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ESCOLA DE ECONOMIA DE SÃO PAULO

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SHORT SELLING RESTRICTIONS AND PUT-CALL PARITY ARBITRAGE

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Dissertação apresentada à Escola de Economia de São Paulo como pré-requisito à obtenção de título de mestre em Economia de Empresas.

Orientador: Fernando Chague
Co-orientador: Bruno Giovannetti.

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Resumo

Short sellers apresentam um papel fundamental para eficiência dos preços. Usando uma medida específica de ineficiência dos preços, desvios da paridade put-call, o presente trabalho evidencia como restrições às vendas a descoberto limitam a arbitragem. Particularmente, é apresentado que restrições às vendas a descoberto limitam a arbitragem não somente pelos maiores custos de transação que são impostos, mas também por meio de uma redução no número de arbitradores presentes no mercado. Nós utilizamos uma base de dados única que permite identificar uma proxy para o número de investidores arbitrando a paridade put-call no mercado brasileiro. Nossos resultados apontam para uma redução do número de arbitradores conforme as taxas de aluguel aumentam, mesmo após controlar por outras características das ações como volume e tamanho de mercado. Além disso, nós encontramos que a dispersão intradiária das taxas de aluguel não afetam o número de arbitradores nem os desvios da paridade put-call.

Palavras-chave: venda a descoberto, paridade put-call, arbitradores, taxas de aluguel.
JEL: G13, G14

Abstract

Short sellers play an important role in price efficiency. Using a specific measure for price inefficiency, that is, violations of the put-call parity relationship, this work provides evidence of how short-selling constraints limit arbitrage. In particular, it is shown that short-selling restrictions limit arbitrage by imposing higher transaction costs and reducing the number of arbitrageurs in the market. We use a unique database that permits us to identify a proxy for the number of investors arbitrating on the put-call parity in the Brazilian market. Our results show a contraction in the number of arbitrageurs as the loan fees increase, even after controlling other stock characteristics such as volume and market size. Additionally, we find that the intraday dispersion of the loan fees does not affect the number of arbitrageur nor the deviations from the put-call parity.

Keywords: short-selling, put-call parity, arbitrageurs, loan fees.
JEL: G13, G14

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1 Introduction

The no-arbitrage condition is a central assumption in many asset pricing models. Simply put, it states that two similar assets with the same risk and return should present the same price. As pointed out in Ofek et al. (2004), if this condition is violated, we should have limits to the arbitrage and a reason for these price divergences. The present work explores how short-selling restrictions limit arbitrage and reduce price efficiency by generating higher costs for arbitrage and reducing arbitrageurs in the market. We use the deviations of put-call parity as a price inefficiency measure and show that these deviations are correlated with short-selling restrictions. Moreover, using a unique database of the number of put-call parity arbitrageurs, we show that high loan fees are associate with a reduction in the number of arbitrageurs.

Short-selling has a central role in conveying information to stock prices. A vast literature suggests that short sellers are informed traders and have an important function in the price discovery process (see, for instance, Boehmer et al. (2008); Diether et al. (2009); Boehmer and Wu (2013)). In addition, given the short-selling nature, benefiting from a stock price decline, numerous studies provided evidence that short-sellers are important to incorporate negative information into stock prices (see, for example, Aitken et al. (1998);Engelberg et al. (2012); Hao et al. (2013)). Therefore, it is possible to say that frictions in the stock lending market may deeply affect stock prices.

A key characteristic of short selling operation is that it requires the investor to borrow a stock. In the great majority of countries, the stock lending market has an over-the-counter nature. Loans are negotiated directly between borrowers and lenders. Different investors may have a highly distinguished ability to find shares to loan and avoid high loan fees (see, for instance, Chague et al. (2017)). This institutional complexity adds frictions in the market that hinder or even prevent short-selling.

The impact of short-selling restrictions on asset prices has been explored theoretically and empirically in many works since the seminal paper Miller (1977). Some works explore that short-selling restrictions may difficult or partially prevent the negative information incorporation into stock prices, looking only to the equity market. Some recent examples are Bonomo et al. (2020), and Chu et al. (2020) that shows that short-selling

constraints have a causal impact on stocks' abnormal returns and some asset pricing anomalies, respectively.

Another part of the literature also incorporates the stock options market examining the relations between put-call parity violations and short-selling restrictions. Indeed, put-call parity should only hold if it is assumed that the investor can short the underlying asset. There is evidence of a strong correlation between deviations from put-call parity and stock loan fees (see, for example, Ofek and Richardson (2003);Lamont and Thaler (2003);Ofek et al. (2004);Evans et al. (2009)).

These previous works showed that higher loan fees would represent higher costs to arbitrate put-call parity deviations. Indeed, if a put-call parity violation is observed in the direction of a short sale restrictions[1], an investor would short the stock and buy the synthetic share to exploit the arbitrage opportunity. If this investor faces a high enough loan fee, it can prevent him from short the stock, and the arbitrage opportunity would not be exploited, which would make the put-call parity deviations remain. However, the price inefficiency generated by short-selling constraints is not generated only by the higher costs that these restrictions impose on arbitrage. High loan fees can make part of the arbitrageurs leave the market since they can severely reduce the profitability of the arbitrage. Considering that arbitrageurs are generally informed traders when their presence is reduced in the market, the price inefficiencies would become more frequent.

As pointed in Ofek et al. (2004), the short-selling constraints imposed by high loan fees would generate deviations from the put-call parity in the direction of the stock prices being higher than the synthetic stock prices. However, if our hypothesis of reducing the number of arbitrageurs is correct, the deviations occurring in the short-selling direction would not be the only "anomaly" present in the market. The reduction of arbitrageurs generated by higher loan fees would make the dispersion of put-call parity deviations increase with the loan fees even if we consider the short-selling costs to calculate the parity. The reduction in arbitrageurs would make more put-call parity occur in both directions, even accounting for the short-selling costs. Furthermore, to verify our hypothesis, we need to identify a negative relation between stock loan fees and the number of put-call parity arbitrageurs.

The main difficulty in testing our hypothesis that short-selling constraints reduce the number of put-call parity arbitrageurs comes from the fact that, in general, the quantity

[1] It means that the stock price is higher than the synthetic stock price.

of arbitrageurs is not observable. However, using a unique data set, we can identify the number of investors that traded a stock, a call, and a put option of the underlying stock on the same day in the São Paulo Stock Exchange. More than that, we can identify the total number of institutional investors trading these three assets conjointly. It gives us a good proxy of the number of investors arbitrating put-call parity deviations. We cannot claim that all investors trading a stock, a call, and a put of the underlying stock exploit put-call parity deviations. However, if they are, in fact, arbitrating the price disparities, they necessarily need to trade these assets. Therefore, the number of investors operating the three assets on the same day should be a good proxy for the number of put-call parity arbitrageurs. The proxy data for the number of arbitrageurs comes from the Brazilian Securities Commission (CVM), an independent agency associated with the Ministry of Finance that regulates the capital markets in Brazil.

Moreover, data regarding the stock loan fees is fundamental to our analysis. Differently from most countries, market-wide data on stock lending fees are publicly available in Brazil. Similar to other countries, it is an over-the-counter market. However, all the transactions are centralized and registered in the São Paulo Stock Exchange (B3), making the data regarding the average loan fees practiced in a given day publicly available. We also obtained from B3 data regarding the standard deviation of the loan fees of all lending deals closed during a business day. This intraday volatility of the loan fees can be used as a measure for short-selling risk. It permits us to evaluate how the short-selling risk affects the put-call parity deviations, similarly to the proposed in Engelberg et al. (2018). Furthermore, B3 also provides intraday data for options quotes and stock prices. We use these intraday data, making it possible to avoid problems related to nonsynchronous trade when we calculate the put-call parity deviations.

