The Liquidity Premium in Virtual Financial Markets

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2017-2019

Tilburg University:	**MSc Data Science: Business and Governance**
Date:	**February 2019**
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Words:	**22191**

Abstract

The liquidity premium theory states that financial products with lower liquidity generate higher returns as opposed to financial products with higher liquidity. While this theory is well-founded in real-world traditional financial markets, there are no studies that investigate whether the theory holds when taken into an entirely different context. The thesis at hand attempts to investigate whether the predictions put forth by the liquidity premium theory hold when taken into the context of virtual worlds. More specifically, it will analyze whether a liquidity premium on items within the virtual financial markets of EVE Online can be found. It does so by employing several liquidity measures within Fama and Macbeth (1973) regressions on EVE Online financial market data for the years 2004-2017. Furthermore, it will investigate how the liquidity of items within EVE Online evolves over time. The results show that there is weak evidence in favor of the liquidity premium theory holding when taken into the context of EVE Online. Additionally, liquidity of items seems to covary to a certain extent with the active average player count of EVE Online, as well as with updates done to the game. More research is required to thoroughly substantiate these claims.

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1. Introduction

The literature on asset-pricing and the effect of liquidity thereon started with the seminal work of Amihud and Mendelson (1986). In their paper, they build a theoretical model that suggests the existence of a link between the liquidity of a stock and its respective return in excess of the risk-free interest rate, which is then backed up by empirical evidence. They reach this conclusion by analyzing how the bid-ask spread (a measure of illiquidity) affects the excess returns of stocks. Where excess returns are defined as the differential between the returns of a given stock and the returns of a 90-day T-bill, where the latter is a financial product which is assumed to generate completely risk-free returns. It is argued by Amihud and Mendelson (1986) that the higher the bid-ask spread of a stock is, the higher its respective excess return will be. Amihud and Mendelson (1989) provide further substantiation in favor of this idea by employing a different dataset and reaching the same conclusions. However, the existence of a liquidity premium is not merely inherent to the stock market. Empirical evidence shows that the treasury bond market displays similar patterns with respect to the relationship between liquidity and yields (see e.g., Amihud & Mendelson, 1991; Longstaff, 2002). Likewise, the same effect can be seen within the options market (Brenner, Eldor & Hauser, 2001), corporate bond market (Bao, Pan & Wang, 2010) and commodity futures market (Chan, Chong & Tsui, 2017).

When looking at past studies into the domain of the liquidity premium it seems that all financial markets display a similar pattern: the liquidity of a financial product likely is a driving force behind its respective excess return. However, while extensive literature has studied this link within traditional financial markets, very little research has yet been done into this effect within non-traditional financial markets. One paper by Wei (2018) investigates the relationship between liquidity and returns within the cryptocurrency market, an emerging and relatively new non-traditional financial market. This type of research, however, seems to be a rare occurrence within the literature. Considering the lack of understanding as to how traditional financial markets behave compared to non-traditional financial markets, this thesis poses to investigate whether theoretical and empirical findings from the former can be extrapolated to the latter. Specifically, this thesis will investigate whether a liquidity premium exists within financial markets residing in virtual worlds, focusing on the game EVE Online.

EVE Online is a so-called Massively Multiplayer Online Role-Playing Game, developed by CCP Games. In many ways the financial markets of EVE Online resemble those of traditional financial markets. Actors within the economy of EVE Online (players of the game) are mostly free to decide on what they spend their ISK (in-game currency). Players within the economy are able to trade in-game items directly with other players, non-playable characters, or can do so within a fully functioning in-game financial market system, which has many of the features that are available in traditional financial markets. Players within the EVE Online Marketplace are able to buy and sell their belongings at market value, or they can create limit-orders to buy or sell their items at a prespecified bid or ask price, respectively. Some of the more advanced features that traditional financial markets offer, such as creating a stop-loss order, are not available within the EVE Online Marketplace. Moreover, it must be noted that the fees charged on selling and buying financial products within traditional financial markets differ significantly from those charged within the EVE Online Marketplace. According to the FCA (2016) the average brokerage fee within the United Kingdom lies at around 1% of a transaction, depending on which financial product is being purchased. However, the minimum EVE Online fee possible when buying items lies between 2-3%. These rates are even higher when players are selling items instead of buying them, which can add anywhere between 1-2% in additional fees to a transaction. Consequently, while financial markets in the traditional sense are closely related to those within EVE Online, they do show dissimilarities. However, while it is apparent that the financial markets within EVE Online do not truly reflect those residing in the real world, the availability of a vast amount of financial market data within EVE Online as opposed to other MMORPGs make it suitable for the analysis performed within this thesis.

While research in virtual economies has mainly emerged since the papers of Castranova (2001) and Castranova (2002), no paper in this domain has yet investigated phenomena that are currently specifically attributable to traditional financial markets. Research does show that it is possible to gain a competitive advantage in amassing wealth within virtual financial markets by creating intelligent trading agents (Anagnostopoulus, Georgiopoulos, Sukthankar & Reeder, 2008). This is, however, a different avenue of research into virtual financial markets than the one posed by this thesis. Furthermore, it is argued by Castranova, Knowles and Ross (2014) that the intersection between real-world economics and virtual world economics is fading, which in their eyes would inevitably cause issues to arise. This argument mostly pertains to the phenomenon within virtual worlds that goes by the name of "real-money trade", in which players of a game sell their virtual assets or cash for real-world assets or cash. The estimated value of the real-money trade of virtual assets or cash was roughly $1.8 billion in 2007 (Heeks, 2009), and has been expected to grow ever since. Considering the sheer size of real-world transactions occurring via virtual worlds, Castranova, Knowles and Ross (2014) argue that this raises real-world policy questions regarding taxation, economic regulation and managing the well-being of citizens of virtual worlds. Hence, in order to make sound policy decisions regarding virtual worlds, it is of importance to understand to what extent virtual financial markets deviate from those residing in the real world.

The current thesis poses to investigate a novel concept in the finance literature. More specifically, it will employ a Fama and Macbeth (1973) regression on data from EVE Online in order to capture the liquidity premium associated with items found on the virtual financial of EVE Online. The problem statement for this thesis hence is: **to what extent does the liquidity premium theory hold when taken into the context of virtual financial markets?** The following research questions will be explored within this thesis:

1. **Is there evidence of a liquidity premium on items within EVE Online?**
As mentioned previously, this thesis will employ the Fama and Macbeth (1973) regression in order to answer this research question. This type of regression is a commonly applied in the literature on the liquidity premium. Various liquidity measures will be employed in order to eliminate any statistical noise that could arise from using merely one measure. Additionally, control variables will be introduced to the regression which are known to be drivers of excess return in past studies.

2. **How does the liquidity of items within EVE Online behave over time?**
Since Ben-Rephael, Kadan and Wohl (2015) it is known that the liquidity premium shows diminishing returns over time within traditional financial markets. If virtual financial markets seem to exhibit similar patterns, it could provide for additional evidence with respect to the idea that the intersection between traditional and virtual financial markets is fading.

The thesis is structured as follows. Chapter 2 will summarize past studies in the domain of the liquidity premium theory within traditional financial markets and non-traditional financial markets, explore virtual economies and summarize the literature on the Fama and Macbeth (1973) methodology. Chapter 3 will describe the methodology that was used to perform the analysis. Chapter 4 will detail and discuss the outcomes of the analysis. Chapter 5 will discuss the answers to both research questions, discuss their implications, describe limitations of the analysis and give pointers for future research. Chapter 6 will conclude.

2. Literature Review

This chapter will provide background research for the thesis. The predominant focus in this chapter will lie on the empirical research done into the liquidity premium theory, as this is closely related to the subject matter at hand. The effect of several liquidity measures on a wide range of financial products will be examined, in order to demonstrate how liquidity affects practically any financial product within real-world traditional financial markets. It should therefore give rise to the idea that the liquidity premium theory might possibly be extrapolated to virtual financial markets as well. On the contrarian perspective, research in the cryptocurrency market, a prominent example of a non-traditional financial market, will be discussed. The aforementioned will demonstrate how liquidity might not affect returns in all financial products. This chapter furthermore serves as an introduction to the liquidity measures employed within this thesis. Additionally, virtual economies and the Fama and Macbeth (1973) regression will be discussed insofar it is relevant to the topic of this thesis. Section 2.1 will discuss the liquidity premium in equity markets. Section 2.2 will discuss the liquidity premium in non-equity markets. Section 2.3 will discuss the liquidity premium in the non-traditional financial market of cryptocurrencies. Section 2.4 will briefly summarize the literature on virtual economies. Section 2.5 will discuss the Fama and Macbeth (1973) regression employed within this thesis.

2.1 Liquidity Premium in Equity Markets

This section of the thesis will discuss the research conducted on the liquidity premium in equity markets. Equity markets consist predominantly of stocks, which represent partial ownership in a company when bought. Hence, investors who buy stocks of a company have the potential to realize future monetary gain based on future performance of the respective company. While equity markets consist of a vast universe of dissimilar equities, the focus in this section of the thesis will lie exclusively on studies that have analyzed public stocks. Moreover, only public stocks that are traded on traditional financial markets will be taken into account.

The liquidity premium theory within these equity markets states that the lower the liquidity of a given equity product, which in this case refers to publicly traded stocks, the higher its respective returns excess of the risk-free interest rate will be. Liquidity herein is an ambiguous term used to more or less describe how easily equities can be traded from one person to another. Since there is no one way to truly measure the liquidity of an equity product with perfect accuracy, studies into this domain have used a vast array of different liquidity measures in order to try and effectively capture the true underlying liquidity of an equity product.

The idea that stocks with lower liquidity generate higher returns as opposed to stocks that have higher liquidity is said to be the result of an increased risk investors will have to bear when they are holding illiquid stocks. Risk in this case comes from the fact that investors are not easily able to buy or sell their stocks, which in times of an economic downturn can be of great importance. Therefore, investors will have to pay a premium for liquidity or, conversely, get a discount for illiquidity when acquiring stocks. Various measures of liquidity employed in past studies will be discussed below insofar they are relevant to the research questions of this thesis. Moreover, the liquidity premium theory will be examined within US and non-US equity markets, in order to show the generalizability of the liquidity premium theory across various equity markets. For the financially inclined reader, studies into other measures of liquidity within stocks can be found in the appendix. Additionally, marketwide liquidity (liquidity risk) is elaborated on in the appendix as well.

2.1.1 Bid-Ask Spread as a Measure of Liquidity

The literature on the liquidity premium theory within equity markets mainly stems from Amihud and Mendelson (1986), who have single-handedly shaped the direction of subsequent research into the topic. Their paper starts with a theoretical model in which all stocks have bid-ask spreads that reflect their respective liquidity. The bid-ask spread herein is a term used to define the differential between the highest buy (bid) offer and the lowest sell (ask) offer. Investors in their model have time-varying portfolio holding periods. The goal of investors in this model is to maximize the expected returns that they will receive over their holding period. In the model equilibrium, investors who have longer expected holding periods will invest more in assets that have higher bid-ask spreads. Amihud and Mendelson (1986) theorize this to be the result of these investors not needing to substitute assets within their portfolios as often as opposed to investors who have shorted expected holding periods. This phenomenon is referred to as the "clientele effect". As a result of the clientele effect it can then be derived that the return of an asset is an increasing and concave function of the bid-ask spread. The relationship between the return of an asset and its respective bid-ask spread is empirically being investigated in Amihud and Mendelson (1986) as well. The predictions put forth by their theoretical model are investigated using data from New York Stock Exchange (NYSE) and American Stock Exchange (AMEX) stocks, for the years 1960-1980. Every year stocks are sorted on their bid-ask spread from the year prior, after which they are grouped into 49 different liquidity-sorted portfolios used for estimation. The model used for estimation of the liquidity premium is a GLS regression. It regresses the portfolios' monthly excess returns on the covariance between the portfolios' monthly excess returns and the monthly returns of the market as a whole (referred to as the "portfolio beta" within the literature), as well as the bid-ask spreads from the year prior. The result of this regression supports the prediction that the return of an asset is an increasing and concave function of the bid-ask spread. In addition to the results of this regression they argue that firm size reflects an aspect of liquidity. That is, the bid-ask spread on companies with a higher market capitalization is smaller, indicating heightened liquidity for these companies. They test this hypothesis by introducing this "size effect" into the equation. When both size and the bid-ask spread are introduced in the equation, the size effect becomes insignificant. This indicates that the bid-ask spread can be used as a crude measure for size, and that it does have a significant effect on returns.

Amihud and Mendelson (1989) provide further substantiation for the idea that a link between the bid-ask spread and stock returns exists. They add to the Amihud and Mendelson (1986) model by accounting for volatility within individual stocks. More specifically, they include the idiosyncratic risk (stock-specific risk, measured by the standard deviation of returns) to the regression, on top of the portfolio beta. Additionally, they employ a different dataset, namely stocks trading on the Nasdaq stock exchange. Considering the fact that the results were similar to those of Amihud and Mendelson (1986), this study provided further evidence for the existence of a link between liquidity and returns. With similar methodology, Eleswarapu and Reinganum (1993) analyze an additional phenomenon found in the data, which is the seasonality of the liquidity premium. In their study they analyze whether the liquidity premium differs significantly between January and non-January months. Within the asset-pricing literature there is a visible difference in returns of small-firm stocks compared to the rest of the market in January alone (Keim, 1983). Consequently, Eleswarapu and Reinganum (1993) find that the liquidity effect is only present with statistical significance in the month of January, but not in non-January months. Their method of deriving results differs only slightly to those of Amihud and Mendelson (1986), as they merely employ the cross-sectional regression withholding the time-series estimation. Moreover, they make use of a bigger time window to do their estimation, using NYSE stock data for the years 1961-1990.

