Universitat Ramon Llull

DOCTORAL THESIS

Title	**THE PRICING BEHAVIOR OF DEPOSITORY RECEIPTS: EVIDENCE FROM EMERGING MARKETS**
Presented by	**ALIAA I. BASSIOUNY**
Centre	**ESADE BUSINESS SCHOOL**
Department	**MARKETING, OPERATIONS AND FINANCE**
Supervisors	**DR. CARMEN ANSOTEGUI** **DR. ESKANDAR TOOMA**

ACKNOWLEDGMENTS

TABLE OF CONTENTS

LIST OF TABLES

1 INTRODUCTION AND FRAMEWORK

1.1 Introduction and Motivation

Stock exchanges in the past three decades have witnessed a 'foreign cross-listing' phenomenon, whereby the stocks of firms not only trade on their local exchanges but also on other foreign international exchanges. This internationalization of trading has attracted extensive attention from academia to understand the dynamics of multi-market trading (Karolyi, 1998; 2006) as more companies opt for foreign cross-listing for its financial, operational and governance benefits (King and Segal, 2008) and more international investors trade these stocks for the promising portfolio diversification rewards (Domowitz et al, 2001).

Depository Receipts(DRs) are considered the most common method for foreign cross-listing. They trade on a foreign stock exchange as claims against the underlying stocks of the company on the local stock exchange. The DRs are issued by a trust bank that holds those underlying stocks on behalf of investors. While DRs are usually denominated in US dollars (USD), their underlying stocks trade in the currency of the local market. DRs that are listed on US exchanges are referred to as American DRs (ADRs) while DRs listed on international exchanges outside the US are usually referred to as Global DRs (GDRs).

Except for their location of trade and currency denomination, the DR and its underlying stock have similar claims against the company's cash flows and are also fully convertible to one another; an important feature referred to as *fungibility*. These characteristics make the DR and the underlying stock to be essentially identical securities and we expect them to be priced with the same fundamentals.

Academic researchers in asset pricing and multi-market microstructure have increasingly become interested in examining the pricing behavior of DRs relative to their underlying stock. They use the results of such analyses as an indicator of whether foreign cross-listing promotes stock market integration, by enhancing cross-market linkages, versus an argument of greater fragmentation, due to the competition between stock exchanges over share of trading in cross-listed securities.

Understanding the role of DRs in stock market integration is important as they are increasingly dominating the world of foreign listing. By the first half of 2011, over 3400 companies from 80 different countries were foreign listed on major international stock markets as DRs, with New York and London attracting the largest number of DR listing. More than 80.5 billion DRs were trading on international exchanges during that period with a value of $1.91 trillion (BNYM, 2011). DRs from emerging markets make up over 70% of listed DRs trading on international exchanges, yet research on them tends to be limited to periods of financial and economic crises. In this thesis, we focus on the pricing behavior of DRs from emerging markets.

Our lack of knowledge about how prices of DRs from emerging markets relate to their underlying stock is hampered by two main factors: first, the lack of quality data on the underlying stocks trading in emerging stock markets required for such analysis (Karolyi, 2006) and second, the trading barriers that exist in those markets and which are hypothesized to distort the theoretical pricing relationship between the DR and its underlying stock.

The purpose of this thesis is to further our understanding of the pricing behavior of DRs and their underlying stocks using a sample of DRs from emerging markets in presence of trading barriers and making use of a proprietary high frequency intraday dataset. The first analysis of this thesis examines the fundamental economic relationship that ties both securities: the law of one price (LOOP). Since both securities have identical claims on the cash flows of the same asset, the LOOP should ensure that they are identically priced in the long run.

Yet, since each security trades on a different market, differential market co-movements, investor sentiment and noise trading can cause prices to diverge in the short term. This can create arbitrage opportunities for active arbitrageurs who can intervene to make risk free profits. Our second empirical methodology focuses on identifying whether arbitrage opportunities exist between emerging market DRs and their underlying stock, especially in presence of large trading barriers that was so hypothesized to hamper such activity. The analysis uses a unique high frequency intraday dataset to identify whether arbitrage opportunities exist and to establish whether arbitrage trades play a role in restoring price parity.

We establish the important role of arbitrageurs in restoring prices to their fundamental values and in keeping prices from drifting away from a common efficient implicit price. This allows us to examine the last empirical question of this thesis, which is whether the local or foreign market plays a more dominant role in the pricing of emerging market DR. This question focuses on the price discovery process of DRs and their underlying stocks which is a key function of stock exchanges. Figure 1 provides an overview of the empirical framework of this thesis.

THE PRICING BEHAVIOR OF DEPOSITORY RECEIPTS		
THE LAW OF ONE PRICE EMPIRICAL METHODOLOGY (A) *Objective* Testing whether the Law of One Price holds between a DR and its underlying stock *Data* Can be operationalized with daily or intraday data. *Test* $H_0 \longrightarrow P_t^{DR} = P_t^{S^*}$	ARBITRAGE EMPIRICAL METHODOLOGY (B) *Objective* Testing whether arbitrage opportunities exist between a DR and its underlying stock *Data* Intraday data is required to capture arbitrage in the frequency it occurs *Test* Identify arbitrage opportunities in the data as those instances in which price deviation exceeds cost of arbtirage $\left\|P_t^{DR} - P_t^{S^*}\right\| > k$	PRICE DISCOVERY EMPIRICAL METHODOLOGY (C) *Objective* To measure whether the local or the foreign market contribute more to the price discovery process *Data* Intraday data is required to operationalize price discovery models *Test* **Vector Error Correction Model using:** Gonzalo and Granger (1995) Component Share Hasbourck (1995) Information Share

Figure 1-1 The Pricing Behavior of DRs: Comparing Methodologies

1.2 The Pricing Behavior of Depository Receipts

This dissertation consists of three empirical examinations on the pricing behavior of DRs from emerging markets. Firstly, it examines the basic fundamental relationship governing the pricing of emerging market DRs and their underlying stock: that of the LOOP. Secondly, we carry out a static analysis of the pricing behavior through an intraday arbitrage analysis which examines whether arbitrage opportunities exist between the cross-listed securities during overlapping trading hours and the role of arbitrage trades in restoring price parity. Thirdly, we conduct a more dynamic analysis that measures the role of the local versus foreign market in the price discovery process of the cross-listed securities.

This section gives a brief summary of each type of analysis and the main results of this dissertation.

1.2.1 The Law of One Price

The first empirical methodology tests whether the LOOP holds between the DR and the underlying stock. Economic theory stipulates that identical goods should trade at identical prices and this approach conducts a long term test of price parity to confirm stock market integration and efficiency.

While a popular empirical methodology that dominated early studies on the pricing behavior of DRs, the analysis is confined by several limitations. First, testing the law of one price involves a direct comparison between the price of the DR and the underlying stock. Early studies, relying on comparing daily closing prices, confuse price parity with lack of arbitrage opportunities in the DR market. Their analysis suffers from non-contemporaneousness due to the trading hour differences between markets and thus give nor real indication of whether arbitrage opportunities exist or not. Second, a rejection of price parity between the DR and its underlying stock does not necessarily mean that both securities are not priced by similar factors. Since various market microstructure differences and trading barriers might exist between the foreign and local market, those price differences might reflect such barriers rather than a lack of price efficiency.

We conduct an empirical analysis on whether the LOOP holds between Egyptian cross-listed securities using daily closing prices and relying on the common methodology in the literature. Since Egyptian stocks are cross-listed on the London Stock Exchange, this is the first test of the LOOP on companies cross-listed on exchanges outside of the US. Other characteristics of the Egyptian sample that make such analysis useful, are the different trading week in Egypt and London as well as assessing the abolishment of a fixed exchange rate regime on the pricing of DRs relative to their underlying stock.

The results of our empirical analysis reveals large deviations from price parity between Egyptian DRs and their underlying stock. This result, while indicating lack of full integration between stock markets trading the same assets, cannot be interpreted as a situation of market inefficiency. The large trading barriers and microstructure characteristics present in the local Egyptian market can cause market segmentation between the local and foreign market which prevents full convergence in prices. Moreover, in order to conclude with certainty whether those large price deviations are indeed arbitrage opportunities, we need to delve deeper into the process of arbitrage, which is only captured using intraday high frequency data (Suarez, 2005; Gagnon and Karolyi, 20101).

1.2.2 Arbitrage Operations

The second approach directly tests whether arbitrage opportunities exist between a DR and its underlying stock. This methodology stems from the argument that price parity should be ensured by active arbitrageurs in the market who act on any mispricing. When arbitrageurs find that prices between the DR and the underlying stock diverge, they will intervene by buying the underpriced security, selling the overpriced one and using the fungibility between both securities to close their positions, making risk free profits in the process.

The arbitrage operation involved in DRs is a very unique situation in equity markets since it is instantaneous similar to the foreign exchange market. Unlike dual listed stocks, mutual funds and exchange traded funds, any deviation between the DR and its underlying stock does not require risky convergence trading whereby arbitrageurs have to wait for prices to close.

Defining a price deviation between the DR and its underlying stock as an arbitrage opportunity requires two conditions. First, that both the foreign and local market are open at the same time so that arbitrageurs can instantly profit from any deviation in prices. Second, due to trading costs, not all price deviations between the DR and the underlying stock are worth arbitraging, creating a no-arbitrage band inside which DR prices deviate from their underlying stock without being profitable arbitrage opportunities.

These conditions entail that studies trying to identify whether arbitrage opportunities exist, have to rely on intraday data that capture the hours during which the DR and its underlying stock are trading at the same time. They should also account for all arbitrage trading costs involved in order to properly identify arbitrage opportunities. Both conditions make studies in this area so far very scarce.

In fully informationally efficient markets, the mere threat of an arbitrage opportunity should keep the prices of DRs and their underlying stock at par. In financial markets the 'word out there' is that arbitrage opportunities between DRs and their underlying stock are frequent and that arbitrageurs make 'good money'. So far, empirical studies that can validate this notion are lacking.

The second methodology we employ in this thesis for examining pricing behavior of DRs studies whether arbitrage opportunities exist between DRs and their underlying stocks and analyzes the role of arbitrage trades in the price convergence process. The empirical analysis was facilitated by the use of a high frequency dataset that consists of approximately two years of intraday transaction data for two emerging markets with trading barriers: Egypt and Argentina. The unique features of our markets and the characteristics of the dataset required several modifications from the traditional methodology involved in studying the pricing behavior of DRs relative to their underlying stock.

We find that not only do arbitrage opportunities exist between our sample of emerging market DRs and their underlying stock, but that arbitrage trades played an important role in restoring prices to equilibrium (defined as a band of price deviations inside which arbitrage is not profitable) . We extract real arbitrage trades form our intraday transaction data which reveals that arbitrageurs are active and profit considerably from large mispricing between the DR and its underlying stock.

While the benefits of the arbitrage analysis in understanding the relationship between prices of the DR and its underlying stock is that it does not suffer from any joint hypothesis problems of relying on certain pricing models, its limitation is that it is a static form of analysis doesn't capture the evolution of prices. A price discovery model that can capture where the price is determined, locally or internationally, provides some useful insights on the role of the foreign market in pricing DRs.

1.2.3 Price Discovery

Finally, we conduct a price discovery analysis to establish whether the foreign or local market plays the more dominant role in the pricing of DRs. When securities trade in different stock markets, the question of where the price is determined amongst the competing trading venues provides an important analysis on the extent to which information that arises in the new overseas market contributes to price discovery.

The role of the foreign market in the pricing of the local stock can provide us with insights on how information flows travel and the role DRs play in enhancing stock market linkages. Our analysis of how the international market contributes to price discovery process of cross-listed stocks has been facilitated by the multi-market price discovery models of Gonzalo and Granger (GG) (1995) and Hasbrouck (1995) which have initially been empirically applied in studies on the role of regional exchanges in pricing of US equities and then adopted by the multi-market literature to measure the contribution of the foreign stock exchange in the price discovery of cross-listed stock.

However, the main obstacle to the application of such models is that they can only be properly operationalized with high frequency data. This makes our understanding of price discovery in a multi-market setting mostly guided by a number of fragmented studies across different settings, time frames and methodologies. While most studies so far have found that the local market continues to dominate the price determination process, with the foreign market acting as a satellite to the local one, the result depends on the share of trading that migrates to the international market.

Our objective is to measure the contribution of the local versus foreign stock exchange in price discovery of Egyptian and Argentinean cross-listed stocks using the high frequency intraday dataset we employ in this thesis. Such an analysis is motivated by the lack of price discovery studies on emerging market DRs that are foreign listed on international exchanges.

Our methodology employs the Component Share methodology of Gonzalo and Granger that relies on estimating a vector error correction model between the DR and underlying stock price, while accounting for exchange rate movements. Before estimating the GG model, we first establish that for all of our sample the DR and its underlying stock are co-integrated and thus they are linked by long term international arbitrage linkages, a results which we verified by our arbitrage analysis.

Our results indicate that whereas the local market for Egyptian securities is the dominant market for price discovery, the price for Argentinean securities is determined in both the local and US stock markets, to the extent that for some stocks the local market acts as a pure satellite to the international exchange. We believe this evidence to be the first of its kind in DRs and corroborates Eun and Sabherwal's (2003) results on dual-listed Canadian stocks. We find that liquidity, volume of trade, and market capitalization are all significant variables that are dynamic, that evolve over time, and that explain the share of price discovery.

1.3 Thesis Strucutre

This thesis is organized as follow. Chapter 2 provides an in-depth literature review of studies on the pricing behavior of DRs. We present our sample of emerging markets and the dataset we employ in this work in Chapter 3.

The articles that make up the core of this thesis are presented in Chapters 4-6. Chapter 4 presents our first empirical study on the Law of One Price titled: *"The Law of One Price in Global Depository Receipts: Empirical Evidence from Egyptian GDRs"*. (accepted for publication in Middle Eastern Finance and Economics). Chapter 5 presents our second empirical study entitled *"The Proof is in the Pudding: Arbitrage is Possible in Limited Markets: Intraday Evidence from the Depository Receipts of Emerging Markets"*.(Submitted to Journal of International Financial Markets, Institutions and Money) We present our price discovery study in Chapter 6 entitled *"An Investigation of Intraday Price Discovery in Cross-Listed Emerging Market Equities"*. (Submitted to Investment Analysts Journal)

Finally Chapter 7 provides a General Discussion of our findings and avenues for future research followed by our references and appendices.

2 LITERATURE REVIEW

In this section, we start by giving an overview of the organization and trading of DRs. We then summarize studies on the pricing behavior of DRs by arranging them around the following three questions: (1) Does the law of one price hold between the DR and the underlying stock? (2) Are there really arbitrage opportunities in the market for DRs? and finally (3) where does price discovery occur for internationally traded DRs?

While much research has been dedicated to the first issue, studies that address the last two questions tend to be mostly guided by data availability, leaving us with a number of fragmented studies across different settings, time frames and methodologies. Our objective is thus not only to present the main results of studies on the pricing behavior of depository receipts, but to take a more critical approach that highlights the differences in data and methodologies.

This review allows us to draw a roadmap for studying pricing behavior of DRs from emerging markets. We start by giving an overview on DR trading and organization and then review the literature on the three questions.

2.1. Overview of Depository Receipt Trading

The New York Stock Exchange and the London Stock Exchange are the two largest stock exchanges that host DR trading, comprising 34% and 18% of total DR listings on the 12 international exchanges around the world, respectively. DRs trading in the U.S. go by the name of American Depositary Receipts (ADRs), while in London and other countries outside the US, they are generally called Global Depository Receipts (GDR). Every DR is a claim on a one or more of the underlying stock, which is set by the 'bundling ratio' of the DR.

Investors can easily exchange DRs to their underlying stocks, a process referred to by 'fungibility'. Gagnon and Karolyi (2010) describe the characteristics of a fully fungible security some of which include no legal restrictions on cross-border ownership and trading, seamless trading between the foreign and home markets and the freedom for investors to hold the underlying stock or the DR.

The process through which DRs are issued (or cancelled) from their underlying stock involves the conversion of local stock to DRs (or vice versa) and requires the interaction of several parties[1]. Suppose an investor in London wants to buy 200 GDRs of the Japanese company Fujitsu which is trading on the Tokyo Stock Exchange . He can either buy them directly through the LSE or can instruct his broker to issue new GDRs through the following process:

1. The investor contacts his **broker** in London with the request.
2. The broker contacts a **local broker** in Tokyo to buy 1000 stocks of the underlying stock (since 1 GDR of Fujitsu is made up of 5 local stocks) on the Tokyo stock exchange.

[1] The process described here is adapted from Bank of New York Mellon website (www.bnymellon.com)

3. The local broker will deposit the stocks in a **Custodian Bank**.
4. The Custodian bank will contact a **Depository Bank** with the instructions to issue 200 GDRs and deliver it to the broker in London.
5. Finally the broker delivers the GDRs in the investor's name in London.

The GDR holder can later trade those GDRs on the LSE or can cancel them (through a process similar to the one described above) and the underlying shares can be sold on the Tokyo Stock Exchange. The latter process will cause a 'flowback' of the GDR to the local market, which is hypothesized to rarely occur unless the volume of trading on the GDR in the foreign market is very low.

The biggest challenge to studying the pricing behavior of depository receipts in relation to their underlying stocks is the time difference between the international exchange in which the DR trades and the local exchange in which trading on the underlying stock occurs. Appendix 1 of this thesis presents a summary of all DRs from different countries that are traded on international exchanges. We have also compiled data related to the trading hours of the underlying stock on the local exchange as well as the DR on the international exchange, outlining the total number of overlapping trading hours[2] between the local and foreign market.

[2] The overlapping trading hours presented are not fixed but change across the year with daily light saving (DST) schemes. They are intended for illustration purposes only and researchers interested in specific markets should obtain exact timings for DST to adjust hours accordingly.

2.2. The Law of One Price(LOOP) in Depository Receipts

2.2.1. Introduction

The Law of One Price is sometimes considered the 'second law of economics' and entails that identical goods trade at identical prices. The mechanism that ensures that the LOOP holds is referred to as arbitrage, whereby the arbitrageur simultaneously purchases the underpriced security and sells the overpriced security to make riskless profit.

The DR market provides for an interesting context to test whether the LOOP holds since the DR and its underlying stock are essentially identical and fungible security. This motivated studies as early as the 1980s to try to test this hypothesis. We mention the most important ones in this section.

2.2.2. Summary of Studies

The law of one price is said to hold if the following condition is satisfied:

$$P_t^{DR} = \frac{P_t^{Stock} * b}{S_t} \qquad \text{(Eq 2.1)}$$

where P_t^{DR} is the price of the DR in listed on the foreign exchange in the foreign currency (usually USD), P_t^{Stock} is price of the underlying stock in the local market in local currency, *b* is the bundling ratio or the number of stocks that make up one DR and $\mathrm{S_t}$ is the Foreign/Local Currency exchange rate. For simplicity we will refer to the adjusted stock price $\frac{P_t^{Stock} * b}{S_t}$ as $P_t^{Stock\prime}$

Testing equation 2.1 is usually done by testing the null hypothesis that the difference between prices P_t^{DR} and $P_t^{Stock\prime}$ is not significantly different from zero. Table 2.1 summarizes the difference measures for price deviation used to test this hypothesis. Studies that rely on econometric models (see below) to measure the speed of prices to converge to price parity also use differences in returns rather than prices as an equivalent measure for parity since returns have better statistical properties for estimation using econometric models.

INSERT TABLE 2.1 HERE

Early studies find that price parity holds between developed market depository receipts and their underlying stock (Maldonado and Saunders, 1983; Kato et al, 1991; Park and Tavakkol, 1994). These early studies suffer, however, from two main limitations. First, the focus on small samples from developed market DRs and second, they suffer from asynchronousity, since stock markets have different trading hours around the world and they compares use daily closing prices from markets with no or little trading overlap. This motivated more recent studies on the issue, which find that indeed the LOOP is violated, especially in emerging market DRs. Two main factors explain this break from this theoretical relationship : Trading Barriers and Special Events.

2.2.2.1. Trading Barriers and the LOOP

More recent studies, however, challenge the early result that the LOOP holds in the DR market, arguing that trading barriers can prevent prices between the DR and its underlying stock from being perfeclty aligned. Those trading barriers include non-overlapping trading hours, large trading costs, capital controls, short selling restriction, foreign ownership restriction and regulatory restriction on fungibility between the DR and its underlying stock. We discuss these next.

Gagnon and Karolyi (2010) provide the largest study of the LOOP yet. They study ADRs from the 39 countries over the period between 1993 and 2002. They overcome the limitation of early studies of price parity, which compare closing prices that do not occur at the same point in time, by using the intraday price of the ADR that corresponds to the closing time of the local market and compare this intraday DR price to the closing prices on the local stock. Despite overcoming non-contemporaneousness of their dataset, they find evidence of the existence of price deviations for most stocks. Although the prices of the cross-listed stocks and those of the home-market stocks lie within a 20 to 85 basis point band of each other, but, for some stocks, they can range from a 66 percent premium to an 87 percent discount.

Gagnon and Karolyi (2010) find that holding and trading costs explain the large deviations from price parity. Trading costs create a band of price deviation between the DR and underlying stock price inside-which are not profitable to arbitrage away. They also note that the violation of price parity can be explained by the wide range of institutional market frictions and trading barriers including short sales restriction, capital controls, foreign ownership restriction and restrictions on

DR-home share fungibility that exist in different countries. Several studies study the effect of each type of trading barrier on the pricing of DRs separately.

Domowitz et al (2001) foreign ownership restrictions in Mexican foreign cross-listed stocks cause significant deviations between the DR and the underlying stock. This clear violation of the LOOP is due to the effect of the foreign ownership restrictions that cause the a 'demand differential hypothesis' whereby foreign and domestic investors have different valuations of cash flows of firms.

Similarly Indian DRs have attracted the attention of researchers, since they traded at large premiums to their underlying stock, which were explained by foreign ownership and fungibility restrictions. Lamont and Thaler's (2003) and Puthenpurackal (2006) study the interesting case of the remarkable price discrepancy of the Indian IT company Infosys, which due to the restrictions of trade on the local stock by foreigners as well as the lack of convertibility between the DR and its stock, the DR was priced at a 136% premium to the local share. This was mainly explained by American investor enthusiasm about the stock (which could be driven by increased investor sentiment to buy in a stock that is not correlated to their portfolios) and the limitations to arbitrageurs to make use of the price discrepancy to make riskless profits.

On the effect of foreign exchange and ownership restrictions, Rabinovitch et al (2003) study the pricing of Argentinean and Chilean ADRs relative to their underlying shares during periods of such restrictions. While prices did deviate, they converged to parity rather quickly, as measured by a self-exciting threshold autoregressive model (SETAR) that takes into consideration trading costs by measuring the speed by which large price deviations resort to equilibrium. They argue however, that this was due to the contemporaneous trading hours of the US and both South American countries, which allows arbitrage activity to take place to close such gaps.

Auguste et al (2006) and Yeyati et al (2008) study the effect of capital controls on the pricing of ADRs. August et al (2006) find that the ADRs of the large stocks in Argentina were used as means for capital flight, which caused the ADRs to trade at premiums to the local stocks since the factors that determine demand for cross-listed stocks in the home market may diverge from those in the foreign market resulting in a discrepancy between the two prices. Yeyati et al (2008) find that capital controls segment the local from the foreign market. Controls on outflows induce cause DRs to trade at discounts to their underlying stock, while controls on inflows generate premiums on DRs. Despite this, they find that price deviations across markets are rapidly arbitraged away particularly so for liquid stocks.

Finally, another hypothesized barrier to price parity is short selling, since it is argues to hamper arbitrage activity. An arbitrageur who wants to profit instantly from a mispricing in DRs, would buy the underpriced security, short sell the overpriced security and lock in the profit. He can thereafter close the short sale position by converting the security he bought to the other one, facilitated by the fungibility feature of DRs. Gagnon and Karolyi (2010) argue that one reason for observing large price deviations from parity in cross-listed emerging market equity is the short selling restriction which prevent arbitrage from taking place.

More recent evidence on short selling by Blau et al (2012) show that short sellers more heavily trade ADRs from countries where short selling is prohibited than from markets where short selling is allowed because these ADRs are more often subject to temporary misevaluation. The action of these short sellers can actually create large deviations from parity to the underlying stock. Whether arbitrageurs are able to correct such deviations is yet to be empirically tested.

2.2.2.2. Special Events and the LOOP

Another explanation for the existence of price deviation are breaks from the LOOP that are observed around special events. Two studies are worth mentioning here. First, Blouin et al (2005) study the unexpected reduction in U.S. capital gains taxes at the announcement of the 1997 budget accord, which changed the pricing of cross-listed stocks relative to their underlying home country stocks, widening the gaps by an average of 40 basis points.

Second, Pasquariello (2008) shows that financial crisis has an effect on the LOOP by studying the mispricing of ADRs relative to their underlying stocks during financial crises in Mexico, East Asia, Russia, Brazil, Turkey, and Argentina. He identified persistent breaks in the LOOP before and during the crises and concludes that during financial crises, the market for emerging ADRs became on average less efficient and more segmented than during more tranquil times.

2.3. Arbitrage

2.3.1. Introduction

Theoretically under market efficiency arguments, arbitrage operations have an important function since they drive prices towards their fundamental valuations and enforce the law of one price (Fama, 1965; Madhavan, 2000; Ross, 2001). The most common textbook definition of arbitrage is the simultaneous purchase and sale of equivalent assets in two different markets in order to profit from discrepancies in their price relationship (Sharpe and Alexander, 1990 and Bodie, Kane and Marucs, 2006).

Whenever a deviation between the price of two equivalent assets appears, arbitrageurs should enter the market to bring back prices to parity. Arbitrage strategies are not unique however, and depend on the mechanisms that link the two equivalent assets.

Equivalent assets can be either two identical assets trading in different markets or perfect substitutes. As Scholes explains "the shares a firm sells are not unique works of art but abstract rights to an uncertain income stream for which close counterparts exist either directly or indirectly via combinations of assets of various kinds" (1972, p. 179) The arbitrage strategy between equivalent shares depends on two factors: Time and Substitutability.

2.3.2. Arbitrage Strategies

When two securities are perfect substitutes of each other and trade during the same time, the arbitrage strategies should require neither capital nor entail any risk. As soon as a price deviation is observed between these securities, an arbitrage operation is carried out in real time to close the gap. The presence of these 'pure arbitrage strategies' is the foundation of the major asset pricing theories as well as price discovery models. In financial markets, pure arbitrage operations can only be carried out in a limited number of contexts mainly in the foreign exchange market and in DRs, since DRs are fully convertible to their underlying stock.

When identical assets are not fully substitutable, arbitrageurs have to rely on risky arbitrage strategies involving opposite positions in the two assets, while waiting for prices to converge. Such a strategy takes place in financial markets between dual listed stocks (which trade in different markets and cannot be exchanged to one another) as well as mutual and exchange traded funds and their underlying stocks. It also takes place in DRs that trade during different trading hours than the underlying stock.

This section will discuss the difference between the pure and risky arbitrage strategy.

2.3.2.1. Pure Arbitrage Strategy

In a pure arbitrage an investor can make profits from the price divergence between DR and stock. An arbitrage opportunity is thus defined as:

$$\left| P_t^{DR} - \frac{P_t^{Stock} * b}{S_t} \right| > 0 \qquad \text{(Eq 2.2)}$$

When the DR is trading at a higher price than the underlying stock (i.e. premium), they short sell the DR and simultaneously they buy the local stock, deposit it at a custodian and have the depository issue a DR. Consequently they can sell the DR at a price higher than what they paid for to create it. The opposite is true in case the DR is selling at a lower price (i.e. discount). The arbitrageur can buy the DR and short sell the local stock, instructs the depositor to release the stocks in the local market, then close the short sale position by returning the stock and lock in the profit net of transaction costs involved. This pure arbitrage occurs when it is usually easy and straightforward to break open a DR and release the underlying locally listed stocks, making the two stocks fungible. (Miller and Morey, 1996; Savasoglu, 2000)

In reality, however, riskless pure arbitrage can never occurs since the real world of market frictions and imperfect information (and the cost of obtaining such information) may discourage an arbitrageur (Merton, 1987). Even in complete absence of any restriction to arbitrage, arbitrage operations can be costly (Pontiff, 1996). Time zone differences, transaction costs and prolonged settlement periods are some of those risks that are involved with above described arbitrage process. For example transactions costs create an arbitrage band around a security's equilibrium value. (Kato et al, 1991) As such, in order for the arbitrage to be lucrative, the price differential has to exceed the cost; that is arbitrageurs will only define a price deviation as an arbitrage opportunity as long as it exceeds transaction costs as follows:

$$\left|P_t^{DR} - \frac{P_t^{Stock} * b}{S_t}\right| > k \qquad \text{(Eq 2.3)}$$

Moreover, it is hypothesized that a short selling restriction on the local stock should prevent arbitrage when the DR is selling at a discount to the stock, since arbitrageurs cannot short sell the local stock.

2.3.2.2. Risky Arbitrage Strategies

Sometimes the simultaneous buying and selling of DRs and the underlying stocks cannot be achieved. This can be due to non-overlapping trading hours and long settlement periods (Kato et al, 1991); as well as trading restrictions such as limits on fungibility (Savasoglu, 2000). Thus, when prices of DR and the underlying stocks diverge, arbitrageurs engage in risky arbitrage. If the DR is trading at a premium, the arbitrageur can short the DR and buy the underlying stock. Instead of making instant profits, he has to wait for prices to converge. The prices will converge if the joint distribution of the DR and the underlying stock is stationary (Hong and Susmel, 2003).

Risky arbitrage falls under the category identified by Bondarenko (2003) as a 'statistical arbitrage'. Bondarenko (2003) defines a Statistical Arbitrage Opportunity(SAO) as "a zero-cost trading strategy for which (i) the expected payoff is positive, and (ii) the conditional expected payoff in each final state of the economy is nonnegative." Unlike a pure arbitrage opportunity, a SAO can have negative payoffs provided that the average payoff in each final state is nonnegative. This form of arbitrage is used frequently by hedge funds to make profits out of statistical mis-pricings or price relationships that are true in expectation, in the long run when repeating a trading strategy.

2.3.3. Summary of Studies

Because of the two arbitrage strategies described above, one might expect that DR prices 'should be aligned with their underlying currency adjusted equivalent in the home market' (Karolyi, 2006). When deviations exist between the price of the DR and that of the underlying asset, the DR is said to be 'mis-priced'.

Thus, arbitrage occurs if it is possible to buy in one market and sell in the other at a higher price net of transaction costs. Since such a activity occurs during the overlapping trading period between the foreign and local market, high frequency intraday data is required to capture arbitrage at the frequency in-which it occurs. Academic studies have thus gauged market efficiency tests by examining whether there are unexploited arbitrage opportunities in the DR market, but tend to be very limited due to lack of quality intraday data.

The first real study on arbitrage opportunities in the DR market is that of Miller and Morey (1996) who were the first to use high frequency data for only company (Glaxo Wellcome PLC) listed on the LSE and its ADR. They found that the price difference in the two markets is small throughout their 2-month sample.

The second study is that of Suarez (2005a) who finds that 2% of the deviations measured from his high frequency data set, where outside a no-arbitrage band that accounts for transaction costs. He makes use of these excess deviations through a trading rule to reach profits of $70,000. These profits are very small and infrequent that he argues are not incentive enough to hire an arbitrageur to monitor the market. He notes that these profits came out of a set of highly traded developed market stocks, and hypothesizes that emerging market stocks can provide larger deviation and more profitable arbitrage.

Using trading strategies to pinpoint the profits from the price deviations is an interesting approach, since it provides a quantifiable analysis of forgone arbitrage. It also highlights the economic significance of the anomaly, since as Jensen (1978) argued, if anomalous return behavior is not definitive enough for an efficient trader to make money trading on it, then it is not economically significant. However, these studies do not attempt to find the reasons for the existence of arbitrage opportunities in the first place.

This area of research provides a promising venue since so far evidence on arbitrage opportunities in the DR market is not clear. Moreover, while several studies hypothesize that less liquid stocks, like those from emerging markets, could present more profitable opportunities, so far an empirical test has not been carried out due to data unavailability.

2.3.4. Why do Arbitrage Opportunities Arise?

Following a traditional view of frictionless economies, stocks move due to a co-movement in their fundamentals. Thus, DRs and their underlying stocks should move together since they are claims on identical future cash flows. However, an alternative view that takes market frictions, noise trading and limits to arbitrage into consideration, giving rise to what Barberis, Schleifer and Wurgler (2005) call "friction based" or "sentiment based" movements, allows for price co-movement that are not linked to fundamental value. Froot and Dabora (1999) examine the prices for twin 'Siamese' stocks and find evidence that each stock pair appears to be closer correlated with the markets on which they are traded most, and, therefore, do not necessarily move together. Gagnon and Karolyi's (2010) also find robust evidence of excess co-movements of DRs with the foreign market inwhich they trade.

The reason for these excess co-movement is sometimes attributes to investor sentiment of owners holding different types of stocks. Empirical research has shown that investors can sometimes over or under-react to news, which are not explained by fundamental values, which was presented in the Investor Sentiment Model of Barberis, Schliefer and Vishny (1998). Thus, Ji (2006) explored the question of whether deviations between DR and the underlying stock are driven by investor sentiment was explored. She found that ownership base affects the deviation from parity, since large excess co-movements can be explained by investor base and that higher US institutional following is associated with larger systematic deviations from parity. Similarly, Grossman et al, (2007) include investor sentiment to explain the price deviation, and find that at price deviation of ADR from underlying stock is more driven by US consumer sentiment than local sentiment. Finally, Arquete et al (2008), show that the discounts attached to Chinese securities, whether trading as ADRs on the NYSE or as H-stocks on the Hong Kong market, appear to have been significantly influenced by changes in both exchange rate expectations and investor sentiment during 1998–2006.

2.4. Price Discovery

2.4.1. Introduction

Price discovery, defined as the process of searching for an equilibrium price (Harris *et al.*, 1995), is a key function of stock exchanges. The question of where price discovery occurs for securities that trade in multiple markets during overlapping trading hours was first examined in US securities that trade on different regional exchanges inside the USA. Two cornerstone methodologies in the literature are the basis of measuring price discovery: Gonzalo and Granger (1995) Component Shares and Hasbrouck (1995) Information Shares.

Harris *et al.* in their studies of IBM (1995) and Dow stocks (2002) use the Component Share of Gonzalo and Granger (1995) that rely on common long-memory error-correction estimation approach to measure price discovery. They demonstrate that that all three US regional exchanges contribute to price discovery.

Hasbrouck (1995) examined the same question by measuring price discovery using the "information share" of each market, which he defines as the fraction of long-term total variation in returns that is explained by each market from a variance-decomposition analysis. Both measures depends on the estimation of a vector error correction model of the different prices of identical securities trading in multiple markets.

Multi-market price discovery studies since then have relied on either the GG Component Share or Hasbrouck's Information Shares to measure contribution to price discovery. A special edition of Journal of Financial Markets (Issue 5, 2002) was dedicated to discuss the differences and merits of each approach (see for example DeJong (2002), Baille et al (2002) and Harris et al. (2002)). The general conclusion is that both methodologies are related and give similar results in most contexts, depending on data type used and the objective of the analysis.

In this section we will start by giving an overview of the econometric methodology behind price discovery models. We will then present a summary of the main studies on the topic focusing on securities that trade in multiple markets around the world.

2.4.2. Measuring Multi-Market Price Discovery

In this section, we discuss how we measure the contribution of multiple markets to price discovery of cross-listed stocks by adapting from the several articles published in the Special Issue 5 on the topic in Journal of Financial Markets 2002, mainly DeJong (2002), Baille et al (2002) and Harris et al. (2002).

In order to formulate the dynamics of price adjustment across informationally-linked exchanges, we consider a common stochastic trends representation of the local stock and depository receipt price series arising from the trades executed by traders on the Local Stock Exchange, P^{DR}, and trades executed by traders on the foreign market P^{S}.

The LOOP underlying both prices should ensure that while each price series is non-stationary in itself, there exists a co-integrating relationship between them which share the implicit efficient price as a common stochastic trend. The implicit efficient price, P_t, follows a random walk and is represented by:

$$P_t = P_{t-1} + w_t \quad w \sim N(0, \sigma_w^2) \qquad \text{(Eq 2.4)}$$

where t is trading time and w_t is the random information arrival. P_t is a non-mean reverting series and therefore can be represented by $P_t = P_0 + \sum_{t=1}^{t} w_t$.

The actual trading that occurs on the stock and depository receipt impound the w_t information arrivals but each differs from the efficient price $P_t$by a zero-mean, covariance-stationary identically distributed random disturbance ε_t^S or ε_t^{DR}:

$$P_t^S = P_t + \varepsilon_t^S \text{ and } P_t^{DR} = P_t + \varepsilon_t^{DR} \qquad \text{(Eq 2.5)}$$

re-writing (2) in first differences:

$\Delta P_t^S = \Delta P_t + \Delta\varepsilon_t^S = w_t + \Delta\varepsilon_t^S$ and

$$\Delta P_t^{DR} = \Delta P_t + \Delta\varepsilon_t^{DR} = w_t + \Delta\varepsilon_t^{DR} \qquad \text{(Eq 2.6)}$$

which can be extended to the following form:

$$P_t^S = P_{t-1}^S + w_t + \Delta\varepsilon_t^S \text{ and } P_t^{DR} = P_{t-1}^{DR} + w_t + \Delta\varepsilon_t^{DR} \qquad \text{(Eq 2.6')}$$

This means that at any realization t=T both prices should impound the same stochastic trend in the implicit efficient price and therefore

$$P_T^S = P_0^S + \sum_{t=1}^{T} w_t + \varepsilon_T^S \text{ and } P_T^{DR} = P_0^{DR} + \sum_{t=1}^{T} w_t + \varepsilon_T^{DR} \qquad \text{(Eq 2.7)}$$

The common stochastic trend in Equation (2.7), is similar to a Stock and Watson (1988) representation, and has a permanent common stochastic $\sum_{t=1}^{T} w_t$ that presents the long term relationship between prices and a short term transitory disturbance which a zero mean covariance stationary term given by ε_T^S and ε_T^{DR}.

Since the DR and stock prices have the same common stochastic trend, the difference between prices

$$(P_T^S - P_T^{DR}) = \varepsilon_T^S - \varepsilon_T^{DR} \qquad \text{(Eq 2.8)}$$

which is a stationary I(0) process with one co-integrating relationship. According to the Granger Representation Theorem, co-integrated series can be represented by a vector error correction model of the form

$$\Delta P_t = \alpha\beta' P_{t-1} + \sum_{j=1}^{k} A_j \Delta P_{t-j} + e_t \qquad \text{(Eq 2.9)}$$

where $P_t = (P_t^S, P_t^{DR})'$, α is the error correction vector, $\beta' P_{t-1}$ is the error correction term represented by $z_t = \beta' P_t = P_t^S - P_t^{DR}$ with the co-integrating vector $\beta = (1, -1)'$ and k is the optimal lag length determined by the AIC or BIC.

The first term $\alpha\beta' P_{t-1}$ represents the long run equilibrium dynamics between the price series while $\sum_{j=1}^{k} A_j \Delta P_{t-j}$ depicts the short term dynamics induced by market imperfections. The error term e_t is a zero mean vector of serially uncorrelated innovations with a co-variance matrix Ω:

$$\Omega = \begin{pmatrix} \sigma_1^2 & \rho\sigma_1\sigma_2 \\ \rho\sigma_1\sigma_2 & \sigma_2^2 \end{pmatrix}$$

2.4.2.1. Gonzalo and Granger's Component Shares

The VECM Equation in 2.9 can be presented in a Stock and Watson's (1988) common trend representation:

$$P_t = f_t + G_t \qquad \text{(Eq 2.10)}$$

Where f_t is the common factor component and $G_t$is the transitory component with no permanent impact on P_t. Gonzalo and Granger (1995) define the common factor of be a combination of the factors $P_t = (\mathrm{p}_{1\mathrm{t},}, \mathrm{p}_{2\mathrm{t},})$, such that $f_t = \Gamma P_t$, where $\Gamma = (\gamma_1, \gamma_2)$ and is a 1x2 common factor coefficient vector. They prove that $\Gamma$is orthogonal to the error correction vector α denoted by $\Gamma = \alpha \perp '$ and is normalized so that $\sum \gamma_{\mathrm{i}} = 1$.

Harris et al (2002) show that the specification $f_t$can be considered as portfolio of prices from each market with Γ serving as portfolio and that therefore the contribution of the first(second) market to price discovery can be measured by $\gamma_1(\gamma_2)$. Since the error correction vector α is orthogonal to Γ, $\alpha_\perp = (\gamma_1, \gamma_2)'$ and so we can empirically measure the contribution of a market as:

$$C_j = \frac{\alpha_j}{\alpha_1 + \alpha_2} \qquad \text{(Eq 2.11)}$$

2.4.2.2. Hasbrouck's Information Shares

Hasbrouck (1995) uses a structural form of equation (2.7) by providing a vector moving average representation of the VECM model of Equation (2.9) as:

$$\mathrm{P_t} = \mathrm{e_t} + \Psi_1 \mathrm{e}_{\mathrm{t}-1} + \Psi_2 \mathrm{e}_{\mathrm{t}-2} + \cdots = \Psi(\mathrm{L})\mathrm{e_t} \qquad \text{(Eq 2.12)}$$

which can be re-written as

$$\mathrm{P_t} = \Psi(1) \sum_{\mathrm{s}=1}^{\mathrm{t}} \mathrm{e_s} + \Psi^*(\mathrm{L})\mathrm{e_t} \qquad \text{(Eq 2.13)}$$

Where $\Psi(1)$ is finite and measures the long run impact of a shock on the level of prices. If we denote $\psi = (\psi_1, \psi_2)$ as the common row vector in $\Psi(1)$ then

$$\mathrm{P_t} = \binom{1}{1}\psi \sum_{s=1}^{t} \mathrm{e_s} + \Psi^*(\mathrm{L})\mathrm{e_t} \qquad \text{(Eq 2.14)}$$

$\psi = (\psi_1, \psi_2)$ is a 2x1 vector with $\psi\alpha = 0$. The term $\psi \sum_{s=1}^{t} \mathrm{e_s}$ is the common stochastic trend component. The increment $\psi\mathrm{e_t}$ from the first part of equation 2.14 is the component of price change that is permanently impounded into the price. If one decomposes the variance of the common factor innovations into $var(\psi\mathrm{e_t}) = \psi\Omega\psi'$, the information share of each market is the proportion of $var(\psi\mathrm{e_t})$ that is attributable to innovations in that market and is gives by:

$$S_j = \frac{\psi_j^2\sigma_j^2}{\psi\Omega\psi'} \qquad \text{(Eq 2.15)}$$

Baillie et al (2002) show that the Component Share and Information Shares are closely linked and that $\frac{\psi_1}{\psi_2} = \frac{\gamma_1}{\gamma_2}$ and therefore information share can be computed as:

$$S_j = \frac{\gamma_j^2\sigma_i^2}{\gamma_1^2\sigma_1^2+\gamma_2^2\sigma_2^2} \qquad \text{(Eq 2.16)}$$

When there is high correlation between the error terms, Hasbrouck's Information shares cannot be measured by Equation 2.15 but rather the variance-covariance matrix uses the Cholesly factorization and is defined as:

$$M = \begin{pmatrix} m_{11} & 0 \\ m_{12} & m_{22} \end{pmatrix} = \begin{pmatrix} \sigma_1 & 0 \\ \rho\sigma_2 & \sigma_2(1-\rho^2)^{0.5} \end{pmatrix} \qquad \text{(Eq 2.17)}$$

where ρ is the correlation between the residuals of the VECM, σ_1 and σ_2 are the variance elements of the residuals of the VECM. The information shares will then be estimated as:

$$S_1 = \frac{(\gamma_1 m_{11} + \gamma_2 m_{12})^2}{(\gamma_1 m_{11} + \gamma_2 m_{12})^2 + (\gamma_2 m_{22})^2} \qquad \text{(Eq 2.18)}$$

Hasbrouck (1995) considers the upper (lower) bound of market j's information share when market j is the first (second) variable in the factorization (Baille et al, 2002).

2.4.3. Summary of Studies

Studying the contribution of competing stock exchanges in determining price discovery becomes more motivating for international cross-listed stocks that trade in local and foreign markets during overlapping trading hours[3]. Because price discovery is concerned with adjustments to prices due to cross-market information flows, the market with more information on the security should contribute more to its price discovery. Assuming that more information on the stock comes from its local market, the hypothesis is, therefore, that the local market will be the dominant one

[3] For studies on price discovery during non-overlapping trading hours, see Agarwal *et al*. (2006) on Hong Kong Shares, Lieberman *et al*. (1996) and Qadan and Yigali (2011) on Israeli shares, Kadapakkam *et al*. (2003) on Indian shares, and Su & Chong (2007) on Chinese shares.

and contribute more to price discovery than would the foreign market, which will act as a pure satellite (Garbade and Silber, 1979).

Several studies use either the GG or the Hasbrouck methodology to test this hypothesis in various settings. The main obstacle to arriving at a general conclusion on the issue is the lack of quality of the intraday data that is required to operationalize such models, so our knowledge is built on various studies that investigate the question in different settings and times. The general finding is that both markets contribute to price discovery, that the local market is generally dominant, and that both findings depend on the proportion of trading volume that migrates to the international exchange. We summarize the most important studies next.