We evaluate the correlation between put-call parity and short selling restriction in the Brazilian market and compare it with the evidence found in other papers for the U.S market. Our results point out a strong correlation between put-call parity deviation and short-selling restrictions in line with the findings for the U.S. market (Ofek et al. (2004), and Evans et al. (2009)). We also show a positive relation between put-call parity dispersion and loan fees even after adjusting the parity by the short-selling costs. Finally, we provide evidence that this last result is generated by a reduction in the number of arbitrageurs when the loan fees rise. Our results point to a considerable contraction of the number of arbitrageurs when the loan fees are very high, above the 95th quantile.

Additionally, our results show that the short-selling risk measured as the loan fees intraday volatility does not explain the put-call parity deviations and is not correlated with the number of arbitrageurs.

The present work aims to contribute to the literature by providing evidence that the higher transaction costs generated by short-selling restrictions are not the only source of price inefficiency when we look to put-call parity deviations. Using a rich data set with the number of put-call parities arbitrageurs, we show that higher loan fees reduce the number of arbitrageurs, and consequently, more price disparity dispersion is observed. According to our findings, short-selling constraints impose limits to arbitrage not only by increasing the transaction costs but also by reducing the number of arbitrageurs in the market.

The paper is organized as follows: after a brief literature review in Chapter 2, we present the theoretical framework and some details regarding the Brazilian equity lending market and options market in Chapter 3. The data and descriptive statistics are presented in Chapter 4. Chapter 5 presents the empirical results. Finally, in Chapter 6, we conclude.

2 Related Literature

Since the classical paper of Miller (1977), many other papers explored theoretically and empirically how frictions on short-selling could impose limits to arbitrage in financial markets. It is theoretically shown in Miller (1977) that the asset prices under short-selling restrictions would reflect only the most optimistic expectations, which can cause overpricing. Further works, such as Hong and Stein (2003) and Hong et al. (2006), provided additional theoretical evidence of the effects of short-selling restrictions over stock prices. The first showed how short-selling constraints limit the negative information incorporation into prices and explain some stylized facts about market crashes. While the second associates the short-selling restriction with speculative bubbles that arises in a model with heterogeneous agents' beliefs.

Additionally, many papers provide empirical evidence that short sellers are informed traders and play a crucial role in market efficiency. For example, Aitken et al. (1998) using intraday data for the Australian stock market showed that short sales are related to bad news. Another work that provides evidence that short-sellers are informed traders is Engelberg et al. (2012). This paper verified that the negative relation between short sales and future returns is much stronger on days with negative news.

Some previous works empirically verified the occurrence of put-call parity violations however without explicitly relate them with short-selling constraints (see, for instance, Klemkosky and Resnick (1979), Nisbet (1992), Kamara and Miller (1995), among others). For example, Klemkosky and Resnick (1979) does not find systematic violations of the put-call parity relationship analyzing a sample of 15 stocks during the first year after the introduction of put option trading on the CBOE. It was shown that part of the put-call parity deviations that they observed occurred in the sense of the stock price being higher than the synthetic stock price, approximately 55% of the deviations occurred in this direction. However, other factors such as the early exercise premium of American options were not considered, so the violations cannot be claimed due to short-selling constraints. Further evidence of put-call parity violations was presented in Nisbet (1992). Using a sample of 55 stocks traded in the London Traded Options Market for six months in 1988, it was shown that most of the put-call parity deviation could not be explored after taking into account the transaction costs. Once again, more deviations occurred in the short-selling

direction; however, American options' early exercise premium was not taken into account. Additionally, Kamara and Miller (1995) does not observe put-call parity violations using a sample of European index options.

The first papers to associate option markets with short-selling impediments were Figlewski and Webb (1993) and Lamont and Thaler (2003). The first one provided evidence that trading options reduce the effects of short sales restrictions and improve information efficiency in the stock market. Their empirical results suggest that short sales constraints impair the negative information incorporation into stock prices and that options seem to alleviate this effect. The second observe severe put-call violations associated with U.S. technology stocks during an equity carve-out. It is shown that high short-selling costs explain these violations.

The other two important references in this literature for our work are Ofek et al. (2004), and Evans et al. (2009). We compare our results with the ones found in these papers. The first one showed that put-call parity violations are asymmetric in the direction of short sales restrictions. Using an extensive dataset with more than 1,500 stocks for the U.S. market, they provided evidence that deviations from put-call parity are associated with high short-selling costs and the options' maturity. We also find these results for the Brazilian market. The second presented evidence that fails to deliver the borrowed stock can, in some cases, alleviate short-selling constraints and consequently diminish the violations of put-call parity. Additionally, it also showed that the put option prices are positively related to the short-selling restrictions.

Some recent papers estimate the causal impacts of short-selling constraints in the stock abnormal returns and asset pricing anomalies, in particular, Bonomo et al. (2020), Chu et al. (2020). The first one used an exogenous variation in Brazilian loan fees generated by a tax arbitrage opportunity to identify the causal effect of short-selling restrictions over stocks' abnormal returns. In Chu et al. (2020), the causal impact of short selling restrictions over some asset pricing anomalies are evaluated using a natural experiment. The author studied the effects of reducing short-selling constraints generated by a pilot program of Regulation SHO on asset pricing anomalies. Another recent work related to this literature is Ramachandran and Tayal (2021). It shows that investors demand more put options for mispriced stocks with restrictions on short sales. In contrast, market makers increase the premium for these put options to compensate for the higher costs of delta hedging generated by the short sales restrictions.

Other papers analyze the Brazilian lending market, especially, Chague et al. (2014) and Chague et al. (2017). These two papers use a unique dataset of lending deals closed in the Brazilian stock market. In Chague et al. (2014) it is provided empirical evidence that short sellers are informed investors and that increases in the short demand are associated with lower returns. Furthermore, it is also shown that the short-selling restriction is related to stock overpricing. Using the same data set Chague et al. (2017) shows an important feature of the stock lending fee market. The over-the-counter nature of this market makes different investors with distinct connections with brokers pay different loan fees.

3 Theoretical Framework, Option Market and Short Selling in Brazil

This chapter is divided into two subchapters. The first subchapter provides some preliminary information regarding the put-call parity, its relation with the stock loan fees, and the number of put-call parity arbitrageurs. The second presents information regarding the options market and stock lending market in Brazil.

3.1 Theoretical Framework

Put-Call Parity

Under the condition of no-arbitrage, the put-call parity states that a portfolio with a European put option on a non-dividend-paying stock plus a share of this stock and a portfolio with a call option with the same maturity and strike plus a zero-coupon bond with a face value equal the option strike must have the same payoff. We have then the following equation:

$$S + P = PV(K) + C, \tag{3.1}$$

where S is the stock price, P is the put option price, $PV(K)$ is the price of a zero-coupon bond with a face value of K being K the strike price, and finally, C is the call option price.

As stated in equation (3.1), the parity is valid for European options on non-dividend paying stocks. If we consider stocks that pay dividends or/and American options, we must add on the right-hand side of the equation (3.1) the present value of the paid dividends or/and an estimate of the early exercise premium as done in Ofek et al. (2004). However, since the options are adjusted for dividend payments in the Brazilian option market, and there are no American put options, we can use the put-call relation as presented in equation (3.1). Indeed this result is summarised in Table1.

Table 1 – Put-Call Parity Dividends: Brazilian Market

		$S_T > K$	$S_T < K$
Portfolio I : Call + Bond(K)	Call	$S_T - (K - D)$	0
	Bond(K)	K	K
	Total	$S_T + D$	K
Portfolio II : Put + Stock	Put	0	$(K - D) - S_T$
	Stock	$S_T + D$	$S_T + D$
	Total	$S_T + D$	K

It is possible to see that independently of the stock price being higher or smaller than the strike at the option maturity (T), Portfolio I and Portfolio II's payoffs are equal. For example, if we have $S_T > K$, the call option will be exercised, resulting in a payoff that equals the stock price at T minus the option strike price (K) discounted by the dividend paid (D) by the stock during the option maturity. The bond will yield a payoff equal to its face value K. Joining these two payoffs, Portfolio I yields a payoff equal to the stock value plus the dividend paid during this period ($S_T + D$). Portfolio II's put option would not be exercised since $S_T > K$ generating a 0 payoff. In contrast, the stock will generate a payoff equal to its value at T plus the dividend paid in this period. Portfolio II will also present a payoff equal to the stock price at T plus the dividends paid ($S_T + D$). The logic for the case when $S_T < K$ is analogous, and as shown in Table 1 both portfolios will have the same payoff. Therefore, we show that equation (3.1) would hold considering the dividend adjustment made in options strikes in the Brazilian market.

