey as an asset is its longevity; it can be preserved in the bottle indefinitely provided it is kept in the right conditions, this is unlike the case for wines which are deemed to have a peak.

This study considers only rare, collectible whiskey - price movements of retail whiskey are not contemplated. Therefore, it will focus on whiskey traded above a certain price point on the secondary market, not available to buy en-masse from a retailer.

2.4 Collectible Indices

Measuring returns of asset classes such as real estate, art, and collectibles is not as straight-forward as it is for traditional assets like equities and bonds. They all have a significant drawback in common; it is difficult to systematically measure their financial performance and value fluctuations because of the high levels of heterogeneity across the asset class (each house, artwork, collectible item differs to a certain extent) and the fact that such assets trade

[1] Whisky Guide. whisky.com
https://www.whisky.com/fileadmin/Webdata/Uploads/Whisky/Free_Stuff/RatgeberA5_en_V1.0.pdf

[2] Rare Whisky 101 Single Grain Index. https://www.rarewhisky101.com/indices/market-performance-indices/single-grain-100-index

infrequently (Ginsburgh, Mei, & Moses, 2006). This drawback does not, however, render index estimation impossible. Regardless of the index construction approach, a sound index can benefit an investor in various ways. Firstly, an index can be a useful tool to appraise an asset's value. If an assumption is made that an underlying asset appreciates at the same rate of the market index, then it is possible to mark-to-market and estimate valuations of said asset. Second, an index provides an overview of market trends which allows for comparisons with other asset classes across time. Further, indexes are able to assess market volatility – correlations amongst other assets can be measured which can therefore provide insight towards possible diversification opportunities. Lastly, one can assess the impact of macroeconomic factors, such as inflation, towards the particular asset market and determine how these impact price movements (Ginsburgh et al., 2006).

2.5 Perspective

This study will take the perspective from a United Kingdom (UK) investor. This is because the United Kingdom is a major financial hub. It can be assumed that a British investor has access to international markets, and therefore they are likely to hold an internationally diversified portfolio. Additionally, whiskey production is concentrated in the UK as well as the country hosting the most international whiskey auctions[3]. The majority of whiskey auction sale records are quoted in British Pounds (GBP). To an extent the choice of a UK investor perspective is somewhat arbitrary: the study considers an alternative asset that has a worldwide reach that any individual could access, and the study places this asset in the context of global financial asset markets. Although sales of rare whiskey are dispersed across the globe, an advantage of using GBP as the base currency is that it becomes possible to control for inflation in the study, where historical UK inflation rates are used.

This study considers data primarily over a monthly, but also over a yearly time horizon. The motivation behind this is that online auctions are commonly held on a monthly basis so the natural graduation would be to match these. Global asset market data is available monthly, however in most cases it is more appropriate to conduct analysis from a yearly perspective.

[3] International Whiskey Auction Houses. https://www.whiskyadvocate.com/where-to-buy-whisky-at-auction/

Further, collectible whiskey has only seen a considerable emergence in the last decade[4] and this study uses data from the beginning of the two thousand and tens onwards.

Collectible whiskey is considered from a financial perspective, that is, as an alternative asset for an individual or institutional investor. This paper does not focus on intrinsic value or the personal, *'emotional assets'* component of value coined by Campbell et al. (2009), neither does it aim to directly answer: *what makes a good bottle of whiskey?* Ultimately, an investor is reasoned only to care about financial return and risk-hedging avenues.

3 Existing Literature

3.1 Investment in Art & Collectibles

In the context of finance alternative assets, namely collectibles, have been studied attentively. This research focuses on the performance of collectibles as a financial investment. A common approach has been to gather sales data for the collectible studied and to construct a hypothetical index for that asset (Mei & Moses, 2002; Campbell, 2008; Masset, Henderson, & Weisskopf, 2010; Ma, 2019). This type of research adapts the collectible so that it may be treated like a financial security, allowing for comparisons and analysis via financial metrics.

Not only do Mei & Moses (2002) analyse returns in art, they address and expand upon previous research that questions whether 'masterpieces' should be bought and also investigate violations of the law of one price. Using data from major auction houses they apply a repeat sales regression approach to create an art index and find that investment in art outperforms fixed-income securities but underperforms relative to stocks. They find that art is less volatile than what previous literature suggests, and that much of this volatility is concentrated amongst masterpieces. From this, they conclude that investors should avoid the most expensive artworks. The law of one price is tested by examining sales prices for identical artworks sold at different houses and mixed results are found, this suggests that auction houses likely operate in imperfect markets where opportunities for arbitrage are available. Surprisingly, Mei & Moses only made a brief investigation into art's correlation with other

[4] Knight Frank Wealth Report 2019. Pg. 78
https://content.knightfrank.com/resources/knightfrank.com/wealthreport/2019/the-wealth-report-2019.pdf

financial assets; something which would have been insightful given that the average investor holds multiple positions. Due to art's heterogeneity (almost every item is unique) and low trading frequency, it can be considered to behave similar to whisky as an asset. Based off these findings, one should consider whether 'masterpiece' whiskies exhibit the same qualities as masterpiece artworks as in the study, and therefore whether they are a worthwhile investment.

Campbell (2008) bridges the gap that Mei & Moses (2002) left open. Like Mei & Moses they investigate returns from art investment but additionally they focus on diversification. As this paper was written in the midst of a global financial crisis the author recognised that many investors were searching for a safe haven to store their wealth. This prompted the question: *how well does art investment perform when diversification is most needed?* This study benefits from a comprehensive dataset as it is one of the first on this topic to use online global auction data, making it more relevant to today's market conditions. Campbell finds that art has considerable diversification benefits, that is, it is extremely uncorrelated with traditional assets - even more so than what previous literature suggested. At the same time, returns on art were in accordance with the findings of Mei & Moses (2002). The paper concludes with some insights for potential art investors. Campbell advises that investors seeking to hold a diversified portfolio should allocate 3%-7% to artworks. A key strength of this paper is that, unlike previous studies, Campbell takes a practical approach to art investment by considering transaction costs and liquidity - the paper is written for the perspective of an investor actually wishing to invest in art. These costs are carefully incorporated into the study so that the performance of art investment can be evaluated as if it were to be practised empirically. This serves as an important consideration for whisky investment as there is the possibility that these often-neglected costs could hinder its performance. In addition, the findings regarding diversification could be benchmarked for this study; does whisky receive a higher or lower portfolio allocation than art?

Masset, Henderson, & Weisskopf (2010) replicate the study of Campbell (2008) but instead they apply it to fine wine. They ruminate around the question: *how well does fine wine perform as an alternative asset and does if offer diversification benefits, especially in times of economic crises?* Again, the authors use auction hammer prices to create a repeat sales index for fine wine and they discover that wine outperforms fixed income as well as equities. This suggests it is superior to art investment. Masset et al. (2010) note that during economic downturns correlations between financial securities tend to increase causing previous diversification benefits to fade away. This was not the case for fine wine, and after constructing optimal portfolios they argue that investors should allocate a small portion of their portfolio towards it. One significant finding of the paper is that the wine market is highly heterogenous in terms of returns: regions [of craft] and price categories evolve differently from one another in terms of sales volume and turnover. This finding is of use to this study as it may be that certain distilleries or whisky-producing regions perform significantly different to others. If this were true a whisky investor could achieve even higher returns by identifying the characteristics of whisky that deliver a premium over others.

As part of a collection of essays, Ma (2019) investigates price determinants and investment performance of paintings. Unlike the previous studies this paper follows a hedonic method in adjacent with a repeat sales method so that an index as well as a regression analysing price determinants can be executed concurrently. The study is the most comprehensive of those discussed, using over two million painting transactions at auction. Ma's (2019) work expands on collectibles literature in two areas: first, it actively decomposes the asset class (paintings) into categories so that it can be identified which types of paintings and which characteristics provide a greater and lesser return than others. This offers detail into a prospective investor's strategy as well as an understanding of art markets. Second, the performance of paintings is compared to other collecting categories in addition to traditional financial assets. While this has been done before (see: Burton & Jacobsen, 1999), this is the first to do so in modern times and with such a large dataset. Doing this allowed collectibles to be benchmarked against one another so that the performance of how paintings fare relative to other collecting categories can be assessed. Ma (2019) finds that paintings share a correlation with certain collectibles as well as commodities and gold, however they are negatively correlated with bonds and equities. Paintings underperform relative to bonds and equities which contradicts the findings of the above researchers, however their risk-return profile is not always inferior. Again, it is found that an optimal portfolio consists of roughly 8% paintings. Ma (2019) makes a refreshing and in-depth review of the characteristics that drive a collectible's price which further bolsters the importance of identifying price determinants within an asset class.

3.2 Investment in Whisky

Research on collectible whisky investment is in its infancy. Hartig, Lennon, & Teltser (2020) investigate the investment performance on a particular type of whisky: Bourbon, which is produced solely in the United States. The authors used two sources: the first was an international whisky auction house based in Germany, and the second was a social media whisky forum in the USA. This second source is of significance as trades were conducted directly from party to party without the intervention of a middleman – this creates a particular setting as laws pose restrictions on the unauthorised sale and re-sale of spirits in certain states of the USA. This created an opportunity to compare prices in a legal market (auction house) with those on an illegal market (social media forum). A Bourbon index is constructed under a repeat sales approach while a hedonic regression is used to analyse price determinants. The authors found that Bourbon prices increased on average 7% per year over the period 2011-2019. They also discovered that markets were fuelled by demand for new releases of Bourbon as opposed to older, perhaps rarer ones. In contrast to Masset et al.'s (2010) findings on fine wine, geography and institution were found not to have an impact on price patterns of Bourbon. The paper is with a few limitations. It is susceptible to sample selection bias as observations without complete information were dropped from the sample; the authors make no indication of using formatting techniques to transfer missing data from one observation to another. Since data from the auction house (the largest sample of the two) was dropped this resulted in a modest quantity of observations for the hedonic regression, and thus no price determinants were analysed for the legal platform: the auction house. The paper furthermore fails to analyse risk or compare the performance of Bourbon to other assets. This gives the research little perspective nor does it provide a clear picture of the investability of this particular type of whisky. Despite these issues Hartig et al. (2020) provide inceptive research on collectible whisky; the findings concerning demand for Bourbon as well as those related to the impact of geography and institution are insightful for this thesis as they contradict previous literatures' sentiment about how markets value and behave towards collectibles.

A limitation encompassing these types of studies is that the avenues to arrive at such an index are diverse. Collectibles are not centralised. Instead they are scattered across different auction houses – some place restrictions on the type of collectible they list, some restrict certain demographics from trading, others will host certain auctions infrequently, and transaction costs can differ greatly. Additionally, and as will be further discussed, indices can differ greatly depending on the approach taken to construct them. The consequence is that this type of literature is sensitive to its inputs, and therefore one must tread carefully when drafting comparisons across works.

3.3 Diversification

The expression: *"don't put all your eggs in one basket"* is synonymous with the concept of portfolio diversification. An investor with a portfolio consisting of a few, closely correlated securities will be subject to a greater degree of risk than the investor with many positions in unrelated ones. Modern Portfolio Theory (Markowitz, 1952) posits that a rational and optimal investor follows a diversified investment strategy, and this has been widely accepted as convention. Nonetheless, while theoretically this should hold true this may not be adopted empirically. Goetzmann and Kumar (2001) investigate this matter and question: *do individual investors hold portfolios that are under-diversified? Which investors are most likely to under-diversify?* This work extends on existing knowledge by splitting diversification into two categories: 'active' diversification which is selecting securities that are uncorrelated with one another, and 'passive' diversification which entails expanding the number of holdings within one's portfolio. Goetzmann & Kumar (2001) focus on three issues: the first is the extent to which individual investors are under-diversified, the second is to explain what is causing under-diversification where it arises, and last to measure the impact that under-diversification has on portfolio performance. Using a large sample (>60,000 individual investors) of U.S. brokerage data over the period 1991-1996 the authors discover a large proportion of individual investors to be under-diversified. This is mainly the case for younger, poorer, and less-educated individuals who tend to be less diversified in their portfolio allocation. They also find that passive diversification tends to be far more prevalent than active diversification. The causes driving under-diversification can be attributed to various factors: transaction costs, incomplete information, stock preferences, and behavioural biases. Although dated, this landmark paper highlights that investors do not behave optimally, that there are many reasons behind this, and that certain investors are generally less optimal than others. This paper benefits this thesis as it provides detail into empirical diversification strategies and the profile of a diversified investor: perhaps an investor diversifying their portfolio with collectible whisky is older, wealthier, and well-educated?

4 Methodology

4.1 Hedonic Regression Methodology

Unlike many conventional financial securities, real assets like housing, art, and whiskey are considerably more illiquid and also highly heterogeneous. Across these assets, price is dependent upon, to some extent, the defining characteristics that belong to it (Gérard-Varet & Ginsburgh, 1995; Ginsburgh, Mei, & Moses, 2006; de Haan & Diewert, 2013.). What this therefore implies is that an asset can be viewed as a bundle of performance characteristics. First proposed by Court (1939) this approach proves that, once isolated, a value can be attributed to each of these defining characteristics which can therefore be used to determine the marginal contribution that each characteristic makes towards the asset's price.

Hedonic methods require a broad perspective as the process involves looking at all the potential factors that may influence the price of the asset as well as those which distinguish one particular asset from another. These can be internal and pertain to the asset itself or can be external which relates to the context in which the asset is placed.

Applying this regression throughout a given time period allows one to produce an estimation of a price index; describing the evolutional pathway of the asset.

Like all financial models, hedonic regressions come with their advantages and disadvantages. A key benefit of the hedonic method is that it reveals consumers' willingness to pay (de Haan & Diewert, 2013). Since data is sourced from actual decisions that consumers have made then it can provide a reliable estimation of value. Another advantage is that, by decomposing characteristics, hedonic methods make it possible to identify and assess asset price determinants. In this way an investor can gain a comprehensive understanding of the asset, they can establish which characteristics have a stronger influence over price than others and apply this knowledge to their investment strategy. Last of all, hedonic methods are versatile; the model can be easily adapted to test for possible interactions between characteristics as introducing additional explanatory variables is a process that can be executed and unwound effortlessly.

One disadvantage in using a hedonic approach is that it can be problematic to source high-quality information on asset characteristics (Case, Pollakowski, & Wachter, 1991). The model’s accuracy is heavily dependent on the data it uses – if the dataset is incomplete, inconsistent, or inaccurate then this will be directly reflected in the regression output and can result in a model that fails to explain return variation. This problem is further amplified when characteristics are not captured because they are hard to identify in the first place, these can be external factors which arise in one period but not necessarily in another. Following this notion, another disadvantage of hedonic models is that they assume that the market’s valuation of characteristics is constant over time. That is, the marginal contribution of a certain characteristic towards price in one period is the same as it is in another. In reality, consumer preferences are fluid. When a hedonic regression is projected over a long timeframe, changing consumer preferences can lead to a distortion of the model.

4.2 Repeat Sales Regression Methodology

A desire to accurately measure growth of the housing industry in the 1960s led to the foundation of repeat sales methodologies. Bailey, Muth, & Nourse (1963) first developed their Repeat Sales Regression (RSR) model which then acted as the framework of further repeat sales designs such as the Case-Shiller Index (1987). While repeat sales has primarily been used in the housing literature, its use has progressed into art index estimation (Goetzmann, 1993; Mei & Moses, 2002) as well as collectibles (Burton & Jacobsen, 1999).
RSR indices are constructed by taking price data on items that have been sold more than once. The return of an asset can be calculated when it is sold in one period, and then again in another. Aggregating these individual returns over a large sample can therefore provide an estimation of value fluctuations of the overall asset class over a particular time period.

An advantage of RSRs is that they are simple: they require few inputs and they are not constructed on a large series of assumptions. The basic repeat sales model requires only an item ID, price, and date of sale in its estimation. Their simplicity allows them to be generated quickly, requiring little computational power, and new sales data can be integrated into an existing model as time progresses. Since RSRs rely on matching assets, then it is unnecessary to control for period-to-period differences in the sample of assets (de Haan & Diewert, 2013). Further, the asset-matching principle allows the model to control for asset characteristics more accurately than hedonic methods which relies on measurement quality of such characteristics and uses them as inputs in the forecasting model (Case & Shiller, 1987).

Mei et al. (2002) note that a major drawback of RSR design is that in most cases only a small sample of the underlying asset is sold more than once. This raises concerns about the extent to which the sample used in the model represents the overall asset class. In this sense, it is important to consider the sample size as a proportion of the total population in the study. Another disadvantage is an assumption the model makes about the quality of the asset over the period in which it is measured (Case & Shiller, 1987). Between the first and second sale, RSRs assume that the quality of the asset does not differ – the extent to which this affects the model depends on the nature of the asset and whether it is likely to be subject to improvement or deterioration, for example: a framed artwork versus a house. Lastly, repeat sales models are vulnerable to sample selection bias. Within the given asset class some assets may trade more frequently than others which could eventually lead to an overrepresentation in the sample. If these particular assets experience price changes that differs from that of the wider asset class then this could potentially distort the index (Mark & Goldberg, 1984).

4.3 Different Index Constructions

There has been considerable debate regarding the method of index construction which is most reliable in measuring returns of art and collectibles. Price indices are usually constructed in one of four ways: hedonic methods, average means, geometric means, and repeat sales regressions. Some have been in favour of repeat sales methods (Case & Shiller, 1987; Goetzmann, 1992) while others argue that hedonic methods provide superior estimation (Mark & Goldberg, 1984; Meese & Wallace, 1997).

Campbell (2008) finds that compared to hedonic approaches, repeat sales methods generate returns that are 10% higher on average. They attribute this to sample selection; under RSRs items that have lost value may not be auctioned for a second time leading to an overrepresentation of assets that have increased in value in the dataset. Despite higher average returns they measure the correlation of both hedonic and repeat sales methods and find them to be almost 90% correlated.

Ginsburgh, Mei, & Moses (2006) compare these methods explicitly. They arrive at the conclusion that there exists an indifference in results across different index construction methods provided that certain sampling conditions are met. Specifically, RSR approaches generate the same results as hedonic methods when the ratio of repeat-sales data to total sales data is high or when the study uses a large timeframe.

The above literature prompts a testable hypothesis for this study. This paper will further the debate by comparing the hedonic approach to the RSR method. Under Ginsburgh et al.'s (2006) theory there should be no difference in index estimation, whereas Campbell's (2008) would suggest higher returns on average for RSRs.