Using transaction prices for a Malaysian cross-listed stock, Ding *et al.* (1999) found that the Kuala Lumpur Stock Exchange (KLSE) contributes more to price discovery than does the Singapore Stock Exchange (SSE). They explain this situation by the greater trading volume for the stock in the local market. In the Grammig *et al.* (2005) study of three German stocks and the Pascual *et al.* (2006) study of six Spanish stocks cross listed as ADRs on the NYSE, the local market dominated, even after the researchers had controlled for exchange rate shocks and trade-related shocks. The Lok and Kalev (2006) and Frijins *et al.* (2010) studies of Australian and New Zealand cross-listed stocks also found that, whereas price discovery occurs on both markets, the local market is the dominant one.

The only research reporting mixed findings seems to be that of Eun and Sabherwal (2003) on 62 Canadian–US cross-listed securities; in that study, the foreign market was found to be dominant for a number of stocks. We can explain the difference between the results of Eun and Sabherwal (2003) and those of the previous studies by the extent to which trading in the host market is "liquidity- rather than information-driven" (Agarwal *et al.*, 2006). US and Canadian markets are informationally linked by virtue of their geographical proximity and shared language; thus the US market is an important one for Canadian companies and is more likely to play an influential role in their price discovery process. In the other studies cited here, language, cultural, and geographical barriers may increase the probability of the host market being more liquidity driven than information-driven. Whether this result is true for emerging market stocks that list on international exchanges such as the USA or London is yet to be studied, and such research is necessary in order to corroborate this hypothesis and explain the factors underlying the price discovery process.

2.5. Discussion and Areas for Research

Various studies have analyzed the pricing behavior of DRs relative to their underlying stocks. The first line of studies focuses on whether the LOOP holds between the identical pair, relying on daily datasets. While price parity is not rejected for developed market securities, emerging markets provided interesting grounds for a more in-depth analysis since their DRs trade at significant price deviations from their underlying stock. Trading barriers such as trading costs, capital controls, fungibility, ownership and short selling restrictions as well as special events have all been found to affect price parity.

While studies on the LOOP conclude that those deviations from parity are a reflection of barriers rather than real arbitrage opportunities, such a result is not accurate since it does not capture arbitrage in the real frequency in which it occurs, which is using intraday data during the overlapping trading hours between both markets to capture real arbitrage opportunities as they arise.

As we increasingly have access to higher frequency data, two studies emerge in the literature that study arbitrage in-depth by identifying whether arbitrage opportunities exist using intraday data between DRs and their underlying stock. Both studies use developed market securities from US and France. While Miller and Morey (1996) do not find any arbitrage opportunities, Suarez (2005a) identified very small arbitrage opportunities that give very small amounts of profit.

Identifying whether arbitrage opportunities exist in the DR market provides a very interesting venue for research since the samples examined so far are very small and ignore emerging market DRs. Since emerging markets have large limitations to arbitrage that cause price parity to be broken, it is only possible to examine whether arbitrage opportunities really arise with intraday data during the overlapping trading hours between the local and foreign market.

What is even more interesting is to try to identify real arbitrage trades from the dataset. The literature on arbitrage in general has so far assumed how the process works, but empirical evidence that reveals actual arbitrage trades is not available. Identifying arbitrage trades from intraday data requires a novel methodology that goes beyond identifying price deviations in the data. Gagnon and Karolyi's (2010) study provides a motivation for further examining this issue since they "believe that the mechanics of arbitrage in the market for cross-listed stocks is complex and the institutional features of this marketplace make it difficult to judge the actual profitability of such trading strategies".

Moreover, further motivation from Gagnon and Karolyi (2010) is for more specialized studies that can accurately account for trading costs and use high frequency data since "arbitrage activity in this market may take place intraday for those markets in which there is some overlap of trading hours…..we cannot know for certain whether the patterns in price deviations are economically real or artifacts of asynchronous trading between the two securities"

Finally, while an intraday arbitrage analysis on emerging market DRs should provide useful insights on whether arbitrage opportunities exist and whether arbitrage trades really occur to cause price convergence, such an analysis is static in nature and doesn't identify which market dominates in terms of price discovery.

Price discovery studies summarized above can help examine the dynamic role of the international stock market in pricing DRs. However, since such models also require intraday data from emerging markets, which are limited, so far no study examines the contribution of the foreign versus local market in the price discovery process of DRs from emerging markets.

This thesis tends to fill the above gaps in the literature review by examining the process of arbitrage and price discovery in DRs from emerging markets using high frequency intraday dataset. The markets that are chosen for the sample are selected to have trading barriers that mask any real patterns in pricing with daily data and to be as different as possible from developed market equities for comparison purposes.

Table 2-1 Measure of Deviations from Parity

PRICE DEVIATION (K) MEASURES		
Measure	Equation	Studies Used In
Price Deviation	$P_t^{DR} - P_t^{Stock\prime}$	Maldonado and Saunders (1983); Kato, Linn and Schallheim (1991); Miller and Morey (1996); Suarez (2005a)
Relative Price Deviation (Premium, Discount)	$\frac{P_t^{DR} - P_t^{Stock\prime}}{P_t^{DR}}$	Koumkwa and Susmel (2008); Grossman et al (2007); Chen et al (2008); Auguste et al (2006), Yeyati et al (2008)
Relative Log Price Deviation	$Ln(\frac{P_t^{DR}}{P_t^{Stock\prime}})$	Gagnon and Karolyi (2005); Kaul and Mehrotra(2007)
RETURN DEVIATION MEASURES		
Return Deviation	$Ln(\frac{P_t^{DR}}{P_{t-1}^{DR}}) - Ln(\frac{P_t^{Stock}}{P_{t-1}^{Stock\prime}})$	Kato et al (1991);Rabinovitch et al (2003); Gagnon and Karolyi (2005);

3 DATA DESCRIPTION

3.1. Sample Markets

We are interested in studying the pricing behavior of DRs from emerging markets. With that, the sample of this thesis is made up of all Egyptian stocks that are listed on the Egyptian Stock Exchange(EGX) and foreign cross-listed as GDRs on the London Stock Exchange (LSE) as well as all Argentinean stocks listed on the Buenos Aires Stock Exchange(BCBA) and cross-listed as ADRs on US exchanges (New York Stock Exchange(NYSE) and NASDAQ).

The different location of foreign cross-listing for Egyptian and Argentinean securities allow us to compare results across different settings and to overcome the focus of the majority of studies on ADRs trading on US exchanges. Moreover, both markets have several characteristics that make them ideal for this study: synchronous trading between the local and foreign market, lack of a fungibility restriction while having other limits to arbitrage and similar market microstructure. We discuss of these criteria next.

3.1.1. Synchronous Trading

Argentina and Egypt have a considerable portion of trading overlap between the international markets in which the DR trades and the local stock exchange in-which the underlying stock trades overcoming asynchronousity problems and ensuring that arbitrage strategies can be carried out in real time.

Egyptian stocks trade on the EGX during regular trading hours from 10:30 a.m. to 2:30 p.m. local Cairo time; the normal trading week starts on Sunday and ends on Thursday. Egyptian GDRs trade on the LSE during regular trading hours from 8:00 a.m. to 4:30 p.m. local UK time from Monday to Friday, giving the two markets only four days each week of overlap, with 4 overlapping trading hours daily.

Argentinean stocks trade on the Mercadoes de Valores de Buenos Aires (BCBA) from Monday to Friday from 11:00 am to 5:00 pm local Buenos Aires time; the ADRs trade during the same trading week on US exchanges from 9:30 am to 4:00 pm US Eastern time, giving both markets 6 overlapping trading hours during winter and 5.5 hours during summer. Figure 3.1 shows the trading hours in each of our markets in GMT time.

INSERT FIGURE 3.1 HERE

Having synchronous trading hours between the foreign and local market should ensure that prices in each market incorporates information fully and thus prices should not deviate. One exception of this synchronistic trading in our sample is due to the different weekend between the EGX and LSE. While Egyptian stocks trade during the same overlapping hours as their GDRs, they do so for only 4 days of the trading week. Our first article in this thesis in Chapter 4 discusses how this variable affects the LOOP between Egyptian GDRs and their underlying stock.

3.1.2. Fungibility

Both local stock exchanges allow full fungibility between the DR and its underlying stock. This should ensure price parity as arbitrage operations are not hampered. We verify the fungibility criterion in Argentina by the study of Auguste et al (2006) who show that when capital controls where imposed in Argentina during the Argentinean crisis, ADRs aided capital flight by allowing investors to buy the stock and convert it to the ADR and sell it in the US. As for Egypt, we support fungibility by data obtained from the Egyptian Depository and Clearing House, revealing large number of issuances and cancellation between Egyptian GDRs and their underlying stock.

3.1.3. Limits to Arbitrage

Despite the lack of restriction on arbitrage operations, we pick Egyptian and Argentinean securities since they trade under some other trading barriers that are hypothesized to limit arbitrage.

First, short selling restrictions are in effect in Egypt and Argentina. While regulatory bodies have loosened up the regulation on short sales in both countries, in practice they remain in effect (Bris et al, 2007). The short selling restriction is one variable we are interested to examine, since studies so far have only hypothesized the effect on arbitrage, arguing that it stop arbitrage activities on the side of the short sale, yet empirical evidence is yet to corroborate this hypothesis.

Second, Egypt and Argentina have large trading costs. Trading costs create a large band around a security's equilibrium price in which prices of the DR and underlying stock can deviate without making them profitable enough to be eliminated by arbitrageurs. This presents an interesting challenge to come up with precise trading costs that we can use in our analysis.

Finally, both markets have capital controls. Argentina has a capital control on inflows in the form of 30% of any money transfers into the country to be deposited with the central bank for a minimum of 1 year. Egypt currently has capital controls on outflows post the January 25th 2011 Egyptian Revolution, however during our sample period Egypt was not subject to capital controls.

Capital controls provide an interesting case for violations from price parity as discussed in Auguste et al (2006). During the Argentinean crisis, the *corralito* was imposed by the Argentinean government, in-which all foreign funds were prohibited from being transferred abroad. The Argentinean ADRs played an important role during the crisis since they served a 'loop-hole' in the financial system that allowed investors to use their bank deposits to purchase Argentine stocks, convert them ADRs and sell them in the US. and the dollar proceeds deposited in a U.S. account. Such action caused the prices of the ADR to sell at huge discounts to the underlying stock and thus cause strong violation of price parity. Much like short selling restrictions, while capital controls reveal violations from the LOOP, current studies cannot establish whether capital controls hamper arbitrage activity in emerging markets or not.

3.1.4. Market Characteristics and Microstructure

Egyptian and Argentinean stock exchanges are very similar. While both are amongst the oldest stock markets in the world, dating back to 1883 and 1854, respectively, they are both relatively small stock exchanges with similar microstructure. Both are order-driven markets, with an electronic trading system for matching trades; they have no taxes on dividends or capital gains.

As in most emerging market stock exchanges, a relatively small set of companies dominates the market and trading value. Table 3-1 presents some indicators from our markets. In Egypt, the 30 most heavily traded firms account for an average of 34% of total market capitalization. The market in Argentina is much thinner, with the largest 10 companies comprising over 70% of market capitalization. We focus on local companies listed in both market.

Table 3-1 shows that the number of traded companies in both exchanges is very small. In Egypt, the number of companies dropped from over 700 companies in 2005 to 289 by end of 2009 due to the restructuring of the exchange which involved the de-listing of inactively traded companies.

INSERT TABLE 3.1 HERE

3.2. Data Description

The sample of this thesis is made up of all Egyptian stocks that are listed on the Egyptian Stock Exchange(EGX) and foreign cross-listed as GDRs on the London Stock Exchange (LSE) as well as all Argentinean stocks listed on the Buenos Aires Stock

Exchange(BCBA) and cross-listed as ADRs on US exchanges (New York Stock Exchange(NYSE) and NASDAQ).

The local Egyptian stocks trade in Egyptian pound (EGP) while their GDRs trade in USD. On the other hand, Argentinean stocks trade in Argentinean peso (ARS) while their ADRs trade in USD. Therefore in studying the prices of each pair, we are not only interested in prices but also in the foreign exchange rates between the EGP/USD and the ARS?USD.

A summary of all Egyptian and Argentinean DRs listed overseas is presented in Table 3-2. We pick DRs whose underlying stocks have ISIN numbers registered on the EGX and BCBA. Since we are interested in the pricing behavior of the DR and its underlying stock the main variables under study in this thesis are the DR price in USD, P_t^{DR}, the underlying stock price P_t^{Stock} in local currency and the foreign exchange rate between the local currency and USD S_t.

INSERT TABLE 3.2 HERE

We rely on both daily and intraday data in this thesis. Daily data are used to test the law of one price in Chapter 4 and to detect whether price parity holds between the DR and its underlying stock. Intraday data are used for studying arbitrage and price discovery in Chapters 5 and 6.

Daily data was obtained from Reuters 3000 Xtra and include daily open prices, closing prices as well as volumes for each of our DRs and their underlying stock. Daily closing exchange rate data was also obtained. The intraday data was obtained with the help of a senior Reuters executive from the Reuters Tick Database. It consists of all intraday transactions on each of the DR and the underlying stock including date, timestamps, prices and volumes. Intraday foreign exchange rate data included both bid and ask quotes for the EGP/USD and ARS/USD.

Table 3-1 Sample Country Market Indicators

Egypt						
Indicator	***2005***	***2006***	***2007***	***2008***	***2009***	***2010***
Value Traded (USD million)	26,247.65	47,396.50	58,459.09	85,744.32	81,724.70	47,011.92
Number of traded companies	441	407	337	322	289	212
Market capitalization (USD billion)	79.30	93.36	139.64	85.41	91.16	84.07
Exchange rate EGP/USD (end of period)	5.75	5.72	5.50	5.55	5.49	5.81

Argentina						
Indicator	***2005***	***2006***	***2007***	***2008***	***2009***	***2010***
Value Traded (USD million)	3,289.38	2,532.76	3,543.00	3,176.01	1,436.99	1,831.31
Number of traded companies	95	96	102	104	101	100
Market capitalization (USD billion)	47.59	51.24	57.07	39.85	45.74	42.67
Exchange rate ARS/USD (end of period)	3.03	3.06	3.15	3.45	3.80	3.92

Table 3-2 Sample Companies

Company	Ticker Symbol	Foreign Listing Exchange	Foreign Listing Date	Bundling Ratio	Reuters Sector Classification
Egypt					
Commercial International Bank	COMI	LSE	1/7/1996	1:1	Banks
EFG-Hermes	HRHO	LSE	1/8/1998	1:2	Financial Services
Orascom Telecom	ORTE	LSE	1/7/2000	1:5	Telecom
Orascom Construction Industries	OCIC	LSE	1/8/2002	1:1	Construction & Materials
Telecom Egypt	ETEL	LSE	1/12/2004	1:5	Telecom
Palm Hills Development Company*	PHDC	LSE	7/5/2008	1:5	Real Estate Inv&Serv
Lecico Egypt	LECI	LSE	11/23/2004	1:1	Industrial Engineer.
Suez Cement	SUCE	LSE	11/29/1996	1:1	Construction & Materials
El Ezz Steel Rebars	AEZD	LSE	12/26/2005	1:3	Indust.Metals&Mining
Argentina					
Banco Macro	BMA	NYSE	3/23/2006	1:10	Banks
BBVA Banco Frances	FRA	NYSE	11/23/1993	1:3	Banks
Edenor	EDN	NYSE	4/30/2007	1:20	Electricity
Grupo Financiero Galicia	GFG	NASDAQ	6/22/2000	1:10	Banks
Inversiones Y Representaciones S.A.	IRS	NYSE	5/1/1994	1:10	Real Estate Inv&Serv
MetroGas	MET	NYSE	2/26/2001	1:10	Gas,H20&Multiutility
Transportadora de Gas del Sur	TGS2	NYSE	10/21/2002	1:5	OilEquip.,Serv.&Dist
Alto Palermo S.A.	SAM	NASDAQ	11/10/2000	1:4	Real Estate Inv&Serv
Cresud	CRES	NASDAQ	3/18/1997	1:10	Food Producers
YPF	YPF	NYSE	6/28/1993	1:1	Oil & Gas Producers

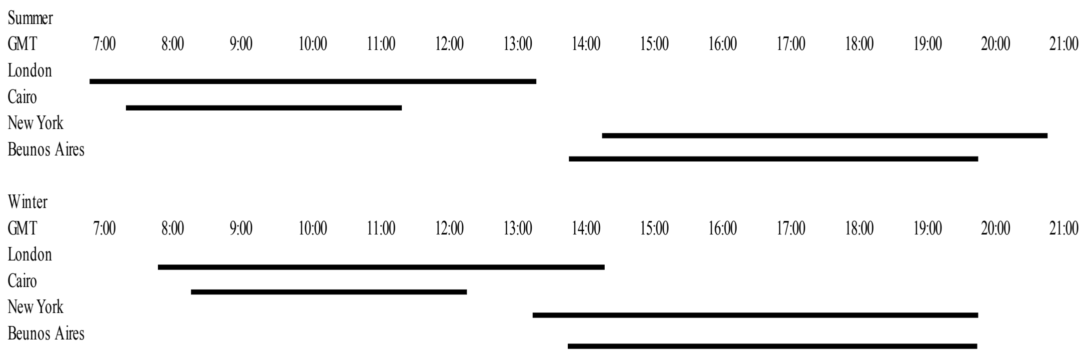


Figure 3-1 Trading Hours in Sample Markets

4 THE LAW OF ONE PRICE IN GLOBAL DEPOSITORY RECEIPTS: EMPIRICAL EVIDENCE FROM EGYPTIAN EQUITIES

4.1 Introduction

The Law of One Price (LOOP), considered the 'second law of economics' (Lamont & Thaler, 2003), states that identical goods must trade at identical prices. One example in financial equity markets where the LOOP should be observed involves stocks that are foreign-listed as depository receipts on international exchanges. Depository receipts(DRs), which are negotiable certificates issued by a trust bank that holds the underlying stock on behalf of investor, is the most common means for foreign-cross listing on international exchanges.

Despite trading in different market and in different currency denominations, the DR and its underlying stock are considered identical securities. Both securities have the same claim on the firm's cash flows and are freely exchangeable to one another. Therefore any difference between the currency adjusted prices should be eliminated by instantaneous arbitrage activity that ensures that the LOOP holds between both securities.

Early studies find that price parity holds between developed market DR and their underlying stock (Maldonado and Saunders, 1983; Kato et al, 1991; Park and Tavakkol, 1994). However, more recent evidence by Gagnon and Karolyi (2010) find that price parity is sometimes violated, especially for emerging markets' securities, due to factors that segment the two markets such as large trading barriers and transaction costs that make arbitrage activity difficult to carry out. All of these studies, however, focus on DRs listed on US exchanges, commonly referred to as American DRs (ADRs). Several cross-listed equity, however, prefer to list on other exchanges around the world, mainly the London Stock Exchange (LSE), as Global DRs (GDRs) for reasons related to business and geographical proximity. This makes the question of whether the LOOP holds between GDRs and their underlying stock so far lacking.

We examine this question in Egyptian stocks that are trading on the Egyptian Stock Exchange(EGX) in Egyptian pound (EGP) and their GDRs trading on the LSE in US dollars (USD). Egyptian GDRs represent the largest and most active cross-listed Arab equity. Many international investors seek to diversify their portfolios through investing in emerging market equity and Egyptian securities offered an attractive option for foreign investors as means for portfolio diversification, especially when it was considered one of the world's best performing stock exchanges from 2003 till 2005 (Saleh, 2004). Moreover, two of the Egyptian GDRs, Orascom Telecom (ORTE) and Orascom Constructions(OCIC), are considered amongst the most actively traded GDRs in London.

Egyptian GDRs also play other important roles in terms of providing liquidity, evident during the uprising in January 2011 since they prevented a complete shutdown of trading on the large Egyptian securities. While the EGX was closed for over 2 months, the Egyptian GDRs of Egyptian companies – including major financial services, telecommunication and construction firms – continued trading on the LSE with no disruption.

"It is very positive that the [Egyptian] DRs are working … I definitely see that this is the right thing [for issuers]." Hisham Ramez, Deputy Governor of the Central Bank of Egypt to Bank of New York Mellon (Bank of New York Mellon DR Report, August 2011)

Our data consists of daily open prices, closing prices and volumes for 10 Egyptian stocks and their GDRs, since their listing on the LSE and until April 2009, as well as daily foreign exchange rate data. While examining whether the LOOP holds in DRs is not new, two main aspects of our sample differentiate this study from previous analysis: studying the effect of the different trading week between the EGX and the LSE and different exchange rate regimes on price parity.

First, the EGX has a different trading week than the LSE. Therefore, while Egyptian stocks trade mostly within the same overlapping hours as their GDRs from Monday-Thursday, the EGX's weekend, Friday and Saturday, is different from LSE's, Saturday and Sunday. Thus, trading occurs on the GDR on Friday while EGX is closed and also trading occurs on Sunday in Egypt while LSE is closed. We study whether the effect of the different trading week on the LOOP.

Second, prior to January 2003 Egypt had a fixed exchange rate regime which was changed to a free-floating regime after that date. Four Egyptian securities that were cross-listed prior to that date allow us to examine whether the LOOP is affected by the type of exchange rate regime of the country.

The results of this paper reveal statistically and economically significant price deviations from parity across our sample. These results are not biased by the non-overlapping trading days nor the exchange rate regime.

This study is thus organized as follows. Section 4.2 data description and basic relationships. The study's tests and results will be presented in Section 4.3. Finally, Section 4.4 concludes and outlines directions for future research

4.2 Data Description and Basic Relationships

4.2.1 Data Description

There are currently 10 Egyptian companies that are foreign listed on the LSE as GDRs. Egyptian companies were motivated to list on the LSE to widen their investor base and gain international visibility.

"Telecom Egypt Launched its GDR program to enhance the company's profile and enlarge its investor base, in addition to creating a convenient mean to our international investors to invest in TE" *Telecom Egypt Investor Relations*

"We have chosen to initiate a GDR program in order to increase the level of awareness of OCI within the international investor and brokerage community. We also believe our listing on the London Stock Exchange will be beneficial as OCI pursues its regional expansion plans."

Mr. Nassef Sawiris, Orascom Constructon CEO

Due to the concentration of market capitalization of the EGX in a few companies, these 10 companies on average constitute over 30% of the market. Our dataset is made up of 9,333 individual data observations for each of the daily open prices, closing prices and volumes for 10 Egyptian GDRs and their underlying stocks as well as daily foreign exchange rate between the Egyptian Pound (EGP) and the US dollar(USD), which were all obtained from Reuters 3000 Xtra. The number of observations are uneven for each company since we use data since each company's GDR listing on the LSE and until 31st of January 2009.

It has been observed that some of the GDRs had a very low volume of trading on the LSE (AEZD, PACH) with less than 50 observations per year and have been excluded from the analysis. Thus our analysis below was conducted on only 8 of the GDR-stock pairs.

Table 4-1 provides a summary of the companies included in our sample. Since DRs are usually issued in bundles of underlying stock, the bundling ratio in column two refers to the ratio of GDR to underlying stocks. For example, one GDR of the Egyptian company ORTE is a claim on five stocks of ORTE stock traded on the EGX, thus the GDR bundling ratio is 1:5. Table 4-1 also shows various descriptive on our GDRs and stocks that reveals the level of heterogeneity amongst our sample. The concentration of the market liquidity on these companies is obviously on the local stock traded on the EGX as apparent from a comparison between the average annual volume of trade on the GDR versus the local stock.

Moreover, for some stocks such as LECI and PHDC, the market activity on the GDR is extremely low compared to the local stocks, since they are traded very infrequently on LSE as shown by the average number of trading days per year.

INSERT TABLE 4-1 HERE

4.2.2 Basic Relationship

The law of one price is said to hold if the following condition is satisfied:

$$P_t^{GDR} = \frac{P_t^{Stock} * b}{S_t} \tag{4.1}$$

Where P_t^{GDR} is the price of the GDR in USD listed on LSE, P_t^{Stock} is price of the underlying stock in EGX in EGP, *b* is the bundling ratio (Table 2-1) *and* S_t is the USD/EGP closing spot exchange rate.

The LOOP is tested by first measuring the price deviation between the depository receipt price and the foreign exchange underlying stock price and testing whether it is significantly different from zero. The two most common measure for price deviation are: Measure (1)Price Deviation $P_t^{GDR} - \frac{P_t^{Stock} * b}{S_t}$ and Measure (2) Relative Price Deviation $Ln\left(\frac{P_t^{GDR}}{\frac{P_t^{Stock} * b}{S_t}}\right)$. The advantage of the second measure is that it allows comparison across the different stocks in the sample. Prices are assumed not to deviate due to the presence of active arbitrageurs who keep the price of the GDR and currency adjusted Egyptian stocks in equilibrium. Should the prices of the

GDR and stock deviate, arbitrageurs should instantaneously intervene to bring prices to parity.

Egyptian stocks trade during non-overlapping days with their GDRs. We thus test for the LOOP during the overlapping trading days which are Monday to Thursday as well as during the non-overlapping days Friday and Sunday. This requires us to construct two price deviation series: Weekday Series and Weekend Series.

- **Weekday Series (I) (**Monday-Thursday Prices) since London closes 4 hours after EGX then prices should incorporate stocks closing prices as well as react to new information while EGX is closed. Thus, these prices series are made up of coinciding daily closing prices of the GDR, the underlying Stock and the Exchange rate from Monday-Thursday when trading occurs on both markets. Three price vectors were constructed:

$P^{GDR}_{t,M-T}$ = daily closing price of the GDR in USD listed on LSE from Monday to Thursday

$P^{Stock}_{t,M-T}$ = daily closing price of the underlying stock in EGX in Egyptian Pounds LE from Monday to Thursday

$S_{t,M-T}$ = daily closing USD/LE exchange rate from Monday to Thursday

We measure price deviation as follows:

Measure (1) $P^{GDR}_{t(M-T)} - \frac{P^{Stock}_{t(M-T)} * b}{S_t}$ (4.2a)

Measure (2) $Ln\ (P^{GDR}_{t(M-T)} / \frac{P^{Stock}_{t(M-T)} * b}{S_t})$ (4.2b)

- **Weekend Series (II):** Friday-Sunday-Monday: This weekend series assesses non-contemporaneous relationships arising from non-overlapping weekends. The price vectors were as follows:

$P^{GDR}_{close,F}$ = Friday closing price of the GDR in USD listed on the LSE

$P^{stock}_{open,S}$ = Sunday opening price of the underlying stock in EGP listed on the EGX

$P^{stock}_{close,S}$ = Sunday closing price of the underlying stock in EGP listed on the EGX

$P^{GDR}_{open,M}$ = Monday open price of the GDR in USD listed on LSE

Regarding the exchange rate to convert the local stock into USD:

S_F = the USD/LE exchange rate on Sunday is the closing price of the USD/LE exchange rate on Friday

We measure the price deviation across non-overlapping weekdays as follows:

Measure (1) $P^{GDR}_{close,F} - \frac{P^{Stock}_{open,S} * b}{S_F}$ $\boldsymbol{and}$ $P^{GDR}_{open,M} - \frac{P^{Stock}_{close,S} * b}{S_k}$ (4.3a)

Measure (2) $Ln(P^{GDR}_{close,F} / \frac{P^{Stock}_{open,S} * b}{S_F})$ ***and*** $Ln(P^{GDR}_{open,M} / \frac{P^{Stock}_{close,S} * b}{S_k})$ (4.3b)

4.3 Tests and Results

The objective of this empirical study is to examine the LOOP between GDR and their underlying stock. We do that by first directly assessing whether price parity holds. In case price parity is violated, we follow this with a test of whether the returns of Egyptian GDRs are identically distributed to their underlying stock.

In our analysis below, we choose to conduct the analysis on our data starting either the foreign date of listing or April 1st 2003, whichever comes earlier. This is to isolate the effect of the change in foreign exchange rate regime in 29th January 2003. We close this section with an analysis of the effect of the foreign exchange rate regime on price parity separately.

4.3.1 Price Parity Assessment

This involves a direct test of the law of one price by measuring the size of price deviations between the DR and the underlying stock. Price parity holds under the null hypothesis that the price deviation is not significantly different from zero. We use the two common measures discussed above: Price Deviation and Relative Price Deviation in both their absolute and non-absolute forms to test the null hypothesis. Results are presented in Table 4-2.

INSERT TABLE 4-2 HERE

It is obvious that on average price deviations can be very big, as high as USD6.68 difference in the case of Palm Hills between the GDR and the underlying stock using the first measure or 117% premium of the price of the GDR to the underlying stock for Lecico during our sample period. Parametric t-test for the null hypothesis reject the null hypothesis of price parity for the majority of stocks, since price deviations under the different measures are significantly different from zero both in weekdays and on weekends and are all different from zero using the absolute version of the price deviation measures.

We comment on the results of the most actively traded companies in both markets: ORTE and OCIC. These two companies are amongst the two most active firms both on EGX as well as from the top 10 most active GDRs on the LSE, and despite this ORTE's GDR trades at an average of -2.63% discount to its stock counterpart during overlapping trading week, and OCIC's GDR at a 2.61% premium to its stock during the overlapping trading week. The only stock that does not show any deviations using non-absolute measures of deviations is that of ETEL. This provided an impetus to examine the number of days in which a stock traded at a premium or a discount, which is provided in Figure 4-1.

INSERT FIGURE 4-1 HERE

It is obvious that the sign of the non-absolute measures of deviation give an indication of whether the GDR are more traded at premiums or discounts. It also explains why ETEL does not have significant deviations on average since the number of days trading at premium is close to those trading at discount.

Our final hypothesis is to examine whether the size of the price deviations during the non-overlapping weekend series are greater than during the weekday series. Results presented in Table 4-3 show that, on average, for all of our companies the weekend and weekday price deviations are not different at the 99% confidence level.

INSERT TABLE 4-3 HERE

The question thus becomes: Why are weekend and weekday deviations not different? One possible explanation could be volume of trading on Fridays and Sundays. Indeed a cross sectional analysis of the average daily volume on the GDR and Stocks on Fridays and Sundays, reveal that these two days on average have the lowest volume proportional to the total weekly volume of trade, Figure 4-2. This means that for the GDR, the lowest volume of trade is on Friday and for the local stock it is Sunday.

INSERT FIGURE 4-2 HERE

We can make sense of these results as follows: On Friday in London, investors rarely observe any new information about the stock, since the markets are closed in Egypt for the weekend. Therefore, the volume of trading is lowest, reflecting only liquidity traders. Similarly, investors trading in Egypt on Sunday react to the trading on the GDR on Friday, but are not aggressive in trading, since these companies are considered "international" so trading on the stock is slow on Sunday as investors wait for information on Monday when both markets are open. This is obvious since the % of the weekly volume of trade occurring on Monday in both markets is much higher than either Friday or Sunday trades.

Our result on the law of one price between Egyptian GDRs and their underlying stock show that price parity is violated for all of our stocks and that violation of price parity is consistent across the overlapping trading weeks and non-overlapping trading weekends. We chart the prices of each DR and its underlying stock in Appendix 2. Our price parity results are verified, in that large price deviations are apparent, however, in the long run both securities follow the same trend which means that prices adjust to each other.

This bring us to an important question: is the GDR a true dollar translation of the underlying stock? We examine this question in the next section.

4.3.2 Return Distribution

Although we find that prices between the GDR and the underlying stock deviate, we examine whether the GDR and the underlying stock are the same security by testing whether one exhibits superior returns to the other. We empirically test this by constructing a return deviation series from the GDR and adjusted local share price. We define a return deviation as follows:

$$ln\left(\frac{P_t^{GDR}}{P_{t-1}^{GDR}}\right) - ln\left(\frac{\frac{P_t^{Stock}{*b}}{S_t}}{\frac{P_{t-1}^{Stock}{*b}}{S_{t-1}}}\right) \qquad (4.4)$$

whereby we test the null hypothesis that this deviation on average is zero. Since we find that both weekend and weekday series provide similar results, we conduct the following analysis on the total series that combines both. The parametric T-Test fails to reject the null hypothesis that the average return deviation between the GDR and Stock is different from zero for all stocks. These results are shown in Table 4-4 and indicate that indeed on average the return deviation between them is zero and thus that one cannot obtain superior returns by buying the GDR over the underlying stock.

INSERT TABLE 4-4 HERE

However, even if the return deviations on average are zero, there is a potential possibility that the average does not capture the direction of returns. Thus, to check that the returns move in the same direction, we conduct two non-parametric tests: the Wilcoxon Rank Sum Test and the Sign Test. The results presented in Table 4-5 also confirm that there is no difference between the direction of the two return series.

INSERT TABLE 4-5 HERE

4.3.3 The Effect of Exchange Rate Regime on Price Parity

On January 29th, 2003, the Egyptian government allowed its currency to float.

Before January 29th, 2003, the Egyptian government had a fixed exchange rate regime whereby the Egyptian pound (EGP) was pegged against the USD. However, a series of economic downturns in 2002 forced the government in January 2003 to free float the currency. (Allam, January 29th, 2003). For the four companies in our sample (COMI, SUCE, OCIC and ORTE) for which we had data prior to January 29th, 2003, this seemed an interesting question how the results of our analysis on the arbitrage between GDR-stock pairs would be affected by the exchange rate regime.

Previous studies, as those by Maldonado and Saunders (1983) and Rabinovitch et al (2003), have found that fixed exchange rate regimes do not affect LOOP between cross-listed stock. Thus, for these four stocks (COMI, SUCE, OCIC and ORTE) we analyze the pre-post fixed exchange rate regime effect on price parity between the GDR and stock. We compare the size of the deviations between the prices of our four GDR-stock pairs.

We measure the price deviations for COMI, SUCE, ORTE and OCIC during the fixed exchange rate regime and after its change to a floating one. Results in Table 4-6 shows that for our different price deviation measures SUCE, ORTE and OCIC price deviations were reduced after the fixed exchange rate regime was abolished. However, for COMI the opposite seems to have occurred. From this brief analysis, we can conclude that the fixed exchange rate regime did affect the size of price deviations, however, despite the direction, deviations were still observed.

INSERT TABLE 4-6 HERE

We also examine whether the return distribution of the GDR and stock is affected by the different exchange rate regimes. The return deviation measures are not different pre and post the exchange rate regime as Table 4-7 shows. Indeed, a t-test of the null hypothesis that the averages of the return deviation before and after the exchange rate regime are equal to zero couldn't be rejected. Moreover, a comparison of averages pre and post also gives insignificant results. Thus, we conclude that the exchange rate regime did not affect the ability of returns of both markets to adjust to each other.

INSERT TABLE 4-7 HERE

4.4 Conclusions

"Does the Law of One Price Hold for Egyptian GDRs?" The evidence presented here indicates clear deviations from parity. Compared to research on the area in the 1980s and 1990s (Maldonado and Saunders, 1983; Kato et al, 1991) which have pre-dominantly focused on ADR-Stock pairs (mostly from developed market stock) and find no deviations from parity, this study uses similar methodology and finds evidence of the presence of statistically large deviations. This deviation from price parity is consistent even across the different weekend days and is not affected by a fixed versus floating exchange rate regime. According to the Law of One Price any such price deviation should be instantly eliminated by active arbitrageurs in the market, who buy the underpriced security and short-sell the overprice security to make risk free profits. The fungibility feature of depository receipts that allows them to be fully convertible to each other makes them attractive for arbitrageurs. However, while our results on the violation of price parity might indicate a lack of market efficiency and hint at the presence of forgone arbitrage opportunities in this market, there are several reasons that make such statements inconclusive.

First, while prices do deviate, the return distributions of Egyptian GDRs and their underlying stocks are not different from each other, which indicates that an investor cannot earn superior returns from investing in one security over the other. Second, the price deviations we observe can easily be explained by large trading costs that create an arbitrage band around a security's equilibrium value (Kato et al, 1991) and as such, in order for the arbitrage to be lucrative, the price differential has to exceed the transaction cost. Moreover, trading restrictions, such as short selling restriction in Egypt, can explain why prices deviate from each other (Gagnon and Karolyi, 2010). Finally, it is important to note that one limitation of this study is that we compare daily closing prices that do not occur at the same point in time due to the different closing times of the EGX and LSE.

The results of this paper should be interpreted with caution since while we observe a clear break from price parity and which we can explain by several market imperfections, this does not give an indication of the presence, or lack of, arbitrage opportunities in Egyptian GDRs. Arbitrage opportunities are better captured using higher frequency data that can capture arbitrage at the frequency in which in actually occurs which is intra-daily. This analysis will be addressed in a separate study.

Table 4-1 Summary of Total Sample Data Series

	Bundling Ratio[a]	GDR: Average Annual Volume (mn stocks)	GDR: Average Number Trading Days/Year	GDR: Price Range (USD)	Stock: Average Annual Volume[b] (mn stocks)	Stock: Average Number Trading Days/Year	Stock: Price Range[c] (USD)
COMI	1:1	13	220	1.125-13.5	166	261	1.125-13.5
SUCE	1:1	1	70	2.73-20.9	17	262	2.86-20.98
HRHO	1:2	2	246	0.88-37.4	373	243	0.85-34.4
ORTE	1:5	52	251	0.66-83.8	67	247	0.71-84.9
OCIC	1:1	10	240	2.57-175	25	245	2.3-171.26
LECI	1:1	2	65	2-7.3	30	223	2.04-8.76
ETEL	1:5	3	156	10-21.5	109	244	9.78-21.54.5
PHDC	1:5	2	67	4.9-20.56	22	178	5.23-20.1

[a] *Source: Bank of New York Mellon* (www.bnymellon.com)
[b] *adjusted for bundling ratio* [c] *adjusted for foreign exchange rate and bundling ratio*

Table 4-2 The Law of One Price Test Results

(A) Daily Price Deviation (USD) $H_0 - : P_t^{GDR} - \frac{P_t^{Stock} * b}{S_t} = 0$

Company	Monday-Thursday					Friday-Sunday				
	Mean	**Minimum**	**Maximum**	**Standard Deviation**	**T-Test**	**Mean**	**Minimum**	**Maximum**	**Standard Deviation**	**T-Test**
COMI	0.286**	-0.114	1.019	0.219	22.249	0.292**	-0.014	1.049	0.222	32.841
SUCE	-0.178**	-3.75	4.72	0.913	-6.628	-0.11**	-4.06	5.7	1.001	-2.71
HRHO	0.576**	-1.07	5.25	0.845	6.329	0.564**	-0.61	4.88	1.003	9.694
ORTE	-0.445**	-5.15	4.71	0.8424	-18.576	-0.4118**	-5.02	4.96	0.966	-7.349
OCIC	0.072**	-0.54	0.51	0.202	4.65	0.0502**	-0.73	0.45	0.234	2.03
LECI	-0.62**	-4.48	4.83	1.69	-3.996	-0.78**	-2.84	2.54	1.35	-4.052
ETEL	0.00	-4.34	3.31	0.58	-0.176	0.04	-2.19	2.54	0.67	0.836
PHDC	0.53**	-0.84	6.68	1.51	2.829	0.34*	-4.42	5.19	1.59	1.142

(B) Daily Absolute Price Deviation (USD) $H_0 -: \left| P_t^{GDR} - \frac{P_t^{Stock} * b}{S_t} \right| = 0$

	Monday-Thursday					Friday-Sunday				
Company	**Mean**	**Minimum**	**Maximum**	**Standard Deviation**	**T-Test**	**Mean**	**Minimum**	**Maximum**	**Standard Deviation**	**T-Test**
COMI	0.292**	0	1.019	0.228	23.35	0.297**	0	1.0493	0.224	34.537
SUCE	0.577**	0	4.72	0.729	22.473	0.592**	0	5.7	0.814	14.076
HRHO	0.592**	0	5.25	0.833	13.374	0.611**	0	4.88	0.975	19.684
ORTE	0.69**	0	5.15	0.62	34.4	0.736**	0	5.02	748	16.319
OCIC	0.177**	0	0.54	0.12	19.19	0.193**	0	0.73	0.138	15.274
LECI	1.51**	0.03	4.83	0.96	17.099	1.41**	0.05	2.84	0.66	14.848
ETEL	0.37**	0	4.34	0.45	16.993	0.43**	0	2.54	0.51	10.981
PHDC	0.88**	0	6.68	1.33	5.359	0.91**	0	5.19	1.34	3.105

*** and * indicate significance at 1% and 5%*

(C) Relative Price Deviation (%) $H_0 - : Ln\left(\frac{P_t^{GDR}}{\frac{P_t^{Stock} * b}{S_t}}\right) = 0$

Company	Monday-Thursday					Friday-Sunday				
	Mean	**Minimum**	**Maximum**	**Standard Deviation**	**T-Test**	**Mean**	**Minimum**	**Maximum**	**Standard Deviation**	**T-Test**
COMI	7.88%**	-7.80%	19.45%	4.56%	31.458	8.01%**	-9.51%	25.26%	4.55%	45.756
SUCE	-2.34%**	-33.92%	36.69%	8.91%	-9.358	-1.73%**	-41.48%	42.98%	8.39%	-5.334
HRHO	7.76%**	-20%	30%	7.22%	8.409	6.71%**	-20%	25%	7.67%	14.663
ORTE	-2.63%**	-26.55%	10.58%	4.29%	-28.584	-2.53%**	-17.00%	12.54%	4.31%	-19.446
OCIC	2.61%**	-15.00%	19.80%	7.00%	6.492	0.78%**	-19.00%	17.00%	12.13%	2.5
LECI	-11.23%**	-71.34%	117.09%	37.11%	-3.288	-14.52%**	-60.60%	71.11%	30.52%	-3.329
ETEL	-0.04%	-47.56%	24.93%	4.39%	-0.195	0.19%	-16.75%	17.30%	4.49%	0.55
PHDC	5.47%**	-12.15%	76.43%	16.75%	2.635	4.71%*	-31.37%	56.72%	16.52%	1.536

(D) Daily Absolute Relative Price Deviation (%) $H_0 -: \left|Ln\left(\frac{P_t^{GDR}}{\frac{P_t^{Stock} * b}{S_t}}\right)\right|$

Company	Monday-Thursday					Friday-Sunday				
	Mean	**Minimum**	**Maximum**	**Standard Deviation**	**T-Test**	**Mean**	**Minimum**	**Maximum**	**Standard Deviation**	**T-Test**
COMI	8.20%**	0.04%	19.45%	3.95%	37.811	8.34%**	0.07%	25.26%	3.91%	55.368
SUCE	6.14%**	0.01%	36.69%	5.65%	34.747	6.92%	0.00%	42.98%	6.47%	22.523
HRHO	9%**	0%	30%	6%	26.275	8%**	0%	25%	6%	13.683
ORTE	3.14%**	0.00%	26.55%	3.93%	35.085	3.21%**	0.00%	17%	3.85%	24.675
OCIC	5.87%**	0.01%	20%	4.61%	39.876	3.07%**	0.00%	19.00%	4.75%	14.423
LECI	32.20%**	0.62%	117.09%	21.42%	16.332	30.06%**	1.77%	71.11%	14.98%	14.045
ETEL	2.56%**	0.00%	47.56%	3.56%	14.924	2.91%**	0.00%	17.30%	3.42%	11.201
PHDC	9.10%**	0.02%	76.43%	15.06%	4.874	8.55%**	0.00%	56.72%	14.84%	3.105

*** and * indicate significance at 1% and 5%*

Table 4-3 T-Test Results for Differences between Weekday and Weekend Price Deviations

Company	H_0 Price Deviation of Weekday Series-Price Deviation of Weekend Series=0		H_0 Log Price Deviation of Weekday Series-Log Price Deviation of Weekend Series=0	
	Mean Difference	**T-statistic**	**Mean Difference**	**T-statistic**
COMI	-0.0056	-0.358	-0.13%	-0.414
SUCE	-0.069	-1.063	-0.57%	-0.893
HRHO	-0.0075	-0.063	0.93%	1.0057
ORTE	-0.0292	-0.605	-0.12%	-0.473
OCIC	-0.11	-1.14	0.05%	0.16
LECI	0.225	0.92	3.22%	0.583
ETEL	-0.052	-0.86	-0.30%	-0.621
PHDC	0.169	0.444	0.63%	0.149

*** and * indicate significance at 1% and 5%*

Table 4-4 T-Test Results on Significance of Daily Return Deviations

$$H_0: ln\left(\frac{P_t^{GDR}}{P_{t-1}^{GDR}}\right) - ln\left(\frac{\frac{P_t^{Stock}*b}{S_t}}{\frac{P_{t-1}^{Stock}*b}{S_{t-1}}}\right)=0$$

Company	Minimum	Maximum	Mean	Standard Deviation	T-Test
COMI	-22.43%	15.63%	-0.02%	2.67%	-0.235
SUCE	-53.29%	59.86%	-0.12%	8.62%	-0.41
HRHO	-27.00%	22.00%	-0.01%	5.47%	0.052
ORTE	-12.09%	12.00%	0%	2.35%	-0.034
OCIC	-20.23%	222.99%	-1.03%	15.83%	0.95
LECI	-101.17%	121.55%	-0.29%	21.85%	-0.147
ETEL	-60.49%	48.05%	-0.19%	5.59%	-0.739
PHDC	-65.38%	44.27%	-1.04%	16.73%	-0.544

*** and * indicate significance at 1% and 5%*

Table 4-5 Non-Parametric Results on GDR and Stock Return Distribution

Company	Wilcoxon Rank Sum Test (p-value)	Sign Test
COMI	-0.320 +ve ranks (0.749)	-0.186 (0.852)
SUCE	1.268 –ve ranks (0.205)	-0.905 (0.365)
HRHO	-0.349 +ve ranks (0.727)	-0.210 (0.834)
ORTE	-1.033 +ve ranks (0.302)	-0.459 (0.625)
OCIC	-0.201 +ve ranks (0.841)	-0.370 (0.712)
LECI	-0.080 –ve ranks (0.936)	-0.096 (0.923)
ETEL	-1.435 –ve ranks (0.151)	-1.498 (0.134)
PHDC	-0.582 –ve ranks (0.561)	--0.125 (0.901)