Using the equation (3.1), we can define the synthetic stock price that is the implied stock price by the put-call parity. The following equation gives it:

$$S^{Synth} = C + PV(K) - P \tag{3.2}$$

We use the equation (3.2) to calculate the put-call parity deviations, that we define as the difference between the actual stock price and the synthetic stock price. The put-call parity deviation is given by:

$$PCD_{i,t} = \left(\frac{S_{i,t} - S_{i,t}^{Synth}}{S_{i,t}} \right) 100 \tag{3.3}$$

where $S_{i,t}$ is the stock price, $S_{i,t}^{Synth}$ is synthetic stock price, i is the index for ticker and t the index for time.

Put-Call Parity Violation, Loan Fees and Arbitrageurs

To the no-arbitrage condition hold, the synthetic stock price must be equal to the stock price. If these prices deviate, we have an arbitrage opportunity. Assume that the actual stock price is higher than the synthetic stock price, i.e., there is a deviation in the short sale direction. In this case, an investor can exploit the arbitrage opportunity by shorting the stock and buying the synthetic share [1].

As pointed in Appendix C, it is expected that the deviations from the put-call parity are correlated with the stock loan fees. A higher loan fee would represent a higher cost to explore a disparity between the stock price and its synthetic price. In fact, previous works such as Ofek et al. (2004) and Evans et al. (2009) reported a strong correlation between put-call parity deviations and loan fees. These previous works showed that the costs associated with short-selling are a direct source of price inefficiency that prevents the convergence between the stock prices and the synthetic ones.

However, there may be other sources of price inefficiency associated with short-selling costs. Higher loan fees not only prevent the convergence of stock prices and synthetic prices but may also reduce the number of arbitrageurs trying to exploit put-call parity violations. It is expected that at least part of the arbitrageurs face an incentive to avoid exploit the put-call parity deviations when there are short-selling constraints since the higher costs reduce the arbitrage profitability. If it is the case, we might observe higher loan fees associated with higher put-call parity deviations even after considering the short-selling cost. Since there may be fewer arbitrageurs when the loan fees rise, we expect to observe a higher dispersion of the put-call parity violations even considering the short-selling costs.

[1] In Appendix C, we present the details of how an investor could possibly explore this arbitrage opportunity.

3.2 Option Market and Short Selling in Brazil

Brazilian Stock Options Market

The Brazilian stock options market is pretty similar to other countries' markets. However, it presents some idiosyncratic characteristics that should be highlighted. It is a market regulated by the São Paulo Stock Exchange (B3); all stock options are traded in the São Paulo bourse. B3 is also responsible for establishing the required margins for all stock options contracts.

One crucial feature of Brazil's stock options market is that only a few option stocks are traded regularly. It is, in general, an illiquid market. It is possible to say that only the 20 largest firms in the Ibovespa Index present options being traded on a regular basis. However, since 2015 the liquidity in this market has been growing. Our dataset could identify almost three times more stock options been traded regularly in the period between 2015 and 2018 than in the period between 2012 and 2014.

Another distinctive characteristic of the Brazilian stock options market is that all put options are European, while the call options can be either European or American. However, all options are "protected" against dividend payments, which means that the strike price is adjusted at the dividend ex-date in order to keep the option price unaffected by the dividend payment. Particularly, in the dividend ex-date, the strike price is reduced by the same amount as the dividend paid per share. This adjustment makes the American call options virtually identical to the European call options. A well-known fact in options trading that it is never optimal to exercise early an American Option in which the underlying stock does not pay dividends (see Hull (2004)). The adjustment made in the options' strikes due to dividend payment makes them equal to options of non-dividend paying stocks. Thus, in the Brazilian market, American call options are nearly identical to European call options[2].

Brazilian Stock Lending Market

The stock lending market in Brazil has a unique microstructure. It is an over-the-counter market; however, all lending transactions are registered and cleared in the

[2] In some cases, it is observed the early exercise of American call options in the Brazilian market; however these events are probably due to liquidity constraints faced by the investor or inattention of individual traders.

São Paulo Exchange (B3). Moreover, this market is regulated by the Brazilian Securities Commission (CVM) and the Brazilian Monetary Council (CMN). The São Paulo Stock Exchange (B3) is responsible for establishing the margins required for the lending contracts and bringing together counterparties in the market, i.e., borrowers and lenders.

B3 also provides an electronic trading platform in which brokers can place their clients' orders directly. In this system, borrowers can electronically hit lenders' offers. It is also possible for the borrowers to place loan bids; however, it is far less frequent than lenders placing their offers, as pointed out in Chague et al. (2014). Despite the possibility of executing lending transactions hitting lenders' orders on the screen, the great majority of the lending contracts are still being negotiated through over-the-counter transactions for the period we analyze here, September 2012 through December 2018. In either case, the transactions are cleared and registered by B3.

Furthermore, the investors are free to determine the lending contract's maturity and other characteristics, such as the lender's possibility of recalling the shares before the contract term. All the contracts also explicitly inform the loan fee that the borrower must pay at the end of the contract. This fee is informed at an annual rate. For example, the monetary value that a borrower pays to the lender at the maturity of the contract is given by the following formula:

$$\varphi = [(1 + f)^{T/252} - 1]S_t,$$

where f is the annual loan fee rate, T is the contract's maturity in days, and S_t is the stock price in the day in which the contract was negotiated.

Another important piece of information is that B3 makes the average loan fees of the stocks contracts opened in a given day public available on its website. The average loan fees are also easily found and aggregated in other financial platforms such as Economatica.

4 Data

This paper analyses the relation between the violations of put-call parity in the stock options market, short-selling constraints measured by stock loan fees, and the number of put-call parity arbitrageurs. We employ three data sets, one for the options market, one for loan fees in Brazil, and another that provides information regarding the number of put-call parity arbitrageurs. The first two come from São Paulo Exchange (B3) and Economatica platform and spams from September 2012 through December 2018, while the data regarding the number of arbitrageurs comes from the Brazilian Securities Commission (CVM) and spams from January 2012 through December 2017.

Put-Call Parity

The options data comes entirely from B3. To calculate the synthetic stock price as given by equation (3.2), we need a put option and a call option with the same strike and maturity[1]. Initially, we identify all options pair traded in the period from September 2012 until December 2018. To calculate the synthetic stock price, we need that the put and call option prices were synchronized. Since the Brazilian option market is illiquid, we would have non-synchronized prices for the put and call that composes the option pair if we use options close price. It is not possible to ensure that the last trade for the put and the call occurred simultaneously.

To deal with this issue, we use intraday data for the option prices. In particular, we use the buy and sell order books provided by B3. These datasets contain all buy and sell orders placed in the options stock market for a given day. We remount these raw datasets to obtain the limit order book, i.e., the bid and ask offers for all options pairs we identified early[2]. After that, we select for each option pair the last bid and ask prices that were available simultaneously for the put and the call option. Doing this, we ensure that the

[1] As explained in the previous section, in the Brazilian market, we have only European put options. Moreover, American calls and European calls are virtually identical since the options are "protected" against dividend payments. The early exercise of an American option would never be optimal. Then we do not need to address issues related to the early exercise of American call options that form our options pairs.

[2] To obtain the limit order book we use an algorithm based on the one provided by the *R* package *GetHFData*. Details about this *R* package can be found in, Perlin and Ramos (2016)

prices used to calculate the synthetic share are simultaneous. Following the same approach of Ofek et al. (2004) and Evans et al. (2009) we use the mid-quote prices.

