Journal of Economic Behavior and Organization 191 (2021) 1025–1045

Contents lists available at ScienceDirect

Journal of Economic Behavior and Organization

journal homepage: www.elsevier.com/locate/jebo

Unbridled spirit: Illicit markets for bourbon whiskey☆

Conor Lennon[a,*], Tom Shohfi[b]

[a] Department of Economics, College of Business, University of Louisville, United States
[b] Lally School of Management, Rensselaer Polytechnic Institute, United States

ARTICLE INFO

Article history:
Received 6 January 2021
Revised 24 September 2021
Accepted 28 September 2021
Available online 23 October 2021

JEL classification:
L66
L14
K42
G11
G14

Keywords:
Bourbon
Whiskey
Alternative investment
Price index
Gray markets
Secondary

ABSTRACT

The market for bourbon whiskey is booming. Demand is so great that bourbon aficionados regularly line up overnight for the chance to purchase a single bottle and high-end bourbons are allocated to consumers via lotteries. The prevalence of such non-price allocation mechanisms, however, leads to reselling in secondary markets. To characterize bourbon secondary markets, we first provide a rich description of how they function. We then use 2011 to 2019 whiskey auction data in a repeat sales regression framework to develop a novel price index for rare and vintage bourbons. Our repeat sales approach suggests that bourbon prices are increasing by about 9.1% per year over our sample period. We complement those estimates by developing a second price index using unique data from an illicit peer-to-peer secondary market that operated on a major social network between 2014 and 2017. Our estimates suggest that price increases are similar, at least during common sample periods, in our auction-house and peer-to-peer settings. We also examine how bourbon's hedonic characteristics are related to secondary market prices and develop hedonic estimates of annual returns that range between 13.1% and 18.8%. While our sample period is relatively short, when examining bourbon's potential as an alternative investment we find that the addition of bourbon can improve the risk-return ratio of typical stock/bond portfolios.

1. Introduction

After decades of decline, bourbon whiskey has experienced a remarkable recent resurgence. In response to bourbon's renewed popularity, larger distilleries have invested millions of dollars to expand production and craft distilleries have reappeared in the American market.[1] In 2017, the *New York Times* referred to this turnaround as "the bourbon boom."[2] As part of this widespread renewal of interest, sales of rare bourbon have become increasingly common at major auction houses. For example, 34 bottles of 24-Year-Old Blade and Bow bourbon sold for $95,550 at Christie's in New York City in December of 2016.[3]

☆ Thank you to Keith Teltser, Brian Meehan, Scott Adams, and two anonymous referees for valuable comments and suggestions. This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

* Corresponding author.
E-mail addresses: conor.lennon@louisville.edu (C. Lennon), shohft@rpi.edu (T. Shohfi).

[1] See https://kybourbon.com/wp-content/uploads/2019/02/KDA-BourbonBoomSheet_2019.pdf.
[2] See this *New York Times* article - https://www.nytimes.com/2017/07/11/opinion/will-trump-kill-the-bourbon-boom.html.
[3] See http://www.christies.com/lotfinder/Lot/one-barrel-of-blade-and-bow-single-6051424-details.aspx.

https://doi.org/10.1016/j.jebo.2021.09.045
0167-2681/

Outside of major auction houses, "secondary markets" - including online auction sites and private groups hosted on major social networks - are also thriving.[4] These secondary markets are prevalent because few distillers, distributors, or retailers have responded to surging demand by increasing wholesale and suggested retail bourbon prices. Instead, many coveted bourbons are allocated using lotteries and overnight queuing, leading to profitable reselling in secondary markets. However, selling alcohol without a license is strictly prohibited in the United States. The illicit nature of these markets makes them interesting objects of study because they occur in an institutional void that allows us to study how price discovery works, the behavior of buyers and sellers, and how trust is established and maintained when there is no central authority to enforce contracts and/or property rights. However, we can rarely obtain the data necessary to study these kinds of markets. A notable recent exception is (Bhaskar et al., 2019) who study how online drug marketplaces work using novel data from the "darknet."

To characterize the operation of secondary markets for bourbon, we first provide a rich description of how and where these markets operate. Then, to quantify the magnitude of the bourbon boom, we use data from two complementary sources. The first consists of over 10,000 "quasi-legal" auction sales occurring between April 2011 and October 2019 on the Germany-based whiskey auction site whiskyauction.com. We refer to this setting as quasi-legal because while the site appears legitimate in its jurisdiction it also engages in legally-questionable behavior (i.e., shipping alcohol to the United States without using a courier service).[5] Note that the whiskyauction.com site is not an eBay-like platform for whiskey. Instead, the site operates as a traditional auction-house by auctioning items in its (temporary) possession. In return for a modest commission, its employees take care of marketing (e.g., high-quality product images), auction logistics, payment, and shipping/packaging for sellers.

We further explore secondary markets for bourbon using data on 3304 bourbon sales occurring between 2014 and 2017, where transactions were arranged via a social network group known as "Strong Water Trading." Sales on this market were not coordinated by a middleman and in contrast to whiskyauction.com, the market operated in violation of both the terms of the host social network and, because participants were selling alcohol without a license to do so, in clear violation of multiple U.S. state and federal laws.[6] While Strong Water Trading was eventually shut down because of these violations, it is easy to confirm that these markets "reconstitute" as quickly as the online drug marketplaces that (Bhaskar et al., 2019) study.[7] We explain how whiskyauction.com and Strong Water Trading operate in greater detail in later sections.

With the available data, we develop two complementary price indices for bourbon using a repeat sales regression framework (Bailey et al., 1963). Our estimates suggest that secondary market bourbon prices increase by about 9.1% per year from 2011 to 2019 when using our whiskyauction.com data.[8] The average across the sample period disguises the fact that much of the overall price increase occurs between 2014 and 2018, where we find annual price increases of about 18% per year. In our Strong Water Trading data, we find that bourbon prices increased by just over 20% per year during the sample period (October 2014 to November 2017).

To provide further depth to our analysis, even though we do not have complete hedonic product characteristics for every whiskey, we then examine how whiskey characteristics - age, alcohol content, and so on - are associated with prices in our two data sources. Our hedonic estimates suggest that these characteristics have relatively similar effects on prices regardless of the data we use, illustrating that illicit secondary markets for bourbon appear to be able to work well despite their unlawful nature. As part of our hedonic analysis, we find hedonic estimates of annual returns that range between 13.1% in our auction data and 18.8% in our social network data (Strong Water Trading).

Our social network setting is of unique interest because it shares many similarities with online markets for illicit drugs where reputation and peer-to-peer references appear to serve crucial roles in helping the market function. When studying these markets, Bhaskar et al. (2019) place a particular emphasis on trust and moral hazard problems and use seller quality ratings and exit decisions to show that the market works better than one might expect. Aside from Bhaskar et al., empirical work on illicit goods in economics tends to focus on the behavior of drug users (Dave, 2008; Jacobi and Sovinsky, 2016; Galenianos and Gavazza, 2017) or on explaining and quantifying illicit market activity that can be viewed as relating to tax evasion (Smith, 1976; Beard et al., 1997; Prieger and Kulick, 2018). Other authors focus on how illicit goods affect crime and criminal organizations (Levitt and Venkatesh, 2000), social outcomes (Fryer Jr et al., 2013), and how prohibition and enforcement affects economic welfare (Becker et al., 2006). We further discuss the challenges faced by buyers and sellers due to the illicit nature of secondary bourbon markets later in the paper.

Our work, however, is perhaps most closely related to studies that examine the price and investment potential of wine. It also closely relates to recent research on the determinants of Scotch whisky prices.[9] Looking at research on wine, work

[4] See https://www.marketplace.org/2017/06/14/business/bourbon-market-heats-creating-black-market-demand.

[5] See https://help.cbp.gov/s/article/Article-212?language=en_US.

[6] A recent whiskyadvocate.com article explains the illicit nature of these kinds of markets. The article also documents the efforts of enforcement agencies in Ohio and Pennsylvania to eliminate this kind of alcohol reselling. For more information see https://www.whiskyadvocate.com/black-market-bourbon-feature/, (last accessed 7/12/2021).

[7] As of mid-2021 there were several such groups operating on the Facebook social network. See https://www.gearpatrol.com/food/drinks/a700726/bourbon-secondary-market-facebook/ for more information (last accessed 7/12/2021).

[8] Specifically, the index value at the end of the sample period is 2.004 (with a base year index value of 1), suggesting a 9.1% rate of return on an annual basis over the eight-year sample period.

[9] Whiskey is the preferred spelling in America and Ireland, and we therefore use the preferred spelling when referring to rye, bourbon, or Irish whiskey. In Scotland, however, Scotch is typically referred to as "whisky."

in this area mostly relies on hedonic analyses (see, for example, Ashenfelter et al., 1995; Ali and Nauges, 2007; Storchmann, 2012; Oczkowski, 2016; Le Fur and Outreville, 2019). Using a hedonic approach to study Scotch whisky price determinants, Moroz and Pecchioli (2019) examine how secondary market prices vary with respect to whisky age, distillation/bottling locations, alcohol content, and so on. Moroz and Pecchioli find that a whisky's age has a large effect on secondary market prices, amounting to an 8.9% price increase per year of maturation (i.e., years of aging prior to bottling).[10] When examining how hedonic product characteristics affect secondary market bourbon prices, we find that age is also very important for bourbon whiskey, with each year of maturation being associated with about a 10.1% increase in secondary market prices. Finally, several studies examine wine as a long run investment opportunity including (Faye et al., 2015; Dimson et al., 2015). While we also examine bourbon's potential as an "alternative" investment, data on vintage wine prices typically comes from legitimate sales at licensed auction houses ensuring that direct comparisons are difficult. Moreover, relative to analyses of investment in wine, we have a shorter sample period and very few sales of "vintage" products, limiting our ability to provide advice to finance professionals.

Indeed, given the costs of transacting and storage along with considerable legal risk, it may seem implausible that bourbon could be a valuable alternative investment option.[11] However, when focusing on bourbon's investment potential, we see that bourbon's real arithmetic return is higher than a variety of stocks, bonds, and other commodities over our sample period. Although, because of greater variance, we acknowledge that bourbon's risk-adjusted returns are not especially appealing as a standalone asset. On the other hand, bourbon returns exhibit low correlation with movements in the prices of other financial assets. From a portfolio diversification standpoint, at least in our limited sample period, we find that adding approximately 5% bourbon to a typical stock/bond portfolio would significantly improve the risk-return ratio of the portfolio.

In sum, our work contributes in three ways. First, we document the existence and operation of quasi-legal and illicit secondary markets for bourbon whiskey that have been previously overlooked. Then, we use data from these markets to develop a novel bourbon price index and also to estimate the returns to bourbon's hedonic product attributes. By examining price determinants and rates of return, we naturally also contribute to the literature on alternative investments, adding new evidence to an emerging literature regarding whiskey/whisky investment (Moroz and Pecchioli, 2019; 2021a). While Moroz and Pecchioli study Scotch whisky through hedonic analyses, we examine bourbon whiskey via repeat-sales analyses. Finally, using the data we have available to us, we explore bourbon's potential as an alternative investment. We emphasize, however, that our goal is not to provide a guide to how to invest in bourbon.

We proceed as follows. In Section 2 we examine the methods used to study markets for collectible goods with investment potential such as wine, art, and antiques. We then provide further background information on secondary markets for bourbon. In Section 3, we describe our data and estimation framework. We present our empirical findings in Section 4 and conclude in Section 5.

2. Background

Burton and Jacobsen (1999) examine the methods, data, and findings of studies that consider returns on art, wine, antiques, ceramics, coins, stamps, books, and even "Beanie Babies."[12] Burton and Jacobsen emphasize that a key empirical challenge in this literature is the fact that sales of such "collectible" items tend to be rare and are not always of an identical item. For what appear to be identical products, the sale price may depend on hard-to-observe details such as the identity and reputation of a seller (or buyer), minor differences in the item's condition, vintage, provenance, or the presence of a guarantee of authenticity.

Burton and Jacobsen explain that authors have tried to address barriers to measurement using three primary approaches. The first is to create composite indices by selecting sets of items whose prices will be measured and averaged over time. This method is subject to the same biases as indices such as the Consumer Price Index and therefore sensitive to the choice of items in the initial basket and changes in the "representative basket." Goetzmann (1996) harnessed some of the drawbacks of this method to examine the consequences of survivorship in the high-end art market whereas (Auer and Schuhmacher, 2013) use this approach to examine the investment performance of diamonds.

A second potential approach is hedonic in nature and attempts to control for objective features of collectibles such as their size or location. This approach is ideal for something like real estate where characteristics are easily observed (such as the number of bedrooms, bathrooms, neighborhood amenities, and so on). Ashenfelter et al. (1995) use this kind of hedonic analysis to examine the relationship between the price of young Bordeaux wine and the weather during its growing season (see also Ali and Nauges, 2007; Storchmann, 2012; Oczkowski, 2016; Le Fur and Outreville, 2019). More recently,

[10] Moroz and Pecchioli (2021a) separately examine the role of expert ratings, finding that a whisky's rating is generally not a useful predictor of secondary market Scotch prices, especially once they control for observable characteristics. Moroz and Pecchioli (2021b) examine whether using posted ("ask") or actual transaction prices matters for how Scotch characteristics are valued, and find that "whisky price estimates are independent of prices employed."