2.1.2 Trading Volume as a Measure for Liquidity

Another measure of liquidity is employed by Brennan, Chordia and Subrahmanyam (1998), who use the natural logarithm of the dollar volume of trading in a stock as a proxy for liquidity. This measure is much easier to obtain than the liquidity measure used above, allowing for an expanded time range in which the study is conducted. The study entails analyzing stock data stemming from the NYSE, AMEX and Nasdaq, for the years 1966-1995. Subsequently, a Fama and Macbeth (1973) regression is conducted, regressing this new measure of liquidity and several control variables on excess returns. These control variables include all three Fama and French (1993) variables (market beta of the stock returns, size of the firm as measured by the market capitalization and the book-to-market ratio of the firm), the momentum effect (Jegadeesh & Titman, 1993) as well as the dividend yield of a stock. These specific controls are commonly applied in the asset-pricing literature, as they are already proven to covary significantly with excess returns of stocks. Brennan, Chordia and Subrahmanyam (1998) show that a one standard deviation increase in the natural logarithm of the dollar volume of trading in a security decreases excess return by 0.11% per month for NYSE and AMEX stocks and by 0.29% per month for Nasdaq stocks, and vice versa.

2.1.3 ILLIQ as a Measure of Liquidity

In the seminal work of Amihud (2002), a novel way of measuring liquidity was introduced, denoted as ILLIQ. It is the daily ratio of absolute stock return to its dollar volume, averaged over a period of time:

$$ILLIQ_{it} = \frac{1}{D_{it}} \sum_{t=1}^{D_{it}} \frac{|R_{itd}|}{VOLD_{itd}}$$

where D_{it} is the number of available trading days for stock *i* in year *t*, $|R_{itd}|$ is the absolute return of stock *i* on day *d* of year *t*, $VOLD_{itd}$ is the trading volume in dollars for stock *i* on day *d* of year *t*. It is similar to a liquidity measure derived in past literature, Kyle (1985) λ. While both measures roughly measure the market impact of a transaction, ILLIQ is much easier to compute. This statement of similarity is further supported within the paper, by means of a cross-sectional regression where ILLIQ is regressed on λ for the year 1984. The results from this regression show a positive and highly statistically significant relationship between ILLIQ and λ, indicating that these measures are closely related. The effect of illiquidity on excess returns is then examined using this novel measure on NYSE stocks for the years 1963-1997. Subsequently, a Fama and Macbeth (1973) regression is employed which regresses excess returns on the mean-adjusted ILLIQ measure, including several control variables. The results conclusively show that the mean-adjusted ILLIQ measure has a positive and statistically significant relationship with excess returns. Moreover, no evidence is found for the existence of a difference between January and non-January months, which suggests that there are no seasonality effects present in the data. Several robustness tests are conducted as well, including tests to examine whether size-sorted portfolios or including bond yield premiums to the regressions would skew the outcome of the aforementioned findings; no evidence is found to suggest that the liquidity premium does not exist.

2.1.4 Liquidity Premium in non-US equity markets

Bekaert, Harvey and Lundblad (2007) employ a simple yet novel proxy of illiquidity, namely the incidence of observed zero-return days. While it is difficult to say whether zero-return days measures liquidity accurately, it is by far the most easily measurable characteristic of a stock. This measure of illiquidity shows high correlation with other measures of illiquidity such as the bid-ask spread, turnover and ILLIQ. The dynamics between liquidity and excess returns is then examined using various vector autoregressions on data from 18 emerging countries, for the years 1987-2003. The results show that zero-return days is indeed a correct proxy for illiquidity and that it significantly predicts excess returns of stocks. Furthermore, the study provides evidence for the fact that the liquidity premium theory holds when taken into the context of non-US equity markets as well. It consequently builds on the idea that the liquidity premium theory holds across a variety of financial markets, whether those may reside in either the real world or in virtual worlds.

Another study that looks at non-US equity markets is that of Amihud, Hameed, Kang and Zhang (2015). They employ data from 45 different countries, of which 26 are developed countries and 19 are emerging, for the years 1990-2011. Measuring liquidity is done with use of the ILLIQ measure as per Amihud (2002). Liquidity-sorted portfolios are constructed by means of creating a single "illiquid-minus-liquid" (IML) portfolio for each country, which is the top quintile of illiquid stock returns minus the bottom quintile of liquid stock returns. Subsequently, the excess returns of the IML portfolios for each country are obtained as the intercept from a regression of the IML returns on the Fama and French (1993) variables. These variables are obtained globally as well as regionally in order to correct for country-specific variance. The results show that the mean excess return of the aggregate all-country IML portfolio is 0.80% per month. Moreover, it seems that the liquidity premium is larger in emerging markets with the mean excess return being 1.11% while the mean excess return in developed markets is 0.58%. All results are highly statistically significant. Additionally, it is shown that in 84.4% of the countries the intercept of the aforementioned regression shows a positive sign. This, in turn, is significantly different from the chance result of 50%, giving additional substantiation to the claim that the liquidity premium theory holds when taken into the context of non-US financial markets. Robustness checks are conducted by first weighting the IML portfolios by their respective prior-month returns, value or volume. When conducting the same analysis but employing these different weightings, the statistical significance becomes lower but still remains within acceptable levels.

2.1.5 Liquidity Premium Disproven

Recent work by Huo, Xue and Zhang (2017) shows how a liquidity premium within the equity market may actually not be present when employing more strenuous conditions for statistical significance. They analyze whether 447 separate variables covary significantly with excess returns or not, of which 102 are liquidity related and have partially been discussed above. This is done by constructing a univariate winners-minus-losers portfolio for each distinct variable, subsequently testing whether the mean monthly excess return of the constructed portfolio is statistically different from zero over the analyzed time period. Data is being employed for the years 1967-2014. While the methodology so far sounds similar to the methodologies discussed above, there are some distinct differences.

Firstly, many statistically significant relationships that are meant to generate excess return become insignificant once the portfolios become value-weighted. That is, once stocks that have a greater market capitalization get assigned higher weights within an analysis than stocks with lesser market capitalization, statistical significance for many variables disappears. Huo, Xue and Zhang (2017) attribute this to the fact that smaller firms generally tend to outperform bigger firms. Consequently, assigning equal-weights to stocks irrespective of their market capitalization tends to includes this effect in an analysis.

Secondly, they only take into account stocks from the NYSE and not those of the Nasdaq or Amex. The reasoning behind this choice is that for Amex and Nasdaq stocks, up to 60% of the total stocks are stocks with an unusually low market capitalization. It is argued that including these stocks into an analysis, especially in combination with the aforementioned equal-weighting, can greatly affect the outcomes of a study.

Lastly, a much higher t-statistic is used as the cut-off point for statistical significance. While the 5% ($t > 1.96$) level is widely regarded as a statistically sound cut-off point, they deem it fit to employ a more rigorous cut-off point at $t > 3$. The reasoning behind this is deduced directly from Harvey, Liu and Zhu (2016) and will not be elaborated on further as it is outside the scope of this thesis to do so.

Using the aforementioned approach only 67 out of the original 447 variables seem to yield statistically significant excess returns different from zero. Moreover, of the 102 liquidity measures that are included in the study, only 2 variables seem to survive the more rigorous testing procedure. Compared to the other categories of variables, liquidity is among one of the worst performers. Hence, looking at the outcomes of this study, the effect of liquidity on excess returns might be overstated in past studies.

2.2 Liquidity Premium in non-Equity Markets

This section of the paper will discuss the various studies conducted on the liquidity premium in non-equity markets, in order to show how these markets exhibit patterns in congruence with the liquidity premium theory as well. The non-equity markets discussed in this section of the thesis include the government bonds market as well as the commodity futures market. Other non-equity markets are elaborated on in the appendix. It must be noted here that fixed-income (e.g. bonds) markets and equity markets behave in different ways because of their inherently contrasting nature. As the name suggests, investors within fixed-income markets can expect to get a fixed cash-flow (referred to as a coupon) that is predefined at the issuance of the asset. Furthermore, at the end of a bond's lifespan (referred to as the maturity), the initial monetary value for which it was issued is paid back in full. This is inherently different from investing in equities, where investors become partial owners of the company whenever they buy equity shares. Their income thus depends on the performance of the company rather than on a prespecified amount. Moreover, a government cannot issue equity shares but it can issue bonds. In general, fixed-income markets are less risky than equity markets, but take note of the fact that this heavily depends on the company or government at hand.

Futures contracts are another type of non-equity financial product. They are legal obligations to buy or sell an underlying commodity or asset at a predetermined and prespecified price and time in the future. A futures contract is the financial product through which commodities and assets can be bought on financial markets, without having to buy the actual commodity or asset immediately. The main benefit of using futures contracts lies in the fact that the price and time for the underlying are fixed at a point in time in the future. This means that a company who produces items now can already know in advance what price he will receive in any number of years from now, as long as a futures contract for that price and date is available. Hence, futures contracts are mostly used in companies that want to decrease their exposure to price volatility, which is more commonly referred to as hedging. Furthermore, futures contracts can be used for speculative purposes, where market participants make bets on price movements of the underlying asset or commodity by either buying or selling futures contracts. It must be noted here that using futures contracts for either hedging or speculative purposes can be very costly, as opposed to buying or selling stocks or bonds.

Consequently, in the case that both bonds and futures contracts exhibit patterns in congruence with the liquidity premium theory, it could provide for additional substantiation in favor of the idea that the liquidity premium theory might also hold when taken into the context of the virtual financial markets of EVE Online. Additionally, in order to further support the idea that the liquidity premium theory is generalizable across countries as well, a selection of research will be presented that showcases how the liquidity premium theory holds when taken into a variety of different contexts.

2.2.1 Government Bonds

After the inception of the liquidity premium theory by Amihud and Mendelson (1986, 1989) in the equity markets, it seems trivial to assume that not only equity markets exhibit signs of a liquidity premium. Hence, Amihud and Mendelson (1991) examine whether the liquidity premium theory holds when taken into the context of the government bonds market. More specifically, their investigation concerns the US treasury bond market. Taking into account that US treasuries are usually deemed as a risk-free asset, it allows for a direct analysis between the yield (return) of a bond and liquidity. This is noteworthy since studies into equity markets usually correct for risk, and therefore analyze the effect of liquidity on excess returns instead of regular returns. Subsequently, they compare the difference in yields between treasury notes and bills with an identical time to maturity. When both these instruments have less than six months to maturity, they behave exactly the same with respect to their payoffs. They are still distinct in the sense that they have different procedures for yield calculation, quotations and trading. Moreover, treasury bills are more liquid than notes. This is the case because treasury notes are usually locked away in investor's portfolios immediately after they are bought, which entails that they are not available for trade anymore. At the time the research was conducted, brokerage fees for notes were around 300-600% higher than those of treasury bills and the typical bid-ask spread on notes was 400% larger as opposed to bills. Because bills are substantially more liquid than notes, Amihud and Mendelson (1991) argue that notes should have higher yields because of their relative illiquidity. This hypothesis is tested by analyzing a sample of 37 trading days between April and November in the year 1987. Consequently, they find that the yield differential between notes and bills is statistically significant, with notes achieving a higher annual yield as well as having a greater bid-ask spread. Hence, this indicates that there does indeed exist a liquidity premium for US treasury bonds and notes.

In a more recent paper by Beber, Brandt and Kavajecz (2008), the effects of liquidity on yields is analyzed for non-US government bonds. More specifically, their study investigates the impact of liquidity on government bonds from countries within the EU. The data spans from April 2003 to December 2004. Furthermore, their methodology is different from Amihud and Mendelson (1991) as it concerns a different type of bond. Contrary to US treasury bonds, some countries within the EU are assumed to have a risk of defaulting (at the time of writing the most prominent example here would be Greece), which should be taken into account when analyzing the effect of liquidity on these bond yields. As has been done previously in equity markets, in order to factor in the risk associated with defaulting, an excess yield measure needs to be constructed. The researchers solve this problem by using yield data for different times of maturity, extracted from Euro-swap rates, which they subsequently employ as their measure of the risk-free interest rate. In addition to these Euro-swap rates being risk-free and being less prone to irregularities than other benchmarks, they provide quotes for several maturities, something that is especially useful when dealing with government bonds. The excess yield is then constructed as the differential between the yield of a specific government bond and the maturity-matched Euro-swap rate. In order to estimate the liquidity of a bond, they employ four different liquidity measures; effective bid-ask spread, average quoted depth, cumulative limit-order book depth and a liquidity index as performed by Bollen and Whaley (1998). Consequently, using various regressions and robustness checks, they conclude that liquidity significantly affects excess yields on governmental bonds inversely, something that is in line with the predictions put forth by the liquidity premium theory. Moreover, there is a dampening effect visible in the strength of the relationship as the maturity of a bond increases.

2.2.2 Commodity Futures Market

Chang, Chong and Tsui (2017) investigate how liquidity affects commodity futures. They do so by analyzing pricing data for futures contracts, as well as interest rate data for the years 1986-2013. In total, 26 commodities are analyzed from four distinct sectors: energy, metals, agriculture and livestock. These particular four sectors were chosen since futures contracts for the commodities stemming from these sectors are widely traded on major exchanges. Subsequently, they sort the analyzed futures contracts in quintiles based on their respective ILLIQ measures. Using these quintiles, they create monthly IML portfolios as per Amihud, Hameed, Kang and Zhang (2015). Consequently, the constructed IML portfolios are shown to generate 0.6% in excess returns, with high statistical significance and lower volatility then the market portfolio. Moreover, correlation between the liquidity measure and other control variables employed in the study is found to be statistically insignificant, indicating that liquidity might be a sole cause of generating excess returns.

2.3 Liquidity Premium in Non-Traditional Financial Markets

This section of the paper will investigate the literature on the liquidity premium in non-traditional financial markets. If it turns out to be the case that the liquidity premium theory holds when taken outside the context of traditional financial markets, it could give rise to the idea that it might also hold within EVE Online. Hence, investigating whether non-traditional financial markets exhibit patterns in congruence with the liquidity premium theory is of vital importance to the empirical substantiation of the analysis performed within this thesis.

One of the most prominent non-traditional financial markets at the current time is that of the cryptocurrency market. With an estimated cumulative market capitalization of around $214 billion at the time of writing[1], it is still orders of magnitude smaller than the cumulative market capitalization of traditional financial markets. However, while the cumulative market capitalization of cryptocurrencies might be negligible comparatively speaking, it poses for an especially relevant research question to see how liquidity affects excess returns within this market when comparing it to the research questions posed by this thesis. Research into the aforementioned topic is all the more relevant when taking into account the non-traditional financial market under investigation by this thesis. Consequently, an attempt will be made below to summarize the sparse literature concerning the liquidity premium in the cryptocurrency market.

