

# Bourbon Whiskey: Useful Alternative Investment or just the next Beanie Baby?

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## Abstract

Over the past 10 to 15 years, bourbon whiskey has experienced a remarkable renaissance. Because of this renewed popularity, certain expressions are now exclusively allocated to consumers via lotteries, and bourbon aficionados queue overnight to obtain coveted products. Such non-price allocation mechanisms naturally give rise to “secondary” markets. In this paper, we examine how such secondary markets work, using two unique data sources. We use that data in a repeat sales regression framework to develop a price index for rare and vintage bourbons. Our estimates show that bourbon prices increased by 7% per year between 2011 and 2019 and suggest that bourbon has the potential to be a unique alternative investment opportunity - similar to wine or fine art. Moreover, secondary markets for alcohol sit in a legal gray area and their existence and operation are naturally of interest to economists.

## 1 Introduction

Since 2010, domestic and international consumption of bourbon whiskey has dramatically increased, major distilleries have invested millions of dollars into capacity expansion, and, after several decades of absence, craft whiskey distilleries have reappeared in the American market.<sup>1</sup> The *New York Times* calls this recent resurgence “the bourbon boom.”<sup>2</sup> The boom shows no signs of abating: the American Craft Spirits association reports that there were 1,835 craft distilleries as of August 2018,

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<sup>1</sup>See <https://kybourbon.com/wp-content/uploads/2019/02/KDA-BourbonBoomSheet.2019.pdf>.

<sup>2</sup>See this *New York Times* article - <https://www.nytimes.com/2017/07/11/opinion/will-trump-kill-the-bourbon-boom.html>.

a 15.5% annual increase compared to August 2017.<sup>3</sup> As part of the boom, sales of rare bourbon have become common at major auction houses. For example, 34 bottles of 24-Year-Old Blade and Bow bourbon sold for \$95,550 on December 9, 2016 at Christie's in New York City.<sup>4</sup> At a price of almost \$3,000 per bottle, the role of consumption in this transaction is questionable and bourbon's potential as an "alternative investment" becomes apparent.<sup>5</sup>

Outside of major auction houses, secondary markets for coveted (but somewhat less expensive) bourbons are also thriving, including online auction sites and private groups hosted on major social networks.<sup>6</sup> These secondary markets exist because - despite the "boom" in demand - few distillers, distributors, or retailers have responded by increasing the price of their products in primary markets. The bourbon market is dominated by a group of pre-boom industry 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. Their aversion, however, to increasing shelf prices creates shortages that incentivize hoarding (referred to as "bunkering" among bourbon enthusiasts) and reselling in secondary markets.

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 begin adding water to their product to reduce the alcohol content from 90 proof to 84 proof (45% to 42% alcohol by volume). Essentially, they wanted to stretch their existing stock to be able to put more bottles on store shelves at existing prices rather than raising prices. Note that they could not simply ramp up production; bourbon's aging process ensures the short-run elasticity of supply is highly inelastic. Customers reacted so vehemently against the idea that Maker's Mark had to backtrack on the decision a week later.<sup>7</sup>

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<sup>3</sup>For more, see [https://americancraftspirits.org/wp-content/uploads/2017/02/182203-ACSA-2018-Annual-Report\\_compressed.pdf](https://americancraftspirits.org/wp-content/uploads/2017/02/182203-ACSA-2018-Annual-Report_compressed.pdf), <http://whiskyadvocate.com/why-bourbon-prices-got-higher/>, and <http://www.discus.org/us-bourbon-and-tn-whiskey-drive-export-records-in-2013/>.

<sup>4</sup>See <http://www.christies.com/lotfinder/Lot/one-barrel-of-blade-and-bow-single-6051424-details.aspx>.

<sup>5</sup>The term "alternative investment" tends to be used as a catch-all for assets other than stocks and bonds. Some alternative investments, such as real estate, private equity, and derivatives contracts, are quite similar to traditional financial assets while others are perhaps better-described as "collectibles," such as wine, fine art, sports memorabilia, stamps, antique furniture, cigars, and so on.

<sup>6</sup>See <https://www.marketplace.org/2017/06/14/business/bourbon-market-heats-creating-black-market-demand>.

<sup>7</sup>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](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.

A second example is the annual release of the infamous "Pappy Van Winkle" line from Buffalo Trace (whose parent company is Sazerac). 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 most liquor stores around the United States do not receive any Van Winkle products in a given year. Instead of raising 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 the suggested retail price (MSRP), ranging from \$70 to \$300 depending on the particular bottle.<sup>8</sup> For store owners, Van Winkle bottles are treated as a marketing opportunity. Stores also use raffles, lotteries, or simply long lines (often overnight) 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.

Using limited-release bourbons to generate publicity for a store may be rational for the store owner but their choice of allocation mechanism creates opportunities for gains from trade in secondary markets. That is, even though selling alcohol without a license is illegal, these products are resold in deep and broad secondary markets at market-determined prices. The operation of these markets is especially interesting because their questionable legality ensures that market participants face unusual risk and there is no external enforcement of property rights.

This paper is the first to describe and examine the unique characteristics of such secondary markets for bourbon. We do so by considering two related questions. The first question is whether bourbon ought to be considered as a collectible item or as a viable "alternative investment." If it is a collectible, then secondary markets exist merely to move items from one person to another among those who value the product for non-pecuniary reasons - such buyers want to display, gift, or consume the product. A defining characteristic of such a market would be relatively mild price increases in the secondary market (as in the market for fine art, wine, or baseball cards - excepting a few unique cases). On the other hand, if the secondary market shows persistent large price

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<sup>8</sup>See <http://bourbonr.com/blog/2019-pappy-van-winkle-announced-with-a-warning/>.

increases, bourbon might instead be considered as an alternative investment opportunity.<sup>9</sup> Our second research question examines if illegal secondary markets are “efficient” despite their status and unusual institutional features.

To help us answer these research questions, we first use auction data collected from [whiskyauction.com](http://whiskyauction.com). The site operates as a centralized market where sellers ship bottles to the company (in Germany). They then handle all aspects of the sale including listing the product on their site, operating a first price auction, collecting payment, and packaging and shipping the product to the auction winner. Using that data, we develop a price index for bourbon using a repeat sales regression approach (see Bailey et al., 1963). Our data consists of roughly 11,000 bourbon sales from April 2011 to October 2019. We find that, on average, bourbon prices increased by about 7% per year from 2011 to 2019.<sup>10</sup> The average across the sample period hides the fact that most of the overall price increase occurred between late 2013 and early 2018. In that shorter time window, the annual price increase was closer to 22% per year.