[11] Bourbon's investment potential would be greater if legislation further relaxes the rules on reselling small quantities of rare and vintage bourbons as has happened recently in Kentucky: https://www.nbcnews.com/business/consumer/check-grandma-s-attic-vintage-bourbon-now-legal-sell-probably-n743066, last accessed 7/5/2020.

[12] As Alan Krueger noted in his *NewYork Times* column in 2005, "[t]he resale price of Beanie Babies ... grew at an astonishing rate of 140 percent a year from 1994 to 1999 and has since crashed." See http://www.nytimes.com/2005/06/23/business/are-collectibles-the-new-real-estate.html, last accessed 12/12/2020.

(Dobrynskaya and Kishilova, 2018) use a hedonic approach to study the returns to investing in LEGO. They find real returns of at least 8% over the past two decades leading the authors to confirm LEGO as "the toy of smart investors."

A third approach creates a repeat sales price index that accounts for the price of similar but perhaps not identical items when there are a variety of types of a given collectible. This kind of approach involves the use of sales data on many similar items over an extended period of time. As just one example, Baumol (1986) used repeated sales of many paintings from 1652 to 1961 and estimated that the rate of return on fine art was about eight percentage points below the rate of return on stocks over the same period. Goetzmann (1993) extended that analysis to 1987. Graddy and Margolis (2011) use a repeat sales approach to study returns to investment in antique violins, finding a 3.5% real annual return. Dimson and Spaenjers (2011) also use a repeat sales approach to determine that the return to investing in stamps was 2.9% in real terms from 1900 to 2008 while (Dimson et al., 2015), again using the repeat sales approach, study the investment performance of Premier Cru Bourdeaux wine from 1900 to 2012, finding a 4.1% real return. These authors use a repeat sales approach because it is ideal for calculating a broad rate of return on a group of similar collectibles such as wine, stamps, and, in the case of this paper, bourbon. We explain the repeat sales method further in Section 3.

Regardless of the approach taken, and as we also see in recent estimates for the returns on collectibles, Burton and Jacobsen (1999) find that "[t]he majority of collectibles yield lower financial returns than stocks, and studies that include a measure of variability over time uniformly find that collectibles embody more risk than most other financial assets." Dimson and Spaenjers (2014) echo such a sentiment finding that collectibles "have outperformed government bonds, Treasury bills, and gold over the long run" while cautioning that from an investment perspective such assets are "attractive only to investors who already have a diversified portfolio of financial assets, who have a long investment horizon, and who can sit out periods of high illiquidity and low demand for luxury consumption." In the case of secondary market bourbon sales, prices, and therefore both risk and return, are dependent upon the unique and evolving institutional details of such markets. Adding an unusual source of risk, these markets are clearly prohibited by state and federal law in the United States. Indeed, when participating in the secondary market for bourbon, buyers and sellers cannot rely on any external authority to rectify problems, including issues of deception and theft. Further, at least in the United States, packages containing alcohol can be seized for violating shipping and licensing restrictions.[13]

Despite the additional risk, bourbon aficionados must turn to secondary markets to obtain coveted products because producers are reluctant, for whatever reason, to significantly raise retail prices, leading to shortages of specific products. Notably, the market for bourbon is dominated by a small group of long-standing incumbents: Heaven Hill, Jim Beam, Maker's Mark, Four Roses, Buffalo Trace, Brown-Forman/Woodford Reserve, and Wild Turkey. These companies produce several times more bourbon than all other American distilleries combined, and each has a number of highly-coveted expressions.[14] It is their aversion to increasing prices for their most-popular bourbons that creates shortages and leads to reselling in secondary markets.[15] Two examples illustrate the extent to which distillers are averse to nominal price increases. The first is the case of Maker's Mark who, on February 9, 2013, announced that in order to satisfy surging demand they would reduce alcohol content from 90 proof to 84 proof (45% to 42% alcohol by volume) within their iconic wax-dipped bourbon bottles. They chose to try to "stretch" their existing stock rather than simply raising prices. Note that they could not simply ramp up production; bourbon's aging process ensures that supply is highly inelastic in the short-run. Customers reacted so vehemently against the idea that Maker's Mark had to backtrack on the decision a week later.[16]

A second example is the annual release of the infamous "Pappy Van Winkle" line from Buffalo Trace. The Van Winkle line includes several "expressions" of varying ages (15-, 20-, and 23-year-old bourbons along with three "brand extensions": Old Rip Van Winkle, Van Winkle Family Reserve Rye, and Van Winkle Family Reserve 12-Year). The number of bottles of each expression is limited and many liquor stores around the United States do not receive any Van Winkle products in a given year. Instead of raising retail prices to market-clearing levels, however, stores that receive a bottle from the Van Winkle line tend to hold lotteries or charity raffles to award someone the right to buy that bottle. The "winning" customer typically pays only the suggested retail price, ranging from $70 to $300 depending on the particular bottle.[17] Stores also use charity raffles, lotteries, or simply long lines (often overnight and sometimes stretching to several days) to ration limited releases such as the Buffalo Trace Antique Collection (an annual release of five whiskeys - George T. Stagg, Thomas H. Handy Rye, Eagle Rare 17, Sazerac 18 Year Rye, and William Larue Weller), Heaven Hill's Parker's Heritage Collection, and Four Roses' Small Batch Limited Edition series, among many others. Such allocation mechanisms ensure that those who obtain limited

[13] Companies such as FedEx and UPS explain that regular customers cannot ship alcohol, but provide exceptions for those who are appropriately licensed. See https://www.fedex.com/en-us/shipping/alcohol/shipping-requirements.html and https://www.ups.com/us/en/help-center/packaging-and-supplies/special-care-shipments/wine.page. The U.S. Postal Service does not grant any such exceptions - https://pe.usps.com/text/pub52/pub52c4_006.htm. Each link last accessed on 9/30/2020.

[14] Renowned bourbon expert Chuck Cowdery explains production capacity at the largest distilleries at http://chuckcowdery.blogspot.com/2017/09/bourbon-distilleries-ranked-by-capacity.html. He lists Jack Daniel and Barton 1792 as large distilleries, but these are owned by Brown-Forman and Buffalo Trace (Sazerac), respectively. These seven incumbents are also listed as the "major [bourbon] distillers" in this article - https://www.kentucky.com/lexgoeat/bourbon/article44427909.html.

[15] It is beyond our scope here to study bourbon producers' strategy. We direct readers interested in such strategic mispricing to Haddock and McChesney (1994) who study why firms might strategically keep prices low in the face of transitory market shortages.

[16] See https://www.washingtonpost.com/lifestyle/food/makers-mark-debacle-the-proof-is-in-the-overreaction/2013/02/25/0aba8564-7c32-11e2-9a75-dab0201670da_story.html?utm_term=.ec5b9e4d5060 for more on this story.

[17] See http://bourbonr.com/blog/2019-pappy-van-winkle-announced-with-a-warning/.

releases from retailers are not those who have the highest willingness-to-pay (at least in monetary terms). Unsurprisingly, these are the kinds of bottles that are easily resold for a significant profit in bourbon secondary markets. To illustrate how tempting this market can be, and the gap between retail and secondary markets, note that there were three sales of 23 year-old Pappy Van Winkle in our 2019 auction-house data with an average sale price of $2,060.[18] In 2019, the suggested retail price of 23 year-old Pappy Van Winkle was under $300. Selling directly in peer-to-peer secondary markets, however, avoids the middleman's commission (10% from both buyer and seller in the case of whiskyauction.com).

Delving a little deeper into peer-to-peer secondary markets, these groups appear to rely heavily on reputation and norms to operate effectively. For example, in contrast to whiskyauction.com, those who wish to participate in a peer-to-peer market first have to be referred by existing members. Sellers and buyers also typically provide personal references when trading with one another for the first time. When selling, group members post their item for sale in the group by making a post that includes pictures, any necessary information regarding the bottle's condition or special features (a distiller's signature, for example, or some other unique attribute), a "buy-it-now" (BIN) price, and details of shipping options and their associated cost. Under typical group rules, the first person to comment "BIN" enters into a binding agreement to purchase the product at the stated price. Until someone chooses the BIN option, the seller can accept offers below the BIN price at any time. Payment is facilitated by PayPal, Zelle, and Venmo. Side conversations, including private messages, are strictly forbidden to ensure there is a public record of prices and transactions.[19] Buyers or sellers who fail to meet the agreed terms of a deal are typically warned and sometimes subsequently banned from the groups by unpaid and largely anonymous administrators/moderators. Somewhat blunting the effectiveness of such moderator action, it is easy to obtain a new account and rejoin bourbon sales groups.

We use data from one particular group, humorously titled "Strong Water Trading" (SWT). At its peak, Strong Water Trading had over 6000 U.S.-based members. It was eventually shut down for violating the terms of service of the social network in question. Replacement groups quickly emerged, however, and at the time of writing there are a wide array of bourbon groups that serve broad and narrow segments of the market, including some that serve particular geographic areas or focus on certain product categories (such as products from a single distillery, time period, or with certain taste profiles).[20] Strong Water Trading, as one of the earliest examples of an online bourbon trading community, uniquely required members to record sales in a publicly-available spreadsheet. It is not clear why sales were recorded, particularly because the records do not provide the identity of the buyer and the seller, which could help to establish reputation. Such records, on the other hand, might help to establish pricing benchmarks that could reduce antagonism among members. Replacement groups do not appear to require sales to be recorded and this is why we only have repeat sales data from SWT for the years 2014 to 2017. From time to time, these replacement groups are also purged from the social network for violating the network's terms of service. Alas, the groups appear to reconstitute swiftly under modified names and rules (especially regarding words not to be used) to help avoid detection by algorithms.[21]

The fact that groups like Strong Water Trading can function relatively smoothly is somewhat surprising, especially given they cannot resort to violence to enforce property rights due to the physical distance between participants and because these markets do not have eBay-like reviews and seller ratings that are common in online drug markets (Bhaskar et al., 2019). Indeed, illicit secondary bourbon markets stand in contrast to Donohue and Levitt (1998) who suggest that violence is likely to be the substitute for enforceable contracts and well-established property rights.

3. Data and empirical framework

3.1. Data

Our first data source involves bourbon sales records from www.whiskyauction.com. The website is one of several similar auction sites but this data is valuable because the website has a global presence, appears to be legally permissible in its jurisdiction, and provides over eight years of data on bourbon auction prices. Note that the site operates strictly as a middleman and only auctions items actually in their (temporary) possession.[22] The company appears to be located in Germany and claims that there are relatively few restrictions on where they can ship to. For the United States, they say they can ship to most states (those they could not ship to during the time period studied were Alabama, Arkansas, Iowa, Kentucky, Mississippi, New Hampshire, North Dakota, Pennsylvania, and Utah).[23]

We summarize our www.whiskyauction.com data in Table 1, presenting information on sale prices, whiskey age, proof ($= 2\times$ percent alcohol by volume), and summary information on sales per product. Because our analysis relies on "repeat

[18] Converted from euros at the 2019 average USD/EUR exchange rate.

[19] It is against the social network's terms of service to "scrape" such data. Moreover, it would be very challenging to parse the conversation, particularly because participants tend to use language and images/emojis designed to avoid detection by network algorithms.

[20] See https://www.gearpatrol.com/food/drinks/a700726/bourbon-secondary-market-facebook/ for more information (last accessed 7/12/2021).

[21] See https://www.whiskyadvocate.com/black-market-bourbon-feature/ for a recent update on such groups.

[22] Sellers send their products to the company, the company then places the item up for the auction (including taking a standard set of high quality pictures), collects payment, and ships the product to the buyer. Sellers get paid a few days after the auction ends and the site makes money from a 10% commission on sales. More info at https://whiskyauction.com/auction/vendor_e.html.

[23] Importing a single bottle for personal use is legally possible but only if using a courier service. Shipping alcohol by mail is strictly prohibited. Rules and associated custom duties vary by state, see https://help.cbp.gov/s/article/Article-212, last accessed 1/5/2021.

Table 1
Summary statistics for whiskyauction.com data (2011 to 2019).