4.4 Portfolio Optimisation: Mean Variance Analysis

Mean Variance Analysis is a section of Modern Portfolio Theory which was developed by Harry Markowitz (1952) who received a Nobel Prize in Economics for his work. It is a simplification of reality in the context of investor portfolio allocation choice wherein investors are concerned only about expected return and risk. Expected return is drafted by calculating the mean return from a historical series, while risk is derived by computing the variance. The end product allows investors to make decisions about which assets to invest in for a given return that is based on the amount of risk that they are willing to accept. Mean Variance framework finds the highest level of return for a given level of risk, or likewise the lowest level of risk for a given return level. Another way of viewing the theory is that it equips investors with the tools to avoid risk that can be deemed unnecessary. This risk-return level can be quantified into a single and comparable form known as the Sharpe ratio (Sharpe, W. 1966). The higher the Sharpe ratio, the better the risk-reward trade-off.

A key takeaway from Modern Portfolio Theory, and one relevant in Mean Variance Analysis, is that instead of looking at the risk of each individual asset an investor can achieve more favourable risk levels through diversification. That is, total risk (variance) can be lower when investing in multiple securities at the same time than the sum of their individual variances. Following this notion, under a selection of securities to choose from which each have differing mean returns, variances, and co-variances, and with a finite amount of wealth to allocate to such securities, a distribution of wealth can be made that offers the highest possible Sharpe ratio.

This paper will employ Mean Variance Analysis to construct a portfolio that has the highest risk-return level, that is, an optimised- or otherwise known as Max Sharpe Ratio Portfolio. In the allocation decision collectible whisky will be pitched against common financial assets. This will determine the relative efficiency of investment in collectible whisky as well as the possibility of bringing diversification benefits into an investor's portfolio.

4.5 Notation and Definition

4.5.1 Hedonic Index Construction

The collectible whisky hedonic price index is constructed in the following way. It first starts with the assumption that the price p_i^t of a bottle i in time t is a function of a fixed number of characteristics, K. Such characteristics are gauged by their quantities, z_{ik}^t. Under $T+1$ time periods from period 0 to period T, $t = 0, \dots, T$, and an error term ε_i^t this gives

$$p_i^t = f(z_{i1}^t, \dots, z_{iK}^t, \varepsilon_i^t) \tag{1.1}$$

This basis must be transformed into a parametric model in order for the marginal contributions of each characteristic to be estimated under standard regression approaches. Since the model suffers from non-constant variance of the error term, it is appropriate to use a logarithmic-linear hedonic model instead of a fully linear hedonic model as suggested by Diewert, 2003.

$$\ln p_i^t = \beta_0^t + \sum_{k=1}^{K} \beta_k^t z_{ik}^t + \varepsilon_i^t \tag{1.2}$$

Where $\ln p_i^t$ is the natural logarithm of the sales price of a bottle of whiskey i in time t. β_0^t denotes the intercept term and β_k^t are the characteristics to be estimated - each are assumed to be time-variant. The K characteristics are composed mostly of categorical variables that are represented by dummies which take the value of 1 if a bottle belongs to that category and takes the value of 0 if it does not, the model also allows the inclusion of continuous variables of which their respective natural logarithm is computed.

Since an objective is to analyse the effect of time on the natural logarithm of price the *time dummy variable method* is selected as the index construction approach (Court, 1939). This approach is otherwise known as the *explicit-time-variable* method (Gatzlaff & Ling, 1994) or the *varying parameter* method (Knight, Dombrow, & Sirmans, 1995). The benefit in using this approach is that it allows for one overall regression on pooled data instead of running multiple regressions over different time periods (de Haan & Diewert, 2013). In this sense, time periods can be isolated so that their relationship with the index price level can be analysed and compared with other periods.

The *time dummy hedonic model*, the main equation for the index regression is as follows.

$$\ln p_i^t = \beta_0 + \sum_{\tau=1}^{T} \delta^\tau D_i^\tau + \sum_{k=1}^{K} \beta_k z_{ik}^t + \varepsilon_i^t \tag{1.3}$$

Where D_i^τ, the time dummy variable has the value of 1 if the sale occurs in period τ and 0 otherwise. δ^τ reflects the time dummy coefficient estimates of the impact of sales in period τ. The base date, April 2011 is left out to avoid perfect multicollinearity.

To arrive at the index the time dummy coefficient estimates are exponentiated so that the index from period 0 to period t is:

$$\Pi_{TD}^{0t} = \exp(\hat{\delta}^t) * 100 \tag{1.4}$$

Doing this controls for varying characteristic quantities whilst also offering a measure of quantity-adjusted whisky bottle price change between period 0, the base period, and other compared periods, t.

The estimated return of the index for period t can therefore be calculated as:

$$r_t = \frac{\Pi_t}{\Pi_{t-1}} - 1 \tag{1.5}$$

Beyond constructing an index this paper also aims to analyse price determinants of collectible whisky; this is not done accurately in the *time dummy hedonic model* since the characteristic quantity coefficients are held constant through time. To overcome this issue, a separate model is used for the price determinants regression: the *log linear time dummy hedonic regression model* (de Haan & Diewert, 2013).

$$\ln p_i^t = \alpha + \sum_{k=1}^{K} \beta_i^t z_{ik}^t + \tau^t + \varepsilon_i^t$$

(1.6)

Using this model alone to construct a price index would provide a less accurate measure than that of equation (1.4) as it places less emphasis on time dummy coefficients. Instead this model shines the spotlight on the characteristics (price determinants) of collectible whiskey which is why it is adopted as the main regression equation.

4.5.2 Repeat-Sales Index Construction

As a starting point, the logarithm of the price p_i^t of a bottle of collectible whiskey i in time t can be derived from a constrained log-linear hedonic model:

$$\ln p_i^t = \beta_0^t + \sum_{k=1}^{K} \beta_k z_{ik} + \varepsilon_i^t$$

(2.1)

Note that this differs slightly from equation (1.2) as a simplifying assumption is made about the characteristic parameters. K denotes the price-determining characteristics of a bottle and the parameters β_k of such characteristics are constrained to be fixed over time. β_0^t is the intercept term to be estimated. Since repeat sales accounts for identical bottle comparisons, it is also assumed that the amounts of characteristics of an individual bottle are held constant: z_{ik} unlike in (1.2) which is the k'th characteristic for bottle i. ε_i^t represents a random error term.

As it is required to find the logarithm of the change in price of a particular bottle i between two periods, for instance s and t $(0 \leq s < t \leq T)$, equation (2.1) is subtracted for such periods. Therefore:

$$r_i^t = \ln p_i^t - \ln p_i^s = \ln (p_i^t / p_i^s) = (\beta_0^t - \beta_0^s) + (\varepsilon_i^t - \varepsilon_i^s)$$
$$= lnP^{st} + (\varepsilon_i^t - \varepsilon_i^s)$$

(2.2)

This implies that the logarithm of the price change is the same for all bottles, P^{st}, plus the error term $(\varepsilon_i^t - \varepsilon_i^s)$.

Given that the sample consists of a collection of bottles that have each been sold at least once over the period $t = 0, \dots, T$ then the data can be combined into a standard repeat sales model estimation equation:

$$r_i^t = \ln(\, p_i^t \,/\, p_i^s \,) = \sum_{t=0}^{T} \beta^t D_i^t + \varepsilon_i^t$$

(2.3)

D_i^t is a dummy variable that equals 1 for the period that the resale occurs, -1 for the first sale of the bottle, and 0 otherwise. From this point, the standard repeat sales model as proposed by Bailey et al. (1963) can be estimated under an OLS regression, holding the assumptions that the error term has a mean of zero and that there is no heteroskedasticity.

The corresponding regression coefficients $\hat{\beta}^t$ are exponentiated to generate the repeat sales index from period 0 to period T.

$$\Pi^{0t} = \exp\,(\hat{\beta}^t)$$

(2.4)

Like under the hedonic approach, the return of the index is estimated using equation (1.6).

The collectible whiskey index is constructed under the house-pricing methodology adopted by Case & Shiller (1987). It follows the same index coefficient estimation procedure as Bailey et al.'s (1963) repeat sales model yet it differs in that it assumes that the variance of the error term is not constant and varies with the holding period of the bottle. Otherwise put, it controls for heteroskedasticity by introducing a *holding period* variable which is the time difference between the first and second sale. Case & Shiller (1987) reason that price changes in the asset are influenced by a component whose variance differs with the time interval between sales, therefore, the assumption of constant variance of the error term is violated. To overcome this they adopted a Weighted Least Squares (WLS) regression where the weight corresponds to the *holding period* variable.

The variable which reflects weight is constructed by regressing the squared residuals from stage one, the BMN repeat sales regression, on a constant term and the time between sales.

$$\varepsilon^2 = c + HP;\ \varepsilon_i^{t^2} = \beta_0 + \sum_{t=1}^{T} \beta_1\, HP_i^t + \mu_i^t \tag{2.5}$$

This arrives at stage two, where the generated constant term is an estimate of the variance of the whisky's specific random error, where c is the constant, HP reflects the holding period, and μ is a further error term of the variance estimate.

Finally in stage three, a Weighted Least Squares regression is ran which repeats the regression from stage one but divides each observation by the square root of the fitted value in the second stage to arrive at the repeat sales whisky index coefficient estimates, where W corresponds to the allocated weight in the WLS regression.

$$\tilde{\beta} = (D'W^{-1}\, D)^{-1} D'W^{-1} r;\ \tilde{r}_i^t = \sum_{t=1}^{T} \tilde{\beta}_t \tilde{D}_i^t + \tilde{\varepsilon}_i^t \tag{2.6}$$

4.5.3 Portfolio Optimisation: Mean Variance Analysis

The Max Sharpe Ratio Portfolio is found by using the 'Solver' function on MS Excel. It is based on a few conditions. First, an investor has a total wealth of 1 in which they distribute across the securities in their portfolio. The total portfolio weights must add up to a value of 1. Second, it is not possible to short sell. This is because this study is not interested in negative security speculation, it is focused on the potential benefits that incorporating collectible whisky into a portfolio could bring. Another restriction is that the allocation follows a 60/40 equity-bond split. This is a typical allocation strategy which has well-documented research (Jorion, P., 1989; Harjoto & Jones, 2006) and is used by many. Bonds typically have the highest Sharpe ratios out of all asset classes meaning that the function would allocate most of the portfolio weight to them; this may not be representative of what choices an investor makes empirically. In this sense, by imposing a maximum portfolio allocation to bonds of 40% the paper creates an optimised portfolio which closely relates to what strategy an actual investor may be adopting. The specification and definitions in this study are adapted from Steinbach, M. (2001).

The first step involves taking the return series for each security and constructing a covariance matrix. Consider that there exists a range of assets n, with returns r that can be chosen from. $\bar{R} = (\bar{R}_1, \bar{R}_2, \dots, \bar{R}_n)$ is a an $n\,x\,1$ vector of the assets' expected monthly returns. The covariance matrix, denoted C, is therefore:

$$\mathrm{C} := \boldsymbol{E}[(r - \bar{r})(r - \bar{r})^*] = \boldsymbol{E}(rr^*) - \bar{r}\bar{r}^* \tag{3.1}$$

Further, denote x^v as the capital invested in asset v, by the portfolio vector $x \in \mathbb{R}^n$. Following this, assets returns can be seen as $r \in \mathbb{R}^n = R = (R_1, R_2, \dots, R_n)$. Total returns from the investment period are therefore: $r^v x^v$.

The expected return of a portfolio can be viewed as:

$$\rho(x) = \boldsymbol{E}(r^* x) = \bar{r}^* x \tag{3.2}$$

The risk of a portfolio is therefore:

$$R(x) = \sigma^2(r^* x) = \boldsymbol{E}[(r^* x - \boldsymbol{E}(r^* x)^2) = x^* \Sigma x \tag{3.3}$$

Since the portfolio is constructed in such a way that all wealth is distributed across the available assets, the total portfolio proportions should add up to 1. This can be written as $\Sigma x = 1$. The Max Sharpe Ratio Portfolio is thus found using quadratic optimisation:

$$min_x \frac{1}{2} x' C x + \lambda\left[\bar{R}_p - x'\bar{R}\right] + \gamma[1 - \Sigma x]$$

(3.4)

λ and γ are Lagrange multipliers to be solved-for, and C is the covariance matrix. Using the 'solver' function on MS Excel the optimal portfolio weights are found using a brute force approach, that is, the program solves for many iterations of portfolio configurations and eventually finds a weight distribution that attains the highest Sharpe ratio.

4.5.4 Sharpe Ratio

The variable that the above function aims to optimise, the Sharpe Ratio, gives an indication of how well an investment performs relative to the level of risk it endures. It is defined as:

$$S_n = \frac{\hat{R}_n - r_f}{\hat{\sigma}_n}$$

(3.5)

Where S_n is the Sharpe Ratio for security n, $\hat{R}_n$ is the arithmetic mean return on such security. r_f is the risk-free rate, which is proxied either by the UK 3 Month Treasury Bill, US 3 Month Treasury Bill, or DE 3 Month Treasury Bill depending on the security. $\hat{\sigma}_n$ is the average volatility of returns for security n.

4.6 Considerations, Assumptions, and Biases

4.6.1 Indices

Both the hedonic and repeat-sales whisky indices should be constructed in a manner that they represent value fluctuations of the whisky market to the highest accuracy and reliability. In order to fulfil this, index construction must be tested against certain conditions as proposed by Ginsburgh et al. (2006).

Quality of information

Data on whisky sales needs to be collected from a source that is reliable and publicly available. This study uses data from two of the largest online auction houses[5]: *Scotch Whisky Auctions,* and *Whisky Auctioneer*. Throughout the period of consideration these houses accounted for the majority of collectible whisky sales across the entire market. Adopting these houses as sources of information ensures that the data used is best representative of the overall asset class. Further, all sales data is freely available on their websites allowing for independent replication.

Comparing both hedonic and repeat sales approaches, the former is more sensitive to data quality because it relies on a greater amount of inputs. As previously noted, a detailed dataset is imperative for a hedonic model to fulfil its purpose whereas repeat-sales methods are less demanding requiring only an ID, sale price, and date of sale. In addition to gathering data from a reliable source it is important to ensure that information on characteristics (e.g. distillery, region, bottle size, …) are consistent within the dataset. A crucial aspect in gathering primary data is ensuring that it is correctly formatted so that the risk of model distortion is reduced all whilst making the most out of the available information.

Should distinguish many different collecting categories

One can encounter high variation in returns dependent on the collecting category that the index comprises. While this issue is more pronounced in cases where an index is broadly specified (e.g. an antiques index covering anything that falls under the definition of 'antique'), this can also apply to whisky indices. For example, returns on collectible whisky can be heavily influenced by the distillery that produced it, of which some are more celebrated than others. The purpose of an index is to capture an overall sentiment of a particular market; distinguishing it by each and every return-driving factor would work against the principle of its conception, although, such return-driving factors are analysed under the hedonic approach following the premise that characteristics in isolation may be influential enough to identify return variation in the wider collectible whisky market.

Assumption: Constant quality of the underlying asset

[5] WhiskyStats. https://www.whiskystats.net/monthly-update/the-whiskystats-price-update-for-april-2020/

With regards to repeat-sales indices, a drawback of the data in this study concerns the constant quality assumption presented by Case & Shiller (1987). As mentioned, the framework of a RSR assumes that the quality of the asset does not change over the time period of consideration. Hedonic methods do not make the same assumption, however too much variation in the condition of the asset across sales will result in biased characteristic estimators and an index that is non-representative.

Whiskies are less susceptible to this problem than other assets studied in the literature (e.g. houses) as they can be preserved relatively easily provided that they are correctly stored, however damage can occur to the presentation box and the bottle's labels. It was not feasible to capture the component reflecting the change in value due to quality inconsistencies across sales. A workaround is to reduce this problem manually; significant price changes between unique bottle sales are identified and the auction listings investigated to determine whether quality is the cause.

Assumption: Hedonic coefficients constant over time

A problem with hedonic models is that, unaltered, they assume that the coefficients of the characteristics remain constant over time. That is, the value that the market attributes towards a particular characteristic does not change. This is rarely the case as consumer preferences tend to be liquid and vary by different degrees. Triplett (2004) proposes two solutions: one can either introduce an interaction variable between a characteristic and time to control for time variation, or one can run adjacent-period regressions to test whether the coefficients are statistically different from one another from one period to the next. This paper tackles this issue by specifying two separate hedonic functions: the *log time dummy model* that holds characteristic coefficients constant over time and is used to estimate the index (equation 1.3), and the *log linear time dummy hedonic regression* that controls for time variation of characteristics (equation 1.6), which is used in the main regression.

Repeat-Sales: Ratio of observations to total sales

As previously mentioned, a commonly known drawback of RSRs is that they often fail to capture a large enough sample of observations out of the total asset class (Mei & Moses 2002). This is because in most cases only a few assets are sold more than once. A low ratio of the number of repeat-sales observations to the total amount of trading activity will produce an index which is misrepresentative of the value fluctuations of the asset it is attempting to model. Ginsburgh et al. (2006) reasons that this is one of the leading reasons driving the disparity between repeat sales models and other model construction techniques.

The data used in this study appears not to be subject to this problem. For in both the data retrieved from *Scotch Whisky Auctions* and *Whisky Auctioneer* the ratio of repeat sales to total sales is high. 83% (34,346 out of 41,205) of total sales were repeat sales for *Scotch Whisky Auctions*, and 80% (28,354 out of 35,440) of total sales were repeat sales for auctions hosted by *Whisky Auctioneer*.

Such high ratios strengthen the reasoning of adopting a repeat sales model as a suitable index construction technique. Further, high ratios of repeat sales reveal an implication about collectible whisky markets: while there exists thousands of different types of whiskies, only an exclusive class of them are traded suggesting that collectible whisky is indeed its own separate category from retail whisky. Another implication considers the nature of market participants; high volumes of unique bottles bought and sold multiple times indicates that such bottles are not being consumed, they are instead potentially traded as an asset. Given this, it could be that the majority of participants in collectible whisky auction houses play the role of an investor as opposed to a consumer.

Repeat-Sales: Sampling Biases

Mark & Goldberg (1984) note that RSRs can be subject to overrepresentation when certain assets within the asset class trade more frequently than others. This leads to index distortion if those particular assets experience price changes that differs from that of the wider asset class. This could greatly impact collectible whiskey since it is a market that is largely affected by supply; some bottles may trade more out of popularity, or there may be simply more of them available to trade relative to others. This sampling issue can be addressed by creating an index which excludes bottles that are traded by a disproportionately large amount.