Table 4-6 Price Deviation Measures Pre-Post Exchange Rate Regime Shift

	Price Deviation Before		After			Relative Price Deviation Before		After		
	Mean	St Deviation	Mean	St Deviation	T-stat	Mean	St Deviation	Mean	St Deviation	T-stat
COMI	0.071**	0.078	0.463*	0.419	-36.234	4.24%**	0.18%	7.96%*	4.55%	-16.874
SUCE	-0.090*	0.188	-0.157*	0.941	2.215	-2.65%*	5.39%	-2.09%*	9.03%	-1.490
OCIC	0.120**	0.218	0.534*	1.780	-8.837	3.76%**	7.45%	2.11%*	7.18%	5.494
ORTE	-0.112**	0.091	-0.422*	1.019	12.355	-8.69%**	6.71%	-2.59%*	4.27%	-20.206

*** and * indicates deviation significance at 1% level and 5% level*

Table 4-7 Return Deviation Pre-Post Exchange Rate Regime Shift

	Before		After		T-stat (Difference of Means)
	Mean	St Deviation	Mean	St Deviation	
COMI	-0.02%	0.07%	-0.02%	0.11%	0.030
SUCE	-0.01%	2.77%	-0.12%	7.35%	0.392
OCIC	-0.06%	3.84%	0.00%	8.89%	-0.145
ORTE	-0.01%	4.29%	-0.02%	2.33%	0.045

*** and * indicates deviation significance at 1% level and 5% level*

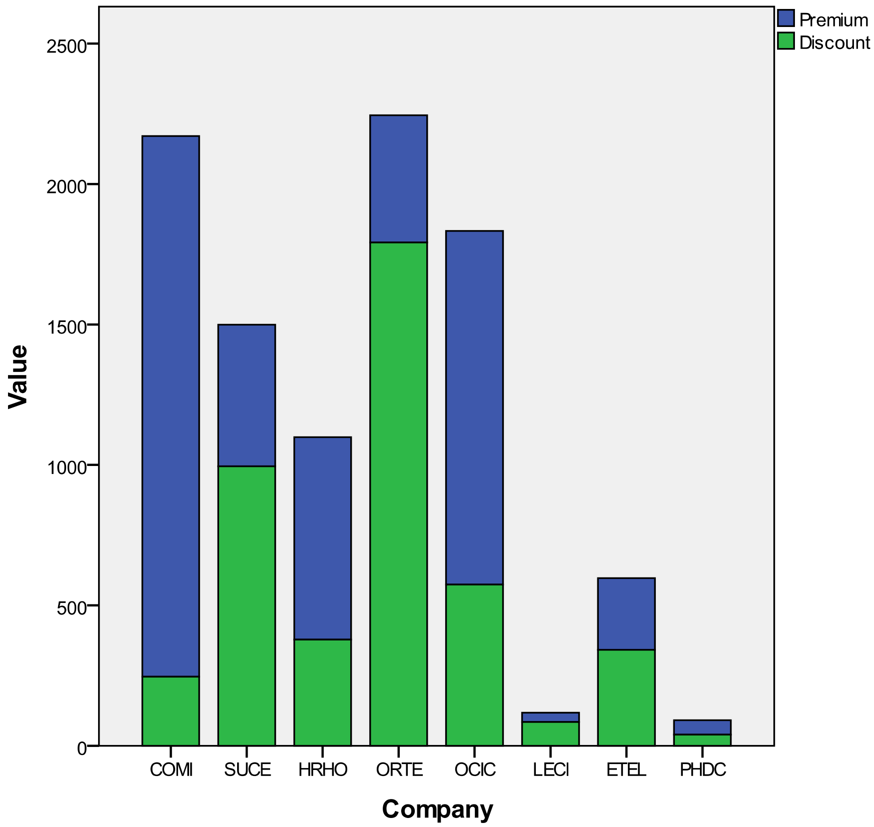


Figure 4-1 Discounts and Premiums in Egyptian GDRs

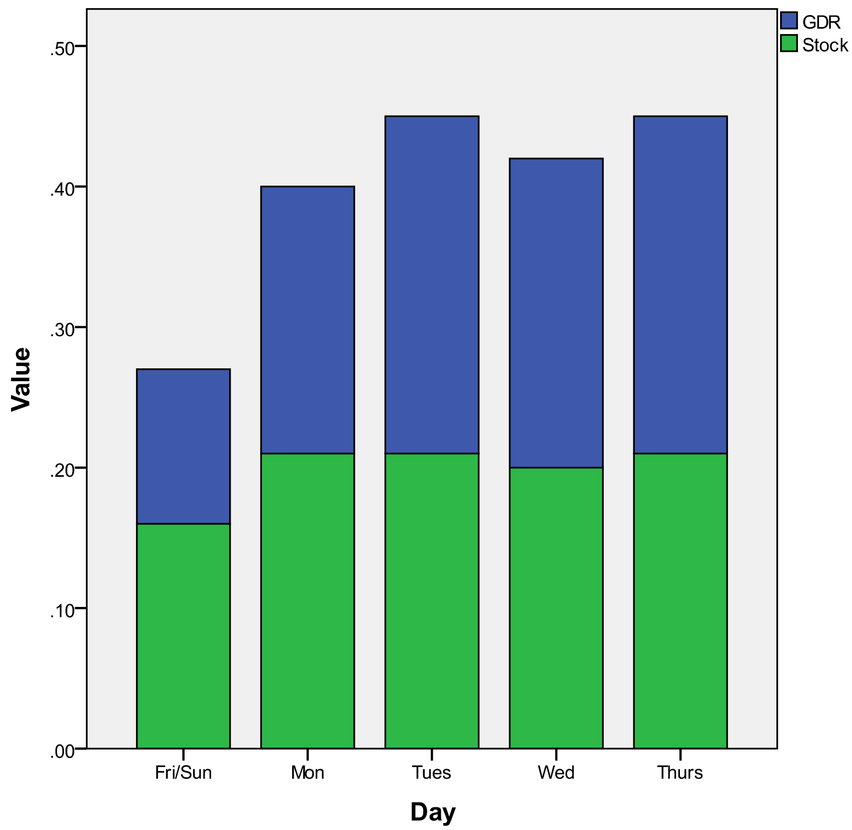


Figure 4-2 Proportion of Weekly Trading Volume Captured on Each Day of Trading

5 THE PROOF IS IN THE PUDDING: ARBITRAGE IS POSSIBLE IN LIMITED MARKETS

"As better data become available and as our econometric sophistication increases, we are beginning to find inconsistencies that our cruder data and techniques missed in the past. It is evidence which we will not be able to ignore"

Michael Jensen, 1978, Journal of Financial Economics

5.1 Introduction

Arbitrage, the simultaneous purchasing and selling of identical assets to take advantage of price differences, has been referred to as "one of the central concepts of financial economics" (Mitchell et al., 2002). Nonetheless, empirical evidence for the contribution of arbitrage trades in price convergence is still limited and tends to involve joint hypotheses. In this paper, we study arbitrage in the market for emerging market depository receipts (DRs).

In theory, arbitrage should keep the prices of a DR in parity with its underlying stock, as long as arbitrage costs are sufficiently small. In financial models, the costs of arbitrage are typically assumed to be zero, so arbitrage opportunities disappear almost as quickly as they appear. As prices diverge, arbitrageurs intervene to bring prices back to parity by buying the underpriced security in one market and selling the other at a higher price in the other market, thereby making risk-free profit. A unique feature of DRs that ensures efficient arbitrage is their *fungibility*, which allows arbitrageurs to exchange freely between the cross-listed pair. Because evidence on arbitrage opportunities in DRs is limited, the role of arbitrage trades in this price convergence process is lacking.

Early studies find no evidence for significant deviations from parity in DRs, supporting a theoretical perspective (Rosenthal, 1983; Kato et al., 1991 and Park and Tavakkol, 1994). These studies have small samples, however, and given the time differences between markets, compare daily closing prices at different points in time. More recent studies using intraday data continue to support the theoretical perspective. They find either zero arbitrage opportunities (Miller and Morey, 1996) or extremely small, infrequent, and short-lived opportunities (Suarez, 2005). These studies focus on developed-market DRs, in which trading costs are relatively low, liquidity is relatively high, and trading barriers are absent. But these conditions do not hold in many emerging markets, and emerging market DRs have increasingly come to dominate foreign cross-listing (Global Finance, 2010). A recent study by Gagnon and Karolyi (2010) provides evidence for large deviations from parity in emerging market DRs. Their underlying data are sampled daily, however, so one cannot infer that it would have been cost-effective or feasible to trade away these apparent price deviations.

Our study uses intraday data to examine whether arbitrage trades influence price convergence in emerging-market DRs with limits to arbitrage. Our sample comprises two years of data on Egyptian stocks listed on the Egyptian Stock

Exchange (EGX) and cross-listed as Global DRs (GDRs) on the London Stock exchange (LSE), as well as Argentinean stocks listed on the Buenos Aires Stock Exchange (BCBA) and cross-listed as US DRs (ADRs) on US exchanges. The inclusion of different host and destination countries enables us to compare results across settings. Furthermore, our sample overcomes asynchronousity problems by focusing on overlapping periods when arbitrageurs could trade both the DR and the underlying stock. In the emerging markets we study, limits to arbitrage include high trading costs and short-sales restrictions (Bris et al., 2007). Argentina also has capital controls, although Egypt did not at the time of our study.[4] Arbitrage trades are hypothesized to be difficult to conduct in such a context, and we provide the first real empirical test for this hypothesis.

Our investigation provides evidence for the notion that arbitrage opportunities exist in emerging-market DRs and that arbitrageurs are active despite substantial limits to arbitrage. We estimate the price deviations between DRs and their underlying stock, and find that, consistent with Gagnon and Karolyi's (2010) findings, economically significant intraday deviations from parity do exist and can be as high as 24% for Egyptian DRs and 57% for Argentinean DRs.

A novel arbitrage identification procedure that incorporates accurate trading cost estimates as well as volumes classifies only 15% of Egyptian and 10% of Argentinean price deviations as profitable arbitrage opportunities. We find that they

4 Argentina has a capital control on inflows: 30% of any money transfers into the country must be deposited with the central bank for a minimum of one year. Egypt currently has capital controls, which were instated after the Egyptian Revolution of 25 January 2011.

linger for an average of 46 minutes in Egyptian securities and 14 minutes in Argentinean securities, and that it takes on average 1.58 trades in Egypt and 1.9 trades in Argentina for those opportunities to disappear. These statistics vary within the sample, with arbitrage opportunities in more liquid and active securities persisting for shorter periods.

We finally consider whether such arbitrage opportunities involve real arbitrage trades that contribute to the convergence of prices to the no-arbitrage bands. Our methodology relies on the application of a filtering algorithm on our transaction data, which extracts real arbitrage trades. A conservative arbitrage trading strategy reveals profits of approximately USD 1.2 million and USD 1.8 million from arbitrage operations involving Egyptian and Argentinean DRs, respectively, over the two-year period we analyzed.

Our paper contributes to two main areas of study in the multimarket microstructure literature. (1) It builds on a number of studies concerned with testing arbitrage efficiency by determining if arbitrage opportunities exist between foreign cross-listed stock and their underlying securities – an open issue despite decades of research. (2) This study draws on a slim body of literature that tests whether trades are important for price convergence between cross-listed stocks (Kaul and Mehrotra, 2007) by using a novel empirical methodology that does not suffer from the joint hypothesis problems inherent in price discovery methodologies.

This paper is organized as follows. Section 5.2 presents our data description and price deviation construction. In Section 5.3, we present our tests and the results of our arbitrage analysis; and Section 5.4 provides a discussion of our results. Section 5.5 concludes.

5.2 Data Description and Price Deviation Construction

In this section, we present our data description as well as the intraday price matching methodology we use to construct the price deviation series and test for price parity between the depository receipt (DR) and its underlying stock.

5.2.1 Data Description

Our intraday transaction data consist of date, timestamps, prices and volumes for Egyptian stocks, and their GDRs from 2 January 2008 to 14 March 2010, as well as Argentinean stocks and their ADRs from 2 January 2008 until 31 December 2009[5]. We also obtain intraday foreign exchange quote data for the EGP-to-USD exchange rate and ARS-to-USD for the period. Our intraday trade and foreign exchange data were obtained from Thomson Reuters Tick History Database[6], providing price resolution of USD .01 or better and a time resolution of 0.001 second. We are therefore provided with individual intraday data of approximately 3.8 million observations on the DRs and stocks, as well as 65,964 Bid-Ask quotes for the EGP/USD exchange rate and 229,045 observations for the ARS/USD.

For identifying arbitrage opportunities, we use trading cost estimates

[5] We pick DRs with underlying stocks having ISIN numbers registered on the Egyptian and Argentinean stock exchanges.

[6] We personally would like to thank Mr. Nader Khattab for his effort in retrieving the intraday ticker data used in this research.

published by Elkins McSherry[7] and arbitrage trading costs from the Bank of New York Mellon website. Our cost estimates provide the most precise and comprehensive estimate of arbitrage trading costs presented in arbitrage studies to date, an issue we discuss in greater depth in Section 3.

A summary of our sample of Egyptian and Argentinean DRs listed overseas is presented in Table 5-1, which includes their ticker symbol, bundling ratio (the number of shares included in each depository receipt), value traded in USD million, and number of intraday trades in the sample. DRs with extremely low activity (less than 75 days trading in either market) were excluded, leaving us with 6 Egyptian GDR stock pairs and 10 Argentinean ADR stock pairs. These companies are among the largest in their local markets, comprising an average of 30% of the Egyptian and 61% of the Argentinean market capitalizations during the sample period.

INSERT TABLE 5-1 HERE

Although the average foreign exchange adjusted price of the underlying stock does not deviate greatly from the DR prices in our sample, we find a large discrepancy in trading activity because the market for the majority of the traded value of the securities varies across the sample. For companies such as ORTE and IRS, most of the value is trading in the foreign market; for the others, the proportion of the traded value varies, with companies such as PHDC having less than 10% of their

7 Trading costs include explicit costs (commissions, taxes, and fees), as well as implicit costs (market impact costs computed by comparing the trade price to a VWAP benchmark price on the day of the trade). Domowitz et al. (2001) and Gagnon and Karolyi (2010) use the same source for trading costs, and they verify its accuracy.

total value trading on the foreign market. In general, Argentinean securities seem to be trading with greater activity in the foreign market than Egyptian ones are.

5.2.2 Price Deviation Construction

The first step in the arbitrage analysis is to measure the deviation between prices. We rely on the most widely used measures of price deviation:

$$D_t = P_t^{DR} - \frac{P_t^{Stock} * b}{S_t} \tag{5.1}$$

$$RD_t = Ln\left(\frac{P_t^{DR}}{\frac{P_t^{Stock} * b}{S_t}}\right) \tag{5.2}$$

where D_t = the price deviation at time *t*, RD_t=relative log price deviation at time *t*, P_t^{DR} = the price of the depository receipt in USD, $P_t^{Stock} *$ is the price of the underlying stock, S_t is the exchange rate measured as USD per unit of foreign currency, and *b* is the bundling ratio.

The price deviation measures are typically measured using daily closing prices. We start by using daily closing prices for our sample of DRs and their underlying stock and present the results in Table 5-2. As expected, daily price deviations show large and significant deviations from parity. Despite this, the correlations between prices is very high, corroborating the evidence that they follow each other in the long run. Moreover, Appendix 3 shows the price charts for our DR-stock pairs which also confirm that the prices move together in the long run.

INSERT TABLE 5-2 HERE

Because markets in different jurisdictions rarely close simultaneously, however, a non-zero measured deviation using daily closing prices would not necessarily correspond to a deviation in real time. We rely on matched intraday prices to capture such real-time deviations, focusing on the hours when trading is active in both relevant markets.

Intraday data, although preferable to daily data, present their own challenges, because true synchronicity among depository receipt prices, share prices, and exchange rates is rare. Miller and Morey (1996), who use quote data to identify forgone arbitrage opportunities, require that all three prices be matched within specific intervals of one minute; Suarez (2005), who also uses quote data, requires a one-second match. Our data, however, comprise trade records rather than quote records, as our aim is not merely to identify arbitrage opportunities, but to identify actual arbitrage trades from the data set. We therefore rely on the *minspan* matching procedure of Harris et al. (1995).

We proceed with the minspan matching algorithm, which requires two steps: (1) to create a USD value for the underlying share, $\frac{P_t^{Stock} * b}{S_t}$ by matching the stock price and exchange rates in time; and (2) to match it with the USD-denominated DR price, P_t^{DR} For Step (1), we adjust every trade on the local stock market with the exchange rate mid-quote, calculated as $(ask+bid)/2$, with the closest time proximity to the price trade. For Step (2), we match the USD-denominated value for the underlying stock $\frac{P_t^{Stock} * b}{S_t}$with the DR price, P_t^{DR}, the trade of which occurs closest in time to the underlying stock trade P_t^{Stock} We look both forward and backward in time to the underlying stock trade $P_t^{Stock}$and match it with the DR trade that occurs within a minimum time span. This intraday matching technique gives us vectors of matched DR- and USD-denominated stock trades that do not always occur at the same timestamp *t,* and we take *t* to denote the time on stock trade P_t^{Stock}.

Table 5-3 presents some statistics of our intraday matching exercise. Our final sample yields 74,899 matched observations for Egyptian DR stock pairs and 162,622 for Argentinean DR stock pairs. The mean time span between the trades is 1 minute 3 seconds in Egypt and 5 minutes 6 seconds in Argentina. The maximum time difference between our trades can go as high as 1:20:38 in Egypt for HRHO and 5:55:38 in Argentina for TGS2, which reflects the illiquidity that sometimes occurs in the trading of emerging market stocks.

INSERT TABLE 5-3 HERE

Table 5-4 presents descriptive statistics of the price deviation measures presented in equation (1) and (2). The average price deviations are significant across our the two different measures for 15 out of our 16 securities (exception is HRHO). Deviations can reach as high as $5 or 25% for Egyptian DR-stock pairs and $10.28 or 56.55% for Argentinean DR-sock pairs. There are two interesting observations. On average, price deviations for Egyptian securities are around -0.61% and for Argentinean securities it is much higher around -2.78%. This indicates that across both samples, Egyptian securities trade at lower price deviations than Argentinean ones.

INSERT TABLE 5-4 HERE

Our price deviations are skewed to the negative side when the DR is trading at a discount to the stock in both markets. Figure 5-1 shows the a graphical illustration of this is by charting the intraday price deviation series for Orascom Telecom (ORTE) and Banco Marco(BMA) and their histograms. Appendix 4 contains all price deviation charts for our sample securities and their histograms. We can see that price deviations fluctuate greatly and are skewed to the discount side. This is evident in more securities than other. For example, BMA, shows a greater frequency of the DR trading at a discount than a premium. It makes more sense to have discounts in our sample as a natural consequence of the short selling restrictions and capital controls. We will discuss this point further in the next section.

INSERT FIGURE 5-1 HERE

There are several takeaways from the price deviation analysis. First, price deviations between the DR-stock pairs are significantly large, and that this result is even across our sample and is not biased by the type of measure nor the size, sector or liquidity of the company. Therefore, this indicates that asynchronous trading hours is not the main reason for such price deviations. The main question is thus whether these large price deviations are indeed an indication of arbitrage opportunities or just a reflection of large trading costs and arbitrage barriers which widen the no- arbitrage band inside which prices deviate without being considered profitable arbitrage opportunities.

Second, comparatively, the fact that Argentinean securities trade at larger deviations forces another question: whether these deviations are due to larger trading costs in Argentinean or that indeed Argentinean securities have larger arbitrage opportunities than Egyptian ones. This comparison is important since it allows us to compare the efficiency of the markets involved, most importantly the efficiency of pricing of securities listed on American Exchanges versus the London Stock Exchange. In order to test these two questions we need to identify whether such price deviations are indeed arbitrage opportunities, which we present in the next section.

5.3 Tests and Results

Theoretically, arbitrage can occur in both direction of the price deviation. If the depository receipt is selling at a higher price than the underlying stock, an arbitrageur should be able to buy the stock and short sell the DR and vice versa, making instant profit as long as such an arbitrage process compensates for the therefore identify them using the absolute form of our price deviation measures. Table 5-5 presents the results of analyzing the absolute form of the price deviation measures.

INSERT TABLE 5-5 HERE

We still find that price deviations are large and significant and this is now consistent across all of our stocks. The question therefore becomes: Are these price deviations really an indication of arbitrage opportunities? To identify arbitrage opportunities in the DR market empirically, we need to capture the exact process of arbitrage. An arbitrageur facing a price deviation between the DR and its USD-adjusted stock price, will conduct an arbitrage trade only if it is profitable. Profitability of arbitrage trades depend on two factors: the arbitrage trading costs involved and whether there are enough volumes to trade in both markets.

In Section 3.1 we introduce a new arbitrage identification procedure that identifies arbitrage opportunities using price deviations, volumes and external estimates of trading and arbitrage costs. After all, if we do not find any arbitrage opportunities in our sample, the issue of whether arbitrage trades contribute to price convergence becomes irrelevant. An affirmative result here establishes that arbitrage opportunities do arise in our markets and in Section 3.2 we examine the frequency, speed of convergence and duration of arbitrage opportunities in our markets.

5.3.1 Identifying Arbitrage Opportunities in Emerging Market DRs

To identify arbitrage opportunities in the DR market empirically, we need to capture the exact process of arbitrage. An arbitrageur facing a price deviation between the DR and its USD-adjusted stock price, will conduct an arbitrage trade only if it is profitable. Profitability of arbitrage trades depend on two factors: the arbitrage trading costs involved and whether there are enough volumes to trade in both markets. Previous efforts in identifying arbitrage opportunities in DRs suffer from two main limitations: the inaccurate estimating of trading cost and failure to account for volumes of trade. Before we introduce our novel identification procedure that recognizes both factors, we discuss their importance in identifying arbitrage opportunities.

Trading costs create an arbitrage band around a security's equilibrium value (Kato et al., 1991), and in order for the arbitrage to be lucrative, the absolute price differential $|D_t|$ must exceed the cost k of implementing the arbitrage. In their intraday arbitrage analysis, Miller and Morey (1996) and Suarez (2005) use historical trading costs that do not match their time series. Moreover, they did not consider some major arbitrage cost components such as global custodian and safekeeping fees, both of which are significant[8]. This issue does not present a serious problem for their results, because they study arbitrage in developed market stocks, which usually have small and stable costs of trade. We need to be extremely careful in estimating the costs of arbitrage in emerging markets, however, as they are known to have large trading costs (Domowitz et al., 2001), which, as we will soon show, fluctuate greatly from year to year. Furthermore, we need to make an accurate account of all costs involved in arbitrage activity.

[8] We conduct two interviews with brokers in EFG Hermes and Pharos and would like for pointing out those costs of arbitrage.

Previous arbitrage identification procedures rely on a comparison of price deviations with trading costs without inclusion of any volumes. In this paper, our sample involves emerging market securities in which liquidity and activity vary greatly across the sample, making volume a significant variable. Without sufficient volumes available to trade, it will be difficult for an arbitrageur to cover the large fixed trading costs, even if the deviation is quite considerable. This volume effect is reinforced by Hsu and Wang (2008), who find that sudden differences in volumes of trade in emerging market cross-listed stocks can create arbitrage opportunities.

Our procedure classifies a matched price deviation as an arbitrage opportunity when:

$$|D_t| > K_t \tag{5.3}$$

where $|D_t|$ is our absolute price deviation and K_t corresponds to the cost of arbitrage in every *t*.

Because the cost of trading in our emerging market sample is relatively large, we gather hand-picked trading cost estimates, as shown in Table 5-6, from a variety of sources, including Elkins & McSherry trading cost averages and the Bank of New York Mellon. We account for all costs of conducting an arbitrage in the DR market, which, besides brokerage fees, includes foreign exchange rate fees, settlement, safekeeping fees, and DR conversion fees.

INSERT TABLE 5-6 HERE

Unlike previous studies, the cost of arbitrage is not fixed across the sample but is dynamically estimated for each price deviation. We define K_t as:

$K_t = \frac{\mathrm{k^{fixed}}}{Vol_t} + \mathrm{k_t^{variable}}$ and

$$\mathrm{k_t^{variable}} = (\mathrm{k_{variable}^{DR}} * R_t) + (\mathrm{k_{variable}^{S}} * \frac{\mathrm{S_t * b}}{\mathrm{FX}_t}) \tag{5.4}$$

Where $\mathrm{k_{fixed}}$ comprises fixed global custodian fees (including safe keeping and settlement fees) and DR conversion fees, $\mathrm{k_{variable}^{DR}}$ and $\mathrm{k_{variable}^{S}}$comprises all costs of trading the DR and stock that are quoted in basis points per share. Vol_t corresponds to the volume of trade available at time *t*. If Vol_t is small, this will make the fixed costs quite large and therefore it will not be profitable to arbitrage the price deviation.

Vol_t can be estimated as the minimum of the volumes associated with the matched prices. However, the volumes associated with the matched trades are not reflective of the actual volume due to order splitting[9]. In our trade data, we observe a split order as a series of consecutive trades executed at the same price, with timestamps that occur within small differences of each other and with small volumes.

We thus design an algorithm that calculates aggregate volumes of trade. With trades matched by the *minspan* approach, assume that we have a matched trade in which the stock trade is followed by the DR trade. For the stock, we identify whether order splitting occurred, by checking previous trades to the matched trade

[9] Order splitting is an order-submission strategy that is used extensively to reduce the cost of order execution and to minimize the price impact of a trade (Tkatch & Alam, 2009)

one by one. If the previous trade to the stock has the same price and a timestamp of less than 10 minutes difference, we automatically aggregate its volume to the matched trade volume and proceed to the previous trade, and so on. We abort the aggregation with the following order criteria: (1) we reach a previously matched DR stock trade, (2) the stock price changes, and (3) the timestamp difference between the first and last aggregated trade is greater than 10 minutes. We save the aggregate as Vol_t^{Stock}. For the DR, we use the same rule, moving forward, stopping the aggregation only when we reach another matched trade, price change, or large time change, and save the aggregate Vol_t^{DR}. Our matched volume Vol_t in equation (3) is the minimum of the two blocks Vol_t^{Stock} and Vol_t^{DR}. We follow the same approach should the DR trade be matched with a subsequent stock trade.

5.3.2 Frequency and Persistence of Arbitrage Opportunities

We compare $|D_t|$ with K_t in order to identify arbitrage opportunities. Table 5-7 presents results of the identification procedure, including the frequency of arbitrage opportunities as well as descriptive statistics of the mispricing. On average, 9.81% of Argentinean and 15.32% of Egyptian trades matched price deviations were identified as profitable arbitrage opportunities. The descriptive statistics of the price deviations classified as arbitrage opportunities give an indication of the size of the thresholds around the no-arbitrage zone. Price deviations need to exceed on average 23 cents or 2.25% in Argentina and 45 cents or 1.29% in Egypt to be classified as arbitrage opportunities.

INSERT TABLE 5-7 HERE

Table 5-8 summarizes the speed of convergence and persistence of arbitrage opportunities. The average time for securities to return to the no-arbitrage zone – defined as time it takes until a non-profitable price deviation occurs – is much slower for Egyptian (46 minutes) than Argentinean securities (14 minutes), with large variation among securities. The speed of convergence is implicitly measured from each dataset to avoid joint-hypothesis problems experienced by Suarez (2005b) and Rabinovitch et al. (2003), who use the Self Exciting Threshold Autoregressive Model (SETAR) to measure convergence speed.

INSERT TABLE 5-8 HERE

Kozhan and Tham (2009) define an efficient arbitrage as the one being eliminated by the next incoming trade. It takes an average of approximately two trades for both Argentinean and Egyptian arbitrage opportunities to disappear. It is striking that arbitrage opportunities can persist in intraday data for as many as 15 trades in the Egyptian sample and 114 trades in the Argentinean sample. We find that arbitrage opportunities were most likely to persist during the financial crisis in September to November 2008,[10]. On average, 35.13% of Argentinean and 40.3% of Egyptian arbitrage opportunities converge to the no-arbitrage zone after one trade. For those arbitrage opportunities that do not disappear in one trade, approximately 51% of Argentinean and 54% of Egyptian arbitrage opportunities disappear by the

[10] This was verified with a separate analysis and result is available upon request.

third trade. The large number of trades required for arbitrage opportunities to disappear is consistent with Yeyati et al. (2008), who attribute illiquidity – due to low demand and volumes of trades on either the DR or the underlying stock – to the creation of a large price disparity that cannot be arbitraged away until the new trades take place.

In summary, large and active companies have the fewest arbitrage opportunities, a much higher speed to convergence relative to the other stocks in the sample, and the lowest level of persistence in arbitrage opportunities. The results are similar in Argentina and Egypt, with the exception of the Argentinean company, BMA, which, although it is a large and active security, has many arbitrage opportunities. A more in-depth analysis reveals that most of the arbitrage opportunities in BMA occurred during the onset of the financial crisis in September and October 2008, which severely affected most other financial institutions and banks as well.

It is obvious that it takes a considerable number of trades and time for an arbitrage opportunity to disappear in our sample. This brings us to a very important question: did these arbitrage opportunities involve real arbitrage activity? This requires analyzing the process of arbitrage in emerging market DRs

5.3.3 The Process of Arbitrage in Emerging Market DRs

Whether the disappearance of arbitrage opportunities identified in the previous section involve arbitrage trades is cast in doubt, theoretically, because those markets have a short-selling restriction and capital controls that are hypothesized to limit arbitrage. As Gagnon and Karolyi (2010) discuss, if short selling is prohibited in the home market, the situation in which the DR is selling at a discount to the stock would be difficult to arbitrage. Moreover, capital controls in Argentina can affect arbitrageurs by preventing them from moving cash to buy the underpriced security (Yeyati et al., 2008). Neither arguments were supplemented by formal empirical tests.

We identify real arbitrage trades from the transaction data. A profitable price deviation is defined as a real arbitrage trade if it involves matching volumes in both markets. Let us assume, for example, that we have a trade on the LSE at 11:00:20 am on the DR of ORTE for USD 59.5 and volume of 1100 , and then at 11:00:22 am we have a similar trade for ORTE stock on the EGX for a volume of 5500 (translated to 1100 DRs at the bundling ratio) and price of USD 60 (adjusted for the closest intraday EGP/USD spot exchange rate). If the price deviation of USD 0.50/share is net profitable, it can also be classified as a real arbitrage trade, because identical trades occurred in both markets within a short time (limited to 10 minutes).

We extract samples from the data of the trades identified as real arbitrage trades. Figure 5.2 illustrates some of trade data of the extracted sample for a sample of our companies. More examples from trade-data for all of our 16 can be found in Appendix 7. Highlighted trades, which were identified as real arbitrage by our classification algorithm, are indeed identical in volume in both markets, corroborating the evidence that they are made by arbitrageurs entering the market for profit. Our extracted trades reveal that they occurred when the DR was selling at a discount to the stock and when the DR selling at a premium to the stock.

INSERT FIGURE 5-2 HERE

The reality for arbitrage trades for all of our 16 DR stock pairs is daunting, especially as it shows that profitable arbitrage trades occur during different times and days, with different volumes (as high as 100,000 shares for Orascom Telecom on 31 March 2008, resulting in over USD 20,000 profit in less than a minute!) and with extreme precision (observe, for example, the 676 shares on both sides of the market on Commercial International Bank). It is noteworthy that our matching algorithm provides a highly conservative estimate of arbitrage activity in our sample, as it matches only trades that are executed within 10 minutes of each other, and we aggregate only trades that were executed at the same price. This may not be always be the case, because arbitrageurs can be risky and fill their arbitrage orders at different prices or within times greater than 10 minutes.

We estimate the profits from real arbitrage trades as:

$$P = \sum_{t=1}^{T} |(D_t| - K_t) Vol_t \qquad (5.5)$$

The First part of Table 5-9 presents the proportion of real arbitrage trades from all our identified arbitrage opportunities. It shows that, on average, 70% of Egyptian and 88% of Argentinean arbitrage opportunities involved real arbitrage activity. The remaining arbitrage opportunities that were not identified as real arbitrage trade (labeled lost) are either a result of our conservative algorithm or a result of such trades being large block trades. Indeed, we find that the average volume of a lost arbitrage trade is triple that of a real arbitrage trade.

INSERT TABLE 5-9 HERE

The second part of Table 5-9 shows that arbitrageurs over our sample period could have made up to USD 1.2 million in profits from cross-listed Egyptian securities and USD 1.77 million from cross-listed Argentinean securities. Whereas most of the profits are made when the DR is selling at a discount to the stock, there is still considerable profit from arbitrage operations when the DR is selling at a premium. Arbitrage profits from Egyptian securities are distributed among the various stocks. Profits in the Argentinean sample are concentrated in one stock, however – BMA – which we have shown to have a large frequency of arbitrage opportunities during the financial crisis.

The results of our arbitrage analysis above confirms the hypothesis set forth in Suarez(2005) that cross-listed stock with lower trading frequencies, such as those from emerging markets, present large arbitrage opportunities and that arbitrage trades are a main contributor in those markets for prices to converge (Kaul and Mehrotra, 2007). Our results of our analysis can be summarized as follows (1) empirically identifying arbitrage opportunities requires intraday data that not only matched prices but also volumes and precise account of arbitrage trading costs, (2) although price of emerging market DRs and their underlying stock deviate greatly, most of those deviations are indeed not profitable due to the large trading costs involved and finally that (3) arbitrage opportunities are real and (4) arbitrage trades are needed for prices to converge.

5.4 Further Discussion

In this section, we provide an in-depth discussion of how arbitrage occurs with limits to arbitrage that were previously hypothesized to hamper arbitrage activity. We also discuss whether arbitrage opportunities are equally distributed across the sample period and try to explain some of the reasons why not all arbitrage opportunities disappear with arbitrage trades.

5.4.1 Arbitrage Operations under Limits to Arbitrage

The most striking result of our arbitrage analysis is that the presence of various limits to arbitrage did not prevent arbitrageurs from exploiting them and did not stop arbitrage operations from occurring. Below we discuss the limits to arbitrage that are present in our sample, mainly trading barriers and time differences, and the mechanisms by which arbitrageurs can overcome them.

5.4.1.1 Capital Controls

Assume that with the capital control in-place on inflows in Argentina, at time *t*, the price of an Argentinean DR quoted on the New York Stock Exchange (NYSE)

$P_t^{DR}$is currently at a premium to the quoted stock price P_t^{Stock} after adjusting for foreign exchange rate using the current S_t and that the price deviation and volumes quoted for the DR-stock pair make this deviation profitable.

We present to this setup a local arbitrageur holding a portfolio of Argentinean pesos(ARS) in Argentinean banks and US dollars in American banks, has cash holdings TCF_{t-1}set at time *t-1* where $TCF_{t-1} = \{CF_{t-1}^{ARS}, CF_{t-1}^{\$}\}$. When this local arbitrageur observes the profitable price deviation at time *t*, she can instantaneously buy the local stock with holding of ARS and short sell the DR and deposit the proceedings in US dollars in her American bank. She will then convert the stock to depository receipts and close her short position on the NYSE. The total value of her cash portfolio is currently better off by the profits net the arbitrage trading costs, although the profits are currently held in a different currency. Should the arbitrageur decide to transfer her dollar proceedings to the local Argentinean peso, she will have to make sure that 30% of the cash transferred is kept in her local bank for the next year to abide by the capital control in Argentina. This should not present a real problem for such a large and savvy international arbitrageur, assuming that the frequency of arbitrage opportunities are large enough to justify this practice .

5.4.1.2 Short Selling Restriction

Two way arbitrage can be done in practice even in the presence of short selling restrictions by arbitrageurs who trade against their own or their clients' accounts with large diversified holdings[11]. Assume that with short selling restriction in Egypt, the price of the Egyptian ORTE DR trading on the London Stock Exchange (LSE) P_t^{DR}currently sells at a discount to the stock price P_t^{Stock} after adjusting for foreign exchange rate using the current $S_t$and that the price deviation and volumes quoted for the DR-stock pair make this deviation profitable.

Now assume an arbitrageur is also an investor (or acts on behalf of one) in the Egyptian market with a diversified portfolio holding of large Egyptian stocks PH_{t-1} and holds a number of share of ORTE H_{t-1}^{ORTE}. When this local arbitrageur observes the profitable price deviation at time *t*, she can instantaneously buy the DR and sell a portion of her holding of ORTE in the local market, then convert the DR to the stock, thus locking instant abnormal returns on her (or her clients') portfolio without affecting their underlying stock inventory $H_{t-1}^{ORTE} = H_t^{ORTE}$

5.4.2 Arbitrage Opportunities Across Sample Period

We compare the frequency of arbitrage opportunities month by month throughout the sample. Appendix 8 shows the frequency of arbitrage opportunities per month in each of our securities.

In Egypt, we find that arbitrage opportunities are evenly distributed across the sample, showing no significant pattern. However, in Argentina arbitrage opportunities appear to be most frequent during May, June and July 2008 as well as

[11] Indeed two interviews with arbitrageurs in Egyptian DRs reveal that this is the case.

during the onset of the financial crisis in September, October and November 2008. This indicates that the volatility and excessive co-movements that characterized these periods created significant price differences between the DR and it underlying stock. Moreover, we find that for Banco Marco (BMA), the Argentinean bank with the largest frequency of arbitrage opportunities, this was a sign of the toll that the crisis took on the pricing behavior of financial services equity.

Our extracted trading subsets show that arbitrage activity was persistent during these months, providing proof that active arbitrageurs monitor the market to make use of the price differences and have made considerable profits from the volatility Argentinean DRs arbitrage during the crisis.

We also analyze whether arbitrage opportunities appear during a certain time of the trading overlap. Miller and Morey (1996) point out that volatility can be high during the opening and closing of the trading overlap as prices adjust to each other. Appendix 9 shows the size of the price deviation by time of the overlap. No significant pattern is observed, similar to the result of Suarez (2005).

5.4.3 Why are deviation skewed to the discount side?

The average price deviations for both Egyptian and Argentinean DRs are significantly skewed to the negative side. This indicates that the DR mostly sell at discounts to their underlying stocks.

Figure 5.3 shows a histogram of the price deviations for all of our sample securities in Egypt and Argentina. Appendix 10 shows the histogram for each individual security. Previous studies such as Gemmill and Thomas (2002) explain the persistent discounts by the short selling restriction that make arbitrage difficult to carry out. However, since we have shown that arbitrage is possible in our markets, the persistent discounts can be explained by trading asymmetry between the foreign and local market since traders are only allowed to take bearish positions on the DR, thus the more incidence of DR discounts to the underlying stock within the no-arbitrage band.

INSERT FIGURE 5.3 HERE

Moreover, since the companies are more active in their local markets, the discounts can be explained by the difference in demand curves of the two markets on the DR and the underlying stock, since foreigners can view the DR as more risky and demand it only at a discount relative to the underlying stock, up until the limits of the no-arbitrage bands. This is especially true due to the period of the sample, which is around the financial crisis. Prior to 2008, there has been an increased demand by large foreign investors and funds to hold emerging market security, which reversed prior to and post the financial crisis.

Our results on the prevalence of discounts on the DR side in Argentina throughout our sample period is contrary to the result of Yeyati et al (2008) who show that when capital controls were first instilled in Argentina, this increased the demand on the DR and caused the DR to trade at a premium. The explanation of this conflicting result could either be that over time foreign investors have found other means of overcoming the capital control, or that the effect of another trading barrier, such as the short selling restriction, has a stronger effect on the direction of the price deviation, which was missing from Yeyati et al's(2008) analysis.

5.4.4 Why aren't all arbitrage opportunities utilized?

Although we show that arbitrage is possible, we attempt to explain the lost arbitrage opportunities which were not utilized by arbitrageurs. Lost arbitrage opportunities can be due to the limits on arbitrageurs' capital (in the case of arbitrageurs under capital control restrictions) or stock holdings (in the case of arbitrageurs circumventing short selling restrictions) as postulated by Shleifer and Vishny (1997). Indeed, we hypothesize that the lost arbitrage opportunities will be those that involve larger volumes of stocks (and thus capital) to conduct the arbitrage, which typically exceed an arbitrageurs capacity to overcome them.

We analyze the difference in the volumes of trades of real versus lost arbitrage opportunities. The results presented in Table 5-10 illustrate that on average the average size of the lost arbitrage trade is three times that of the real arbitrage trade and that the first and third quartile are higher for the lost arbitrage trades.

INSERT TABLE 5-10 HERE

5.5 Conclusions

This paper provides the first real time evidence of arbitrage opportunities in the

DR market for cross-listed emerging market stocks in presence of limits to arbitrage. We find statistically significant absolute price deviations from parity that average around 0.61% between Egyptian DRs and their underlying stock and 2.78% for Argentinean DR and stock pairs. However, using a novel identification procedure for identifying arbitrage opportunities that takes prices and volumes into consideration, we find that only 15% and 10% of trades in our sample are considered profitable arbitrage opportunities in Egypt and Argentina, respectively, reflecting the large and cumbersome costs of arbitrage in this market.

Our results reveal that approximately 70% and 88% of arbitrage opportunities in Egypt and Argentina, respectively, involved real arbitrage activity, as identified by symmetric arbitrage trades in the stock and DR extracted from the trade data. Arbitrageurs in our sample markets seem to be doing a good job in maintaining price efficiency by allowing most trades to converge to no-arbitrage zones in two trades, but which might take a long period of time averaging 46 minutes in Egyptian DRs and 14 minutes in Argentinean ones, reflecting the lower activity of trade on some stocks in the sample. However, we observe that there is a large disparity between the size, frequency, duration and speed of convergence amongst the individual stocks that are all related to the liquidity of the DR. For liquid DRs that have a considerable part of their value trading in the foreign market such as ORTE and OCIC from Egypt and GFG, FRA and MET from Argentina, we find that they have the smallest price deviation, the lowest frequency of arbitrage opportunities and the fastest speed and duration to converge to no-arbitrage zones. This confirms the hypothesis that the higher the liquidity of DRs, the smaller the number of arbitrage opportunities.

We reach a point in our analysis that necessitates discussing why such large and profitable arbitrage opportunities exist in emerging markets, even in presence of limits to arbitrage such as large trading costs, short selling restrictions and capital controls. Arbitrage opportunities arise because of differential price movements between markets, which can occur as a result of information asymmetry, differential co-movements of assets with the markets in which they trade and different consumer sentiments (Grossman et al, 2007;Arquete et al, 2008). Moreover, special events such as wars, financial crises and regulatory changes (Hsu and Wang, 2008) can cause prices to deviate during these special periods. Indeed, we can see that during the financial crises, prices of Argentinean DRs greatly deviated from each other, creating large and profitable arbitrage opportunities.

Our paper contributes to pre-existing studies on arbitrage in the DR market as follows. It supplements the study of Gagnon and Karolyi (2010) by dissecting their observations on large price deviations in cross-listed emerging market equity with limits to arbitrage to show that arbitrage opportunities do exist. It also provides empirical proof to the results of Kaul and Merhotra (2007) on the role of trades in price convergence. To the authors' knowledge, this is the first evidence of the presence of arbitrage trades in DRs, which was probably concealed so far from studies by arbitrageurs who profit from such an anomaly. However, whether we as individuals can take a piece of the pie might prove difficult since such activity must be institutionalized by large traders with large capital holdings to overcome the limits present. Further studies to this one need to explore whether arbitrage activity persist in other samples of DRs around the world.

Table 5-1 Summary of Egyptian and Argentinean Companies

Ticker Symbol	Bundling Ratio	Market Cap (USD Million)	Value Traded During Sample (USD Million)		Number of Trading Days		Average Price in Sample (USD)	
			Stock	DR	Stock	DR	Stock	DR
COMI	1:1	2,969.05	3,756.22	551.12	542	533	10.16	10.27
HRHO	1:2	1,318.33	5,843.81	201.65	542	351	12.34	13.04
ORTE	1:5	3,672.07	7,216.55	13,858.65	535	557	8.09	8.02
OCIC	1:1	9,622.32	7,943.14	7,726.08	542	558	47.64	47.46
ETEL	1:5	4,370.13	76,341.78	103.51	543	337	15.81	15.47
PHDC	1:5	441.71	1,112.63	95.17	458	96	7.20	8.56
LECI	1:1	151.69	330.86	33.95	542	73	8.22	12.25
SUCE	1:1	1,164.04	131.90	0.19	543	22	7.50	7.84
AEZD	1:3	1,011.38	30,808.18	0.06	543	2	11.24	78.50
BMA	1:10	2,361.13	581.22	570.25	491	505	18.74	18.41
FRA	1:3	1,914.88	162.13	95.81	491	505	5.03	4.94
EDN	1:20	239.24	252.64	161.69	491	497	9.54	9.32
GFG	1:10	1,382.89	369.51	190.01	491	505	4.29	4.20
IRS	1:10	822.15	44.11	223.36	484	505	8.15	7.94
MET	1:10	62.75	7.41	4.58	473	448	2.54	2.54
TGS2	1:5	307.38	42.26	15.81	501	491	3.10	3.02
SAM	1:4	706.01	2.62	1.55	219	195	9.56	8.57
CRES	1:10	831.15	48.14	359.79	505	487	13.38	11.73
YPF	1:1	18,661.63	19.96	60.72	391	500	40.77	42.09

*Data for PHDC start only start from its listing date 5/7/2008.