Additionally, to calculate the put-call parity violations as stated in equation (3.3), we need a stock price measure simultaneous to the options prices. Then we use intraday data for stock prices; in particular, we use minute by minute data for the stocks' trade prices and select the stock trade price verified at the same minute as the selected options bid-ask prices. It ensures that we are comparing synchronous prices for both options and stocks.

We have initiated with a total of 163,430 option pairs and 68 tickers for the analyzed period. However, based on Ofek et al. (2004) and Evans et al. (2009), we apply some filters in our data to eliminate bad data, possible record errors, and shallow liquidity options. First, we select only the options pairs near the money that is $|ln(S/K)| < 0.1$ and which maturity is between 6 and 100 trading days. We also apply another set of filters mainly to deal with record errors and low liquidity options. This set of filters is detailed in Appendix B. After passing all the filters, we have 158,219 option pairs and 63 tickers on our sample.

Loan Fee and Loan Fee Intraday Volatility

The loan fee data comes from the Economatica platform for the period between May 2014 until December 2018 and from B3 for the period prior to May 2014[3]. We use the average loan fee for the open contracts in a given day that is public information provided by B3[4]. The loan fee intraday volatility is the standard deviation of the loan fee of all lending deals closed in a given day for a given stock. This data comes directly from B3 and it is not publicly available. We have loan fee data and the intraday volatility of the loan fees for all the 63 tickers present in our option pair sample.

Number of Arbitrageurs

The number of arbitrageurs is given by the total of investors that operates a stock and a call and put options of this underlying stock in the same day. It is possible to obtain the total of investors and the total of institutional investors that operate the stock and the

[3] In fact, all data regarding the stock lending market comes from B3, the Economatica platform only aggregate the information provided by B3. We use loan fee data directly from B3 for the period before May 2014 because the Economatica platform does not maintain data before this date for this variable.

[4] For now onwards, we refer to average loan fees as loan fees for simplicity.

call and put options of this underlying stock. This data comes from CVM and is available for the 63 stocks present in our database of the put-call parity deviations. It is worth mention that it is not possible to say that all investors operating a stock, a put and a call option of the underlying stock are arbitrating the put-call parity. However, if they are arbitrating, they will necessarily trade these three assets. Therefore, it is reasonable to think that this variable is a good proxy for the number of put-call parity arbitrageurs.

Other Variables

To calculate the stock synthetic price we assume that the investor can lend at the risk free rate. We use the 30-day DI Swap as a measure of the risk-free rate. This data is provided by the Brazilian Center for Research in Financial Economics of the University of São Paulo (NEFIN) website. Other variables that will be used as controls in our regressions such as the stock volume, size, book to market ratio, stock return and stock volatility are all obtained in the Economatica platform.

Descriptive Statistics

Table 2A describes our sample of put-call parity deviations after we apply all filters. It is possible to see that a total of 63 different tickers appears on the entire sample and 158,219 option pairs; however, we have an average of almost 16 different tickers per day. The option pair negotiations are concentrated mainly in highly capitalized Brazilian firms such as PETR4, VALE3, B3SA3, ITUB4, BBDC4, among others. Smaller firms appear on our sample, however, not regularly. Moreover, it is also possible to note that call options present a much higher volume and smaller bid-ask spread than the put options. It is a pattern also presented by the U.S. stock options, as shown in Ofek et al. (2004).

Table 2B describes our sample of the number of put-call parity arbitrageurs. We consider the same stocks present in the put-call parity sample; however, we do not have data available of the number of arbitrageurs for some stocks. Therefore, we observe the number of arbitrageurs in 57 different tickers that are also present in our put-call parity sample. Additionally, it is essential to note that the arbitrageurs' sample is aggregate in the stock level, while our other database is aggregated in the option pair level. It explains some differences in the descriptive statistics of some variables that are present in both data sets. Moreover, the sample period is slightly different for these two data sets, as mentioned at the beginning of this section.

5 Empirical Results

This chapter is divided into two subchapters. The first one presents how short-selling constraints are correlated with put-call parity violations and that the dispersion of put-call parity deviations adjusted by short-selling costs increases with loan fees. The second explores the relationship between loan fees and the number of put-call parity arbitrageurs.

5.1 Short-Selling Constraints and Put-Call Parity

This subchapter is divided in two sections. In the first one, we explore the correlation between put-call parity violations and short-selling constraints in the Brazilian market and compare it with the U.S. market results reported by other papers. In the second subsection, we show that loan fees are correlated with the price disparities dispersion even after we account for the short-selling cost.

5.1.1 Short-Selling Costs and Put-Call Parity Deviations

To estimate the correlation between loan fee and the put-call parity deviations, we use the full sample of options pairs presented in the last chapter. It is important to highlight that the option and stock prices we use are synchronized. The put-call violations is calculated using the equation 3.3. It is used the last mid-quote prices available simultaneously for put and call options in a given day and the stock trade price at that same minute.

Table 3 presents a description of the put-call parity deviation conditional on the loan fees. It is possible to note that the average put-call violation increases considerably when we condition our sample in the loan fees that are in the 95th quantile. The average put-call parity deviation increases from 0.18% in the full sample to 1.36% in the sample considering only the loan fees in the 95th quantile. Furthermore, the great majority of the put-call deviations occurs in the direction of short sales restrictions, i.e., the stock price higher than the synthetic stock price making $PCD_{i,t} > 0$. In fact, 77.03% of the violations are generated by stocks having higher prices than synthetic shares; this proportion rises to

93.75% when we condition our sample on the highest loan fees (fees in the 95th quantile). It provides preliminary evidence of a positive relationship between put-call parity violations and short-selling restrictions. As pointed out in Ofek et al. (2004), if the short-selling constraints play no role in the parity violation, it would be expected that the proportion of the deviations occur equally in both directions, $PCD_{i,t} > 0$ and $PCD_{i,t} < 0$, and it would not differ when conditioned in higher fees. Additionally, further evidence is provided by Figure 1 in which it is possible to see the empirical distribution of the put-call parity conditioned on the loan fees. It is possible to observe that the left tails are identical regardless of the loan fees; however, as we condition our sample in higher loan fees, the right tails become denser. This preliminary evidence is also in line with Ofek et al. (2004).

The regressions presented in Table 4 shows a positive relation between put-call parity deviations and loan fees, which is expected given the preliminary evidence showed earlier. We find a positive slope for loan fees in relation to deviations from put-call parity. Considering the regression with all controls presented in column 3 of Table 4, an increase of 1% in the annual loan fee would represent an increase of almost 0.06% on the parity deviation at a 1% significance level. The magnitude found for the loan fee coefficient is very close to the one verified for the American market in Evans et al. (2009). Furthermore, the adjusted R^2 of the specification in column (3), including the loan fees, controls, and fixed effects, is almost twice the adjusted R^2 of a specification (4) that includes the controls and fixed effects but does not add the loan fees.

On the other hand, the intraday loan fee volatility does not appear to be significant. This variable can be interpreted as a measure of the short-selling risk. A higher intraday loan fee volatility would represent a higher risk for a short-seller considering that if the investor has his position recalled, he will face a larger dispersion of the loan fees to reestablish his short position. A previous work of Engelberg et al. (2018) found that the short-selling risk can be understood as another source of constraint to short sales. Moreover, they showed that the short-selling risk is correlated with the put-call parity violations. We do not find this result for the Brazilian market, at least when we use the intraday loan fee volatility to measure the short-selling risk. It is necessary to mention that Engelberg et al. (2018) do not use intraday volatility of loan fees. They used the volatility of the average loan fees during the maturity of the options pairs.