		2011	2012	2013	2014	2015	2016	2017	2018	2019
Price	Mean	$60.53	$97.50	$148.71	$291.46	$283.21	$304.08	$294.77	$ 293.08	$202.85
	Std. Dev.	(52.06)	(117.68)	(217.38)	(338.70)	(369.67)	(481.85)	(457.65)	(539.72)	(350.17)
	Median	$42.03	$54.07	$ 66.46	$165.10	$144.44	$130.27	$145.55	$ 142.48	$ 92.63
	Min	$ 9.99	$11.29	$6.60	$9.52	$7.51	$7.79	$ 10.38	$ 5.68	$5.51
	Max	$ 360.17	$ 926.83	$ 2,015.74	$ 2,438.65	$ 2,868.75	$ 5,224.83	$ 6,386.32	$ 13,797.09	$ 5,039.74
Whiskey Age (Years of Maturation)	Mean	8.8	10.4	10.6	12.4	11.6	10.8	10.6	10.9	9.7
	Std. Dev.	(4.00)	(4.72)	(4.62)	(5.21)	(5.15)	(4.58)	(4.44)	(4.30)	(4.36)
	Median	8	10	10	12	12	10	10	10	9
	Min	3	4	3	3	3	3	3	3	2
	Max	20	23	23	28	27	28	28	27	28
Proof (Alcohol by Volume ×2)	Mean	89.84	92.52	94.01	97.83	96.94	96.68	96.2	97.56	92.93
	Std. Dev.	(12.93)	(14.34)	(14.82)	(15.56)	(15.34)	(15.14)	(14.89)	(15.57)	(13.15)
	Median	86	88.3	90	93	90.2	90.4	90.4	93	90
	Min	80	80	80	80	80	74	80	80	74
	Max	143	144.8	144.8	144.8	172	150	160	172	172
Sales per Year	Mean	3.56	3.65	4.76	7.81	8.27	11.17	12.78	11.03	9.53
	Std. Dev.	(2.48)	(2.95)	(4.05)	(9.41)	(8.10)	(11.44)	(16.78)	(19.24)	(16.67)
	Median	3	3	3	4	5	7	6	4	4
	Min	1	1	1	1	1	1	1	1	1
	Max	11	12	17	40	33	43	66	87	82
	Observations	302	256	540	886	1322	1631	1598	1647	1891
	N	138	128	219	329	443	480	494	604	672

Note: The table presents summary statistics for bourbons with repeat sales occurring between 2011 and 2019 from www.whiskyauction.com. All values converted to nominal dollars in the year of sale using euro-dollar exchange rates in the actual month of sale provided by the U.S. Federal Reserve (see https://fred.stlouisfed.org/tags/series?t=exchange+rate%3Bmonthly). Notice that, taking 2015 as an example, the observation and N numbers refer to a total of 1322 records for 443 unique products. Neither number refers to pairs of repeat sales.

sales," we exclude products that appear only once in the data (= 1960 records). We collected this data in November 2019 and organized it using a variety of text analysis tools designed to extract the hedonic characteristics of each product, including sale prices, age, alcohol content, and so on. We then manually checked the data for any remaining errors.

Throughout, we focus only on sales records relating to "750 ml" or "fifth" (referring to the bottle being about a fifth of a U.S. gallon) size bottles. Other sizes are not common, particularly for highly-regarded products, and usually do not appear more than once in the data in any case. In the summary statistics we see that average sale prices increase markedly after 2013 but there is a slight decline in 2019. However, notice that the average age of products sold peaks in 2014 and is close to its minimum in 2019. The same pattern is true for proof (= a measure of alcohol content, where 100 proof equals 50 percent alcohol by volume). Typically, higher proof and more mature bourbons have higher retail prices in primary markets, which helps to explain why average prices are lower in 2019. Finally, we present summary information on sales per product. For sales per product, note that the mean refers to the average number of sales of each product in a given year, conditional on appearing more than once across the sample period (that is why the minimum in a given year can be 1). For example, in 2018, we have about 11 sales records per unique product. Note that this does not mean the exact same bottle is sold 11 or more times in a year. Instead, we consider repeat sales to be sales of products with the same name, proof, and years of maturity (age) as another record. In economic terms, that means that a sale is considered a repeat sale only if the products are perfect substitutes. As a specific example, any given bottle of 2016 Pappy Van Winkle 23-Year-Old is, for all intents and purposes, a perfect substitute for any other Pappy Van Winkle 23-Year-Old from 2016. In contrast, Pappy Van Winkle 23-Year-Old from 2017 is close but not quite a perfect substitute for the 2016 vintage.

Our analysis also takes advantage of data from Strong Water Trading, a decentralized secondary market operated by U.S. bourbon aficionados on a major social network from 2014 to early 2018 (although we have "repeat" sales through November 2017 only). In Table 2, as in Table 1, we report summary statistics only for products that are observed more than once in our SWT data.[24] Note that while the data from SWT is well-organized and very detailed it is harder to analyze than the whiskyauction.com data because members tend to communicate using colloquial, group-specific bourbon terms. The auction website data is easier to manipulate using text analysis because the site uses a standard listing format. When looking at our SWT data, we continue to focus on "fifth" size bottles (750 ml), excluding 363 observations of bottles of varying alternate sizes (handles, shoulders, and mini/airplane size bottles). As with the auction data, many of these less common sizes appear

[24] The restriction to repeat sales excludes a number of products sold only once in the time period studied. These items are often unique/vintage products such as antique medicinal whiskey bottles from the prohibition era or bottles with one-off designs, unusual sizes, or that possess celebrity/distiller signatures.

Table 2
Summary statistics for *Strong Water Trading* data (2014 to 2017).

		2014	2015	2016	2017	2018
Price	Mean	$ 307	$ 381	$ 508	$ 487	$ 900
	Std. Dev.	(278)	(364)	(448)	(460)	.
	Median	$ 225	$ 270	$ 375	$ 335	$ 900
	Min	$ 25	$ 25	$ 32.5	$ 32.5	$ 900
	Max	$ 2350	$ 4100	$ 3100	$ 2500	$ 900
Whiskey Age (Years of Maturation)	Mean	14	14	14	13	20
	Std. Dev.	(4)	(5)	(4)	(5)	.
	Median	12	12	12	12	20
	Min	2	2	4	4	20
	Max	28	28	28	27	20
Proof (Alcohol by Volume ×2)	Mean	107	107	107	105	90
	Std. Dev.	(17)	(17)	(17)	(15)	.
	Median	101	101	100	101	90
	Min	80	80	80	80	90
	Max	145	145	145	144	90
Sales per Year	Mean	11	10	4	2	1
	Std. Dev.	(12)	(10)	(3)	(2)	.
	Median	7	6	3	2	1
	Min	1	1	1	1	1
	Max	50	42	14	8	1
	Observations	995	1372	560	195	1
	N	265	347	237	118	1

Note: The table presents summary statistics for 2014 to 2017 Strong Water Trading data limited to bourbons that have repeat sales in our data. The spreadsheet of sales records is publicly available at https://docs.google.com/spreadsheets/d/1CAh7Rl_si750ruEVNbubV3Pghf78HcfbOqNhGjLP_lc/htmlview (link last accessed 11/1/2019). Notice that, using 2015 as an example, the observation and *N* numbers refer to a total of 1372 records for 347 unique products. Neither number refers to pairs of repeat sales.

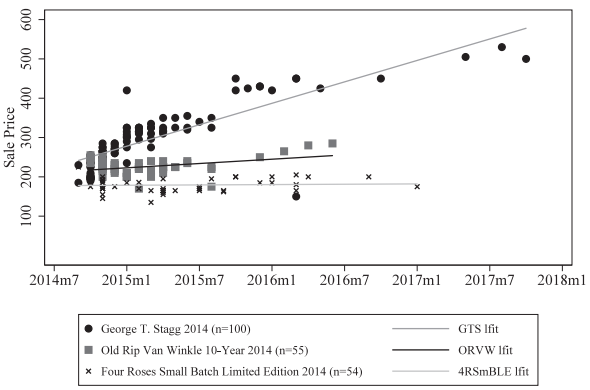
only once in the data. When appropriate, we adjust reported sale prices to exclude the cost of shipping.[25] Finally, about 1200 of the SWT records have an associated note that explained the deal was part-trade or that the price included a "taster" of some other bourbon, and so on. Other notes stated that the sale later "fell through" or that the bottle (rather than its contents) was unique in that it had some kind of celebrity or distiller signature or a quirky packaging error/flaw that made this particular bottle different to otherwise similar bottles in the data set. For our estimation sample, whenever the transaction notes indicated that a sale was not comparable to others we eliminate the observation from the sample.

In the summary data, we can see that the Strong Water Trading group featured sales of products that had higher alcohol content and were aged longer prior to bottling (relative to the whiskyauction.com data). As both age and proof tend to be positively correlated with a whiskey's desirability, it is not surprising to see that the average sale price is higher across the 2014 to 2017 period in our SWT data, relative to the whiskyauction.com data.

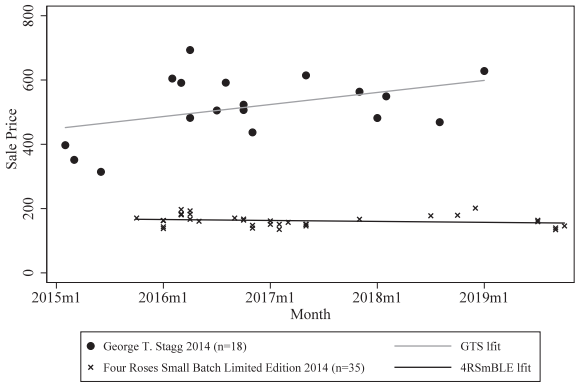
The advantage of using two distinct data sources is that it allows us to compare outcomes from a peer-to-peer decentralized illicit market with those of a centralized and quasi-legal auction house. Such an analysis, however, requires an apples to apples comparison and it is clear from the summary statistics that the products being sold in these two markets are different. The repeat sales regression approach can help deal with differences in the type of product for sale in each market. However, if changes in bourbon prices are concentrated among older, higher-proof expressions then average returns in the two markets will likely differ. Moreover, it is worth noting here that these transaction records exist only because members of the SWT group were "required" to document all sales or trades that occurred and that compliance may have been imperfect. Further, because SWT sales occur among members of a private and relatively geographically-concentrated group the data is potentially not representative of the bourbon market as a whole. On the other hand, the open nature of sales ("private" deals are not allowed and are cause for a warning and subsequent expulsion from the group) might allow for efficient price discovery, once the market is sufficiently "thick."

To provide just a little further context, Fig. 1a illustrates how prices have changed over time in the SWT market for three bourbons released in the fall of 2014 - George T. Stagg (GTS), Old Rip Van Winkle (ORVW), and Four Roses Small Batch Limited Edition (4RSmBLE). These three are the most common products appearing in the SWT data and had retail prices at time of release of $80, $50, and $100, respectively. The figure shows how the SWT secondary market quickly established a different price for each bourbon - there is a flurry of activity with lots of observations. Over time, activity diminishes. This pattern characterizes all of the annual release bourbons observed in our data (although more recent releases have had less time for activity to diminish). There are several potential explanations for this pattern: bottles could have reached investors who plan to buy and hold for a long time, many of the finite number of bottles have been consumed, or new bourbons

[25] SWT records indicate whether shipping was included or excluded from the price and how much shipping cost (typically the cost is a flat rate $10 in the continental U.S.). In our auction data, shipping costs are determined after the auction is over based upon the winner's location. Therefore, shipping costs are not included in the sale price and are not available at all in the data.



(a) 2014 - 2017 Strong Water Trading Data



(b) 2011 - 2019 whiskyauction.com Data

Fig. 1. Observed sale prices over time, selected bourbons. *Note:* The figures plot sale prices over time for selected bourbons from Strong Water Trading Sales Records 2014 to 2017 and whiskyauction.com Sales Records from 2011 to 2019. GTS = George T. Stagg, 4RSmBLE = Four Roses Small Batch Limited Edition, ORVW = Old Rip Van Winkle, lfit = Regression Fit.

deflect attention from the 2014 releases. Most strikingly, it is clear that returns are variable even for frequently traded products: some bourbons appreciate considerably while others remain at or around their initial secondary market price.

Fig. 1b illustrates prices from for 2014 GTS and 2014 4RSmBLE in the whiskyauction.com data. We cannot include 2014 ORVW because our auction data does not provide enough information to separate 2014 ORVW from other years' ORVW releases. Indeed, SWT data typically provides much more information on each product, allowing us to identify repeat sales with greater granularity. Taking ORVW as an example, our SWT data can identify each year's release as a unique product whereas our whiskyauction.com data cannot. While a similar caveat is true for other annual release bourbons, we can sometimes determine the difference between various years using age/maturation and proof. For example, George T. Stagg is released annually but has a different proof and age each year, which allows us to separate the different vintages.[26] Ultimately, however, because of such differences, we cannot easily combine the two data sets and in our repeat sales framework, which we explain in detail in the next subsection, the difference in granularity means that our whiskyauction.com data is a little more lenient regarding what counts as a repeat sale.

3.2. Repeat sales framework

Having explained how and why secondary bourbon markets operate, we estimate a price index for bourbon as a product category. To do so, we focus on the information contained in "log-price relatives," where each log-price relative is the difference between the log of consecutive sale prices of the same product, regardless of the time between the sales. The repeat-sales approach relies on the idea that the expected difference in prices for sales of the same product at different times is equal to the change in the price predicted by the overall category price index between those times plus an error term; Bailey et al. (1963) developed this method to estimate real estate price indices.[27] Specifically, for sales of good i, prices and indices between t and t' are related as follows:

$$\frac{P_{it'}}{P_{it}} = \frac{B_{t'}}{B_t} U_{itt'}. \tag{1}$$

In (1), P_{it} is the sale price of i in time period $t \in T$. For any two consecutive sales, t is the time of the first sale and t' is the time of the subsequent sale ($t' > t$). The B_t term represents the general price index for that type of good at time t and $U_{itt'}$ is the multiplicative error term for the sale pair and follows a log-normal distribution. Taking the natural logarithm of each side gives:

$$r = b_{t'} - b_t + u_{itt'}. \tag{2}$$

In (2), $r = p_{it'} - p_{it}$ and p, b, and u refer to the logarithms of P, B, and U (therefore, $u_{itt'}$ is an independent and identically distributed homoscedastic random error). The empirical analog of the repeat-sales methodology involves an estimating equation of the form:

$$r = X\beta + \mu. \tag{3}$$

[26] A bourbon's age is the years of maturation of the youngest barrel that contributed to the bottle. All bottles of bourbon, except for aptly-named "single barrel" bourbons, are a mix of many dozens (and often hundreds) of barrels to help maintain a consistent taste profile.