Wei (2018) analyzes 456 distinct cryptocurrencies on market efficiency and liquidity characteristics for the year 2017. The methodology entails sorting cryptocurrencies into five liquidity-sorted quantiles based on their respective ILLIQ measure. In order to test for the existence of a liquidity premium a comparison is made between the top and bottom quintile of the most and least liquid cryptocurrencies, respectively. It is shown that there is no observable difference in mean returns between both quintiles, indicating that a liquidity premium is not present in the market for cryptocurrencies. Furthermore, using a total of six market efficiency metrics it is concluded that cryptocurrencies with higher liquidity exhibit patterns of higher efficiency. The latter finding can be explained by the fact that smaller cryptocurrencies go through cycles of extreme up and down trends more frequently as opposed to bigger cryptocurrencies. Given the fact that bigger cryptocurrencies are found to be more liquid, it entails that a higher liquidity does equal higher efficiency.

Unfortunately, the aforementioned paper is an isolated exception in the literature with regards to analyzing the liquidity premium within the cryptocurrency market itself. The following papers will therefore analyze the supposed effect of the liquidity premium in cryptocurrencies with regards to the aggregated real-world financial markets. Mingyang, Simon and Wolfgang (2017) show how including cryptocurrencies within a portfolio otherwise consisting of purely stocks can

[1] 17/08/2018 from https://coinmarketcap.com/

increase the risk-return relationship positively compared to a pure stock portfolio. Moreover, it is shown that cryptocurrencies have lower liquidity comparative to stocks. The reasoning behind these findings is that cryptocurrencies exhibit low covariance with stocks, rendering them ideal for inclusion in a pure stock portfolio due to the benefits of diversification (Markowitz, 1952). Findings in support of this statement and of similar nature can be found in Guo, Lee and Wang (2018).

The findings discussed above do not directly prove that a liquidity premium within the cryptocurrency market itself is present. Rather, they show how the decreased liquidity of cryptocurrencies positively affects the risk-return relationship from a portfolio perspective. While causality cannot be assumed in this regard, it shows a correlation between low liquidity and increased returns, which is in line with the liquidity premium theory. More studies into this domain would need to be done to thoroughly substantiate the claim of causality between liquidity and returns in cryptocurrency markets.

2.4 Virtual Economies

This section will summarize the available literature on virtual economies. While this literature is not in direct relationship with either of the research questions posed by this thesis, it provides some insights into how economies within games behave. Whenever the intersection of the economy as a whole and the financial markets within these games becomes apparent, it will be further expanded on. Unfortunately, there is no literature available at the time of writing that has specifically investigated how financial markets behave within virtual economies of games. It therefore renders the aforementioned approach as an inconvenient necessity.

2.4.1 Intersection between Virtual Economies and Real-World Economies

In order to understand how virtual economies operate in comparison to real-world economies, it is of importance to define in what kind of environment these virtual economies exist. Castranova (2001) defines the following three conditions for virtual worlds to exist: Interactivity, Physicality and Persistence. Interactivity is the idea that multiple people can simultaneously access the same virtual world, with the actions of one player directly being able to affect the results of other players. Physicality is the idea that players can access an interface that simulates a physical environment, and where that same environment is governed by some or all laws of Earth, including the scarcity of resources. Persistence is the idea that the virtual world keeps existing irrespective of the number of players actually playing. Moreover, the virtual world should also keep track of the location and ownership of objects, players and other things.

An important takeaway from the above is the principle of scarcity of resources. Within virtual worlds, players face scarcity of resources, just as is the case in the real world. Obtaining resources requires players to actively go out and look for them, with an associated risk tied to it. Furthermore, every player fills a societal role. Not everyone will, or can, fulfill the same roles due to the inherent scarcity present within these virtual worlds. Consequently, players attempt to gain prestige over other players, as people attempt to do in the real world, making them work vigorously towards incrementally improving their characters within these virtual worlds. In a sense, players of virtual worlds closely mimic people in the real world. Taking this into account, it could easily be extended to financial markets, as these are merely a reflection of the world they exist in. Hence, virtual financial markets could exhibit the same patterns that real-world financial markets do, as the players and people within are more or less equivalent.

Furthermore, Castranova (2001) looks specifically into the market system of Everquest, a game that was the industry leader within the MMORPG genre at the time the paper was written. Within Everquest there are two types of markets, player-to-player and player-to-shop. Note here that financial markets such as the ones found in EVE Online are not present within Everquest. Nevertheless, the player-to-player market is said to be prominently present within the game. The main explanation behind this, as pointed out in the paper, is that shops within Everquest are not willing to pay a premium for scarce resources, while players are. Moreover, as is the case within real-world financial markets, resources that are scarce will be more expensive as opposed to less scarce resources. Therefore, it can be concluded that the effects of supply and demand are present in the virtual markets of Everquest, just as they are in real-world financial markets. Extending the aforementioned factors to the research questions posed by this thesis, it may be theorized that players within virtual worlds behave similarly to humans within real-world financial markets, a statement further supported by Castranova, Knowles and Ross (2014). Consequently, players within virtual worlds might value the liquidity of the resources they are keeping as well. In turn, this could lead them to pay a premium for resources with heightened liquidity or, conversely, make them require a discount for resources with lowered liquidity.

2.4.2 Ambiguities between Virtual Economies and Real-World Economies

Further research into virtual economies is found in Castranova (2002), who investigated how virtual economies within MMORPGs behave and in how far they intersect with real-world economies. Two out of the four conclusions drawn in this regard are of great interest to the research questions within this thesis. Firstly, it is concluded that controlling prices within virtual economies might make sense (which is not the case in the real world). The reasoning behind this is that governments within the real world will always incur costs when they control prices of resources, be that for the consumers or for the producers of said resources; this, however, is not necessarily the case in virtual worlds. Secondly, it is concluded that economic growth within virtual economies might not always be favorable, while it is widely regarded to be favorable in real-world economies. The reason that economic growth might not be favorable in virtual economies, is that increases in a player's wealth year-over-year might lower the challenge level of the game at hand, leading to a less enjoyable playing experience.

Translating the above to the virtual financial markets of EVE Online it may be argued that prices on these markets are artificially inflated or deflated due to the creators of the game tampering with them. While this may be a real concern with respect to the first research question of this thesis, in the case of EVE Online the artificial inflation or deflation of prices within its financial markets seems highly unlikely. The reason that it is unlikely is that EVE Online advertises itself as a "sandbox" game, indicating that it tries to be minimally involved in how the entirety of the game evolves, letting players decide for themselves what happens within the virtual world. However, while artificially inflating or deflating prices is not something the creators of EVE Online would engage in, game updates (which may influence prices and resources) are an important feature to take into consideration. Game updates are essential for the longevity of a game, as not performing these would make a game generally less enjoyable as time goes on. When updates to EVE Online concern the way resources and items are gathered, it may have serious consequences for the game's economy. This particular issue will be further elaborated on in section 4.4 of this thesis.

Furthermore, economic growth within EVE Online can be considered an issue when relating it to the research questions posed by this thesis. Considering the fact that EVE Online is a game that revolves around massive battles between groups of players, vast amounts of wealth can be removed from the economy this way. Given the fact that this is the inherent nature of EVE Online, it causes for an outflow of wealth each time the possession of a player is removed from the game. Comparing this to the inflow of wealth that is generated from other activities within the game, such as killing non-playable characters or doing missions, it may be the case that growth fluctuations of the economy of EVE Online are extremely volatile. This, in turn, could also affect the prices that are being paid for all items within EVE Online. It therefore makes investigation into the liquidity premium theory within these markets challenging.

2.5 Fama and Macbeth (1973) Regression

Much of the empirical literature regarding the liquidity premium theory employs panel datasets. Furthermore, when the observations within these datasets concerns stocks, it is not uncommon to see the same stocks overlapping over time. Hence, since most companies (and thus their respective stock price) are expected to grow over time, the variables of interest within each observation are often cross-sectionally and serially correlated. Consequently, the assumption of independence in the OLS error term is usually violated within studies employing panel datasets.

The Fama and Macbeth (1973) methodology corrects for cross-sectional correlation by running multiple cross-sectional regressions for each period t within the panel, and reporting the average regression coefficient for each variable over all periods. However, it does not correct for serially correlated variables. Petersen (2009) shows that if serial correlation is present within a dataset, the Fama and Macbeth (1973) methodology can hugely understate the correct standard error. In the case of serially correlated variables, Petersen (2009) suggests applying the Newey and West (1987) procedure in conjunction with the Fama and Macbeth (1973) methodology to derive standard errors that are robust to serial correlation being present. Nevertheless, the Fama and Macbeth (1973) methodology is one way to alleviate the issue of cross-sectional correlation in panel data. Consequently, it is to this date still commonly applied within the literature regarding the liquidity premium theory. Further specifications on how the Fama and Macbeth (1973) methodology will be applied within this thesis will be given in section 3.4.

3. Method

This chapter will provide information on the methodologies that were employed to obtain the results within this thesis. Section 3.1 will describe the raw data. Section 3.2 will detail the selection procedure chosen to limit the scope of the analysis. Section 3.3 will present information on how the liquidity and control variables are derived. Section 3.4 will specify the altered version of the Fama and Macbeth (1973) regression applied in this thesis. Section 3.5 will discuss how liquidity will be measured over time.

3.1 Raw Data

The raw data is obtained directly from the developers of EVE Online, CCP Games, who have published a 16.6 gigabyte file containing 269,257,439 rows of daily market data for all 22381 items and all regions within EVE Online between October 2003 and March 2018[2]. The file consists of the following eight columns.

- **regionID.** A region within EVE Online is the largest geographical sub-division of the playable world map. There exists a total of 64 regions within Eve Online, each of which have their own distinct characteristics in terms of the availability of resources, among others.

- **typeID.** Every item that exists within EVE Online has a name within the game as well as a typeID that is tied to the corresponding name. Hence, in order to locate items by name it is first required to find the matching typeID.

- **date.** This column could be seen as the index of the file and it contains all of the dates in string format between October 2003 and March 2018, with daily increments.

- **lowPrice.** The lowPrice column indicates the lowest price an item has sold for on a given date. This column could therefore be seen as a crude proxy for the bid price in the context of the bid-ask spread.

- **highPrice.** The highPrice column indicates the highest price an item has sold for on a given date. It could thus serve as a crude proxy for the ask price in the context of the bid-ask spread.

- **avgPrice.** The avgPrice column shows the average price an item has sold for on a given date.

- **volume.** This column shows the total number of items per typeID that were traded from one player to another via the market system on a given date.

- **orders.** Total number of orders executed via the market system per typeID on a given date. By definition the value within this column will always be less than or equal to the value in the volume column.

[2] The raw data can be obtained from the following link: https://www.eveonline.com/article/p5bttu/monthly-economic-report-february-2018

3.2 Selection Procedure

In order to ensure that the analysis performed within this thesis will lead to results that are able to answer research questions one and two, it must be ensured that the items subject to investigation are closely related to the financial products investigated in past literature. While it would be possible to perform an analysis on items within EVE Online that are not closely related to those residing in the real world, a new theoretical model should in that case serve as the foundation for such research. Since the aforementioned is beyond the scope of this thesis, only items within EVE Online that are closely related to financial products within the real world will be taken into account.

Consequently, as there are no such things such as exchange-traded stocks or bonds within the virtual world of EVE Online, another subset of items will have to be selected. Hence, the choice was made to only analyze the commodity class of items within EVE Online. More specifically, this thesis will only investigate "Raw Materials" and "Minerals", both of which are used within the game for the production of almost every craftable item. Given past research by Chang, Chong and Tsui (2017), who show that futures contracts on commodities exhibit patterns in congruence with the liquidity premium theory, it gives rise to the idea that commodities within EVE Online might display similar patterns. It must be noted here, however, that commodities within the real world are not directly traded on financial markets, but rather through use of futures contracts. This is in contrast to EVE Online, where individuals can buy commodities instantaneously whenever they are in close proximity to a financial market. Moreover, futures contracts are used for different reasons within the real world as opposed to the virtual world of EVE Online. Where the main purpose of commodities within EVE Online is usage or speculation, companies or individuals residing in the real world predominantly use futures contracts on commodities for hedging purposes. Thus, this difference should be taken into account when analyzing the results.

In addition to the selection procedure as described above, the number of regions subject to investigation was limited. More specifically, all non-NPC controlled regions were excluded from further analysis. Regions within EVE Online that are not controlled by NPCs are inherently more dangerous than their NPC controlled counterparts. Consequently, fewer players within the world of EVE Online fill up the orderbooks (a collection of all bid and ask prices) of financial markets located in these non-NPC controlled regions. Thus, as a result of reduced competition, individuals or collectives of individuals can more easily manipulate the financial markets within non-NPC controlled regions. Selecting a region that is controlled by NPCs will therefore partly mitigate the issue of market manipulation. Preventing market manipulation from influencing the results is of crucial importance, as market manipulation within real-world traditional financial markets is strictly forbidden. Hence, in order to ensure that the financial markets under investigation within EVE Online more closely resemble those of the real world, the selection procedure mentioned above should be able to partly mitigate the issues of market manipulation.

After all non-NPC regions were excluded, the decision was made to choose "The Forge" as the region to be analyzed. This choice was made since The Forge contains the largest financial market as measured by its value of the total outstanding market offers. Within EVE Online it is more commonly referred to as "Jita 4-4". Historically, Jita 4-4 had the best selection of possible missions players could complete, which, in combination with its advantageous location in the world, has made it the most active financial market within EVE Online over time. Compared to other major financial markets, Jita 4-4 has a value of total market offers around four times higher than the second-largest financial market[3]. Selecting the region with the most active financial market ensures that the items that survived the aforementioned selection procedure will actually be traded as well. Hence, this thesis will analyze only Raw Materials and Minerals traded on the financial market by the name of Jita 4-4, for a total of 160 items to be analyzed.