Note that the only controls that presented a significance level of at least 10% are: option volume, maturity, and moneyness. Options volume has a positive coefficient, which

provides evidence that investors increase their participation in the options market when the actual and synthetic stock prices drift apart. It may result from the investor identifying put-call parity violations and trying to exploit the arbitrage opportunity. The moneyness coefficient is also positive, similarly to the result obtained for the U.S. market in Evans et al. (2009). Finally, it is worth mentioning that the option's maturity is another variable related to the short-selling risk and this variable is statistically significant in our model. We find that a higher maturity is positively correlated with departures from the parity. It can be related to the difficulty of short increases within the time horizon, as the investors must pay the loan fees for more extended periods and are more exposed to the risk of having their position recalled.

5.1.2 Short Adjusted Put-Call Parity Deviations

In the previous section, we show that loan fees explain a large part of the put-call parity deviations. Considering this result, it is expected that when we account the short-selling costs in the put-call parity the deviations will reduce. To do it, we calculate the synthetic stock prices adjusted by the short-selling costs and compare them with the actual stock prices. The adjusted synthetic prices are given by:

$$S_{i,t}^{Synth_Adj} = C + PV(K) - P + \varsigma \tag{5.1}$$

where $\varsigma = \frac{(1+f)^{T/252}-1}{(1-r)^{T/252}} S_{it}$, i.e., it is the present value of the short-selling cost that an investor would pay to short the stock S_{it} in a period of T business day. Then, we calculate the put-call parity violations using the adjusted synthetic stock prices[1].

Table 5 presents a description of the adjusted put-call parity deviation conditional on the loan fees. It is possible to see that after adjusting for the short-selling costs, the average put-call parity deviations are considerably reduced when we compare it with the results presented in Table 3. For example, considering our whole sample, the put-call parity deviation adjusted for the short-selling costs is on average 0.05% while without consider the short-selling costs, it is 0.18%. For the subsample conditioned on the loan fees of the 95th quantile, the average deviation of the adjusted put-call parity deviations is negative. It results from the fact that the short-selling costs are elevated in this subsample, and when we add these costs to the synthetic prices, they tend to become higher than

[1] We will denote the put-call parity violations calculated using the synthetic price as stated in equation (5.1) as adjusted put-call parity.

the actual stock price. However, for all other subsamples in Table 5, the average adjusted put-call parity deviations are smaller in absolute value than the average put-call parity deviations observed in Table 3.

Despite the significant reduction on the average put-call parity deviation when we account for the short-selling cost, Figure 2 shows that the dispersion of the adjusted put-call parity violation increases as we condition our sample in higher loan fees. It is possible to observe that both the right and left tail of the distributions become denser conditional on higher loan fees. It can be view as preliminary evidence that disparities in stock prices and synthetic prices become more frequent when the loan fee increase. Accounting for the short-selling costs, we see that the disparities occur in both directions.

To provide more robust evidence of the relationship between adjusted put-call parity deviations and the loan fees, we regress the square of the adjusted put-call violations against the loan fees and the same controls used in the regression on Table 4. We use the adjusted put-call parity violation square since the deviations, in this case, occur in both directions and not predominately in the short-selling direction like when we do not account for the short-selling costs in the put-call parity deviations. We are looking here for the effect of loan fees on the dispersion of the adjusted put-call parity deviations.

Table 6 presents the results of the regression of the adjusted put-call parity deviations square and the adjusted put-call parity deviations absolute value against the loan fees. We find that the loan fee is positively correlated with the adjusted put-call parity dispersion for all specifications. Even considering the short-selling costs in the put-call parity relationship, we find that higher loan fees are associated with larger price disparity dispersion. This result is consistent with our hypothesis that the short-selling constraints not only affect the put-call parity deviation by generating a higher cost to arbitrage but also by reducing the number of arbitrators, which would generate a higher dispersion of the price disparities. Considering only the regressions on Table 6, it is not possible to say that the positive correlation between the adjusted put-call parity dispersion and loan fees results from the fact that higher loan fees reduce the number of put-call parity arbitrageurs. In the next subchapter, we examine how the stock loan fees affect the number of put-call parity arbitrageurs.

5.2 Arbitrageurs and Short-Selling Restrictions

To show that the positive relationship between adjusted put-call parity dispersion and loan fees is generated by a reduction in the number of arbitrageurs, it is necessary to understand the relationship between loan fees and the number of put-call parity arbitrageurs. We regress the number of institutional arbitrageurs against the loan fee and a set of controls. Additionally, we also consider an alternative specification in which we regress the number of arbitrageurs against a dummy variable for high loan fees and a set of controls. This dummy variable assumes the value 1 when the loan fee is above the 95th quantile and 0 otherwise. We standardize all variables in the regression to facilitate the interpretation of the results.

Table 7 present the results. It is possible to observe that the loan fee has a negative effect on the number of institutional arbitrators. Considering the specification with all controls presented in columns 2, a one standard deviation increase of the loan fee is correlated with a reduction in the number of institutional arbitrageurs of 0.06 standard deviations. The magnitude of the coefficient is not elevated; however, it is statistically significant at a 1% significance level. Considering an alternative specification that replaces the loan fee variable by a dummy for loan fees above the 95th quantile, we find a larger impact of loan fees over the number of institutional arbitrageurs. Considering the specification in column 4, it is possible to see that stocks with high loan fees (above 95th quantile) have 0.3 standard deviations fewer arbitrageurs on average than those with loan fees below 95th quantile. It shows that the stocks with very high loan fees have, on average, fewer arbitrageurs than the other stocks.

Another interesting result is that the loan fees intraday volatility do not affect the number of arbitrageurs. The coefficient of this variable is not statistically significant. It indicates that the arbitrageurs do not leave the market due to a higher dispersion of the loan fees. If we consider the loan fees intraday volatility as a measure of the short-selling risk, it is possible to say that the short-selling risk does not affect the quantity of put-call parity arbitrageurs. One possible explanation for this result is that arbitrageurs and institutional investors are well connected with brokers and face smaller search costs, as showed in Chague et al. (2017), which can mitigate the negative impact of a higher dispersion of loan fees.

Additionally, the other controls added to the regressions on Table 7 shows that

stock and option volume is positively correlated with the number of arbitrageurs. These results are expected since liquid stocks and options would be easier to arbitrate. The size and the number of option pairs with the same strike price and maturity are also positively related to the number of arbitrageurs. Moreover, we find that the book to market ratio is positively related to the number of arbitrageurs while the daily stock return is negatively related. If we consider all the arbitrageurs instead of considering only the number of institutional arbitrageurs, our results still qualitatively the same.

Our results point to a strong correlation between the number of put-call parity arbitrageurs and the loan fees, especially for elevated loan fees. This result is in line with our hypothesis that the short-selling constraints affect the price efficiency by imposing higher costs for arbitrage and making part of the arbitrageurs leave the market. The fact that the number of arbitrageurs is reduced when the loan fees increase explains the result we presented in the previous section that the dispersion of the adjusted put-call parity deviation increases as loan fees rise. The stocks with higher loan fees present fewer put-call parity arbitrageurs, and consequently, the dispersion of the price disparities is higher.

It is worth mentioning that the relation between the number of arbitrageurs and loan fees is possibly endogenous. A higher loan fee would reduce the profitability of the arbitrage, diminishing the number of arbitrageurs. On the other hand, a reduction in the number of investors arbitrating would increase the loan fees since the arbitrageurs, in general, can avoid high loan fees, as pointed in Chague et al. (2017). Therefore, it is not possible to claim that the relation we find between loan fees and the number of arbitrageurs is causal. However, considering that we do not have a higher number of put-call parity arbitrageurs, for example, Table 2 Panel B shows that we have on average six institutional arbitrageurs for each stock. It is plausible to think that the impact of the number of arbitrageurs on the loan fees would be very small.

6 Concluding Remarks

We provided evidence that there are two channels from which short-selling restrictions impose limits to arbitrage. The first one is generating higher costs to arbitrage. Previous works presented evidence related to this channel for the U.S. market, and our results for the Brazilian market are in line with them. The second one is reducing the number of arbitrageurs in the market. As long as we know, we are the first to provide empirical evidence that short-selling restrictions negatively impact the number of arbitrageurs.