5-2 Long Term Price Parity Tests

	Daily Price Deviation(USD)				Daily Relative Log Price Deviation				DR Stock Price Correlation
	Mean	Stdev	Min	Max	Mean	Stdev	Min	Max	
COMI	-0.076**	0.179	-0.670	0.800	0.181**	1.92%	-12.46%	8.43%	0.997**
HRHO	-0.008	0.436	-2.630	2.050	0.227	3.33%	-12.28%	12.88%	0.997**
OCIC	-0.204**	1.224	-4.056	21.374	0.839**	2.53%	-11.00%	44.07%	1.000**
ORTE	-0.054**	0.166	-0.645	2.060	0.142**	2.13%	-7.72%	28.07%	1.000**
ETEL	-0.095*	0.651	-2.159	2.259	0.275*	4.25%	-15.36%	13.14%	0.957**
PHDC	-0.057	0.617	-2.050	2.526	0.145	9.02%	-29.39%	37.39%	0.978**
BMA	-0.326**	0.384	-1.466	0.905	0.436**	2.71%	-15.55%	3.20%	0.999**
FRA	-0.079**	0.171	-0.524	0.739	0.127**	3.93%	-18.89%	16.18%	0.995**
EDN	-0.220**	0.239	-0.939	0.292	0.240**	3.17%	-18.78%	5.89%	0.999**
GFG	-0.086**	0.107	-0.430	0.189	0.108**	3.46%	-19.70%	3.99%	0.998**
IRS	-0.165**	0.230	-1.123	0.475	0.204**	3.50%	-19.86%	5.94%	0.998**
MET	-0.042**	0.133	-0.455	0.370	0.065**	7.26%	-32.74%	21.63%	0.992**
TGS2	-0.057**	0.113	-0.418	0.257	0.078**	4.42%	-22.46%	11.17%	0.994**

*** and * indicate significance at 1% and 5%.*

Table 5-3 Price Matching Descriptives

Company	Total Number of Observations in Sample		Number of Matched Trades					MinSpan Descriptive	
	Stock	DR	S(all)	S15	S10	S5	S1	Mean Span (min)	Max Span (min)
COMI	234,853	10,710	3,800	3,734	3,704	3,580	2,703	0:01:37	1:06:45
HRHO	482,830	1,866	739	728	728	721	645	0:01:06	1:20:38
ORTE	721,854	141,923	41,528	41,502	41,486	41,396	38,759	0:00:19	0:55:33
OCIC	402,162	83,544	27,985	27,941	27,902	27,686	23,921	0:00:34	0:57:53
ETEL	398,201	1,189	469	462	461	454	402	0:01:09	0:55:24
PHDC	288,289	1,038	378	368	366	353	307	0:01:35	1:00:21
All	**2,528,189**	**240,270**	**74,899**	**74,735**	**74,647**	**74,190**	**66,737**	**0:01:03**	**1:20:38**
BMA	84,258	137,422	46,831	46,602	46,283	44,675	33,713	0:01:09	1:18:34
FRA	52,796	63,177	22,427	22,022	21,609	20,082	12,982	0:02:05	1:17:52
EDN	60,815	49,033	17,412	17,078	16,686	15,528	10,659	0:02:05	1:57:19
GFG	120,472	166,653	43,324	43,193	42,958	41,658	30,772	0:01:07	1:26:37
IRS	12,345	60,294	8,214	7,482	7,048	6,025	3,282	0:05:19	4:00:42
MET	7,301	7,913	2,024	1,499	1,393	1,186	767	0:16:27	4:53:09
TGS2	20,655	13,657	5,830	4,990	4,641	3,943	2,290	0:07:28	5:55:38
CRES	16,982	164,505	15,816	15,495	15,161	13,901	8,946	0:02:14	1:43:56
SAM	634	919	132	39	35	30	13	1:25:10	5:53:01
YPF	8,541.0	4,400.0	612	2,232	1,584	1,422	1,135	0:15:51	5:09:46
All	**384,799**	**667,973**	**162,622**	**160,632**	**157,398**	**148,450**	**104,559**	**0:05:06**	**5:55:38**

Table 5-4 Intraday Price Deviation Results

	Price Deviation (USD)				Relative Price Deviation (%)			
Ticker Symbol	Mean	Standard Deviation	Minimum	Maximum	Mean	Standard Deviation	Minimum	Maximum
COMI	-0.08**	0.14	-0.71	0.70	-1.00**	1.76	-12.86	14.88
HRHO	0.05	0.35	-1.87	1.74	0.11	2.82	-12.14	12.41
ORTE	-0.05**	0.10	-1.50	1.50	-0.51**	1.28	-24.48	15.02
OCIC	-0.21**	0.48	-3.46	5.35	-0.49**	1.04	-9.51	7.70
ETEL	-0.15**	0.60	-2.14	2.55	-1.04**	3.89	-15.97	17.37
PHDC	-0.05**	0.34	-1.16	1.73	-0.73**	4.24	-17.00	22.27
ALL	**-0.08**	**0.19**	**-3.46**	**5.35**	**-0.61**	**1.36**	**-24.48**	**22.27**
BMA	-0.40**	0.41	-1.81	1.45	-2.76**	2.97	-19.72	5.84
FRA	-0.11**	0.18	-1.15	0.92	-2.46**	3.90	-26.82	13.86
EDN	-0.29**	0.25	-1.18	0.67	-3.59**	3.69	-21.99	8.10
GFG	-0.10**	0.12	-0.78	0.41	-3.10**	4.06	-31.02	15.27
IRS	-0.18**	0.24	-1.37	0.46	-2.29**	3.46	-27.53	10.75
MET	-0.04**	0.16	-0.61	1.00	-1.74**	7.42	-42.33	24.18
TGS2	-0.09**	0.12	-0.67	0.56	-2.59**	4.44	-25.97	17.65
CRES	-0.28**	0.30	-1.67	1.10	-2.39**	3.25	-24.79	10.05
SAM	-0.52**	1.25	-4.60	2.10	-5.09**	15.31	-56.55	29.14
YPF	-0.75**	1.39	-3.99	10.28	-1.78**	3.77	13.70	-41.27
ALL	**-0.28**	**0.47**	**-4.60**	**2.10**	**-2.78**	**3.75**	**-56.55**	**29.14**

*** and * indicate significance at 1% and 5%*

Table 5-5 Intraday Absolute Price Deviations Results

	Mean	Standard Deviation	Min	Max	Mean	Standard Deviation	Min	Max
	Absolute Price Deviation (USD)				Absolute Relative Price Deviation (%)			
COMI	0.14**	0.09	0.00	0.71	1.63**	1.21	0.00	14.88
HRHO	0.26**	0.24	0.00	1.87	2.08**	1.90	0.00	12.41
ORTE	0.08**	0.08	0.00	1.50	1.06**	0.88	0.00	24.48
OCIC	0.38**	0.36	0.00	5.35	0.87**	0.76	0.00	9.51
ETEL	0.47**	0.39	0.00	2.55	3.08**	2.59	0.00	17.37
PHDC	0.24**	0.24	0.00	1.73	2.84**	3.23	0.00	22.27
ALL	**0.26**	**0.13**	**0.00**	**5.35**	**1.93**	**1.00**	**0.00**	**24.48**
BMA	0.47**	0.32	0.00	1.81	3.02**	2.70	0.00	19.72
FRA	0.17**	0.13	0.00	1.15	3.44**	3.07	0.00	26.82
EDN	0.32**	0.22	0.00	1.18	3.88**	3.38	0.00	21.99
GFG	0.12**	0.10	0.00	0.78	3.54**	3.69	0.00	31.02
IRS	0.23**	0.20	0.00	1.37	2.90**	2.96	0.00	27.53
MET	0.13**	0.11	0.00	1.00	5.14**	5.63	0.00	42.33
TGS2	0.12**	0.09	0.00	0.67	3.89**	3.36	0.00	25.97
CRES	0.32**	0.25	0.00	1.67	2.77**	2.93	0.00	24.79
SAM	1.08**	0.81	0.00	4.60	12.86**	9.69	0.00	56.55
YPF	1.09**	1.15	0.00	10.28	2.69**	3.19	0.00	41.27
ALL	**0.40**	**0.35**	**0.00**	**10.28**	**4.41**	**2.14**	**0.00**	**56.55**

*** and * indicate significance at 1% and 5%*

Table 5-6 Trading Costs in Sample Markets

Market	2008 Trading Costs	2009 Trading Costs
Egypt (bp*)	56.04	27.4
Argentina(bp)	42.23	67.03
NYSE(bp)	13.89	15.40
LSE purchases (bp)	72.25	74.45
LSE sales(bp)	22.65	22.59
NASDAQ(bp)	17.51	17.97
FX Conversion Fee (bp)	6.00	6.00
Global Safe Keeping on ADR (bp)	22.00	22.00
Global Safe Keeping on GDR (bp)	45.00	45.00
Global Settlement Fees on ADR (USD)	60	60
Global Settlement Fees on GDR (USD)	115	115
DR Conversion Fee (USD)	0.05	0.05

Source: Bank of New York Mellon DR Converter www.bnym.com and ElKins/McSherry Transaction Cost Estimates for Trading published by Institutional Investor.

*basis points

Table 5-7 Arbitrage Opportunities: Frequency and Descriptive Statistics

Stock	Arbitrage Frequency		Absolute Price Deviation (USD)				Absolute Relative Price Deviation (%)			
	No Arb(%)	*Arb (%)*	Mean	Minimum	Maximum	Standard Deviation	Mean	Minimum	Maximum	Standard Deviation
COMI	91.45	8.55	0.269	0.124	1.283	0.165	3.39	1.45	13.37	1.79
HRHO	87.14	12.86	0.507	0.134	1.871	0.396	3.71	1.24	8.68	2.10
ORTE	96.72	3.28	0.232	0.110	1.351	0.074	2.63	1.23	11.32	1.16
OCIC	93.98	6.02	0.953	0.247	5.353	0.464	2.09	0.95	7.93	1.11
ETEL	57.57	42.43	0.636	1.936	0.524	0.356	4.07	1.42	14.40	2.27
PHDC	81.22	18.78	0.417	0.161	2.685	0.398	4.64	1.45	35.43	5.49
Average	***84.68***	***15.32***	***0.502***	***0.452***	***2.178***	***0.309***	***3.42***	***1.29***	***15.19***	***2.32***
BMA	77.87	22.13	0.845	0.190	1.703	0.281	5.89	1.20	18.53	3.11
FRA	93.66	6.34	0.343	0.120	0.920	0.124	7.35	2.00	26.00	3.75
EDN	84.84	15.16	0.575	0.122	1.106	0.213	6.40	1.30	23.82	4.27
GFG	94.95	5.05	0.291	0.086	0.782	0.090	10.10	1.95	30.47	5.50
IRS	94.51	5.49	0.543	0.180	1.349	0.214	7.52	1.84	28.03	5.43
MET	96.64	3.36	0.319	0.107	1.196	0.176	13.40	3.33	36.83	9.65
TGS2	94.67	5.33	0.242	0.082	0.545	0.063	7.37	2.31	26.45	3.55
CRES	89.52	10.48	0.669	0.208	1.671	0.259	6.52	1.64	24.79	4.93
SAM	89.39	10.61	1.580	0.619	2.278	0.633	16.24	5.67	25.98	5.26
YPF	85.8	14.2	2.216	0.584	8.980	1.335	5.18	1.23	41.27	4.21
Average	***90.19***	***9.81***	***0.762***	***0.230***	***2.053***	***0.339***	***8.60***	***2.25***	***28.22***	***4.96***

Table 5-8 Convergence Speed and Persistence of

Stock	Average Time to Converge	Number of Trades to Converge			Persistence of Arbitrage		
		Mean	*Stdev*	*Max*	*One Trade*	*Two Trades*	*Three Trades*
COMI	0:26:01	1.41	0.88	8	49.54%	9.54%	4.31%
HRHO	1:27:03	1.32	0.75	4	48.42%	5.26%	3.16%
ORTE	0:02:43	1.36	0.71	7	54.04%	14.24%	3.74%
OCIC	0:04:03	1.5	1.05	13	48.22%	10.08%	4.74%
ETEL	1:57:01	2.05	2.06	15	17.59%	5.53%	3.02%
PHDC	0:40:10	1.87	1.42	8	23.94%	14.08%	1.41%
Average	***0:46:10***	***1.58***	***0.52***	***15***	***40.29%***	***9.79%***	***3.40%***
BMA	0:05:44	2.82	3.92	114	17.11%	7.45%	3.23%
FRA	0:06:11	1.48	0.92	10	47.01%	12.88%	4.29%
EDN	0:07:18	1.85	1.42	13	30.54%	12.24%	5.08%
GFG	0:02:44	1.62	1.26	12	41.91%	10.42%	4.71%
IRS	0:16:33	1.7	1.62	18	38.80%	10.20%	4.88%
MET	0:16:07	1.36	0.8	5	55.88%	8.82%	4.41%
TGS2	0:11:58	1.41	0.84	6	51.45%	13.50%	3.22%
CRES	0:10:10	2.02	2	23	28.12%	10.86%	4.22%
SAM	0:20:33	2.8	2.95	8	14.29%	14.29%	-
YPF	0:48:30	1.97	1.55	10	26.22%	9.45%	3.96%
Average	***0:14:35***	***1.9***	***1***	***114***	***35.13%***	***11.01%***	***4.22%***

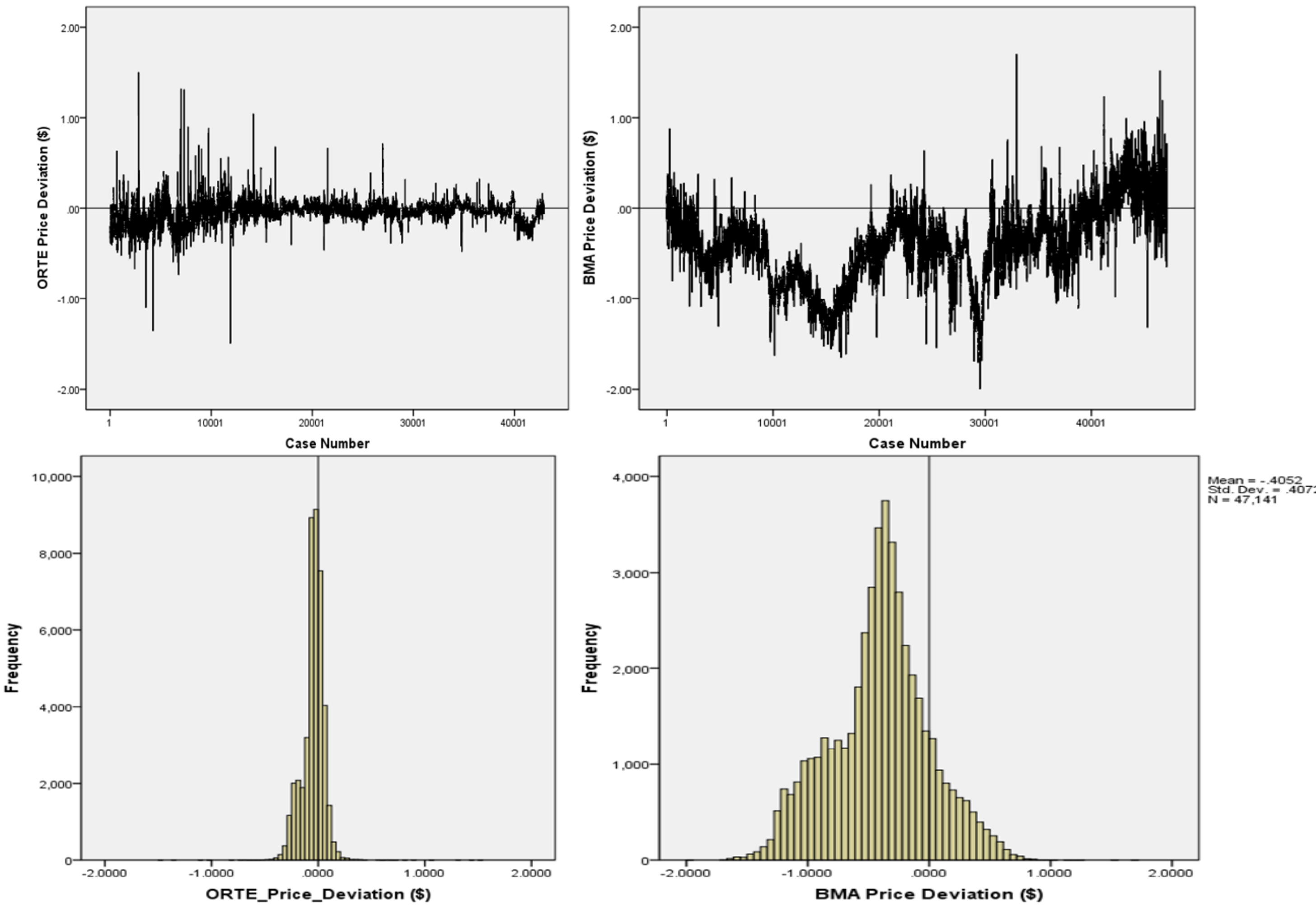
Table 5-9 Frequency and Profitability from Arbitrage

Stock	Real Arbitrage	Lost Arbitrage	Total Profits	Profits Premium	Profits Discount
COMI	74.15%	25.85%	$106,910.72	$17,695.52	$89,215.20
HRHO	70.53%	29.47%	$27,605.06	$19,613.57	$7,991.49
ORTE	73.42%	26.58%	$339,269.72	$25,784.74	$313,484.99
OCIC	29.44%	70.56%	$513,605.83	$46,836.89	$466,768.94
ETEL	89.95%	10.05%	$178,917.94	$32,867.14	$146,050.79
PHDC	80.28%	19.72%	$23,673.34	$8,004.51	$15,668.83
	69.63%	**30.37%**	**$1,189,982.61**	**$150,802.37**	**$1,039,180.24**
BMA	91.66%	8.34%	$1,124,634.48	$1,039.14	$1,123,595.34
FRA	88.95%	11.05%	$101,060.62	$11,941.98	$89,118.64
EDN	89.62%	10.38%	$194,622.52	$165.62	$194,456.90
GFG	93.88%	6.12%	$156,470.33	$584.58	$155,885.74
IRS	84.26%	15.74%	$31,108.95	$113.10	$30,995.85
MET	86.76%	13.24%	$2,987.42	$1,060.32	$1,927.10
TGS2	89.71%	10.29%	$28,314.86	$843.21	$27,471.65
CRESY	84.73%	15.27%	$73,228.51	$924.52	$72,303.99
SAM	85.71%	14.29%	$2,035.29	$0.00	$2,035.29
YPF	87.31%	12.69%	$57,084.78	$1,266.76	$55,818.02
	88.26%	**11.74%**	**$1,771,547.75**	**$17,939.23**	**$1,753,608.53**

Table 5-10 Volumes of Real versus Lost Arbitrage

	Volume Real Arbitrage/Trade			Volume Lost Arbitrage/Trade		
Stock	Mean	First Quartile	Third Quartile	Mean	First Quartile	Third Quartile
COMI	6,176	2,968	10,000	8,276	4,000	10,000
HRHO	2,241	702	3,772	5,049	2,644	7,938
ORTE	5,637	1,750	5,694	9,045	3,145	10,000
OCIC	1,238	400	1,714	2,579	1,053	3,657
ETEL	3,025	975	5,000	10,272	2,375	6,475
PHDC	2,784	1,500	3,000	3,494	1,500	5,750
All	***3,517***	***1,383***	***4,863***	***6,453***	***2,453***	***7,303***
BMA	295	100	300	922	200	900
FRA	750	300	900	1,838	700	2,300
EDN	516	200	500	1,098	400	1,100
GFG	843	300	900	2,186	800	2,975
IRS	467	200	500	1,079	300	1,200
MET	698	300	500	1,689	1200	1,400
TGS2	1133	500	1200	2,718	1000	2,575
CRESY	228	100	300	432	200	500
SAM	187	137.5	200	300	250	350
YPF	170	100	100	361	100	200
All	***529***	***224***	***814***	***1262***	***515***	***1350***

Figure 5-1 Price Deviation for ORTE and BMA



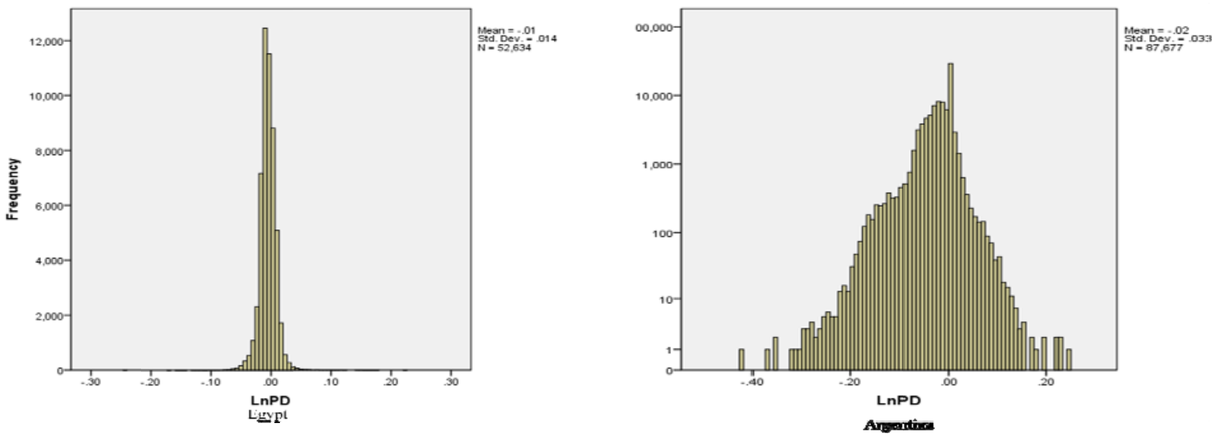
Stock Trades Date	Time	Price	Volume	DR Trades Date	Time	Price	Volume
Commercial International bank							
				31-Jul-08	11:08:53	10.00	1750
				31-Jul-08	11:09:24	10.00	6230
31-Jul-08	11:10:10	9.4	150				
31-Jul-08	11:10:10	9.4	500				
31-Jul-08	11:10:10	9.4	4886				
31-Jul-08	11:10:10	9.4	2444				
				31-Jul-08	11:10:42	9.99	676
31-Jul-08	11:11:15	9.4	676				

Stock Trades Date	Time	Price	Volume	DR Trades Date	Time	Price	Volume
Grupo Financiero Galicia							
				3-Jun-08	18:40:58	5.46	100
				3-Jun-08	18:41:23	5.46	100
3-Jun-08	18:41:33	5.77	200				
				3-Jun-08	18:41:39	5.46	100
				3-Jun-08	18:41:46	5.46	500
3-Jun-08	18:41:47	5.77	100				
3-Jun-08	18:41:56	5.77	487.3				
3-Jun-08	18:41:56	5.77	12.7				
				3-Jun-08	18:42:03	5.46	100
3-Jun-08	18:42:11	5.77	100				
				3-Jun-08	18:42:24	5.46	100
				3-Jun-08	18:42:36	5.46	100
				3-Jun-08	18:42:55	5.46	100
3-Jun-08	18:43:16	5.77	100				
3-Jun-08	18:43:24	5.77	200				

Stock Trades Date	Time	Price	Volume	DR Trades Date	Time	Price	Volume
Orascom Telecom							
31-Mar-08	12:19:32	13.8	5000				
31-Mar-08	12:19:32	13.8	3750				
31-Mar-08	12:19:32	13.8	4577				
31-Mar-08	12:19:32	13.8	5000				
31-Mar-08	12:19:32	13.8	3073				
31-Mar-08	12:19:32	13.8	100				
31-Mar-08	12:19:32	13.8	10000				
31-Mar-08	12:19:32	13.8	500				
31-Mar-08	12:19:32	13.8	500				
31-Mar-08	12:19:32	13.8	5000				
31-Mar-08	12:19:32	13.8	62500				
				31-Mar-08	12:19:44	13.5	50000
				31-Mar-08	12:19:45	13.5	2940
				31-Mar-08	12:19:45	13.5	47060

Stock Trades Date	Time	Price	Volume	DR Trades Date	Time	Price	Volume
YPF							
				23-Jun-08	18:10:30	47.7	500
23-Jun-08	18:10:58	50.37	500				
				23-Jun-08	18:11:02	47.7	500
23-Jun-08	18:11:05	50.37	500				
				23-Jun-08	18:11:10	47.7	500
23-Jun-08	18:11:28	50.37	500				
				23-Jun-08	18:11:31	47.7	500
23-Jun-08	18:15:38	50.37	1000				
				23-Jun-08	18:15:47	47.7	500
				23-Jun-08	18:15:47	47.7	500
23-Jun-08	18:16:07	50.37	1000				
				23-Jun-08	18:16:12	47.7	500
				23-Jun-08	18:16:12	47.7	500

Figure 5-2 Extracted Trade Data of Real Arbitrage Activity



5-3 Histogram of Relative Price Deviation

6 AN INVESTIGATION OF INTRADAY PRICE DISCOVERY IN CROSS-LISTED EMERGING MARKET EQUITIES

6.1 Introduction

Price discovery, defined as the process of searching for an equilibrium price (Harris *et al.*, 1995), is a key function of stock exchanges. With the pheonmenal increase in the number of companies cross listing their stocks on large international exchanges in recent years, competition among exchanges for a larger proportion of trading has raised the question of whether the location of price discovery remains local or shifts to the large international market. Recent evidence demonstrates that although both markets contribute to the price discovery process, the local market is usually the dominant location of price discovery, with a greater proportion occuring in the foreign market—depending on the amount of trading and how well the markets are informationally linked.

The main contribution of this paper is to provide evidence about the intraday price discovery of emerging market stocks that are cross listed on international exchanges as depository receipts (DRs): US dollar (USD)-denominated receipts that represent claims against local-market stocks, during overlapping trading hours. Although emerging markets currently dominate the market for DRs (Global Finance, 2010), the literature is currently lacking an intraday price discovery analysis that evaluates the share contributed to the process by the international exchange, while examining its evolution over time. We therefore study this issue using Egyptian and Argentinean stocks that are cross listed as Global DRs (GDRs) and American DRs (ADRs) on the London and US stock exchanges.

Our sample is best suited for our analysis because, unlike prior studies, we compare DRs that are foreign listed on two international exchanges during the same period to allow cross-comparisons. Furthermore, we consider cross-listed equities in local and international market with different trading hours but a significant period of trading overlap. Finally, our price discovery analysis benefits from a large number of observations because we use two-year intraday transaction data for Egyptian and Argentinean stocks and their DRs, as well as intraday foreign exchange data for the USD to Egyptian pound (EGP) and USD to Argentinean peso (ARS).

We hypothesize that, consistent with previous studies, price discovery should occur primarily in the local market, especially given that the markets we chose are informationally segmented, due to language, cultural, and trading barriers[12]. Our methodology follows those of Ding *et al.* (1999) and Eun and Sabherwal (2003). We begin by verifying that our sample of DRs and their underlying stocks are linked by international arbitrage conditions by conducting unit root and co-integration tests. We follow with our price discovery analysis, which relies on the Granger and

---

12 Both markets had large trading costs and short-selling restrictions during the sample period. Moreover, Argentina also has capital conrols.

Gonzalo (GG) (1995) common long-memory error-correction estimation approach to measure the contribution of each market to price discovery. Finally we run panel regressions on our data to try to explain the contribution of each market to price discovery.

Our results indicate that whereas the local market for Egyptian securities is the dominant market for price discovery, the price for Argentinean securities is determined in both the local and US stock markets, to the extent that for some stocks the local market acts as a pure satellite to the international exchange. We believe this evidence to be the first of its kind in DRs and corroborates Eun and Sabherwal's (2003) results on dual-listed Canadian stocks. We find that liquidity, volume of trade, and market capitalization are all significant variables that are dynamic, that evolve over time, and that explain the share of price discovery.

This paper is organized as follows. Section 6.2 presents institutional background, and Section 6.3 presents our data description and preliminary analysis. Methodology and results are presented in Section 6.4, and we conclude in Section 6.5.

6.2 Data Description

The analysis of a cross-listed stock trading in two markets can be based on either transaction prices or quoted prices. Whereas quote prices are preferred because they do not suffer from the autocorrelation present in transaction prices, they are difficult to obtain for emerging market stocks. Indeed, Ding et al. (1999) also relied on transaction prices for their intraday price discovery analysis on one Malaysian stock: Sime Darby Berhad and its dual-listed stock in Singapore. We believe that the objective of our analysis is not affected by the use of transaction prices because Eun and Sabherwal (2003) have shown that the results do not differ qualitatively with the use of either data type.

For the price discovery analysis, we use the same intraday dataset developed in Chapter 5, which was matched using the minspan approach. However, since price discovery models are very sensitive to the number of observations, we go in line with Eun and Sabherwal (2003) and we pick securities with a minimum of 2000 observations in either market, leaving us with 4 Egyptian GDR-stock pairs and 9 Argentinean ADR-stock pairs for our price discovery analysis.

Our analysis is based on the natural logarithm of the price series for the underlying stocks after converting it to USD[13], and the natural logarithm of the USD price of the DRs. This conversion facilitates the specification of the error correction term in error correction models, as well as the assessment of equality of prices in the between the foreign markets and our local emerging markets.

---

[13] The price discovery analysis can be done on the foreign exchange adjusted stock price, thereby endogenizing the exchange rate effect, or on the stock price in local currency and including FX as an exogenous variable. We find no qualitative differences in results.

6.3 Tests and Results

Besides their location of trade and currency denomination, the DR and the underlying stock are both identical securities that are fully fungible. This should ensure that both prices are equal; otherwise active arbitrageurs will interfere to bring prices to parity. Although temporary information asymmetry and differential co-movements of the DR and its underlying stocks to their respective markets may cause prices to deviate in the short term, the long-run equilibrium relationship between prices should cause them to adjust toward parity, as ensured by their arbitrage linkages.

This theoretical pricing relationship can be empirically tested by first establishing that the DR and underlying stock price series are co-integrated in the long run, and then by showing that any deviation from this equilibrium in the short term is corrected by an adjustment in either one or both of the price series. This latter test allows us to assess the relative contribution of each market to price discovery by measuring the extent to which the price of the DR adjusts to a change in the price of the local stocks and vice versa. We use the GG common long-memory error-correction approach to characterize the price discovery process and to determine whether both markets do, in fact, contribute to price discovery.

Our methodology for examining price discovery is undertaken through an analysis of the error-correction mechanism between the two markets. A necessary precondition of using the error correction model is (1) to ensure that whereas each price is non-stationary with a unit root, a linear combination of stationary prices exists, and (2) that there is a long-run co-integration equation that links both price series. Following these preliminary tests for unit roots and co-integration, we then estimate the GG common long-memory error-correction model. We finally close this section with a panel regression that explains the relative contribution of markets to price discovery.

6.3.1 Unit Root Test

Following standard methodology in the literature, we use the Augmented Dickey and Fuller (ADF) approach to determine if each price series is non-stationary and exhibits a unit root. The ADF test will identify whether or not each of the DR Price P_t^{DR} and foreign exchange adjusted stock price $P_t^{S'}$[14] has a unit root and thus non-stationary root of I(1), which is an expected feature of prices, because they are non-mean reverting. It involves testing three regression variations: (1) random walk, (2) random walk with a drift, and (3) random walk with a drift and time trend:

$$\Delta Y_t = \rho Y_{t-1} + \sum_{j=1}^{p} \beta_j \Delta Y_{t-j} + \mu_t \ , \qquad (6.1)$$

$$\Delta Y_t = \alpha_0 + \rho Y_{t-1} + \sum_{j=1}^{p} \beta_j \Delta Y_{t-j} + \mu_t \, , \qquad (6.2)$$

[14] $P_t^{S'} = \frac{P_t^{Stock} * b}{S_t}$

$$\Delta Y_t = \alpha_0 + \alpha_1 t + \rho Y_{t-1} + \sum_{j=1}^{p} \beta_j \Delta Y_{t-j} + \mu_t \ , \tag{6.3}$$

where the test is for the null hypothesis in which the coefficient $\rho = 0$ (i.e. the data is non-stationary and needs to be differenced to make it stationary and thus has a unit root I(1)) and the alternative hypothesis that ρ <0 (i.e. the data is stationary without differencing and does not have unit root). The significance of the unit root test is assessed with the regression's *t*-statistic against Mackinnon's (1991) critical values. Results are presented in Table 6-1 and show that all price series under three model variations contain a unit root, because we fail to reject the null hypothesis at 5%.

INSERT TABLE 6-1 ABOUT HERE

6.3.2 Co-integration

We test for co-integration using two approaches. In the first approach, we directly test for co-integration using the result of the non-stationarity of prices and test whether the price deviation between the matched DR and adjusted underlying stock price $P_t^{S'} - P_t^{DR}$ is stationary. In the second approach, we rely on the Johansen co-integration test for the null hypothesis: the number of co-integrating vectors between prices, *r,* is equal to 0, with maximum eigenvalue and trace tests.

In the first approach, the objective is to show that despite non-stationary prices, the deviation between these prices is stationary and linear and thus a long-run no-arbitrage relationship holds. To illustrate, non-stationary prices of the DR, stock, and the exchange rate should take the following AR(1) form:

$$P_t^{S'} = P_{t-1}^{S'} + v_t$$

$$P_t^{DR} = P_{t-1}^{DR} + u_t,$$

where v and u and are the innovations in prices. Now, using these two equations, the deviation in prices can be defined as

$$P_t^{S'} - P_t^{DR} = v_t - u_t,$$

meaning that there is a stationary linear combination of these prices, x_t defined as

$$x_t = v_t - u_t. \tag{6.4}$$

We should therefore expect that if the price series are co-integrated, the ADF test on the price deviation should reject the null hypothesis, and thus deviation is stationary of I(0).

The second approach for testing co-integration of the price series uses the Johansen co-integration test [15]. If the DR price and the adjusted underlying stock

[15] As described in Eun and Saberhwal (2003), the Johansen test depends on the estimation of a path order autoregressive process, in which the first difference lag operator of an (n x 1) vector of I(1) time-series variables is a 0 mean n-dimensional white noise (n x n) matrix of parameters. This matrix rank is equal to the number of independent co-integrating vectors r = 1. Cointegration is tested by both a maximum eigenvalue test, which tests the null hypothesis that the number of cointegrating vectors is r against the alternative of $r+1$ cointegrating vectors, and a trace test, which tests the null hypothesis that the number of distinct cointegrating vectors is less than or equal to r against a general alternative.

price are co-integrated of order (1,1), the necessary condition for the co-integration is that there is a co-integrated vector $\beta = \{\beta_{S'}, \beta_{DR}\}$, such that:

$$\beta_{S'}\mu_{P_t^{S'}} + \beta_{DR}\mu_{P_t^{DR}} = 0 \qquad (6.5)$$

where μ represents the trend in the random walk processes of each price series defined in the ADF test above. If the DR and stock price series are indeed co-integrated, then $\mu_{P_t^{S'}}$ must be identical to $\mu_{P_t^{DR}}$ and $\beta_{S'} - \beta_{DR} = 0$.

The results of the two co-integration tests, presented in Table 6-2 show that both price series are indeed co-integrated. The ADF *t*-statistic is highly significant across all stock and DR prices, indicating that a stationary combination of prices exist. The Johansen test results reject the null of no co-integrating vectors against a co-integrating vector of $r = 1$. The coefficients of the test on both price series trends are close and do not deviate from each other. The Johansen test also reports the number of autoregressive lags using the Schwarz Bayesian criterion, which will be employed for the error correction model estimation.

INSERT TABLE 6-2 ABOUT HERE

6.3.3 The Gonzalo and Granger Error Correction Model for Price Discovery

The issue of price discovery is concerned with finding the relative contributions of two markets to the price determination process of a stock. The two most established econometric models for testing the contribution of price discovery in a multi-market trading setting are the Gonzalo and Granger (GG) common long-memory error-correction estimation approach and the Hasbrouck (1995) information stocks. We rely on the GG model to measure the relative contribution to price discovery made by the local and foreign market. With this approach, we identify the relative contribution of each exchange to the common long-run trend of prices and we interpret the relative contribution of an exchange to the long-memory trend as its relative contribution to price discovery.

The GG method is the most suitable for our sample of cross-listed stocks, as they do not trade with the high frequency required for properly running the Hasbrouck method. Moreover, as discussed in Harris *et al.* (2002) and Eun and Sabherwal (2003), the information stocks computed from the Hasbrouck methodology rely on ordering prices, that cannot be used to run regressions on the results. Because our final objective is to explain the difference in relative contribution of price discovery across our sample, the GG approach is the most relevant.

The GG price discovery model depends on a co-integrated vector error correction model presented through the following equations:

$$\Delta P_t^{S'} = \alpha_0^{S'} + \alpha^{S'}(P_{t-1}^{S'} - \beta^{DR} P_{t-1}^{DR}) + \sum_{i=1}^{l} \gamma_i \Delta P_{t-i}^{S'} + \sum_{i=1}^{l} \delta_i \Delta P_{t-i}^{DR} + \varepsilon_t^{S'} \qquad (6.6)$$

$$\Delta P_t^{DR} = \alpha_0^{DR} + \alpha^{DR}(P_{t-1}^{S'} - \beta^{DR} P_{t-1}^{DR}) + \sum_{i=1}^{l} \gamma_j \Delta P_{t-j}^{S'} + \sum_{j=1}^{l} \delta_j \Delta P_{t-j}^{DR} + \varepsilon_t^{DR} \qquad (6.7)$$

The coefficients of main interest in these two equations are $\alpha^{S'}$ and α^{DR} of the co-integration equation $(P_{t-1}^{S'} - \beta^{DR} P_{t-1}^{DR})$ estimated with the Johansen co-integration test, where $\beta^{S'}$ is normalized to 1. The coefficient denote the amount of adjustment in price to a deviation between the prices in both markets and reflects the relative portion of price discovery occurring in each market. The larger and more significant the sign, the greater the adjustment of the price to a change occurring in the other market. Results of the test are presented in Table 6-3.

INSERT TABLE 6-3 ABOUT HERE

The results are noteworthy. The coefficients for price adjustment are significant for 11 of the 13 securities in the foreign market and for 12 of the 13 securities in the local market, indicating that, in general, both markets contribute to the price discovery process. In order to measure the share that each market contributes to price determination in the other market, we use Eun and Sabherwal's (2003) Component Share(CS), which measures of the reaction of DR price to changes in the local stock price, estimated as

$$Y^{DR} = \frac{\left|\alpha^{DR}\right|}{\left|\alpha^{S'}\right| + \left|\alpha^{DR}\right|} \tag{6.8}$$

Although there is large variation across results, 75.6% of the Egyptian DR prices, on average, are determined in the local market, signifying that the foreign market is only a satellite to the local market. The result for Argentina is surprising, as it shows that most of the price determination occurs on the US exchanges, with only 41.67% of US DR prices determined locally.

6.3.4 Robustness

6.3.4.1 Foreign Exchange Rate as Exogenous Variable

We re-run the VECM model with unadjusted stock price (i.e. stock price in local currency) and with the foreign exchange rate as an exogenous variable. Table 6-4 includes results. While the first approach slightly underestimate the reaction of the foreign market to the local market, no qualitative differences in results are present.

INSERT TABLE 6-4 ABOUT HERE

6.3.4.2 Hasbrouck Information Shares

We estimate the contribution of each market with Hasbrouck Information Shares. While we argued that they are not best suited for our sample, we estimate it nevertheless to examine robustness of our tests. Hasbrouck's (1995) Information Share is more concerned with the amount of variation prices and how much of it is explained by the price changes on the foreign versus local market (De Jong, 2002). It is calculated from the variance of the residuals of the VECM model. Hasbrouck's Information shares, in presence of high correlation in residuals, are captured by

$$IS^{DR} = \frac{(\alpha_1 m_{11} + \alpha_2 m_{12})^2}{(\alpha_1 m_{11} + \alpha_2 m_{12})^2 + (\alpha_2 m_{22})^2} \tag{6.9}$$

Where the variance-covariance matrix uses the Cholesly factorization and is defined as:

$$M = \begin{pmatrix} m_{11} & 0 \\ m_{12} & m_{22} \end{pmatrix} = \begin{pmatrix} \sigma_1 & 0 \\ \rho\sigma_2 & \sigma_2(1-\rho^2)^{0.5} \end{pmatrix} \tag{6.10}$$

where ρ is the correlation between the residuals of the VECM, σ_1 and σ_2 are the variance elements of the residuals of the VECM. Hasbrouck (1995) considers the upper (lower) bound of market j's information share when market j is the first (second) variable in the factorization (Baille et al, 2002).

A mid-point Hasbrouck measure is calculated as the average of the lower and upper bound and is usually considered an adequate measure of a single market contribution to price discovery. (Baille et al, 2002) One disadvantage of using Hasbourck's measure in our sample is that it is best suited for markets in which trading is very frequent, which is usually not the case in emerging market. This makes the range between the upper and lower bounds quite large and thus there are non-unique measures of price discovery.

Table 6-5 includes results of Upper, Lower and Mid-point Information Shares of the DR. The last two columns qualitatively compare the results from the two price discovery measures. With the exception of ORTE, the measures are consistent in defined the dominant market for price discovery. The mixed result for

ORTE can be due to the high correlation between the prices of ORTE GDR and stock that is not captured by the GG measure.

INSERT TABLE 6-5 ABOUT HERE

6.3.4.3 Granger Causality Tests

We further verify the price discovery results through a Granger Causality test, presented in Table 6-6, confirming that for 3 of the 4 Egyptian stocks, price discovery occurs both ways, with the local market still dominating. The price of HRHO seems to be completely determined locally, given that the coefficient on stock is not significant, as verified by the Granger causality test.

INSERT TABLE 6-6 ABOUT HERE

For Argentinean stocks, the local market contributes more to price discovery in 5 of our 9 stocks, yet it seems that trading on US exchanges plays a dominant role in the process for some cases, such as BMA, CRES, and IRS. To the best of our knowledge, this is the first evidence of its kind in the literature, showing the international host market playing the dominant role in price discovery of emerging market equities, and it warrants an in-depth analysis to try to explain it.

6.3.5 Explaining the Contribution to Price Discovery

In this section, we try to explain the factors that affect the contribution to price discovery. Because we have two years of intraday data for our securities, we measure the evolution of the Component Share Y^{DR} over time, providing us with a larger number of observations than would be the case for a regular cross-sectional regression analysis. We divide our total sample into four six-month sub-samples—first half of 2008, second half of 2008, first half of 2009, and second half of 2009—and estimate the error correction model parameters under each. The average reactions of the DR prices to stock price Y_p^{DR} (where p refers to sub-period) across the various sub-samples are shown in Figure 6-1.

INSERT FIGURE 6-1 ABOUT HERE

One could hypothesize that due to the financial crisis, local stock price reactions to the volatile movements on the international exchanges in the USA and London would cause an increase in the share of price discovery in the foreign market and therefore a decrease in the reaction to local market Y_{DR}. This hypothesis is contrary to our finding, as there was an increase in the reaction of the foreign market to local prices during our second period—the second half of 2008, which includes the financial crisis. During the financial crisis, prices deviated greatly, creating arbitrage opportunities that required active arbitrageurs to intervene to bring prices to parity; thus arbitrage trades on the stock, and the DR may be a plausible reason for local market domination of the price discovery process during that period.

We attempt to explain the change in reaction of DR prices to a change in underlying stock price, Y_{DR}, by running the following panel regression:

$$Y_{p,i}^{DR} = \beta_0 + \beta_1 TV_{p,i} + \beta_2 Spread_{p,i} + \beta_3 Cap_{p,i} + \beta_4 Exchange_{p,i} + \omega_{p,i} \qquad (6.8)$$

where Y_p^{DR} is the dependent variable. We use the explanatory variables of *TV* or Relative Trading Value (defined as the ratio of DR Trading Value to Local Trading Value over each six-month period), *Spread* or Spread Ratio (defined as the ratio of Average Bid-Ask Spread of DR to Average Bid-Ask Spread of Local Stock over each six-month period), *Cap* or Market Capitalization (defined as the logarithm of the market capitalization of the company at the end of each six-month period), as well as the dummy variable for exchange: *Exchange*.

Following Frijins *et al.* (2010), we use a fixed-effects panel regression to control for firm-specific fixed effects, the results of which are presented in Table 6-7. Our regression model has overall significance and explains 54.88% of the variation in the ratio of price discovery adjustment. All our explanatory variables are statistically significant. Trading volume is negatively correlated with DR price adjustment: the greater the trading value, the lower the reaction of DR price to local prices, a finding that is consistent with results from prior studies (Eun and Sabherwal, 2003; Frijins et al, 2010). The spread ratio, which is a measure of liquidity, is also significant; it demonstrates that the larger the spread ratio in the DR, the lower the liquidity, and thus the higher its adjustment to local prices. The market capitalization variable is also significant, indicating that the larger the market capitalization of the company, the greater the significance of the local market in price discovery and the larger the proportion of adjustment of DR price to local price. Finally, the exchange dummy is significant at the 5% level, indicating that market-specific variables explain a portion of the variation in price adjustment.

INSERT TABLE 6-7 ABOUT HERE

6.4 Conclusion

In this paper, we study price discovery for Egyptian and Argentinean stocks that are cross listed as DRs on the London and US exchanges. Our analysis contributes to the literature in a number of ways. Not only do we present what appears to be the first analysis of intraday price discovery of emerging market stocks that are cross listed on international exchanges, but we do so for two international markets serving as the host foreign market during the same period. Moreover, we study price discovery in markets with a much greater overlap in trading hours than has typically been considered, and we study them for a longer period (two years).