[3] https://eve-marketdata.com/rank/markethubs

3.3 Liquidity and Control Variables

The liquidity premium theory describes how illiquid financial products tend to outperform more liquid financial products, as measured by their respective excess returns. Analyzing whether these theorized results are present within the virtual world of EVE Online entails carefully selecting the appropriate liquidity and control variables. Furthermore, selecting liquidity measures that accurately measure liquidity is essential to show how liquidity of items within EVE Online varies over time. Fong, Holden and Trzcinka (2009) empirically analyze which of the many liquidity measures effectively capture liquidity. They do so by comparing monthly estimates of several liquidity measures against different liquidity benchmarks that are deduced from high-frequency data. Deriving liquidity from high-frequency data is the most accurate way of measuring the true liquidity of a financial product. However, since deriving liquidity this way is computationally very expensive, it is not a common practice in the literature. Hence, liquidity measures are employed that are meant to proxy the true liquidity of a financial product.

Subsequently, using the aforementioned methodology, it is found that ILLIQ measures best the price impact of a transaction when dealing with monthly time intervals, while the Closing Percent Quoted Spread (CPQS) measures best the cost of transacting when dealing with the same monthly time interval. Consequently, alongside the natural logarithm of ISK denoted trading volume (LNVOLI), these two liquidity measures will be included in the analysis performed within this thesis. While LNVOLI was not subject to investigation by Fong, Holden and Trzcinka (2009), it has shown to accurately predict excess returns in past studies (as described in section 2.1.2 of this thesis). Moreover, it is easy to compute. Hence, this thesis will employ ILLIQ, CPQS and LNVOLI as measures of liquidity, as described below:

$$ILLIQ_{iy} = \frac{1}{D_{iy}} \sum_{y=1}^{D_{iy}} \frac{|R_{iyd}|}{VOLI_{iyd}}$$

where $ILLIQ_{iy}$ is the illiquidity measure from Amihud (2002) for item *i* in year *y*, D_{iy} is the number of available trading days for item *i* in year *y* within EVE Online, $|R_{iyd}|$ is the absolute return of item *i* on day *d* of year *y*, $VOLI_{iyd}$ is the trading volume denoted in ISK for item *i* on day *d* of year *y*. Note that D_{iy} is a constant with value 365.25 since items within EVE Online are available for trading every day of the year.

$$CPQS_{im} = \frac{1}{D_{im}} \sum_{m=1}^{D_{im}} \frac{Closing\ highPrice_{imd} - Closing\ lowPrice_{imd}}{(Closing\ highPrice_{imd} + Closing\ lowPrice_{imd})\ /\ 2}$$

where $CPQS_{im}$ is the Closing Percent Quoted Spread of item *i* in month *m*, D_{im} is the number of available trading days for an item *i* in month *m*, $Closing\ highPrice_{imd}$ is the highPrice as described in section 3.1 of item *i* at the end of day *d* of month *m*, $Closing\ lowPrice_{imd}$ is the lowPrice as described in section 3.1 of item *i* at the end of day *d* of month *m*.

$$LNVOLI_{im} = \frac{1}{D_{im}} \sum_{m=1}^{D_{im}} \ln(volume_{imd} * avgPrice_{imd})$$

where $LNVOLI_{im}$ is the natural logarithm of trading volume denoted in ISK for item *i* in month *m*, D_{im} is the number of available trading days for an item *i* in month *m*, $volume_{imd}$ is the total number of items *i* traded on day *d* of month *m*, $avgPrice_{imd}$ is the avgPrice as described in section 3.1 of item *i* on day *d* of month *m*.

Lastly, several control variables are introduced which are known to be drivers of excess returns within real-world stocks. However, since items within EVE Online are not directly comparable to stocks residing in the real world, it is impossible to include all of these drivers in the analysis performed within this thesis. More specifically, as opposed to recent literature by Ben-Rephael, Kadan and Wohl (2015), this thesis will not be able to employ Beta, Dividend Yield, Book-to-Market or Size as control variables. Excluding the aforementioned variables is an inconvenient necessity due to the inherently different nature of stocks and items within EVE Online. Therefore, this thesis will only be able to employ R100, R100YR and STDY as control variables. R100 and R100YR are the accumulated returns over the last 100 days of the year and the accumulated returns from the beginning of the year until the last 100 days, respectively. STDY is the yearly standard deviation measured by daily returns. R100 and R100YR are included to capture the momentum effect (Jegadeesh & Titman, 1993), which states that stocks that have performed well in the recent past will continue to do so, and vice versa. STDY is included since it measures idiosyncratic risk, which in real-world financial markets positively covaries with excess returns.

3.4 Regressions

As discussed previously, this thesis will apply the Fama and Macbeth (1973) methodology in order to investigate whether the liquidity premium theory holds when taken into the context of virtual financial markets. The methodology entails running a cross-sectional regression over all items *i* for each month *m* in each year *y*, as follows.

$$R_{imy} = \alpha_{imy} + \sum_{j=1}^{J} \beta_{jmy} X_{ji,y-1} + \varepsilon_{imy}$$

where R_{imy} is the return of item *i* in month *m* of year *y*, α_{imy} is the intercept of the regression, $X_{ji,y-1}$ is liquidity or control variable *j* of item *i* taken from data in year *y-1*, such that information about the item is already known when players of EVE Online make the decision whether or not to acquire the respective item, β_{jmy} is the regression coefficient of liquidity or control variable *j* in month *m* of year *y* and ε_{imy} is the error term. The monthly regressions are run as described above. This produces an estimate for every month and for each coefficient β_{jmy}, *j* = 1, 2, 3, …, *J*. Final regression coefficients are consequently obtained independently for each liquidity or control variable *j* over a total of *T* months, as follows:

$$\hat{\beta}_j = \frac{1}{T} \sum_{t=0}^{T} \beta_{t,j}$$

Finally, standard errors are obtained following the regular procedure:

$$\sigma^2(\hat{\beta}_j) = \frac{1}{T^2} \sum_{t=0}^{T} (\beta_{t,j} - \hat{\beta}_j)^2$$

Using the aforementioned information, t-statistics for all $\hat{\beta}_j$ are deduced (against the null hypothesis that the average is zero). This thesis does not apply a Newey and West (1987) procedure in order to correct for serial correlation as the Durbin and Watson (1951) statistic indicated no signs of serial correlation in the error term.

3.5 Liquidity over Time

As shown by Ben-Rephael, Kadan and Wohl (2015), the liquidity premium shows diminishing returns over time. In the case that the virtual financial markets of EVE Online exhibit the same pattern that real-world financial markets exhibit, it might provide evidence for the idea initially proposed by Castranova, Knowles and Ross (2014), who argue that the intersection between the real world and virtual worlds is fading. In order to show how the liquidity of items within EVE Online evolves over time, the liquidity measures employed within this thesis will be averaged yearly over all 160 items. These graphs should enable the reader to get a general understanding of how liquidity has evolved over time, since the inception of EVE Online.

Additionally, next to the initial regressions that will be run over the entire sample period, two regressions in different subsets of the entire sample period will be run. This methodology allows for differences in the liquidity premium over different sample periods and is also performed in Ben-Rephael, Kadan and Wohl (2015). Since it is known to be true by the aforementioned paper that there is a diminishing return over time with respect to the liquidity premium in real-world traditional financial markets, it would be of interest to investigate whether EVE Online exhibits similar patterns. If it is the case that the liquidity premium within EVE Online shows diminishing returns over time as well, it could provide for additional evidence in favor of the idea that the intersection between virtual worlds and the real world is fading.

4. Results

This chapter of the thesis will elaborate on the results obtained from the analysis. Moreover, the research questions will be answered and briefly discussed. Further discussion of the results can be found in chapter 5 of this thesis. Section 4.1 will discuss the summary statistics and cross-sectional correlations of all variables of interest. Section 4.2 will discuss the outcomes of the Fama and Macbeth (1973) regressions that were run over the entire sample period. Section 4.3 will discuss the outcomes of the Fama and Macbeth (1973) regressions that were run over two subsets of the entire sample period. Section 4.4 will portray how liquidity of the investigated items has changed over time.

4.1 Summary Statistics and Cross-sectional Correlations

In order to get a general idea of what the data looks like and how the variables are correlated cross-sectionally, this section will show summary statistics and a correlation matrix of all variables of interest. Following Amihud (2002), among others, only items that have more than 200 days of return and volume data per year will be included in the analysis. This leaves a total of 73 items out of the original 160 for subsequent analysis. Summary statistics are extracted both before and after exclusion of outlier values, as will be further expanded upon below. Table 1 shows the summary statistics before outlier exclusion.

Table 1: Summary Statistics Before Outlier Exclusion

This table shows the summary statistics for all items in every month within the sample. For each month in the sample the average of each variable is taken. Summary statistics are reported at the end. There is a total of 168 months in the sample, in the years 2004-2017. Only items that have more than 200 days of return and volume data per year available are included. Return is the monthly return in percentages. ILLIQ is the illiquidity measure as described by Amihud (2002) and is introduced in section 3.3. CPQS is the Closing Percent Quoted Spread as described in section 3.3. LNVOLI is the natural logarithm of monthly trading volume denoted in ISK. R100 is the accumulated return over the last 100 days of the year. R100YR is the accumulated returns from the beginning of the year until the last 100 days of the year. STDY is the standard deviation of daily returns. OBS is the number of observations per month.

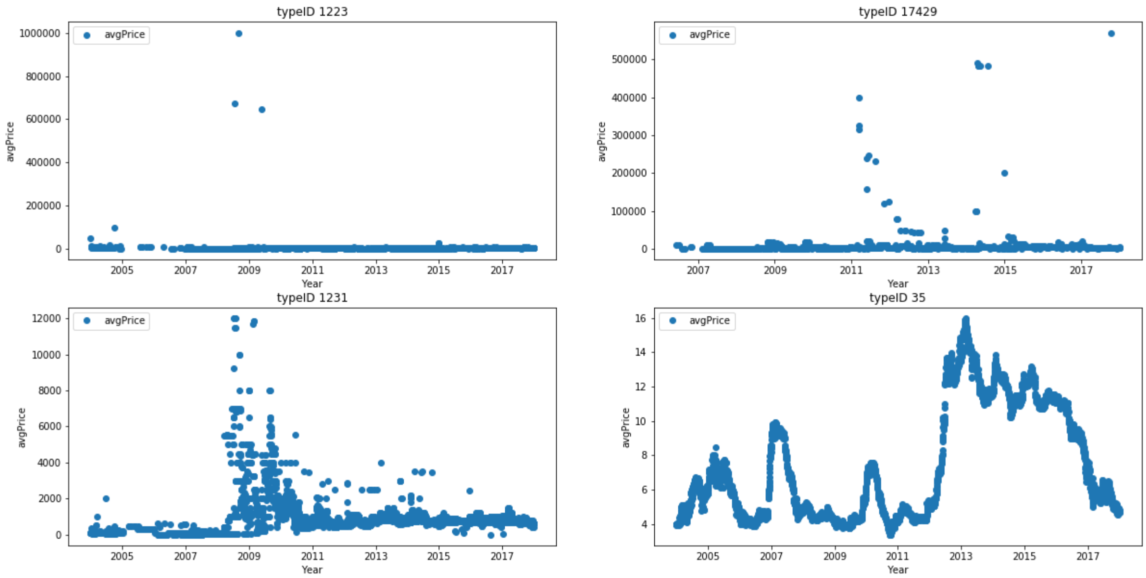
Variables	Mean	Median	Min	Max	Std
Return (%)	784.05	6.76	-12.98	112158.82	8691.67
ILLIQ	0.004427	0.000482	0.000003	0.027102	0.007421
CPQS (%)	4.56	4.53	2.30	8.35	0.99
LNVOLI	16.94	17.84	12.35	19.02	1.68
R100 (%)	104.23	36.90	-8.93	555.56	140.01
R100YR (%)	171.23	42.81	-7.09	1388.63	348.43
STDY (%)	2155971.20	34200.53	279.54	19011425.38	5040638.99
OBS	63.31	64	23	73	10.60

What immediately becomes apparent from looking at the above summary statistics is that the data contains various major outliers. It can clearly be seen that the Return, R100, R100YR and STDY columns are mostly affected by these outliers, as the mean and median of these columns are generally widely apart. All of these columns are related to the returns of items, so it is no coincidence that these columns in particular exhibit similar patterns. The fact that outlier values appear in the data can most likely be attributed to "fat-finger errors", as well as market manipulation. A fat-finger error in this case refers to a human error that occurs when a wrong input is given, subsequently leading to an undesirable output. In the case of EVE Online, where inexperienced players have easy access to its financial markets as well, this type of error is likely to be a common occurrence. Thus, due to these errors occurring, the price of items can change radically day-to-day. Consequently, it follows that the returns of these items will change radically as well. Furthermore, market manipulation can be an issue within the virtual financial markets of

EVE Online, as financial markets regulation is virtually non-existent. Therefore, players who have acquired a disproportionate amount of the total ISK in circulation can easily manipulate prices of items they deem fit. Hence, these players are able to buy out the entire orderbook of the respective item, clearing it of any sell orders, which allows them to subsequently set a sell offer at a much higher price. Since these players now have a monopoly in the market of the respective item, this allows them to generate immense profits for a short period of time. Figure 1 portrays how the average price has moved over time for some of the selected 73 items.

Figure 1: Examples of Outliers versus No Outliers.

This figure shows how the average daily price of 4 out of the selected 73 items has moved over time.



It can clearly be seen that on some days, for every graph except the bottom-right, the price of an item reaches a level that is much higher than the level it was on the day prior.

As can be seen in the top-left graph, the price immediately drops down to the price level it was at the day prior to the price spike. Therefore, these price spikes can most likely be attributed to fat-finger errors.

In the top-right graph it can be seen that, for the item concerned, around the beginning of 2011 the price level spikes tremendously. Subsequently, the price does not immediately return to the original price level but, rather, gradually goes down as time passes, eventually settling at a price close to the original price level. While it is outside the scope of this thesis to investigate exactly why price movements like these happen, a possible explanation is that it is attributable to market manipulation.