We show that higher loan fees are correlated with disparities between stock prices and synthetic stock prices in the Brazilian stock and option markets. This result is totally in line with the findings of Ofek et al. (2004), and Evans et al. (2009) that also reported a strong correlation between put-call parity violations and loan fees. Our main results are related to the empirical evidence we provide of the contraction in the number of arbitrageurs as the loan fees rise. First, we show that the dispersion of the short adjusted put-call parity deviation is positively related to the loan fees, which is in line with our hypothesis of the reduction on arbitrageurs. We expect that with a smaller number of arbitrageurs, we would observe more price disparities dispersion. Finally, using a unique data set that provided a proxy for the number of put-call parity arbitrageurs, we show that stocks with high loan fees have, on average, fewer arbitrageurs even after control for other stock characteristics such as volume, market size, book to market ratio among others.

In addition, we find that the put-call parity deviations are not correlated with the loan fees intraday volatility. Considering that the loan fee intraday volatility can be a measure of the short-selling risk, our result differs from the one presented by Engelberg et al. (2018) that found a positive correlation between short-selling risk and put-call parity violation for the U.S. market. However, it is necessary to remember that the short-selling risk measure they use is not the same used here. Furthermore, we also provide evidence that the loan fees intraday volatility do not affect the number of put-call parity arbitrageurs.

In sum, our work adds to the literature on the limits to arbitrage imposed by short-selling constraints. It is shown that short-selling restrictions impact price efficiency by generating higher transaction costs and reducing the number of arbitrageurs. We complemented the evidence provided by Ofek et al. (2004) and Evans et al. (2009) showing

that the increase in transaction costs is not the only channel in which short-selling constraints reduce the price efficiency. Our results showed that short-selling restrictions are also associate with contractions in the number of arbitrageurs in the market.

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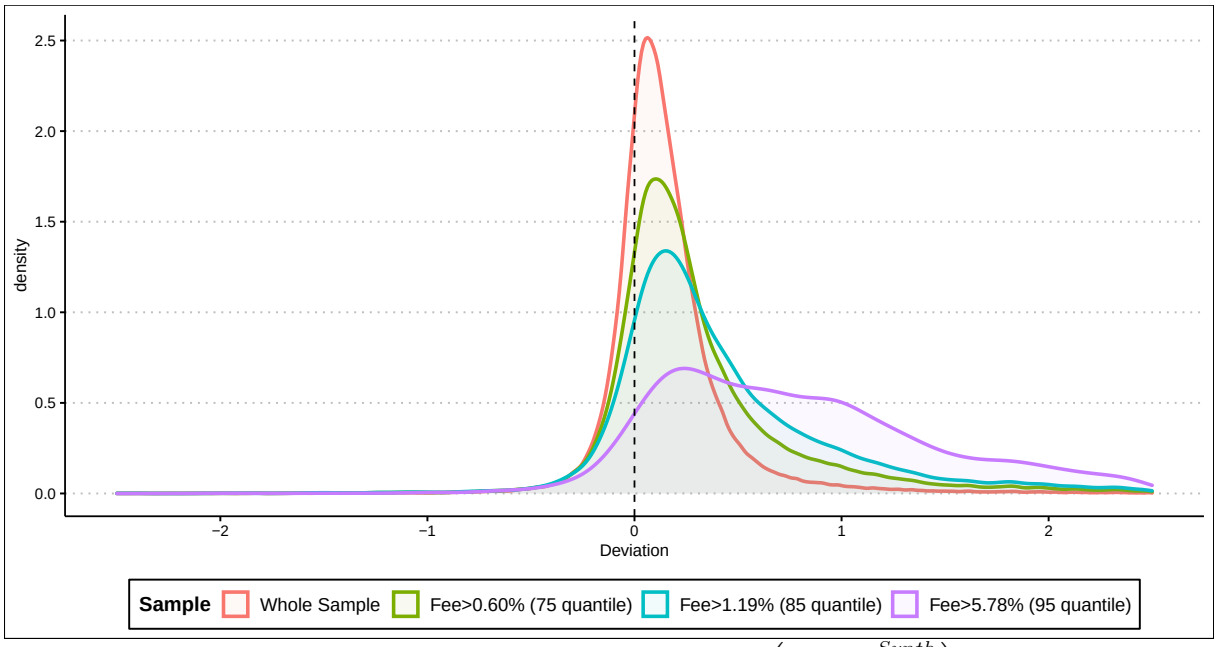
Appendix

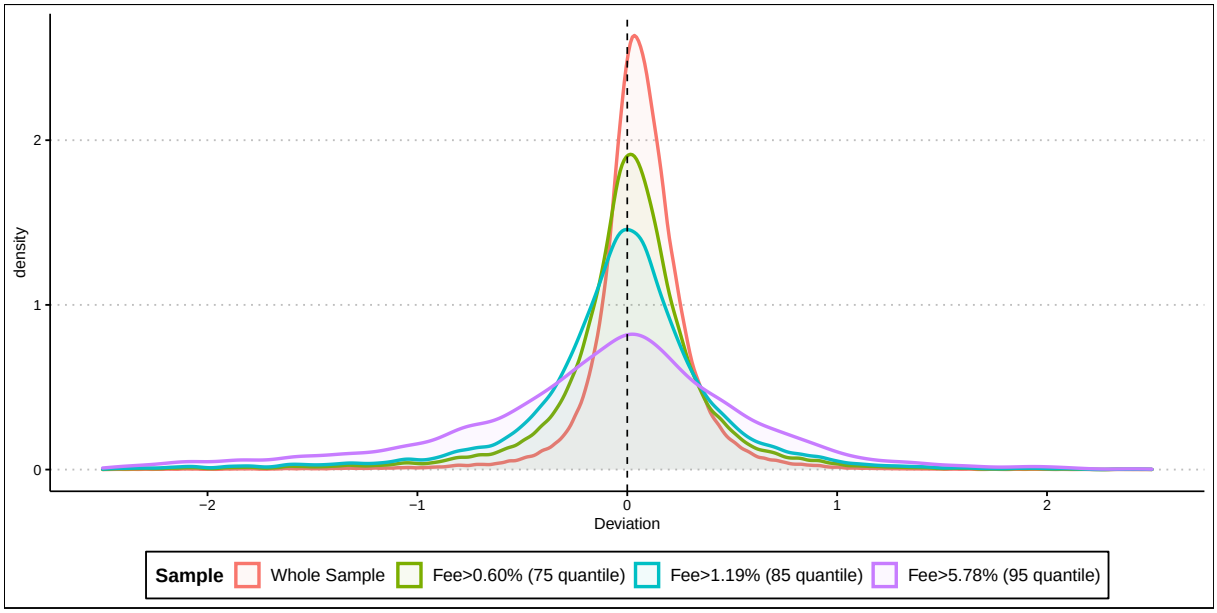
APPENDIX A – Figures

Figure 1 – Empirical Distribution of Put-Call Parity Violations



Notes: The put-call parity deviations are given by $PCD_{i,t} = \left(\frac{S_{i,t} - S_{i,t}^{Synth}}{S_{i,t}} \right) 100.$

Figure 2 – Empirical Distribution of Adjusted Put-Call Parity Violations



Notes: The short-selling costs adjusted put-call parity deviations are given by $PCD_{i,t} = \left(\frac{S_{i,t} - S_{i,t}^{Synth_Adj}}{S_{i,t}} \right) 100$, where $S_{i,t}^{Synth_Adj}$ is the synthetic stock price adjusted by the short-selling costs as stated in equation (5.1).

APPENDIX B – Tables

Table 2 – Sample Description

Notes: Panel A reports the put-call parity sample's descriptive statistics, from September 2012 until December 2018. There are a total of 158,219 option pairs and 63 tickers. Panel B reports the Arbitrageurs number sample's descriptive statistics from January 2012 until december 2017. There are a total of 23,217 observations and 57 tickers. All prices are measured in Brazilian Reais (R$).