Our results show that, in line with previous research (Ding *et al.*, 1999; Grammig *et al.*, 2005; Pascual *et al.*; 2006; Lok and Kalev, 2006 and Frijins *et al.*, 2010), there is a clear dominance in terms of intraday price discovery for the Egyptian stocks cross listed in London. In the case of Argentina, however, we find that the US market plays a large and sometimes dominant role in price discovery, to the extent that for some stocks the local market acts as a pure satellite. This result can be compared to that of Eun and Sabherwal (2003), which, to the best of our knowledge, is the only study that found the US market playing the dominant role for dual-listed Canadian stocks. We try to explain this result through a panel regression on the most active securities.

Our regression results indicate that the role of the foreign market in price determination fluctuates as a function of the trading value, liquidity, and market capitalization of companies. It seems, therefore, that those trading variables are reflective of the direction of information flow between markets, and that they determine the informational linkage of the markets. Our results contribute to a growing interest among scholars in understanding the impact of cross listing on security trading mechanisms. Future research should undertake an in-depth study of the reasons for the migration of trading between markets.

Table 6-1 Augmented Dickey Fuller Test Statistic

	Stock			DR		
	Model 1	Model 2	Model 3	Model 1	Model 2	Model 3
Egyptian						
COMI	-0.1514	-1.3068	-1.4960	-0.1382	-1.3259	-1.5069
HRHO	-1.1366	-1.4249	-0.8979	-1.0455	-1.3753	-0.9469
ORTE	-1.8113	-2.1892	-1.4757	-1.8122	-2.1854	-1.4433
OCIC	-0.8950	-1.5654	-1.2071	-0.8781	-1.5685	-1.2054
Argentinean						
BMA	0.0645	-0.9057	-0.5465	0.0474	-0.9718	-0.6607
FRA	-0.5149	-1.4238	-0.9374	-0.5526	-1.5855	-1.2260
EDN	-1.5807	-1.4056	-0.0697	-1.4321	-1.4384	-0.2676
GFG	-0.6901	-1.2378	-0.3154	-0.6963	-1.3551	-0.6122
IRS	-0.8316	-1.1254	0.2035	-0.7117	-1.2309	-0.3263
MET	-1.1652	-1.4440	-1.6668	-1.1855	-1.8317	-2.2744
TGS2	-1.4473	-1.9480	-1.7243	-1.2953	-2.1532	-2.2819
CRES	-0.6248	-1.5681	-0.8404	-0.5840	-1.6857	-1.1442
YPF	-0.1080	-1.2722	-1.4048	-0.0166	-1.5058	-1.6319

Notes: Table 6-1 presents the *t*-statistic results of the ADF test on Equations (6.1), (6.2), and (6.3). The 1% and 5% critical values taken from Mckinnon (1991) for (1) are -2.566 and -1.941, for (2) are -3.433 and -2.863, and for (3) are -3.962 and -3.412, respectively.
*** = significant at 1%; * = significant at 5%.*

Table 6-2 Co-integration Tests

	A. ADF *t*-statistic Price Deviation	B. Johansen Test					
		Max Eigenvalue	Trace	β_{SP}	β_{DR}	Difference	BIC Lags
Egyptian							
COMI	-9.8413**	157.7116**	157.7324**	-56.3814	56.5927	0.2114	1
HRHO	-9.3495**	89.4481**	90.7216**	-53.3416	53.3178	-0.0238	1
ORTE	-15.6323**	675.7053**	680.5967**	-86.0815	86.6204	0.5389	1
OCIC	-15.8655**	659.8906**	660.7205**	-104.3063	104.4417	0.1354	1
Argentinean							
BMA	-5.3437**	89.3907**	89.3959**	-31.7825	32.0584	0.2760	1
FRA	-6.3169**	116.2630**	116.5424**	-24.4681	24.7660	0.2979	1
EDN	-5.8131**	70.9474**	73.5971**	-24.7630	25.0880	0.3251	1
GFG	-5.2555**	117.6871**	118.1706**	-21.6389	21.9774	0.3385	1
IRS	-9.1391**	126.9036**	127.4741**	-28.5282	28.7955	0.2673	1
MET	-8.5651**	68.1118**	69.4894**	-14.2098	14.3215	0.1117	1
TGS2	-7.3758**	95.7763**	99.3699**	-23.5496	23.5145	-0.0352	1
CRES	-7.3619**	118.2518**	118.6048**	-30.4000	30.6600	0.2600	1
YPF	-8.3520**	80.2769**	82.7442**	-29.6851	29.5029	-0.1823	1

Notes: Table 6-2 presents the co-integration test results. Part A presents the results of first approach using the *t*-statistic of the ADF test on the price deviation series Equation (6.4). Part B shows the Johansen test results related to Equation (6.5)

*** = significant at 1%; * = significant at 5%.*

Table 6-3 Contribution to Price Discovery

	α^{DR}	*t*-stat	$\alpha^{S'}$	*t*-stat	Y_{DR}
Egyptian					
COMI	0.1387**	-11.1655	-0.0295*	2.5758	82.44%
HRHO	0.4211**	-9.9230	-0.0617	1.5572	87.23%
ORTE	0.0583**	-23.1415	-0.0238**	14.1060	71.02%
OCIC	0.0712**	-18.7074	-0.0427**	14.2582	62.53%
All Sample					**75.80%**
Argentinean					
BMA	0.0060**	-5.9634	-0.0090**	10.6603	39.95%
FRA	0.0141**	-7.8796	-0.0121**	9.7758	53.85%
EDN	0.0156**	-7.5915	-0.0105**	6.7192	59.70%
GFG	0.0118**	-11.1072	-0.0070**	10.6109	62.73%
IRS	0.0111**	-3.0717	-0.0367**	11.9808	23.19%
MET	0.0828**	-6.4209	-0.0440**	6.4837	65.32%
TGS2	0.0383**	-7.4877	-0.0219**	6.7640	63.62%
CRES	0.0015	-0.7475	-0.0211**	12.4574	6.50%
YPF	0.0006	-0.0810	-0.0608**	9.6223	0.96%
All Sample					**41.76%**

Notes: Table 6-3 presents results of Equations (6.6) and (6.7), where the coefficients of interest are α^{DR} and $\alpha^{S'}$, showing the average adjustment of the local (foreign) market price to foreign (local) market price. The numbers in brackets indicate t-statistic values of the coefficients. Y_{DR} measures the reaction of DR Prices to the stock price estimated as

$$Y^{DR} = \frac{\left|\alpha^{DR}\right|}{\left|\alpha^{S'}\right| + \left|\alpha^{DR}\right|}$$

*** = significant 1%; * = significant at 5%.*

Table 6-4 Contribution to Price Discovery with Exogenous FX Effects

	α^{DR}	*t*-stat	$\alpha^{S'}$	*t*-stat	α^{fx}	*t*-stat	Υ_{DR} %
Egyptian							
COMI	0.1406**	11.1431	-0.0301*	-2.6053	0.0010	0.7957	81.89
HRHO	0.4345**	10.0419	-0.0513	-1.2869	0.0049	2.3290	88.56
ORTE	0.0579**	23.1394	-0.0220**	-13.4690	0.0016*	23.1394	71.06
OCIC	0.0721**	18.8433	-0.0415**	-14.0328	0.0015*	2.7106	62.62
All Sample							**76.03**
Argentinean							
BMA	0.0093**	7.7726	-0.0110**	-11.0712	-0.0001	-0.3413	45.54
FRA	0.0251**	10.6221	-0.0179**	-11.0832	-0.0006*	-3.0032	57.58
EDN	0.0267**	10.5083	-0.0124**	-5.6479	-0.0009	-0.7872	66.61
GFG	0.0182**	13.9245	-0.0089**	-11.2891	-0.0001	-0.6863	66.78
IRS	0.0193**	4.5771	-0.0443**	-12.5449	-0.0010*	-2.4075	29.85
MET	0.1081**	6.7720	-0.0598**	-7.1992	-0.0022*	-2.6653	63.53
TGS2	0.0547**	8.7740	-0.0303**	-7.7897	-0.0012*	-2.1743	63.48
CRES	0.0032**	1.4169	-0.0260**	-13.3502	-0.0006*	-2.0803	10.87
YPF	-0.0016	-0.2001	-0.0733**	-10.5395	0.0000	0.0487	-2.18
All Sample							**44.67**

Table 6-5 Hasbrouck Information Shares (%)

	HL^{DR}	HU^{DR}	H^{DR} mid-point	Market Dominant Under GG	Market Dominant Under IS
Egyptian					
COMI	55.48	98.54	77.01	local	local
HRHO	52.10	99.18	75.64	local	local
ORTE	1.87	21.96	11.92	local	foreign
OCIC	51.13	91.53	71.33	local	local
All Sample			***58.97***		
Argentinean					
BMA	20.06	65.75	42.90	foreign	foreign
FRA	50.01	82.24	66.13	local	local
EDN	51.62	85.26	68.44	local	local
GFG	71.81	90.50	81.15	local	local
IRS	6.74	28.71	17.72	foreign	foreign
MET	80.31	94.62	87.46	local	local
TGS2	70.44	91.27	80.85	local	local
CRES	0.42	22.83	11.63	foreign	foreign
YPF	1.49	19.95	10.72	foreign	foreign
All Sample			***51.89***		

Table 6-6 Granger Causality Tests

		F-Statistic
Egyptian		
COMI	STOCK does not Granger Cause DR	165.2370**
	DR does not Granger Cause STOCK	6.9541**
HRHO	STOCK does not Granger Cause DR	106.4420**
	DR does not Granger Cause STOCK	2.2506
ORTE	STOCK does not Granger Cause DR	894.5500**
	DR does not Granger Cause STOCK	185.5520**
OCIC	STOCK does not Granger Cause DR	545.5330**
	DR does not Granger Cause STOCK	369.6820**
Argentinean		
BMA	STOCK does not Granger Cause DR	121.3590**
	DR does not Granger Cause STOCK	376.6610**
FRA	STOCK does not Granger Cause DR	73.2342**
	DR does not Granger Cause STOCK	228.8360**
EDN	STOCK does not Granger Cause DR	103.0240**
	DR does not Granger Cause STOCK	129.0770**
GFG	STOCK does not Granger Cause DR	118.1190**
	DR does not Granger Cause STOCK	228.6230**
IRS	STOCK does not Granger Cause DR	5.0165**
	DR does not Granger Cause STOCK	169.0360**
MET	STOCK does not Granger Cause DR	30.6400**
	DR does not Granger Cause STOCK	33.0729**
TGS2	STOCK does not Granger Cause DR	46.7084**
	DR does not Granger Cause STOCK	66.5138**
CRES	STOCK does not Granger Cause DR	10.6519**
	DR does not Granger Cause STOCK	144.2380**
YPF	STOCK does not Granger Cause DR	**0.**9624
	DR does not Granger Cause STOCK	96.8847**

Notes: Table 6-4 presents results of Granger Causality tests of DR Reaction to Stock Price and vice versa.
*** = significant at 1%; * = significant at 5%.*

Table 6-7 Panel Regression Results

	β	*t*-statistic
Relative Trading Value	-0.0448**	-6.86417
Spread Ratio	0.0074**	2.65885
Market Capitalization	0.0243**	9.22449
Exchange	0.1462*	1.98529
R-squared	54.88%	

Notes: Table 6-5 summarizes the results of a panel regression of Equation 6.8
*** = significant at 1%; * = significant at 5%.*

7 REVOLUTIONARY EFFECTS ON THE INTRADAY PRICE DISCOVERY OF EGYPTIAN CROSS-LISTED EQUITY

7.1 Introduction

In this article, we measure the relative contribution of local versus foreign market in the pricing of cross-listed equity before and after a political event. Our laboratory consists of Egyptian stocks trading on the Egyptian Stock Exchange (EGX) and that are cross-listed as Global Depository Receipts[16] (GDRs) on the London Stock Exchange (LSE). The Egyptian revolution that commenced on January 25th 2011 with wide spread youth movements against Mubarak's 30 year political regime, forced the EGX to close for a complete 2 months. This created an interesting setting in which Egyptian equities were solely trading as GDRs on the foreign market, the LSE, with no trade on the local stocks.

We use a high frequency intraday transaction dataset for Egyptian stocks and their underlying securities to examine price discovery in a unique laboratory that makes use of a natural experiment in equity financial markets. Our experiment compares the contribution of the EGX vs. LSE to price discovery of cross-listed Egyptian securities over two sub-periods. The first period consists of 1 month prior

[16] GDRs are dollar denominated receipts trading on international exchange and that represent claims against the home-market shares. Each GDR is a claim on one or more of the underlying stock as set by the GDR's bundling ratio.

to the closure of the EGX and the second period corresponds to 1 month after the EGX opened and both market resumed concurrent trading.

In assessing the relative contribution to price discovery of each market, we measure the Gonzalo and Granger (1995) Component Share and Hasbrouck (1995) Information Share, both estimated from running a vector error correction model on our GDR and stock price series in the two sub-periods. For robustness, we also employ a Granger causality test to confirm the direction of price discovery.

Using both measures, we find that while in the first period prior to the revolution, securities were dominantly priced in the local market, the situation is reversed in the second period after the revolution, with the foreign market playing a more dominant role in the price discovery process for securities in which a larger trading value migrated to the foreign market. This result reveals the importance of cross-listing in maintaining market continuity and impounding information into security prices.

This chapter is organized as follows. Section 7.2 provides data description and preliminary descriptive statistics. Section 7.3 provides tests and results on price discovery over the two periods and finally we conclude in Section 7.4.

7.2 Data Description and Preliminary Analysis

7.2.1 Data Description

Our dataset consists of intraday transaction data, including dates, timestamps, prices and volumes, for all 10 Egyptian cross-listed stocks and their GDRs for period of 1 month prior to the revolution (29 December 2010-27 January 2012) and 1 month post the opening of the market (23 March 2012-26 April 2012) as well as intraday foreign exchange quote data between the EGP/USD over both periods.

We exclude from our sample securities with less than 50 matched observations, leaving us with four GDRs and their underlying stock. These four companies, Commercial International Bank (COMI), Egyptian Financial Group (HRHO), Orascom Telecom Holding (ORTE) and Orascom Construction (OCIC), on average constitute over 30% of the market capitalization of the entire EGX and, as a sample size, comparable to sample sizes used in previous price discovery analysis such as Ding et al (1999) and Furstenberg and Tabora (2004). We start with over 210,000 observations from our securities. The two companies in our sample with the most observations, Orascom Telecom(ORTE)and Orascom Construction Industries (OCIC) are the largest companies on the EGX as well as amongst the most actively traded GDRs on the LSE.

7.2.2 Preliminary Analysis

The price discovery analysis requires the construction of two matched price series of the GDR price P_t^{DR} and the underlying stock price $P_t^{S'} = \frac{P_t^S * b}{FX_t}$ where $P_t^{S'}$ is the foreign exchange adjusted stock price, which is calculated by combining the underlying stock price in the local currency P_t^S at time t, the USD to local currency exchange rate FX_t at time t, and the bundling ratio *b* (the number of shares that each DR represents).

Figure 1 charts the logarithmic price of our securities. Period 1 and 2 correspond to concurrent trading pre and post the 2 month market closure at the EGX. The figure
confirms that trading continued on the GDRs in the LSE while the local market was closed.

Table 7.1 provides some trading statistics related to the three periods including average price as well as value traded. There is an observable loss in value from Period 1 to Period 2, reflecting the effect of political instability on the market. We can also see the importance of trading on the LSE in the interim period when the EGX was closed since a large trading value migrated there for all of the stocks. Most of the trading value on the LSE remained even after the EGX re-opened probably due to speculations that the local market might close again. For a company such as ORTE, most of the trading value in Period 2 remains in London.

INSERT TABLE 7.1 HERE

To measure the relative contribution to price discovery of the foreign versus local market during the overlapping trading hours between market in Period 1 and 2 we rely on intraday data for the DR and adjusted stock price P_t^{DR} and $P_t^{S'} = \frac{P_t^S * b}{FX_t}$ and match them using the minspan matching algorithm, which matches prices that are closest in time to each other, yields our final dataset consisting of over 7500 observations on the underlying stock as well as 7500 on the GDR.

Table 7.2 provides some descriptive statistics related to the returns on the GDR and underlying stock prices in each market during our sub-periods. It is obvious that the returns have become extremely volatile in the second period with an increases in range of returns and standard deviation. This reflects the instability that occurred following the re-opening of the local market on prices of cross-listed Egyptian securities.

INSERT TABLE 7.2 HERE

Since the GDR and its underlying stock are essentially the same security, we also compare whether large deviations between the prices and returns of the pair exist. Table 7.3 summarizes descriptive statistics related to price deviations and Table 7.4 summarize descriptive statistics related to return deviations. Moreover, we compare the size of those the deviations between the two periods and report the t-statistic of difference in mean in the last column of both tables.

INSERT TABLE 7.3 HERE

Large price deviations from parity exist in both periods and are significantly larger in the second period. Price deviations between cross-listed emerging market equity exist due to trading barriers, most important of which are large trading costs that prevent arbitrageurs from completely closing the gap between prices. We also observe that for three of our securities, the prices of the GDRs in the second period are on average higher than the underlying stock. These larger GDR premia in the second period can be explained by the higher demand on trading the GDR relative to the underlying stock due to risk involved in trading the underlying stock on the local market.

Despite the significant difference in prices, the returns on both securities are identically distributed in both periods, Table 7.4. This shows that on average neither security provides superior return to the other.

INSERT TABLE 7.4 HERE

7.3 Tests and Results

The main objective of this paper is to measure the change in the relative contribution of the LSE versus the EGX in pricing cross-listed Egyptian securities following the 2 months closure of the EGX. While we observe from the preliminary analysis that the returns of both securities are identical, prices do deviate from each other. A price discovery assessment can establish how the price of one security responds to such pricing errors. Our hypothesis is that since the LSE dominated trading during the 2 months when the local market was closed, we expect the share that the foreign market contributed to price discovery increases in the second period after resumption of trade in both markets, relative to the first period before the revolution.

Investigating the mechanics of price discovery in a multi-market setting can be done using one of two established models in the literature: the Gonzalo and Granger (GG) (1995) Component Share and the Hasbrouck (1995) Information Share. Both models rely on the estimation of a VECM that captures how prices adjust to disequilibria from their co-integrate state. The difference lies in that while the GG model focus solely on the error correction process captured by the VECM model, Hasbrouck defines price discovery in terms of the variance of innovations. An extensive discussion on the two methodology can be found in De Jong (2002) and Baille et al (2002). While the Hasbrouck methodology is argued to capture the true share of each market to price discovery, especially when the residuals of the VECM are correlated as usually is the case, it suffers from relying on the Cholesky factorization that creates upper and lower bounds for price discovery that can be far apart, especially in less liquid traded securities like emerging market DRs. We measure price discovery using both measures and comment on their results.

A necessary pre-condition before measuring the contribution of the EGX and LSE to price discovery in both periods is to first establish that the GDR and its underlying stock price are non-stationary and that both prices are co-integrated. We then estimate our price discovery models. Our tests will be based on the natural logarithm of the price series for the underlying stocks after converting it to USD, and the natural logarithm of the USD price of the GDRs. This conversion facilitates the specification of the error correction term in error correction models of price discovery.

We test the stationarity of prices using the Augmented Dickey Fuller Test (ADF) test for the presence of unit root (Dickey & Fuller, 1979) and the Kwiatkowski, Phillips, Schmidt and Shin (KPSS) test for stationarity (Kwiatkowski, Phillips, Schmidt, & Shin, 1992). Results in Table 7.5 present the results of the ADF t-statistic for the DR and its underlying stock in both periods under three models for the ADF test: with no time trend, with time trend and with an intercept and time trend. Non-significant t-statistics indicate the fail to reject the null hypothesis of a unit root. The significance of the KPSS test in the last column shows the rejection of the null hypothesis of stationarity in favor for non-stationarity. We can see that the individual price series are indeed non-stationary under most of the ADF models. The KPSS model confirms that all series are indeed non-stationary.

INSERT TABLE 7.5 HERE

Second, we examine whether the prices are have a co-integrating relationship using the Johansen Co-integration test. The test specification is based on the unit root test results. Trace Test and Eigenvalue, Table 7.6, both reject the hypothesis of no co-integrating relationship in favor for the existence of 1 co-integrating equation between each GDR and its underlying stock . We also use the Johansen co-integration test to identify the number of lags using the Akaike Information Criterion (AIC).

INSERT TABLE 7.6 HERE

In the presence of co-integration, the short-term dynamics between the prices of the GDR and its underlying stock are characterized by a vector error correction model (VECM). Price discovery in the two periods is measured using the Gonzalo and Granger (1995) Component Share and Hasbrouck (1995) Information Share, both of which rely on the estimation of the VECM between prices of the GDR and the underlying stock that takes the following form:

$$\Delta P_t^{S'} = \alpha_0^{S'} + \alpha_1 (P_{t-1}^{S'} - P_{t-1}^{DR}) + \sum_{i=1}^{l} \gamma_i \Delta P_{t-i}^{S'} + \sum_{i=1}^{l} \delta_i \Delta P_{t-i}^{DR} + \varepsilon_t^{S'}$$

$$\Delta P_t^{DR} = \alpha_0^{DR} + \alpha_2 (P_{t-1}^{S'} - P_{t-1}^{DR}) + \sum_{i=1}^{l} \gamma_j \Delta P_{t-j}^{S'} + \sum_{j=1}^{l} \delta_j \Delta P_{t-j}^{DR} + \varepsilon_t^{DR}$$

Table 7.7 reports the VECM variance-covariance matrices of residuals for each of our sample securities. It is obvious that the covariance between the residuals of the VECM is relatively large yielding correlation that range from 0.2-0.6.

INSERT TABLE 7.7 HERE

Table 7.8 and 7.9 report the results of the price discovery assessment from the two periods. Under the different measures of price discovery, the results of the first period in Table 9 show that the GDR price is more reactive to the movements in the underlying stock price. This can be interpreted as the local market being the more dominant location for price discovery. However, for OCIC and ORTE, the error correction coefficient of the reaction of the local stock to the foreign market α_1 is significant revealing that the foreign market also contributes to price discovery, yet at a lesser share. This is different from the result on COMI and HRHO, in which the insignificance of α_1 can be interpreted as the foreign market acting as a pure satellite with GDR prices solely moving to react to movement in the local market.

INSERT TABLE 7.8

Table 7.9 presents results from the second period. A somewhat different picture is drawn for each security. While the share of price discovery for COMI generated in the local market is still dominant, α_1 of the local market is now significant, indicating that the local and foreign market both contribute to price discovery. For HRHO, the foreign market remain a satellite.

INSERT TABLE 7.9 HERE

The results are quite notable for OCIC and ORTE. The share of price discovery located in the foreign market has increased considerably, with the foreign market becoming the dominant market for price discovery. This is indeed confirmed under all measures. The situation is quite dynamic for a company such as ORTE, where the coefficient of the DR reaction to mispricing α_2 has even become insignificant, indicating that the local market price has become a complete satellite to movements on the GDR. This reveals the complete shift of the location of price discovery to the foreign market in the second period for those two companies. This is logical since as we have seen in Table 7.1 , the value traded on ORTE remains mostly concentrated on the LSE in Period 2.

To corroborate our results, we also present the Granger causality test on the direction of price discovery in Table 7.10. Indeed, we fail to accept the hypothesis that movements in the GDR do not cause movements in the stock for COMI, OCIC and ORTE. Again, we confirm that for ORTE the location of price discovery has totally shifted to the local market, since we fail to reject the hypothesis that movements in the Stock affect the GDR.

INSERT TABLE 7.10 HERE

7.4 Conclusions

The main objective of this study is to assess the change in the location of price discovery in cross-listed Egyptian securities following a complete 2 month local market closure. We compare our price discovery results across two periods: before and after local market closure. Our result indicates that the location of price discovery totally shifted to the foreign market, which became the dominant location of price discovery following the resumption of trade on the EGX.

Table 7-1 Trading Descriptive Statistics

Ticker Symbol	Average Price (USD) Period 1		Average Price (USD) Interim Period		Average Price (USD) Period 2		Total Value Traded (USD million) Period 1		Total Value Traded (USD million) Interim Period		Total Value Traded (USD million) Period 2	
	GDR	Stock	GDR	Stock	GDR	Stock	GDR	Stock	GDR	Stock	GDR	Stock
COMI	7.286	7.308	5.750	NA	5.213	5.171	49.510	311.517	79.186	NA	50.664	409.193
HRHO	11.396	11.373	6.626	NA	6.882	6.909	1.455	25.570	7.026	NA	6.902	33.790
OCIC	46.367	46.406	40.614	NA	39.503	39.116	169.804	336.489	548.251	NA	145.164	138.403
ORTE	3.594	3.547	2.311	NA	3.623	3.561	143.125	48.265	160.554	NA	328.716	49.736

Table 7-2 Descriptive Statistics of Returns (%)

		Period 1				Period 2			
		COMI	HRHO	OCIC	ORTE	COMI	HRHO	OCIC	ORTE
GDR	Mean	-0.031	-0.570	-0.021	-0.009	-0.007	-0.259	0.015	0.007
	Standard Deviation	0.573	2.473	0.527	0.365	0.723	2.370	0.777	0.474
	Minimum	-2.437	-11.482	-6.666	-6.727	-4.272	-6.899	-9.734	-3.209
	Maximum	3.204	2.863	2.582	7.832	4.001	8.004	10.206	7.024
Stock	Mean	-0.027	-0.436	-0.025	-0.010	-0.027	-0.347	0.014	0.012
	Standard Deviation	0.398	1.526	0.366	0.296	1.652	2.332	0.768	0.814
	Minimum	-2.291	-6.313	-3.886	-3.336	-19.443	-12.017	-10.067	-14.462
	Maximum	1.717	3.940	2.463	2.368	17.032	5.696	12.016	18.551

Table 7-3 Descriptive Statistics Price Deviations (USD)

	Period 1				Period 2				Mean Difference
	Mean	Standard Deviation	Minimum	Maximum	Mean	Standard Deviation	Minimum	Maximum	
COMI	-0.022	0.078	-0.169	0.180	0.041	0.136	-1.035	0.774	-0.063**
HRHO	0.029	0.177	-0.401	0.328	-0.032	0.328	-0.994	0.634	0.062
OCIC	-0.039	0.315	-1.748	1.799	0.386	0.466	-3.297	5.235	-0.426**
ORTE	0.047	0.022	-0.021	0.297	0.061	0.097	-0.411	0.522	-0.015**

Price Deviation Measured as $P_t^{DR} - P_t^{S'}$

Table 7-4 Descriptive Statistics on Return Deviations (%)

	Period 1				Period 2				Mean Difference
	Mean	Standard Deviation	Minimum	Maximum	Mean	Standard Deviation	Minimum	Maximum	
COMI	-0.004	0.502	-2.420	2.207	0.020	1.730	-17.389	19.083	-0.023
HRHO	-0.133	1.808	-7.196	3.750	0.088	2.963	-6.874	15.376	-0.221
OCIC	0.004	0.544	-4.307	3.607	0.001	1.062	-13.841	11.037	0.003
ORTE	0.001	0.416	-6.488	7.354	-0.004	0.922	-17.558	15.214	0.005

Return Deviation measured as $(\frac{P_t^{DR} - P_{t-1}^{DR}}{P_{t-1}^{DR}}) - (\frac{P_t^{S'} - P_{t-1}^{S'}}{P_{t-1}^{S'}})$

Table 7-5 ADF T-statistic

	Level	Level with Intercept	Level with Intercept and Trend	KPSS
		Period 1		
COMI GDR	-1.471	-1.416	-0.409	1.972**
COMI Stock	-1.400	-1.394	-0.623	1.916**
HRHO GDR	-1.657	1.038	-1.187	0.891**
HRHO Stock	-2.039*	1.905	-1.453	0.914**
OCIC GDR	-2.236	1.364	-1.612	3.362**
OCIC Stock	-2.467	2.191	-0.948	3.283**
ORTE GDR	-1.997*	0.589	-1.866	0.975**
ORTE Stock	-1.649	0.395	-2.201	1.262**
Period 2				
COMI GDR	-0.302	-0.942	-2.361	1.558**
COMI Stock	-1.164	-0.892	-1.337	1.369**
HRHO GDR	-1.074	-1.334	-2.941	0.969**
HRHO Stock	-1.455	-1.227	-3.029	1.067**
OCIC GDR	1.451	-2.273	-1.544	3.412**
OCIC Stock	0.847	-1.993	-2.176	3.372**
ORTE GDR	0.513	-2.881*	-2.628	5.101**
ORTE Stock	0.941	-3.992**	-3.380**	5.088**

*** and * denotes significance at 1% and 5%*

Table 7-6 Variance-Covariance Matrices for Residuals from VECM

	Period 1 Variance-Covariance Matrix	Period 2 Variance-Covariance Matrix
COMI	$\begin{pmatrix} 0.0020\% & 0.0010\% \\ 0.0010\% & 0.0030\% \end{pmatrix}$	$\begin{pmatrix} 0.0040\% & 0.0010\% \\ 0.0010\% & 0.0050\% \end{pmatrix}$
HRHO	$\begin{pmatrix} 0.0017\% & 0.0200\% \\ 0.0200\% & 0.0380\% \end{pmatrix}$	$\begin{pmatrix} 0.0520\% & 0.0150\% \\ 0.0150\% & 0.0450\% \end{pmatrix}$
OCIC	$\begin{pmatrix} 0.0010\% & 0.0010\% \\ 0.0010\% & 0.0020\% \end{pmatrix}$	$\begin{pmatrix} 0.005\% & 0.001\% \\ 0.001\% & 0.005\% \end{pmatrix}$
ORTE	$\begin{pmatrix} 0.0008\% & 0.0003\% \\ 0.0003\% & 0.0011\% \end{pmatrix}$	$\begin{pmatrix} 0.0025\% & 0.0013\% \\ 0.0013\% & 0.0028\% \end{pmatrix}$

Table 7-7 Price Discovery Measures Period 1

	Period 1					
	α_1	α_2	GG^{DR}	HL^{DR}	HU^{DR}	H^{DR} *midpoint*
COMI	0.011	0.302**	96.62%	65.58%	99.95%	82.76%
HRHO	0.428	1.333**	75.72%	29.21%	98.63%	63.92%
OCIC	-0.050*	0.164**	76.60%	71.10%	96.61%	83.85%
ORTE	-0.057**	0.120**	67.86%	64.48%	89.38%	76.93%

*** and * denotes significance at 1% and 5%*

Table 7-8 Price Discovery Measures Period 2

	Period 2					
	α_1	α_2	GG^{DR}	HL^{DR}	HU^{DR}	H^{DR} *midpoint*
COMI	-0.030*	0.077**	71.77%	77.46%	89.47%	83.47%
HRHO	-0.101	0.169*	62.57%	49.77%	79.43%	64.60%
OCIC	-0.141**	0.047**	24.88%	5.52%	25.02%	15.27%
ORTE	-0.020**	0.005	18.98%	3.59%	41.10%	22.34%

*** and * denotes significance at 1% and 5%.*

Table 7-9 Granger Causality Tests

	Period 1		Period 2	
	F-Statistic	Probability	F-Statistic	Probability
COMI				
GDR does not Granger Cause Stock	0.155	0.69	8.098	0.00
Stock does not Granger Cause GDR	48.282	0.00	34.955	0.00
HRHO				
GDR does not Granger Cause Stock	1.632	0.21	1.733	0.19
Stock does not Granger Cause GDR	27.817	0.00	5.979	0.02
OCIC				
GDR does not Granger Cause Stock	18.729	0.00	94.147	0.00
Stock does not Granger Cause GDR	96.327	0.00	35.747	0.00
ORTE				
GDR does not Granger Cause Stock	21.388	0.00	8.857	0.00
Stock does not Granger Cause GDR	49.839	0.00	4.754	0.03

*** and * denotes significance at 1% and 5%.*

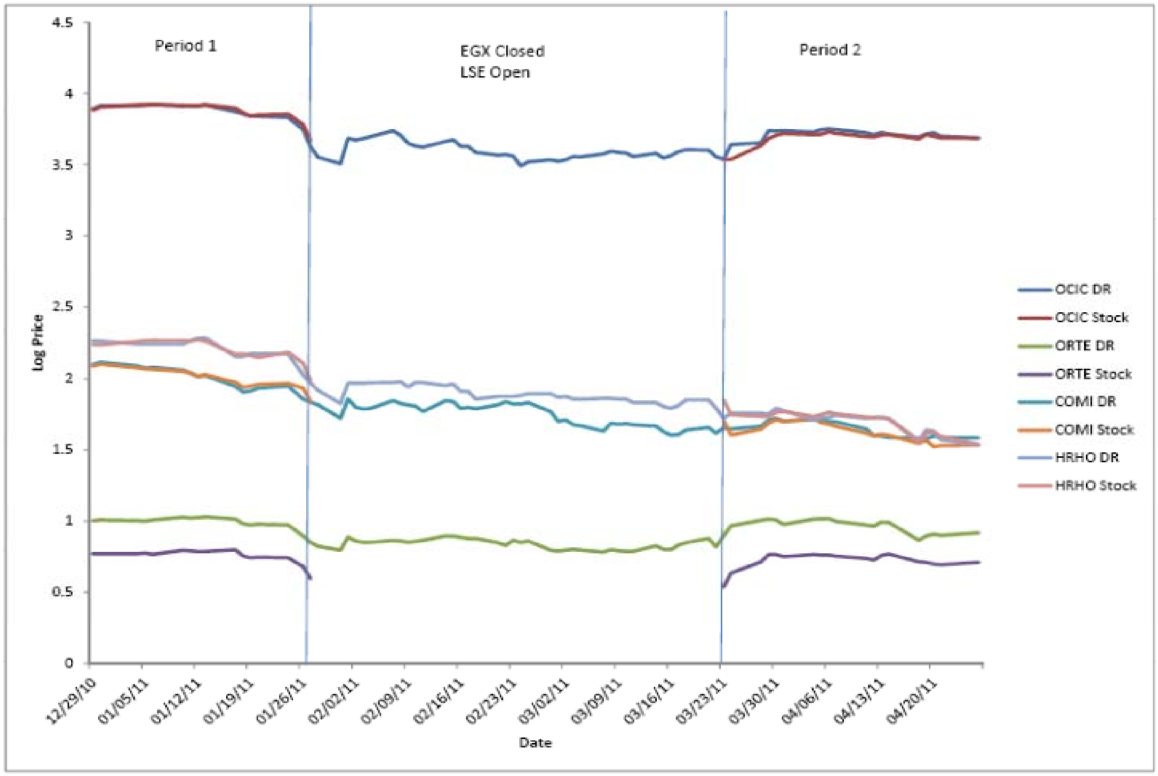


Figure 7-1 Prices of Sample GDRs and Stock

8 GENERAL DISCUSSION

A recent survey by Price Water-House Coopers (PWC) on the future of capital markets in 2025, shows that the trend is for rising interest amongst companies to list in new trading centers outside the current dominating ones. Singapore, China and other emerging markets are believed to be the future financial centers and to be the choice for future companies seeking to list.

This trend, combined with the increasing numbers of emerging market firms around the world to foreign list abroad, will create new dynamics for capital markets. Understanding the complexities, and sometimes absurdities, of how such market work, is imperative for the sound working of future financial systems.

Using a unique intraday dataset for Egyptian and Argentinean cross-listed equity, this dissertation examined the pricing behavior of DRs from emerging markets relative to their underlying stock. The pricing of emerging market DRs has created an interesting puzzle for previous empirical studies, since they exhibit significant deviations from price parity. We confirm this result in our sample with daily closing prices, showing that large significant price deviations exist between DRs and their underlying stock. Two questions, however, were so far left unanswered for DRs from emerging markets: (1) whether the price deviations reflect real arbitrage opportunities between the cross-listed securities and (2) whether the location of price discovery shift internationally or stays locally for emerging market DRs.

Early studies on the pricing of DRs have confused long run price parity with the lack of arbitrage opportunities. More recent results showing violation from price parity in DRs from emerging markets, still confuse them for lack of arbitrage opportunities, citing the large trading barriers present in those markets to the lack of arbitrage activity, and as such, price deviations signify market segmentation rather than profitable arbitrage opportunities.

We challenge this result, and use a high frequency intraday dataset from two emerging markets, Egypt and Argentina, to reveal that not only do large profitable arbitrage opportunities exist between their DRs and underlying stock, but that such opportunities involve real arbitrage activity that brings back prices to no-arbitrage zones, in which price deviations are not profitable.

Our result reveals that DRs and their underlying stock truly trade in segmented markets that are driven by differential demand curves and investor sentiment. Active arbitrageurs in this market truly keep market efficient by intervening to eliminate large mispricing between the identical pair. Perfect price parity, however, cannot be achieved between the DRs from emerging markets and their underlying stock, due to the presence of large trading barriers in those markets.

On another front, this dissertation also contributes to the literature on the location of price discovery in a multi-market setting, by revealing that for most of our securities in the sample, the international market in-which the DR trades plays a significant and sometimes dominant role in the pricing of such securities. This result shows that information from the international markets gets compounded into the pricing of cross-listed securities, revealing on one end the role of cross-listing in creating stock market linkages and information flow from large international financial centers to small local ones.

Our sample of Egyptian and Argentinean DRs have proven to be helpful in understanding the factors that affect the pricing of DR from emerging market with large trading barriers. By examining our sample securities, we find that liquidity and activity play important roles in the pricing of DRs. The low liquidity and activity create large profitable arbitrage opportunities that persist for longer periods of time. Moreover, liquidity and activity are also important determinants of the location of price discovery, as the lower they are in a certain market, the lower is that market's contribution to the price discovery process.

The low liquidity of emerging market securities have also motivated us to develop a more precise methodology for identifying arbitrage opportunities. Arbitrage opportunities till now, have been empirically identified through a simple measure that compares price deviation between the DR and its underlying stock to a static cost parameter. Such a simple measure for identifying arbitrage is not suitable for identifying arbitrage opportunities in our complex markets characterized by large low liquidity and large trading costs, that include several fixed components that make arbitrage only profitable beyond certain threshold. With that we propose using another identification procedure that only identifies a price deviation as an arbitrage opportunity if the gross profit from arbitraging it exceeds the cost of arbitrage.

Our novel procedure proves quite successful, and we are able to identify arbitrage opportunities between our sample DRs and their underlying stock. We verify the accuracy of our procedure by extracting arbitrage trades from the data set around such profitable arbitrage opportunities. Our arbitrage trades provide us with the first empirical evidence on the reality of arbitrage in the DR market, beyond what statistical models can help us comprehend. Arbitrage plays a key role in the price convergence between stocks and in upholding the long run co-integrating relationship between DR and underlying stock price.

While the static pricing analysis of arbitrage reveals that markets are not fully integrated, and that prices deviate quite often creating profitable opportunities from such mispricing, more dynamic price discovery model shows that the international market contributes to the pricing of DRs in such a way that information flows from international to the local market through DRs.

Our price discovery analysis, shows that in the long run, both the DR and its underlying stock are identical securities, following each other and adjusting to deviations from their co-integrating relationship, described by the Gonzalo Granger vector error correction model for measuring the component share of each market to the price discovery process.

Several caveats are in order. Our study, while presenting the first intraday evidence from DRs from emerging markets, relied on intraday transaction data rather than quote data, which is very limited in such markets. While transaction data was needed for our arbitrage analysis to extract arbitrage trades, price discovery models are argued to be better suited for quote data, which could have allowed us to use the Hasbrouck information share methodology and compare at par with other results.

Finally, such evidence as presented here, provides motivation to explore other samples from emerging markets to pinpoint any structural differences in pricing of DRs.

9 REFERENCES

Agarwal S, Liu C, Ghon Rhee S. 2007. Where Does Price Discovery Occur for Stocks Traded in Multiple Markets? Evidence from Hong Kong and London. *Journal of International Money and Finance* **26**: 46-63.

Allam Abeer, 2003. Egypt: Currency to Float. *The New York Time*. January 29

Arquette, Gregory C.; William O. Brown and Richard Burdekin, 2008. US ADR and Hong Kong H-share discounts of Shanghai-listed firms. Journal of Banking & Finance, vol. 32, issue 9, pages 1916-1927.

Auguste, S., Dominguez, K., Kamil H., Tesar L., 2006. "Cross-border trading as a mechanism for implicit capital flight: ADRs and the Argentine crisis." Journal of Monetary Economics 53, 1259–1295.

Baille, Richard, G. Geoffrey Booth, Yiuman Tse and Tatyana Zabotina, 2002. Price Discovery and Common Factor Models. *Journal of Financial Markets*. 5: 309-321.

Bank of New York Mellon, August 2011. The Depositary Receipt Markets 2011 Mid-Year Review.

Bris, A., Goetzmann, W., Zhu, N., 2007. Efficiency and the bear: short sales and markets around the world. Journal of Finance 62, 1029–1079.

De Jong F. 2002. Measures of Contributions to Price Discovery: A Comparison. *Journal of Financial Markets* **5**: 323-327.

Dickey, D. A., & Fuller,W. A. 1979. Distribution of the estimators for autoregressive time series with a unit root. *Journal of the American Statistical Association*, 74, 427–431.

Ding D, Harris F H deB, Lau S T, McInish T. 1999. An Investigation of Price Discovery in Informationally-Linked Markets: Equity Trading in Malaysia and Singapore. *Journal of Multinational Financial Management* **9**, 317-329.

Domowitz, I., J. Glen, et al. 2001. "Liquidity, Volatility and Equity Trading Costs Across Countries and Over Time." International Finance 42: 221-255.

Eun C S, Sabherwal S. 2003. Cross-Border Listings and Price Discovery: Evidence from U.S.-Listed Canadian Stocks. *Journal of Finance* **58**: 549-575.

Frijns B, Gilbert A, Tourani-Rad A. 2010. The Dynamics of Price Discovery for Cross-Listed Shares: Evidence from Australia and New Zealand. *Journal of Banking & Finance* **34**: 498-508.

Gagnon, L. and G. Andrew Karolyi 2010. Multi-market trading and arbitrage. *Journal of Financial Economics* 971: 53-80.

Garbade K D, Silber W L. 1979 . Structural Organization of Secondary Markets: Clearing Frequency, Dealer activity and Liquidity risk. *Journal of Finance* **34**: 577-593.

Global Finance. 2010. DR Trading Sets Record In First Half As BRIC Countries Raise Most Capital. Sep 2010; 24, 8.

Gonzalo J, Granger C W J. 1995. Estimation of Common Long-Memory Components in Cointegrated Systems. *Journal of Business and Economic Statistics*. **13**: 1-9.

Grammig J, Melvin M, Schlag C. 2005. Internationally Cross-Listed Stock Prices during Overlapping Trading Hours: Price Discovery and Exchange Rate Effects. *Journal of Empirical Finance*, **12**: 139-164.

Grossmann, A., Ozuna, T., Simpson, M. 2007. ADR mispricing: Do costly arbitrage and consumer sentiment explain the price deviation? Journal of International Financial Markets, Institutions & Money 17, 361–371.

Harris F H deB, McInish T H, Shoesmith G, Wood R A. 1995. Cointegration, Error Correction and Price Discovery on Informationally-Linked Security Markets. *Journal of Financial and Quantitative Analysis*. **30**: 563-579.

Harris F H deB, McInish T, Wood R A. 2002. Security Price Adjustment across Exchanges: An Investigation of Common Factor Components for Dow Stocks, *Journal of Financial Markets* **5**, 277-308.

Hasbrouck J. 1995. One Security, Many Markets: Determining the Contributions to Price Discovery. *Journal of Finance*, **50**, 1175-1199.

Hsu, J. and H.-Y. Wang 2008. "Why do Price Spreads Between Shares and their ADRs Vary Over Time? " Pacific Economic Review 134: 473-491.

Jensen, M. C. 1978. "Some Anomalous Evidence Regarding Market Efficiency." Journal of Financial Economics, Vol. 6, Nos. 2/3, pp. 95-101, 1978.

Kadapakkam P, Misra L , Tse Y. 2003. International Price Discovery for Emerging Stock Markets: Evidence from Indian GDRs. *Review of Quantitative Finance and Accounting* **21**, 179-199.

Kato, K., S. Linn, et al. 1990. Are There Arbitrage Opportunities in the Market for American Depository Receipts? *Journal of International Financial Markets, Institutions & Money* 11: 73-89.

Kaul, A. and V. Mehrotra 2007. "The role of trades in price convergence: A study of dual-listed Canadian stocks." Journal of Empirical Finance 142: 196-219.

Lamont, O. A. and R. H. Thaler 2003. Anomalies: The Law of One Price in Financial Markets. *The Journal of Economic Perspectives* 174: 191-202.

Lieberman O, Ben-Zion U, Hauser S. 1999. A Characterization of the Price Behavior of International Dual Stocks: An Error Correction Approach. *Journal of International Money and Finance* **18**, 289-304.

Lok E, Kalev P. 2006. The Intraday Price Behavior of Australian and New Zealand Cross-Listed Stocks. *International Review of Financial Analysis* **15**, 377-397.

Maldonado, W., Saunders, A., 1983. Foreign exchange futures and the law of one price. *Financial Management* 12, 19–23.

Miller, D., & Morey, M. 1996. "The Intraday Pricing Behavior of International Dually Listed Securities." Journal of International Financial Markets, Institutions and Money 64: 79-89.

Mitchell, M., Pulvino, T. and Stafford, E. 2002 "Limited arbitrage in equity markets." Journal of

Finance 57, 551–548

Park, J., and Tavakkol, A. 1994. Are ADRs a Dollar Translation of Their Underlying Securities?: The Case of Japanese ADRs. 4: 77-87.

Rabinovitch, R., A. C. Silva, et al. 2003. "Returns on ADRs and arbitrage in emerging markets." Emerging Markets Review 43: 225-247.