Another sampling bias relates to the inclusion of repeat sales in the sample. Goetzmann (1993) suggests that, for instances where an asset has decreased in value since bought investors are more likely to hold on to it in the hopes that it will increase in the future. This is an example of the 'disposition effect' (Shefrin & Statman, 1985) which would lead to a decrease in the number of repeat sales occurrences that results in an upward bias of the estimated return. This can apply to whisky investing as the preservability of a bottle reduces the pressure on an investor to engage in a sale, furthermore an owner may decide to consume the bottle altogether if it no longer presents payoff opportunities.

Combined, these biases cause the mean annual return to collectible whiskey investment to be considered as an approximate measure. Since these biases relate primarily to instances where value is lost, the index can be regarded as an optimistic view on the expected returns of collectible whiskey investment. The inclusion of transaction costs in the index would further reduce realised returns. Compared to traditional financial assets this is not too great a concern, as Mei & Moses (2002) highlight that their return estimates could suffer in a similar manner: lack of market liquidity, survivorship bias, and the presence of transaction costs.

Price inflation

Inflation must be controlled-for so that return comparisons across time periods are consistent with one another. This is done by deflating individual sale prices to the base year of the study, 2011. For example, a bottle sold in 2012 which is then sold again in 2016 has both values quoted in 2011 price levels so that the entire index is estimated in real terms with 2011 as the base year. Put otherwise, auction sale prices are converted from nominal to real values. The UK annual inflation rate[6] is used since sales are quoted in GBP. The same notion is applied to the index prices of the common assets; in some cases these assets are quoted in Euros, therefore European inflation rates are instead applied.

4.6.2 Mean Variance Framework

Mean Variance Analysis: Normal Distribution of Returns

A key assumption in MV analysis is that returns follow a normal distribution (Markowitz, H. 1952). If this is not the case, then the 'efficient' portfolio may not be entirely accurate leading to the model underestimating risk. Unfortunately this assumption is rarely satisfied; empirical evidence has shown that stock and bond returns tend not to be normally distributed (Fama & Miller, 1972). It is often found that returns are not evenly spread about the mean. Furthermore, return distribution of financial data carries a lot of tail-end risk where, one can experience tremendous gains or losses in extreme cases. Because of this problem one must

[6] Bank of England. Inflation Rates. https://www.bankofengland.co.uk/monetary-policy/inflation/inflation-calculator

interpret the results from the optimised portfolio with a pinch of salt. In the case of whisky, if it is found that returns are not normally distributed then this would not be deemed too alarming given the context of the other assets. Tests of normality will be conducted to verify this issue.

Mean Variance Analysis: Taxes & Transaction Costs

Another assumption regarding MV analysis is the absence of taxes or transaction costs. This is also rarely the case. In order to access capital markets one finds themselves subject to costs such as brokers' fees, they then might be liable to pay taxes on any capital gains. The problem is that these transaction costs and tax levels vary from country to country, from brokerage firm to brokerage firm, and from one asset to another. This also applies to collectible whisky where the listing fees vary between *Scotch Whisky Auctions* and *Whisky Auctioneer.* MV analysis fails to capture these differences and can therefore produce inaccurate estimations as these costs can be influential of the risk profile of the given asset. Again, this problem cannot be easily solved so one must interpret results carefully.

Mean Variance Analysis: Risk Aversion

MV analysis makes the assumption that investors are risk averse. That is, ceteris paribus, when choosing amongst investments for a given level of return an investor will always opt for the portfolio that has the lowest volatility. Many agents will argue that they behave this way, but in reality individuals are often found to be irrational. A prime example is Kahneman & Tversky's (1979) *prospect theory*. The theory bases itself upon behavioural biases that seemingly rational agents fall susceptible to and argues that individuals value gains and losses separately. A key determinant in an agent's decision-making process is the way in which the situation is framed and furthermore, agents tend to exhibit narrow framing. In the context of capital markets this can lead to *the disposition effect*: agents tend to be risk-averse when they are making gains, and risk-seeking when they are making losses. Otherwise put, an investor can be less inclined to take risks when they are gaining relative to their initial investment and more inclined to take risks when they are losing relative to their initial investment. With regards to this study, this degree of irrationality impacts both collectible whisky and traditional financial assets and therefore should not prove too much of a hinderance to the results, however, this once again weakens the precision of the Mean Variance analysis.

4.6.3 Collectibles

Emotional Assets

An important element to remember when analysing investment in collectible whisky is that investors do not approach it like they would a traditional asset. Campbell, Koedijk, & de Roon (2009) propose that investment in collectibles stems from emotive as opposed to purely financial reasons, coining the term *Emotional Assets*. The authors explain that real assets have a consumption value in conjunction with the intrinsic value they provide – an artwork can be hung on the wall, a car can be driven, and a whisky can be drank. A number of investment firms exist where an individual can invest in collectibles without physically holding the asset. The authors hypothesize that if investors are willing to pay more to own the physical asset themselves, then there must exist a high emotional value component. Along with finding evidence to support this theory, they also find that some investors are willing to forgo financial returns in order to invest in certain emotional assets.

This could have some noteworthy implications for this paper: *how large is the emotional component of value for collectible whisky?* If this component is significantly large then it could result in sudden and/or severe price changes, and therefore high return volatility in the future should individuals' preferences change. The demographics of whisky drinkers have traditionally been concentrated amongst older men however this has been shifting as of recent[7]. Given these factors this can cause the predictability of future returns to become less certain as they would for assets whose consumer base is more stable.

5 Data

5.1 Overview

This paper draws its sample from two sources, both are online auction houses specialised in the sales of collectible whisky: *Scotch Whisky Auctions*[8], and *Whisky Auctioneer*[9]. The use of

[7] Who is the average whisky drinker? Scottish Field. https://www.scottishfield.co.uk/food-and-drink-2/whisky/the-average-whisky-drinker-isnt-who-youd-expect/
[8] Scotch Whisky Auctions. https://www.scotchwhiskyauctions.com/
[9] Whisky Auctioneer. https://www.whiskyauctioneer.com/

auction websites has the advantage that only collectible bottles are listed on the website exempting the sample from containing non-collectible, retail bottles. In this sense an isolated environment in which it is possible to track the evolution of collectible whiskey is created. Furthermore, these websites are transparent providing a database on all previous sales records. A disadvantage in using auction websites is that prices are subject to the winner's curse; a tendency for the winning bid to exceed the intrinsic value or market price of that item causing value and prices to be mismatched (Thaler, R. 1988). While this bias may be problematic, it is not a phenomenon that is unique to real assets as financial markets are also prone to their own biases and shortcomings.

Both *Scotch Whisky Auctions* and *Whisky Auctioneer* (hereafter: *SWA* and *WA,* respectively) are leaders in the secondary market for collectible whisky[10]. These platforms operate as 'middle-men' whereby sellers send their bottles to the auction house where it is sold on their behalf. The auction house then takes a commission from the sale: *SWA* charges a flat fee of £5 per listing[11], whereas *WA* charges a listing fee of £5 plus 5% commission from the hammer price[12].

SWA started operations in April 2011 and hosted a total of 41,205 listings from this month until the end period of consideration, February 2020. *WA* debuted in January 2014 and listed 35,440 auctions until the same end date. Together this formed a sample of 76,645 auction sales from April 2011 to February 2020 with a total turnover exceeding 72 million GBP (in real, 2011 terms).

For both *SWA* and *WA,* auctions are hosted on a monthly basis. This remained true from the date at which each website started operations until the end date of the analysis period meaning that there is a complete dataset based on monthly intervals. Because of this and due to the relatively short time period of analysis (2011-2020) index returns are calculated on a monthly basis as this tracks price changes from auction to auction.

Prices are deflated to the base year, 2011 using annual inflation rates from The Bank of England. This produces a shortcoming – since the study analyses price returns on a monthly scale, deflating all prices within a year under the same rate distorts the price levels. This is

[10] WhiskyStats. https://www.whiskystats.net/monthly-update/the-whiskystats-price-update-for-april-2020/
[11] Scotch Whisky Auctions. Selling Information. https://www.scotchwhiskyauctions.com/selling/
[12] Whisky Auctioneer. Selling Information. https://www.whiskyauctioneer.com/help/sell-whisky-auction/sellers-fees-and-payment-terms

especially the case for auctions hosted in December of one year and in January of the following – prices for these auctions are discounted at different rates although only a month apart from one another.

This study is only concerned with collectible whisky; a drink made from fermented grain mash. Whisky broadly falls into the following categories denoting the region from which they are produced: Scotch (Scotland), Bourbon (North America), Irish Whisky, and Japanese. A small percentage (2%) of whiskies originate from elsewhere. The typical size of a bottle of whisky is 70- or 75cl, these constituted 94% of the total sample. The remaining 6% consisted of irregular sized bottles (such as 50- and 100cl) which were kept but denoted as irregular with a control variable. Some listings contained collections of two or more bottles, where this occurred a dummy variable was created in a similar fashion to that of before alongside a *collection size* variable which indicated the total volume of whisky in the listing. Collections made up 2% of the sample. A cut-off point was set such that no bottle observations with a vintage before 1900 or after 2020 were included with the former chosen as a limit since many bottles frequently trade that whose vintage originates from the early 20th century, yet few appeared before 1900. While both sources list whisky in the vast majority of their sales in some instances this is not the case. Sales of rum, brandy, and champagne occasionally appeared in the sample and were discarded.
After implementing these restrictions, the final dataset consisted of 64,277 unique collectible whisky auction sales.

The repeat sales index requires that a unique bottle must be sold at least twice over the period of consideration. Of the 64,277 bottles in the sample, 57,556 were sold repeatedly (90%). A high number of repeat sales was not only promising for the accuracy of the index estimation, but also suggests that whisky is not illiquid – the same group of bottles being frequently traded is of benefit to the prospective investor. After dealing with unique bottles that were sold more than once on the same auction date, the repeat sales index was left with a total of 31,462 repeat sales pairs.

5.2 Holding Periods

This paper studies two different time horizons for collectible whisky investment: April 2011 – February 2020, and January 2014 – February 2020. Note that these periods overlap. The rationale behind these dates is linked to the evolution of the market and the time in which both auction houses were jointly operating. From April 2011 – January 2014, only *Scotch Whisky Auctions* operated. Not only did *Whisky Auctioneer* commence operations from 2014 onwards, but the whisky market saw a tremendous amount of growth from this date. Both factors combined meant that sales volumes were high from this point whilst before 2014 the market was only slowly gaining pace. For a market characterised by fewer sales it would be expected to see high price volatility, while as the market picks up one would expect volatility to decrease due to a higher number of participants setting and enforcing prices.

Although it may have been tempting to drop data before 2011 keeping the older data series in the study allows the evolution of whisky to be viewed. Having a separate time period from the point where the market grew substantially allows one to conduct analysis on price returns that are more representative of the current state of the market.

5.3 Variables: Hedonic Regression

The auction house, *Whisky Auctioneer*, provided detailed information about the characteristics of each bottle of whisky. The same did not hold for *Scotch Whisky Auctions* so a solution was to match unique bottles which appeared on both websites and apply the missing information from WA to SWA where available. The information obtained constituted the characteristics variables of the hedonic regression, K, (see: equations (1.1) and (1.6)). Such characteristics are categorised into four groups: *Bottle Characteristics, Distillery Characteristics, Cask Characteristics,* and *Transaction Characteristics.*

Details of each constructed variable are as follows:

Bottle Characteristics

These variables were drawn or derived from the auction listing and involve elements that pertain to the characteristics of the bottle itself.

- *Age* – The number of years the whisky spent ageing in barrels before it was bottled, treated as a discrete variable.
- *Vintage* – The year in which the whisky was distilled, treated as discrete.
- *Size* – A continuous variable displaying the volume of the bottle in cl.

- *Strength* – Continuous variable expressed as a percentage, the alcoholic strength of a bottle.
- *Collection Dummy* – A dummy variable equal to 1 if the listing contained two or more bottles and 0 otherwise.
- *Collection Size* – A discrete variable indicating the number of bottles in a listing.
- *Imported* – A dummy variable equal to 1 if the bottle was sold on the export market and 0 otherwise.
- *Damaged* – A dummy variable equal to 1 if the bottle was damaged in some way and 0 otherwise.
- *Contains Buzzword* – A dummy variable equal to 1 if the listing contained a buzzword and 0 otherwise. Examples include: "Exclusive", "Rare", "Special", "Limited".

Distillery Characteristics

These variables directly relate to the distiller, the producer of the whisky.

- *Region* – A categorical variable transformed into dummies which indicate the geographical region in which a distillery operates. The four main categories are: *Scotland, Ireland, N. America*, *Japan,* and *Elsewhere*. Since there are vastly differing regions of whisky production in Scotland, it is further broken down into those main six: *Campbeltown, Islay, Lowland, Speyside, Highland,* and *Island.*
- *Operational* – A dummy variable equal to 1 if the distillery is still operational (currently produces whisky) and 0 otherwise.
- *Inaugural* – A dummy variable equal to 1 if the bottle was of the first batch of releases from the distillery and 0 otherwise.
- *Distillery* – A categorical variable consisting of the top thirty distilleries in terms of sales volume. These distilleries accounted for 84% of total sales.

Cask Characteristics

The cask refers to the container in which the whisky was stored throughout the ageing process. This is an integral factor in the production process as small adjustments to the cask can have a dramatic effect on the overall taste of the drink.

- *Wood* – A categorical variable which was split into three dummy variables indicating the type of wood in which the whisky was aged, which has an impact on taste. These three dummies are: *US Oak, European Oak, and Japanese Oak*.
- *Preceding Alcohol* – A categorical variable split into dummies which indicate the previous alcohol that was aged in the cask before used in the current one. Whiskies are typically aged in used casks as this delivers additional, and significant flavour notes to the final drink. The dummies are: *Ex Sherry, Ex Bourbon, Ex Wine, Ex Port, Ex Rum,* and *Ex Beer*.
- *Cask Size* – Three dummy variables indicate the size of the cask in which the whisky was aged: *Small, Medium,* and *Large.*
- *Single Cask* – A dummy variable equal to 1 if the whisky was aged in one single container for the entire ageing process and 0 otherwise.
- *Private Cask* – A dummy variable equal to 1 if the whisky was aged in a private cask and 0 otherwise. A private cask is a custom 'brew' that is tailored by the distillery for a particular individual.

Transaction Characteristics

The following dummy variables relate to the date of sale of each listing and its source.

- *Log(Real_Price)* – The natural logarithm of the hammer price of each sale, in real 2011 terms.
- *Month* – A set of dummy variables of each month equal to 1 if the sale occurred in that given month and 0 otherwise.
- *Year* – A set of dummy variables of each year, from 2011 to 2020, equal to 1 if the sale occurred in that given year and 0 otherwise.
- *Auction House* – A pair of dummy variables, one for each auction house, equal to 1 if the sale took place on that particular auction house or 0 otherwise.

6 Results and Discussion

6.1 Hedonic Summary Statistics

[Insert Table 1 Here]

Table 1 presents sales characteristics of 64,277 collectible whisky sales on both *SWA* and *WA*. The average nominal hammer price is roughly 1,337 GBP with the median being 755 GBP and the highest paid for a bottle at 110,000 GBP. 46% of sales occurred on *Scotch Whisky Auctions* while the remaining 54% featured on *Whisky Auctioneer*. There is a hike in sales volume as of 2014 but this is expected given that this date is when *WA* began operations. Beyond this, sales volume increases dramatically from 2016 onwards: since this occurred for both auction houses it is likely that this is due to market growth as opposed to a particular auction house gaining popularity. 2020 only includes sales for the months of January and February which explains why sales volume for this year is considerably low. From a monthly perspective, sales tend to be evenly distributed throughout the year with a slight increase in November - this is likely associated with increased consumer spending over the festive period.

73% of whiskies originated from Scotland, 19% from Japan, 5% from North America, and 1% from Ireland. Scotland is further divided into the six main whisky-producing regions of which 46% are produced in *Speyside*, 26% from *Islay*, 16% from *Highland*, 5% from *Island,* 4% from *Lowland,* and 3% from *Campbeltown*. The top 30 distilleries in terms of sales volume are listed in descending order. *Macallan* is by far the most popular with 22% of the entire sample being bottles produced by this distillery. The second highest was Karuizawa with a share of 7%. With respect to whether or not a bottle was sold from a distillery operational at the time, this was the case for 76% of the 64,277 sales meaning that roughly a quarter of total sales were of bottles from distilleries that have ceased operations.

The average age of a bottle of whisky was 24 years, and an average vintage dating to 1983. Unsurprisingly, the mean volumetric size of a bottle was 77cl which is close to the conventional standard. The mean alcoholic strength of a bottle was 50% ABV. 1,464 listings contained more than two bottles, with the highest collection consisting of 96 individual bottles. Of the entire sample 2,703 (4%) bottles were produced for the export market. Only 13 bottles were labelled as 'damaged'. The number of bottles that contained a buzzword (*special, rare, limited, etc.)* in their name was 5,258 which constituted 8% of the entire sample. The most common preceding alcohol used in the ageing cask was sherry. Sherry casks constituted 26% of the sample. This was followed by bourbon, and then wine. Compared to second, third, and fourth fill it appears that it is more common for virgin casks to be used in the ageing process, however the data fails to capture casks that have been used more than four times which is presumed to be used more often than virgin casks based off the low values for this variable as a whole. European and American oaks are more popular than Japanese oak although this is likely because there are fewer Japanese whiskies sold compared to North American and European. In addition, Japanese whisky took a lot of influence from Scotland hence they potentially would have used the same types of wood. Large casks are more popular than medium casks, and medium casks are more popular than small ones. Surprisingly, only 11% of whiskies are stated to have been aged in one single cask meaning that the vast majority get transferred into another throughout the ageing process. This has important implications when interpreting the other cask characteristics as they may not be mutually exclusive from one another. Otherwise put, a whisky aged in an ex sherry cask may also have been aged in an ex bourbon cask at one point in the ageing process.

6.2 Market Sales Characteristics

The next section takes a closer look at market share, sales levels, and price information outlined in Table 2. Panel A displays total sales and market share by (real) £ price band as sales frequencies and in proportions. The results indicate a clear shift in bottle sales from lower price bands to higher ones. That is, the market increasingly listed and sold greater amounts of relatively more expensive bottles and thus lower amounts of relatively cheaper bottles. In 2014, roughly 70% of sales consisted of bottles under 500 GBP while by 2019 this figure dropped to 36%. This weight was primarily transferred across the 500 – 999 GBP and 1,000 – 2,499 GBP price brackets although those above also saw an increase.