The bottom-left graph exemplifies how volatile the prices of some of the items can be, as was previously made apparent in table 1. Moreover, outlier exclusion for this item would likely not yield any positive outcomes with respect to mitigating the volatility issues within subsequent analysis. This is clearly demonstrated by the fact that prices rise from close to 0 ISK to more than 4000 ISK quite regularly in the years 2009-2011. Considering the aforementioned, it is hard to distinguish outlier values from non-outlier values within this item. Therefore, returns derived from this pricing data will naturally contain many anomalies as well. There are several items within the dataset that display similar patterns to the example provided in the bottom-left graph.

Lastly, the bottom-right graph shows an item that exhibits no anomalies in its pricing data. However, there are some major price fluctuations that can clearly be identified. Most notably it can be seen that the price level more than doubles between 2012 and 2013, a common occurrence across several items within the data. An in-depth analysis as to why this might have happened will be given in section 4.3 of this thesis.

Considering the fact that outliers can form a problem for any subsequent analysis, as has been demonstrated above, an outlier exclusion methodology is applied for all variables before proceeding with further analysis. Outliers are herein classified as such when the value on a specific day of a certain variable is greater than 5 times the mean of the respective variable over the entire sample period. Outlier values are then replaced with the value seen one day prior to the outlier being detected. This methodology ensures that enough months remain within the dataset for use in further analysis. Furthermore, outright removing all outliers would lead to issues in subsequent calculations of all variables related to the returns of an items. On average, 98.43 outliers per item were removed and replaced in every column. Table 2 shows the summary statistics after applying the aforementioned outlier exclusion to the data.

Table 2: Summary Statistics After Outlier Exclusion

This table shows the summary statistics for all items in every month within the sample, after outlier exclusion was applied. For each month in the sample the average of each variable is taken. Summary statistics are reported at the end. There is a total of 168 months in the sample, in the years 2004-2017. Return is the monthly return in percentages. ILLIQ is the illiquidity measure as described by Amihud (2002) and is introduced in section 3.3. CPQS is the Closing Percent Quoted Spread as described in section 3.3. LNVOLI is the natural logarithm of monthly trading volume denoted in ISK. R100 is the accumulated return over the last 100 days of the year. R100YR is the accumulated returns from the beginning of the year until the last 100 days of the year. STDY is the standard deviation of daily returns. OBS is the number of observations per month.

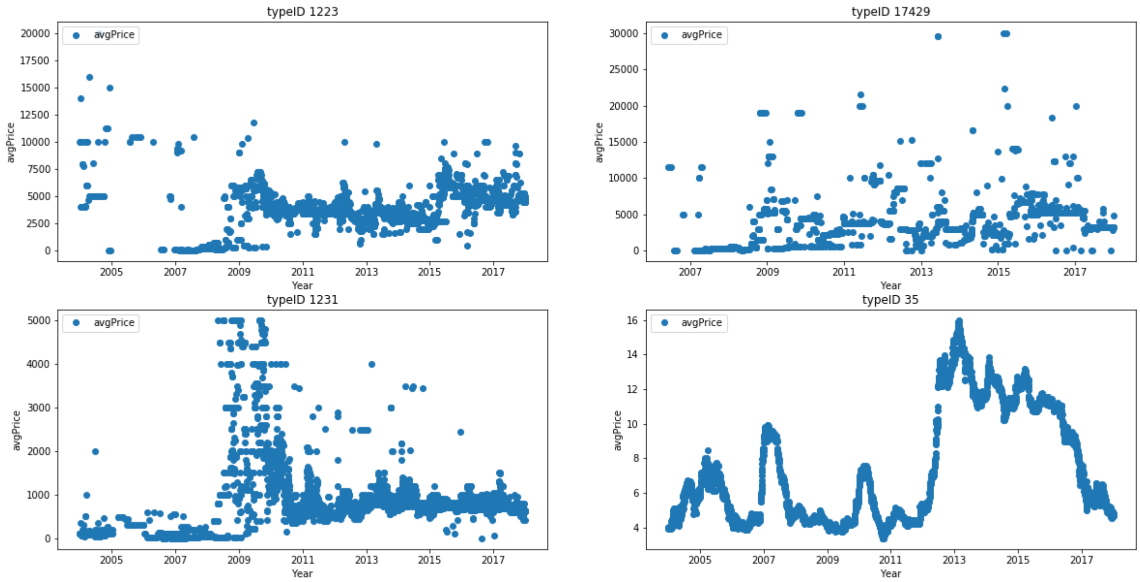
Variables	Mean	Median	Min	Max	Std
Return (%)	741.97	3.88	-12.32	11280.26	8688.74
ILLIQ	0.001707	0.000082	0.000003	0.009140	0.002584
CPQS (%)	4.47	4.54	0.97	8.25	1.05
LNVOLI	16.90	17.80	12.35	18.88	1.66
R100 (%)	58.84	28.21	-8.94	337.13	76.60
R100YR (%)	167.04	44.47	-6.67	1388.63	344.15
STDY (%)	372.30	176.85	45.55	1904.98	470.61
OBS	63.31	64	23	73	10.60

Comparing table 1 to table 2 there is a noticeable improvement in the disparity between the mean and median in most columns. This is a clear indicator that the outlier exclusion methodology has successfully removed at least some influential outliers. However, it is still quite abnormal to see mean monthly returns of 741.97%, a number that is economically exceptionally large. Moreover, the standard deviation of the returns of items within EVE Online is abnormally high. The same pattern can be found in the R100, R100YR and STDY variables. Thus, while improvements have clearly been made, the data still suffers from several abnormalities.

Figure 2 portrays how the average price has moved over time for some of the selected 73 items, after excluding outliers from the data. It shows how the outlier exclusion methodology as described above has successfully removed the most extreme outliers in the data. However, when looking at the graphs made after excluding outliers, it is immediately apparent that most of the items still have extremely volatile price movements. All graphs, apart from the bottom-right, clearly portray this. Since the aforementioned volatility of price movements can negatively influence the significance of subsequent analysis, this issue will be dealt with further in section 4.2 of this thesis.

Figure 2: Outcomes of Outlier Exclusion.

This figure shows how the average daily price of 4 out of the selected 73 items has moved over time, after outliers were excluded from the data.



Lastly, a correlation matrix is given in order to portray how the variables of interest covary with one another. Table 3 shows this correlation matrix, which is obtained from monthly data. Interestingly, the signs of 4 out of a total of 6 interactions seem in line with past studies into real-world traditional financial markets. Both ILLIQ and CPQS covary with Return negatively, contrary to what is predicted by the liquidity premium theory. Note here that ILLIQ and CPQS are both measures of illiquidity, such that higher values of these measures indicate a decrease in liquidity. Conversely, LNVOLI does behave as expected by the liquidity premium theory, since the sign of the interaction is negative as well. Considering the fact that LNVOLI is a measure of liquidity, such that higher values indicate an increase in liquidity, the sign of the interaction should be negative if it were to be in line with the liquidity premium theory. The sign of the interactions between R100 and R100YR on Return indicates that the momentum effect of Jegadeesh and Titman (1993) might be present as well. Lastly, the positive sign of the interaction between STDY and Return indicates that items with a higher risk yield higher average monthly returns, something that is in line with past studies. Note, however, that the magnitude of all of the interactions is economically very small.

Table 3: Correlation Matrix

This table presents the Pearson correlation between all variables of interest over every month in the sample. There is a total of 168 months in the sample, in the years 2004-2017. Return is the monthly return. ILLIQ is the illiquidity measure as described by Amihud (2002) and is introduced in section 3.3. CPQS is the Closing Percent Quoted Spread as described in section 3.3. LNVOLI is the natural logarithm of monthly trading volume denoted in ISK. R100 is the accumulated return over the last 100 days of the year. R100YR is the accumulated returns from the beginning of the year until the last 100 days of the year. STDY is the standard deviation of daily returns.

	Return	ILLIQ	CPQS	LNVOLI	R100	R100YR	STDY
Return	1	-0.0009	-0.0050	-0.0148	0.0160	0.0087	0.0041
ILLIQ		1	0.0492	-0.0779	0.0043	-0.0042	0.1384
CPQS			1	-0.0663	0.0195	-0.0190	0.0350
LNVOLI				1	-0.1332	-0.1075	-0.0574
R100					1	-0.0063	0.0207
R100YR						1	0.0074
STDY							1

4.2 Fama and Macbeth (1973) Regression Outcomes over the Entire Sample Period

In order to test whether the liquidity premium theory holds when taken into the context of EVE Online, as described by research question one, this thesis will employ a Fama and Macbeth (1973) styled regression. The three variables of interest herein are all three liquidity measures ILLIQ, CPQS and LNVOLI. Additionally, three control variables are included that are expected to have a relationship with returns in traditional financial markets, based on past literature. These variables are R100, R100YR and STDY. The exact methodology that will be employed for all subsequent regressions is described in section 3.4 of this thesis.

As was pointed out in section 4.1, there are still some obvious anomalies in the data that will need to be dealt with. More specifically, the price level of some of the items is highly volatile, even after the outlier exclusion methodology as described before was applied. Hence, before proceeding with further analysis, an additional exclusion of outlier months will be made. As the Fama and Macbeth (1973) methodology entails running cross-sectional regressions over all items for each month *m* in the sample, it was decided to remove months from the sample that portrayed patterns which could be attributed to outliers being present in the data. An outlier month herein is classified as follows: if at any month *m* the standard deviation of one of the variables that goes into the regression exceeds the average standard deviation of the respective variable over all months *m* by a factor Ψ, this month will be excluded from the sample. Where Ψ is the exclusion factor and will take on different values, as it is impossible to a priori deduce a value of this factor that will inherently lead to a statistically sound outcome.

Table 4: Fama and Macbeth (1973) Regression Outcomes over Entire Sample Period for Different Exclusion Factors.

This table presents the average of the coefficients obtained from monthly cross-sectional regressions of returns on all other variables over the entire sample period. There is a total of 168 months in the sample, in the years 2004-2017. Ψ is the exclusion factor as described in section 4.2. Items who are in the highest or lowest 5% tails of the distribution, as sorted by the respective liquidity measure, are excluded from the regression. ILLIQ is the illiquidity measure as described by Amihud (2002) and is introduced in section 3.3. CPQS is the Closing Percent Quoted Spread as described in section 3.3. LNVOLI is the natural logarithm of monthly trading volume denoted in ISK. R100 is the accumulated return over the last 100 days of the year. R100YR is the accumulated returns from the beginning of the year until the last 100 days of the year. STDY is the standard deviation of daily returns. R^2 is the average R-squared derived from all monthly regressions. T-statistics against the null hypothesis that the average is zero are reported in parenthesis below the respective coefficient.

Variables	**ILLIQ**			**CPQS**			**LNVOLI**		
Ψ	**5**	**7.5**	**10**	**5**	**7.5**	**10**	**5**	**7.5**	**10**
Intercept	0.0020	0.0040	0.1919	0.0483	0.0382	0.047	0.2973	0.274	0.7715
	(0.03)	(0.08)	(0.99)	(3.09)	(2.93)	(3.74)	(2.41)	(2.69)	(1.74)
ILLIQ	155.9007	108.9656	329.8232						
	(0.11)	(0.10)	(0.32)						
CPQS				-0.2898	-0.1788	-0.201			
				(1.69)	(1.18)	(0.93)			
LNVOLI							-0.015	-0.0139	-0.0361
							(2.24)	(2.52)	(1.91)
R100	-0.0451	-0.0348	-0.1180	-0.0307	-0.023	-0.0314	-0.041	-0.0348	-0.0963
	(1.15)	(1.09)	(1.80)	(0.87)	(0.80)	(1.18)	(0.78)	(0.81)	(1.56)
R100YR	0.0439	0.0334	0.0293	0.0076	0.0035	-0.0039	-0.0183	-0.0165	-0.0141
	(0.57)	(0.54)	(0.50)	(0.44)	(0.25)	(0.29)	(1.21)	(1.35)	(0.46)
STDY	0.0010	0.0009	0.0008	0.0005	0.0004	0.0005	0.0000	0.0000	-0.0001
	(1.33)	(1.41)	(1.46)	(1.61)	(1.80)	(2.12)	(0.02)	(0.07)	(0.42)
R^2	0.2081	0.2137	0.2161	0.2142	0.2262	0.2198	0.2254	0.2258	0.2239

Table 4 reports the result of the Fama and Macbeth (1973) regressions for different exclusion factors Ψ. The values Ψ takes on are 5, 7.5 and 10 which led to excluding 26, 13 and 1 month(s) from the sample, respectively. Following Amihud (2002), among others, items who are in the highest or lowest 5% tails of the distribution are excluded from the regression, as sorted by their respective liquidity measure. It immediately becomes apparent that very few variables of interest have a significant relationship to the monthly returns of items within EVE Online. Both ILLIQ and CPQS are insignificant for every value of Ψ. Moreover, ILLIQ seems to be extremely volatile when looking at the high values of the coefficients paired with the low t-statistics.

However, in all regressions concerning ILLIQ and CPQS, STDY might seem to hold some value, as the sign of the interaction remains constant and it is paired with moderately high t-statistics. The coefficient of STDY is even found to be statistically significant in one of the regressions of CPQS on monthly returns, with a t-statistic of 2.12. The magnitude of this interaction however is small, as an increase of 1% of the previous-year standard deviation of daily returns would only lead to an increase of the monthly returns this year by 0.0005% on average, ceteris paribus. Hence, while the coefficient might be statistically different from zero, the impact it would make is economically very small. Furthermore, R100 and R100YR are not found to be statistically different from zero in any of the regressions, indicating that there is no momentum effect present for items within EVE Online.