We then use records of over 3,300 bourbon sales from 2014 to 2018 from “Strong Water Trading,” a private social network group that, at its peak, had over 6,000 members. The group operated on norms and trust. For example, new members needed a referral and sellers and buyers had to provide personal references when interacting with those they had not interacted with before. Helpfully, members were required to record sales in a publicly-available spreadsheet.<sup>11</sup> Estimates using Strong Water Trading records suggest that bourbon prices increased 21% per year in the sample period. That is, between 2014 and 2018, our centralized and decentralized markets feature very similar bourbon price increases. Our findings imply that bourbon could be a unique alternative investment opportunity - similar to wine or fine art. Moreover, our findings show that illegal decentralized markets can operate efficiently.

In Section 2 we examine the literature on and methods used to study markets for collectibles and alternative investments. In Section 3, we describe our data and estimation framework. Section 4 contains the paper’s main findings. We conclude in Section 5.

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<sup>9</sup>Particularly 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>

<sup>10</sup>The index value at the end of the sample period is 166.2, suggesting a 7% rate of return on an annual basis.

<sup>11</sup>Note that the group was banned from the social network in mid-2016 because it facilitated illegal liquor sales. However, many sales records are dated long after the group was shut down suggests that a successful replacement quickly emerged. At the time of writing this paper, several similar groups still exist on major social networks.

## 2 Alternative Investments and Collectibles

Burton and Jacobsen (1999) examine the state of the literature on collectibles in a review article for the *Journal of Economic Perspectives*. They explain that, because collectibles have non-pecuniary value, the rate of return on collectibles should be lower than the returns to non-collectible assets with similar risk. Paraphrasing Burton and Jacobsen, if you own a Picasso painting you can hang it on your wall and show it off to your friends. Burton and Jacobsen then examine the rate of return on a variety of collectibles including art, wine, antiques, ceramics, coins, stamps, and books.<sup>12</sup> Each paper they examine makes methodological choices given their data and the state of econometric knowledge at the time of their work. However, none of these papers examine the rate of return on whiskey, in general, and bourbon, in particular.

Burton and Jacobsen note that a key challenge the literature on collectibles has faced is the fact that sales of collectibles 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 specifics including the identity and reputation of a seller (or buyer), difficult-to-observe differences in the item's condition, vintage, provenance, or the presence of a guarantee of authenticity.

Authors have tried to address these barriers to measurement using three primary methods. 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.

A second potential approach is hedonic in nature. It 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, and so on). Ashenfelter et al. (1995) used this kind of hedonic analysis to examine the relationship between the price of young Bordeaux wine and the weather during its growing season.

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<sup>12</sup>Somewhat humorously, their examination of the payoff from holding "Beanie Babies" will forever date their work. As Alan Krueger noted in his *New York Times* column in 2005, "[t]he resale price of Beanie Babies, for instance, 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>.

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 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. Goetzmann (1993) extended that analysis to 1987. The repeat sales approach 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.

Regardless of the approach taken, Burton and Jacobsen 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.” This implies that those who buy and hold collectibles are doing so for non-pecuniary reasons. The immediate implication is that they value ownership of the collectible (at least in addition to being interested in returns on investment). The fact that they buy and hold items that do not achieve the returns of (and are riskier than) traditional financial assets is evidence in favor of such a claim.

In this paper, we propose that if the rate of return is low and the risk is high, bourbon should be considered more like a collectible item, purchased and held mainly for its non-pecuniary benefits. If the rate of return on bourbon is high and the risk is low, then it could be considered an alternative investment. Of course, sale prices, and therefore both risk and return, are dependent upon the unique and evolving institutional details of the secondary market for bourbon. Such markets are, strictly speaking, prohibited by state and federal law in the United States. We therefore also examine the effect of these legal prohibitions on prices and price discovery by comparing rates of return in a centralized “legal” market in Europe and a decentralized U.S.-based market.

### **3 Data and Empirical Framework**

#### **3.1 Data**

Our analysis relies on two complementary data sources. The first involves bourbon sales records from [www.whiskyauction.com](http://www.whiskyauction.com). The whiskyauction.com site is one of several similar auction websites. The data is valuable because the website has a global presence, appears to be legal in its

Table 1: Summary Statistics for *whiskyauction.com* Data

		2011	2012	2013	2014	2015	2016	2017	2018	2019
Sale Price	Mean	\$ 64.60	\$ 96.23	\$ 135.23	\$ 256.29	\$ 265.29	\$ 263.94	\$ 268.72	\$ 262.56	\$ 198.57
	Std. Dev.	(52.81)	(116.36)	(185.67)	(307.77)	(377.79)	(419.57)	(403.02)	(401.33)	(339.30)
	Median	\$ 45.32	\$ 52.95	\$ 64.43	\$ 137.74	\$ 127.00	\$ 112.34	\$ 135.52	\$ 125.15	\$ 91.26
	Minimum	\$ 9.99	\$ 11.29	\$ 6.60	\$ 9.52	\$ 7.51	\$ 7.79	\$ 10.38	\$ 5.68	\$ 5.51
	Maximum	\$ 360.17	\$ 926.83	\$ 1,459.73	\$ 2,438.65	\$ 5,152.18	\$ 5,224.83	\$ 3,562.94	\$ 3,583.03	\$ 5,039.74
Whiskey Age	Mean	8.05	9.80	9.77	11.85	11.13	10.29	10.17	10.40	9.48
	Std. Dev.	(3.77)	(4.71)	(4.54)	(5.42)	(5.40)	(4.66)	(4.59)	(4.46)	(4.39)
	Median	7	8	8	10	10	10	10	10	8
	Minimum	3	4	3	3	3	1	3	3	2
	Maximum	20	23	23	27	27	27	28	27	28
Proof	Mean	88.48	91.21	92.33	95.67	95.53	95.48	94.99	96.20	92.79
	Std. Dev.	(11.27)	(13.48)	(13.58)	(14.85)	(14.54)	(14.75)	(14.23)	(15.11)	(12.79)
	Median	86	86	90	90	90	90	90	90	90
	Minimum	80	80	80	80	74	74	74	80	74
	Maximum	143	144.8	144.8	150	172	142.8	160	172	172
Sales per Product	Mean	4.62	3.25	4.73	6.17	6.62	6.95	8.57	7.35	5.95
	Std. Dev.	(4.00)	(2.72)	(5.19)	(6.74)	(6.98)	(7.13)	(12.96)	(10.19)	(6.60)
	Median	3	2	3	3	4	4	4	3	3
	Minimum	1	1	1	1	1	1	1	1	1
	Maximum	15	9	23	28	32	30	66	51	29
	N	395	289	641	978	1,444	1,755	1,736	1,755	1,887

Source: 2011 to 2019 data from [www.whiskyauction.com](http://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>).

jurisdiction, and provides almost a decade of data on bourbon auction prices. The site operates as a middleman. In particular they only auction items actually in their (temporary) possession.<sup>13</sup> The site operates from a European location 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).<sup>14</sup> One thing to note is that, given the transparent and homogeneous nature of listings on the website, we might expect their prices to be less susceptible to arbitrage opportunities.