[Insert Table 2 Here]

The first sale of a bottle exceeding the 10,000 GBP price barrier occurred in 2014 and from this point onwards it became extremely common. In 2019 there totalled 304 unique sales of bottles that exceeded this price point.

Total sales increased dramatically throughout the period 2011 – 2020. Notably in 2014, the first year in which both auction houses were operational at the same time, total sales amounted to 3,775 bottles while in 2019 this increased to 21,161.

The above findings indicate significant growth in the collectible whisky market in terms of sales volume and price increases. This is the first green light for the speculative collectible whisky investor as it suggests that the market is taking an upward direction.

Panel B investigates the top thirty distilleries by sales volume, sales revenue, and mean hammer prices. The top thirty distilleries accounted for roughly 84% of all sales in the sample with the highest distillery, *Macallan*, having a greater sales volume than the following four distilleries combined. Naturally, the ranking of the top distilleries by sales volume closely relates to the ranking of the top distilleries by (real) sales revenue, although the order is not exactly identical. While the second highest distillery, *Karuizawa,* had less than a third of total sales compared to *Macallan* their sales revenue was almost half. The top fifteen distilleries by sales revenue each exceeded 1,000,000 GBP over the sample period. The top thirty highest mean (real) sales price by distillery ranges from roughly 950 GBP to 2,200 GBP. *Bowmore* had the highest mean (real) sales price at roughly 2,164 GBP, followed by Japanese distilleries: *Karuizawa*, and *Hanyu* at 2,107 - and 2,039 GBP respectively. These figures could help an investor choose which bottles to invest in. If they are searching for bottles that are highly liquid, then the strategy would be to select one from a distillery that has a high sales volume. Similarly, they could identify bottles that on average sell for relatively more if they would rather follow a premium-based strategy.

Panel C explores price volatility by distillery and individual bottle sales. The fifteen distilleries with the highest price volatility are listed alongside the fifteen distilleries with the lowest price volatility. The most volatile distillery was *Bowmore* (which incidentally had the highest mean sales price), which is closely followed by *Royal Lochnagar.* There is a slight connection between these top volatile distilleries and those with the highest sales volume but this does not apply in all cases. The least volatile distillery was *Glenflagler*. The fifteen most and least volatile individual bottles with a minimum of five repeat sales was computed. Bottles from the *Macallan* distillery frequently appeared on the most volatile list with the *Macallan 1959 Fine & Rare 43-Year-Old* taking the spot of the most volatile. Japanese bottles tended to be the least volatile (7 of the 15 least volatile are Japanese), with the very least being a *Blanton's Single Barrel Dumped 2018*. Volatility is a large component in an investor's strategy. Those willing to forgo returns in exchange for safer whiskies ought to invest in bottles from the least volatile distilleries. It would appear that Japanese whiskies, whilst having high sales volumes and mean sales prices also tend to be less volatile – perhaps these are the hidden gems of the whisky market?

6.3 Baseline Hedonic Regression

[Insert Table 3 Here]

Table 3 displays the results of the baseline hedonic regression, the *log linear time dummy hedonic regression model* from equation (1.6). The natural logarithm of the sales price deflated to 2011 is regressed on the independent variables detailed above using an Ordinary Least Squares (OLS) regression approach. Column 1 displays the regression coefficients while column 2 shows the price impact which is approximated by taking the exponent of the regression coefficient and subtracting one. There was complete information for 31,994 of the 64,277 sales hence this constitutes the number of observations in this baseline hedonic model.

In line with predictions about market growth, the price impacts of the monthly date coefficients increase throughout the period of April 2011 to February 2020 up to a premium of 232% at the end of the time series. The price impacts associated with individual distilleries use the base of the approximate 16% lesser-known distilleries by sales volume; varying greatly from one to another. That is, for example, a bottle sold from the distillery *Ardbeg* carries a 30% premium over bottles produced by the least popular distilleries. The highest coefficients and price impacts are concentrated amongst Japanese distilleries, further supporting the case that Japanese whiskies offer a premium. The number one distillery in terms of sales volume, *Macallan*, has a price premium of 67%.

The results indicate that bottle strength and bottle size share a linear relationship with price. Vintage shares a slight negative association, meaning whiskies distilled more recently are valued lower than older whiskies. The same intuition follows a whisky's age; for each additional year a whisky is aged in-cask, a 4% price premium is rewarded. Whiskies from distilleries that have ceased operations carry a 15% premium over whiskies sold from operational distilleries. These results are unsurprising given that there are direct costs for the distillery associated with ageing a whisky longer, the effects of vintage and operational can be argued to be supply-driven – as rarity and scarcity increase, so does the price.

The cask coefficients must be interpreted carefully, that is, they must be read with the base notion of 'unless stated otherwise'. Amongst wood types, casks made from European or Japanese oak carry a 64-77% premium over bottles which have no wood type specified. Ex sherry casks offer the greatest premium amongst preceding alcohol types. Single cask whiskies present a 13% price premium which indicates that whiskies aged in one single cask throughout the ageing process are valued over whiskies that are not. Whiskies produced for the export market carry an 11% price premium which is likely due to their scarcity. Lastly, whiskies sold on the auction website *Scotch Whisky Auctions* have a lower selling price on average by roughly 5%. Since sales were not identical across both websites, it is likely that *SWA* listed cheaper bottles in general. If not, given that *Whisky Auctioneer* charges sellers a 5% commission on all sales, a seller in this case may be indifferent between operating on either website.

6.4 Indices and Returns

The price indices under the hedonic- and repeat sales regressions are constructed based off the regression coefficients from the functions outlined earlier above in section 4.5. Since April 2011 is the base date, price levels are set to 100 at this period. Under the hedonic method, a price index of real price levels is generated alongside a price index using nominal values. For the repeat sales method the foundational approach developed by Bailey, Mouth, & Nourse (1963) labelled *BMN* is executed as well as the later approach developed by Case & Shiller (1987), labelled *CS.* The results can be found in table 4.

[Insert Table 4 Here]

The two approaches most important for analysis are the Real Hedonic Index and the *CS* repeat sales index. The other two can be seen as supplementary but not essential since they have shortcomings when pitched in comparison: the nominal index fails to capture a true evolution of prices, and the *BMN* index makes a false assumption about heteroskedasticity of the error term. Besides this, they are kept in the study out of convention. All the indices tend to fluctuate in tandem with one another.

[Insert Figure 1 Here]

Figure 1 graphs the indices. In this way the evolution of collectible whisky can be visualised throughout the sample period April 2011 to February 2020. The hedonic- and repeat sales approaches closely follow one another although the price returns estimated by the real hedonic regression are far more volatile, especially over the 2012-2014 period. Despite this, the hedonic and repeat sales indices each terminate at roughly the same index value. There is little growth from the period April 2011 until January 2014, but from this point onwards collectible whisky follows a steady growth path for the majority of the rest of the period. The period which saw the fastest growth spanned from January 2015 until autumn 2018 - from this point onwards growth stagnated, ending up at an index level of 250 for the hedonic index and 259 for the repeat sales index. The hedonic index peaked at a price level of 289 in May 2019, for the repeat sales index this occurred in September 2018 at a level of 267. Although it is not possible to invest in these indices as they don't exist, they provide an indication as to what level of return one would expect from having invested in a broad range of bottles in the collectible whisky market: A hypothetical individual investing a certain sum of money in collectible whisky in April 2011 would have seen a 150 – 160% real return on their investment by February 2020.

A previous point of discussion revolved around Ginsburgh et al.'s (2006) assertion of an indifference between hedonic and repeat sales index construction techniques. They argued that under the right circumstances an index generated by either repeat sales or hedonic regression methods would produce the same results. On the other hand, Campbell (2008) argued that RSRs tend to be estimated higher on average due to sample selection bias of items that have sold more than one. The results here do not agree with Campbell's (2008) theory, as for most of the time-series the hedonic index sits higher than the repeat sales index. There is some support for Ginsburgh et al.'s (2006) proposal since the indices track one another fairly well although the hedonic index is far more volatile than the repeat sales index – this difference has serious implications when analysing risk-return measures.

6.5 Returns & Risks

The following section investigates risk and risk-return metrics of the index return series. This is done for the real and nominal hedonic indices as well as the *CS* repeat sales index across two time periods: April 2011 – February 2020 and January 2014 – February 2020. Table 5 presents these results.

[Insert Table 5 Here]

Panel A presents various measures of risk: volatility, skewness, excess kurtosis, semi-deviation, VaR 95%, and max drawdown. In line with a visual assessment of Figure 1, the volatility for the period April 2011 – February 2020 was far greater than the volatility of the shorter period across all indices. Skewness reveals information about the distribution of the returns. In the longer holding period: April 2011 – February 2020, returns are significantly more positively skewed than returns of the shorter period across all indices, again this is consistent with the results for volatility. The highest value was a skewness of 5.3 for the real hedonic index of the longer holding period, this can be desirable for an investor as they would expect frequent small losses that are then covered by occasional large gains. Semi-deviation, otherwise known as downside deviation, measures below-mean fluctuations in a return series – it is the volatility of returns that are below the expected return. Value at risk (VaR) indicates how much an investment might lose over a given time period. Both semi-deviation and VaR, were greater across all indices in the longer holding period compared to the shorter one, suggesting that the longer period was characterised by greater amounts of risk - this was indeed the case given the volatility metrics. Max drawdown measures the maximum observed loss from a peak to a trough. The longer holding period had higher max drawdown values of which the real index had the highest max drawdown of -66%. Overall, collectible whisky appears to be a far safer investment in the later time periods.

Panel B displays a range of risk-return measures: arithmetic mean return, geometric mean return, excess arithmetic mean return, Sharpe ratio, adjusted Sharpe ratio, Sortino ratio, and return/VaR. The arithmetic mean return was greater for all index constructions over the longer holding period than for the one commencing January 2014. The opposite held true for the geometric mean return, whereby the period January 2014 – February 2020 had higher averages across the board. The excess arithmetic mean return, calculated as the arithmetic mean return less the risk-free rate was greater across all indices for the holding period commencing April 2011 than it was for the shorter period.

The Sharpe ratio is a measure of how well an investment performs compared to a risk-free rate, relative to the level of risk it endures. The higher the value, the greater the risk to return trade-off. The Sharpe ratio remained effectively the same across all three indices between both holding periods, suggesting that there was not a significant change in risk (return volatility) nor a change in the difference between the average return and the risk-free rate from the expanded period to the contracted one. The Sharpe ratio was highest in the repeat sales index for the contracted period, reaching a value of 0.18. These Sharpe ratios are all fairly low, suggesting initially that collectible whisky fails to offer a desirable risk-return profile. It is plausible that there exists other assets that offer a higher return for the same level of risk that collectible whisky endures.

The adjusted Sharpe ratio makes adjustments for skewness and excess kurtosis. Making these adjustments, however, did not produce any significantly different results from the standard Sharpe ratio calculation.

The Sortino ratio follows the same notion of the Sharpe ratio but instead it is calculated using downside risk instead of overall volatility. The Sortino ratio is generally considered more appropriate when considering highly volatile investments. This metric produces fairly inconsistent results with the distribution of the previous ratios. It is highest for the repeat sales index from January 2014 – February 2020 at a value of 0.94. As expected, the values of the Sortino ratio are higher than all Sharpe ratio values – this is likely because, while being highly volatile, collectible whisky has experienced a lot of growth. The high levels of up-side volatility would have contributed towards an unfavourable Sharpe ratio, however when the up-side volatility is taken out the risk-return measures become more favourable. This provides evidence to suggest that investment in collectible whisky is not as sub-optimal as the Sharpe ratios suggest.

6.6 Comparison with other financial assets

The following section introduces traditional financial investments into the analysis. In this way the performance of investment in collectible whisky can be compared to conventional investments. The purpose of this is twofold: first, other financial assets can serve as a benchmark so that the performance of collectible whisky can be assessed from a point of reference. Second, one can determine whether introducing collectible whisky into a portfolio would offer diversification benefits.

[Insert Figure 2 Here]

The financial assets consist of world indices, as collectible whisky has a global reach, and UK assets since this study takes perspective of a UK investor and the majority (73%) of whiskies in the sample originate here. Data for the *MSCI World Index (EUR)*, *FTSE250 Index, FTSE100 Index, MSCI UK Index, FTSE Small Cap Index, HSBC Gold Index, FTSE350 Mining Index, Ziman Real Estate Index, and FTSE Oil & Gas Index* are collected from The University of Pennsylvania Wharton Research Database Services and used to calculate real returns. Real returns of the *Bloomberg Barclays Global Aggregate Bond Index* are downloaded from Bloomberg. The UK 3-month Treasury Bill (Gilt), US 3-month Treasury Bill, and German 3-month Treasury Bill are each downloaded from The Federal Reserve Bank of St. Louis, serving as proxies for the risk-free rates for US, UK, and European assets.

6.6.1 Correlation with other financial assets

Table 6 consists of a correlation matrix showing pairwise correlations between the whisky indices and the above-mentioned financial assets.

[Insert Table 6 Here]

Correlation refers to how two assets react in the same environment: if two investments increase or decrease by the exact same rate then they share a correlation of 1. If two investments behave exactly opposite to one another then their correlation is -1. The closer the correlation to zero, then the weaker is the correlation between two assets. The results are supportive that collectible whisky is uncorrelated with common financial assets. Taking the real hedonic whisky index as the first point of inspection, the index with which it is most strongly correlated with is the *Bloomberg Barclays Global Aggregate Bond Index* with a correlation of -0.11. This alone is relatively low. The remaining assets have correlations that range from -0.1 to 0.05. That is to say, the real hedonic whisky index is uncorrelated with global- and UK equities, gold, real estate, and commodities.

The repeat sales whisky index (*CS*) proves to be slightly more correlated with other financial assets than for the hedonic, yet these rates are still remarkably low. It is most strongly correlated with the *FTSE350 Mining Index* at a correlation value of 0.18, which, yet again is relatively low. The same conclusion can be derived from before but this suggests that the correlations estimated by the real hedonic whisky index may be optimistically low and that the true correlations may lie somewhere within these margins.

The low correlations present a favourable case for investment in collectible whisky. If each component of a portfolio reacts in the same way, then the portfolio is no stronger than any one component (Blumenthal, S. 2015). The evidence suggests that collectible whisky has a fundamentally different return pattern from other assets. Although being highly volatile, an investor holding positions in whisky as well as for example global equities, and bonds would be protected in their whisky investment in the circumstance of those other markets crashing since whisky does not share the same reactions.

Diversification means strength through variety. This is why risk-return metrics alone do not tell the whole story, if there were two assets and one had a higher Sharpe ratio but that one with the higher Sharpe ratio had a stronger correlation with a third asset then the overall portfolio may be superior holding the less correlated asset.

Further supporting the validity of the findings is the high correlation that exists amongst the common financial assets with one another. For instance, the *MSCI World Index* is highly correlated with the *FTSE 250-, 100-,* and *Small Cap* indices, as well as the *MSCI UK* index.

6.6.2 Return-Risk Comparison

Table 7 displays return-risk comparisons between collectible whisky and common financial assets. Specifically, it lists the average monthly excess return, average monthly volatility, and Sharpe ratios for each security over the period April 2011 – February 2020, and the period January 2014 – February 2020.

[Insert Table 7 Here]

For the first period, a brief glance reveals that the collectible whisky indices, namely the real hedonic index and the *CS* repeat sales index, outperform all of the common financial assets by average monthly excess return. The hedonic index has an average monthly excess return of 3.1% and the repeat sales index has a return of 0.9%. The closest trailing common financial asset is the *US 3 Month Treasury Bill* with a return of 0.7%. The returns of the common financial assets are not surprising given that this period suffered a financial crisis at the start of the term and that worldwide growth until the end of the period was not spectacular. On the other hand, the average monthly volatility of collectible whisky was generally higher than that of the common assets. The real hedonic index had an average monthly volatility of 28% and the *CS* repeat sales index had an average monthly volatility of 7.9%. These were closely followed by the real assets indices: *HSBC Gold* (9.8%), *FTSE350 Mining* (8.2%), *Ziman Real Estate* (10.7%), *FTSE Oil & Gas* (6.9%). The volatility of the equity indices ranged from 3 – 3.6%. The lowest volatilities were clustered around the *Bloomberg Barclays Global Aggregate Bond Index* (0.8%) and, naturally, the proxies of the risk-free rate. The Sharpe ratios were slightly higher for collectible whisky than for the common assets, with the exception of the *Bloomberg […]* bond index which had a Sharpe ratio of 0.18. The majority of the common assets had Sharpe ratios that were negative or close to zero, while the collectible whisky Sharpe ratios ranged from 0.06 – 0.12.

The second holding period, January 2014 – February 2020 produced similar results. The most notable exception is that throughout this period the *Bloomberg […]* bond index had a greater excess average monthly return and a lower average monthly volatility. This boosted the Sharpe ratio to 0.52. The Sharpe ratios of the collectible whisky indices did not change. Asides from the bond index, only for the gold and mining indices did the Sharpe ratio improve. Returns throughout this period were generally lower across all assets.

These findings serve as a benchmark for the performance of collectible whisky. Earlier, when risk-return measures were calculated for whisky alone it seemed that the asset had an unfavourable risk-return profile. However, compared to the other assets it appears that collectible whisky offers a superior profile (with the exception of bonds) - this again makes an attractive case for investment in whisky.

6.6.3 Max Sharpe Ratio Portfolio

The following section concerns the Mean Variance Analysis portfolio optimisation approach. The first stage was to test the MV assumption about normal return distribution. This is done by conducting the Shapiro-Wilk test (Shapiro, & Wilk. 1965), alongside measures of skewness and kurtosis for the returns of the whisky indices as well as the common financial assets. This is done for the two holding periods. The results are shown in table 8:

[Insert Table 8 Here]

In both holding periods there was evidence to suggest that roughly half of the assets had a normal return distribution while the other half were non-normal. The Shapiro-Wilk test is conducted at the 95% confidence level and reports a p-value that, if lower than 0.05, one can reject the hypothesis that returns are normally distributed around the mean. Skewness and kurtosis each produce a value that indicates the shape and magnitude of the distribution of returns. Generally speaking, under normality skewness should be close to zero and kurtosis should be close to three. In either period, the bond index, the oil & gas index, and the equity indices: *FTSE 250, FTSE 100, MSCI UK* had normal return distribution. Collectible whisky was non-normal in both periods asides from the *CS* repeat sales index in the shorter holding period. These findings suggest that the upcoming MV analysis may have a weaker significance than one would otherwise think; the model may be underestimating risk.