Rosenthal, L. 1983. "An empirical test of the efficiency of the ADR market." Journal of Banking & Finance 71: 17-29.

Pascual R, Pascual-Fuster B, Climent F. 2006. Cross-Listing, Price Discovery and the Informativeness of the Trading Process, *Journal of Financial Markets* **9**, 144-161.

Saleh, Heba, 2004. Cairo Alexandria Stock Exchange: Heady days of record highs as bourse is re-discovered. *Financial Times London*: Nov 22 pg. 1

Shleifer, A and Vishny, Robert W. 1997. The Limits of Arbitrage. Journal of Finance 521, pp. 35-55.

Stock, J., Watson, M.W., 1988. Testing for common trends. Journal of the American Statistical Association 83, 1097–1107.

Su Q, Chong T. 2007. Determining the Contributions to Price Discovery for Chinese Cross-Listed Stocks. *Pacific-Basin Finance Journal* 15, 140-153.

Suarez, Dante 2005. "Arbitrage opportunities in the depositary receipts market: Myth or reality?" Journal of International Financial Markets, Institutions and Money 155: 469-480.

Suarez, Dante 2005b "Enforcing the Law of One Price: Nonlinear Mean Reversion in the ADR Market", Managerial Finance, Vol. 31 Iss: 8, pp.1 – 17

Tkatch, I. and Z. S. Alam 2009. "Strategic Order Splitting in Automated Markets." SSRN eLibrary.

Yeyati, Levi E., S. L. Schmukler, et al. 2009. "International financial integration through the law of one price: The role of liquidity and capital controls." Journal of Financial Intermediation 183: 432-463.

10 APPENDICES

10.1 Appendix 1 Depository Receipts and Trading Hours

Country of Origin	Number of DRs Listed	Local Stock Exchange	International Exchange	Local Exchange Trading Hours GMT	International Exchange Trading Hour GMT	Number of Overlapping Trading Hours
Argentina	2	Buenos Aires Stock Exchange	London Stock Exchange	14:00-20:00	08:00-16:30	2:30
Argentina	3	Buenos Aires Stock Exchange	NASDAQ Stock Market	14:00-20:00	14:30-21:00	5:30
Argentina	13	Buenos Aires Stock Exchange	New York Stock Exchange	14:00-20:00	14:30-21:00	5:30
Australia	3	Australian Securities Exchange	NASDAQ Stock Market	00:00-06:10	14:30-21:00	0:00
Australia	5	Australian Securities Exchange	New York Stock Exchange	00:00-06:10	14:30-21:00	0:00
Australia	2	Australian Securities Exchange	NYSE Amex	00:00-06:10	14:30-21:00	0:00
Bahrain	2	Bahrain Stock	London	6:30-9:30	08:00-16:30	1:30

		Exchange	Stock Exchange			
Bangladesh	1	Dhaka Stock Exchange	London Stock Exchange - AIM	4:00-9:00	08:00-16:30	0:00
Belgium	2	Euronext N.V.	New York Stock Exchange	8:00-16:30	14:30-21:00	2:00
Brazil	1	BOVESPA	NASDAQ Stock Market	13:00-20:00	14:30-21:00	5:30
Brazil	32	BOVESPA	New York Stock Exchange	13:00-20:00	14:30-21:00	5:30
Canada	1	Toronto Stock Exchange	Lusaka Stock Exchange	14:30-21:00	8:00-9:00 and 10:00-11:00	0:00
Channel Islands	3	Channel Island Stock Exchange	Luxembourg Stock Exchange	9:00-16:30	8:00-16:35	7:30
Chile	12	Santiago Stock Exchange	New York Stock Exchange	13:30-21:30	14:30-21:00	6:30
China	1	Shanghai Stock Exchange/Shezhen Stock Exchange	London Stock Exchange	01:30-3:30 and 5:00-7:00	08:00-16:30	0:00

China	51	Shanghai Stock Exchange/Shezhen Stock Exchange	NASDAQ Stock Market	01:30-3:30 and 5:00-7:00	14:30-21:00	0:00
China	71	Shanghai Stock Exchange/Shezhen Stock Exchange	New York Stock Exchange	01:30-3:30 and 5:00-7:00	14:30-21:00	0:00
Colombia	2	Colombian Stock Exchange	New York Stock Exchange	13:00-21:00	14:30-21:00	6:30
Croatia	2	Zagreb Stock Exchange	London Stock Exchange	9:00-15:00	08:00-16:30	6:00
Cyprus	2	Cyprus Stock Exchange	London Stock Exchange	8:00-15:00	08:00-16:30	7:00
Czech Republic	1	Prague Stock Exchange	London Stock Exchange	8:15-15:20	08:00-16:30	7:05
Denmark	1	OMX Copenhagen	NASDAQ Stock Market	08:00-16:00	14:30-21:00	1:30
Denmark	1	OMX Copenhagen	New York Stock Exchange	08:00-16:00	14:30-21:00	1:30
Egypt	10	Egyptian Stock Exchange	London Stock	8:30-12:30	08:00-16:30	4:00

			Exchange			
Estonia	1	Tallin Stock Exchange	London Stock Exchange	8:00-14:00	08:00-16:30	6:00
Finland	1	OMX Helsinki	New York Stock Exchange	08:00-16:30	14:30-21:00	2:00
France	1	Euronext	Luxembourg Stock Exchange	8:00-16:30	8:00-16:35	7:30
France	2	Euronext	NASDAQ Stock Market	8:00-16:30	14:30-21:00	2:00
France	7	Euronext	New York Stock Exchange	8:00-16:30	14:30-21:00	2:00
Georgia	1	Georgian Stock Exchange	London Stock Exchange	13:00-13:35	08:00-16:30	0:35
Germany	1	FSE /Xetra	NASDAQ Stock Market	08:00-19:00	14:30-21:00	4:30
Germany	6	FSE/Xetra	New York Stock Exchange	08:00-19:00	14:30-21:00	4:30
Greece	3	Athens Stock Exchange	London Stock	9:00-16:20	08:00-16:30	7:20

Greece	3	Athens Stock Exchange	Exchange New York Stock Exchange	9:00-16:20	14:30-21:00	1:50
Hong Kong	4	Hong Kong Stock Exchange	NASDAQ Stock Market	1:20-3:00 and 4:30-8:00	14:30-21:00	0:00
Hong Kong	1	Hong Kong Stock Exchange	New York Stock Exchange	1:20-3:00 and 4:30-8:00	14:30-21:00	0:00
Hungary	2	Budapest Stock Exchange	London Stock Exchange	8:00-15:30	08:00-16:30	5:30
India	24	Bombay Stock Exchange/National Stock Exchange of India	London Stock Exchange	03:45-10:00	08:00-16:30	2:00
India	61	Bombay Stock Exchange/National Stock Exchange of India	Luxembourg Stock Exchange	03:45-10:00	8:00-16:35	2:00
India	82	Bombay Stock Exchange/National Stock Exchange of India	Luxembourg Stock Exchange - Euro MTF	03:45-10:00	8:00-16:35	2:00

India	2	Bombay Stock Exchange/National Stock Exchange of India	NASDAQ Dubai	03:45-10:00	6:00-10:00	0:00
India	3	Bombay Stock Exchange/National Stock Exchange of India	NASDAQ Stock Market	03:45-10:00	14:30-21:00	0:00
India	10	Bombay Stock Exchange/National Stock Exchange of India	New York Stock Exchange	03:45-10:00	14:30-21:00	0:00
India	8	Bombay Stock Exchange/National Stock Exchange of India	Singapore Exchange	03:45-10:00	01:00-09:00	4:15
Indonesia	2	Indonesia Stock Exhange	New York Stock Exchange	2:30-9:00	14:30-21:00	0:00
Ireland	3	Irish Stock Exchange	NASDAQ Stock Market	7:00-15:30	14:30-21:00	1:00
Ireland	4	Irish Stock Exchange	New York Stock Exchange	7:00-15:30	14:30-21:00	1:00
Israel	2	Tel Aviv Stock	London	7:30-14:30	08:00-16:30	6:30

		Exchange	Stock Exchange			
Israel	5	Tel Aviv Stock Exchange	NASDAQ Stock Market	7:30-14:30	14:30-21:00	0:00
Israel	1	Tel Aviv Stock Exchange	New York Stock Exchange	7:30-14:30	14:30-21:00	0:00
Italy	1	Milan Stock Exchange	NASDAQ Stock Market	08:00-16:25	14:30-21:00	2:25
Italy	6	Milan Stock Exchange	New York Stock Exchange	08:00-16:25	14:30-21:00	2:25
Japan	3	Tokyo Stock Exchange	NASDAQ Stock Market	00:00-2:00 and 3:30-06:00	14:30-21:00	0:00
Japan	18	Tokyo Stock Exchange	New York Stock Exchange	00:00-2:00 and 3:30-06:00	14:30-21:00	0:00
Japan	1	Tokyo Stock Exchange	The Stock Exchange of Hong Kong	00:00-2:00 and 3:30-06:00	1:20-3:00 and 4:30-8:00	2:10
Jordan	1	Amman Stock Exchange	London Stock Exchange	08:00-10:00	08:00-16:30	2:00
Kazakhstan	7	Kazakhstan Stock	London	5:30-11:00	08:00-16:30	3:00

		Exchange	Stock Exchange			
Kazakhstan	4	Kazakhstan Stock Exchange	Luxembourg Stock Exchange - Euro MTF	5:30-11:00	08:00-16:35	3:00
Korea	12	Korea Stock Exchange	London Stock Exchange	00:00-06:00	08:00-16:30	0:00
Korea	1	Korea Stock Exchange	Luxembourg Stock Exchange	00:00-06:00	08:00-16:35	0:00
Korea	1	Korea Stock Exchange	Luxembourg Stock Exchange - Euro MTF	00:00-06:00	08:00-16:35	0:00
Korea	1	Korea Stock Exchange	NASDAQ Stock Market	00:00-06:00	14:30-21:00	0:00
Korea	8	Korea Stock Exchange	New York Stock Exchange	00:00-06:00	14:30-21:00	0:00
Korea	1	Korea Stock Exchange	Singapore Exchange	00:00-06:00	01:00-09:00	5:00
Kuwait	1	Kuwait Stock Exchange	London Stock	6:00-9:30	08:00-16:30	1:30

			Exchange			
Lebanon	3	Beirut Stock Exchange	London Stock Exchange	7:30-10:30	08:00-16:30	2:30
Lebanon	1	Beirut Stock Exchange	Luxembourg Stock Exchange - Euro MTF	7:30-10:30	08:00-16:35	2:35
Lithuania	1	OMX Vilnius Stock Exchange	London Stock Exchange	8:00-14:00	08:00-16:30	6:00
Luxembourg	1	Luxembourg Stock Exchange	New York Stock Exchange	08:00-16:35	14:30-21:00	2:35
Malawi	1	Malawi Stock Exchange	London Stock Exchange	7:00-10:00	08:00-16:30	2:00
Malta	1	Malta Stock Exchange	London Stock Exchange	9:45-11:30	08:00-16:30	1:45
México	3	Mexican Stock Exchange	NASDAQ Stock Market	14:30-20:30	14:30-21:00	6:00
México	16	Mexican Stock Exchange	New York Stock Exchange	14:30-20:30	14:30-21:00	6:00

México	1	Mexican Stock Exchange	NYSE Amex	14:30-20:30	14:30-21:00	6:00
Morocco	1	Casablanca Stock Exchange	London Stock Exchange	10:00-15:30	08:00-16:30	5:30
Netherlands	1	Euronext	London Stock Exchange	08:00-16:30	08:00-16:30	8:30
Netherlands	3	Euronext	NASDAQ Stock Market	08:00-16:30	14:30-21:00	2:00
Netherlands	7	Euronext	New York Stock Exchange	08:00-16:30	14:30-21:00	2:00
New Zealand	1	New Zealand Stock Exchange	New York Stock Exchange	22:00-05:00	14:30-21:00	0:00
Nigeria	2	Nigerian Stock Exchange	London Stock Exchange	9:00-15:00	08:00-16:30	6:00
Norway	1	Oslo Stock Exchange	New York Stock Exchange	08:00-16:30	14:30-21:00	2:00
Oman	1	Muscat Stock Exchange	London Stock Exchange	6:00-9:00	08:00-16:30	1:00

Pakistan	4	Karachi Stock Exchange	London Stock Exchange	4:30-10:15	08:00-16:30	2:15
Perú	1	Lima Stock Exchange	New York Stock Exchange	14:30-18:30	14:30-21:00	4:00
Philippines	1	Philippines Stock Exchange	London Stock Exchange	01:30-05:00	08:00-16:30	0:00
Philippines	1	Philippines Stock Exchange	Luxembourg Stock Exchange	01:30-05:00	08:00-16:35	0
Philippines	1	Philippines Stock Exchange	New York Stock Exchange	01:30-05:02	14:30-21:00	0
Poland	4	Warsaw Stock Exchange	London Stock Exchange	8:00-15:30	08:00-16:30	5:30
Portugal	1	Euronext	New York Stock Exchange	08:00-16:30	14:30-21:00	2:00
Qatar	2	Qatar Exchange	London Stock Exchange	6:30-10:00	08:00-16:30	2:00
Russia	1	RTS/Moscow Stock	Frankfurt	6:00-14:45	08:00-16:30	6:45

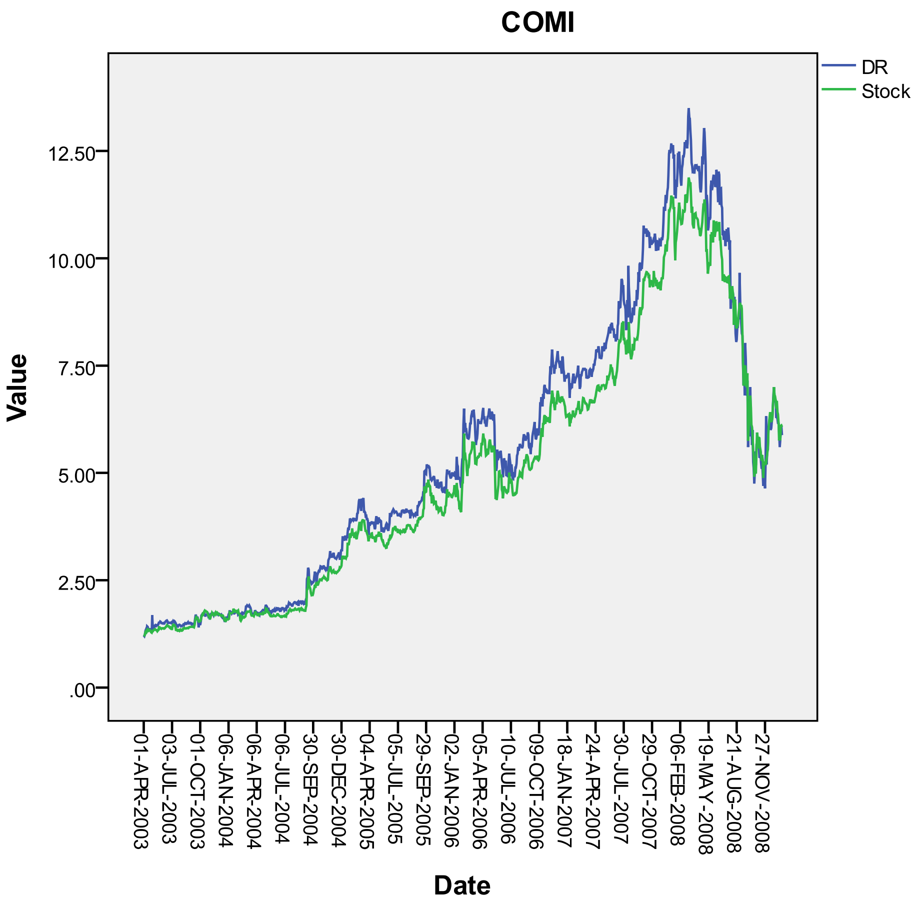
		Exchange	Stock Exchange			
Russia	43	RTS/Moscow Stock Exchange	London Stock Exchange	6:00-14:45	08:00-16:30	6:45
Russia	4	RTS/Moscow Stock Exchange	New York Stock Exchange	6:00-14:45	14:30-21:00	0:15
Russia	1	RTS/Moscow Stock Exchange	NYSE Euronext - Paris	6:00-14:45	08:00-16:30	6:45
South Africa	2	Johansberg Stock Exchange	NASDAQ Stock Market	07:00-15:00	14:30-21:00	0:30
South Africa	5	Johansberg Stock Exchange	New York Stock Exchange	07:00-15:00	14:30-21:00	0:30
Spain	1	Spanish Stock Exchange	NASDAQ Stock Market	08:00-16:30	14:30-21:00	2:00
Spain	5	Spanish Stock Exchange	New York Stock Exchange	08:00-16:30	14:30-21:00	2:00
Sri Lanka	1	Colombo Stock Exchange	Luxembourg Stock Exchange	04:00-09:00	8:00-16:35	0:00
Sweden	1	Stockholm Stock	NASDAQ	08:00-	14:30-21:00	2:00

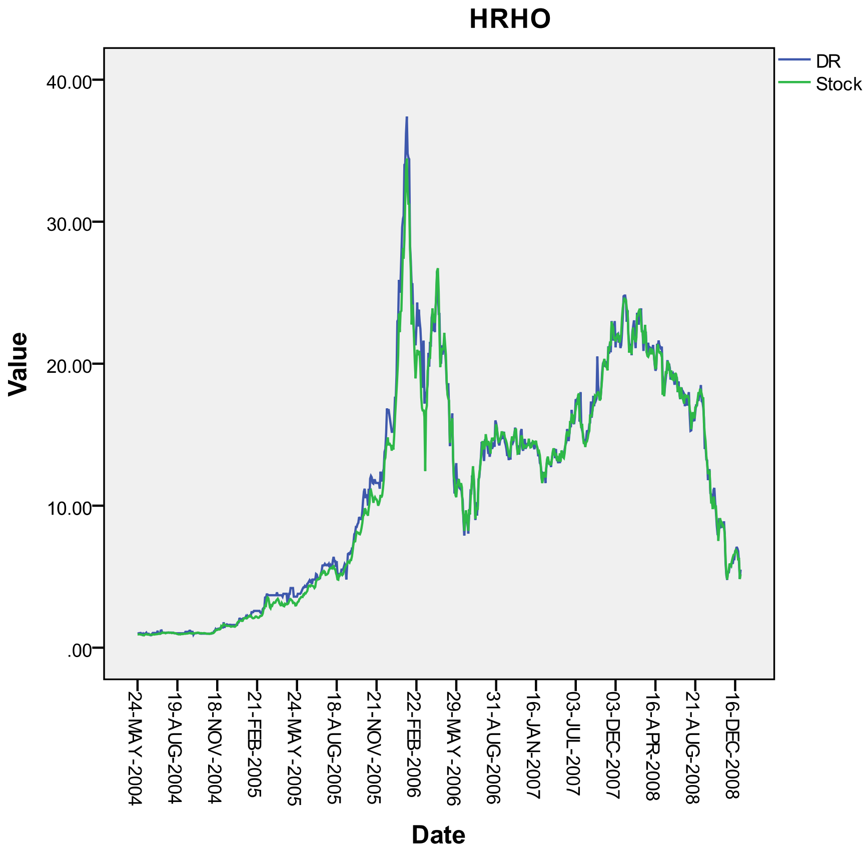
		Exchange	Stock Market	16:30		
Switzerland	1	Swiss Exchange	NASDAQ Stock Market	08:00-16:30	14:30-21:00	2:00
Switzerland	5	Swiss Exchange	New York Stock Exchange	08:00-16:30	14:30-21:00	2:00
Taiwan	10	Taiwan Stock Exchange	London Stock Exchange	01:00-04:30	8:00-16:30	0:00
Taiwan	21	Taiwan Stock Exchange	Luxembourg Stock Exchange	01:00-04:30	8:00-16:35	0:00
Taiwan	18	Taiwan Stock Exchange	Luxembourg Stock Exchange - Euro MTF	01:00-04:30	8:00-16:35	0:00
Taiwan	3	Taiwan Stock Exchange	NASDAQ Stock Market	01:00-04:30	14:30-21:00	0:00
Taiwan	5	Taiwan Stock Exchange	New York Stock Exchange	01:00-04:30	14:30-21:00	0:00
Tunisia	1	Tunisian Stock Exchange	London Stock Exchange	9:00-13:00	8:00-16:30	4:00
Turkey	9	Istanbul Stock	London	7:30-10:30	8:00-16:30	4:30

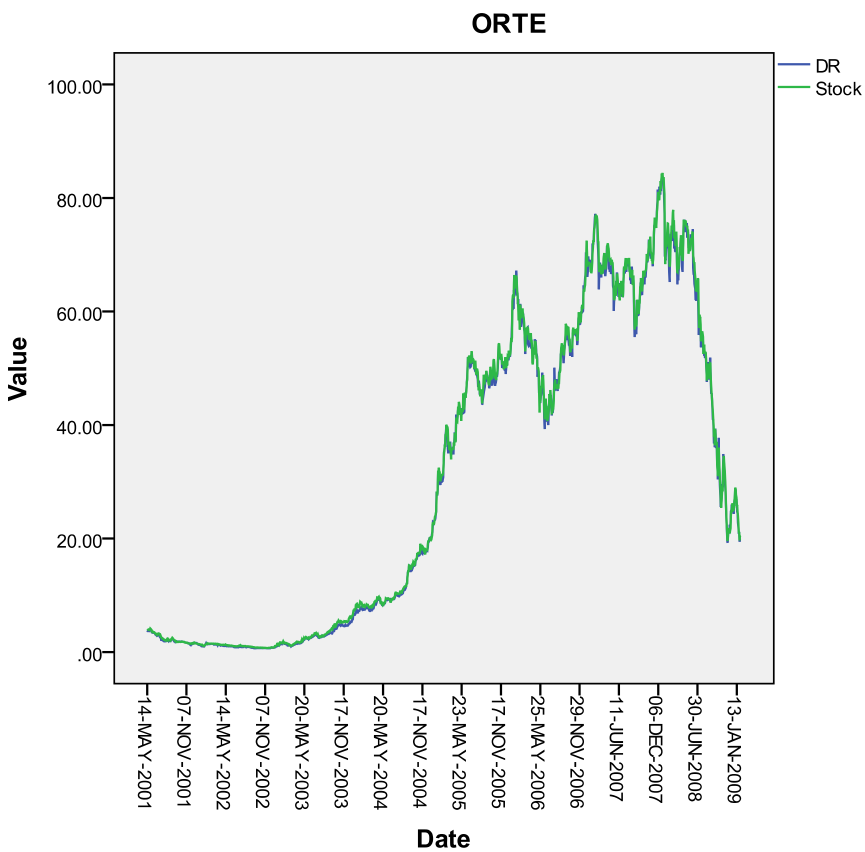
		Exchange	Stock Exchange	and 12:00-15:00		
Turkey	1	Istanbul Stock Exchange	New York Stock Exchange	7:30-10:30 and 12:00-15:00	14:30-21:00	0:30
Ukraine	6	Ukraine Stock Exchange	Frankfurt Stock Exchange	7:30-15:00	8:00-16:30	7:00
Ukraine	2	Ukraine Stock Exchange	London Stock Exchange	7:30-15:00	8:00-16:30	7:00
United Arab Emirates	2	Dubai Financial Market	London Stock Exchange	6:00-10:00	8:00-16:30	2:00
United Kingdom	1	London Stock Exchange	London Stock Exchange	08:00-16:30	8:00-16:30	7:30
United Kingdom	1	London Stock Exchange	Luxembourg Stock Exchange	08:00-16:30	8:00-16:35	7:30
United Kingdom	1	London Stock Exchange	NASDAQ Dubai	08:00-16:30	6:00-10:00	2:00
United Kingdom	7	London Stock Exchange	NASDAQ Stock Market	08:00-16:30	14:30-21:00	2:00
United	39	London Stock	New York	08:00-	14:30-21:00	2:00

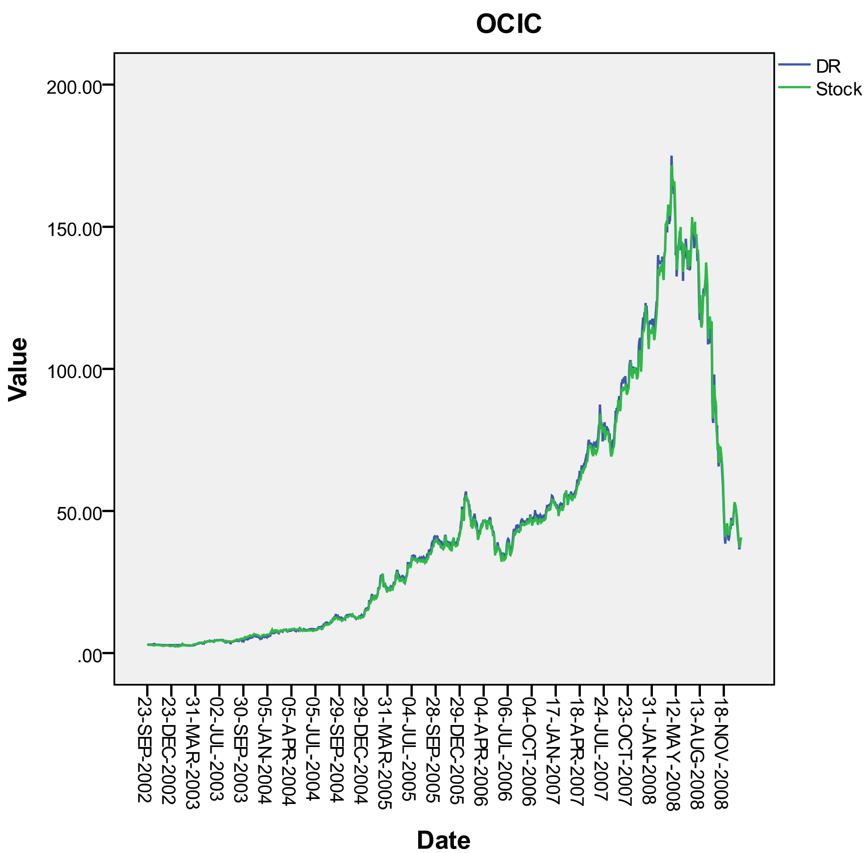
Kingdom		Exchange	Stock Exchange	16:30		
United Kingdom	1	London Stock Exchange	NYSE Amex	08:00-16:30	14:30-21:00	2:00
Vietnam	1	Vietnam Stock Exchange	London Stock Exchange	1:30-4:00	8:00-16:30	0:00

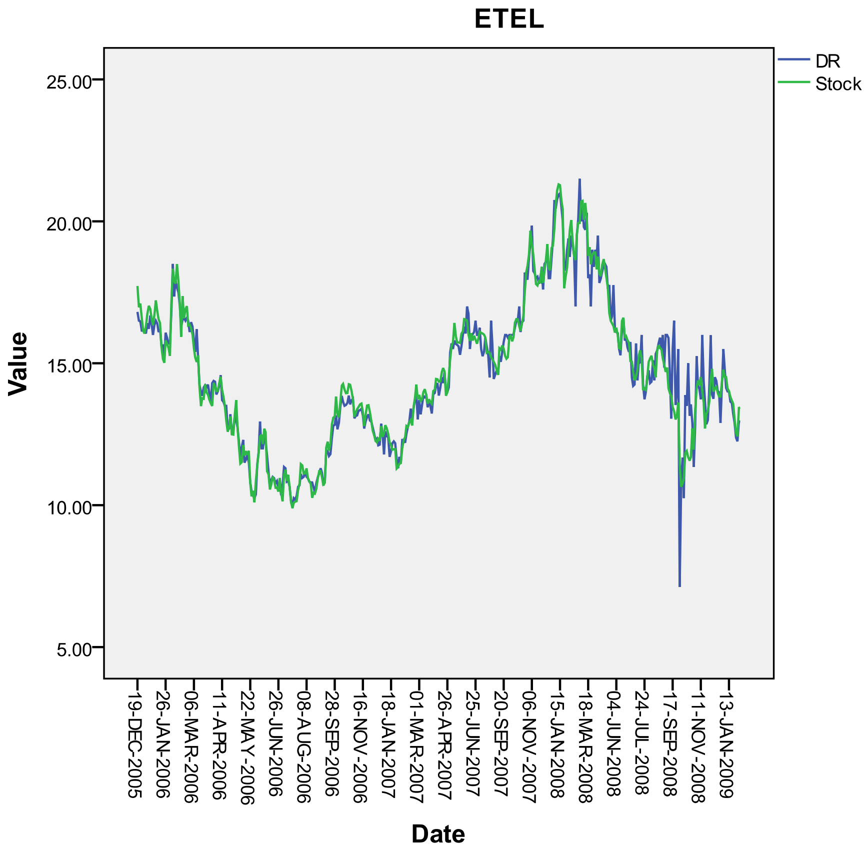
10.2 Appendix 2 Daily Price Charts for Egyptian GDRs

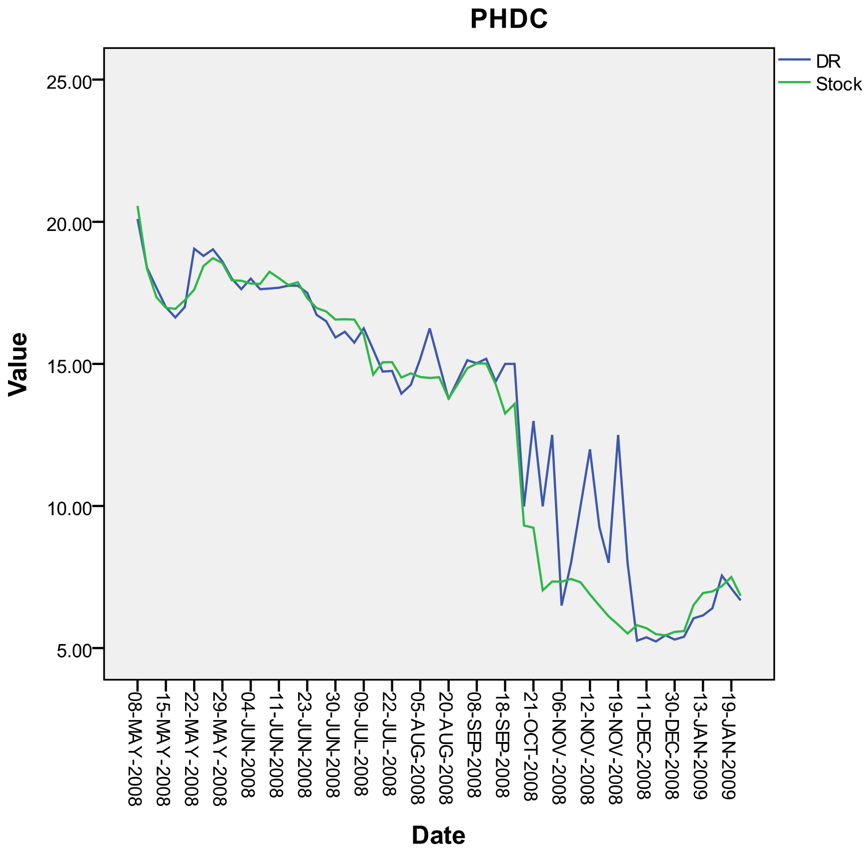


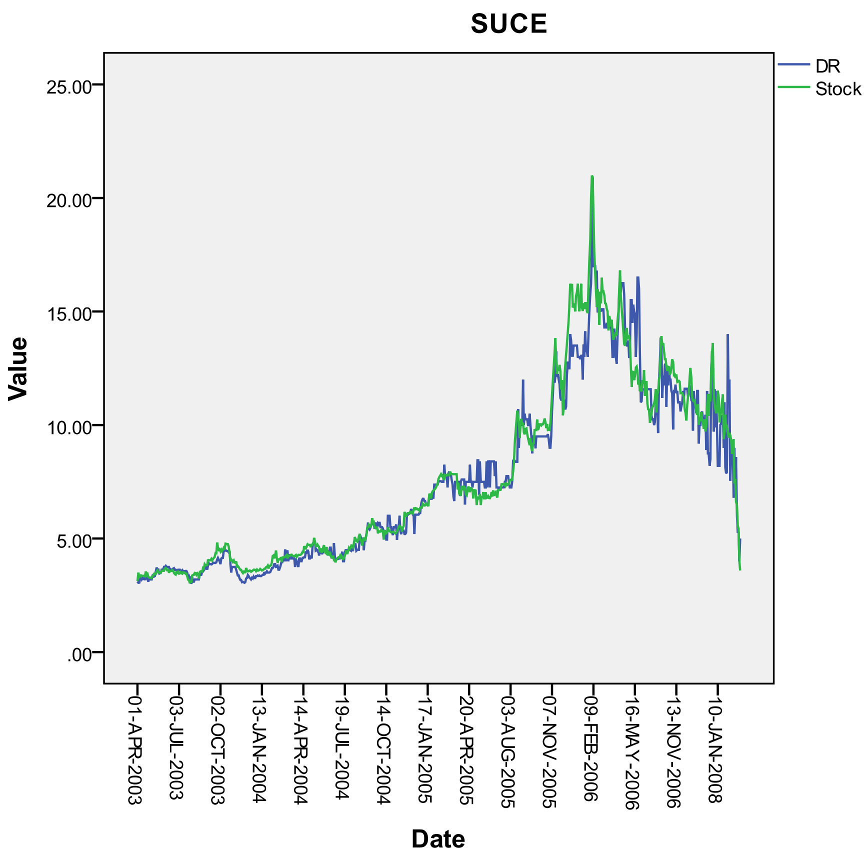

HRHO
DR
Stock
Value
40.00
30.00
20.00
10.00
.00
24-MAY-2004
19-AUG-2004
18-NOV-2004
21-FEB-2005
24-MAY-2005
18-AUG-2005
21-NOV-2005
22-FEB-2006
29-MAY-2006
31-AUG-2006
16-JAN-2007
03-JUL-2007
03-DEC-2007
16-APR-2008
21-AUG-2008
16-DEC-2008
Date

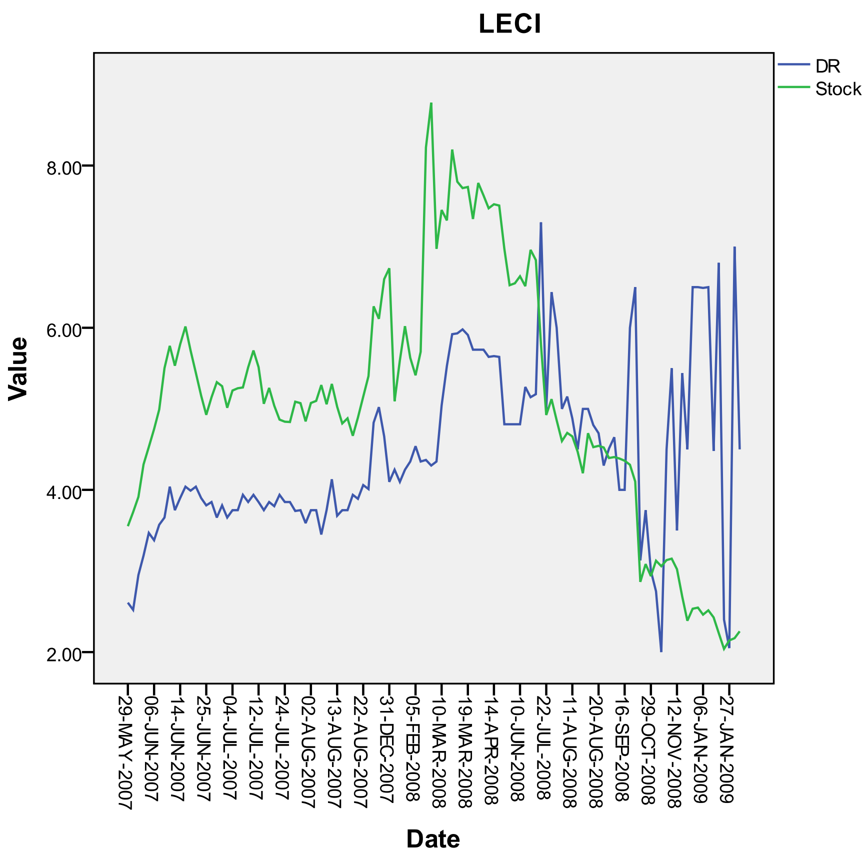

ORTE
DR
Stock
Value
100.00
80.00
60.00
40.00
20.00
.00
14-MAY-2001
07-NOV-2001
14-MAY-2002
07-NOV-2002
20-MAY-2003
17-NOV-2003
20-MAY-2004
17-NOV-2004
23-MAY-2005
17-NOV-2005
25-MAY-2006
29-NOV-2006
11-JUN-2007
06-DEC-2007
30-JUN-2008
13-JAN-2009
Date


OCIC
Value
200.00
150.00
100.00
50.00
.00
DR
Stock
23-SEP-2002
23-DEC-2002
31-MAR-2003
02-JUL-2003
30-SEP-2003
05-JAN-2004
05-APR-2004
05-JUL-2004
29-SEP-2004
29-DEC-2004
31-MAR-2005
04-JUL-2005
28-SEP-2005
29-DEC-2005
04-APR-2006
06-JUL-2006
04-OCT-2006
17-JAN-2007
18-APR-2007
24-JUL-2007
23-OCT-2007
31-JAN-2008
12-MAY-2008
13-AUG-2008
18-NOV-2008
Date

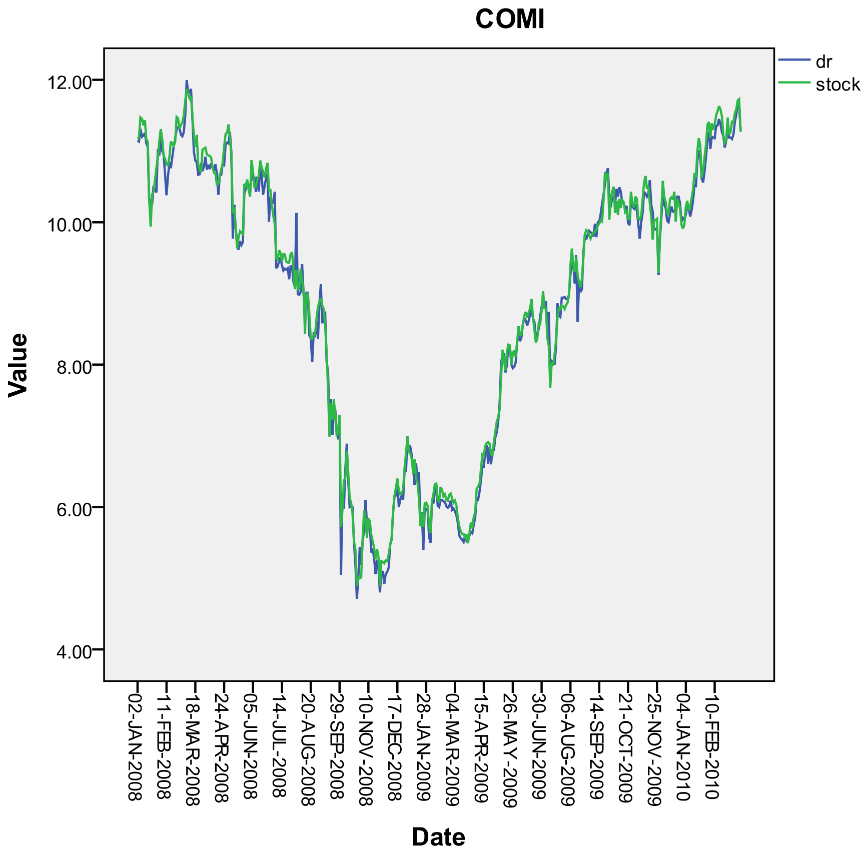

ETEL
Value
25.00
20.00
15.00
10.00
5.00
DR
Stock
19-DEC-2005
26-JAN-2006
06-MAR-2006
11-APR-2006
22-MAY-2006
26-JUN-2006
08-AUG-2006
28-SEP-2006
16-NOV-2006
18-JAN-2007
01-MAR-2007
26-APR-2007
25-JUN-2007
20-SEP-2007
06-NOV-2007
15-JAN-2008
18-MAR-2008
04-JUN-2008
24-JUL-2008
17-SEP-2008
11-NOV-2008
13-JAN-2009
Date

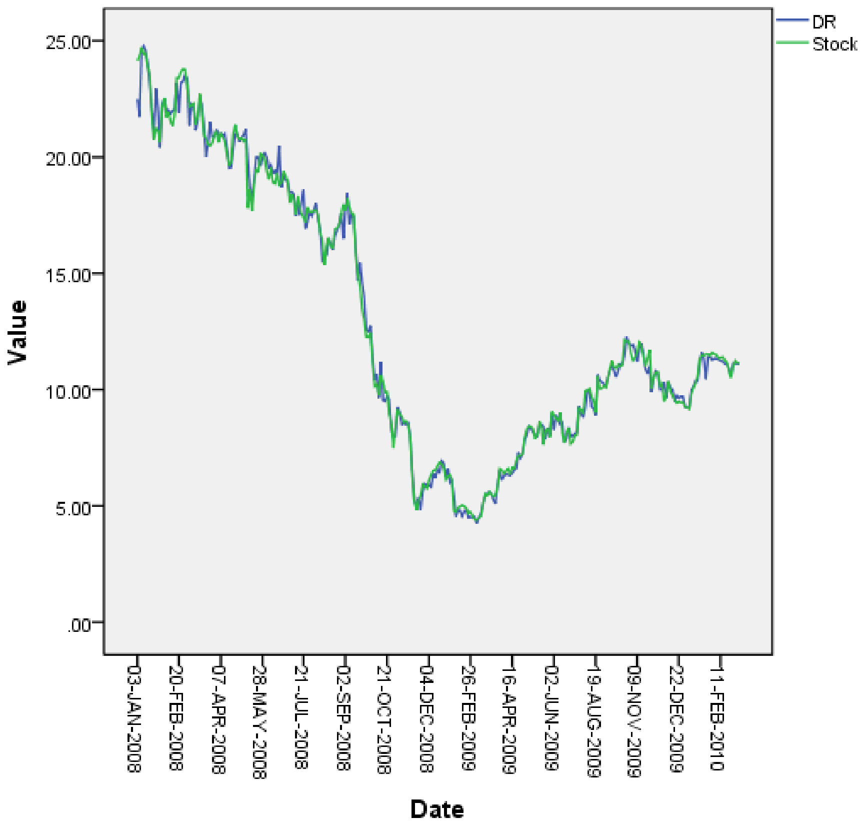

PHDC
DR
Stock
Value
25.00
20.00
15.00
10.00
5.00
08-MAY-2008
15-MAY-2008
22-MAY-2008
29-MAY-2008
04-JUN-2008
11-JUN-2008
23-JUN-2008
30-JUN-2008
09-JUL-2008
22-JUL-2008
05-AUG-2008
20-AUG-2008
08-SEP-2008
18-SEP-2008
21-OCT-2008
06-NOV-2008
12-NOV-2008
19-NOV-2008
11-DEC-2008
30-DEC-2008
13-JAN-2009
19-JAN-2009
Date


SUCE
DR
Stock
Value
25.00
20.00
15.00
10.00
5.00
.00
01-APR-2003
03-JUL-2003
02-OCT-2003
13-JAN-2004
14-APR-2004
19-JUL-2004
14-OCT-2004
17-JAN-2005
20-APR-2005
03-AUG-2005
07-NOV-2005
09-FEB-2006
16-MAY-2006
13-NOV-2006
10-JAN-2008
Date

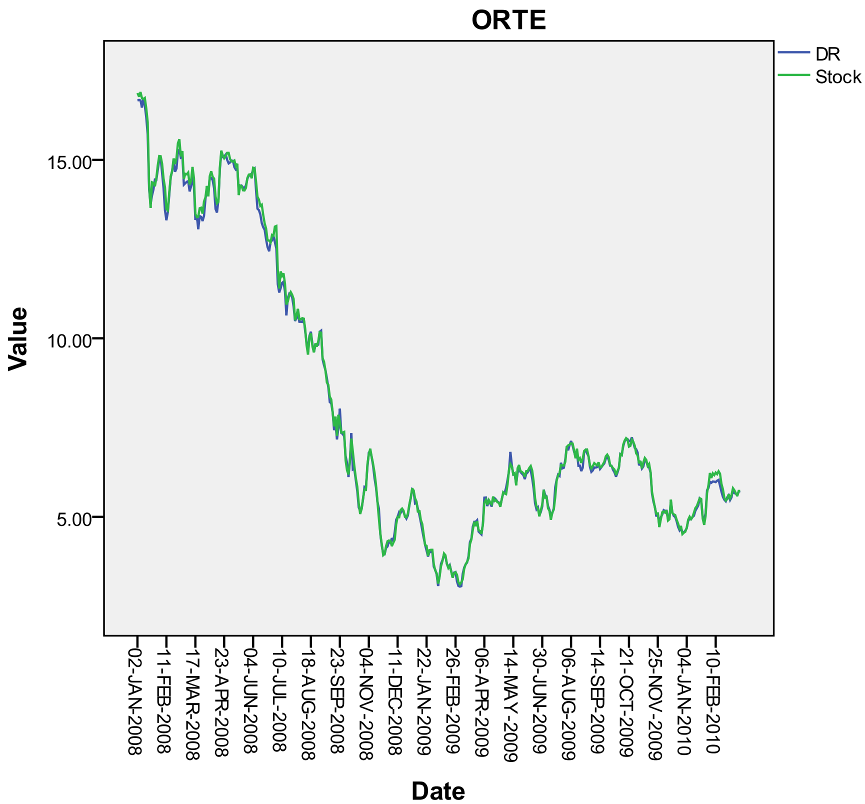

LECI
DR
Stock
Value
8.00
6.00
4.00
2.00
29-MAY-2007
06-JUN-2007
14-JUN-2007
25-JUN-2007
04-JUL-2007
12-JUL-2007
24-JUL-2007
02-AUG-2007
13-AUG-2007
22-AUG-2007
31-DEC-2007
05-FEB-2008
10-MAR-2008
19-MAR-2008
14-APR-2008
10-JUN-2008
22-JUL-2008
11-AUG-2008
20-AUG-2008
16-SEP-2008
29-OCT-2008
12-NOV-2008
06-JAN-2009
27-JAN-2009
Date