Furthermore, LNVOLI seems to hold some value as well. When Ψ is set to either 5 or 7.5 it can be seen that the regression coefficient of LNVOLI on monthly returns is statistically different from zero. When Ψ is set to 10, the regression coefficient becomes only barely insignificant at the 5% level. Moreover, the sign of all of the interactions is what would be expected by the liquidity premium theory. Looking at the regression coefficient that is statistically most significant, it can be seen that an increase of the previous-year LNVOLI by 1% would lead to a decrease of the monthly returns this year by 0.0139% on average, ceteris paribus. While the magnitude of the interaction can be considered relatively small, it is definitely not negligible and does have some interesting implications. It shows how the theorized results put forth by the liquidity premium theory might hold in a weak form when taken into the context of virtual financial markets. Additionally, it is of interest to note that the regression coefficient of STDY on monthly returns becomes virtually non-existent and statistically insignificant when the regression includes LNVOLI. This makes sense, as the standard deviation of daily returns is tied to the liquidity in a market. Higher volume would indicate higher liquidity, thus making the impact of a single transaction on the price of an item lower. Therefore, it may be theorized that the standard deviation of daily returns reflects an aspect of liquidity within EVE Online.

4.3 Fama and Macbeth (1973) Regression Outcomes over Two Subsets of the Sample Period.

Since Ben-Rephael, Kadan and Wohl (2015), it is known that real-world traditional financial markets show diminishing returns over time with respect to the liquidity premium. In fact, they argue in their paper that the liquidity premium is non-existent for the current year. If the same could be said for the virtual financial markets of EVE Online, it may provide additional evidence in favor of the idea that that the intersection between the real world and virtual worlds is fading. In order to analyze whether the supposed liquidity premium in EVE Online shows diminishing returns over time, the sample period will be split into two subsets. The first subset of the sample period will span the years 2004-2011. It contains exactly half the number months of the entire sample period. The second subset contains the other half of the months and spans the years 2011-2017. If it is indeed true that the intersection between virtual financial markets and real-world financial markets is fading, the expectation would be that the liquidity measures employed in the regressions would be statistically significant in the first subset of the sample period, but statistically insignificant in the second subset.

Table 5: Fama and Macbeth (1973) Regression Outcomes over the First Subset of the Sample Period for Different Exclusion Factors.

This table presents the average of the coefficients obtained from monthly cross-sectional regressions of returns on all other variables over a subset of the sample period. There is a total of 84 months in the subset of the sample period, in the years 2004-2011. Ψ is the exclusion factor as described in section 4.2. Items who are in the highest or lowest 5% tails of the distribution, as sorted by the respective liquidity measure, are excluded from the regression. ILLIQ is the illiquidity measure as described by Amihud (2002) and is introduced in section 3.3. CPQS is the Closing Percent Quoted Spread as described in section 3.3. LNVOLI is the natural logarithm of monthly trading volume denoted in ISK. R100 is the accumulated return over the last 100 days of the year. R100YR is the accumulated returns from the beginning of the year until the last 100 days of the year. STDY is the standard deviation of daily returns. R^2 is the average R-squared derived from all monthly regressions. T-statistics against the null hypothesis that the average is zero are reported in parenthesis below the respective coefficient.

Variables		**ILLIQ**			**CPQS**			**LNVOLI**	
Ψ	**5**	**7.5**	**10**	**5**	**7.5**	**10**	**5**	**7.5**	**10**
Intercept	-0.0513	0.4017	0.4017	0.0854	0.0860	0.0860	0.5759	1.6006	1.6006
	(0.29)	(0.93)	(0.93)	(2.55)	(3.43)	(3.43)	(1.88)	(1.64)	(1.64)
ILLIQ	9.7458	2297.05	2297.05						
	(0.01)	(1.10)	(1.10)						
CPQS				-0.7615	-0.5685	-0.5685			
				(2.15)	(1.28)	(1.28)			
LNVOLI							-0.0302	-0.0754	-0.0754
							(1.82)	(1.82)	(1.82)
R100	-0.1167	-0.2611	-0.2611	-0.0768	-0.0568	-0.0568	-0.1323	-0.1931	-0.1931
	(1.05)	(1.80)	(1.80)	(0.89)	(0.80)	(0.80)	(0.93)	(1.42)	(1.42)
R100YR	0.1576	0.082	0.082	0.0508	0.078	0.078	-0.0022	-0.0141	-0.0141
	(0.72)	(0.63)	(0.63)	(1.14)	(0.27)	(0.27)	(0.06)	(0.21)	(0.21)
STDY	0.0031	0.0015	0.0015	0.0008	0.0009	0.0009	-0.0005	-0.0002	-0.0002
	(1.53)	(0.63)	(0.63)	(1.04)	(1.86)	(1.86)	(0.86)	(0.37)	(0.37)
R^2	0.2066	0.2427	0.2427	0.1905	0.2170	0.2170	0.2030	0.2437	0.2437

Table 5 reports the outcomes of the regressions conducted on the first subset of the sample period. Setting Ψ to 5, 7.5 and 10 results in 19, 2 and 2 months being excluded from the analysis, respectively. Hence, it can be seen that the regressions where Ψ is set to either 7.5 or 10 yield identical results. As with table 4, it becomes apparent that not many of the regressions produce statistically significant estimates. Looking at the regression of ILLIQ on monthly returns there is no regression coefficient that exceeds the threshold of statistical significance *($t > 1.96$).*

Comparing the results to those found in table 4 does not yield any additional insights either. However, the regressions of CPQS on monthly returns have altered slightly. It can be seen that, when Ψ is set to 5, the regression coefficient of CPQS becomes statistically significant. However, the sign of the interaction is not in line with the predictions put forth by the liquidity premium theory. More specifically, an increase of the previous-year Closing Percent Quoted Spread by 1% would lead to a decrease of the current-year monthly returns of 0.7615% on average, ceteris paribus. Furthermore, the regression coefficients of LNVOLI on monthly returns have become statistically insignificant. The difference in significance is, however, not a major one and the sign of the interaction has remained constant across the different samples as well. It can also be seen that the regression coefficients of R100 and R100YR are statistically insignificant for every Ψ and liquidity variable, providing for additional evidence in favor of the idea that there is no momentum effect present for items within EVE Online. Lastly, STDY has become less statistically significant across regressions, as opposed to table 4. This could be attributed to the fact that prices were more volatile in the initial starting phase of EVE Online, hence causing the standard deviation of price returns to vary wildly between these initial years.

Table 6: Fama and Macbeth (1973) Regression Outcomes over the Second Subset of the Sample Period for Different Exclusion Factors.

This table presents the average of the coefficients obtained from monthly cross-sectional regressions of returns on all other variables over a subset of the sample period. There is a total of 84 months in the subset of the sample period, in the years 2011-2017. Ψ is the exclusion factor as described in section 4.2. Items who are in the highest or lowest 5% tails of the distribution, as sorted by the respective liquidity measure, are excluded from the regression. ILLIQ is the illiquidity measure as described by Amihud (2002) and is introduced in section 3.3. CPQS is the Closing Percent Quoted Spread as described in section 3.3. LNVOLI is the natural logarithm of monthly trading volume denoted in ISK. R100 is the accumulated return over the last 100 days of the year. R100YR is the accumulated returns from the beginning of the year until the last 100 days of the year. STDY is the standard deviation of daily returns. R^2 is the average R-squared derived from all monthly regressions. T-statistics against the null hypothesis that the average is zero are reported in parenthesis below the respective coefficient.

Variables	**ILLIQ**			**CPQS**			**LNVOLI**		
Ψ	**5**	**7.5**	**10**	**5**	**7.5**	**10**	**5**	**7.5**	**10**
Intercept	0.0084	0.0079	0.0127	0.0069	0.0061	0.0123	0.0681	0.0661	0.0632
	(1.37)	(1.32)	(1.76)	(0.77)	(0.70)	(1.22)	(2.01)	(2.00)	(1.95)
ILLIQ	-848.01	-821.62	-1147.67						
	(1.04)	(1.04)	(1.37)						
CPQS				-0.0037	0.0076	-0.0143			
				(0.02)	(0.04)	(0.08)			
LNVOLI							-0.0029	-0.0029	-0.0025
							(1.79)	(1.80)	(1.56)
R100	0.0100	0.0088	0.0069	-0.0009	-0.0007	-0.0022	-0.0175	-0.0164	-0.0174
	(0.85)	(0.76)	(0.62)	(0.06)	(0.80)	(0.16)	(1.37)	(1.31)	(1.44)
R100YR	-0.0012	-0.0116	-0.0116	-0.0122	-0.0119	-0.0132	-0.0164	-0.0157	-0.0150
	(1.52)	(1.51)	(1.56)	(1.74)	(1.74)	(1.86)	(2.03)	(2.01)	(1.97)
STDY	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0000	0.0001	-0.0003
	(2.1)	(2.11)	(2.35)	(2.11)	(2.11)	(2.15)	(0.21)	(0.21)	(0.76)
R^2	0.2119	0.2128	0.2081	0.2309	0.2328	0.2329	0.2145	0.2168	0.2153

Table 6 reports the outcomes of the regressions conducted on the second subset of the sample period. Setting Ψ to 5, 7.5 and 10 results in 2, 1 and 0 months being excluded from the analysis, respectively. Looking at the outcomes of the regressions it provides more statistically significant regression coefficients as opposed to the ones found in table 5. Note, however, that all of the reported regressions are similar, as the total outlier months differential over all exclusion factors is exceedingly small. Nevertheless, it can be seen that STDY is statistically significant in 6 out of 9 regressions. Furthermore, R100YR is statistically significant in 3 out of 9 regressions. The fact that STDY is significant in all regressions but the one of LNVOLI on monthly returns further substantiates the idea that the riskiness of an item may be a driving force behind its respective return, and that it proxies liquidity to a certain extent. This effect was already found to be marginally present in table 4. Additionally, an interesting note is that R100YR is statistically significant for all regressions of LNVOLI on monthly returns. The negative sign of the interaction, however, indicates the opposite of what would be expected by the momentum effect. More specifically, an increase of the price of an item in the first 265 days of the previous year would lead to a decrease in the price of an item in the current year, which is an effect found across all regressions.

Subsequently looking at the reported regression coefficients of all liquidity measures and their respective t-statistics leads to an additional insight as well. Where some of the regression coefficients of CPQS on monthly returns were statistically significant in the first subset of the sample period, they are insignificant over the second subset of the sample period. Lastly, the regressions of both ILLIQ and LNVOLI have not changed much compared to the first subset of the sample period. While the sign of the interaction of ILLIQ on monthly returns has swapped from positive to negative, the statistical significance is still sufficiently low to assume this may be attributed to chance. The regressions of LNVOLI on monthly returns yield no novel information as opposed to the first subset of the sample period, as both the sign of the interaction as well as the statistical significance have remained mostly constant.

4.4 Liquidity Movements Over Time

Analyzing how liquidity has evolved over time is a notoriously hard task considering the fact that quantifying liquidity within stocks or items is non-trivial. However, there is a possibility to proxy liquidity through so-called liquidity measures. This section of the thesis will demonstrate how liquidity has changed over time within EVE Online with help of all of the liquidity measures employed in previous analysis. It will do so by analyzing the equal-weighted average of all of the liquidity measures across all 73 selected items within a given year. Furthermore, indications as to why particular movements of liquidity might have happened will be given with help of external factors of influence. Lastly, a comparison will be made between the evolvement of liquidity over time in real-world financial markets as opposed to the evolvement of liquidity over time within the virtual financial markets of EVE Online.

Figure 3: Average ILLIQ per Year over Time

This figure portrays the average ILLIQ measure over all items within a given year over the entire sample period.

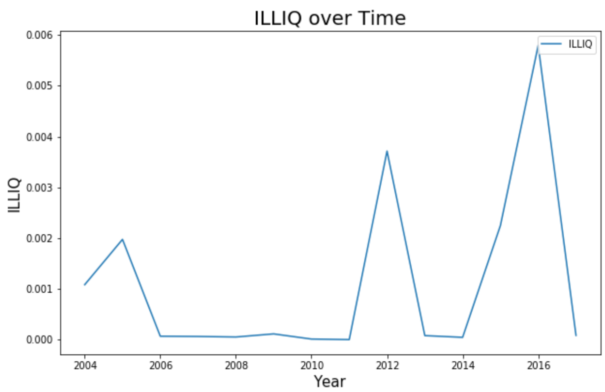


Figure 3, 4 and 5 display the average ILLIQ, CPQS and LNVOLI measures per year over the entire sample period, respectively. When looking at the figures it is hard to distinguish any noticeable patterns between them, as the directionality of change seems to be relatively volatile. Looking at the ILLIQ measure it becomes apparent that the volatile nature of this specific measure throughout the years can in part explain the insignificance of the results found in section 4.2 and 4.3 of this thesis. Moreover, it does not come as a surprise to see this measure be volatile throughout the years, as it is derived as a function of returns. Given the fact that returns of the investigated items have already been demonstrated to be extremely volatile, the ILLIQ measure hence displays a volatile pattern as well.

Figure 4: Average CPQS per Year over Time
This figure portrays the average CPQS measure over all items within a given year over the entire sample period

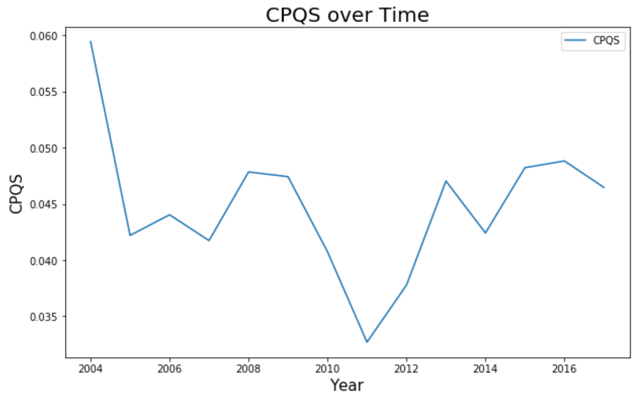
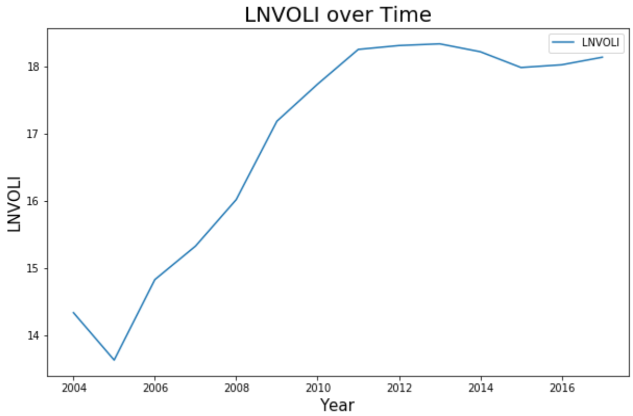


Figure 5: Average LNVOLI per Year over Time
This figure portrays the average LNVOLI measure over all items within a given year over the entire sample period



In contrast, a pattern does emerge when comparing the graph of CPQS to the graph of LNVOLI. Since the inception of EVE Online in the beginning of 2004 until around 2011, there is a clear increase in liquidity, as can be seen by both measures (note that CPQS is a measure of illiquidity). Overall liquidity subsequently decreases marginally after 2011 for the LNVOLI measure, but more so for the CPQS measure. Explaining why the aforementioned liquidity reversal might have happened can be found partially in the changes through time of the active player base, as well as updates done to EVE Online by CCP Games.