<sup>13</sup>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](https://whiskyauction.com/auction/vendor_e.html).

<sup>14</sup>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/app/answers/detail/a\\_id/212/~/requirements-for-importing-alcohol-for-personal-use](https://help.cbp.gov/app/answers/detail/a_id/212/~/requirements-for-importing-alcohol-for-personal-use).

We summarize our [www.whiskyauction.com](http://www.whiskyauction.com) data in Table 1.<sup>15</sup> There, we present information on sale prices, whiskey age, proof (= 2× percent alcohol by volume), and summary information on sales per product. Because our analysis relies on a “repeat sales” regression, we naturally exclude products that appear only once in the data (= 1,960 sales records). Also, in our sample, 2,390 records refer to American Whiskeys, Ryes, Corn Whiskeys, and so on. Because they are not bourbon they are eliminated from the sample.

The summary statistics highlight that average sale prices increase markedly from 2014 onward. The fall in prices in 2019 highlights the importance of using a repeat sales approach to control for differences in sample composition over time. Further emphasizing the need to consider the composition of the sample, notice that the average age 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 bourbons have higher retail prices in primary markets so products auctioned in 2019 may have been less expensive to begin with. For each characteristic we also present the median, minimum, and maximum value in our data. Last, we present summary information on sales per product. For sales per product, the mean refers to the average number of sales per product in a given year, conditional on appearing more than once across the sample period. For example, in 2018, the average bourbon appears 7.35 times. Note that this does not mean the exact same bottle is sold 7+ times in a year. Instead, a product is considered a repeat sale if the record has the same name, proof, age, and state of distillation as an earlier record. Putting this in economic terms, a sale is considered a repeat sale if the products are perfect substitutes. As a concrete 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 not a perfect substitute for the 2016 vintage. The summary statistics highlight that many expressions appear dozens of times per year.

Our repeat sales analysis also takes advantage of data on several thousand transactions from a decentralized secondary market operated by U.S. bourbon aficionados (known as Strong Water Trading - “SWT”) on a major social network from 2014 to early 2018. These transaction records exist because members of the SWT group were “required” to document all sales or trades that occurred.

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<sup>15</sup>We collected the data via “scraping.” The process produced more than 15,000 records, but in a relatively messy text format. We then organized the data using a variety of text analysis tools and regular expressions to extract the necessary hedonic characteristics of each product, including sale prices, age, alcohol content, and so on.



Table 2: Summary Statistics for *Strong Water Trading* Data

		2014	2015	2016	2017	2018
Sale Price	Mean	\$ 307	\$ 385	\$ 521	\$ 460	\$ 900
	SD	(280)	(377)	(504)	(446)	(.)
	Median	\$ 225	\$ 270	\$ 370	\$ 325	\$ 900
	Min	\$ 25	\$ 25	\$ 26	\$ 33	\$ 900
	Max	\$ 2,350	\$ 4,100	\$ 5,000	\$ 2,500	\$ 900
Whiskey Age (at time of bottling)	Mean	14	14	14	13	20
	SD	(4)	(5)	(4)	(5)	(.)
	Median	12	12	12	12	20
	Min	2	2	4	4	20
	Max	28	30	28	27	20
Proof	Mean	106	106	106	105	90
	SD	(17)	(17)	(17)	(15)	(.)
	Median	101	101	100	101	90
	Min	80	80	80	80	90
	Max	145	147	145	144	90
Sales per Product	Mean	11	9	4	2	1
	SD	(12)	(10)	(3)	(2)	(.)
	Median	6	6	3	2	1
	Min	1	1	1	1	1
	Max	50	42	14	8	1
N		1,039	1,436	603	226	1

Source: 2014 to 2018 Strong Water Trading Secondary Market Sales.

Of course, compliance may have been imperfect. Moreover, because the sales are among members of a closed and geographically-concentrated group the data is potentially not representative of the bourbon market as a whole. For these reasons, the findings from this data source might diverge from the [www.whiskyauction.com](http://www.whiskyauction.com) data. On the other hand, the open nature of sales (in these groups, “private” deals are not allowed and are cause for a warning and subsequent expulsion from the group) might allow for efficient price discovery and could work to preclude arbitrage opportunities between secondary markets. The advantage of using two distinct data sources allows us to compare outcomes from a peer-to-peer decentralized, illegal, market with those of a centralized, “legal,” auction house.

Such an analysis, however, requires an apples to apples comparison and highlights the value of our repeat sales regression framework. We describe that framework in detail in the next subsection. For now, note that our analysis must be restricted to bourbons that appear more than once in our

data. Therefore, in Table 2, as in Table 1, we report summary statistics only for bottles that are observed more than once.<sup>16</sup> Further, the data from SWT was well-organized and very detailed but harder to analyze than the whiskyauction.com data. The main problem is that analysis required familiarity with colloquial, group-specific bourbon terms. The auction website data was easier to manipulate using text analysis due to the centralized nature of the site and its standard listing formats. Also, note that we focus on “fifth” size bottles of bourbon (750ml), which excludes 363 observations of bottles of varying sizes (handles, shoulders, and mini bottles) many appearing in that size only once in the data, in any case. One exception to this rule is Blanton’s, which is always sold in 700ml bottles.

When appropriate, we adjust reported sale prices to exclude the cost of shipping (records indicate shipping was included or excluded from the price and the associated cost). In addition, we eliminate all records involving a trade (87 observations). Last, about 1,200 of the SWT records have an associated note that explained the deal was part-trade, or that shipping cost was split between the buyer and seller, 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 the bottle had some kind of celebrity or distiller signature or a quirky packaging error/flaw that made this particular bottle quite different to other similar bottles in the data set. For the estimation sample, whenever these notes indicated that a sale was not comparable to others we eliminate the observation from the sample.