The repeat sales and hedonic whisky indices were run through the optimisation process individually since it would be conceptually impossible to invest in both at the same time, not to mention that neither index actually exists on the market. The findings give an indication of how well investment in a broad base of whiskies traded on *SWA* and *WA* perform against common assets. The common assets used in the Max Sharpe Ratio portfolio are the same as those from before where the excess return for each is drafted. The exception to this is the risk-free rate proxies since they are already incorporated in the process. Figures 3 and 4 display these results:

[Insert Figure 3 Here]

Figure 3 presents the optimised portfolio that uses the real hedonic whisky index. As expected, 40% of the portfolio is allocated to the *Bloomberg Barclays Global Aggregate Bond Index*. 29% is allocated to *FTSE Small Cap Index*, there is a 24% allocation to the *Ziman Real Estate Index*, and finally a 7% allocation to the hedonic whisky index. The major equity indices, as well as the gold, mining, and oil & gas indices attain no portfolio allocation. The overall Sharpe ratio of this optimised portfolio is found to be 0.16.

[Insert Figure 4 Here]

Figure 4 shows the optimised portfolio using the *CS* repeat sales whisky index. Again, 40% of the portfolio is allocated to the *Bloomberg* […] bond index. 23% is allocated to *FTSE Small Cap* index, 21% is now allocated to the *CS* repeat sales whisky index, and the remaining 16% is allocated to the *Ziman Real Estate Index*. Like before, the major equity indices, gold, mining, and oil & gas receive zero portfolio allocation. The overall Sharpe ratio of this optimised portfolio is 0.14.

The weights allocated towards collectible whisky suggest that it is not the most optimal asset choice out of the selection, yet it is preferred over equities and commodities. Under the hedonic index an investor should have a small holding in collectible whisky but should not devote their entire portfolio towards it, probably because it is so volatile. This is precisely the asset allocation strategy that is seen in practice: the average *Ultra High Net Worth Individual* (UHNWI) devotes 5% of their portfolio to collectibles[13]. Often, an investor's portfolio will consist primarily of safe assets but then contain a small fraction of risky ones with the potential to make high gains or losses so that it does not pose a significant detriment to their wealth. Investors following this strategy should consider collectible whisky.

When ran using the less-volatile repeat sales index whisky should constitute roughly a fifth of an investors' portfolio. This is higher than the estimation under the hedonic method and could therefore have positive implications for whisky in the asset allocation decision. The different weights allocated under each index method could serve as a rough interval for the weight that a potential whisky investor chooses.

7 Conclusion

This paper studies investment in collectible whisky by analysing risk-return characteristics and comparing its performance to common assets over a time period of nine years; evidence supports the notion that collectible whisky outperforms relative to others and offers diversification benefits to an investor's portfolio. The market for collectible whisky has experienced tremendous growth in the last decade with a clear shift in sales of bottles in a

[13] Knight Frank. The Wealth Report 2020. pp. 21

lower price band to those in higher ones. Price determinants are found by running a comprehensive hedonic regression that employs bottle, distillery, distillation process, and sales characteristics. A handful of distilleries comprise the majority of sales in the collectible whisky market and it appears that Japanese distilleries produce bottles that provide the highest price impact as well as being amongst the least volatile. Evidence suggests that, like most collectibles, whisky is a supply-driven economy where scarcity factors positively impact price. A repeat sales regression is run concurrently with the hedonic regression to derive price indices for collectible whisky. The monthly real return for collectible whisky is found to be 3.44% under the hedonic model and 1.19% under the repeat sales model. Return volatility is calculated as 27.7% for the hedonic model while the repeat sales model produces a volatility of 7.87%. The sample is split into a shorter holding period, January 2014 – February 2020 and monthly real returns become 1.35% and 1% for the hedonic and repeat sales models respectively. Return volatilities are lower, respectively: 9.01% and 3.65%. The period which saw the highest growth spanned from 2015 Q1 to 2018 Q3.

The paper provided a natural setting to compare index construction techniques. Contrary to previous literature, although both collectible whisky indices followed a similar paths and index levels the hedonic index was considerably more volatile than the repeat sales index. This has serious implications when conducting risk analysis.

Sharpe ratios for collectible whisky are undesirable, ranging from 0.11 to 0.18, however they do not tell the full story. When up-side risk is removed from the equation collectible whisky offers a far more desirable risk-return profile.

Collectible whisky is then compared with other financial assets and outperforms under each measure in most cases. With the exception of fixed income securities the Sharpe ratio of collectible whisky is greater than the Sharpe ratio of the other assets. Furthermore, collectible whisky is found to be strongly uncorrelated with the other assets; its return pattern is fundamentally different. This evidence suggests that collectible whisky presents diversification benefits. To test this a Max Sharpe ratio portfolio was constructed and collectible whisky received a 7% allocation using the hedonic model returns and a 21% allocation when using those of the repeat sales model. This is in-line with allocations that collectibles receive in previous literature, although whisky's is slightly greater.

All in all, this paper builds a favourable case for investment in collectible whisky. It contributes to the literature by being one of the first to study whisky from a financial perspective and uses a timeframe and dataset larger than any existing literature. A detailed analysis of returns and risk transformed collectible whisky into a financial security so that its characteristics could be compared with other assets. An interesting avenue of future research could be to study the 'emotional' component (Campbell, et al. 2009) of collectible whisky, the decomposition of which would enable steadier forecasts of its price evolution.

Bibliography

Bailey, M. J., Muth, R. F., & Nourse, H. O. (1963). *A regression method for real estate price index construction.* Journal of the American Statistical Association, 58(304):933–942.

Belk, R. (1995). *Collecting as Luxury Consumption: Effect on Individuals and Households.* Journal of Economic Psychology. 16 (1995) 477-490

Blumenthal, S. (2015). *Understanding Correlation Diversification.* CMG Wealth. CMG Capital Management. Online resource. Retrieved: http://www.cmgwealth.com/wp-content/uploads/2015/07/Understanding-Correlation-Diversification.pdf

Burton, B. J. & Jacobsen, J. (1999). *Measuring returns on investments in collectibles.* Journal of Economic Perspectives, 13(4):193–212.

Campbell, R. (2008). *Art as a Financial Investment and the Underperformance of Masterpieces.* Journal of Alternative Investments. Spring 2008, 10 (4) 64-81; DOI: https://doi.org/10.3905/jai.2008.705533

Campbell, R., Koedijk, K., & de Roon, F. (2009). *Emotional Assets and Investment Behaviour.* Available at SSRN: http://dx.doi.org/10.2139/ssrn.1341875

Case, B., Pollakowski, H., & Wachter, S. (1991). *On Choosing Among House Price Index Methodologies.* Journal of Real Estate Economics, 19(3):286-307.

Case, K., & Shiller, R. (1987). *Prices of Single Family Homes Since 1970: New Indexes For Four Cities.* NBER Working Paper Series #2393.

Chambers, D., Anson, M., Black, K., Kazemi, H. (2015). *Alternative Investments: CAIA Level I, 3rd Edition.* Wiley Finance: CAIA Knowledge Series. ISBN: 978-1-119-00336-6

Court, AT. (1939). *Hedonic Prices Indexes with Automotive Examples.* The Dynamics of Automobile Demand. General Motors, New York. Pp. 98-119

De Haan, J. & Diewert, E. (2013). *Repeat Sales Methods*. Handbook on Residential Property Price Indices. Eurostat. Luxembourg. DOI: https://doi.org/10.1787/9789264197183-7-en

De Haan, J. & Diewert, E. (2013). *Hedonic Regression Methods*. Handbook on Residential Property Price Indices. Eurostat. Luxembourg. DOI: https://doi.org/10.1787/9789264197183-7-en

Diewert, W. (2003). *Hedonic Regressions. A Consumer Theory Approach.* NBER Chapters, in: Scanner Data and Price Indexes, pages 317-348, National Bureau of Economic Research, Inc.

Dimson, E., & Spaenjers, C. (2014). *The Investment Performance of Art and other Collectibles:* Risk and Uncertainty in the Art World. A&C Black Business Information and Development; 1st ed. Chapter 10. 219-234. ISBN: 978-1472902900

Fama, E.F. & Miller, M.H. (1972). *The Theory of Finance*. Graduate School of Business, University of Chicago. Holt, Rinehart, and Winston: New York.

Gatzlaff, H., & Ling, D. (1994). *Measuring Changes in Local House Prices: An Empirical Investigation of Alternative Methodologies.* Journal of Urban Economics, Elsevier vol. 35(2), pages 221-244, March.

Gérard-Varet, O. & Ginsburgh, V. (1995). *The Relevance of Hedonic Price Indices, The Case of Paintings.* The Journal of Cultural Economics, 20 (1996). 1-24.

Ginsburgh, V., Mei, J., & Moses, M. (2006). *The Computation of Prices Indices*. Handbook of the Economics of Art and Culture. 27. DOI: 10.1016/S1574-0676(06)01027-1

Goetzmann, W., (1992). *The accuracy of real estate indices: repeat-sales estimators,* Journal of Real Estate Finance and Economics 5 (1992), 71-84.

Goetzmann, W., (1993). *Accounting for taste: Art and financial markets over three centuries. American Economic Review* 83, 1370-1376.

Goetzmann, W., & Kumar, A. (2001). *Equity Portfolio Diversification.* Review of Finance, Oxford University Press for European Finance Association, vol. 12(3), pages 433-463

Harjoto, M., & Jones, F. (2006). *Rebalancing Strategy for Stocks and Bonds Asset Allocation.* The Journal of Wealth Management. (Summer 2006), 9 (1) pp. 37-44

Hartig, C., Lennon, C., Teltser, K. (2020). *Bourbon Whiskey: Useful Alternative Investment or just the next Beanie Baby?* Retrieved: http://www.conorjlennon.com/uploads/3/9/6/0/39604893/bourbon_as_investment_paper_spring_2020.pdf

Jorion, P. (1989) *Asset Allocation with Hedged and Unhedged Foreign Stocks and Bonds.* Journal of Portfolio Management. New York. Vol. 15 Issue 4. (Summer 1989): 49.

Kahneman, D. & Tversky, A. (1979). *Prospect Theory: An Analysis of Decision Under Risk.* Journal of the Econometric Society. Vol. 47. No.2 (March 1979). Pp. 263 – 291.

Knight Frank. (2020). *The Wealth Report 2020. The Global Perspective on Prime Property and Management.* 14th Ed.

Knight, J., Dombrow, J., Sirmans, C. (1995). *A Varying Parameters Approach to Constructing House Price Indexes.* Journal of Real Estate Economics. vol. 23, issue 2, 187-205.

Mark, J., & Goldberg, M. (1984). *Alternative House Price Indices: An Evaluation.* Real Estate Economics, 12: 30-49

Markowitz, H. (1952). *Portfolio Selection.* The Journal of Finance, Vol. 7 No. (March, 1952), pp. 77-91.
http://links.jstor.org/sici?sici=00221082%28195203%297%3A1%3C77%3APS%3E2.0.CO%3B2-1

Ma, X. (2019). *Essays on Alternative Investments.* CentER Issue 595. Tilburg University School of Economics and Management.

Masset, P., Henderson, C., Weisskopf, J-C. (2010). *Wine as an Alternative Asset Class.* Available at SSRN: https://ssrn.com/abstract=1123733 or http://dx.doi.org/10.2139/ssrn.1123733

Mei, J., & Moses, M. (2002). *Art as an Investment and the Underperformance of Masterpieces.* The American Economic Review. Vol. 92, No. 5, pp. 1656 – 1668.

Meese, R. & Wallace, N. (1997). *The construction of residential housing price indices. A comparison of repeat-sales, hedonic regression and hybrid approaches*, Journal of Real Estate Finance and Economics 14, 51-73.

Shapiro, S. & Wilk, M. (1965). *An analysis of variance test for normality (complete samples).* Biometrika. Vol. 52. Pp. 591 – 611.

Sharpe, W. (1966). *Mutual Fund Performance*. The Journal of Business. Vol. 39, No. 1, Part 2: Supplement on Security Prices. (Jan 1966), pp. 119 – 138.

Shefrin, H., & Statman, M. (1985). *The disposition to sell winners too early and ride losers too long: Theory and evidence*. The Journal of Finance, 40, 777-790.

Steinbach, M. (2001). *Markowitz Revisited: Mean-Variance Models in Financial Portfolio Analysis.* Society for Industrial and Applied Mathematics. Vol. 43 No. 1. Pp. 31 – 85.

Triplett, J. (2004). *Handbook on hedonic indexes and quality adjustments in price indexes: special application to information technology products.* STI Working Paper 2004/9. OECD Science, Technology and Industry Working Papers.

World Economic Forum. (2015). *Alternative Investments 2020: An Introduction to Alternative Investments.* Online Article, retrieved: http://www3.weforum.org/docs/WEF_Alternative_Investments_2020_An_Introduction_to_AI.pdf

9 Appendix

Table 1 Hedonic Descriptive Statistics

This table provides a descriptive overview of the hedonic variables. *Age* is a discrete variable referring to the number of years the whisky spent in cask before bottling. *Vintage* is a discrete variable indicating the year in which the whisky was distilled. *Size* is continuous referring to the volume in ml of the bottle. *Strength* is continuous indicating the alcoholic strength of the bottle in %. *Collection* is a dummy equal to 1 if the listing was part of a collection. *Collection size* is a discrete variable referring to the number of bottles sold in one listing. *Imported* is a dummy variable equal to 1 if the bottle was produced for the export market and 0 otherwise. *Damaged*, and *Buzzword* are dummy variables equal to 1 if the bottle was damaged or contained a buzzword, respectively. *Region* dummies refer to the region in which the whisky was produced, taking the value of 1 if the whisky was produced there and 0 otherwise. *Operational* and *Inaugural* are dummies taking the value of 1 if the distillery is still operational as of 2020 and whether the whisky was of the first batch of releases from the distillery, respectively. *Distillery* dummies take the value of 1 if the whisky was produced in that particular distillery and 0 otherwise. *Wood* dummies take the value of 1 if the cask in which the whisky was aged was made from that particular type of wood. *Preceding Alcohol* dummies take the value of 1 to indicate the previous alcohol that was used in the cask. *Uses* and *Cask Size* are dummy variables referring to the number of uses and the size of cask that was used in the ageing process. *Single Cask* and *Private Cask* are dummy variables indicating whether the whisky was aged in one sole cask, and whether it was a custom whisky, respectively. *Month* and *Year* dummies refer to the month and year in which the bottle was sold at auction. *Auction House* are dummies that take the value of 1 to indicate the source of the sale. *Price* gives a summary of nominal hammer prices in GBP. For all variables, the number of observations, mean, standard deviation, minimum, maximum, and binary count of 0s and 1s are given.

Bottle Characteristics

	N	Mean	S.D.	Min	Max	Zeros	Ones
Bottle							
Age	46,610	24.3	9.5	1	75	N/A	N/A
Vintage	43,219	1983	17.2	1900	2020	N/A	N/A
Size	64,225	76.9	419	0.1	43270	N/A	N/A
Strength	63,414	0.50	0.07	0.17	0.74	N/A	N/A
Collection							
Collection	64,277	0.02	0.15	0	1	62,813	1,464
Collect. Size	34,769	1.14	1.15	1	96	N/A	N/A
Type							
Imported	64,277	0.04	0.20	0	1	61,574	2,703
Damaged	64,277	0.00	0.01	0	1	64,264	13
Other							
Buzzword	64,277	0.08	0.27	0	1	59,019	5,258

Distillery Characteristics

	N	Mean	S.D.	Min	Max	Zeros	Ones
Region							
Scotland	64,277	0.73	0.45	0	1	17,613	46,664
Campbeltown	64,277	0.02	0.14	0	1	63,064	1,213
Islay	64,277	0.19	0.39	0	1	52,227	12,050
Lowland	64,277	0.03	0.17	0	1	62,283	1,994
Speyside	64,277	0.33	0.47	0	1	42,840	21,437
Highland	64,277	0.12	0.32	0	1	56,827	7,450
Island	64,277	0.04	0.19	0	1	61,809	2,468
Ireland	64,277	0.00	0.09	0	1	63,697	580
N. America	64,277	0.05	0.21	0	1	61,202	3,075
Japan	64,277	0.19	0.39	0	1	51,856	12,421
Type							
Operational	64,277	0.76	0.43	0	1	15,696	48,581
Inaugural	64,277	0.00	0.04	0	1	64,159	118

Distillery							
Macallan	64,277	N/A	N/A	0	1	50,422	13,855
Karuizawa	64,277	N/A	N/A	0	1	59,892	4,385
Port Ellen	64,277	N/A	N/A	0	1	60,922	3,355
Yamazaki	64,277	N/A	N/A	0	1	61,769	2,508
Ardbeg	64,277	N/A	N/A	0	1	61,806	2,471
Bowmore	64,277	N/A	N/A	0	1	62,137	2,140
Brora	64,277	N/A	N/A	0	1	62,425	1,852
Highland Park	64,277	N/A	N/A	0	1	62,446	1,831
Balvenie	64,277	N/A	N/A	0	1	62,553	1,724
Buffalo Trace	64,277	N/A	N/A	0	1	62,619	1,658
Chichibu	64,277	N/A	N/A	0	1	62,802	1,475
Hibiki	64,277	N/A	N/A	0	1	62,901	1,376
Laphroaig	64,277	N/A	N/A	0	1	63,001	1,276
Lagavulin	64,277	N/A	N/A	0	1	63,113	1,164
Springbank	64,277	N/A	N/A	0	1	63,127	1,150
Glendronach	64,277	N/A	N/A	0	1	63,150	1,127
Glenfarclas	64,277	N/A	N/A	0	1	63,153	1,124
Hanyu	64,277	N/A	N/A	0	1	63,346	931
Glenfiddich	64,277	N/A	N/A	0	1	63,427	850
Bruichladdich	64,277	N/A	N/A	0	1	63,501	776
Glenmorangie	64,277	N/A	N/A	0	1	63,539	738
Rosebank	64,277	N/A	N/A	0	1	63,550	727
Clynelish	64,277	N/A	N/A	0	1	63,766	511
Dalmore	64,277	N/A	N/A	0	1	63,804	473
Glenlivet	64,277	N/A	N/A	0	1	63,816	461
Glen Grant	64,277	N/A	N/A	0	1	63,828	449
Yoichi	64,277	N/A	N/A	0	1	63,862	415
Bunnahabhain	64,277	N/A	N/A	0	1	63,867	410
Hakushu	64,277	N/A	N/A	0	1	63,876	401
Talisker	64,277	N/A	N/A	0	1	63,879	398