Figure 6: Average Player Count per Day over Time
This figure portrays how the average daily player count has changed day-to-day over the entire sample period.

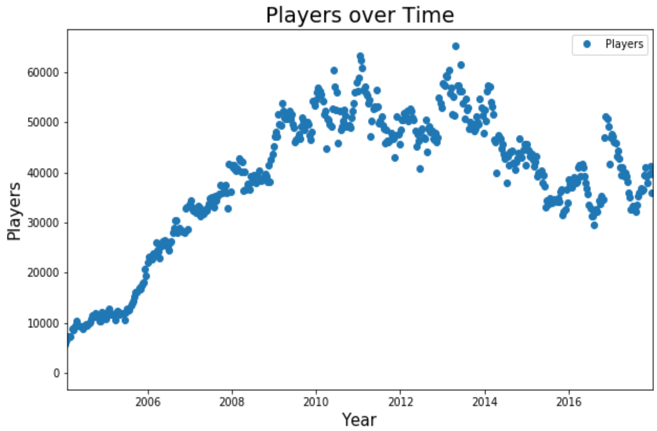


Figure 6 graphs the daily average active user count for the entire sample period. Investigating the graph more closely shows how the active player count was steadily rising until around the year 2011, after which it remained relatively constant for a while, only to go down again around the year 2013. When comparing figure 6 to figures 4 and 5 it seems that the active player count covaries positively with liquidity. This makes intuitive sense as well, as a higher active player count within EVE Online would yield more financial market activity and thus an increased liquidity of the items traded. While the magnitude of the interaction seems to be weaker when looking at the LNVOLI measure as opposed to the CPQS measure, they both exhibit the aforementioned pattern. Furthermore, aside from looking at the active player count, the "Carebearing 2.0" [4] update might have had an effect on the change in liquidity at around 2011. This update to the game fully removed "alloys" as a possible reward for killing highly sought-after NPCs within the game. Alloys within EVE Online are items that can be reprocessed into a predetermined quantity of multiple different minerals. Considering the fact that minerals were included as a class of items for analysis within this thesis, this update has most likely had an effect on all of the outcomes reported previously. Moreover, due to the fact that the Carebearing 2.0 update led to a decreased quantity of minerals entering the financial markets, the liquidity thereof declined, while prices rose due to a lack of supply. The latter effect on prices was briefly touched upon in section 4.1 of this thesis and can clearly be seen in the bottom-right graph of figure 2.

Comparing all of the above to the liquidity movements over time as shown in Ben-Rephael, Kadan and Wohl (2015), there seems to be a minor congruency as to how the evolvement of liquidity portrays itself. More specifically, the evolvement of liquidity within real-world traditional financial markets generally shows an upward trend as time goes on. When comparing this pattern to the evolvement of liquidity portrayed in figures 4 and 5, it seems to be that both financial markets behave in a similar way. However, it must be stressed that this conclusion should be approached with caution, as there are several clear distinctions to be made. These distinctions will be further elaborated in the next chapter of this thesis.

[4] https://www.eveonline.com/article/carebearing-2.0-1

5. Discussion

This chapter of the thesis will discuss the outcomes of the analysis performed within this thesis, and put them into context. Section 5.1 will answer the research questions of this thesis, put the results thereof into context, as well as discuss the implications these results can have for future research. Section 5.2 will discuss several limitations of the analysis performed within this thesis. Section 5.3 will give indications that can help guide future research into the topic.

5.1 Research Questions and Implications

In the introduction of this thesis two research questions were put forth that shaped the direction of subsequent chapters. An answer to these research questions will be given in this section of the thesis. The implications of the results will be further elaborated upon, as well as a cautionary reminder with respect to the significance thereof.

5.1.1 Research Question One

The first research question of this thesis stated the following: "Is there evidence of a liquidity premium on items within EVE Online?" In order to answer this research question, a selection of items was made out of a total of 22000 possible items, some of which are rarely ever traded on the financial markets of EVE Online. The decision was made to limit the selection of items to those that are most comparable to the financial products residing in the real world. This selection procedure yielded a total of 160 distinct items that could either be categorized as Raw Materials or Minerals. Subsequently, this thesis employed Fama and Macbeth (1973) regressions in conjunction with several measures of liquidity. These measures of liquidity were derived from the literature into the domain of the liquidity premium theory. Furthermore, several control variables were introduced into the regressions, which are known to be drivers of excess returns within the real world. All regressions were conducted over the entire sample period, and for various exclusion factors Ψ (as described in section 4.2 of this thesis), in order to correct for the extreme volatility present within the analyzed data. The results showed that little of the proposed effects by the liquidity premium theory seem to hold when taken into the context of EVE Online. Both ILLIQ and CPQS seem to have no significance when it comes to predicting monthly returns. There is, however, weak evidence in favor of LNVOLI being a predictor for monthly returns, with statistically significant relationships occurring in 2 out of 3 regressions of LNVOLI on monthly returns. Furthermore, STDY potentially proxies liquidity to a certain extent, and might interact directly with monthly returns as well. Lastly, no indications are present to suggest that R100 or R100YR have any significance with respect to predicting monthly returns. Considering all of the above, there is only weak evidence in favor of the idea that virtual financial markets exhibit patterns in congruence with the liquidity premium theory.

5.1.2 Research Question Two

The second research question of this thesis stated the following: "How does the liquidity of items within EVE Online behave over time?" In order to answer this research question, a similar approach to Ben-Rephael, Kadan and Wohl (2015) was taken. The entire sample period was split into two subsets, each containing exactly half the total number of months. Fama and Macbeth (1973) regressions were subsequently conducted over each of the two subsets for various exclusion factors Ψ, after which the results were analyzed. Additionally, liquidity movements over time were analyzed by means of looking at the evolvement of the yearly averaged liquidity measures employed within this thesis. The outcome of the regressions showed that the coefficients and statistical significance of most variables remained constant, as opposed to the regressions conducted over the entire sample period. A few notable exceptions were LNVOLI, CPQS and STDY. Firstly, the coefficient of LNVOLI did not show up as statistically significant in any of the regressions. Secondly, CPQS was shown to be statistically significant in the first subset of the data when Ψ was set to 5. Lastly, STDY was shown to be strongly significant in the second subset of the data, while not showing up as statistically significant in any of the regressions conducted over the first subset of the data. Furthermore, the analysis of liquidity over time portrayed how the active average player count and game updates are likely to have an impact on the liquidity of items present in the financial markets of EVE Online. Both LNVOLI and CPQS covaried to a certain extent with both of the aforementioned external factors. Note, however, that these covariances may be spurious and should be investigated further in order to gain more certainty.

5.1.3 Implications

Castranova, Knowles and Ross (2014) argued in their paper that the intersection between virtual worlds and the real world is slowly fading. Following this line of reasoning, the assumption can be made that the intersection between virtual financial markets and real-world financial markets is fading as well. This thesis has attempted to investigate whether this is actually the case. While the results are mostly inconclusive, weak evidence was found in favor of the idea that a liquidity premium is present on items within EVE Online. If this claim holds up under further scrutiny, it has two important implications. Firstly, financial market regulation should be taken seriously by virtual world developers. This entails ensuring that (1) market manipulation cannot run rampant, (2) financial market stability is guaranteed and (3) market confidence is retained, among others. Secondly, policymakers and virtual world developers should be in close contact with regards to how major virtual economies, and thus their respective virtual financial markets, function. The latter implication seems rather extreme, but if the intersection between virtual worlds and the real world truly is fading, and if virtual economies within these virtual worlds are continuing to grow in size, the way these virtual economies can affect real-world economies can have far-reaching consequences. In the most unfavorable scenario an economic recession in one or multiple virtual economies could significantly affect growth adversely in real-world economies.

5.2 Limitations

This section will describe several limitations with respect to the analysis performed within this thesis. Doing so will ensure that the outcomes of the performed analysis can be better put into a broader context. Both the methodology of this thesis as well as any external factors of influence will be discussed.

5.2.1 Lack of Data

Compared to most literature into the domain of the liquidity premium theory, this thesis employed data over a timeframe that is much shorter than usual. This is an important and relevant limitation with respect to any financial data analysis, where prolonged periods of time can be characterized by either growth or contractions of an economy. Economic contractions and economic growth, to a certain extent, can be found in EVE Online as well. While EVE Online is usually referred to as a “sandbox” game, indicating that there is no clear goal to achieve, there are certain aspects of the game that players engage in more frequently, relative to others. One of the most prominent aspects of the game is the player-versus-player combat, in which items can be removed from the game entirely. When two major groups of players fight over a certain objective for a prolonged period of time, destroying several billions of ISK in item value, this can lead to the economy of EVE Online as a whole to contract. On the contrary, when there are very little players engaging in player-versus-player combat, the production of items can exceed the destruction thereof, causing the economy to grow. Naturally, both economic growth and economic contractions have an impact on the prices of items within EVE Online, and thus their respective returns. Hence, in order to mitigate these relatively short-term influences on the prices of items, analyzing data over a longer timespan should lead to improved outcomes that are able to generalize better. Note that since virtual worlds are a rather novel concept, and that most do not survive the “test of time”, this limitation is not inherently tied to EVE Online, but to virtual worlds in general.

5.2.2 Comparability of Financial Products and Items

Items within EVE Online serve an entirely different purpose than financial products. Financial products are mostly intended to help finance projects, governments or individuals, while items within EVE Online mostly serve the sole purpose of usage. That is, items within EVE Online do not have an expectation of future return. While futures contracts, as discussed in previous chapters, attempt to mimic certain characteristics that items within EVE Online might have, they remain financial products and are not directly usable. Taking into account all of the above, actors in financial markets, whether those reside in the virtual world or the real world, may behave differently when they approach the acquisition or disposal of said financial products or items. This causes for differences to arise in both the returns and liquidity of financial products and items, two key determinants of all previous analysis.

5.2.3 Omitted Variable Bias

As has been touched upon previously, items are mostly incomparable to financial products. Thus, the availability of the variables of interest that pertain to either items or financial products differs significantly. Comparing the number of independent variables in the regressions employed by this thesis to a recent study by Ben-Rephael, Kadan and Wohl (2015) shows how only half of the independent variables were available for investigation within this thesis. Some of these variables, such as the dividend yield and the book-to-market ratio, are impossible to obtain for items within EVE Online. In contrast, the size and beta variables could theoretically be obtained for items within EVE Online. Beta herein is defined as the covariance of an items return with respect to the return of the market portfolio. Deriving what exactly the market portfolio should be within EVE Online was beyond the scope of this thesis. However, deriving it could yield for additional insights in future research. Lastly, in order to obtain the size variable for items within EVE Online it is imperative to know what the total number of items in circulation is. Since this information is not public knowledge within EVE Online, the cooperation of CCP Games would be required to obtain this information. An attempt to do so had been made by the author of this thesis, but cooperation was unfortunately not granted. Nevertheless, introducing more relevant variables to the regressions could lead to entirely different outcomes. It is thus of importance to take the aforementioned into account when analyzing the results presented within this thesis.

5.2.4 Ease of Access

The accessibility of real-world financial markets is certainly non-trivial as opposed to the accessibility of the financial markets of EVE Online. Within EVE Online every new player gets provided with a basic tutorial into the functionality of the financial markets within. However, a person in the real world would have to actively seek out information as to how operating on financial markets works, something not everyone is willing to do. Furthermore, most volume in real-world financial markets is not driven by individuals. Rather it is driven by highly specialized companies that have as sole purpose to do operations on said financial markets. These operations include, but are not limited to, buying and selling stocks, bonds and futures contracts. Given the fact that most volume is derived from these highly specialized companies, it naturally follows that most volume is created by highly skilled individuals that, in general, are experts at operating on these financial markets. The volume in EVE Online, however, is derived from every single player that chooses to operate on its financial markets. As a result, the discrepancy between highly skilled professionals and generally uneducated players causes the financial markets that these groups of people operate on to differ significantly. Hence, this leads to the financial markets of EVE Online displaying more signs of market inefficiencies as opposed to real-world financial markets, as can be exemplified by, for instance, the high incidence of fat-finger errors.

5.3 Future Research

There are several interesting avenues for future research this thesis was not able to address. Some of these have been briefly covered in previous chapters within this thesis. Nevertheless, this section of the thesis elaborates further on how exactly some of these research questions may shape the direction of subsequent research into virtual financial markets. Firstly, using other items entirely could provide for some essential insights as to how the financial markets of EVE Online function as a whole. Within this thesis the choice was made to limit the scope of the analysis to only 160 items derived from two item classes; Raw Materials and Minerals. However, there are around 22000 total items within EVE Online that could be investigated. Choosing another subset of items based on a different selection procedure could hence yield results that will either strengthen or discredit the outcomes of this thesis. Secondly, as has been pointed out above, more variables of interest could possibly be introduced into the regressions. The main issue herein is acquiring the cooperation of CCP Games, as well as forming an adequate market portfolio within the virtual economy of EVE Online, such that both the size and beta variables could be derived for every item under investigation. Thirdly, additional investigation could be done into the inner workings of the financial markets within EVE Online as a whole. For instance, it was briefly shown in section 4.1 that market manipulation might have a considerable impact on the returns of items within EVE Online. However, since it is beyond the scope of this thesis to investigate whether this is truly the case, future research could look specifically at this phenomenon. Lastly, other virtual financial markets could be investigated. While this thesis specifically focused on investigating whether a liquidity premium could be found on items within the virtual financial markets of EVE Online, there is a plethora of other virtual worlds that could be investigated. Doing so would provide for additional evidence in favor, or against, the notion that there is evidence of a liquidity premium being present in virtual financial markets.