[27] Our description of the repeat sales methodology borrows nomenclature and notation from Nagaraja et al. (2014).

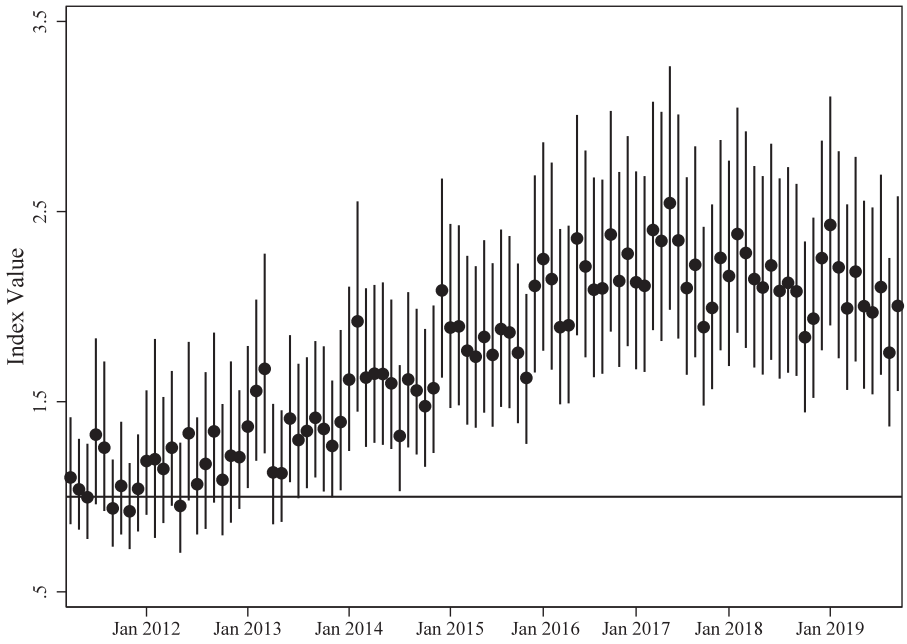


Fig. 2. Monthly price index - whiskyauction.com data April 2011 to October 2019. *Note:* The figure plots the coefficient estimates from Table 3 based on a repeat sales regression using www.whiskyauction.com data from April 2011 to October 2019. The figure plots the coefficients (as dots) and associated 95% confidence intervals (as bars).

In (3), r and μ are n-dimensional vectors where n is the number of log-price relatives that can be calculated. A log price relative r for sales that occur in periods t and t' is $r = \log(p_{t'}) - \log(p_t)$. The matrix X is $n \times T$-dimensional where T refers to the number of time periods in which sale prices are observed for any item in the data set. Completing the equation, β is a T-dimensional column vector of logarithms of the price indices to be estimated. There is no constant term in the regression, so that first value of the index is normalized at zero ($\beta_0 = 0$). The β_t coefficients (from $t = 0, \ldots, T$) can then be converted into a price index with a base value equal to 1 by taking the inverse log of each coefficient.

In practice, for any bourbon sold in $k \leq T$ time periods we calculate $k - 1$ log price relatives, which approximate the percent increase in price between two given time periods. We regress the log-price relatives on a set of T indicator variables. That is, we create a $T \times 1$ column vector for each time period $t \in T$ and each row of the vector is set to zero except the time of the later sale is set to $+1$ in the row corresponding to that t's log price relative. In the same row, we enter a -1 in the vector corresponding to the time period of the prior sale. Because our whiskyauction.com data provides only the year and month of each sale, we focus on monthly average sale prices by product. That is, each log-price relative is equal to the difference in the log of average sale price between two months where we observe a sale occurring. With this approach, we obtain 6499 monthly average log price relatives in our whiskyauction.com data and 1509 in our SWT data. Appendix A provides more information on the repeat sales method and Table A1 provides an example of the required data structure.

4. Main findings

We present our main empirical findings in three subsections. First, we determine the rate of return on bourbon implied by our whiskyauction.com and SWT data by creating a bourbon price index using the repeat sales regression framework we lay out in Section 3. We then examine bourbon whiskey price determinants (and develop complementary measures of annual returns) in a hedonic framework. Our hedonic analysis is limited, however, by missing data on many of the bottles in each data set, particularly among the whiskeys in our auction data. Finally, we use our bourbon price index values to examine bourbon's potential as an alternative investment.

4.1. Bourbon repeat sales price index

Using the repeat sales approach that we describe in Section 3 we obtain the estimates in Table 3. Specifically, in Table 3, we are presenting the inverse log of the regression coefficients as monthly index values from April 2011 (2011m4) to October 2019 (2019m10) across multiple columns. By construction, the April 2011 index value is the base value and is set equal to 1. Interpreting the estimates, the 2.43 index value in February 2019 suggests a 143% return in under eight years. The index value for October 2019, at the end of the sample period, is 2.004, implying about a 9.1% annual return over the eight-year sample period. Fig. 2, which perhaps better illustrates our estimates, is a plot of the values in Table 3 over time.

Table 3
Bourbon price index based on repeat sales regressions - whiskyauction.com data (2011 to 2019).

Month	Index value	Month	Index value	Month	Index value	Month	Index value
2011m4	1						
	–						
2011m5	1.102	2013m6	1.124	2015m7	1.746	2017m10	1.892
	(0.142)		(0.148)		(0.217)		(0.237)
2011m6	1.039	2013m7	1.411	2015m8	1.882	2017m11	1.993
	(0.121)		(0.195)		(0.236)		(0.245)
2011m7	0.997	2013m8	1.298	2015m9	1.864	2018m1	2.256
	(0.126)		(0.178)		(0.229)		(0.279)
2011m8	1.327	2013m9	1.346	2015m10	1.757	2018m2	2.161
	(0.219)		(0.174)		(0.212)		(0.273)
2011m9	1.258	2013m10	1.415	2015m11	1.625	2018m3	2.382
	(0.197)		(0.181)		(0.199)		(0.299)
2011m10	0.939	2013m11	1.357	2016m1	2.109	2018m4	2.282
	(0.116)		(0.192)		(0.262)		(0.288)
2011m11	1.057	2013m12	1.267	2016m2	2.250	2018m5	2.145
	(0.149)		(0.155)		(0.277)		(0.268)
2011m12	0.924	2014m1	1.393	2016m3	2.145	2018m6	2.101
	(0.114)		(0.212)		(0.275)		(0.264)
2012m1	1.042	2014m2	1.616	2016m4	1.892	2018m7	2.217
	(0.129)		(0.218)		(0.233)		(0.287)
2012m2	1.188	2014m3	1.923	2016m5	1.902	2018m8	2.082
	(0.165)		(0.278)		(0.236)		(0.266)
2012m3	1.198	2014m4	1.627	2016m6	2.359	2018m9	2.125
	(0.259)		(0.211)		(0.293)		(0.273)
2012m4	1.146	2014m5	1.647	2016m7	2.211	2018m10	2.080
	(0.167)		(0.210)		(0.275)		(0.255)
2012m5	1.258	2014m6	1.646	2016m8	2.089	2018m11	1.839
	(0.179)		(0.216)		(0.265)		(0.227)
2012m6	0.952	2014m7	1.597	2016m9	2.096	2018m12	1.937
	(0.146)		(0.199)		(0.258)		(0.240)
2012m7	1.334	2014m8	1.320	2016m10	2.379	2019m1	2.255
	(0.209)		(0.167)		(0.293)		(0.279)
2012m8	1.066	2014m9	1.617	2016m11	2.135	2019m2	2.430
	(0.155)		(0.206)		(0.259)		(0.304)
2012m9	1.173	2014m10	1.559	2017m1	2.278	2019m3	2.207
	(0.206)		(0.194)		(0.279)		(0.275)
2012m10	1.344	2014m11	1.476	2017m2	2.128	2019m4	1.991
	(0.224)		(0.183)		(0.263)		(0.247)
2012m11	1.089	2014m12	1.571	2017m3	2.110	2019m5	2.184
	(0.173)		(0.196)		(0.260)		(0.272)
2012m12	1.216	2015m1	2.085	2017m4	2.403	2019m6	2.002
	(0.212)		(0.264)		(0.303)		(0.250)
2013m1	1.208	2015m2	1.890	2017m5	2.346	2019m7	1.970
	(0.158)		(0.244)		(0.304)		(0.248)
2013m2	1.369	2015m3	1.896	2017m6	2.544	2019m8	2.103
	(0.188)		(0.239)		(0.323)		(0.266)
2013m3	1.556	2015m4	1.768	2017m7	2.348	2019m9	1.758
	(0.214)		(0.224)		(0.298)		(0.224)
2013m4	1.673	2015m5	1.737	2017m8	2.098	2019m10	2.004
	(0.264)		(0.215)		(0.262)		(0.258)
2013m5	1.128	2015m6	1.841	2017m9	2.220		
	(0.160)		(0.229)		(0.280)		
Repeat sales	6499						

Note: The table reports the inverse log of monthly coefficients from a repeat sales regression using www.whiskyauction.com data from 2011 to 2019. Note that 2015m3 refers to March of 2015, and so on. April 2011 is the base value (=1). Note that some months are missing because the website operator appears to have taken vacation around the holiday season in 2015, 2016, and 2017.

Given the estimates in Table 3 and Fig. 2 are based on repeat sales, the secondary market appears to be "cooling" off a little toward the end of our sample period. Even with this slight downturn, the rate of return on bourbon over the sample is larger (at least during our sample time period) than the typical rate of return on wine, stamps, violins, or art implied by the analyses of Burton and Jacobsen (2001); Mei and Moses (2002); Dimson and Spaenjers (2011); Graddy and Margolis (2011); Dimson et al. (2015). Note that the repeat sales regression methodology ensures that the price increases we observe cannot be due only to changes over time in the underlying sample of bourbons used to construct the index.

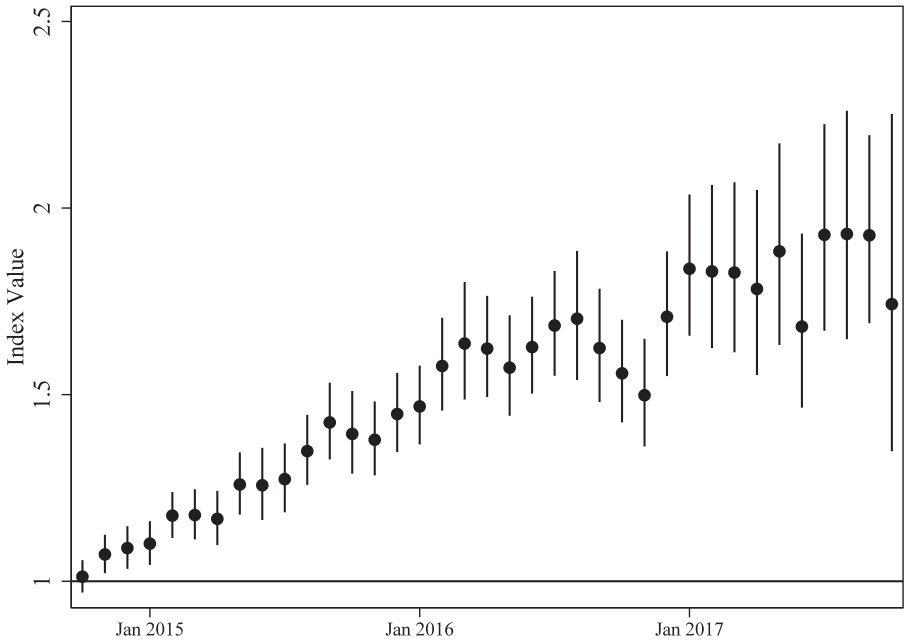


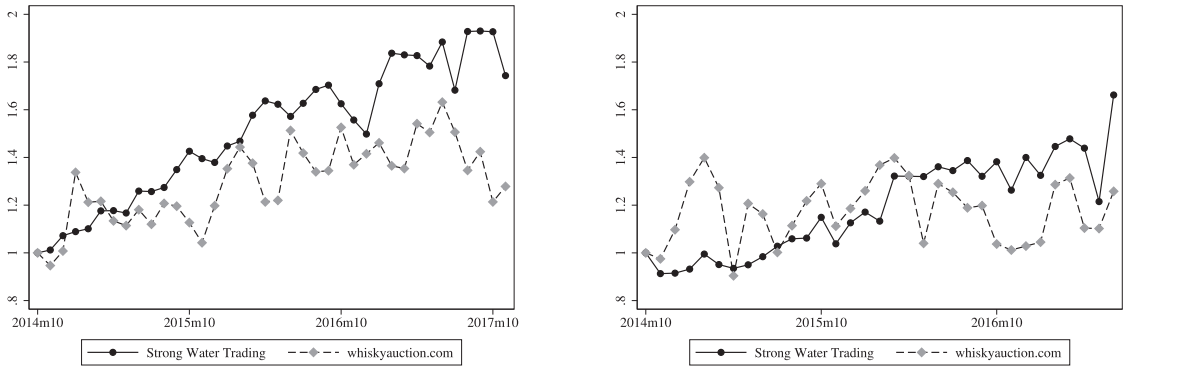
Fig. 3. Monthly price index (SWT Data - Oct 2014 to No. 2017). *Note:* The figure plots the coefficients (as dots) and 95% confidence intervals (as bars) from Table 4, which presented estimates based on a repeat sales analysis using Strong Water Trading sales records from 2014 to 2017.