			Cask Characteristics				
	N	**Mean**	**S.D.**	**Min**	**Max**	**Zeros**	**Ones**
Wood							
US Oak	64,277	0.02	0.15	0	1	62,825	1,452
EU Oak	64,277	0.02	0.13	0	1	63,151	1,126
JP Oak	64,277	0.01	0.08	0	1	63,874	403
Preceding alcohol							
Ex Sherry	64,277	0.26	0.44	0	1	47,724	16,553
Ex Bourbon	64,277	0.04	0.20	0	1	61,654	2,623
Ex Wine	64,277	0.01	0.07	0	1	63,979	298
Ex Port	64,277	0.01	0.07	0	1	63,990	287
Ex Rum	64,277	0.00	0.03	0	1	64,216	61
Ex Beer	64,277	0.00	0.01	0	1	64,271	6
Uses							
Virgin	64,277	0.02	0.15	0	1	62,826	1,451
Second Fill	64,277	0.00	0.03	0	1	64,207	70
Third Fill	64,277	0.00	0.03	0	1	64,223	54
Fourth Fill	64,277	0.00	0.01	0	1	64,267	10
Cask Size							
Large	64,277	0.08	0.27	0	1	58,990	5,287
Medium	64,277	0.05	0.22	0	1	61,137	3,140
Small	64,277	0.00	0.02	0	1	64,262	15
Other							
Single Cask	64,277	0.11	0.32	0	1	57,073	7,204
Private Cask	64,277	0.00	0.03	0	1	64,229	48

Transaction Characteristics							
	N	Mean	S.D.	Min	Max	Zeros	Ones
Month							
January	64,277	0.09	0.28	0	1	58,774	5,503
February	64,277	0.1	0.30	0	1	58,031	6,246
March	64,277	0.07	0.26	0	1	59,469	4,808
April	64,277	0.07	0.25	0	1	59,856	4,421
May	64,277	0.07	0.26	0	1	59,662	4,615
June	64,277	0.07	0.26	0	1	59,594	4,683
July	64,277	0.09	0.28	0	1	58,747	5,530
August	64,277	0.07	0.26	0	1	59,637	4,640
September	64,277	0.09	0.29	0	1	58,350	5,927
October	64,277	0.09	0.29	0	1	58,437	5,840
November	64,277	0.1	0.29	0	1	58,130	6,147
December	64,277	0.09	0.29	0	1	58,360	5,917
Year							
2011	64,277	0.002	0.05	0	1	64,118	159
2012	64,277	0.005	0.07	0	1	63,980	297
2013	64,277	0.014	0.12	0	1	63,406	871
2014	64,277	0.059	0.24	0	1	60,502	3,775
2015	64,277	0.063	0.24	0	1	60,218	4,059
2016	64,277	0.094	0.29	0	1	58,265	6,012
2017	64,277	0.152	0.36	0	1	54,508	9,769
2018	64,277	0.234	0.42	0	1	49,263	15,014
2019	64,277	0.329	0.47	0	1	43,116	21,161
2020	64,277	0.049	0.22	0	1	61,117	3,160
Auction House							
WhiskyAuctioneer	64,277	0.54	0.50	0	1	29,508	34,769
Scotch Whisky Auctions	64,277	0.46	0.50	0	1	34,769	29,508

Hammer Price						
	N	Mean	S.D.	Min	Max	Median
Price (Nominal in GBP)						
Hammer Price	64,277	1337.18	2621.5	20	110,000	755

Table 2 Market Sales Characteristics

Table 2 displays sales characteristics of the dataset. Panel A shows market share categorised by price band. The frequency of sales across several price bands are given along with the percentage of sales in that price band for that given year. Panel B provides a distillery analysis showing the top distilleries by sales volume (listings), revenue (real hammer price, GBP), and average sales price (real hammer price, GBP). Collections are removed from sales volume and average sales price to control for misspecification. Panel C lists the most and least volatile distilleries and individual bottles, using the standard deviation of the natural logarithm of real hammer prices. Each required a minimum of 5 (repeat) sales to be included in the specification.

Panel A: Market Share Per £ Price Band (Real)

			Frequency				
Year/Price	**< £500**	**£500-£999**	**£1,000-£2,499**	**£2,500-£4,999**	**£5,000-£9,999**	**>£10,000**	**Total Sales**
2011	147	11	1	0	0	0	159
2012	181	96	19	1	0	0	297
2013	342	415	104	9	1	0	871
2014	2640	858	232	31	10	1	3775
2015	1504	1540	849	135	22	9	4059
2016	1627	2358	1643	208	64	17	6012
2017	2790	3812	2546	452	120	48	9769
2018	4495	5053	4017	1081	203	165	15014
2019	7602	7,068	4,636	1,242	308	304	21161
2020	1205	1041	638	188	51	37	3160
			% of Total Sales				
	< £500	**£500-£999**	**£1,000-£2,499**	**£2,500-£4,999**	**£5,000-£9,999**	**>£10,000**	
2011	92.45%	6.92%	0.63%	0.00%	0.00%	0.00%	
2012	60.94%	32.32%	6.40%	0.34%	0.00%	0.00%	
2013	39.27%	47.65%	11.94%	1.03%	0.11%	0.00%	
2014	69.93%	22.73%	6.15%	0.82%	0.26%	0.03%	
2015	37.05%	37.94%	20.92%	3.33%	0.54%	0.22%	
2016	27.06%	39.22%	27.33%	3.46%	1.06%	0.28%	
2017	28.56%	39.02%	26.06%	4.63%	1.23%	0.49%	
2018	29.94%	33.66%	26.76%	7.20%	1.35%	1.10%	
2019	35.92%	33.40%	21.91%	5.87%	1.46%	1.44%	
2020	38.13%	32.94%	20.19%	5.95%	1.61%	1.17%	

Panel B: Top Distilleries by Sales Volume, Revenue, & Highest Avg. Sales Price					
Sales Volume		Sales Revenue		Average Sales Price	
Distillery	**Freq.**	**Distillery**	**Real Hammer Price, £'s**	**Distillery**	**Real Hammer Price, £'s**
Macallan	13,855	Macallan	20,747,148	Bowmore	2164
Karuizawa	4,385	Karuizawa	9,225,918	Karuizawa	2107
Port Ellen	3,355	Bowmore	4,631,895	Hanyu	2039
Yamazaki	2,508	Port Ellen	3,178,685	Tamdhu	1596
Ardbeg	2,471	Yamazaki	2,702,044	Dalmore	1530
Bowmore	2,140	Ardbeg	2,068,760	Macallan	1499
Brora	1,852	Hanyu	1,893,744	Bomberger's	1444
Highland Park	1,831	Brora	1,653,313	Medley's	1427
Balvenie	1,724	Laphroaig	1,565,755	Pennco	1411
Buffalo Trace	1,658	Highland Park	1,473,935	Uitvlugt	1356
Chichibu	1,475	Springbank	1,331,504	Old Midleton	1322
Hibiki	1,376	Glenfarclas	1,250,672	Glen Garioch	1306
Laphroaig	1,276	Hibiki	1,182,263	Longrow	1241
Lagavulin	1,164	Balvenie	1,198,721	Laphroaig	1288
Springbank	1,150	Buffalo Trace	1,106,074	Springbank	1162
Glendronach	1,127	Glendronach	956,758	Jura	1154
Glenfarclas	1,124	Chichibu	916,037	Eden Mill	1147
Hanyu	931	Lagavulin	890,289	Kawasaki	1133
Glenfiddich	850	Glenfiddich	795,957	Glenfarclas	1113
Bruichladdich	776	Dalmore	723,640	Mitcher	1111
Glenmorangie	738	Rosebank	476,439	Ben Nevis	1098
Rosebank	727	Clynelish	455,033	West Overton	1098
Clynelish	511	Glenlivet	425,383	Yamazaki	1079
Dalmore	473	Hakushu	425,374	Hakushu	1061
Glenlivet	461	Bruichladdich	423,905	Stitzel-Weller	1029
Glen Grant	449	Glenmorangie	419,255	Speyburn	1028
Yoichi	415	Glen Grant	403,156	Bow Street	1022
Bunnahabhain	410	Yoichi	319,149	Mortlach	1003
Hakushu	401	Talisker	308,253	Tullibardine	987
Talisker	398	Bunnahabhain	278,664	George T. Stagg	953

Panel C: Distilleries & Bottles by Volatility

Most Volatile Distilleries		Least Volatile Distilleries	
Distillery	**Std. Dev. Log of Real Hammer Prices**	**Distillery**	**Std. Dev. Log of Real Hammer Prices**
Bowmore	1.1	Glenflagler	0.15
Royal Lochnaga	1.09	Buffalo Trace	0.19
Tamdhu	1.07	Heaven Hill Berr	0.20
Glen Esk	1.03	Wolfburn	0.20
Dalmore	1.02	Hillside	0.21
Royal Brackla	0.94	Killyloch	0.22
Hanyu	0.89	Wild Turkey	0.24
Laphroaig	0.85	Convalmore	0.24
Glen Garioch	0.83	Amrut	0.26
Cardhu	0.83	Ben Wyvis	0.28
Glenfiddich	0.82	Miltonduff	0.29
Springbank	0.82	Daftmill	0.29
Mortlach	0.82	Ancient Age	0.33
Isle of Jura	0.81	Millburn	0.33
Tullibardine	0.80	Craigellachie	0.35

Most Volatile Bottles		Least Volatile Bottles	
Bottle	**Std. Dev. Log of Real Hammer Prices**	**Bottle**	**Std. Dev. Log of Real Hammer Prices**
Macallan 1959 43 Y.O.	2.43	Blanton's Single Barrel 2018	0.01
Bowmore 1967	2.34	Port Charlotte 12 Y.O. Polar	0.01
Glenmorangie 1974	2.07	Macallan Aera	0.02
Macallan 1958 43 Y.O.	1.85	Glen Moray 1987 SMWS 31 Y.O	0.02
Hanyu 1990 Ichiro's Malt 'Card'	1.72	Karuizawa 1999/2000 Cask	0.02
Bowmore Legend	1.70	Avonside 1938 G&M 33 Y.O.	0.02
Macallan 1950 52 Y.O.	1.65	Chichibu US Edition 2019 75CL	0.02
Springbank Single Cask #251	1.58	Clynelish 12 Y.O. Ainslie 1973	0.03
Johnnie Walker 1939 Red Label	1.55	Glenugie 1977 Signatory 32 Y.O.	0.03
Macallan 1965 36 Y.O.	1.52	Chichibu 2019S	0.03
Laphroaig 10 Y.O.	1.51	Chichibu 2011 Belgian Cask	0.03
Yamazaki 1998 Single Cask	1.49	Chichibu 2013 Ichiro's Malt	0.03
Macallan 1967 35 Y.O.	1.40	Macallan Re-Awakening 12 Y.O.	0.03
Longrow Samaroli Fragm. of Sco	1.38	Karuizawa 1969 Single Cask	0.03
Macallan 1966 35 Y.O.	1.36	Yamazaki 18 Year Old	0.03

Table 3 Baseline Hedonic Regression

Table 3 displays the results from the hedonic regression. The regression is estimated using Ordinary Least Squares (OLS) with the dependent variable the natural logarithm of auction hammer prices deflated to 2011. Column 1 reports the regression coefficients with standard errors in parenthesis. Column 2 reports the price impact which is calculated as the exponent of the estimated coefficient minus one. *, **, and *** indicate statistical significance at the 10%, 5%, and 1% levels, respectively.

VARIABLES	(1) Coefficient	(2) Price Impact
May-11	-0.7919***	-54.70%
	(0.2848)	
Jun-11	0.3570	42.90%
	(0.2193)	
Jul-11	0.6707*	95.56%
	(0.3828)	
Aug-11	0.0935	9.80%
	(0.1781)	
Sep-11	-0.0091	-0.91%
	(0.2204)	
Oct-11	-0.1148	-10.85%
	(0.2025)	
Nov-11	0.2815	32.51%
	(0.2020)	
Dec-11	0.4358**	54.62%
	(0.2220)	
Jan-12	0.5802**	78.64%
	(0.2357)	
Feb-12	0.3193*	37.62%
	(0.1747)	
Mar-12	0.6752***	96.44%
	(0.1751)	
Apr-12	0.5465***	72.72%
	(0.1750)	
May-12	0.6133***	84.65%
	(0.1899)	
Jun-12	0.4334***	54.25%
	(0.1673)	
Jul-12	0.2787	32.14%
	(0.1758)	
Aug-12	0.5390***	71.43%
	(0.1962)	
Sep-12	0.5985***	81.94%
	(0.1777)	
Oct-12	0.7337***	108.28%
	(0.1877)	
Nov-12	0.9492***	158.36%
	(0.1878)	
Dec-12	0.6910***	99.57%
	(0.1712)	

Jan-13	0.6378*** (0.1799)	89.23%
Feb-13	0.9149*** (0.1846)	149.65%
Mar-13	0.8493*** (0.1735)	133.80%
Apr-13	0.5584*** (0.1682)	74.79%
May-13	0.7968*** (0.1699)	121.84%
Jun-13	0.6304*** (0.1743)	87.84%
Jul-13	0.6710*** (0.1631)	95.62%
Aug-13	0.8329*** (0.1849)	130.00%
Sep-13	0.5662*** (0.1690)	76.16%
Oct-13	0.6833*** (0.1670)	98.04%
Nov-13	0.6638*** (0.1685)	94.22%
Dec-13	0.6431*** (0.1708)	90.24%
Jan-14	0.4492*** (0.1619)	56.71%
Feb-14	0.4186** (0.1653)	51.98%
Mar-14	0.2997* (0.1690)	34.95%
Apr-14	0.3036* (0.1622)	35.47%
May-14	0.3677** (0.1636)	44.44%
Jun-14	0.5002*** (0.1616)	64.91%
Jul-14	0.3996** (0.1605)	49.12%
Aug-14	0.4420*** (0.1597)	55.58%
Sep-14	0.3391** (0.1608)	40.37%
Oct-14	0.3671** (0.1609)	44.35%
Nov-14	0.6604*** (0.1605)	93.56%
Dec-14	0.6475*** (0.1607)	91.08%
Jan-15	0.6685*** (0.1604)	95.13%
Feb-15	0.8703*** (0.1589)	138.76%

Mar-15	0.7284*** (0.1628)	107.18%
Apr-15	0.8305*** (0.1583)	129.45%
May-15	0.7286*** (0.1599)	107.22%
Jun-15	0.7136*** (0.1590)	104.13%
Jul-15	0.7586*** (0.1576)	113.53%
Aug-15	0.9002*** (0.1590)	146.01%
Sep-15	0.8446*** (0.1599)	132.70%
Oct-15	0.9122*** (0.1582)	148.98%
Nov-15	0.8661*** (0.1587)	137.76%
Dec-15	0.8532*** (0.1590)	134.71%
Jan-16	0.8425*** (0.1578)	132.22%
Feb-16	0.8700*** (0.1573)	138.69%
Mar-16	0.9593*** (0.1577)	160.99%
Apr-16	0.9003*** (0.1591)	146.03%
May-16	0.9225*** (0.1578)	151.56%
Jun-16	0.9904*** (0.1582)	169.23%
Jul-16	1.0634*** (0.1574)	189.62%
Aug-16	1.0892*** (0.1575)	197.19%
Sep-16	1.0484*** (0.1579)	185.31%
Oct-16	1.0893*** (0.1575)	197.22%
Nov-16	1.2172*** (0.1584)	237.77%
Dec-16	1.0930*** (0.1570)	198.32%
Jan-17	1.1092*** (0.1577)	203.19%
Feb-17	1.0782*** (0.1575)	193.94%
Mar-17	1.0799*** (0.1569)	194.44%
Apr-17	1.0278*** (0.1575)	179.49%

May-17	1.0937*** (0.1569)	198.53%
Jun-17	1.1500*** (0.1575)	215.82%
Jul-17	1.0781*** (0.1569)	193.91%
Aug-17	1.0932*** (0.1575)	198.38%
Sep-17	1.1120*** (0.1570)	204.04%
Oct-17	1.1600*** (0.1567)	218.99%
Nov-17	1.1602*** (0.1567)	219.06%
Dec-17	1.2561*** (0.1569)	251.17%
Jan-18	1.2147*** (0.1573)	236.93%
Feb-18	1.2490*** (0.1572)	248.69%
Mar-18	1.2327*** (0.1573)	243.05%
Apr-18	1.2391*** (0.1568)	245.25%
May-18	1.2520*** (0.1571)	249.73%
Jun-18	1.3009*** (0.1572)	267.26%
Jul-18	1.3024*** (0.1573)	267.81%
Aug-18	1.3113*** (0.1577)	271.10%
Sep-18	1.2541*** (0.1565)	250.47%
Oct-18	1.2715*** (0.1568)	256.62%
Nov-18	1.3094*** (0.1566)	270.40%
Dec-18	1.2792*** (0.1566)	259.38%
Jan-19	1.1739*** (0.1565)	223.46%
Feb-19	1.2574*** (0.1565)	251.63%
Mar-19	1.2591*** (0.1564)	252.23%
Apr-19	1.3143*** (0.1567)	272.21%
May-19	1.3234*** (0.1569)	242.95%
Jun-19	1.2807*** (0.1564)	259.92%

Jul-19	1.2244*** (0.1565)	240.21%
Aug-19	1.2334*** (0.1570)	243.29%
Sep-19	1.2404*** (0.1565)	245.70%
Oct-19	1.2641*** (0.1567)	253.99%
Nov-19	1.3046*** (0.1567)	268.62%
Dec-19	1.2095*** (0.1568)	235.18%
Jan-20	1.3002*** (0.1572)	267.00%
Feb-20	1.2005*** (0.1566)	232.18%
Ardbeg	0.2645*** (0.0635)	30.28%
Balvenie	0.2091*** (0.0673)	23.26%
Bowmore	0.4467*** (0.0650)	56.31%
Brora	-0.0597 (0.0752)	-5.80%
Bruichladdich	-0.4597*** (0.0649)	-36.85%
Buffalo Trace	0.1934*** (0.0631)	21.34%
Bunnahabhain	-0.6717*** (0.0692)	-48.92%
Chichibu	0.6174*** (0.0650)	85.41%
Clynelish	-0.0361 (0.0665)	-3.55%
Dalmore	0.1661** (0.0759)	18.07%
Glen Grant	-0.8721*** (0.0716)	-58.19%
Glendronach	-0.3232*** (0.0645)	-27.62%
Glenfarclas	-0.7072*** (0.0670)	-50.70%
Glenfiddich	0.0563 (0.0658)	5.79%
Glenlivet	-0.5896*** (0.0748)	-44.55%
Glenmorangie	-0.0175 (0.0688)	-1.73%
Hakushu	0.4514*** (0.0788)	57.05%
Hanyu	0.5425*** (0.0843)	72.03%