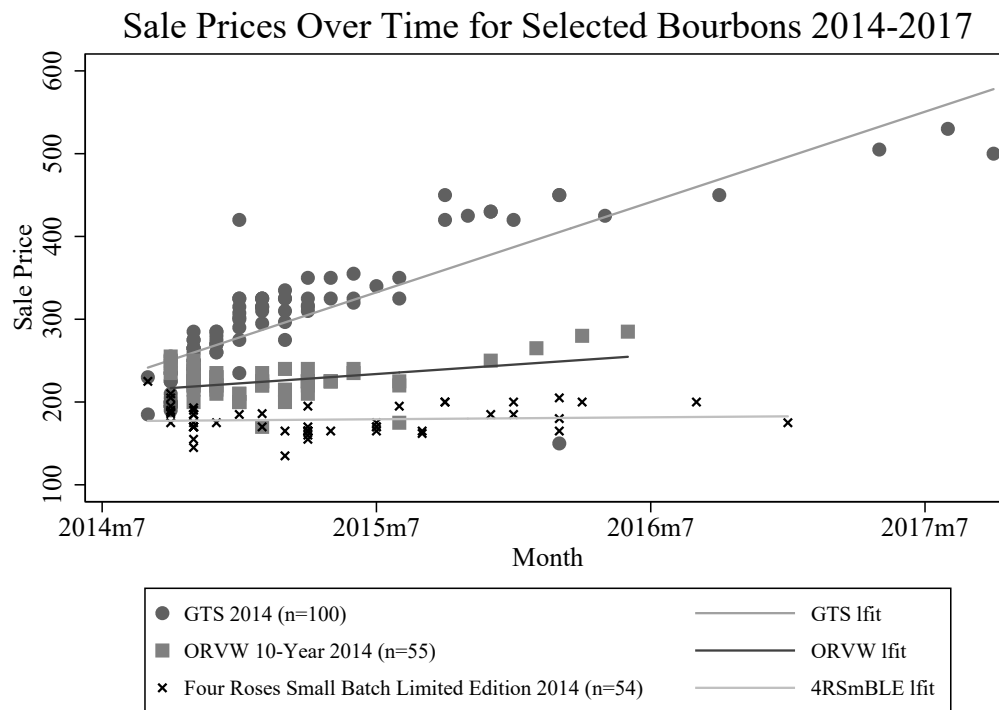
In the summary data, we can see that the Strong Water Trading group featured sales of products that had higher alcohol content and were aged longer prior to bottling (relative to the whiskyauction.com data). As both age and proof tend to be associated positively with price, it is not surprising to see that the average sale price is higher across the 2014 to 2018 period relative to the whiskyauction.com data.

Last, and to provide just a little further context, Figure 1 illustrates how prices have changed over time for three bourbons released in the fall of 2014. These three bourbons are the most frequent in the SWT data. For the three bourbons depicted - George T. Stagg (GTS), Old Rip Van Winkle (ORVW), and Four Roses Small Batch Limited Edition (4RSmBLE) - the retail prices at time of

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<sup>16</sup>The restriction to repeat sales excludes a number of products sold only once in the time period studied. However, these items are typically 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.

Figure 1: Observed Sale Prices Over Time



Data Source: Strong Water Trading Sales Records 2014-2018

release were \$80, \$50, and \$100, respectively. The figure shows that the secondary market quickly established a different price for each bourbon: there is a flurry of activity with lots of observations. Over time, the frequency diminishes. This pattern characterizes all of the annual release bourbons observed repeatedly in the 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 deflect attention from the 2014 releases. Most strikingly, it is clear that returns are variable even for frequently traded products: some bourbons appreciate considerably, some only a little, while others remain at or around their initial secondary market price.

### 3.2 Repeat Sales Methodology

The paper's chief empirical goal is to examine secondary markets for bourbon by using the available data to estimate a price index for bourbon as a product category. To do so, our analysis focuses

on the information contained in product-specific “log-price relatives.” A log-price relative is the difference between the log of consecutive sale prices of the same product, regardless of the time between the sales. Our approach is the same as the repeat sales regression framework Burton and Jacobsen (2001) used to calculate the rate of return on wine and that Baumol (1986), Goetzmann (1993), and Mei and Moses (2002) used to estimate the rate of return on fine art.

The repeat-sales approach is built 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).<sup>17</sup> Specifically, for sales of good  $i$ , prices and indices between  $t$  and  $t'$  are related as follows:

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

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

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

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

$$r = X\beta + \mu. \quad (3)$$

In (3),  $r$  and  $\mu$  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

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<sup>17</sup>The description of the repeat sales methodology provided here borrows some nomenclature and notation from Nagaraja et al. (2014).

observed for any item in the data set. Completing the equation,  $\beta$  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  $\beta_t$  coefficients (from  $t = 0, \dots, T$ ) can then be converted into a price index with a base value equal to 1 by taking the inverse log of each coefficient.

Practically, for any bourbon sold in  $k \leq T$  time periods we calculate  $k - 1$  log price relatives. The log price relative approximates the percent increase in price between two time periods. We regress these log-price relatives on a set of  $T$  “dummy” variables. That is, we create a  $T \times 1$  column vector for each time period  $t \in T$ . 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 earlier sale. Appendix A provides more info on the repeat sales method and Table A1 provides an example of the required data structure.