Table 4
Bourbon index based on repeat sales regressions - SWT data (2014 to 2017).

Month	Index	Month	Index	Month	Index	Month	Index
2014m10	1						
	–						
2014m11	1.012	2015m9	1.349	2016m7	1.627	2017m5	1.783
	(0.0221)		(0.0478)		(0.0661)		(0.126)
2014m12	1.072	2015m10	1.426	2016m8	1.685	2017m6	1.884
	(0.0262)		(0.0524)		(0.0715)		(0.137)
2015m1	1.089	2015m11	1.395	2016m9	1.703	2017m7	1.682
	(0.0291)		(0.0564)		(0.0881)		(0.119)
2015m2	1.101	2015m12	1.379	2016m10	1.625	2017m8	1.928
	(0.0299)		(0.0505)		(0.0773)		(0.141)
2015m3	1.176	2016m1	1.448	2016m11	1.557	2017m9	1.930
	(0.0314)		(0.0541)		(0.0700)		(0.155)
2015m4	1.177	2016m2	1.468	2016m12	1.498	2017m10	1.927
	(0.0343)		(0.0538)		(0.0734)		(0.128)
2015m5	1.167	2016m3	1.577	2017m1	1.709	2017m11	1.743
	(0.0370)		(0.0633)		(0.0850)		(0.228)
2015m6	1.259	2016m4	1.637	2017m2	1.837		
	(0.0425)		(0.0802)		(0.0963)		
2015m7	1.257	2016m5	1.623	2017m3	1.830		
	(0.0492)		(0.0690)		(0.111)		
2015m8	1.274	2016m6	1.572	2017m4	1.827		
	(0.0470)		(0.0686)		(0.116)		
Observations	1509						

Note: The table presents repeat sales regression coefficient estimates based on data from Strong Water Trading from 2014 to 2017. Standard errors in parentheses. *Note:* 2014m11 refers to November of 2014, and so on. October 2014 is the base month (index value=1). The spreadsheet of sales records is publicly available at https://docs.google.com/spreadsheets/d/1CAh7Rl_si750ruEVNbubV3Pghf78HcfbOqNhGjLP_lc/htmlview (link last accessed 11/1/2019).

We present index values developed using our Strong Water Trading data in Table 4 (and in Fig. 3 where we plot the estimated index values over time to aid interpretation). Again, our table of estimates spans several columns. However, we have just over three years of data between late 2014 and late 2017, meaning that the time period is significantly shorter than our auction data. For comparability, we again average sale prices for each product *within* a calendar month. Therefore, each bourbon's log-price relative is based on differences in the log of the average sale price between two months in which sales are observed.



(a) 2014-2017 Complete Strong Water Trading and Whiskyauction.com Data (b) 2014-2017 Most Common Whiskeys from Strong Water Trading and Whiskyauction.com Data

Fig. 4. Monthly price index comparison - Oct 2014 to No. 2017. *Note:* The figure plots the inverse log of the coefficients from a repeat sales regression using Strong Water Trading sales records and whiskyauction.com data from October 2014 to November 2017 in (a). In (b), the data is further limited to the 20 bourbons appearing most frequently in the Strong Water Trading data, except for 2013 Four Roses Small Batch Limited Edition (because it does not appear in the whiskyauction.com data). We do not plot confidence intervals with the point estimates, because they would make it challenging to see differences in the two series.

In Table 4, an estimate of 1.012 (November 2014) implies that bourbon prices increased by 1.2% relative to the base month (October 2014). By November of 2017, the index is 1.743, representing a 74.3% increase in bourbon prices relative to late 2014 (or about 20.4% per year).[28] Note that between October 2014 and November 2017, the whiskyauction.com index value increased from 1.559 to 1.993 (implying a 27.8% total increase in prices, or about 9% per year). We present the values of both price indices from October 2014 to November 2017 (the time period that is common to both data sources) in Fig. 4a - normalized so that October 2014 is the base month in each series - where we can see larger increases in the SWT market prices during the sample period.

We speculate that the "new" nature of the SWT secondary market in 2014 perhaps contributed to lower initial prices, allowing for a greater increase over time. Alternatively, if there were relatively fewer participants in 2014 it might inhibit efficient price discovery. The price patterns of 2014 George T. Stagg in Fig. 1 perhaps support such a narrative. The SWT market price was below $300 in early 2015 while the whiskyauction.com price was closer to $400 but prices are more similar in each market by late 2017 (at around $500). On the other hand, while the SWT data index values in Fig. 4a are generally greater than the whiskyauction.com data index values throughout 2015, 2016, and 2017, the indices diverge only towards the end of the sample period. From our SWT data summary statistics (Table 2), we see that the frequency of observations declines in 2017, perhaps contributing to the divergence in the index values toward the end of the sample period. Supporting the idea that the SWT market took some time to become efficient, however, price changes are similar across markets if we allow a wider time-frame. For example, the whiskyauction.com index values for August 2014 relative to January of 2018 (1.32, 2.26) imply a 71.2% increase in prices between the two months (about an 18% annual return).

Such data and timing issues suggest that focusing on frequently traded products might see greater concordance between the indices. In Fig. 4b, therefore, we present index values from both data sources but limit our sample to the most frequently sold bourbons in our Strong Water Trading data (and to the SWT sample period). We focus on the 20 most commonly-observed products in the Strong Water Trading data. Of those 20 bourbons, 19 of them appear in the whiskyauction.com data, the one exception being 2013 Four Roses Small Batch Limited Edition. We therefore exclude that product from the analysis. Note also that in a handful of cases (Old Rip Van Winkle 2014, Eagle Rare 17 2014, and Pappy Van Winkle of any maturity) we cannot determine exact vintages (i.e., release year) in the whiskyauction.com data to be able to align the data sources perfectly. When limiting the sample to frequently sold bourbons, we observe 266 repeat sales in our SWT data and 348 in the whiskyauction.com data between October 2014 to June 2017. In Fig. 4b, we see that when we limit the sample to a similar set of products, the index values over time are more aligned. Products that appear most frequently in our data are naturally older, and have perhaps reached a stable secondary market price, limiting price increases over time. We caution, however, that comparing prices for specific products across the two markets is challenging in our setting, particularly because of missing information regarding vintage/release year in our whiskyauction.com data.

4.2. Hedonic analysis

We next examine the role of hedonic characteristics in bourbon price determination. We present a summary of the available hedonic characteristics, by year, in Table 5 for our SWT data. We include information on sale price, age (in years), proof

[28] We calculate an approximate annual rate of return using the standard formula $A = P(1+r)^t$ where A is the final index value, P is the initial index value, r is the unknown annual return and t is the number of years. For example, in our SWT data, the final value is 1.743, the initial value is 1, and $t \approx 3$; plugging these values in we get $1.743 = 1(1+r)^3$ and solving for r, $r \approx 20.4\%$.

Table 5
Summary hedonic characteristics for SWT bourbons (2014 to 2018).

	2014	2015	2016	2017	2018
Price ($)	307.24	384.80	521.12	460.18	900.00
	(279.88)	(376.97)	(503.83)	(446.37)	(.)
Years of Maturation (Age)	13.67	13.53	13.62	13.25	20.00
	(4.33)	(4.68)	(4.46)	(4.51)	(.)
Proof	106.29	106.27	106.37	104.61	90.40
	(16.71)	(16.54)	(17.11)	(14.90)	(.)
Barrel Proof (Proportion)	0.31	0.29	0.30	0.26	0.00
Annual Release (Proportion)	0.50	0.44	0.50	0.43	1.00
Observations	1039	1436	603	226	1

Note: The table presents hedonic characteristics for 2014 to 2017 transaction records maintained by the "Strong Water Trading" (SWT) bourbon aficionado social network group. Standard deviation in parentheses where appropriate.

Table 6
Hedonic price analysis - SWT data (2014 to 2018).

	Dependent variable = price					
	(1)	(2)	(3)	(4)	(5)	(6)
Year = 2015	77.56***	76.93***	85.17***	96.42***	99.74***	88.86***
	(16.93)	(17.00)	(16.85)	(18.63)	(18.54)	(20.70)
Year = 2016	213.88***	213.56***	212.24***	216.07***	213.80***	236.09***
	(31.63)	(31.53)	(31.84)	(34.65)	(34.76)	(52.91)
Year = 2017	152.94***	151.33***	160.60***	174.01***	208.74***	83.91*
	(40.77)	(40.91)	(38.83)	(43.01)	(39.44)	(49.63)
Barrel Proof Indicator		−35.69	−96.96**	−162.25**	−124.87**	−440.79***
		(35.91)	(43.10)	(68.95)	(48.71)	(158.37)
Annual Release Indicator			178.39***	168.33***	139.66***	211.37*
			(45.73)	(49.36)	(47.03)	(113.10)
Proof				2.36	3.01	4.21**
				(1.61)	(1.82)	(2.02)
Years of Maturation (Age)					39.61***	3.90
					(6.71)	(12.48)
Observations	3,304	3,304	3,304	2,837	2,520	716
Adjusted *R*-Squared	0.036	0.038	0.084	0.083	0.258	0.214

Note: The table presents hedonic regression estimates using transaction records maintained by the "Strong Water Trading" bourbon aficionado social network from 2014 to 2017. Standard errors in parentheses, clustered at the product level (*** $p < 0.01$, * $p < 0.05$, * $p < 0.1$). Note that 2014 is the omitted year.

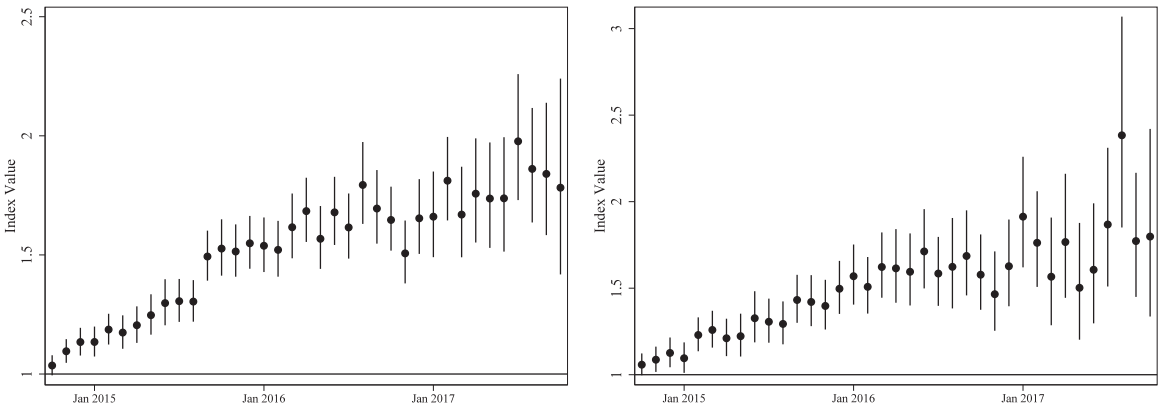
(= 2× the percentage of alcohol in the bottle), an indicator for barrel proof (=1 if no water has been added after maturation), and annual release (=1 if the product is only released once per year). We continue to focus on "fifth" size bottles but because this analysis is not restricted to repeat sales, our sample is now larger.[29] We use the available information on hedonic characteristics to further explore how secondary market prices are determined. In particular, we examine an estimating equation of the following form:

$$Price_{it} = \alpha + X_i\beta + \gamma_t + \epsilon_{it}.$$

In the estimating equation, $Price_{it}$ refers to the price of product i at time t, α is a constant, X_i contains some or all (depending on specification) of the hedonic characteristics of interest laid out in Table 5, γ_t is a year-of-transaction fixed effect, and ϵ_{it} is an idiosyncratic error term. The coefficient on the year-of-transaction fixed effect provides a second estimate of annual bourbon price increases.

Our SWT data generally contains information on these hedonic characteristics for a greater proportion of products and, for that reason, we focus mainly on SWT data in this part of our analysis. We present estimates that rely on our SWT data in Table 6. The first column of the table presents a parsimonious specification that includes only year-of-transaction fixed effects. We then progressively add product information in each subsequent specification. The coefficients relating to year-of-transaction fixed effects should be viewed as relative to prices in 2014. In each specification, we see a familiar pattern; prices in 2015, 2016, and 2017 are significantly higher than 2014. Compared to the repeat sales regression, however, the annual price increases we see in the hedonic analysis are a little lower. For example, the estimates suggest prices in 2017 were at most $208.74 higher relative to prices in 2014 (when using the largest 2017 coefficient estimate in column five).