6. Conclusion

This thesis investigated a novel concept in the finance literature. More specifically, it employed several Fama and Macbeth (1973) regressions in order to see whether the liquidity premium theory holds when taken into the context of the virtual financial markets of EVE Online. This thesis builds on previous research into the domain of the liquidity premium, as well as research into the domain of virtual worlds and virtual economies, by analyzing whether the intersection between the real world and virtual worlds is fading. Analyzing whether the latter statement is true was done by means of two research questions, which were formalized as follows.

1. **Is there evidence of a liquidity premium on items within EVE Online?**

2. **How does the liquidity of items within EVE Online behave over time?**

In order to answer the first research question, a selection of items to investigate had to be made. There is a total of 22000 items available within EVE Online, some of which are rarely ever traded. Eventually, the decision was made to select an item class that is most comparable to financial products within the real world. Considering the fact that futures contracts on commodities exist in the real world, the choice was made to limit the item classes under investigation to Raw Materials and Minerals, for a total of 160 distinct items in the years 2004-2017. Furthermore, the analyzed financial market was Jita 4-4, a major center of financial market activity within EVE Online. Subsequently, liquidity measures were introduced that were proven to accurately capture true liquidity in real-world financial markets. The employed liquidity measures were the Amihud (2002) liquidity measure (ILLIQ), the Closing Percent Quoted Spread (CPQS) and the natural logarithm of daily trading volume denoted in ISK (LNVOLI). Furthermore, control variables were introduced which are known to be drivers of return in real-world financial markets. All liquidity measures and control variables were then regressed on the monthly returns of items within EVE Online, using the Fama and Macbeth (1973) methodology. The outcomes of these regressions were reported for various exclusion factors Ψ, in an attempt to correct for extreme volatility within the prices of certain items. The results showed that both ILLIQ and CPQS had no significance when it comes to predicting monthly returns of items. However, weak evidence was found which suggests that LNVOLI significantly has an inverse relationship with monthly returns of items. Considering all of the above, there is only weak evidence in favor of the liquidity premium theory holding when taken into the context of EVE Online.

The second research question of this thesis investigated how the evolvement of liquidity within EVE Online behaved over time, and if these evolvements were congruent with those of the real world. This question was answered in two parts. Firstly, the sample period was split in two equal halves, after which identical regressions on both subsets of the sample period were conducted. Secondly, liquidity movements were analyzed by looking at the evolvement of the yearly averaged liquidity measures over time. With respect to the regression methodology, an identical approach to research question one was taken. The outcomes of the regressions conducted on each subset of the sample showed no relation to the real world. However, it was shown that LNVOLI did not significantly covary inversely with monthly returns in any of the regressions conducted in either subset, as opposed to the regressions conducted over the entire sample period. Furthermore, the evolvement over time of all of the liquidity measures employed within this thesis was analyzed. This results showed how both LNVOLI and CPQS covaried with the active average player count of EVE Online, as well as with certain game updates. Therefore, the answer to the second research question is that there is no conclusive evidence that suggests the liquidity premium shows diminishing returns over time within EVE Online, and that liquidity comoves with the active average player count, as well as with certain game updates.

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Appendix

Other Liquidity Measures

Brennan and Subrahmanyam (1996) employ two other measures of liquidity. Their measure is derived from Kyle (1985) λ, which defines the market impact of a transaction. Additionally, the fixed cost of a transaction gets included through using the coefficient of the differential between two trading days Dt-Dt-1 where Dt = 1 is a buy order and Dt = -1 is a sell order. This coefficient gets denoted by ψ. Afterwards, the coefficients used for the regression are formed. Kyle (1985) λ gets transformed into $C_q = \lambda\ q/P$ where q is the average size of a transaction in the security and P is its average price, C_q therefore denotes the proportional cost of transacting in a said security. In order to capture the fixed costs of transacting they employ ψ/P. Both transformed measures of liquidity then get used within a cross-sectional regression on NYSE stock data for the years 1984-1991, including all three Fama and French (1993) variables; market beta, firm size and book-to-market ratio. This method differs substantially from all of the literature mentioned before, as it introduces several new independent variables to the regression. The results show that an increasing and concave relationship between returns and illiquidity exists for C_q. However, while a liquidity premium is seen to be statistically significant for ψ/P, the predicted concavity is not present. Rather, it seems to be the case that for ψ/P a convex liquidity premium is present. Furthermore, an additional investigation is conducted into the seasonality of the liquidity premium as reported by Eleswarapu and Reinganum (1993). Both using the bid-ask spread as a measure of liquidity as well as C_q and ψ/P, no seasonality effects can be found when they are being used in conjunction with the Fama and French (1993) three factor model.

Datar, Naik and Radcliffe (1998) use yet another measure of liquidity that is derived from a stocks turnover rate, which is the number of shares traded as a fraction of the number of shares outstanding. They employ a Litzenberger and Ramaswamy (1979) methodology, which is a modified version of the Fama and Macbeth (1973) regression but with a GLS setup. The dataset consists of NYSE stocks for the years 1963-1991. Controlling for all three Fama and French (1993) variables they find that turnover has a negative and statistically significant relationship with excess returns as expected by the liquidity premium. More specifically, a 1% drop in the turnover rate of a stock on average leads to an increase in return of 0.045%. It must be noted here that the effect of turnover on excess returns seems to be order of magnitudes smaller than the effect of other measures of liquidity on excess returns.

Contrary to most findings above, as well as those mentioned in section 2.1 of this thesis, Rouwenhorst (1999) finds that there is no liquidity premium within 20 emerging markets. His methodology entails sorting stocks of each emerging market based on their turnover rate and then extracting the top and bottom 30% of highest and lowest turnover stocks, respectively. A "winners minus losers" portfolio is then constructed that goes long in the top 30% of highest turnover stocks and short in the bottom 30% of lowest turnover stocks respectively. It is found that the returns of these portfolios are not statistically different from zero, indicating that a turnover-return relationship does not exist for emerging markets. However, all three Fama and French (1993) variables including the momentum effect are found to be statistically significant when taken into the context of emerging markets. It can be argued that the difference in methodology and the inclusion of emerging markets leads to a different outcome, but the results do indicate that the liquidity premium theory does not hold in all cases.

Marketwide Liquidity

Pastor and Stambaugh (2003) take the literature on the liquidity premium in a different direction by analyzing whether aggregate marketwide liquidity (liquidity risk) is priced in when looking at the cross-section of excess stock returns. They propose that investors who require higher expected returns on their assets have higher exposure to the fluctuations in aggregate liquidity. With the observation of Campbell, Grossman and Wang (1993), who present evidence that lower liquidity corresponds to stronger price changes driven by volume, they extract their aggregate liquidity measure they define as γ. With some transformations they analyze this measure of aggregate liquidity on NYSE, AMEX and Nasdaq stock data for the years 1966-1999. It is concluded that stocks which exhibit higher covariance with liquidity risk perform better than stocks that exhibit lower covariance in the case of an adverse liquidity shock. Therefore, it provides for evidence that liquidity risk is priced within stocks.

Acharya and Pedersen (2005) analyze both aggregate liquidity and stock-specific liquidity on NYSE and AMEX stocks for the period 1964-1999. They employ ILLIQ as a measurement for stock-specific liquidity and aggregate these values over the cross-section of analyzed stocks to obtain the liquidity risk. Subsequently, three different liquidity beta's are derived which measure how strongly a stock's return covaries with liquidity risk. In principle, this model extends the CAPM model as proposed by Merton (1973) by adding additional liquidity beta's to the equation. This new model is found to be statistically significant, with a higher R^2. Using this new model, they estimate the return premium investors can achieve when they expose themselves to higher stock-specific liquidity as well as higher aggregate liquidity. The results show that the total monthly liquidity premium for stock-specific liquidity is 0.29% and the total monthly liquidity premium for being exposed to higher aggregate liquidity is 0.09%.

Liquidity Premium in the Corporate Bond Market

One of the earliest papers in the domain of the liquidity premium in corporate bonds is that of Perraudin and Taylor (2003). They analyze 1430 bonds of mostly European companies that are US dollar-denominated, for the years 1991-1998. These bonds are carefully selected in such a way that they are comparable and only AAA, AA and A graded bonds are taken into account. Since corporate bonds are inherently different from government bonds as they are issued by companies instead of governments, they are assumed to have a larger chance of defaulting. In order to correct for this an excess yield needs to be constructed for each of these bonds. The approach taken in their paper is to subtract an estimation of the risk-free interest rate of treasury bonds from the corporate bond in question. The outcome of this subtraction is from there on defined as the corporate spread. Furthermore, in order to model liquidity, they employ three different proxies; issue size, age of the issue and relative issue frequency. Subsequently, a multitude of regressions is run that regress corporate spreads on liquidity. Fama and French (1993) risk variables are employed as controls, among miscellaneous other variables that are of lesser importance with regards to the liquidity premium theory. The results show that their measures of liquidity have a statistically significant relationship with corporate spread. Moreover, as the time to maturity increases, the premium investors pay for liquidity seems to increase. The latter is in line with the findings previously discussed, with regards to governmental bonds.

De Jong and Driessen (2005) investigate whether liquidity risk has an effect on the expected returns of corporate bonds. They consider two types, equity market and treasury bond market liquidity risk. In order to capture the liquidity risk present in the equity market they extract the cross-sectional median from the ILLIQ measure from 1500 different stocks. Capturing the liquidity risk present in the treasury bond market is done by analyzing the bid-ask spread of long-term US treasury bonds. The data employed in the study is US corporate bonds for the years 1993-2002. In contrast to Perraudin and Taylor (2003), the full range of AAA-rated bonds to CCC-rated bonds is taken into account. Subsequently, they regress excess yields on both liquidity measures as well as control variables. These control variables control for market risk and volatility risk, whereby market risk is measured by the return of the value weighted returns of NYSE, AMEX and Nasdaq stocks, and volatility risk is taken from the Dow Jones Euro Stoxx 50 Volatility Index. After these regressions are run it is estimated that the liquidity risk premium is around 0.45% for investment grade (AAA-BBB) bonds and around 1% for speculative grade (BBB-CCC) bonds.

Lastly, Chen, Lesmond and Wei (2007) analyze 4000 investment and speculative grade US corporate bonds for the years 1995-2003. They analyze the effects of liquidity, measured in three distinct ways, on the corporate yield spread. The yield spread herein is computed as the differential between a bond's yield and the maturity-matched treasury bond, which is in line with earlier literature on the topic. Furthermore, in order to capture liquidity, they employ multiple liquidity measures. These liquidity measures include the bid-ask spread, the incidence of zero return days and the LOT (Lesmond, Ogden & Trzcinka, 1999) measure. The latter measure is based on the difference between the buying cost and selling cost of an asset, whereby a greater spread indicates greater transaction costs and thus higher illiquidity. Controlling for a multitude of bond-specific variables, macroeconomic conditions, tax effects, equity products volatility measures and accounting variables they find a positive and statistically significant relationship between all three measures of liquidity and excess yields. Moreover, the LOT estimate alone explains 7.57% and 21.83% of the variation in the yield spread of investment and speculative grade bonds respectively. A subsequent analysis in the magnitude of the explainable variability shows that as the bid-ask spread goes up by 0.01%, the yield spread increases by 0.042% and 0.023% for investment and speculative grade bonds respectively.

Liquidity Premium in the Options Market

Brenner, Eldor and Hauser (2001) investigate the effects of liquidity in options. Options are financial derivatives that offer the buyer a right to buy or sell an underlying asset at a prespecified price during a certain period of time. This type of financial asset is used predominantly for hedging or speculative purposes and is inherently different from the financial assets previously discussed. Consequently, it is of interest to see whether they exhibit patterns commonly found in the financial products mentioned in earlier sections of this thesis. In order to investigate whether these patterns are visible they analyze options put into the market by the Central Bank of Israel (BI) and those traded on that are exchange traded (ET). The difference between these options is that BI options cannot be traded prior to their expiration date, whilst ET options can be. The result is that ET options are considered to be the more liquid option. In order to test whether ET options trade at a comparative price differential they analyze 566 options for the years 1994-1997. Because the BI options are not actually tradable, they devised several methodologies in order to simulate its price behavior over time based on historical information. As a result, they conclude that BI options trade at a discount of around 18 to 21% as opposed to similar ET options. Therefore, since the discount is economically very large and statistically highly significant, a liquidity premium is seemingly present within these options.

On the contrary, Deuskar, Gupta and Subrahmanyam (2010) show how illiquid over-the-counter (OTC) options trade at a premium comparative to their liquid variant. They arrive at this conclusion by analyzing various OTC options over a period of 29 months from 1999-2001. The difference between OTC options and the aforementioned type of options is that OTC options do not trade over an exchange. These options are traded directly from buyer to seller and vice versa, which implies that participants can define their own terms. Regardless, they are tradable and thus pose for an interesting avenue of research. Within the paper they employ the bid-ask spread as a measure of liquidity, since this is the only measure available in OTC markets. Controlling for the risk-free interest rate, volatility, skewness and kurtosis of historical interest rates and trading volume of interest rate futures they conclude that more liquid OTC options trade at a premium as opposed to their less liquid variant. This finding is contradictory to the paper discussed above and in sharp contrast to the liquidity premium theory. Their explanation for this phenomenon lies in the fact that buyers and sellers have to directly negotiate within OTC markets. Within markets, and in line with the liquidity premium theory, buyers of financial products demand a reduction in price to be compensated for illiquidity while sellers demand an increase. While buyers predominate over sellers in most markets, the opposite is said to be true for OTC markets. Consequently, since sellers predominate over buyers in OTC markets they require to be compensated with higher prices.