## 4 Main Findings

### 4.1 Auction Data

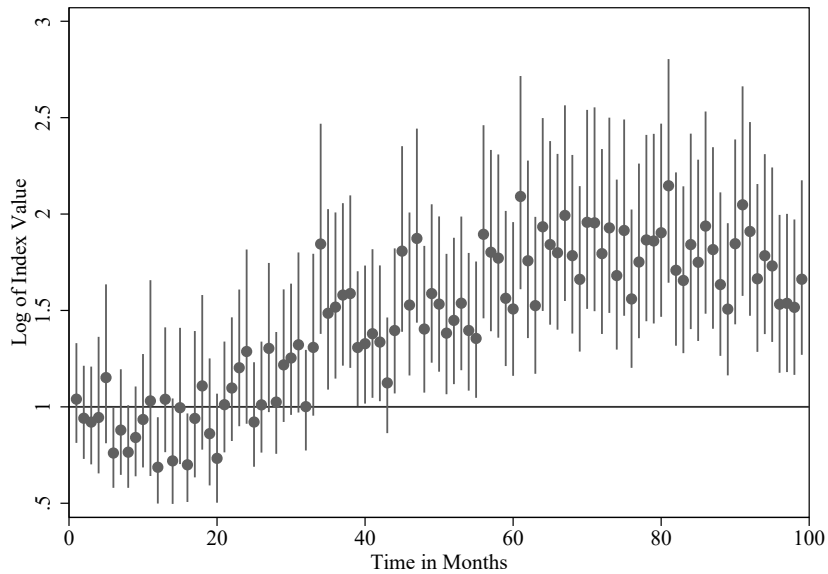
Because we know only the year and month of each sale, we aggregate our [whiskyauction.com](http://whiskyauction.com) data into monthly average sale prices by product. Each bourbon's log-price relative is equal to the difference in the log of average sale price between two months where sales are observed. Our analysis, therefore, involves a total of 6,955 monthly log price relatives. Using the repeat sales regression described in Section 3 we obtain the estimates in Table 3.

Table 3: Bourbon Price Index Based on Repeat Sales Regressions - January 2011 to November 2019

Month	Index Value	Month	Index Value	Month	Index Value
2011m4	1	2014m2	1.845	2017m1	1.993
	-		(0.274)		(0.256)
2011m5	1.040	2014m3	1.485	2017m2	1.784
	(0.131)		(0.235)		(0.234)
2011m6	0.941	2014m4	1.517	2017m3	1.661
	(0.122)		(0.217)		(0.216)
2011m7	0.921	2014m5	1.580	2017m4	1.957
	(0.128)		(0.212)		(0.260)
2011m8	0.945	2014m6	1.588	2017m5	1.955
	(0.177)		(0.225)		(0.266)
2011m9	1.152	2014m7	1.308	2017m6	1.795
	(0.206)		(0.176)		(0.242)
2011m10	0.760	2014m8	1.327	2017m7	1.928
	(0.105)		(0.180)		(0.255)
2011m11	0.879	2014m9	1.379	2017m8	1.681
	(0.137)		(0.194)		(0.222)
2011m12	0.765	2014m10	1.336	2017m9	1.915
	(0.108)		(0.178)		(0.257)
2012m1	0.841	2014m11	1.124	2017m10	1.560
	(0.117)		(0.151)		(0.207)
2012m2	0.935	2014m12	1.396	2017m11	1.751
	(0.148)		(0.190)		(0.228)
2012m3	1.031	2015m1	1.808	2018m1	1.866
	(0.250)		(0.243)		(0.244)
2012m4	0.687	2015m2	1.528	2018m2	1.860
	(0.112)		(0.213)		(0.248)
2012m5	1.039	2015m3	1.874	2018m3	1.903
	(0.163)		(0.254)		(0.253)
2012m6	0.720	2015m4	1.404	2018m4	2.147
	(0.136)		(0.192)		(0.292)
2012m7	0.996	2015m5	1.588	2018m5	1.708
	(0.177)		(0.207)		(0.227)
2012m8	0.700	2015m6	1.533	2018m6	1.655
	(0.115)		(0.203)		(0.218)
2012m9	0.940	2015m7	1.382	2018m7	1.842
	(0.189)		(0.184)		(0.255)
2012m10	1.109	2015m8	1.448	2018m8	1.750
	(0.200)		(0.191)		(0.237)
2012m11	0.861	2015m9	1.538	2018m9	1.938
	(0.164)		(0.201)		(0.264)
2012m12	0.733	2015m10	1.396	2018m10	1.816
	(0.141)		(0.180)		(0.238)
2013m1	1.011	2015m11	1.355	2018m11	1.634
	(0.145)		(0.178)		(0.214)
2013m2	1.098	2016m1	1.895	2018m12	1.507
	(0.161)		(0.253)		(0.199)
2013m3	1.203	2016m2	1.802	2019m1	1.846
	(0.178)		(0.237)		(0.242)
2013m4	1.287	2016m3	1.771	2019m2	2.048
	(0.226)		(0.240)		(0.274)
2013m5	0.921	2016m4	1.563	2019m3	1.910
	(0.136)		(0.203)		(0.253)
2013m6	1.010	2016m5	1.508	2019m4	1.664
	(0.145)		(0.201)		(0.220)
2013m7	1.303	2016m6	2.091	2019m5	1.784
	(0.195)		(0.279)		(0.235)
2013m8	1.025	2016m7	1.758	2019m6	1.731
	(0.159)		(0.232)		(0.228)
2013m9	1.218	2016m8	1.525	2019m7	1.532
	(0.173)		(0.205)		(0.206)
2013m10	1.253	2016m9	1.934	2019m8	1.537
	(0.172)		(0.252)		(0.207)
2013m11	1.322	2016m10	1.842	2019m9	1.516
	(0.208)		(0.240)		(0.203)
2013m12	1.001	2016m11	1.799	2019m10	1.662
	(0.132)		(0.230)		(0.228)
2014m1	1.308				
	(0.211)				
Observations			6,955		

Standard errors in parentheses (\*\*\*)  $p < 0.01$ , \*  $p < 0.05$ , +  $p < 0.1$ . Note: 2015m3 refers to March of 2015, and so on. April 2011 is the base value (=1). Estimates are based on [www.whiskyauction.com](http://www.whiskyauction.com) from early 2011 to late 2019.

Figure 2: Monthly Price Index (whiskyauction.com Data - 2011 to 2019)



Data Source: Strong Water Trading Sales Records 2014-2017

The first column of the table refers to the time period (where “2011m4” refers to April of 2011). We report the inverse log of the regression coefficient associated with that time period. The inverse log approximates an index value. These can be interpreted as a measure of the rate of return on bourbons purchased in early 2011 up to each date. For example, the 2.048 index value in February 2019 suggests a 104.8% return in just under eight years. The index for October 2019, however, is only 1.662, implying about a 7% annual return over the sample period. Given these estimates are based on repeat sales, the secondary market appears to be “cooling” off a little toward the end of the sample. In any case, these price increases are larger than the typical rate of return on wine or art (at least during the sample time period) implied by the analyses of Burton and Jacobsen (2001) and Mei and Moses (2002).

Figure 2 is a plot of the index values over time. 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.