[29] Note that there is one observation in our SWT data for 2018. However, because it is not a repeat sale it does not appear in our repeat sales analysis. We therefore continue to exclude it here as it is not possible to draw any significant conclusions about bourbon prices in 2018 based on one observation. Note also that we provide information on the correlations among hedonic characteristics in each of our data sources as an appendix item.



(a) Annual Releases Only (b) Barrel Proof Products Only

Fig. 5. Monthly price index - SWT data 2014 to 2017). *Note:* The figure presents the inverse log of the coefficients from a repeat sales regression using Strong Water Trading Sales Records 2014–2017. The figure plots the coefficients (as dots) and 95% confidence intervals (as bars) from samples limited to Annual Release Products and Barrel Proof Products as noted in the sub-figure captions.

Given the mean sales price among the full sample was $307.24 in 2014, a $208.74 price increase over three years, amounting to a 67.9% change (18.8% on an annual basis), is similar but a little less than the 74.3% return over the same sample period predicted by our repeat sales approach.

We have a total of 3304 transactions in our SWT data. For each of these, we know if the bottle is barrel proof and/or if it is a limited once-per-year release. For that reason, we first add the indicator for barrel proof (bottled without dilution, typically at a proof of 120 or above, which amounts to 60% alcohol by volume) in the specification in the second column and then add an indicator for annual release in the third column of estimates. In the fourth column we control for the actual proof of the bottles in question. A bourbon's proof is legally required to be printed on the bottle but we could not determine the proof for about 500 of the bottles in the SWT data. In the fifth column we add the bourbon's age as measured by the number of years spent in maturation in oak containers. There is no legal requirement on how long a bourbon must be allowed to mature, and the bottle must indicate the age only if the bourbon is less than four years old. For this reason, a bourbon's age is not always available; we therefore lose several hundred further observations.

The coefficients in Table 6 suggest that annual release bourbons are associated with higher prices while being a barrel proof product seems to have a consistent negative association with secondary market prices. It is worth noting here that the once-per-year Pappy Van Winkle expressions, consistently some of the most expensive products on the secondary market, are not bottled at barrel proof. To further study these patterns we return to the repeat sales analysis from earlier but restrict the sample first to only annual release bourbons and then to barrel proof products. Fig. 5 contains plots of the coefficient estimates (i.e., the estimated index values) from those repeat sales regressions. The figure illustrates the importance of the repeat sales approach: the annual release bourbons increase significantly in price but not by significantly more than barrel proof products (note that there is considerable overlap). Specifically, the index values are 1.78 and 1.80 for the final month of the SWT sample when the sample is restricted to annual release and barrel proof products, respectively.

In the estimates in Table 6, because data is sometimes missing in these categories, we are less confident in the coefficients associated with whiskey age and proof. That said, it is worth noting that each year of maturation is associated with a $39.61 increase in observed SWT secondary market prices. That amounts to a 10.1% increase relative to the mean transaction price in our SWT data of $390.60.[30] This is remarkably similar to the 8.9% increase in price per year of maturation that (Moroz and Pecchioli, 2019) find when examining secondary market Scotch prices.[31]

While we do not have as much product information on each of these bottles (relative to our SWT data), we present summary statistics and then regression estimates that examine returns to hedonic characteristics in our auction data in Tables 7 and 8. In those estimates, we see that the indicator for "barrel proof" has a mixed effect on prices, whereas the continuous measure of proof, the annual release indicator, and maturation/age are generally positively associated with prices. While the point estimates for the effect of these characteristics on prices differs between our auction and SWT data, the qualitative patterns suggest that these markets value characteristics similarly. On the other hand, these markets feature different average prices and product composition (see Tables 5 and 7), ensuring that point estimates of the association between specific

[30] The $390.60 figure is based on a weighted average of the price data that we present in Table 5.

[31] In estimates not presented here, we follow (Moroz and Pecchioli, 2021a) to incorporate the effect of expert review ratings on prices in our analysis. Limiting such an analysis, review scores are available only for a small subset of the products in our data from any one review website. When we add review scores from whiskyadvocate.com to the specification in column 5 of Table 6, the estimates imply only a $3.37 increase in secondary market price per review point on a 0 to 100 scale and the point estimate is not statistically significant at conventional levels. Part of the problem is that the sample size is only 716 transactions because of unavailable review scores.

Table 7
Summary hedonic characteristics for whiskyauction.com bourbons by year.

	2011	2012	2013	2014	2015	2016	2017	2018	2019
Price ($)	60.53	97.50	148.71	291.46	283.21	304.08	294.77	293.08	202.85
	(52.06)	(117.68)	(217.38)	(338.70)	(369.67)	(481.85)	(457.65)	(539.72)	(350.17)
Years of Maturation (Age)	8.80	10.44	10.61	12.35	11.60	10.81	10.63	10.85	9.70
	(4.00)	(4.72)	(4.62)	(5.21)	(5.15)	(4.58)	(4.44)	(4.30)	(4.36)
Proof	89.84	92.52	94.01	97.83	96.94	96.68	96.20	97.56	92.93
	(12.93)	(14.34)	(14.82)	(15.56)	(15.34)	(15.14)	(14.89)	(15.57)	(13.15)
Barrel Proof (Proportion)	0.06	0.11	0.08	0.14	0.14	0.14	0.13	0.15	0.09
Annual Release (Proportion)	0.06	0.08	0.16	0.21	0.12	0.14	0.12	0.08	0.06
Observations	302	256	540	886	1322	1631	1598	1647	1891

Note: The table presents summary statistics for 2011 to 2019 bourbon sales from www.whiskyauction.com. Standard deviation in parentheses where appropriate.

Table 8
Hedonic price analysis - 2011 to 2019 whiskyauction.com data.

	Dependent variable = price				
	(1)	(2)	(3)	(4)	(5)
Year = 2011	−230.92***	−221.14***	−170.85***	−146.39***	−89.09***
	(40.62)	(42.71)	(22.46)	(25.64)	(29.29)
Year = 2012	−193.95***	−189.53***	−145.08***	−127.71***	−117.25***
	(40.24)	(41.70)	(23.12)	(25.43)	(29.55)
Year = 2013	−142.75***	−135.74***	−122.83***	−114.25***	−64.24***
	(41.32)	(42.98)	(26.59)	(29.55)	(21.54)
Year = 2015	−8.24	−8.02	23.64	25.47	44.08**
	(25.77)	(26.12)	(16.37)	(16.35)	(21.81)
Year = 2016	12.62	13.53	37.64*	40.11*	127.69***
	(29.59)	(29.66)	(22.12)	(23.54)	(29.62)
Year = 2017	3.31	5.44	38.38*	41.14*	107.71***
	(31.43)	(32.02)	(22.03)	(23.37)	(27.97)
Year = 2018	1.62	0.99	48.61**	46.18**	109.18***
	(34.05)	(34.51)	(22.35)	(22.91)	(29.88)
Year = 2019	−88.61**	−82.37**	−32.64	−20.35	72.53***
	(35.73)	(37.00)	(19.86)	(21.94)	(21.80)
Barrel Proof		116.76***	33.57	−157.51**	−22.70
		(42.23)	(47.36)	(64.17)	(100.30)
Annual Release Indicator			375.47***	324.82***	100.47
			(92.23)	(102.81)	(65.78)
Proof				5.87***	0.93
				(1.51)	(2.53)
Years of Maturation (Age)					49.28***
					(6.57)
Observations	10,073	10,073	10,073	10,045	6357
Adjusted *R*-Squared	0.022	0.030	0.105	0.122	0.268

Note: The table presents hedonic regression estimates using sales records from whiskyauction.com 2011 to 2019. Standard errors in parentheses, clustered at the product level (*** $p < 0.01$, * $p < 0.05$, * $p < 0.1$). Note that 2014 is the omitted year.

characteristics and price will be different. We again include year-of-transaction fixed effects in each regression and report those estimates in the table. We choose 2014 as the omitted year to enable a direct comparison with Table 6. As in Table 6, the estimates suggest that prices generally increase after 2014, but the price increases are not as large as the increases we observe in our SWT data. Compared to the average price in 2011, the estimates suggest that bourbon prices increase 167% over the 2011 to 2019 period, amounting to a 13.1% annual increase.[32] In the next subsection, we examine bourbon's potential as an alternative investment.

4.3. Bourbon's investment potential

Given we observe large price increases over time, we next examine bourbon's appeal as a viable alternative investment. Pedersen et al. (2014) suggest that portfolio allocations to alternative investments are driven in part by low correlations with publicly traded investments (e.g., stocks, bonds, and so on). Therefore, we first examine simple pairwise correlations of monthly bourbon returns with stocks (as proxied by the Standard and Poor's Depository Receipt S&P 500 Exchange Traded

[32] That is, a 13.1% increase per year would leave an investor with a 167% return after eight time periods.

Table 9
Investment performance: correlations among assets and the CPI.

	Bourbon (PtoP)	Stocks	Bonds	Commodities	CPI	60/40	50/30/20
Bourbon (Auction)	−0.020	−0.243	0.320	−0.070	0.107	−0.189	−0.174
Bourbon (Peer-to-Peer / PtoP)		−0.043	0.210	−0.118	0.268	0.003	−0.061
Stocks (SPY)			−0.121	0.508	0.094	0.985	0.941
Bonds (BND)				−0.129	−0.064	0.053	−0.022
Commodities (DBC)					0.303	0.489	0.751
Consumer Price Index (CPI)						0.084	0.179
60/40 Stocks (SPY) /Bonds (BND)							0.943

Note: The table reports correlations among various financial indexes and the repeat sales regression index values for whiskyauction.com data from 2011 to 2019 and from Strong Water Trading data from 2014 to 2017 from Tables 3 and 4. CPI from the Bureau of Labor Statistics. SPY = Standard and Poor's Depository Receipt S&P 500 Exchange Traded Funds Trust, BND = Vanguard Total Bond Market Exchange Traded Funds, DBC = Invesco DB Commodity Index Tracking Fund.

Fund Trust, abbreviation "SPY"), bonds (Vanguard Total Bond Market Exchange Traded Fund, abbreviation "BND"), commodities (Invesco DB Commodity Index Tracking Fund, abbreviation "DBC"), and, as a measure of inflation, the Consumer Price Index (CPI). We also examine the correlation of bourbon with two common portfolio weightings: a 60/40 mix of stocks and bonds and a 50/30/20 mix of stocks, bonds, and commodities.[33] Again, we note that we are not providing investment advice.

We first present correlations between monthly bourbon returns and different investment options (and the CPI) in Table 9. Interestingly, our auction (whiskyauction.com) and peer-to-peer (Strong Water Trading) bourbon market returns exhibit a mild negative correlation with one another. However, visual inspection of returns in Fig. 4 show that negative correlation is likely driven by larger increase in prices over time in our social network-based sales data. We suspect that, because whiskyauction.com had a multi-year headstart on Strong Water Trading, it allowed greater room for prices to increase in our social network sales data. Bourbon prices are also negatively related to stocks (SPY) and commodities. In contrast, both exhibit positive correlation with bonds and the CPI. The relationship with typical diversified portfolios is generally negative except for a small positive correlation between returns in our peer-to-peer bourbon sales data and the 60/40 stock/bond portfolio, suggesting that an investor who participated in the auction rather than peer-to-peer markets might experience greater portfolio enhancements.

In Table 10 we present asset returns, volatility, distribution characteristics, and risk-adjusted performance for the assets we examine in Table 9.[34] Nominal arithmetic returns in our auction and peer-to-peer data are high relative to other assets/portfolios but geometric returns are lower.[35] In isolation, these returns come with greater volatility; auction bourbon returns have a standard deviation of 12.63% while the peer-to-peer data has a standard deviation of 7.94%, each higher than the nearest asset (commodities at 4.5%). Kraus and Litzenberger (1976) indicate that investors prefer risky assets with positive skewness, which bourbon exhibits in our auction data but not the peer-to-peer market data. On the other hand, both bourbon assets also have higher likelihood of fat tail events (i.e., higher excess kurtosis). While the standalone risk-adjusted performance of bourbon in our auction data seems poor relative to other assets (Sharpe ratio = 0.12), our peer-to-peer bourbon returns exhibit a higher Sharpe ratio at 0.21.[36] We caution that this finding may be driven by a smaller sample size and return smoothing from less frequent pricing (for a similar example in the real estate asset class, see Geltner, 1991).

Notably, when we examine a 5% addition of bourbon to traditional portfolios, bourbon's ability to enhance portfolio returns becomes apparent. A 60/40 stock/bond portfolio with bourbon has higher returns, lower volatility, and exhibits positive return skewness. Focusing on nominal returns, the Sharpe ratio of the 60/40 portfolio improves from 0.33 to 0.37 (0.41) if we include auction (peer-to-peer) monthly bourbon returns. We find similar improvements from the addition of bourbon to a 50/30/20 stock/bond/commodity portfolio. Standalone real returns (i.e., returns adjusted for monthly changes in the Consumer Price Index) are generally similar. Indeed, the high correlation of auction bourbon returns with inflation, positive standalone returns, and positive return skewness make the asset class a valuable inflation hedge relative to commodities (although commodities have higher correlation with inflation). We again find higher Sharpe ratios in traditional portfolios when real bourbon returns are added.