Hibiki	1.4183***	313.01%
	(0.1587)	
Highland Park	-0.2589***	-22.81%
	(0.0645)	
Karuizawa	0.4840***	62.26%
	(0.0753)	
Lagavulin	0.1042*	10.98%
	(0.0629)	
Laphroaig	0.3122***	36.64%
	(0.0691)	
Macallan	0.5130***	67.03%
	(0.0632)	
Port Ellen	-0.2133***	-19.21%
	(0.0734)	
Rosebank	-0.4089***	-33.56%
	(0.0747)	
Springbank	0.0222	2.24%
	(0.0664)	
Talisker	-0.2796***	-24.39%
	(0.0692)	
Yamazaki	0.7498***	111.66%
	(0.0753)	
Yoichi	0.3370***	40.07%
	(0.0662)	
Log Bottle Strength	0.8358***	130.67%
	(0.0339)	
Log Bottle Size	0.5604***	75.14%
	(0.0226)	
Vintage	-0.0149***	-1.48%
	(0.0004)	
Collection	0.3757***	45.60%
	(0.0656)	
Operational	-0.1626***	-15.01%
	(0.0412)	
Cask US Oak	-0.1142***	-10.79%
	(0.0202)	
Cask EU Oak	0.4942***	63.92%
	(0.0269)	
Cask JP Oak	0.5732***	77.39%
	(0.0619)	
Cask Sherry	0.1895***	20.86%
	(0.0113)	
Cask Bourbon	-0.0031	-0.31%
	(0.0169)	
Cask Wine	-0.2392***	-21.27%
	(0.0401)	
Cask Virgin	-0.0587***	-5.70%
	(0.0221)	
Cask Second Fill	0.0413	4.22%
	(0.0735)	
Cask Third Fill	-0.4483***	-36.13%
	(0.0577)	

Cask Port	-0.2209***	-19.82%
	(0.0474)	
Cask Rum	0.1609	17.46%
	(0.1016)	
Cask Large	-0.2321***	-20.71%
	(0.0130)	
Cask Medium	-0.0886***	-8.48%
	(0.0162)	
Cask Small	-0.5333***	-41.33%
	(0.0782)	
Single Cask	0.1189***	12.63%
	(0.0116)	
Imported	0.1041***	10.97%
	(0.0171)	
Inaugural	0.0887	9.28%
	(0.1036)	
Cask Private	-0.1331	-12.46%
	(0.0912)	
Buzzword	-0.0177	-1.75%
	(0.0141)	
Age	0.0373***	3.80%
	(0.0006)	
Damaged	-0.2420	-21.49%
	(0.1929)	
SWA	-0.0506***	-4.93%
	(0.0064)	
Constant	32.4330***	
	(0.8565)	
Observations	31,994	
R-squared	0.5718	

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 4 Indices & Returns

Table 4 presents the four different index constructions for collectible whisky. The hedonic index deflated to 2011 (real), the hedonic index in nominal terms, the repeat sales index under the Case & Shiller (1987) approach which introduces a holding period variable, and the repeat sales index under the Bailey, Muth, & Nourse (1963) approach. All indices are set to the base level off 100 at the start period: April 2011. Real returns for each period are also computed in adjacent columns.

Date	Whisky Hedonic (Real)	Return	Whisky Hedonic (Nom)	Return
Apr-11	100		100	
May-11	34.42	-65.58%	62.93	-37.07%
Jun-11	113.36	229.33%	105.59	67.80%
Jul-11	145.46	28.31%	117.67	11.44%
Aug-11	76.76	-47.23%	89.15	-24.24%
Sep-11	90.67	18.13%	95.84	7.51%
Oct-11	78.78	-13.12%	90.16	-5.93%
Nov-11	117.62	49.30%	107.30	19.02%
Dec-11	111.24	-5.43%	104.74	-2.39%
Jan-12	153.25	37.77%	122.03	16.51%
Feb-12	106.55	-30.48%	104.21	-14.61%
Mar-12	141.81	33.10%	117.99	13.22%
Apr-12	126.39	-10.87%	112.23	-4.88%
May-12	131.42	3.98%	114.15	1.70%
Jun-12	112.09	-14.71%	106.53	-6.67%
Jul-12	113.58	1.33%	107.14	0.57%
Aug-12	146.33	28.84%	119.60	11.63%
Sep-12	127.72	-12.72%	112.75	-5.73%
Oct-12	154.48	20.95%	122.45	8.60%
Nov-12	213.49	38.20%	140.92	15.08%
Dec-12	159.41	-25.33%	124.14	-11.91%
Jan-13	143.53	-9.96%	120.14	-3.22%
Feb-13	211.40	47.29%	142.13	18.31%
Mar-13	192.86	-8.77%	136.59	-3.90%
Apr-13	127.52	-33.88%	114.12	-16.45%
May-13	172.44	35.23%	130.11	14.01%
Jun-13	147.37	-14.54%	121.53	-6.59%
Jul-13	157.18	6.65%	124.97	2.83%
Aug-13	166.48	5.92%	128.13	2.53%
Sep-13	137.16	-17.61%	117.79	-8.08%
Oct-13	142.13	3.62%	119.63	1.56%
Nov-13	157.37	10.72%	125.03	4.52%
Dec-13	140.03	-11.01%	118.85	-4.94%
Jan-14	124.12	-11.36%	114.01	-4.07%
Feb-14	129.16	4.06%	116.00	1.75%
Mar-14	100.19	-22.43%	103.88	-10.44%
Apr-14	100.63	0.44%	104.08	0.19%
May-14	109.10	8.42%	107.80	3.57%
Jun-14	127.47	16.84%	115.33	6.98%
Jul-14	113.48	-10.97%	109.66	-4.92%
Aug-14	117.42	3.47%	111.29	1.49%
Sep-14	104.13	-11.32%	105.63	-5.09%
Oct-14	106.64	2.41%	106.74	1.05%
Nov-14	146.02	36.93%	122.35	14.63%
Dec-14	142.72	-2.26%	121.13	-1.00%
Jan-15	148.88	4.32%	123.87	2.27%
Feb-15	180.69	21.36%	134.73	8.76%
Mar-15	149.51	-17.25%	124.10	-7.89%
Apr-15	171.36	14.61%	131.67	6.10%
May-15	156.64	-8.59%	126.63	-3.82%
Jun-15	153.57	-1.96%	125.55	-0.86%
Jul-15	162.00	5.49%	128.49	2.35%
Aug-15	186.43	15.08%	136.57	6.29%

Sep-15	176.07	-5.56%	133.23	-2.45%
Oct-15	190.39	8.13%	137.82	3.45%
Nov-15	173.97	-8.63%	132.54	-3.83%
Dec-15	174.25	0.16%	132.63	0.07%
Jan-16	173.07	-0.68%	133.32	0.52%
Feb-16	176.60	2.04%	134.50	0.88%
Mar-16	198.81	12.58%	141.59	5.27%
Apr-16	180.74	-9.09%	135.85	-4.06%
May-16	189.33	4.75%	138.62	2.04%
Jun-16	204.15	7.83%	143.25	3.33%
Jul-16	219.20	7.37%	147.73	3.13%
Aug-16	223.83	2.11%	149.08	0.91%
Sep-16	210.56	-5.93%	145.16	-2.62%
Oct-16	224.01	6.39%	149.12	2.73%
Nov-16	258.36	15.34%	158.66	6.40%
Dec-16	222.93	-13.71%	148.82	-6.20%
Jan-17	234.62	5.24%	154.45	3.78%
Feb-17	224.59	-4.28%	151.54	-1.88%
Mar-17	223.94	-0.29%	151.36	-0.12%
Apr-17	211.26	-5.66%	147.57	-2.51%
May-17	227.69	7.78%	152.46	3.31%
Jun-17	241.74	6.17%	156.47	2.63%
Jul-17	229.06	-5.25%	152.85	-2.31%
Aug-17	231.17	0.92%	153.46	0.40%
Sep-17	233.40	0.96%	154.10	0.41%
Oct-17	242.49	3.89%	156.67	1.67%
Nov-17	243.22	0.30%	156.88	0.13%
Dec-17	259.43	6.66%	161.35	2.85%
Jan-18	250.03	-3.62%	160.96	-0.24%
Feb-18	267.01	6.79%	165.62	2.89%
Mar-18	265.25	-0.66%	165.15	-0.28%
Apr-18	264.72	-0.20%	165.00	-0.09%
May-18	271.23	2.46%	166.76	1.07%
Jun-18	276.71	2.02%	168.20	0.86%
Jul-18	278.74	0.73%	168.74	0.32%
Aug-18	284.99	2.24%	170.39	0.97%
Sep-18	267.27	-6.22%	165.70	-2.75%
Oct-18	271.23	1.48%	166.76	0.64%
Nov-18	273.74	0.92%	167.43	0.40%
Dec-18	274.01	0.10%	167.50	0.04%
Jan-19	247.19	-9.79%	161.96	-3.30%
Feb-19	262.74	6.29%	166.31	2.69%
Mar-19	265.67	1.12%	167.11	0.48%
Apr-19	277.99	4.63%	170.44	1.99%
May-19	288.81	3.89%	173.29	1.67%
Jun-19	269.07	-6.84%	168.03	-3.03%
Jul-19	255.69	-4.97%	164.36	-2.19%
Aug-19	262.53	2.68%	166.26	1.16%
Sep-19	269.18	2.53%	168.07	1.09%
Oct-19	269.04	-0.05%	168.03	-0.02%
Nov-19	267.01	-0.76%	167.48	-0.33%
Dec-19	241.81	-9.43%	160.43	-4.21%
Jan-20	279.57	15.62%	172.77	7.69%
Feb-20	249.53	-10.75%	164.44	-4.82%

Date	Whisky RSR CS	Return	Whisky RSR BMN	Return
Apr-11	100		100	
May-11	100	0.00%	100	0.00%
Jun-11	129.37	29.37%	128.02	28.02%
Jul-11	160.66	24.18%	136.03	6.26%
Aug-11	131.26	-18.30%	130.01	-4.42%
Sep-11	106.55	-18.83%	107.18	-17.57%
Oct-11	104.74	-1.70%	110.43	3.04%
Nov-11	106.89	2.06%	109.60	-0.76%
Dec-11	109.60	2.53%	107.75	-1.68%
Jan-12	115.33	5.23%	116.64	8.25%
Feb-12	98.16	-14.89%	101.49	-12.99%
Mar-12	96.06	-2.14%	98.95	-2.50%
Apr-12	127.03	32.24%	121.04	22.32%
May-12	110.49	-13.02%	113.11	-6.55%
Jun-12	101.75	-7.91%	106.57	-5.78%
Jul-12	112.09	10.16%	113.44	6.45%
Aug-12	131.55	17.35%	129.09	13.80%
Sep-12	131.59	0.03%	127.51	-1.22%
Oct-12	130.71	-0.67%	132.27	3.73%
Nov-12	136.10	4.12%	138.16	4.45%
Dec-12	131.79	-3.16%	132.53	-4.07%
Jan-13	114.45	-13.16%	119.01	-10.21%
Feb-13	141.00	23.20%	139.94	17.59%
Mar-13	129.62	-8.07%	129.24	-7.65%
Apr-13	130.42	0.62%	130.33	0.84%
May-13	131.09	0.51%	132.03	1.31%
Jun-13	130.03	-0.81%	130.71	-1.00%
Jul-13	135.68	4.35%	134.79	3.12%
Aug-13	144.52	6.52%	144.79	7.42%
Sep-13	125.40	-13.23%	130.12	-10.13%
Oct-13	146.82	17.08%	145.17	11.57%
Nov-13	126.01	-14.17%	127.23	-12.36%
Dec-13	127.23	0.97%	128.57	1.06%
Jan-14	131.31	3.21%	135.29	5.22%
Feb-14	134.35	2.32%	134.88	-0.30%
Mar-14	122.36	-8.92%	124.72	-7.53%
Apr-14	129.83	6.10%	131.02	5.05%
May-14	146.49	12.83%	146.96	12.17%
Jun-14	149.00	1.71%	149.91	2.00%
Jul-14	141.65	-4.93%	144.60	-3.54%
Aug-14	151.07	6.65%	156.25	8.05%
Sep-14	150.48	-0.39%	155.43	-0.52%
Oct-14	149.17	-0.87%	151.22	-2.71%
Nov-14	144.81	-2.92%	148.71	-1.66%
Dec-14	145.33	0.36%	148.86	0.10%
Jan-15	145.65	0.22%	150.92	1.39%
Feb-15	155.33	6.65%	159.15	5.45%
Mar-15	149.22	-3.93%	154.24	-3.09%
Apr-15	153.88	3.13%	158.50	2.77%
May-15	155.26	0.90%	158.97	0.29%
Jun-15	157.06	1.16%	161.45	1.56%
Jul-15	159.98	1.86%	162.89	0.89%
Aug-15	171.04	6.91%	173.85	6.73%
Sep-15	165.93	-2.99%	170.39	-1.99%
Oct-15	167.03	0.67%	169.94	-0.27%
Nov-15	163.03	-2.40%	166.81	-1.84%
Dec-15	170.06	4.32%	173.01	3.71%
Jan-16	162.73	-4.31%	166.25	-3.90%
Feb-16	173.38	6.54%	176.94	6.43%
Mar-16	180.95	4.37%	183.91	3.94%
Apr-16	179.13	-1.01%	182.42	-0.81%
May-16	181.42	1.28%	184.94	1.38%

Jun-16	184.03	1.44%	186.52	0.86%
Jul-16	197.05	7.08%	200.85	7.68%
Aug-16	204.47	3.76%	209.15	4.13%
Sep-16	198.18	-3.07%	202.24	-3.30%
Oct-16	211.45	6.69%	215.13	6.37%
Nov-16	220.34	4.21%	223.67	3.97%
Dec-16	216.22	-1.87%	219.65	-1.80%
Jan-17	210.89	-2.46%	214.35	-2.41%
Feb-17	203.65	-3.43%	207.78	-3.06%
Mar-17	210.38	3.31%	213.58	2.79%
Apr-17	207.65	-1.30%	210.45	-1.46%
May-17	210.59	1.42%	214.57	1.95%
Jun-17	224.39	6.56%	227.04	5.81%
Jul-17	221.61	-1.24%	224.90	-0.94%
Aug-17	218.64	-1.34%	222.33	-1.14%
Sep-17	219.93	0.59%	223.32	0.44%
Oct-17	227.57	3.47%	231.38	3.61%
Nov-17	230.57	1.32%	234.82	1.49%
Dec-17	239.22	3.75%	242.65	3.34%
Jan-18	233.06	-2.57%	236.74	-2.44%
Feb-18	233.74	0.29%	237.57	0.35%
Mar-18	227.95	-2.48%	231.63	-2.50%
Apr-18	229.24	0.57%	232.17	0.23%
May-18	239.96	4.67%	243.27	4.78%
Jun-18	246.47	2.72%	249.63	2.61%
Jul-18	258.13	4.73%	261.40	4.71%
Aug-18	267.12	3.48%	271.28	3.78%
Sep-18	266.72	-0.15%	270.04	-0.46%
Oct-18	268.09	0.52%	272.24	0.81%
Nov-18	258.97	-3.40%	262.75	-3.49%
Dec-18	256.95	-0.78%	260.21	-0.97%
Jan-19	241.64	-5.96%	245.64	-5.60%
Feb-19	247.55	2.44%	251.26	2.29%
Mar-19	243.10	-1.80%	246.59	-1.86%
Apr-19	250.57	3.07%	253.50	2.80%
May-19	254.86	1.71%	258.09	1.81%
Jun-19	253.13	-0.68%	256.76	-0.52%
Jul-19	258.94	2.29%	262.66	2.30%
Aug-19	260.18	0.48%	263.55	0.34%
Sep-19	257.03	-1.21%	259.98	-1.35%
Oct-19	251.33	-2.22%	254.56	-2.09%
Nov-19	247.89	-1.37%	251.25	-1.30%
Dec-19	250.77	1.16%	253.00	0.70%
Jan-20	259.52	3.49%	261.18	3.23%
Feb-20	258.67	-0.33%	261.30	0.05%

Table 5 Risk & Return

Table 5 presents risk and return measures for the nominal hedonic-, real hedonic-, and Case-Shiller (1987) repeat sales indices. These are split over two holding periods: April 2011 – February 2020, and January 2014 – February 2020. Panel A presents various measures of risk: Volatility which is the standard deviation of the natural logarithm of returns, skewness and excess kurtosis, semi-deviation, VaR 95% (1 month), and max drawdown. Panel B displays various return measures: arithmetic mean return, geometric mean return, excess arithmetic mean return, Sharpe ratio, adjusted Sharpe ratio, Sortino ratio, and Return/VaR 95%.

Panel A: Risk		**Apr-11 - Feb-20**			**Jan-14 - Feb -20**	
	Nominal	Real	Repeat Sales	Nominal	Real	Repeat Sales
Volatility	10.0%	27.7%	7.87%	3.87%	9.01%	3.65%
Skewness	2.3	5.1	1	0.3	0.6	0.3
Excess Kurtosis	22.2	43.6	7.1	5.0	5.6	3.7
Semi-deviation	2.2%	4.2%	1.7%	0.9%	2%	0.7%
VaR 95%	2.0%	5.4%	1.5%	0.8%	1.8%	0.7%
Max drawdown	-37.1%	-65.6%	-40.2%	-10.40%	-22.4%	-9.9%
Panel B: Return		**Apr-11 - Feb-20**			**Jan-14 - Feb-20**	
	Nominal	Real	Repeat Sales	Nominal	Real	Repeat Sales
Arithmetic Mean Return	0.93%	3.44%	1.19%	0.58%	1.35%	1.00%
Geometric Mean Return	0.47%	0.87%	0.91%	0.51%	0.97%	0.95%
Excess Arithmetic Mean Return	0.58%	3.09%	0.85%	0.23%	1.01%	0.66%
Sharpe Ratio	0.06	0.11	0.11	0.06	0.11	0.18
Adjusted Sharpe	0.06	0.12	0.11	0.06	0.11	0.18
Sortino Ratio	0.26	0.74	0.50	0.26	0.50	0.94
Return/VaR	0.29	0.57	0.57	0.29	0.56	0.94

Table 6 Correlation with Other Assets

Table 6 presents pairwise correlations between collectible whisky and other financial assets. Equity indices: MSCI World, FTSE 250, FTSE 100, MSCI UK, and FTSE Small Cap. The fixed income security: Bloomber Barclays Global Aggregate Bond. Commodities: FTSE 350 Mining, and FTSE Oil & Gas. Real Estate, the Ziman REIT index. HSBC Gold. The UK, US, and DE 3 Month T-Bill's are used as proxies for the risk-free rate.