Table 4: Bourbon Index Based on Repeat Sales Regressions - October 2014 to 2017

Month	Index Value	Month	Index Value	Month	Index Value	Month	Index Value	Month	Index Value
2014m10	1								
	-								
2014m11	1.024 (0.0223)	2015m7	1.259*** (0.0483)	2016m3	1.654*** (0.0667)	2016m11	1.622*** (0.0746)	2017m7	1.659*** (0.128)
2014m12	1.081*** (0.0263)	2015m8	1.309*** (0.0477)	2016m4	1.735*** (0.0829)	2016m12	1.618*** (0.0862)	2017m8	2.096*** (0.154)
2015m1	1.130*** (0.0303)	2015m9	1.350*** (0.0483)	2016m5	1.691*** (0.0716)	2017m1	1.737*** (0.0843)	2017m9	2.022*** (0.171)
2015m2	1.149*** (0.0317)	2015m10	1.449*** (0.0528)	2016m6	1.579*** (0.0692)	2017m2	1.910*** (0.0986)	2017m10	1.841*** (0.135)
2015m3	1.194*** (0.0326)	2015m11	1.408*** (0.0559)	2016m7	1.654*** (0.0691)	2017m3	1.946*** (0.115)	2017m11	2.114*** (0.286)
2015m4	1.205*** (0.0348)	2015m12	1.394*** (0.0509)	2016m8	1.840*** (0.0796)	2017m4	1.887*** (0.122)		
2015m5	1.208*** (0.0381)	2016m1	1.445*** (0.0542)	2016m9	1.789*** (0.0901)	2017m5	1.843*** (0.120)		
2015m6	1.341*** (0.0442)	2016m2	1.497*** (0.0550)	2016m10	1.649*** (0.0755)	2017m6	1.999*** (0.150)		
Observations					1,246				

Standard errors in parentheses (\*\* p<0.01, \* p<0.05, . p<0.1). Note: 2014m11 refers to November of 2014, and so on. October 2014 is the base month (index value=1). The estimates presented are based on records from a spreadsheet that was maintained by the members of a social network group that ran a secondary market for bourbon over the time period in the analysis. The data is publicly available.

## 4.2 SWT Data

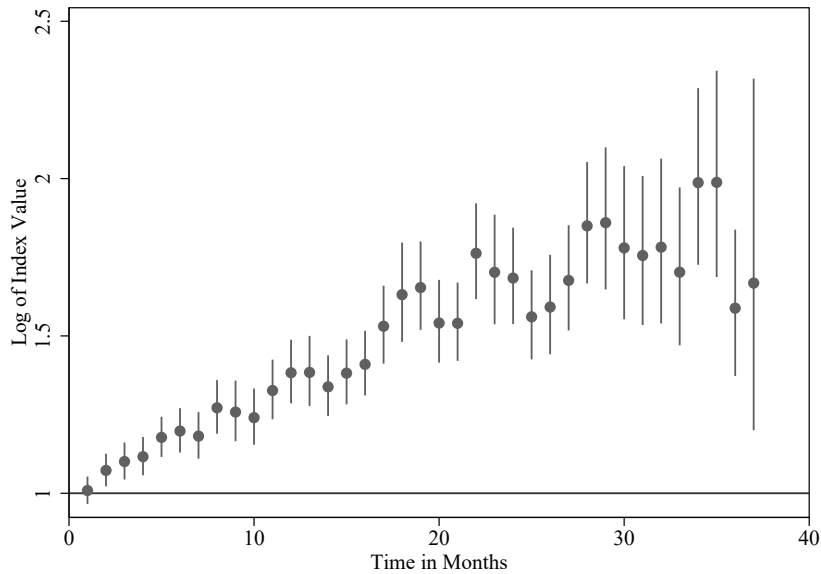
Our second data source is the SWT secondary market for bourbon described in Section 3.<sup>18</sup> The data spans about three and a half years between 2014 and early 2018 and there are several thousand observations. For ease of comparison, we average sale prices for each product *within* a calendar month. Therefore, each bourbon's log-price relative is based on differences in the log of the average sale price between any two months in which sales are observed.

We present our findings using the SWT data in Table 4. The estimates span several columns. The first estimate of 1.024 is the index value in November of 2014. By construction, the October 2014 index value is the base value and is equal to 1. An estimate of 1.024 implies that bourbon prices increased by 2.4% relative to the base month. The index value rapidly increases throughout 2015 and 2016. By November of 2017, the index is 2.114, representing a 111.4% increase in bourbon prices relative to late 2014 (or approximately 21% on an annual basis). Note that between October 2014 and November 2017, the whiskyauction.com index value increased only from 1.336 to 1.751 (implying a 31.1% increase in prices). However, the price changes across the samples are more similar if we

<sup>18</sup>This spreadsheet is publicly available at [https://docs.google.com/spreadsheets/d/1CAh7RLsi750ruEVBubV3Pghf78HcfbOqNhGjLP\\_lc/htmlview](https://docs.google.com/spreadsheets/d/1CAh7RLsi750ruEVBubV3Pghf78HcfbOqNhGjLP_lc/htmlview) as of late 2019.



Figure 3: Monthly Price Index (SWT Data - 2014 to 2017)



Data Source: Strong Water Trading Sales Records 2014-2017

allow a slightly wider timeframe. For example, by April 2018 the whiskyauction.com data index value is 2.147 implying a 114.7% increase in prices relative to December 2013 (approximately 22% on an annual basis).

Figure 3 is a plot of the index values over time. Again, because of the repeat sales regression methodology, where estimates are based only on changes in prices for a given product, the price increases we observe cannot be due only to changes over time in the underlying sample of bourbons used to construct the index.

### 4.3 Hedonic Analysis

In this subsection, we examine the role of hedonic characteristics on bourbon prices. These include years of maturation (“age”), proof, and distiller, along with review scores from [whiskeyadvocate.com](http://whiskeyadvocate.com). We also include indicators for annual release bourbons (these include Pappy Van Winkle products, “BTAC,” and others) and whether or not the bourbon is bottled at “barrel proof.” The summary statistics associated with these two indicators are the share of the sample that they constitute. The SWT generally contains more of these hedonic characteristics so we rely only on that data in this subsection, in this version of the paper. We present the available hedonic characteristics, by year,