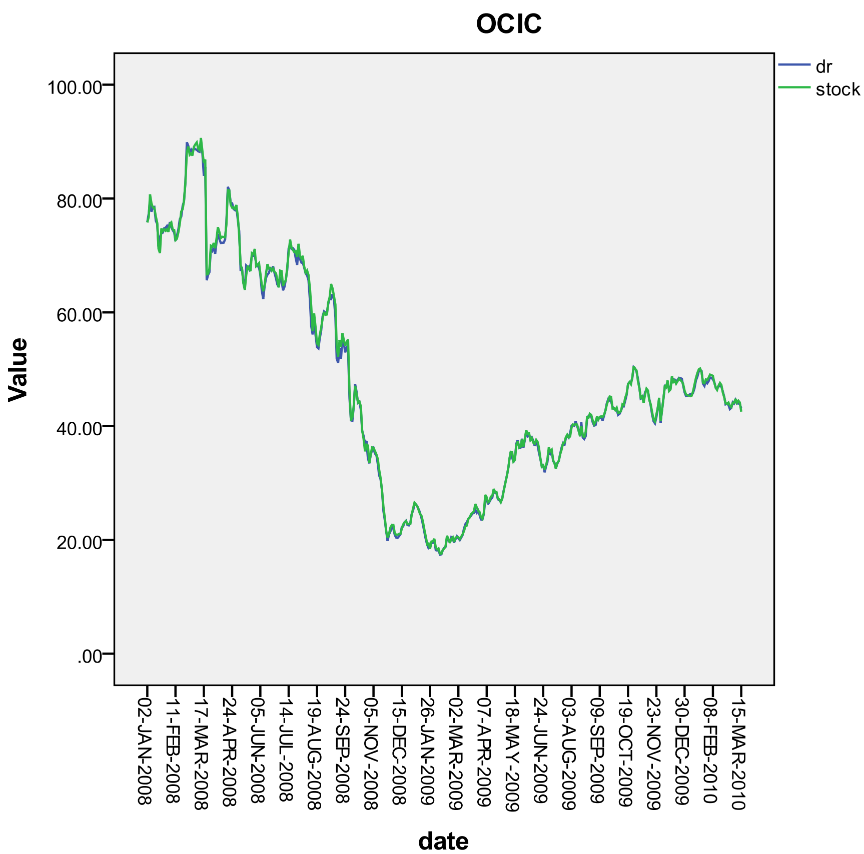
10.3 Appendix 3 Price Charts for Egyptian and Argentinean DRs and their Underlying Stock



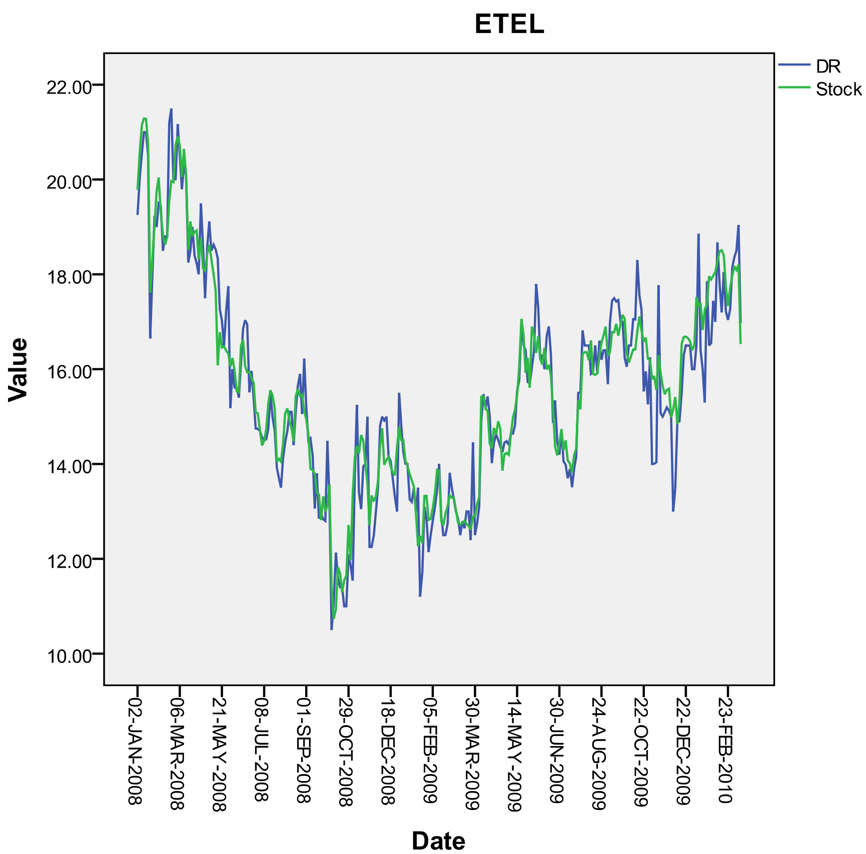


DR
Stock
25.00
20.00
15.00
10.00
5.00
.00
Value
03-JAN-2008
20-FEB-2008
07-APR-2008
28-MAY-2008
21-JUL-2008
02-SEP-2008
21-OCT-2008
04-DEC-2008
26-FEB-2009
16-APR-2009
02-JUN-2009
19-AUG-2009
09-NOV-2009
22-DEC-2009
11-FEB-2010
Date

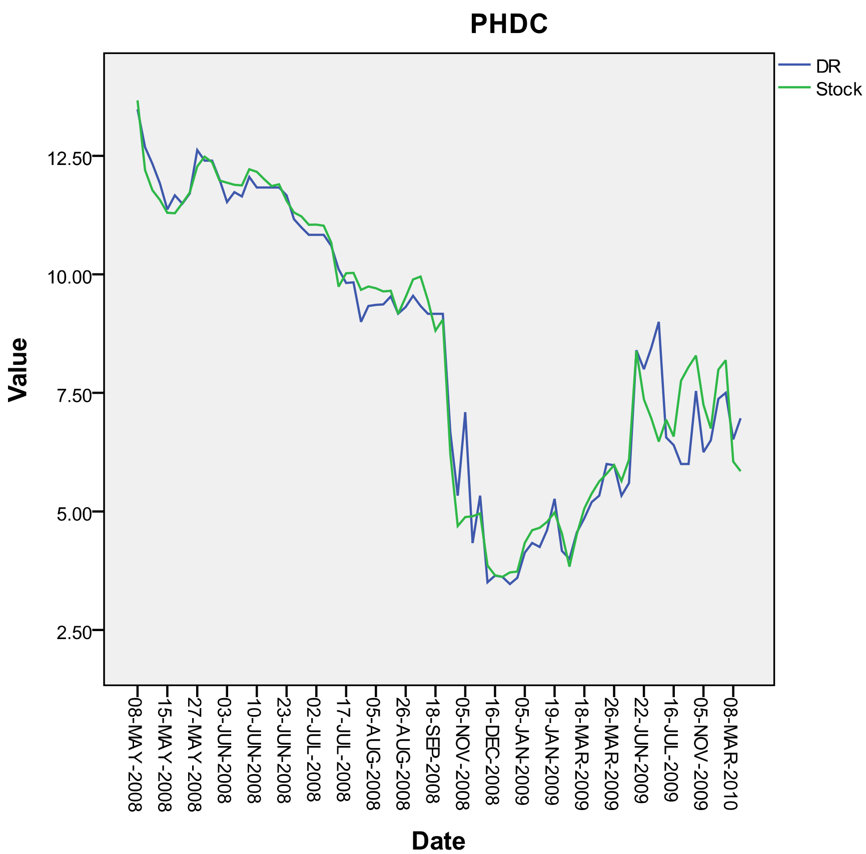

ORTE
DR
Stock
Value
15.00
10.00
5.00
02-JAN-2008
11-FEB-2008
17-MAR-2008
23-APR-2008
04-JUN-2008
10-JUL-2008
18-AUG-2008
23-SEP-2008
04-NOV-2008
11-DEC-2008
22-JAN-2009
26-FEB-2009
06-APR-2009
14-MAY-2009
30-JUN-2009
06-AUG-2009
14-SEP-2009
21-OCT-2009
25-NOV-2009
04-JAN-2010
10-FEB-2010
Date



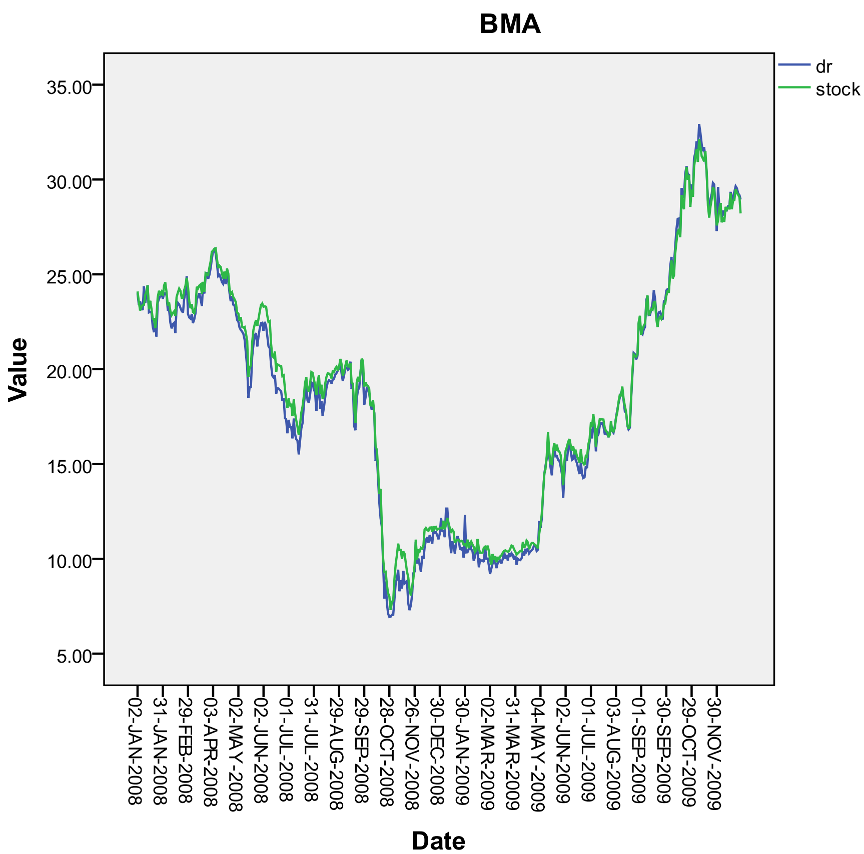
OCIC
100.00
80.00
60.00
40.00
20.00
.00
Value
dr
stock
02-JAN-2008
11-FEB-2008
17-MAR-2008
24-APR-2008
05-JUN-2008
14-JUL-2008
19-AUG-2008
24-SEP-2008
05-NOV-2008
15-DEC-2008
26-JAN-2009
02-MAR-2009
07-APR-2009
18-MAY-2009
24-JUN-2009
03-AUG-2009
09-SEP-2009
19-OCT-2009
23-NOV-2009
30-DEC-2009
08-FEB-2010
15-MAR-2010
date



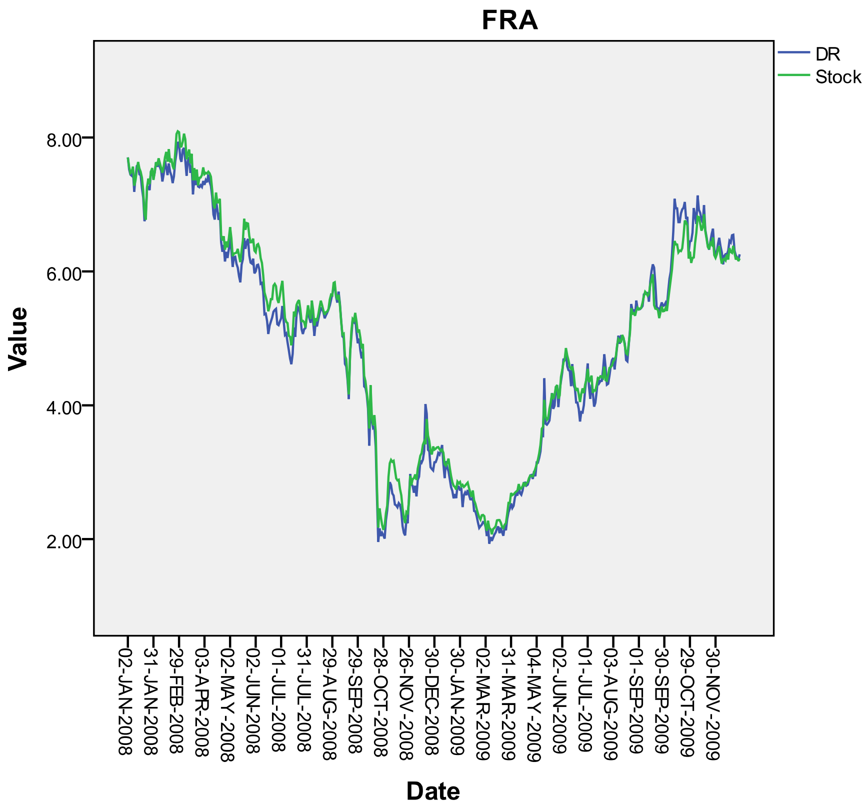
ETEL
DR
Stock
Value
22.00
20.00
18.00
16.00
14.00
12.00
10.00
02-JAN-2008
06-MAR-2008
21-MAY-2008
08-JUL-2008
01-SEP-2008
29-OCT-2008
18-DEC-2008
05-FEB-2009
30-MAR-2009
14-MAY-2009
30-JUN-2009
24-AUG-2009
22-OCT-2009
22-DEC-2009
23-FEB-2010
Date

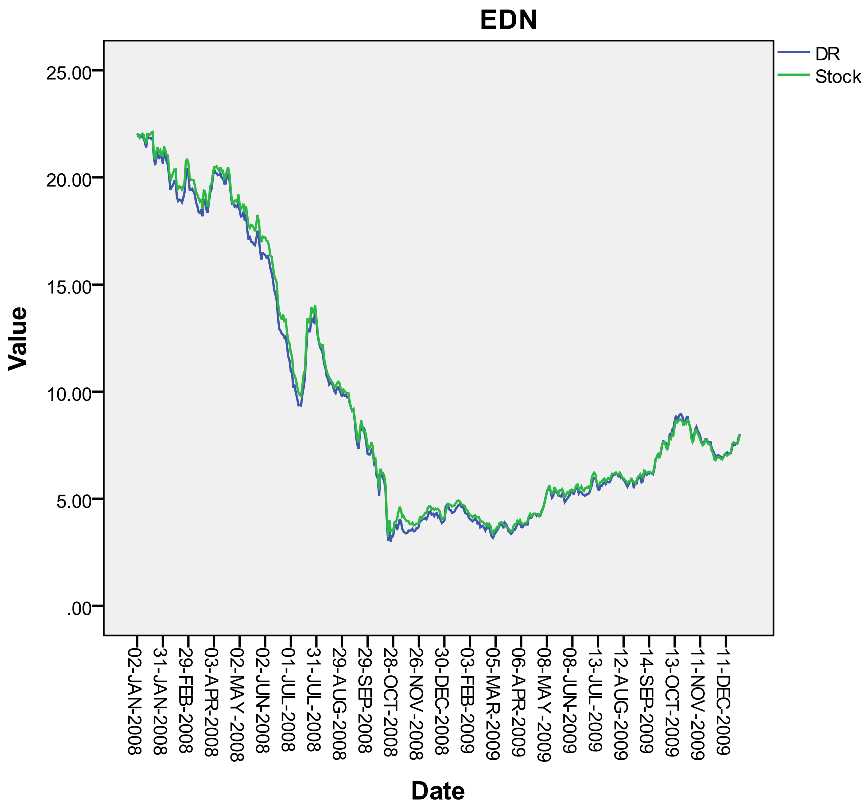


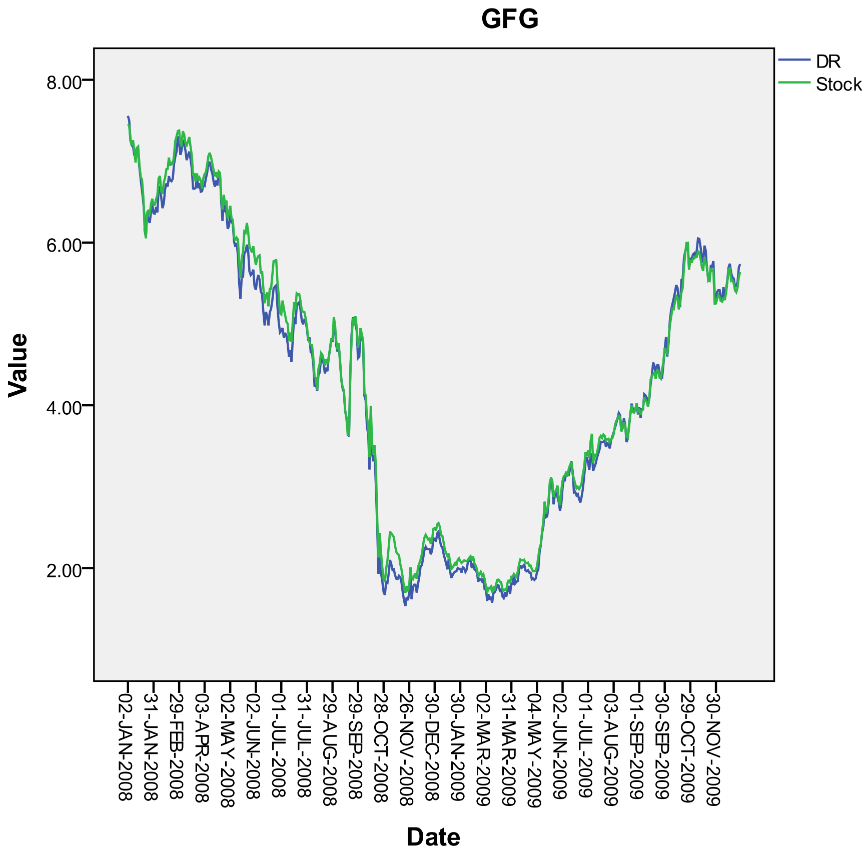
PHDC
DR
Stock
Value
12.50
10.00
7.50
5.00
2.50
08-MAY-2008
15-MAY-2008
27-MAY-2008
03-JUN-2008
10-JUN-2008
23-JUN-2008
02-JUL-2008
17-JUL-2008
05-AUG-2008
26-AUG-2008
18-SEP-2008
05-NOV-2008
16-DEC-2008
05-JAN-2009
19-JAN-2009
18-MAR-2009
26-MAR-2009
22-JUN-2009
16-JUL-2009
05-NOV-2009
08-MAR-2010
Date

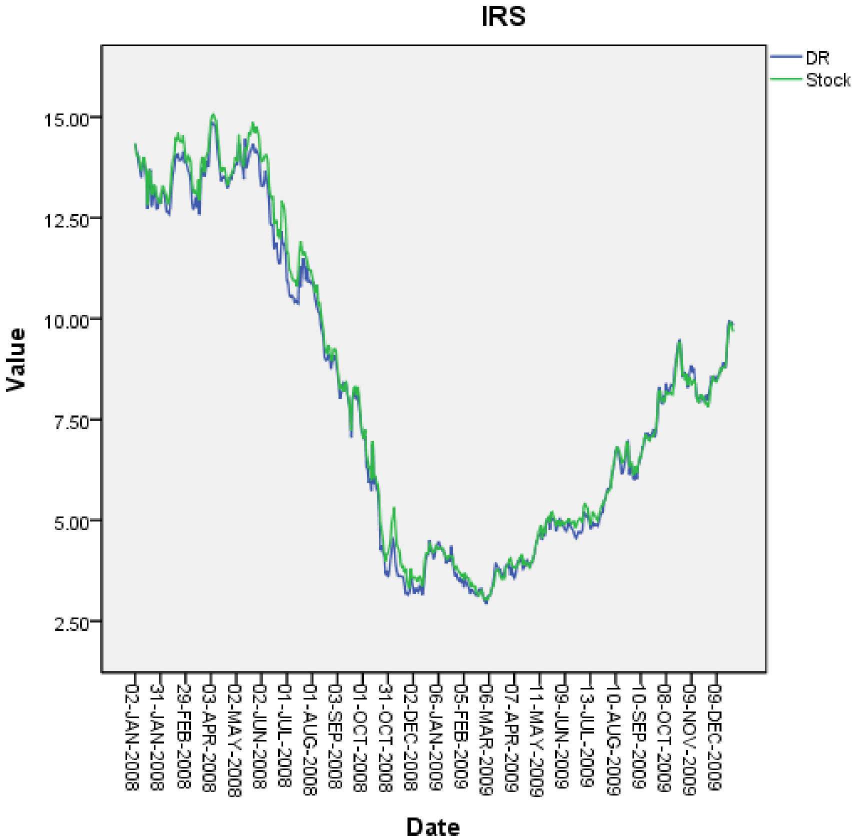


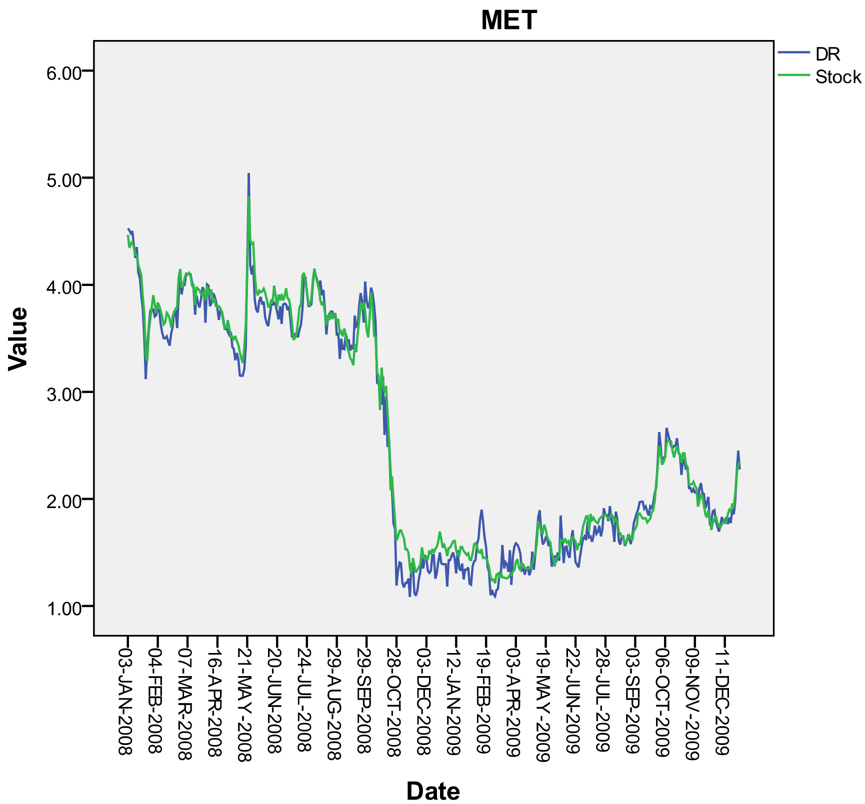
BMA
dr
stock
Value
35.00
30.00
25.00
20.00
15.00
10.00
5.00
02-JAN-2008
31-JAN-2008
29-FEB-2008
03-APR-2008
02-MAY-2008
02-JUN-2008
01-JUL-2008
31-JUL-2008
29-AUG-2008
29-SEP-2008
28-OCT-2008
26-NOV-2008
30-DEC-2008
30-JAN-2009
02-MAR-2009
31-MAR-2009
04-MAY-2009
02-JUN-2009
01-JUL-2009
03-AUG-2009
01-SEP-2009
30-SEP-2009
29-OCT-2009
30-NOV-2009
Date

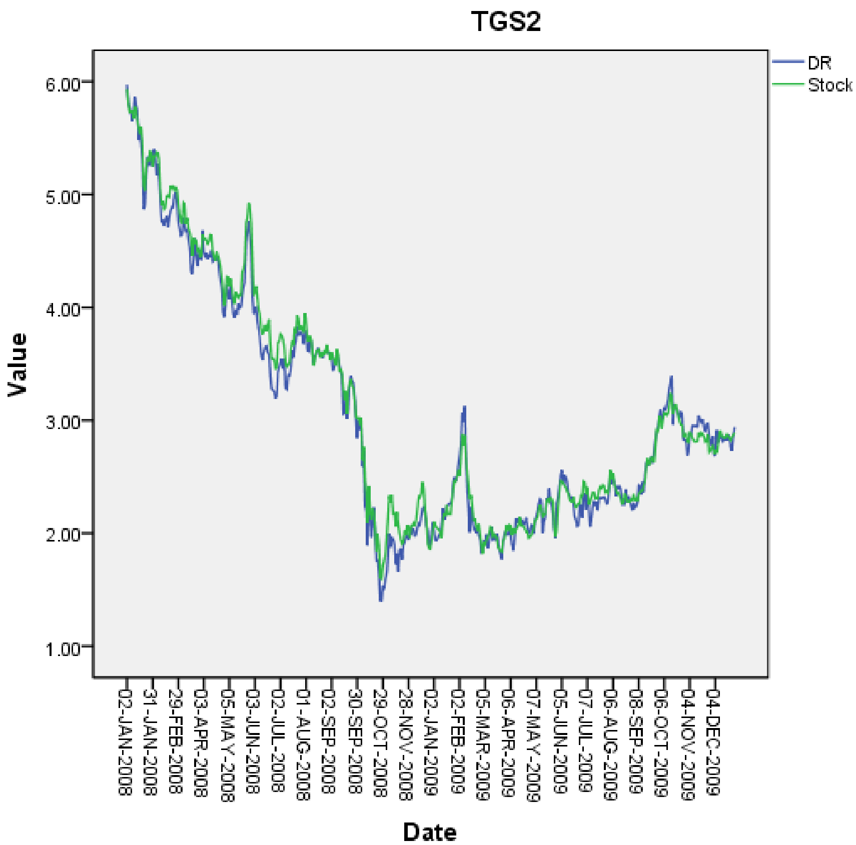

FRA
DR
Stock
Value
8.00
6.00
4.00
2.00
02-JAN-2008
31-JAN-2008
29-FEB-2008
03-APR-2008
02-MAY-2008
02-JUN-2008
01-JUL-2008
31-JUL-2008
29-AUG-2008
29-SEP-2008
28-OCT-2008
26-NOV-2008
30-DEC-2008
30-JAN-2009
02-MAR-2009
31-MAR-2009
04-MAY-2009
02-JUN-2009
01-JUL-2009
03-AUG-2009
01-SEP-2009
30-SEP-2009
29-OCT-2009
30-NOV-2009
Date

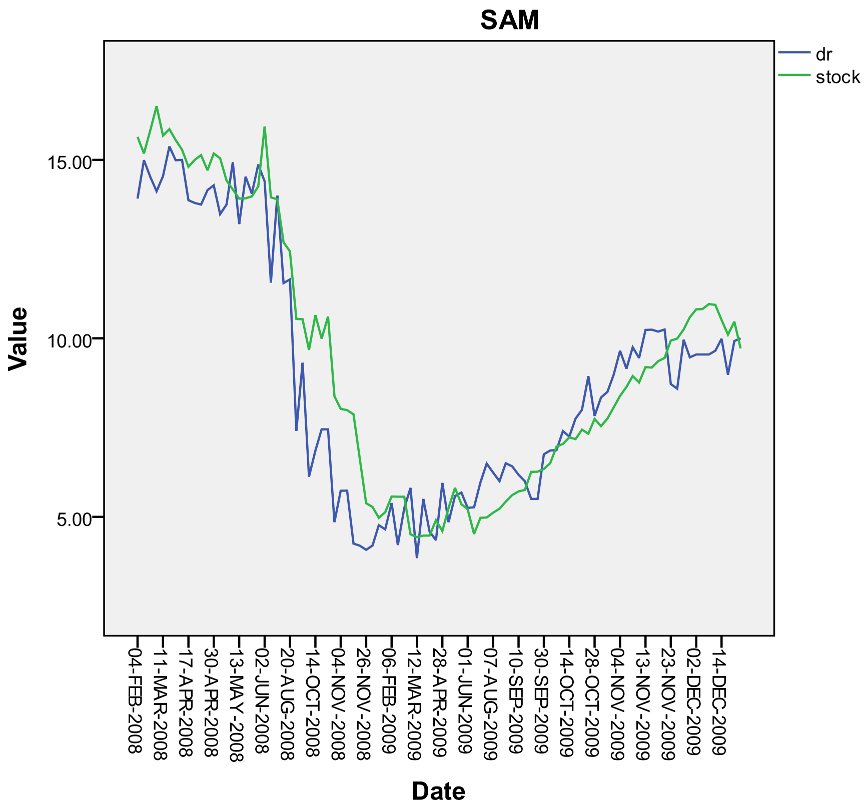

EDN
DR
Stock
Value
25.00
20.00
15.00
10.00
5.00
.00
02-JAN-2008
31-JAN-2008
29-FEB-2008
03-APR-2008
02-MAY-2008
02-JUN-2008
01-JUL-2008
31-JUL-2008
29-AUG-2008
29-SEP-2008
28-OCT-2008
26-NOV-2008
30-DEC-2008
03-FEB-2009
05-MAR-2009
06-APR-2009
08-MAY-2009
08-JUN-2009
13-JUL-2009
12-AUG-2009
14-SEP-2009
13-OCT-2009
11-NOV-2009
11-DEC-2009
Date


GFG
Value
Date
DR
Stock
8.00
6.00
4.00
2.00
02-JAN-2008
31-JAN-2008
29-FEB-2008
03-APR-2008
02-MAY-2008
02-JUN-2008
01-JUL-2008
31-JUL-2008
29-AUG-2008
29-SEP-2008
28-OCT-2008
26-NOV-2008
30-DEC-2008
30-JAN-2009
02-MAR-2009
31-MAR-2009
04-MAY-2009
02-JUN-2009
01-JUL-2009
03-AUG-2009
01-SEP-2009
30-SEP-2009
29-OCT-2009
30-NOV-2009

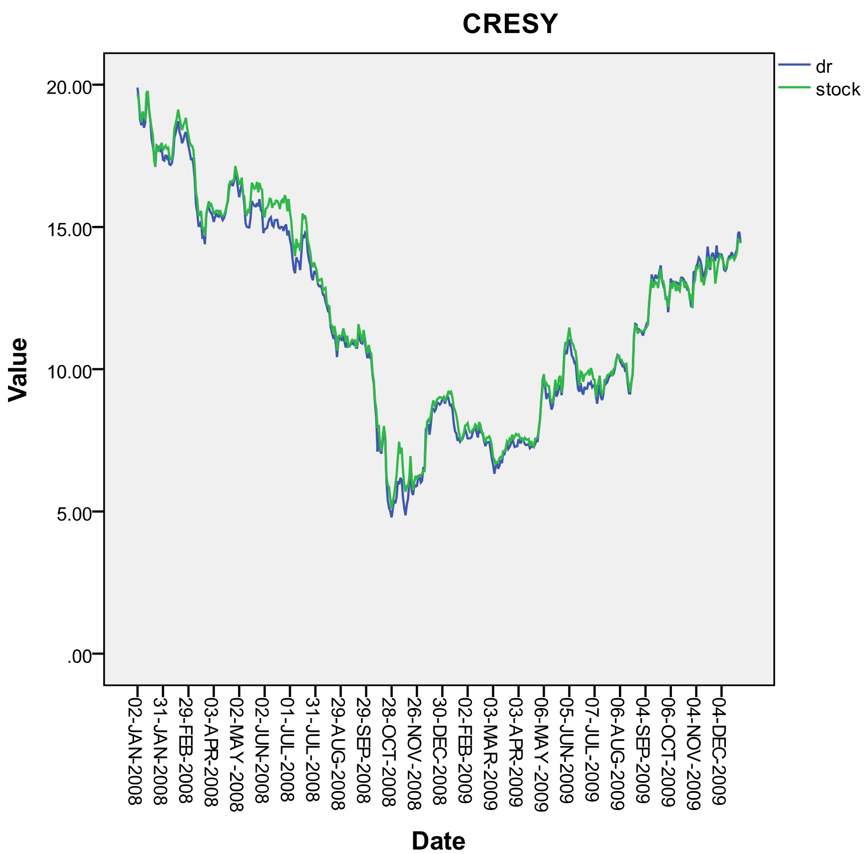

IRS
DR
Stock
Value
15.00
12.50
10.00
7.50
5.00
2.50
02-JAN-2008
31-JAN-2008
29-FEB-2008
03-APR-2008
02-MAY-2008
02-JUN-2008
01-JUL-2008
01-AUG-2008
03-SEP-2008
01-OCT-2008
31-OCT-2008
02-DEC-2008
06-JAN-2009
05-FEB-2009
06-MAR-2009
07-APR-2009
11-MAY-2009
09-JUN-2009
13-JUL-2009
10-AUG-2009
10-SEP-2009
08-OCT-2009
09-NOV-2009
09-DEC-2009
Date


MET
DR
Stock
Value
6.00
5.00
4.00
3.00
2.00
1.00
03-JAN-2008
04-FEB-2008
07-MAR-2008
16-APR-2008
21-MAY-2008
20-JUN-2008
24-JUL-2008
29-AUG-2008
29-SEP-2008
28-OCT-2008
03-DEC-2008
12-JAN-2009
19-FEB-2009
03-APR-2009
19-MAY-2009
22-JUN-2009
28-JUL-2009
03-SEP-2009
06-OCT-2009
09-NOV-2009
11-DEC-2009
Date

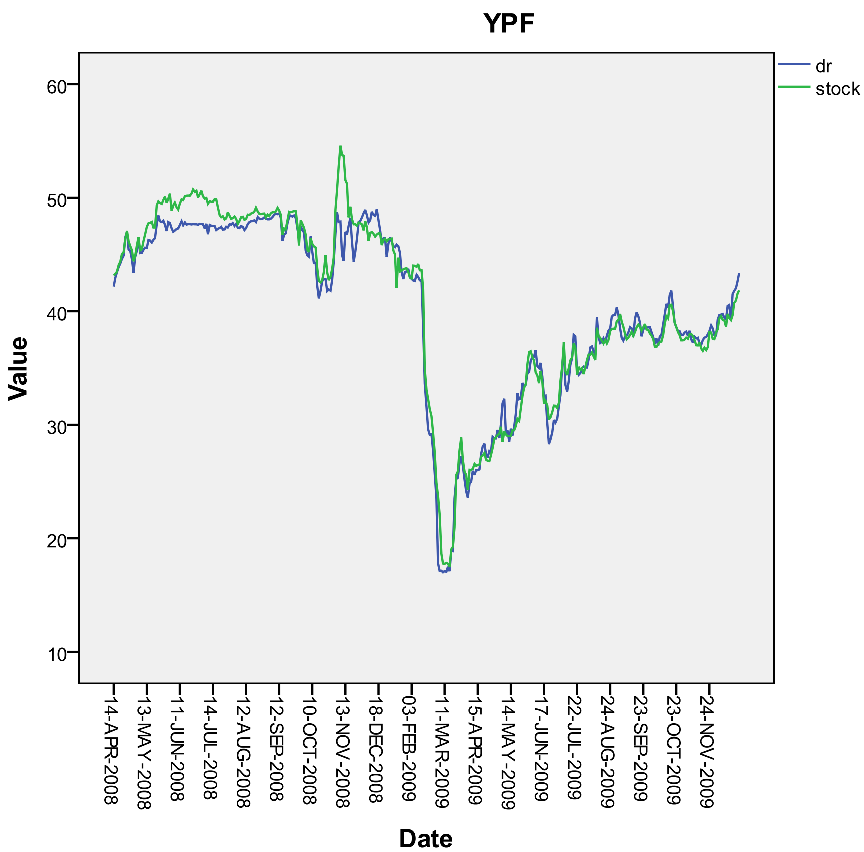

TGS2
DR
Stock
6.00
5.00
4.00
3.00
2.00
1.00
Value
02-JAN-2008
31-JAN-2008
29-FEB-2008
03-APR-2008
05-MAY-2008
03-JUN-2008
02-JUL-2008
01-AUG-2008
02-SEP-2008
30-SEP-2008
29-OCT-2008
28-NOV-2008
02-JAN-2009
02-FEB-2009
05-MAR-2009
06-APR-2009
07-MAY-2009
05-JUN-2009
07-JUL-2009
06-AUG-2009
08-SEP-2009
06-OCT-2009
04-NOV-2009
04-DEC-2009
Date



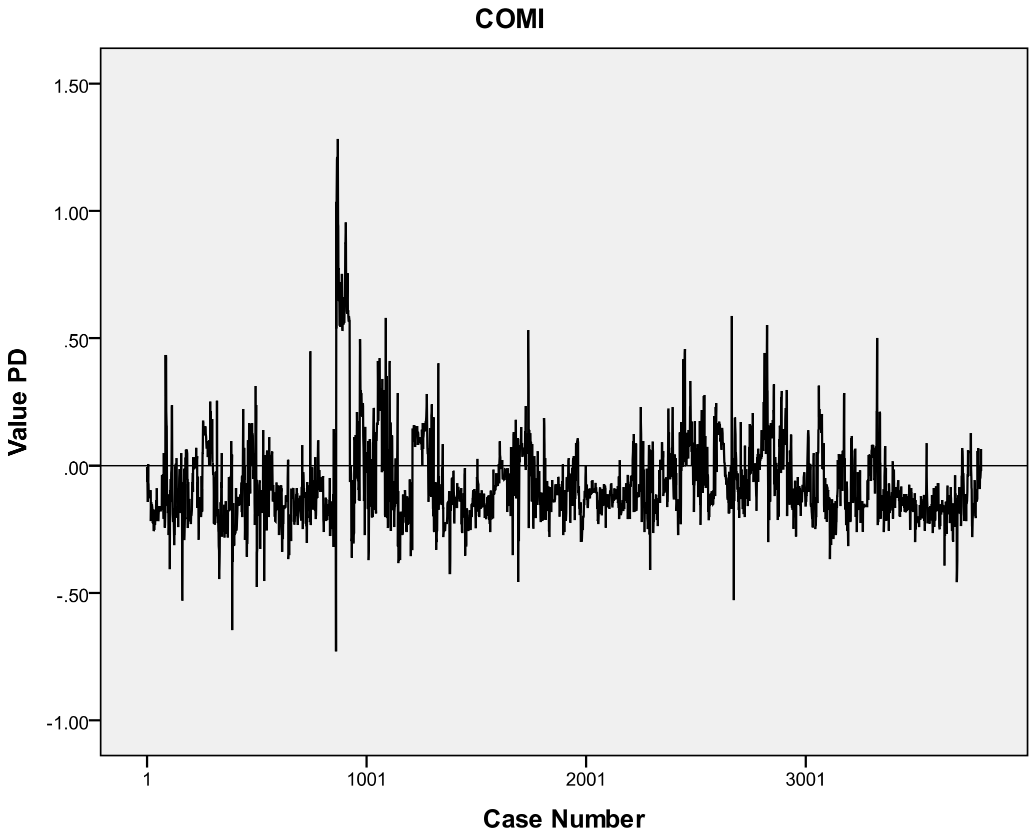
SAM
dr
stock
Value
15.00
10.00
5.00
04-FEB-2008
11-MAR-2008
17-APR-2008
30-APR-2008
13-MAY-2008
02-JUN-2008
20-AUG-2008
14-OCT-2008
04-NOV-2008
26-NOV-2008
06-FEB-2009
12-MAR-2009
28-APR-2009
01-JUN-2009
07-AUG-2009
10-SEP-2009
30-SEP-2009
14-OCT-2009
28-OCT-2009
04-NOV-2009
13-NOV-2009
23-NOV-2009
02-DEC-2009
14-DEC-2009
Date

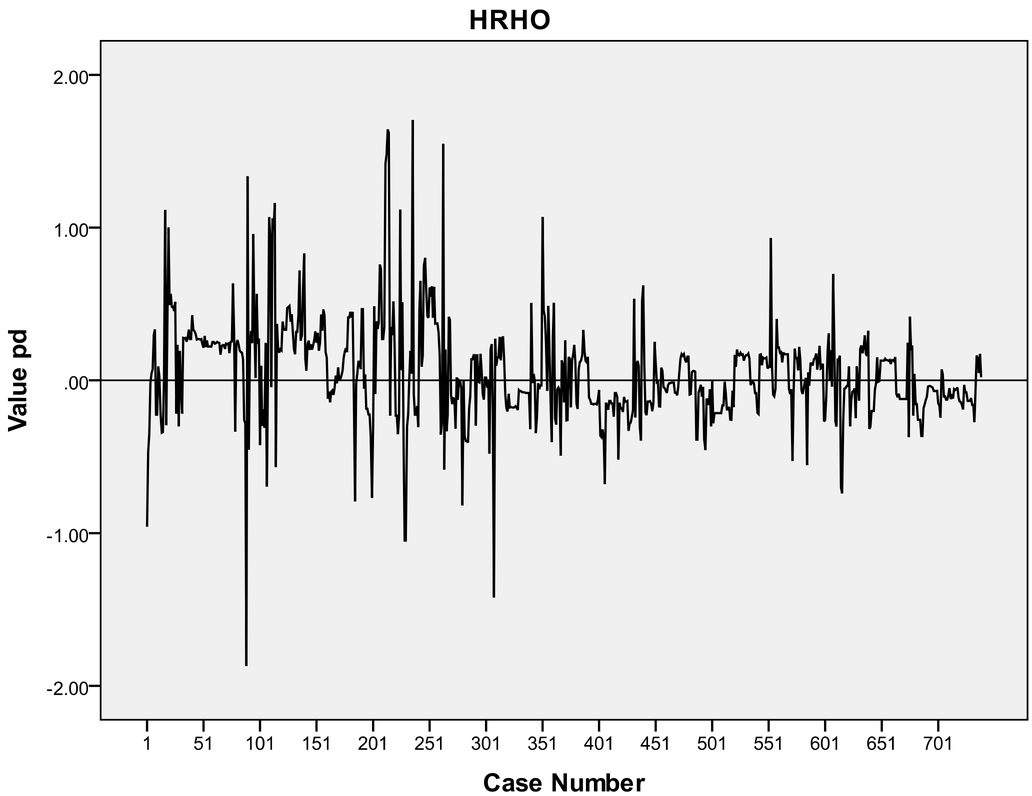


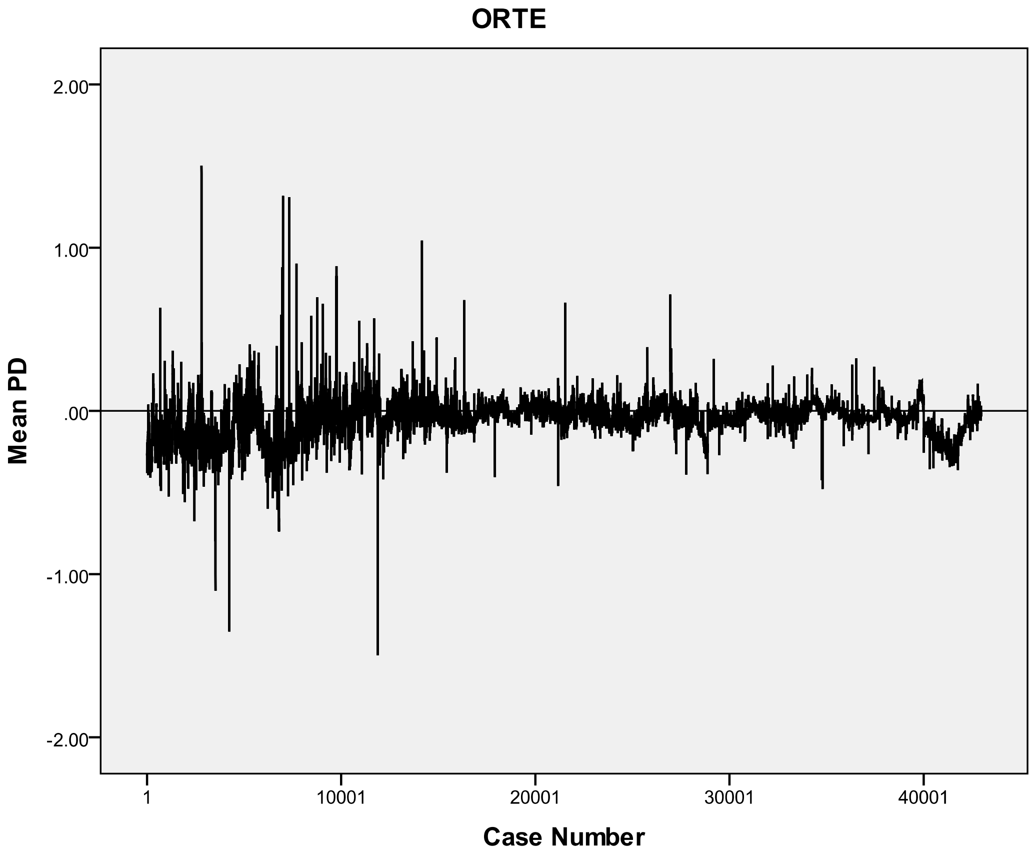
CRESY
dr
stock
20.00
15.00
10.00
5.00
.00
Value
02-JAN-2008
31-JAN-2008
29-FEB-2008
03-APR-2008
02-MAY-2008
02-JUN-2008
01-JUL-2008
31-JUL-2008
29-AUG-2008
29-SEP-2008
28-OCT-2008
26-NOV-2008
30-DEC-2008
02-FEB-2009
03-MAR-2009
03-APR-2009
06-MAY-2009
05-JUN-2009
07-JUL-2009
06-AUG-2009
04-SEP-2009
06-OCT-2009
04-NOV-2009
04-DEC-2009
Date