Pedersen et al. (2014) find that returns for alternative assets including private equity, real estate, farmland, and timberland "have significant exposure to the same risk factors" that drive traditional asset volatility. To examine this possibility for

[33] We use a 60/40 stock/bond portfolio as a starting point because it is one of the most common diversified portfolio asset allocations used historically by pension funds and other investors (Ambachtsheer, 1987). With more recent outperformance of real assets (e.g., commodities, etc.) and the desire to improve inflation-adjusted portfolio returns, practitioners have recommended moving to a 50/30/20 stock/bond/commodity portfolio (for example, Invesco's "Investment Menu Design: The Real Deal" - https://www.invesco.com/pdf/II-DCTRD-ART-1-E.pdf). Ankrim and Hensel (1993) also provide early motivation for including a commodity component in a traditional stock/bond portfolio.

[34] In Table A2 we present summary statistics for annual returns.

[35] Arithmetic returns are a simple average return where we sum the series of returns and then divide by the number of returns. Geometric returns are calculated by multiplying all n returns, taking the nth root and subtracting the initial capital.

[36] The Sharpe ratio for asset m is $r_m - r_f/\sigma_m$ where r_m is the asset's average return in a specific time period, r_f is the risk-free rate of return during that time period, and σ_m is the standard deviation of asset m's returns. A Sharpe ratio therefore calculates an asset's average return in excess of the risk-free rate per unit of volatility.

Table 10
Investment performance: portfolio returns (monthly).

	Mean returns per month		Dispersion of monthly returns			Higher moments		
	Geometric	Arithmetic	Std. Dev.	Min	Max	Skewness	Kurtosis	Sharpe ratio
Nominal Returns								
Bourbon (Auction) $N = 102$	0.68%	1.46%	12.63%	−32.58%	40.13%	0.37	0.80	0.12
Bourbon (Peer-to-peer) $N = 37$	1.51%	1.65%	7.94%	−30.90%	14.63%	−1.73	5.88	0.21
Stocks (SPY)	0.93%	1.00%	3.62%	−9.71%	11.96%	−0.25	1.02	0.27
Bonds (BND)	0.28%	0.28%	0.95%	−2.58%	3.08%	0.12	0.79	0.30
Commodities (DBC)	−0.70%	−0.60%	4.50%	−14.62%	9.71%	−0.50	0.51	−0.13
Inflation (CPI)	0.13%	0.13%	0.29%	−0.57%	0.82%	−0.11	−0.38	0.45
60/40 Stocks Bonds	0.69%	0.71%	2.16%	−5.17%	7.22%	−0.13	0.94	0.33
with 5% Bourbon (Auction)	0.73%	0.75%	2.05%	−4.71%	6.70%	−0.06	0.89	0.37
with 5% Bourbon (Peer-to-peer)	0.68%	0.69%	1.69%	−3.50%	5.12%	0.28	1.25	0.41
50/30/20 Stocks/Bonds/Commodities	0.43%	0.46%	2.37%	−6.75%	7.54%	−0.19	1.11	0.19
with 5% Bourbon (Auction)	0.43%	0.46%	2.26%	−6.38%	7.21%	−0.20	1.14	0.20
with 5% Bourbon (Peer-to-peer)	0.43%	0.44%	1.82%	−2.95%	4.57%	0.25	−0.13	0.24
Real Returns								
Bourbon (Auction) $N = 102$	0.55%	1.32%	12.60%	−32.75%	40.29%	0.39	0.86	0.11
Bourbon (Peer-to-peer) $N = 37$	1.41%	1.54%	4.85%	−30.66%	14.33%	−2.63	18.09	0.32
Stocks	0.80%	0.86%	3.61%	−9.39%	12.16%	−0.20	1.05	0.24
Bonds	0.14%	0.15%	1.01%	−2.42%	3.55%	0.21	0.82	0.15
Commodities	−0.83%	−0.73%	4.42%	−14.77%	9.23%	−0.48	0.55	−0.17
60/40 Stocks Bonds	0.55%	0.58%	2.34%	−4.86%	7.42%	−0.04	1.00	0.27
with 5% Bourbon (Auction)	0.60%	0.62%	2.03%	−4.79%	6.51%	0.01	0.90	0.30
with 5% Bourbon (Peer-to-peer)	0.58%	0.59%	1.66%	−3.36%	5.17%	0.31	1.26	0.36
50/30/20 Stocks/Bonds/Commodities	0.30%	0.33%	2.34%	−6.90%	7.75%	−0.13	1.32	0.14
with 5% Bourbon (Auction)	0.30%	0.32%	2.22%	−6.54%	7.42%	−0.13	1.35	0.15
with 5% Bourbon (Peer-to-peer)	0.33%	0.34%	1.71%	−2.80%	4.42%	0.25	0.04	0.20

Note: The table reports financial performance data estimated using whiskyauction.com repeat sales regression index values from 2011 to 2019 and from Strong Water Trading index values from 2014 to 2017. CPI from the Bureau of Labor Statistics. SPY = Standard and Poor's Depository Receipt S&P 500 Exchange Traded Funds Trust, BND = Vanguard Total Bond Market Exchange Traded Funds, DBC = Invesco DB Commodity Index Tracking Fund.

Table 11
Investment performance: factor models.

	Bourbon (Auction)				Bourbon (Peer-to-Peer)			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Alpha (% Monthly Return)	2.346*	2.183*	2.057	2.071	1.721*	1.721*	1.947**	1.949**
	(1.255)	(1.289)	(1.305)	(1.315)	(0.933)	(0.947)	(0.965)	(0.980)
Market minus Risk Free Rate (Mkt-RF)	−0.930***	−0.876**	−0.793**	−0.795**	−0.076	−0.114	−0.272	−0.271
	(0.341)	(0.369)	(0.388)	(0.390)	(0.304)	(0.314)	(0.343)	(0.349)
Small-Minus-Big Factor (SMB)		−0.162	−0.160	−0.163		0.228	0.209	0.217
		(0.585)	(0.586)	(0.590)		(0.409)	(0.408)	(0.418)
High-Minus-Low Factor (HML)		−0.420	−0.208	−0.198		−0.374	−0.598	−0.595
		(0.540)	(0.621)	(0.628)		(0.364)	(0.414)	(0.421)
Momentum Factor (MOM)			0.317	0.316			−0.347	−0.341
			(0.455)	(0.457)			(0.311)	(0.318)
Liquidity Factor (LIQ)				0.044				0.034
				(0.286)				(0.214)
N (Monthly Returns)	102	102	102	102	37	37	37	37
Adjusted *R*-Squared	0.002	0.034	0.080	0.081	0.002	0.034	0.070	0.071

Note: The table reports estimates from various factor models using our repeat sales regression index values for bourbon returns from SWT (37 months from October 2014 to November 2017) and whiskyauction.com data (102 monthly returns from April 2011 to October 2019). We obtain Mkt-RF, SMB, HML and MOM monthly data for the sample period from Ken French's data library (http://mba.tuck.dartmouth.edu/pages/faculty/ken.french/data_library.html). We add monthly liquidity factor returns from Robert Stambaugh's website (http://finance.wharton.upenn.edu/~stambaug/liq_data_1962_2019.txt). Standard errors in parentheses (*** $p < 0.01$, * $p < 0.05$, * $p < 0.1$).

bourbon, we present estimates from various factor models in Table 11. These model specifications include a basic market model, a three-factor Fama–French model (= the market model plus the "small-minus-big" factor, which accounts for the excess return that smaller market capitalization companies return versus larger companies, and the high-minus-low book-to-market factor, referring to the excess returns for high book value-to-market firms, see Fama and French, 1993), a four-factor model including momentum (momentum refers to returns from a strategy of buying past winners and selling past losers, see Carhart, 1997), and a five-factor model including a liquidity factor (which accounts for excess risk and returns for those equities that are less frequently traded than others in the market, see Pástor and Stambaugh, 2003). Accounting for these last two factors is particularly important because we observe significant auto-correlation (−0.31 for auction returns and −0.18 for peer-to-peer returns) in bourbon returns and bourbon markets are less liquid than traditional asset classes. For

the three-factor model, the estimating equation is of the following type:

$$R_{it} - R_{ft} = \alpha_{it} + \beta_1(R_{mt} - R_{ft}) + \beta_2 SMB_t + \beta_3 HML_t + \epsilon_{it}.$$

In the model, R_{it} is the total return of asset i at time t (in our case, i =bourbon), R_{ft} is the risk free rate (as proxied by one-month Treasury Bill returns), $R_{mt} - R_{ft}$ represents the difference between the market portfolio return and the risk free rate at time t, SMB_t is the size premium (returns from small market capitalization firms relative to big firms), HML_t is the value (high minus low) premium, and ϵ_{it} is an independent and identically distributed error term. Relative to the three-factor model, the basic market model eliminates SMB_t and HML_t, whereas four and five factor models add measures of momentum and liquidity, respectively.

The estimates in Table 11 show that bourbon returns exhibit negative sensitivity to the market factor, particularly in our bourbon auction data. Bourbon returns appear to have the highest sensitivity to the momentum factor though the direction reverses when examining returns in the peer-to-peer market data. In each specification, the monthly return estimates (alphas) are economically large (1.72% to 2.35% monthly) and are statistically significant in most specifications at the 10% level or better. We want to specifically note, however, that these estimates should be viewed with caution as the sample size is relatively small (e.g., we have only 37 monthly observations in the case of our peer-to-peer/decentralized data).

Overall, it appears that bourbon returns have low correlation with major asset classes (stocks, bonds, and commodities) and bourbon appears to provide better inflation protection, enhances the risk-adjusted returns of traditional portfolios, and generates economically significant alpha (investment returns) across a variety of factor models. As an asset class, while bourbon may not be sufficiently scalable for the needs of large institutional investors, our findings suggest that bourbon may be an effective alternative investment in modestly sized portfolios.[37]

5. Discussion and conclusion

We document and quantify secondary markets for bourbon whiskey using data on bourbon transactions from whiskyauction.com and a unique social network-based secondary market ("Strong Water Trading"). Using a repeat sales approach, we find price increases of 18% per year in our auction data and 20% or more in our Strong Water Trading data during common sample periods. Complementary hedonic estimates suggest price increases of 13.1% in our auction data and 18.8% in our Strong Water Trading data. While we do not have complete product information, our hedonic estimates also show similar patterns in the returns to whiskey characteristics such as age and indicators for annual release and barrel proof status across our two data sources. Our findings therefore suggest that illicit markets might be able to operate effectively even in the absence of an authority to enforce property rights and contracts. While we would like to further analyze the potential for arbitrage and the applicability of the "law of one price" across our markets, we cannot confidently and systematically match products across our two data sources because of differences in available product information that we discuss in earlier sections. Further, transaction timing, variable shipping costs, issues regarding customs and excise, auction fees, and differences in risk on the two markets make it next to impossible to determine whether varying prices for a single product transacting in the same time period on each market represents an arbitrage opportunity or merely reflects the unique characteristics of each market.

When studying bourbon's investment performance, we find that bourbon returns have low correlation with stocks, bonds, and commodities, provide solid inflation protection, and appear to enhance the risk-adjusted returns of traditional portfolios. Our analysis is limited, however, by a short sample and, in some cases, by unknown and/or unavailable product details.[38] Still, it appears that bourbon may be an effective alternative investment in smaller portfolios. For example, when looking at the entire 2011 to 2019 period, we find annual returns of 9.1%, which compares favorably to long run annual returns on wine, art, stamps, and other collectible items.

Secondary bourbon market participants, however, face unusual risks because they cannot resort to authorities to resolve issues of theft or deception. They also risk getting themselves into legal trouble. On the other hand, the prevalence of online auction sites and peer-to-peer sales groups suggests that law enforcement agencies are not particularly concerned about high-end bourbon sales. Notably, there are movements underway to legalize the sale of vintage and rare bottles. One example is a recent revision to Kentucky's alcoholic beverage statute that allows licensed retailers to purchase rare and vintage distilled spirits from individuals who are unlicensed.[39] Sales facilitated by licensed auction houses (e.g., Sotheby's, Christie's, and so on) will also become more attractive if prices continue to increase. It remains to be seen what effect any such changes will have on the secondary markets we study here.

Note that we provide no specific investment advice. Instead, our goal is to document the recent resurgence in bourbon popularity and how it has led to reselling in previously-unstudied illicit secondary markets that feature large price increases over time. The boom, of course, could easily be the next "Beanie Baby" phenomenon: here today and gone tomorrow. For

[37] Note, however, that Wave Financial Group launched a $25 million Kentucky Whiskey 2020 Digital Fund by tokenizing 2500 barrels of bourbon purchased from Wilderness trail distillery (see https://www.barrons.com/articles/inside-this-fund-managers-bet-on-kentucky-whiskey-as-a-crypto-asset-51610200861).

[38] Some product details are unknown because our data is incomplete and/or the information we have does not allow us to determine the exact product. In other cases, information is missing because it is simply not available at all from the distiller/producer.