Table 5: Summary Hedonic Characteristics for SWT Bourbons by Year

	2014	2015	2016	2017	2018
Price	307.24 (279.88)	384.80 (376.97)	521.12 (503.83)	460.18 (446.37)	900.00 (.)
Years of Maturation (Age)	13.67 (4.33)	13.53 (4.68)	13.62 (4.46)	13.25 (4.51)	20.00 (.)
Proof	106.29 (16.71)	106.27 (16.54)	106.37 (17.11)	104.61 (14.90)	90.40 (.)
Barrel Proof	0.31 (0.46)	0.29 (0.45)	0.30 (0.46)	0.26 (0.44)	0.00 (.)
Annual Release	0.50 (0.50)	0.44 (0.50)	0.50 (0.50)	0.43 (0.50)	1.00 (.)
Review Score (out of 100)	93.19 (3.17)	92.87 (3.29)	92.37 (3.78)	92.10 (4.18)	. (.)
Sales Per Year	5.83 (7.39)	5.24 (6.25)	2.33 (1.88)	1.60 (1.09)	1.00 (.)
Observations	1,039	1,436	603	226	1

Data comes from sales records maintained by the “Strong Water Trading” (SWT) bourbon aficionado social network.

in Table 5. We include sale price (secondary, not retail), age (when available), proof (= 2× the percentage of alcohol in the bottle), an indicator for barrel proof (=1 if no water has been added after maturation), annual release (=1 if the product is only released once per year), review score out of 100, and the number of sales per product per year in the SWT data. Notice that the sample is no longer restricted to products sold more than once and that only one 2018 sale appears in the SWT data. We use these hedonic characteristics to further explore how secondary market prices work. In particular we examine an estimating equation of the following form;

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

In the equation,  $Price_{it}$  refers to the price of product  $i$  at time  $t$ ,  $\alpha$  is a constant,  $X_i$  contains some or all (depending on specification) of the hedonic characteristics of interest laid out in Table 5,  $\gamma_t$  is a year fixed effect, and  $\epsilon$  is an idiosyncratic error term. We present the associated estimates, based upon our SWT data, in Table 6. Specifically, we present six specifications and include year fixed effects in all specifications. The first column presents a parsimonious specification with only these year fixed effects. The coefficients should be viewed as relative to prices in 2014. We see a familiar pattern. Prices in 2015, 2016, and 2017 were significantly higher than 2014. However, compared to

Table 6: Hedonic Price Analysis

	Dep. Var = Price					
	(1)	(2)	(3)	(4)	(5)	(6)
Year=2015	77.56*** (16.93)	76.93*** (17.00)	85.17*** (16.85)	96.42*** (18.63)	99.74*** (18.55)	88.86*** (20.70)
Year=2016	213.88*** (31.64)	213.56*** (31.53)	212.24*** (31.84)	216.07*** (34.65)	213.80*** (34.77)	236.09*** (52.91)
Year=2017	152.94*** (40.77)	151.33*** (40.92)	160.60*** (38.83)	174.01*** (43.02)	208.74*** (39.45)	83.91* (49.63)
Year=2018	592.76*** (23.06)	581.84*** (28.67)	473.29*** (49.22)	495.69*** (52.02)	274.97*** (64.51)	
Barrel Proof Indicator		-35.69 (35.92)	-96.96** (43.11)	-162.25** (68.96)	-124.87** (48.72)	-440.79*** (158.37)
Annual Release Indicator			178.39*** (45.74)	168.33*** (49.36)	139.66*** (47.04)	211.37* (113.10)
Proof				2.36 (1.61)	3.01 (1.82)	4.21** (2.02)
Years of Maturation (Age)					39.61*** (6.71)	3.90 (12.48)
Review Score (out of 100)						3.37 (10.06)
Observations	3305	3305	3305	2838	2521	716

Data comes from sales records maintained by the "Strong Water Trading" bourbon aficionado social network. Standard errors in parentheses (\*\*\*) p<0.01, \* p<0.05, \* p<0.1) and are clustered at the product level.

the repeat sales regression, the effect on price is muted. For instance, the estimates suggest prices in 2017 were only \$152.94 higher than prices in 2014. Given the mean sales price among the full sample was \$390, a \$152 price increase over three years is smaller than that predicted by the repeat sales approach. The type of bottle on the market in 2017, however, was different and is why the repeat sales method is generally viewed as superior to a hedonic price analysis for collectibles or alternative investments. The 2018 estimate is not reliable given there is only one 2018 observation.

We progressively add hedonic characteristics of interest across specifications. We have a total of 3,305 observations. For each of these, we always know if the bottle is barrel proof and/or if it is a limited once-per-year release. For that reason, we include 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 second column and add an indicator for annual release in the third column of estimates. Surprisingly, across specifications barrel proof does not seem to be associated with higher prices. It is worth noting here that most of 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. Emphasizing the importance of annual release bourbons, we find that the indicator for annual release is associated with large and statistically significant positive effects on prices.

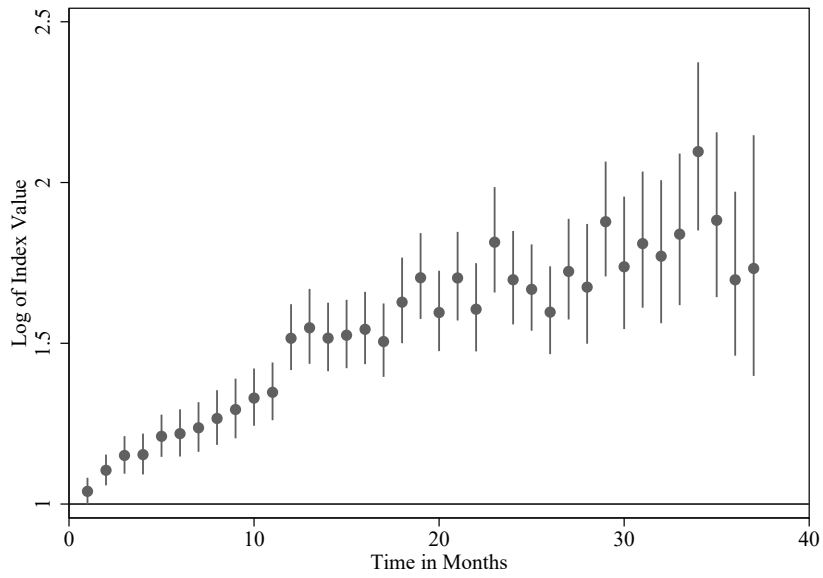
In the fourth column we control for the actual proof of the bottles in question. Bourbon must be bottled at at least 80 proof (40% alcohol by volume). A bourbon's proof is legally required to be printed on the bottle but we could not determine the proof for about 500 of the bottles in the SWT data. In 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, but if it is less than four years, the bottle must indicate the age. For this reason, a bourbon's age is not always available; we therefore lose several hundred further observations. Finally, we include review scores from [whiskeyadvocate.com](http://whiskeyadvocate.com) for as many bourbons as we could. The coefficient associated with age, proof, and review scores are noisy and because data is missing in these categories we are hesitant to draw any confident conclusions.