Variable	***Mean***	***Median***	***5th quantile***	***95th quantile***
Panel A: Put-Call Parity Sample				
Option Maturity (days)	24.12	22	7	47
Moneyness	0.05	0	-7.75	7.88
Daily Call Volume (R$)	703,606	42,756	825	3,089,328
Daily Put Volume (R$)	139,136	16,256	367.95	652,184
Call Price (Mid-Quote) (R$)	1.15	0.91	0.18	2.92
Put Price (Mid-Quote) (R$)	0.94	0.74	0.15	2.36
Implied Volatility Call (%) a.r.	37.68	33.92	22.44	63.96
Implied Volatility Put (%) a.r.	39.29	35.08	24	66.36
Spread Call (% Mid)	5.44	3.48	0.73	17.39
Spread Put (% Mid)	6.66	4.53	1.09	20
Stock Price (R$)	23.48	21.61	6.59	46.8
Synthetic Stock Price (R$)	23.45	21.58	6.56	46.76
Daily Stock Volume (In thousand R$)	386,346	275,384	44,664	1,084,487
Risk Free Rate (%) a.r.	10.1	10.47	6.41	14.17
Loan Fee (%) a.r.	1.45	0.3	0.15	5.78
Intraday Volatility Fee (%) a.r.	13.85	5.09	0.04	33.79
Number of ticker per date	15.69	14	10	26
Panel B: Arbitrageurs Sample				
Number of Arbitrageurs	8.5	4	1	33
Number of Inst. Arbitrageurs	6.02	4	1	19
Daily Call Volume (R$)	8,879,988	443,004	11,161	57,591,336
Daily Put Volume (R$)	1,661,683	188,394	1,700	8,604,493
Number of Option Pairs	11.15	7	1	42
Daily Stock Volume (In thousand R$)	197,782.80	127,708	19,852.24	613,850.82
Stock Volatility (%) a.r.	38	32.1	13.32	80.3
Daily Stock Return (%)	4	0	-434.33	462.13
Stock Size (in million R$)	8,434,573	32,768	3,307.90	86,277,262
Book/Market	1.13	0.8	0.14	3.28
Loan Fee (%) a.r.	2.67	0.37	0.1	11.53
Intraday Volatility Fee (%) a.r.	17.1	6.78	0.07	42.95
Number of ticker per date	15.66	14	11	26

Table 3 – Put-Call Deviation Conditional on Loan Fees

Notes: The put-call parity deviations are defined by: $PCD_{i,t} = \left(\frac{S_{i,t} - S_{i,t}^{Synth}}{S_{i,t}}\right) 100$. The table presents some descriptive statistics for the put-call parity violation considering the whole sample and also the samples conditional on five different loan fees quantiles. In the table, f refers to the per annum loan fee rate.

	Whole Sample	***Above quantile 95th*** **f > 5.78**	***Between quantile 95th and 75th*** **0.60 < f < 5.78**
Obs:	158,219	7,917	31,845
Mean	0.18	1.26	0.2
Median	0.11	0.79	0.16
5th Quantile	-0.16	-0.05	-0.17
95th Quantile	0.66	3.89	0.73
Prob. > 0(%)	77.03	93.75	80.56

	Between quantile 75th and 50th **0.30 < f < 0.60**	***Between quantile 50th and 25th*** **0.22 < f < 0.30**	***Bellow quantile 25th*** **f < 0.22**
Obs:	39,922	42,652	35,885
Mean	0.12	0.11	0.08
Median	0.11	0.1	0.07
5th Quantile	-0.15	-0.16	-0.18
95th Quantile	0.45	0.44	0.38
Prob. > 0(%)	77.69	75.91	70.9

Table 4 – Put-Call Parity Deviation and Loan Fees

*Notes:*The dependent variable is defined by $PCD_{i,t} =; \left(\frac{S_{i,t} - S_{i,t}^{Synth}}{S_{i,t}}\right) 100$. The loan fees are given at annual percentage rates. The fee intraday volatility is the standard deviation of the loan fees of all lending deals closed in a given day. The maturity variable is the number of trading days until the option pairs maturity. The options volume is given by the log of the average of the put and call daily financial volume. The option bid-ask spread is given by the average between put and call spreads scaled by the option respective mid-quote price. The moneyness is defined by $100 * ln(S/K)$. The stock volume is the log of the daily financial volume. Finally, the implicit volatility is calculated based on the Black-Scholes model.
All specifications consider ticker and time fixed effects and the standard errors are clustered by ticker and time.

	Dependent variable:			
	$PCD_{i,t}$			
	(1)	(2)	(3)	(4)
Fee	0.048**	0.048**	0.057***	
	(0.019)	(0.019)	(0.021)	
Fee Intraday Volatility			−0.025	
			(0.016)	
Opt. Bid-Ask Spread		0.001	0.001	0.006
		(0.002)	(0.002)	(0.004)
Moneyness		0.002***	0.002***	0.001
		(0.001)	(0.001)	(0.001)
Maturity		0.007***	0.007***	0.007***
		(0.001)	(0.001)	(0.002)
Ln Option Volume		0.010**	0.009**	0.016**
		(0.004)	(0.004)	(0.008)
Ln Stock Volume		−0.009	−0.001	−0.077
		(0.016)	(0.017)	(0.048)
Implicit Volatility Call		0.0001	−0.001	0.006
		(0.003)	(0.003)	(0.010)
Observations	158,335	158,335	158,335	158,335
Adjusted R^2	0.403	0.419	0.435	0.227
F (p-value):	0.01	0.00	0.00	0.00
Num. Days:	1536	1536	1536	1536
Num. Tickers:	63	63	63	63
Note:				*p<0.1; **p<0.05; ***p<0.01

Table 5 – Adjusted Put-Call Deviation Conditional on Loan Fees

Notes: The short-selling cost adjusted put-call parity deviations are defined by: $PCD_{i,t} = \left(\frac{S_{i,t} - S_{i,t}^{Synth_Adj}}{S_{i,t}}\right) 100$, where $S_{i,t}^{Synth_Adj}$ is the synthetic stock price adjusted by the short-selling costs as stated in equation (5.1). The table presents some descriptive statistics for the adjusted put-call parity violation considering the whole sample and also the samples conditional on five different loan fees quantiles. In the table, f refers to the per annual loan fee rate.

	Whole Sample	***Above quantile 95th*** **f > 5.78**	***Between quantile 95th and 75th*** **0.60 < f < 5.78**
Obs:	158,219	7,917	31,845
Mean	0.05	-0.23	0.03
Median	0.06	-0.06	0.03
5th Quantile	-0.29	-2.45	-0.37
95th Quantile	0.43	1.11	0.45
Prob. > 0(%)	65.55	45.24	56.22

	Between quantile 75th and 50th **0.30 < f < 0.60**	***Between quantile 50th and 25th*** **0.22 < f < 0.30**	***Bellow quantile 25th*** **f < 0.22**
Obs:	39,922	42,652	35,885
Mean	0.08	0.09	0.07
Median	0.07	0.08	0.06
5th Quantile	-0.19	-0.18	-0.19
95th Quantile	0.4	0.41	0.36
Prob. > 0(%)	69.6	71	67.32

Table 6 – Adjusted Put-Call Parity Dispersion and Loan Fees

Notes: The dependent variables are the adjusted put-call parity square and the absolute value of the adjusted put-call parity. The short-selling cost adjusted put-call parity deviations are defined by: $PCD_{i,t} = \left(\frac{S_{i,t} - S_{i,t}^{Synth_Adj}}{S_{i,t}}\right) 100$, where $S_{i,t}^{Synth_Adj}$ is the synthetic stock price adjusted by the short-selling costs as stated in equation (5.1). The loan fees are given at annual percentage rates. The control variables are the same described in Table 4.
All specifications consider ticker and time fixed effects and the standard errors are clustered by ticker and time