[39] See https://www.go-wine.com/wine-article-1047-The-Bourbon-Secondary-Market-Is-Now-Legal-in-Kentucky-Sort-of.html, last accessed 1/5/2021.

example, distillers might increase production enough to clear the market at retail prices and end bourbon shortages, substitutes (rye whiskey, scotch, and so on) may become more attractive options, or regulators could begin to really crack down on secondary market sales. That might be a welcome turn of events to many who bemoan that their favorite bourbon whiskey is missing from their local liquor store's shelves.

Declaration of Competing Interest

Authors declare that they have no conflict of interest.

Appendix A. Additional information

Table A1 provides an example of the data structure required to perform a repeat sales analysis. The table highlights the intuition behind the repeat sales method. In particular, the log price relatives r are the difference between the sale price in

Table A1
Sample of repeat sales data structure.

Product	Price	r	t	$t=1$	$t=2$	$t=3$	$t=4$	$t=5$	$t=6$	$t=7$	$t=8$
A	1	.	1	1	0	0	0	0	0	0	0
B	2	.	1	1	0	0	0	0	0	0	0
A	1.11	.	2	−1	1	0	0	0	0	0	0
B	2.69	.	2	−1	1	0	0	0	0	0	0
A	2.07	0.273	3	0	−1	1	0	0	0	0	0
B	3.67	0.135	3	0	−1	1	0	0	0	0	0
A	2.65	0.108	4	0	0	−1	1	0	0	0	0
B	4.19	0.058	4	0	0	−1	1	0	0	0	0
A	2.72	0.011	5	0	0	0	−1	1	0	0	0
B	4.96	0.073	5	0	0	0	−1	1	0	0	0
A	2.78	0.009	6	0	0	0	0	−1	1	0	0
B	5.22	0.022	6	0	0	0	0	−1	1	0	0
A	2.86	0.014	7	0	0	0	0	0	−1	1	0
B	5.73	0.041	7	0	0	0	0	0	−1	1	0
A	3.62	0.102	8	0	0	0	0	0	0	−1	1
B	6.52	0.056	8	0	0	0	0	0	0	−1	1

Note: Sample data structure required for a repeat sales regression analysis.

Table A2
Investment performance: portfolio returns (Annual).

	Mean returns per annum		Dispersion of annual returns	
	Geometric	Arithmetic	Standard deviation	Sharpe ratio
Nominal Returns				
Bourbon (Auction)	8.21%	17.48%	43.74%	0.40
Bourbon (Peer-to-peer)	18.16%	19.78%	27.51%	0.72
Stocks (SPY)	11.17%	11.95%	12.54%	0.95
Bonds (BND)	3.31%	3.36%	3.28%	1.03
Commodities (DBC)	−8.44%	−7.21%	15.58%	−0.46
Inflation	1.59%	1.59%	1.01%	1.57
60/40 Stocks Bonds	8.24%	8.51%	7.48%	1.14
with 5% Bourbon (Auction)	8.76%	9.01%	7.09%	1.27
50/30/20 Stocks/Bonds/Commodities	5.21%	5.54%	8.22%	0.67
with 5% Bourbon (Auction)	5.16%	5.46%	7.82%	0.70
Real Returns				
Bourbon (Auction) $N = 102$	6.65%	15.89%	43.64%	0.36
Bourbon (Peer-to-peer) $N = 37$	16.95%	18.54%	16.81%	1.10
Stocks (SPY)	9.58%	10.35%	12.49%	0.83
Bonds (BND)	1.71%	1.77%	3.49%	0.51
Commodities (DBC)	−9.99%	−8.80%	15.30%	−0.58
60/40 Stocks Bonds	6.65%	6.92%	8.10%	0.85
with 5% Bourbon (Auction)	7.17%	7.41%	7.04%	1.05
50/30/20 Stocks/Bonds/Commodities	3.62%	3.95%	8.10%	0.49
with 5% Bourbon (Auction)	3.58%	3.87%	7.71%	0.50

Note: The table reports investment performance information using index values of bourbon returns estimated from whiskyauction.com data from 2011 to 2019 and from Strong Water Trading data from 2014 to 2017 using a repeat sales approach. CPI from the Bureau of Labor Statistics. SPY = Standard and Poor's Depository Receipt S&P 500 Exchange Traded Funds Trust, BND = Vanguard Total Bond Market Exchange Traded Funds, DBC = Invesco DB Commodity Index Tracking Fund

Table A3
Correlations among hedonic characteristics.

	Barrel proof indicator	Annual release	Proof	Age (years of maturation)
Panel A - whiskyauction.com Data				
Barrel Proof Indicator	1.0000			
Annual Release	0.2008	1.0000		
Proof	0.8303	0.3286	1.0000	
Age (Years of Maturation)	0.0694	0.3769	0.2302	1.0000
Panel B - Strong Water Trading Data				
Barrel Proof Indicator	1.0000			
Annual Release	0.2706	1.0000		
Proof	0.8091	0.1849	1.0000	
Age (Years of Maturation)	−0.1541	−0.0376	−0.1624	1.0000

Note: The table reports information on the correlations among hedonic characteristics in our whiskyauction.com data from 2011 to 2019 (in Panel A) and from Strong Water Trading data from 2014 to 2017 (Panel B).

time t and $t-1$ for each product (in the table, products A and B). These log price relatives are then regressed on the "time period" variables.

In such a regression, and because the dependent variable is roughly equal to a percentage price change for the various products, the estimated difference, on average, between β_3 and β_4 has to be the best estimate of the difference in the percentage price increase (as captured by the log price relative) between time periods $t = 3$ and $t = 4$ across all products.

We present annual asset returns along with summary information on volatility, distribution characteristics, and risk-adjusted performance in Table A2. There, we see similar patterns as in Table 10 in the main text, where we use monthly returns.

In Table A3, we provide information on the correlation among hedonic characteristics in each of our data sources. There we see that in most cases, bourbon's hedonic characteristics are positively correlated. The long exception is, in our Strong Water Trading data, age (in terms of years of maturation) is mildly negatively correlated with the other characteristics. Additionally, when studying how hedonic characteristics are associated with prices we found that being a barrel proof product was not a strong predictor of higher prices after controlling for other characteristics. Table A3 suggests that the patterns in our hedonic analyses are likely because of collinearity among the various characteristics.

References

Ali, H.H., Nauges, C., 2007. The pricing of experience goods: the example of en primeur wine. Am. J. Agric. Econ. 89 (1), 91–103.
Ambachtsheer, K.P., 1987. Pension fund asset allocation: in defense of a 60/40 equity/debt asset mix. Financ. Anal. J. 43 (5), 14–24.
Ankrim, E.M., Hensel, C.R., 1993. Commodities in asset allocation: a real-asset alternative to real estate? Financ. Anal. J. 49 (3), 20–29.
Ashenfelter, O., Ashmore, D., Lalonde, R., 1995. Bordeaux wine vintage quality and the weather. Chance 8, 7–14.
Auer, B.R., Schuhmacher, F., 2013. Diamonds-a precious new asset? Int. Rev. Financ. Anal. 28, 182–189.
Bailey, M.J., Muth, R.F., Nourse, H.O., 1963. A regression method for real estate price index construction. J. Am. Stat. Assoc. 58 (304), 933–942. doi:10.1080/01621459.1963.10480679.
Baumol, W.J., 1986. Unnatural value: or art investment as floating crap game. Am. Econ. Rev. 76 (2), 10–15.
Beard, T.R., Gant, P.A., Saba, R.P., 1997. Border-crossing sales, tax avoidance, and state tax policies: an application to alcohol. South. Econ. J. 64 (1), 293–306.
Becker, G.S., Murphy, K.M., Grossman, M., 2006. The market for illegal goods: the case of drugs. J. Polit. Econ. 114 (1), 38–60 http://www.jstor.org/stable/10.1086/498918.
Bhaskar, V., Linacre, R., Machin, S., 2019. The economic functioning of online drugs markets. J. Econ. Behav. Organ. 159, 426–441.
Burton, B.J., Jacobsen, J., 1999. Measuring returns on investments in collectibles. J. Econ. Perspect. 13 (4), 193–212.
Burton, B.J., Jacobsen, J., 2001. The rate of return on investment in wine. Econ. Inq. 39 (3), 337–350.
Carhart, M.M., 1997. On persistence in mutual fund performance. J. Finance 52 (1), 57–82.
Dave, D., 2008. Illicit drug use among arrestees, prices and policy. J. Urban Econ. 63 (2), 694–714.
Dimson, E., Rousseau, P.L., Spaenjers, C., 2015. The price of wine. J. Financ. Econ. 118 (2), 431–449.
Dimson, E., Spaenjers, C., 2011. Ex post: the investment performance of collectible stamps. J. Financ. Econ. 100 (2), 443–458.
Dimson, E., Spaenjers, C., 2014. Investing in emotional assets. Financ. Anal. J. 70 (2), 20–25.
Dobrynskaya, V., Kishilova, J., 2018. Lego-the toy of smart investors. Available at SSRN 3291456, https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3291456.
Donohue, J.J., Levitt, S.D., 1998. Guns, violence, and the efficiency of illegal markets. Am. Econ. Rev. 88 (2), 463–467.
Fama, E.F., French, K.R., 1993. Common risk factors in the returns on stocks and bonds. J. Financ. Econ. 33 (1), 3–56.
Faye, B., Le Fur, E., Prat, S., 2015. Dynamics of fine wine and asset prices: evidence from short-and long-run co-movements. Appl. Econ. 47 (29), 3059–3077.
Fryer Jr, R.G., Heaton, P.S., Levitt, S.D., Murphy, K.M., 2013. Measuring crack cocaine and its impact. Econ. Inq. 51 (3), 1651–1681.
Galenianos, M., Gavazza, A., 2017. A structural model of the retail market for illicit drugs. Am. Econ. Rev. 107 (3), 858–896.
Geltner, D.M., 1991. Smoothing in appraisal-based returns. J. Real Estate Finance Econ. 4 (3), 327–345.
Goetzmann, W.N., 1993. Accounting for taste: art and the financial markets over three centuries. Am. Econ. Rev. 83 (5), 1370–1376.
Goetzmann, W.N., 1996. How costly is the fall from fashion? Survivorship bias in the painting market. In: Ginsburgh, V.A., Menger, P.M. (Eds.), Economics of the Arts - Selected Essays. Elsevier, Amsterdam, pp. 71–84.
Graddy, K., Margolis, P.E., 2011. Fiddling with value: violins as an investment? Econ. Inq. 49 (4), 1083–1097.
Haddock, D.D., McChesney, F.S., 1994. Why do firms contrive shortages? The economics of intentional mispricing. Econ. Inq. 32 (4), 562–581.
Jacobi, L., Sovinsky, M., 2016. Marijuana on main street? Estimating demand in markets with limited access. Am. Econ. Rev. 106 (8), 2009–2045.
Kraus, A., Litzenberger, R.H., 1976. Skewness preference and the valuation of risk assets. J. Finance 31 (4), 1085–1100.
Le Fur, E., Outreville, J.-F., 2019. Fine wine returns: a review of the literature. J. Asset Manag. 20 (3), 196–214.
Levitt, S.D., Venkatesh, S.A., 2000. An economic analysis of a drug-selling gang's finances. Q. J. Econ. 115 (3), 755–789.
Mei, J., Moses, M., 2002. Art as an investment and the underperformance of masterpieces. Am. Econ. Rev. 92 (5), 1656–1668.

Moroz, D., Pecchioli, B., 2019. Should you invest in an old bottle of whisky or in a bottle of old whisky? A hedonic analysis of vintage single malt scotch whisky prices. J. Wine Econ. 14, 145–163. doi:10.1017/jwe.2019.13.
Moroz, D., Pecchioli, B., 2021. Do whisky investors read the bible? The effect of expert ratings on the vintage single malt secondary market. J. Wine Econ. 16 (1), 86–101.
Moroz, D., Pecchioli, B., 2021. Transaction price vs. ask price in hedonic regressions: evidence from the vintage scotch whisky market. Appl. Econ. Lett. 28 (2), 129–132.
Nagaraja, C.H., Brown, L.D., Wachter, S.M., 2014. Repeat sales house price index methodology. J. Real Estate Lit. 22 (1), 23–46. http://www.jstor.org/stable/24885063
Oczkowski, E., 2016. Hedonic wine price functions with different prices. Aust. J. Agric. Resour. Econ. 60 (2), 196–211.
Pástor, L., Stambaugh, R.F., 2003. Liquidity risk and expected stock returns. J. Polit. Econ. 111 (3), 642–685.
Pedersen, N., Page, S., He, F., 2014. Asset allocation: risk models for alternative investments. Financ. Anal. J. 70 (3), 34–45.
Prieger, J.E., Kulick, J., 2018. Cigarette taxes and illicit trade in Europe. Econ. Inq. 56 (3), 1706–1723.
Smith, R.T., 1976. The legal and illegal markets for taxed goods: pure theory and an application to state government taxation of distilled spirits. J. Law Econ. 19 (2), 393–429.
Storchmann, K., 2012. Wine economics. J. Wine Econ. 7 (1), 1–33.