On the other hand, the estimates from the hedonic analysis strongly suggest that annual release bourbons are contributing to the price increases seen in the repeat sales regressions while being a barrel proof product seems relatively less important. To check on this finding 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. Figure 4 contains plots of the coefficient estimates 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 much more than barrel proof products (note that there is considerable overlap). Specifically, the index values are 1.73 and 1.57 for the final month of the SWT sample when the sample is restricted to annual release and barrel proof products.<sup>19</sup>

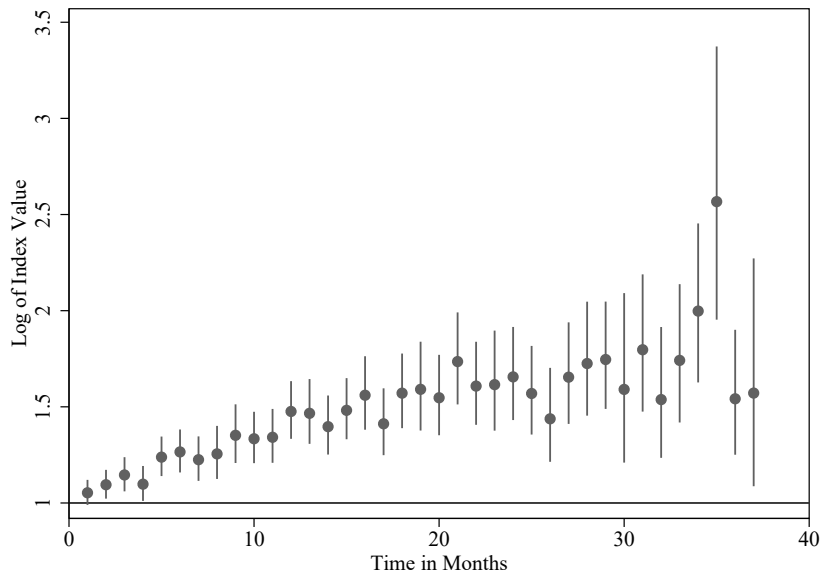
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<sup>19</sup>Full sets of estimates are available from the authors upon request.

Figure 4: Monthly Price Index (SWT Data - 2014 to 2017)



(a) Annual Releases Only



(b) Barrel Proof Products Only

Data Source: Strong Water Trading Sales Records 2014-2017

## 5 Discussion and Conclusion

In this paper, we examine secondary markets for bourbon whiskey. Using two complementary sources of data, our findings suggest that secondary markets are fueled by demand for recently released products rather than unique or vintage collectible items. We then show that significant price increases are occurring across geographically separate and institutionally-different markets, suggesting that these markets work efficiently despite their questionable legal status. For these reasons, bourbon could be a viable alternative investment.

Our estimates imply that anyone who bought a mixture of limited edition bourbons several years ago (and held them) has probably experienced a significant gain in their “portfolio’s” value - but realizing those gains is legally troublesome.<sup>20</sup> There are movements underway, however, to legalize the sale of vintage and rare bottles. One example is a recent revision to Kentucky’s existing alcoholic beverage statute.<sup>21</sup> It remains to be seen what effect these changes will have on the secondary markets we study here.

Future updates will examine the robustness of these estimates to alternative measures of prices (including minimum and median sale prices rather than time-period averages) and will examine a variety of relevant sub-samples (including by location, distillery, and “collection”). Following Mei and Moses (2002), the next version of the paper will also attempt to characterize and estimate the systematic risk of bourbon as an asset over this short time period.

Note that this paper provides absolutely no investment advice. It merely seeks to describe what is happening in the market for bourbon over recent years. The recent bourbon boom could easily be the next “beanie baby” phenomenon: here today and gone tomorrow. Suppliers might increase production enough to clear the market at MSRP, substitutes (rye whiskey, scotch, and so on) may become more attractive options, or regulators could heavily crack down on secondary market sales. That might be a welcome turn of events to many who bemoan that their favorite whiskey is missing from their local liquor store’s shelves.

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<sup>20</sup>Formal and legal auction houses will become more attractive if prices continue along the same trend. Also, those who operate in these markets tend to suggest liquor law enforcement agencies are not concerned about high-end trading among “hobbyists.”

<sup>21</sup>The statute now says that “[a] person holding a license to sell distilled spirits by the drink or by the package at retail may sell vintage distilled spirits purchased from a nonlicensed person upon written notice to the department in accordance with administrative regulations promulgated by the department.” See <https://www.go-wine.com/wine-article-1047-The-Bourbon-Secondary-Market-Is-Now-Legal-in-Kentucky-Sort-of.html>.

## References

- Ashenfelter, O., Ashmore, D., and Lalonde, R. (1995). Bordeaux wine vintage quality and the weather. *Chance*, 8:7–14.
- Bailey, M. J., Muth, R. F., and Nourse, H. O. (1963). A regression method for real estate price index construction. *Journal of the American Statistical Association*, 58(304):933–942.
- Baumol, W. J. (1986). Unnatural value: Or art investment as floating crap game. *The American Economic Review: Papers and Proceedings of the Ninety-Eight Annual Meeting of the American Economic Association*, 76(2):10–15.
- Burton, B. J. and Jacobsen, J. (1999). Measuring returns on investments in collectibles. *Journal of Economic Perspectives*, 13(4):193–212.
- Burton, B. J. and Jacobsen, J. (2001). The rate of return on investment in wine. *Economic Inquiry*, 39(3):337–350.
- Goetzmann, W. N. (1993). Accounting for taste: Art and the financial markets over three centuries. *The American Economic Review*, 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. and Menger, P. M., editors, *Economics of the Arts - Selected Essays*, pages 71–84. Elsevier (Amsterdam).
- Mei, J. and Moses, M. (2002). Art as an investment and the underperformance of masterpieces. *The American Economic Review*, 92(5):1656–1668.
- Nagaraja, C. H., Brown, L. D., and Wachter, S. M. (2014). Repeat sales house price index methodology. *Journal of Real Estate Literature*, 22(1):23–46.

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

The table presents a sample of the data structure required for a repeat sales regression analysis.

## A Appendix A

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 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  $\beta_3$  and  $\beta_4$  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.