Asset	Hedonic (Real)	Hedonic (Nom)	RSR CS	RSR BMN	MSCI World	Bloomberg Barcl.	FTSE250
Whisky Hed (Real)	1						
Whisky Hed (Nom)	0.9736	1					
Whisky RSR CS	0.4986	0.4937	1				
Whisky RSR BMN	0.5311	0.5070	0.9418	1			
MSCI World	-0.0462	-0.0197	0.0508	0.0290	1		
Bloomberg Barclays Bond	-0.1064	-0.1252	0.0135	0.0001	-0.1412	1	
FTSE250	0.0087	0.0301	0.1239	0.1115	0.7942	-0.1087	1
FTSE100	0.0152	0.0369	0.1014	0.0760	0.7485	0.0330	0.7779
MSCI UK	0.0142	0.0354	0.0994	0.0743	0.7461	0.0320	0.7729
FTSE Smallcap	-0.0044	0.0184	0.1744	0.1501	0.7609	-0.1233	0.8982
HSBC Gold	-0.0012	0.0276	0.0556	0.0905	0.1380	0.2834	0.1111
FTSE350 Mining	0.0576	0.0769	0.1784	0.1964	0.4784	-0.0629	0.4143
Ziman Real Estate	-0.0918	-0.1095	0.0021	-0.0097	0.2491	0.1573	0.2751
FTSE Oil & Gas	0.0193	0.0636	0.0808	0.0624	0.4799	-0.1635	0.5024
UK 3M T-Bill	0.0576	0.0100	-0.0050	-0.0124	-0.1610	0.1963	-0.1773
US 3M T-Bill	-0.0765	-0.0477	-0.0530	-0.0598	0.0132	-0.0556	-0.0628
DE 3M T-Bill	0.1884	0.0958	0.0496	0.0411	-0.1190	0.2137	-0.0917

Asset	FTSE100	MSCI UK	FTSE Smallcap	HSBC Gold	FTSE350 Mining	Real Estate	FTSE Oil & Gas
Whisky Hed (Real)							
Whisky Hed (Nom)							
Whisky RSR CS							
Whisky RSR BMN							
MSCI World							
Bloomberg Barclays Bond							
FTSE250							
FTSE100	1						
MSCI UK	0.9994	1					
FTSE Smallcap	0.7538	0.7497	1				
HSBC Gold	0.2636	0.2647	0.1444	1			
FTSE350 Mining	0.5873	0.5917	0.4665	0.6017	1		
Ziman Real Estate	0.2837	0.2798	0.2018	0.0469	0.1558	1	
FTSE Oil & Gas	0.4640	0.4599	0.5684	0.2358	0.4663	0.0901	1
UK 3M T-Bill	-0.1847	-0.1868	-0.2483	0.0750	-0.1814	-0.0085	-0.2001
US 3M T-Bill	-0.0296	-0.0325	-0.0912	0.1145	0.0765	-0.0889	0.0747
DE 3M T-Bill	-0.0652	-0.0605	-0.1287	-0.1121	-0.1493	0.0765	-0.0869

Asset	UK 3M T-Bill	US 3M T-Bill	DE 3M T-Bill
Whisky Hed (Real)			
Whisky Hed (Nom)			
Whisky RSR CS			
Whisky RSR BMN			
MSCI World			
Bloomberg Barclays Bond			
FTSE250			
FTSE100			
MSCI UK			
FTSE Smallcap			
HSBC Gold			
FTSE350 Mining			
Ziman Real Estate			
FTSE Oil & Gas			
UK 3M T-Bill	1		
US 3M T-Bill	0.0364	1	
DE 3M T-Bill	0.2617	-0.5672	1

Table 7 Return-Risk Comparison

Table 7 presents average monthly excess return, average monthly volatility, and Sharpe ratios amongst collectible Whisky and other financial assets: MSCI World, Bloomberg Barclays Global Aggregate, FTSE 250, FTSE 100, MSCI UK, FTSE Small Cap, HSBC Gold, FTSE 350 Mining, Ziman REIT Real Estate, FTSE Oil & Gas, UK 3 Month T-Bill, US 3 Month T-Bill, DE 3 Month T-Bill. The left column concerns the holding period: April 2011 – February 2020, and the right column concerns the holding period January 2014 – February 2020.

	Apr-11 - Feb-20			Jan-14 - Feb-20		
Asset	Avg. Monthly Excess Return	Avg. Monthly Volatility	Sharpe Ratio	Avg. Monthly Excess Return	Avg. Monthly Volatility	Sharpe Ratio
Whisky Hed (Real)	3.09%	27.7%	0.11	1.01%	9.01%	0.11
Whisky Hed (Nom)	0.58%	10.0%	0.06	0.23%	3.87%	0.06
Whisky RSR CS	0.85%	7.87%	0.11	0.66%	3.66%	0.18
Whisky RSR BMN	0.75%	6.20%	0.12	0.62%	3.45%	0.18
MSCI World	-0.16%	3.64%	-0.04	-0.44%	3.38%	-0.13
Bloomberg Barclays Bond	0.15%	0.82%	0.18	0.38%	0.73%	0.52
FTSE250	0.16%	3.47%	0.05	0.00%	3.18%	0.00
FTSE100	-0.21%	3.31%	-0.06	-0.28%	3.18%	-0.09
MSCI UK	-0.25%	3.31%	-0.08	-0.32%	3.20%	-0.10
FTSE Smallcap	0.16%	2.99%	0.05	-0.05%	2.66%	-0.02
HSBC Gold	-0.48%	9.79%	-0.05	0.57%	10.11%	0.06
FTSE350 Mining	-0.53%	8.21%	-0.06	-0.06%	8.47%	-0.01
Ziman Real Estate	0.23%	4.01%	0.06	0.02%	3.71%	0.01
FTSE Oil & Gas	-1.78%	6.93%	-0.26	-1.82%	6.55%	-0.28
UK 3M T-Bill	0.35%	0.12%	-	0.35%	0.14%	-
US 3M T-Bill	0.65%	0.82%	-	0.92%	0.87%	-
DE 3M T-Bill	0.07%	0.53%	-	-0.19%	0.21%	-

Table 8 Tests of Normality

Table 8 presents various tests of normality. The Shapiro-Wilk test produces a p-value where normality is rejected at the 95% confidence level if the value is below 0.05. Skewness produces a measure of the distribution of returns – 0 is considered normal. Kurtosis describes the shape of the return distribution where a value of 3 is considered normal. The tests are conducted over both holding periods: April 2011 – February 2020, and January 2014 – February 2020 for collectible whisky and the following assets: MSCI World, Bloomberg Barclays Global Aggregate, FTSE 250, FTSE 100, MSCI UK, FTSE Small Cap, HSBC Gold, FTSE 350 Mining, Ziman REIT Real Estate, FTSE Oil & Gas, UK 3 Month T-Bill, US 3 Month T-Bill, DE 3 Month T-Bill.

	Apr-11 - Feb-20				**Jan-14 - Feb-20**			
Asset	Shapiro-Wilk	Skewness	Kurtosis	Normal?	Shapiro-Wilk	Skewness	Kurtosis	Normal?
Hedonic Whisky (Real)	0.000	5.058	43.17	Yes	0.007	0.639	5.64	Yes
RSR Whisky CS (Real)	0.000	1.000	7.08	Yes	0.495	0.276	3.67	No
MSCI World	0.011	-0.448	3.62	Yes	0.016	-0.501	3.48	Yes
Bloomberg Barclays Bond	0.883	-0.049	2.97	No	0.740	0.176	3.21	No
FTSE250	0.193	-0.369	3.09	No	0.660	-0.303	2.99	No
FTSE100	0.472	-0.322	3.14	No	0.195	-0.472	3.07	No
MSCI UK	0.507	-0.391	3.13	No	0.187	-0.481	3.08	No
FTSE Smallcap	0.006	-0.559	3.94	Yes	0.100	-0.522	4.44	No
HSBC Gold	0.035	0.455	4.11	Yes	0.019	0.548	4.32	Yes
FTSE350 Mining	0.753	0.265	3.08	No	0.206	0.444	2.81	No
Ziman Real Estate	0.000	-8.053	76.77	Yes	0.000	-7.253	58.82	Yes
FTSE Oil & Gas	0.218	0.194	3.44	No	0.610	-0.163	2.46	No
UK 3M T-Bill	0.000	-0.848	2.92	Yes	0.000	-0.960	2.57	Yes
US 3M T-Bill	0.000	1.014	2.44	Yes	0.000	0.432	1.63	Yes
DE 3M T-Bill	0.000	1.510	4.48	Yes	0.000	1.110	2.98	Yes

Figure 1 Collectible Whisky Indices

Figure 1 displays timeseries graphs of the collectible whisky indices. Each are set to an index level of 100 in the base month, April 2011. Index returns are calculated on a monthly basis and follow the index levels from Table 4.

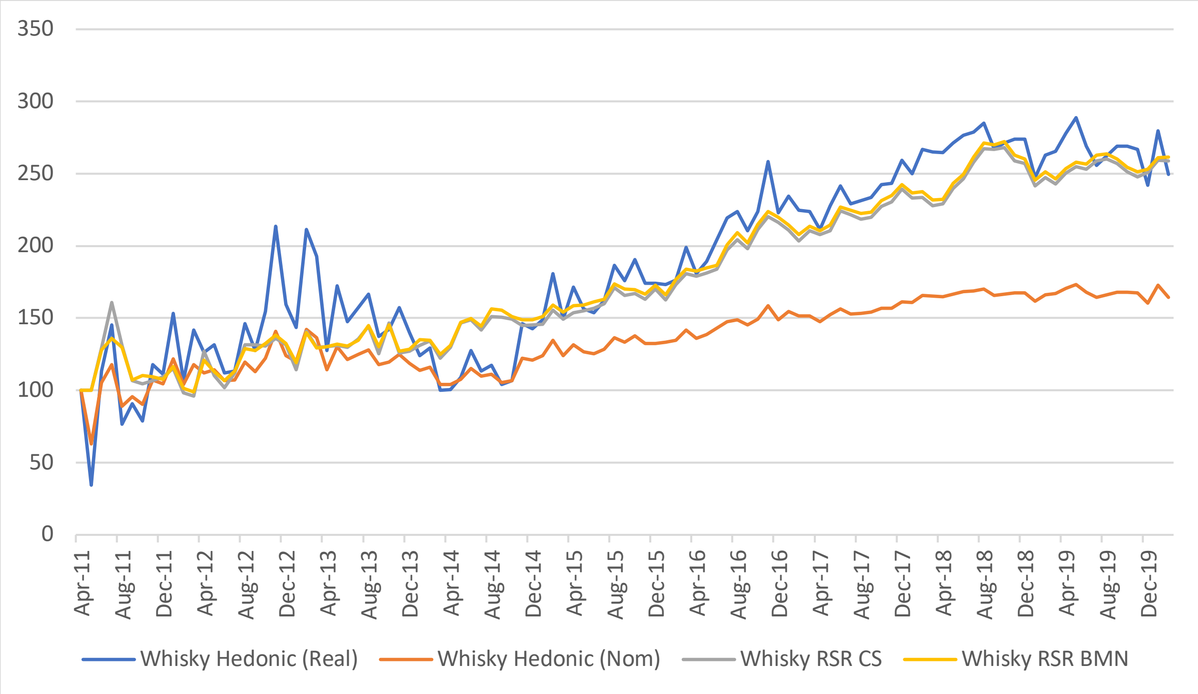

Figure 2 Collectible whisky and other assets

Figure 2 plots the index returns of the collectible whisky and the other financial assets: MSCI World, Bloomberg Barclays Global Aggregate, FTSE 250, FTSE 100, MSCI UK, FTSE Small Cap, HSBC Gold, FTSE 350 Mining, Ziman REIT Real Estate, FTSE Oil & Gas. Each are set to an index level of 100 in the base month, April 2011. Index returns are calculated on a monthly basis.

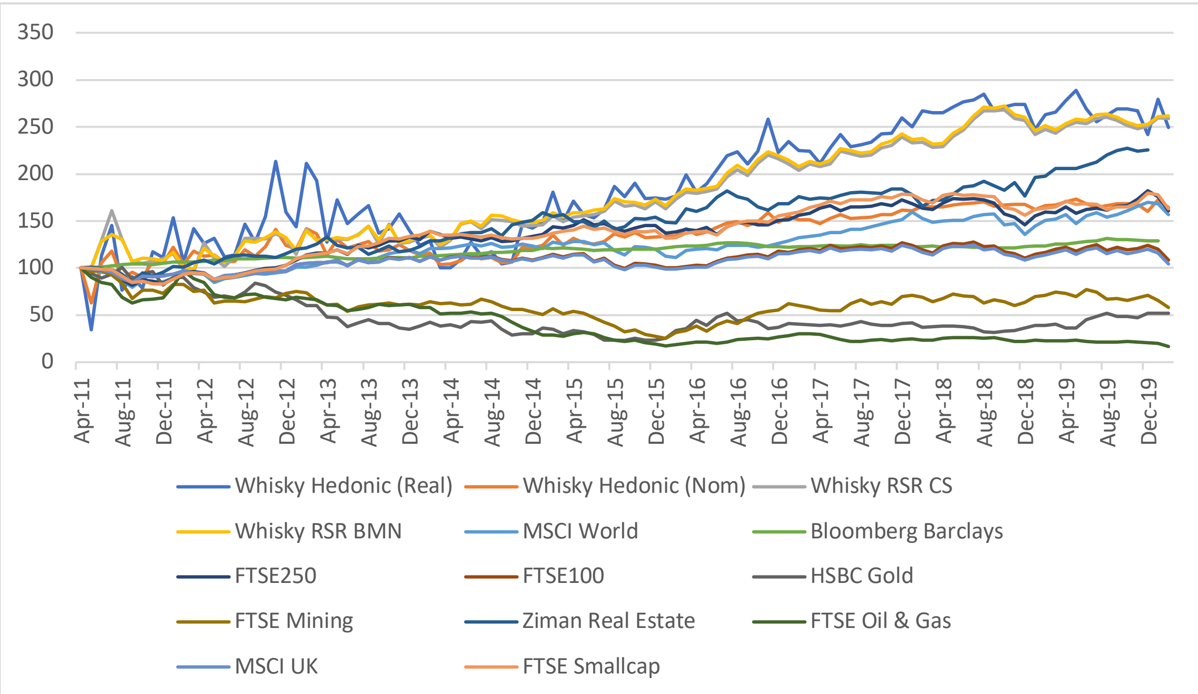

Figure 3 Max Sharpe Ratio Portfolio (Hedonic)

Figure 3 presents portfolio allocations in % for the Max Sharpe Ratio portfolio. The real hedonic collectible whisky index is ran through the program against MSCI World, Bloomberg Barclays Global Aggregate, FTSE 250, FTSE 100, MSCI UK, FTSE Small Cap, HSBC Gold, FTSE 350 Mining, Ziman REIT Real Estate, FTSE Oil & Gas. The portfolio follows a standard 60:40 equity-bond split restriction.

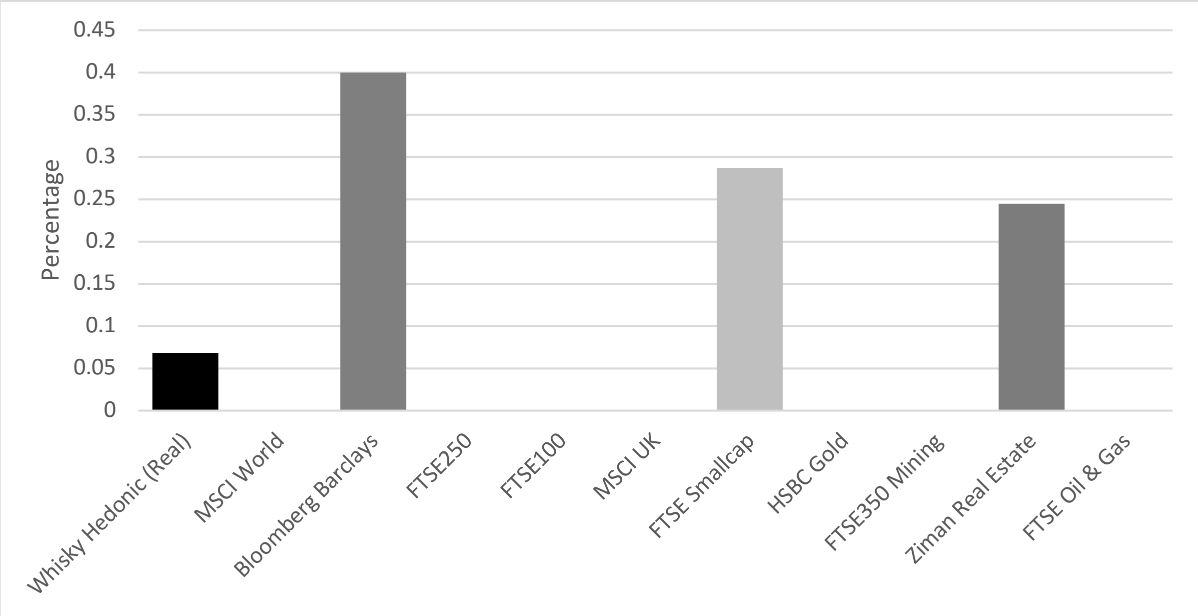

Figure 4 Max Sharpe Ratio Portfolio (Repeat Sales)

Figure 4 presents portfolio allocations in % for the Max Sharpe Ratio portfolio. The repeat sales collectible whisky index is ran through the program against MSCI World, Bloomberg Barclays Global Aggregate, FTSE 250, FTSE 100, MSCI UK, FTSE Small Cap, HSBC Gold, FTSE 350 Mining, Ziman REIT Real Estate, FTSE Oil & Gas. The portfolio follows a standard 60:40 equity-bond split restriction.