	Dependent variable:			
	$(PCD_{i,t})^2$		$\lvert PCD_{i,t}\rvert$	
	(1)	(2)	(3)	(4)
Fee	0.425***	0.399***	0.045***	0.042***
	(0.096)	(0.078)	(0.007)	(0.007)
Fee Intraday Volatility		0.092		0.008***
		(0.074)		(0.003)
Opt. Bid-Ask Spread		−0.004		0.005***
		(0.008)		(0.001)
Moneyness		0.002		0.001***
		(0.003)		(0.0004)
Maturity		0.011***		0.004***
		(0.004)		(0.0003)
Ln Option Volume		−0.028		−0.001
		(0.020)		(0.002)
Ln Stock Volume		0.333***		0.032***
		(0.114)		(0.009)
Implicit Volatility Call		−0.022**		−0.001
		(0.009)		(0.001)
Observations	158,335	158,261	158,335	158,261
Adjusted R^2	0.267	0.273	0.455	0.472
F (p-value):	0.00	0.00	0.00	0.00
Num. Days:	1536	1536	1536	1536
Num. Tickers:	63	63	63	63
Note:				*p<0.1; **p<0.05; ***p<0.01

Table 7 – Number of Arbitrageurs and Loan Fees

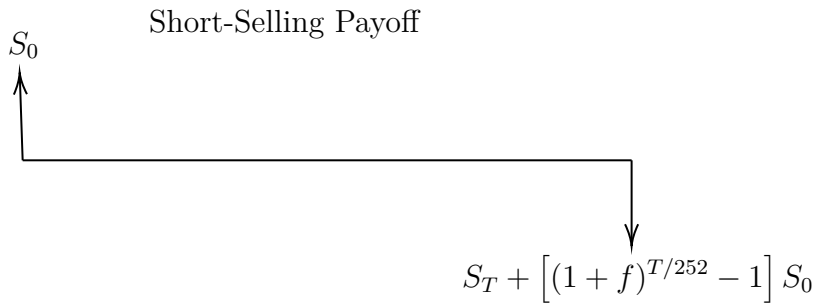
All variables in the regressions are standardized by ticker, excepted the loan fee and intraday volatility fee that are standardized considering all deals in all tickers. The dependent variable is the number of institutional investors that buy or sell a stock, a call, and a put option of the underlying stock in the same day. The loan fee is the same variable used in the previous regressions. Dummy high fee is a dummy variable that assumes the value 1 if the loan fee is above the 95th quantile and 0 otherwise. The maturity variable is the number of trading days until the option pairs maturity. The moneyness is defined by $100 * ln(S/K)$. The options volume is the average between all calls and puts daily financial volume of a given stock. # Options Pairs is the number of option pairs with the same maturity and the same strike for a given ticker. The stock volume is the daily financial volume. Stock Return is the daily stock return. Size is the firm size calculated as the number of shares outstanding multiplied by the stock close price. B/M is the book to market ratio obtained in Economatica platform. Stock Volatility is calculated using the stock's returns over the previous month.
All specifications consider ticker and time fixed effects and the standard errors are clustered by ticker and time.

	Dependent variable:			
	# Institutional Arbitrageurs			
	(1)	(2)	(3)	(4)
Fee	-0.091^{***}	-0.065^{***}		
	(0.013)	(0.010)		
Intraday Volatility Fee		0.022		-0.001
		(0.016)		(0.014)
Stock Return (1 day)		-0.025^{***}		-0.024^{***}
		(0.008)		(0.008)
Stock Volatility		0.011		0.011
		(0.023)		(0.024)
B/M		0.081^{**}		0.079^{***}
		(0.031)		(0.029)
Stock Volume		0.152^{***}		0.151^{***}
		(0.027)		(0.027)
Size		0.079^{**}		0.075^{**}
		(0.031)		(0.029)
Option Volume		0.201^{***}		0.203^{***}
		(0.025)		(0.025)
# Option Pairs		0.212^{***}		0.213^{***}
		(0.025)		(0.024)
Dummy High Fee			-0.455^{**}	-0.307^{***}
			(0.178)	(0.089)
Observations	23,200	23,200	23,200	23,200
Adjusted R^2	0.082	0.235	0.083	0.236
F (p-value)	0.00	0.00	0.01	0.00
Num. Tickers:	57	57	57	57
Num. Days:	1483	1483	1483	1483
Note:				*p<0.1; **p<0.05; ***p<0.01

APPENDIX C – Put-Call Parity and Loan Fees

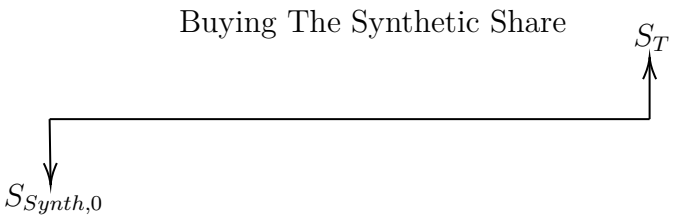
Assume that the synthetic stock price is lower than the actual stock price. An arbitrageur would short the stock and buy the synthetic share to exploit the arbitrage opportunity. The payoff of these operations will be given as follow:

The payoff from shorting the stock is given in the following cash flow:

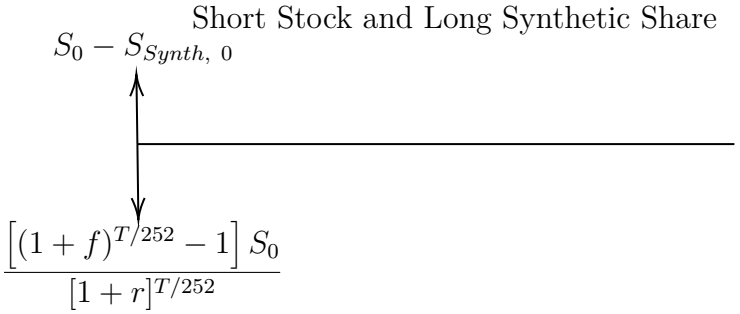


Initially, we have a cash inflow due to the sale of the borrowed stock and a cash-out flow in the end due to the repurchase of the stock and the loan paid to the lender that is given by $[(1+f)^{T/252} - 1]S_0$ as explained before.

The payoff from buying a synthetic share is given in the following cash flow:



In this case, there is a cash-out flow in the beginning due to the synthetic share purchase and a cash inflow in the end. Combining these two operations and bringing the loan value paid to the lender to its present value, we have:



Then we can find the relation between the put-call parity deviations and the stock loan fees:

$$\frac{S_t - S_{Synth,t}}{S_t} = \frac{\left[(1+f)^{T/252}-1\right]}{[1+r]^{T/252}}, \tag{C.1}$$

where r is the risk free interest rate and T is the options maturity in days.

APPENDIX D – Database Filters

To increase the quality of the data, we apply the following set of filters:

I) We eliminate all options pair that presented moneyness inferior to 10% in absolute terms ($|ln(S/K)| < 0.1$);

II) We eliminate all options pairs with a maturity higher than 100 trading days and inferior to 10 trading days;

III) We eliminate option pairs if the put or call bid-ask spread is greater than 50% of the option price (at the mid-quote price). It eliminates record errors and very illiquid options;

IV) We eliminate option pairs if the bid or ask prices of the call options are under the call options theoretical lower-bound ($C \leqslant S - PV(K)$) or above the call options theoretical upper-bound ($C \geqslant S$). It eliminates record errors and calls options that are impossible to calculate implied volatility;

V) We eliminate option pairs if the bid or ask prices of the put options are under the put options theoretical lower-bound ($P \leqslant PV(K) - S$) or above the put options theoretical upper-bound ($P \geqslant PV(K)$). It eliminates record errors and put options that are impossible to calculate implied volatility;

VI) We eliminate option pairs if the put or call presents a negative bid-ask spread. It eliminates record errors.