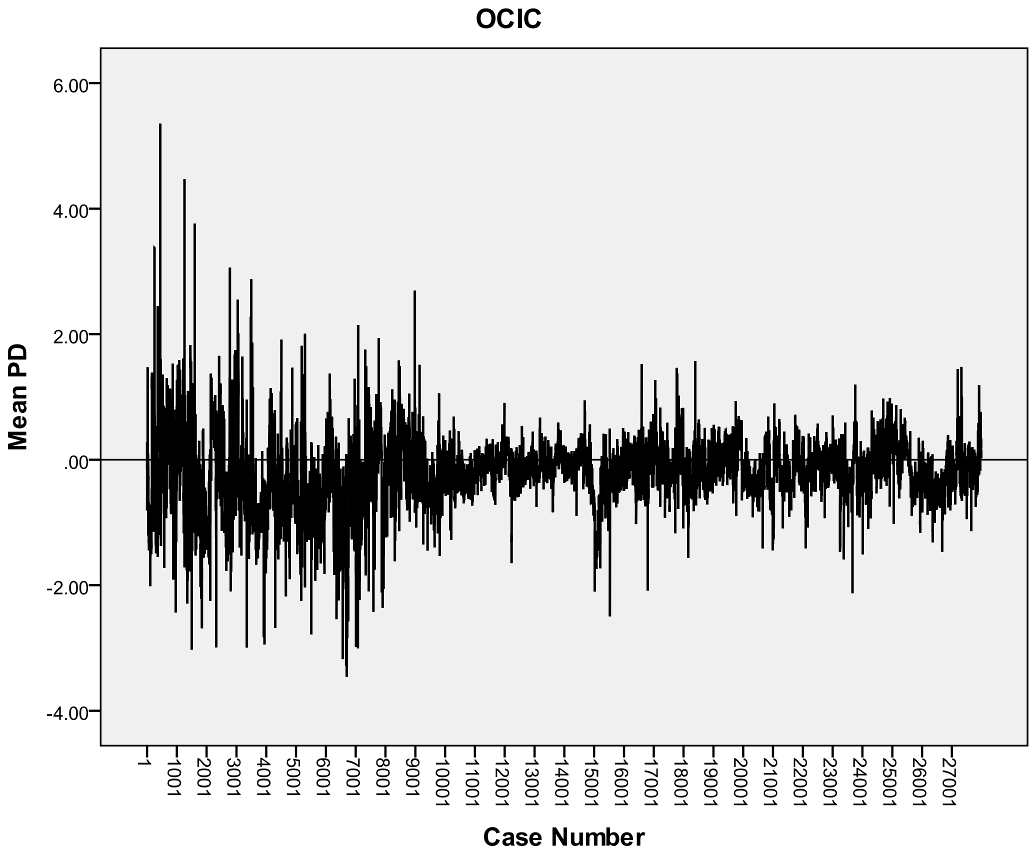

YPF
dr
stock
Value
60
50
40
30
20
10
14-APR-2008
13-MAY-2008
11-JUN-2008
14-JUL-2008
12-AUG-2008
12-SEP-2008
10-OCT-2008
13-NOV-2008
18-DEC-2008
03-FEB-2009
11-MAR-2009
15-APR-2009
14-MAY-2009
17-JUN-2009
22-JUL-2009
24-AUG-2009
23-SEP-2009
23-OCT-2009
24-NOV-2009
Date

10.4 Appendix 4 Price Deviation Chart for Egyptian and Argentinean Securities

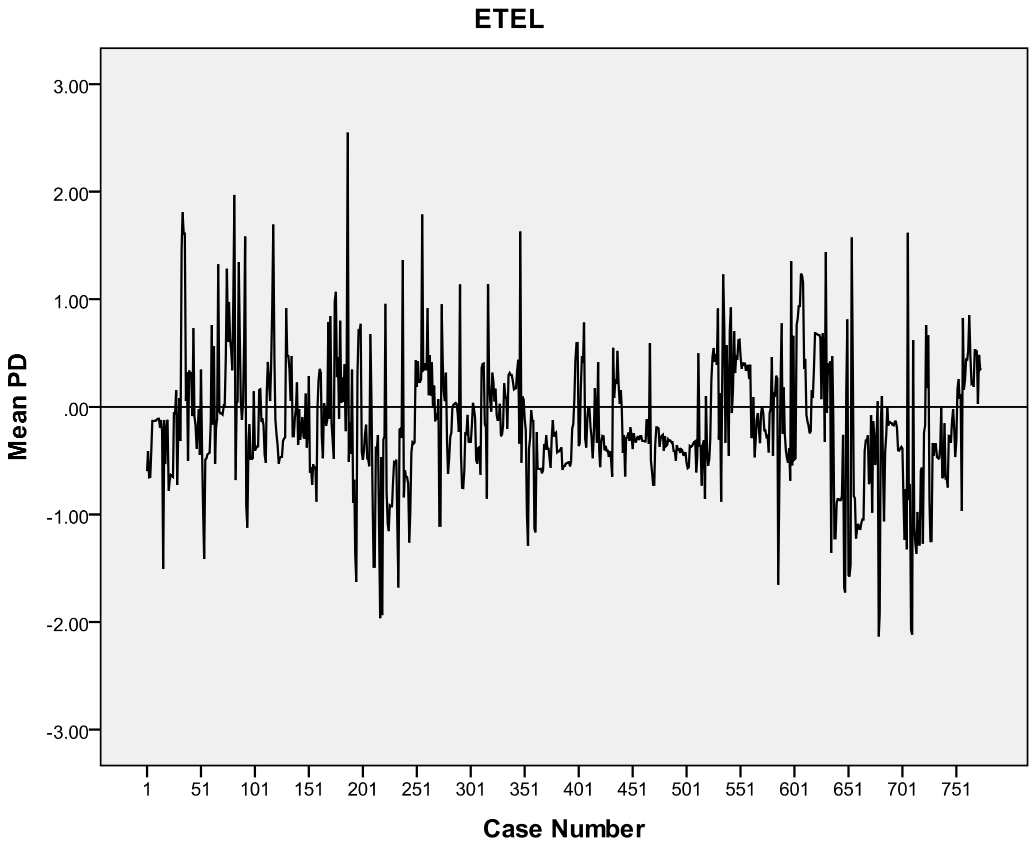


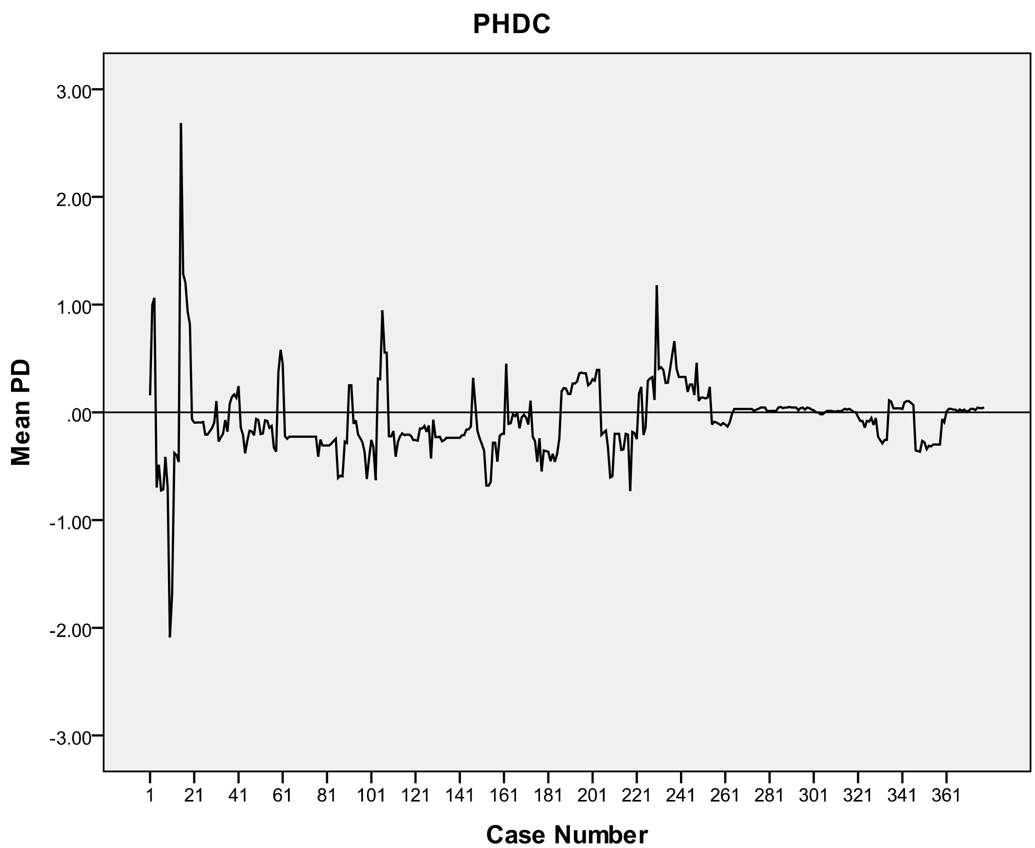

HRHO
2.00
1.00
.00
-1.00
-2.00
Value pd
1
51
101
151
201
251
301
351
401
451
501
551
601
651
701
Case Number

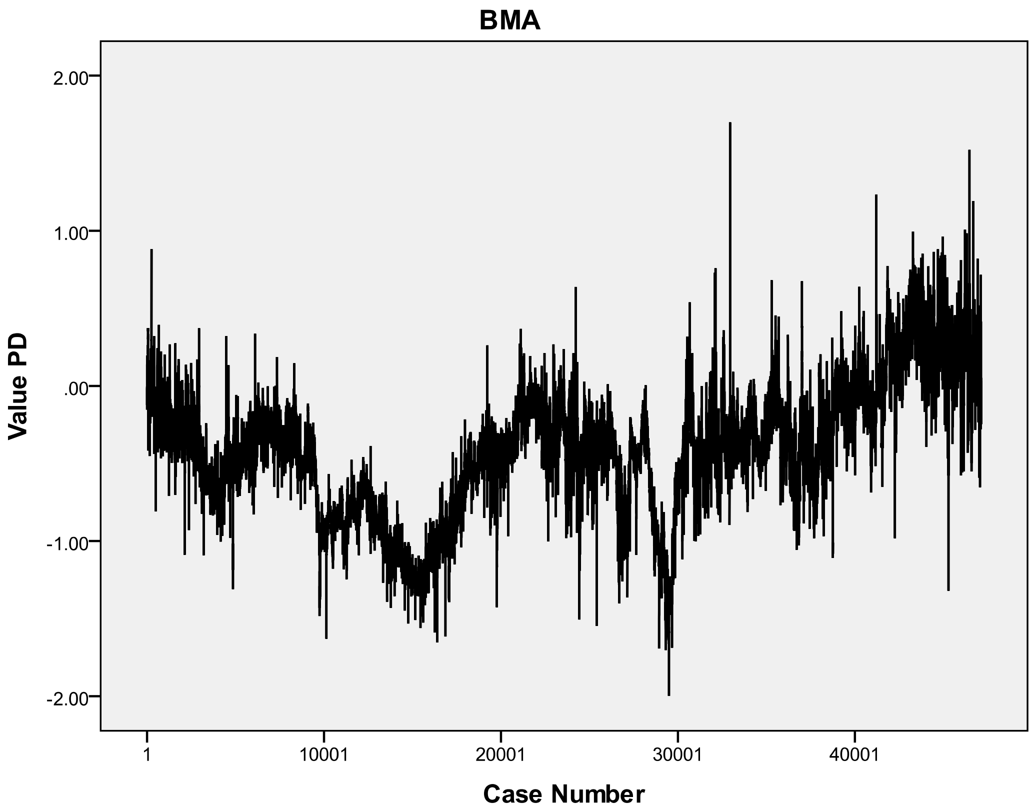

ORTE
2.00
1.00
.00
-1.00
-2.00
Mean PD
1
10001
20001
30001
40001
Case Number



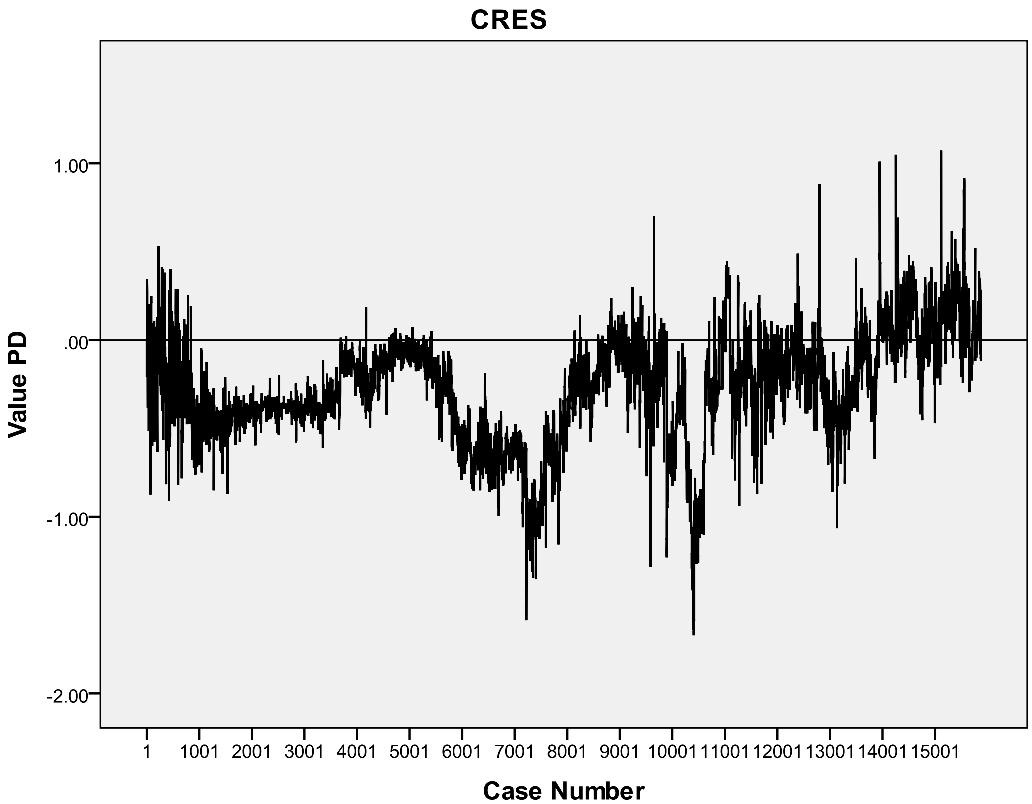
OCIC
6.00
4.00
2.00
.00
-2.00
-4.00
Mean PD
1
1001
2001
3001
4001
5001
6001
7001
8001
9001
10001
11001
12001
13001
14001
15001
16001
17001
18001
19001
20001
21001
22001
23001
24001
25001
26001
27001
Case Number

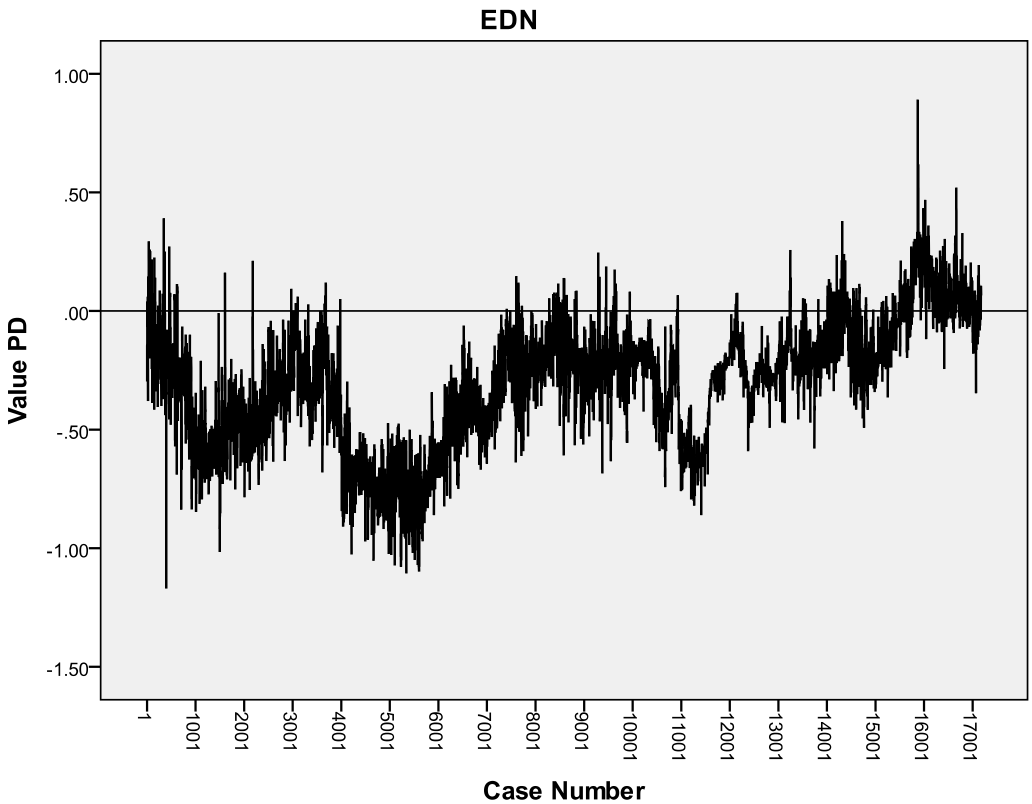

ETEL
3.00
2.00
1.00
.00
-1.00
-2.00
-3.00
Mean PD
1
51
101
151
201
251
301
351
401
451
501
551
601
651
701
751
Case Number

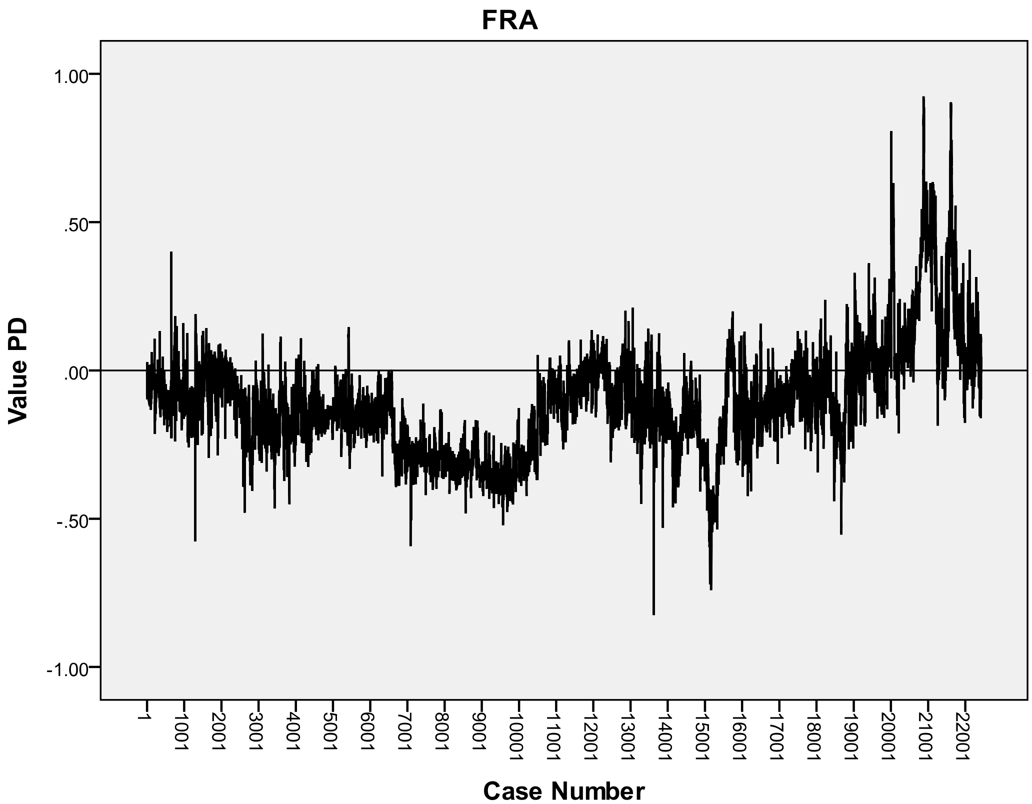

PHDC
Mean PD
3.00
2.00
1.00
.00
-1.00
-2.00
-3.00
1
21
41
61
81
101
121
141
161
181
201
221
241
261
281
301
321
341
361
Case Number



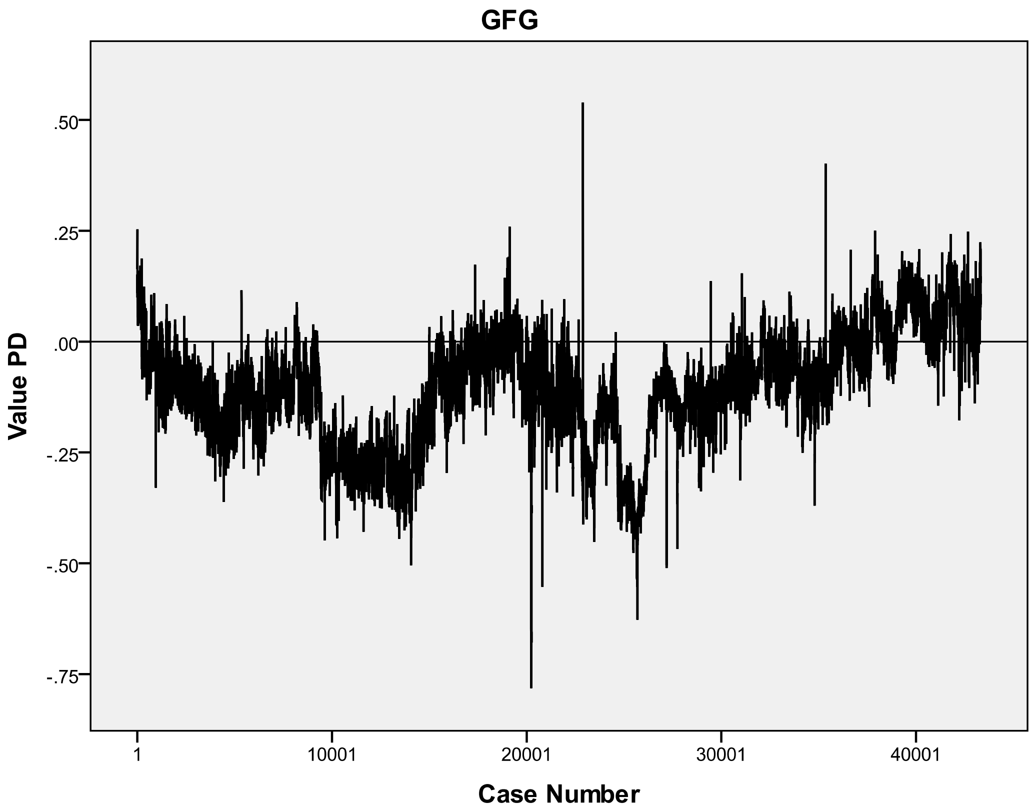
BMA
2.00
1.00
.00
-1.00
-2.00
Value PD
1
10001
20001
30001
40001
Case Number


CRES
Value PD
1.00
.00
-1.00
-2.00
1
1001
2001
3001
4001
5001
6001
7001
8001
9001
10001
11001
12001
13001
14001
15001
Case Number

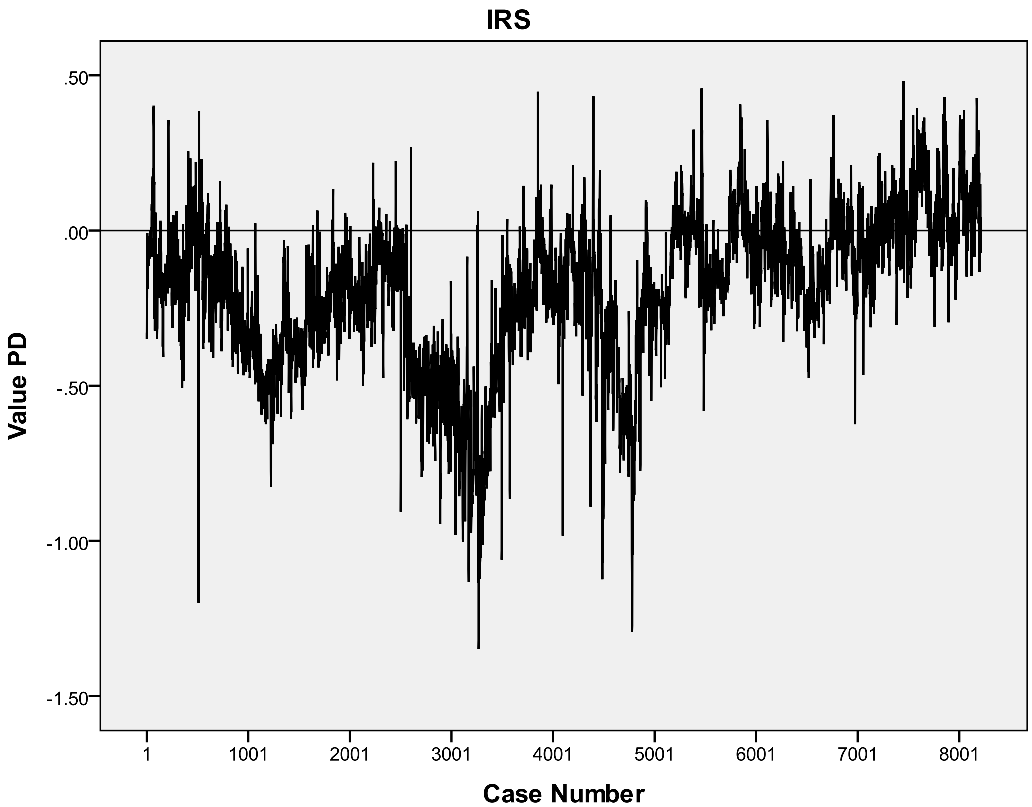

EDN
1.00
.50
.00
-.50
-1.00
-1.50
Value PD
1
1001
2001
3001
4001
5001
6001
7001
8001
9001
10001
11001
12001
13001
14001
15001
16001
17001
Case Number



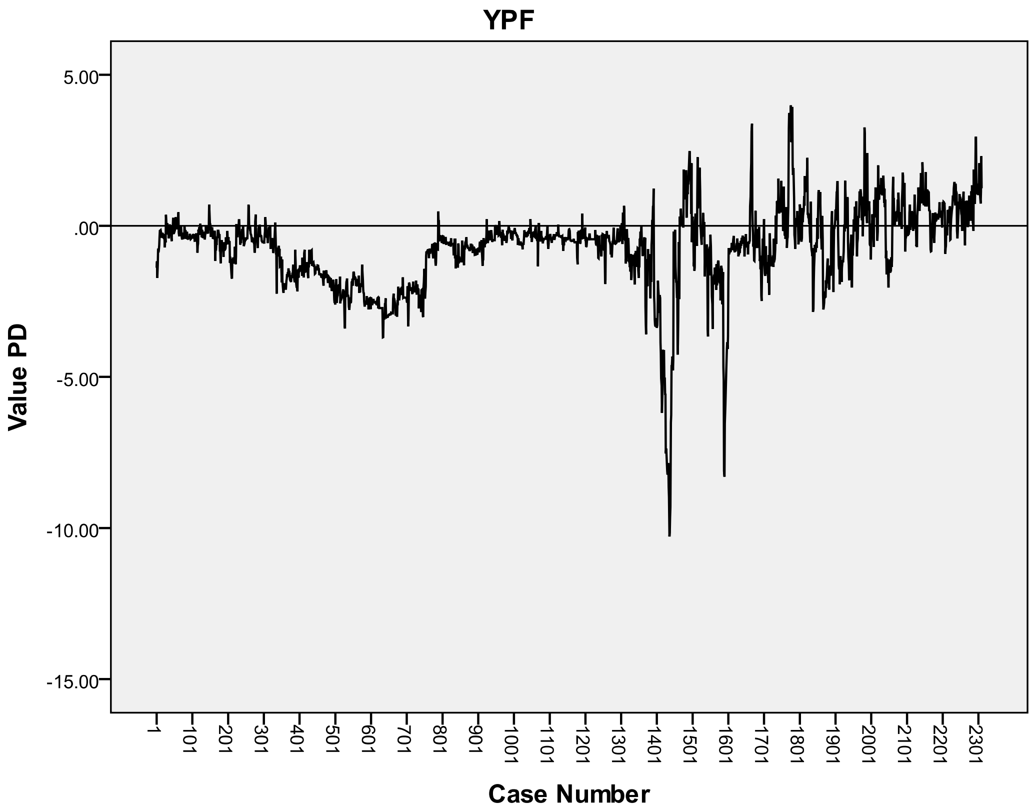
INSERT TABLE 5-7 HERE

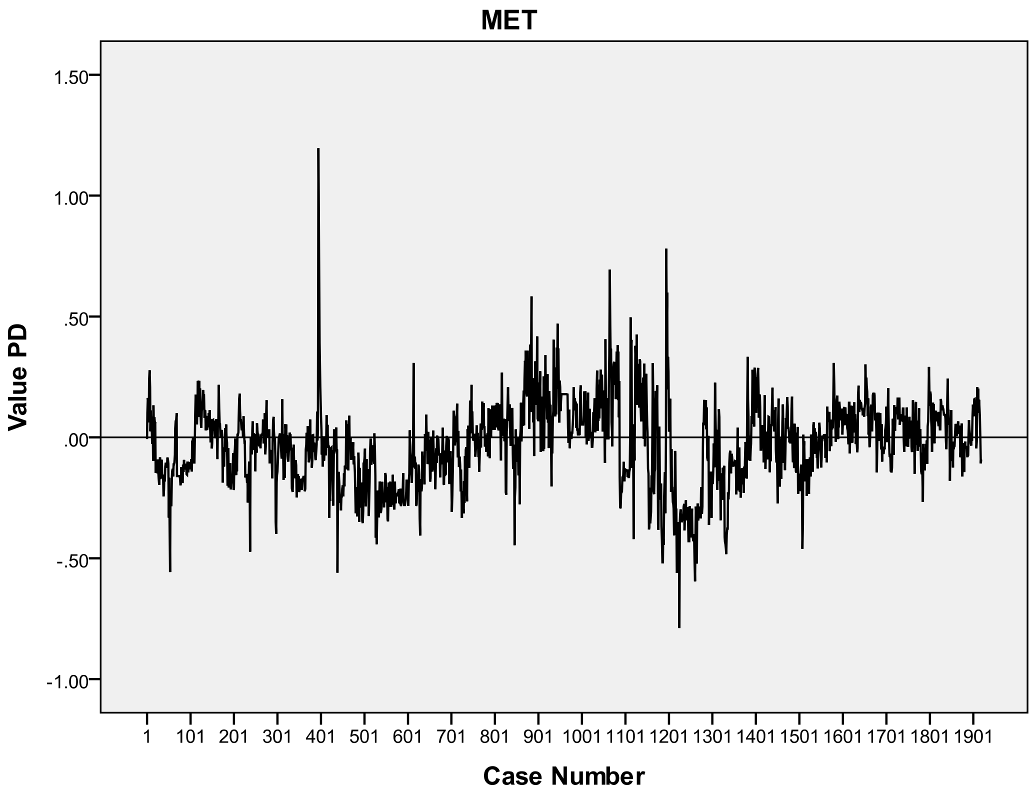


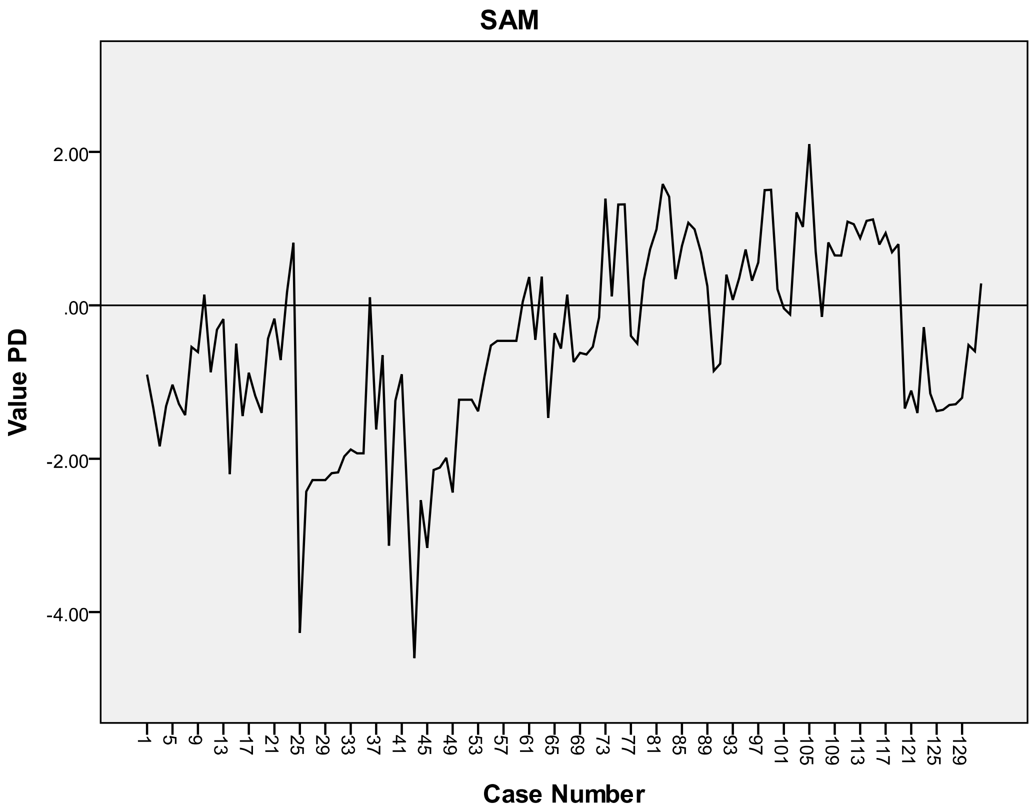
GFG
.50
.25
.00
-.25
-.50
-.75
Value PD
1
10001
20001
30001
40001
Case Number



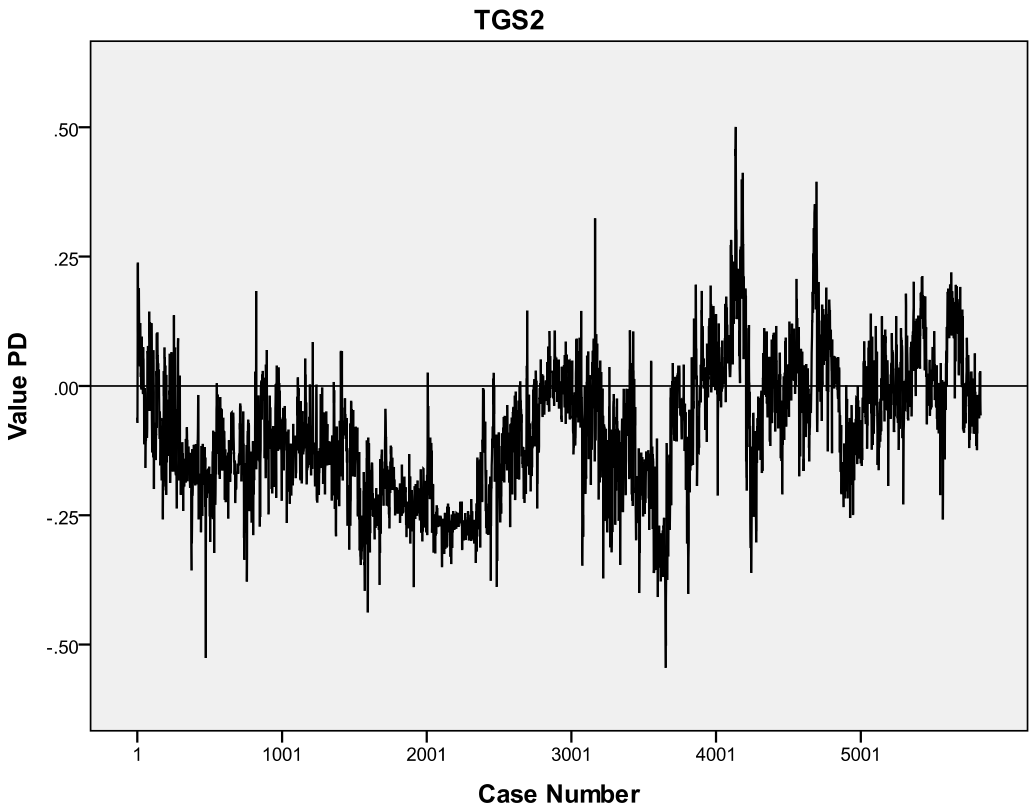
IRS
.50
.00
-.50
-1.00
-1.50
Value PD
1
1001
2001
3001
4001
5001
6001
7001
8001
Case Number


YPF
Value PD
5.00
.00
-5.00
-10.00
-15.00
1
101
201
301
401
501
601
701
801
901
1001
1101
1201
1301
1401
1501
1601
1701
1801
1901
2001
2101
2201
2301
Case Number


MET
Value PD
1.50
1.00
.50
.00
-.50
-1.00
1 101 201 301 401 501 601 701 801 901 1001 1101 1201 1301 1401 1501 1601 1701 1801 1901
Case Number

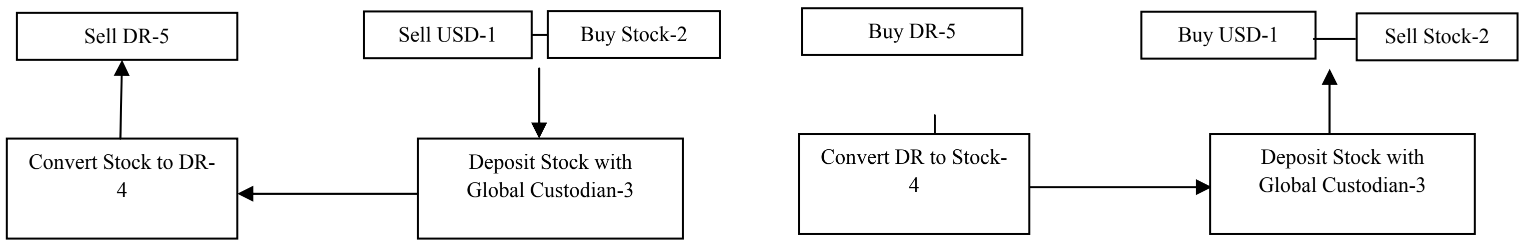


SAM
2.00
.00
-2.00
-4.00
Value PD
1
5
9
13
17
21
25
29
33
37
41
45
49
53
57
61
65
69
73
77
81
85
89
93
97
101
105
109
113
117
121
125
129
Case Number



TGS2
.50
.25
.00
-.25
-.50
Value PD
1
1001
2001
3001
4001
5001
Case Number

10.5 Appendix 5 Example of Arbitrage Strategy



DR Selling at Premium   DR Selling at Discount

1 Foreign Exchange Rate Conversion 6 bps

2 Trading Costs Fee in Local Markets Table 3-5 for trading costs in our sample markets

3 Global Custodian Fees Global Settlement Fees of $115 for GDRs and $60 for ADRs and Global Safe Keeping Fees of 45bps for GDRs and 22bps for ADRs

4 DR Conversion Fees of maximum of 5 cents per DR

5 Trading Costs in Foreign Market Table 3-5 for trading costs in our sample markets

Source: Bank of New York Mellon DR Converter www.bnym.com and Elkins/McSherry

Figure A.1 Overview of Arbitrage Operations and its Costs in the DR market

On July 16th 2009 at 9:43:18GMT a bid order comes to the EGX for OCIC demanding 2000 shares at EGP196 and there is another ask order for 5000 shares at EGP198 equivalent to $35.13 converted at the latest EGP/$ exchange rate of $/EGP5.58 at 10:42:03 and a second later in LSE there is a demand on 1000 shares of the GDR for a bid of $35.56 and ask for 2000 GDRs for $35.59. An active arbitrageur will first identify that there is a price deviation of 46cents/share since the bundling ratio of GDR to stock for OCIC is 1:1 and that she can buy 2000 shares of the underpriced stock on the EGX and short sell 2000 share of the overpriced GDR making a gross profit of $920 instantly. However, she first needs to identify if this deviation will be profitable to her by calculating the following trading costs involved with this arbitrage:

i. *Direct Trading Costs:* this includes the commissions, taxes, and fees involved with buying and selling in each market. Table 5 summarizes average trading costs in basis points of trading in each of the markets in our sample. To be conservative in our estimates of the arbitrageur's trading costs, we will include trading costs estimates that include direct and indirect costs of trade. We will also include 6bp/share foreign exchange rate commission for buying Egyptian pounds to convert the stock price to dollar. To carry on with our example, the trading costs in Egypt in 2009 averaged at 27bp per share and in LSE at 23bp per share. This makes the total fees of $0.174/share, totaling $348.5 for the arbitrage trade.

ii. *Global Custodian and Safe Keeping Fees:* The arbitrageur will then have to deposit the shares with a global custodian and pay a fixed one time settlement fee of $115 per trade and pay a global safe keeping fee of 45bp/share. This totals another $ 115.5

iii. *DR Conversion Fees:* The arbitrageur will then have to instruct the global custodian to convert the shares to GDRs by giving instructions to the depository bank which charges a maximum of $0.05 per DR issuance fee, which totals another $100.

The arbitrageur now knows that she will make a net profit of $920-$348.5-$115.5-$100=$356. Since the trade is profitable, the arbitrageur will then execute the order buying 2000 shares on the EGX and selling 2000 shares on the GDR. In the intraday trade data, we can empirically identify the previous arbitrage by observing the trade or series of trades on the EGX at 9:43:20 for 2000 shares at EGP196 and a trade at 9:43:24 for 2000 GDRs $35.5

10.6 Appendix 6 Example of Extracted Arbitrage Trade Data for Egyptian and Argentinean Stocks and DRs

Commercial International Bank COMI							
Stock Trades				DR Trades			
Date	Time	Price$	Vol	Date	Time	Price$	Vol
				31-Jul-08	11:05:37	10.00	10000
31-Jul-08	11:05:44	9.4	200				
31-Jul-08	11:05:44	9.4	100				
31-Jul-08	11:05:44	9.4	4133				
31-Jul-08	11:05:44	9.4	61				
31-Jul-08	11:05:44	9.4	2000				
31-Jul-08	11:05:44	9.4	100				
31-Jul-08	11:05:44	9.4	100				
31-Jul-08	11:05:44	9.4	200				
31-Jul-08	11:05:44	9.4	500				
31-Jul-08	11:05:44	9.4	500				
31-Jul-08	11:05:44	9.4	40				
31-Jul-08	11:05:44	9.4	150				
31-Jul-08	11:05:44	9.4	1916				
31-Jul-08	11:06:19	9.4	200				
31-Jul-08	11:06:19	9.4	34				
31-Jul-08	11:06:19	9.4	500				
31-Jul-08	11:06:19	9.4	100				
31-Jul-08	11:06:19	9.4	100				
31-Jul-08	11:06:19	9.4	1000				
31-Jul-08	11:06:19	9.4	100				
31-Jul-08	11:06:19	9.4	1500				
31-Jul-08	11:06:19	9.4	1466				
				31-Jul-08	11:06:39	10.00	10000
31-Jul-08	11:06:51	9.4	34				
31-Jul-08	11:06:51	9.4	200				
31-Jul-08	11:06:51	9.4	100				
31-Jul-08	11:06:51	9.4	4666				
31-Jul-08	11:08:33	9.4	5114				
31-Jul-08	11:08:33	9.4	834				
				31-Jul-08	11:08:53	10.00	1750
				31-Jul-08	11:09:24	10.00	6230
31-Jul-08	11:10:10	9.4	150				
31-Jul-08	11:10:10	9.4	500				
31-Jul-08	11:10:10	9.4	4886				
31-Jul-08	11:10:10	9.4	2444				
				31-Jul-08	11:10:42	9.99	676
31-Jul-08	11:11:15	9.4	676				

EGF Hermes HRHO							
Stock Trades				DR Trades			
Date	Time	Price$	Vol	Date	Time	Price$	Vol
22-Jan-08	9:42:21	20.6	4628.5				
22-Jan-08	9:42:21	20.6	12.5				
22-Jan-08	9:42:21	20.6	50				
22-Jan-08	9:42:21	20.6	3000				
22-Jan-08	9:42:33	20.6	2309				
22-Jan-08	9:42:33	20.6	191				
22-Jan-08	9:42:55	20.6	60				
				22-Jan-08	9:42:57	21.8	10000
4-Feb-10	10:50:10	11.6	4400.5				
4-Feb-10	10:50:26	11.6	599.5				
				4-Feb-10	10:52:33	11.3	2500
				4-Feb-10	10:52:37	11.3	2500

Orascom Construction ORTE							
Stock Trades				DR Trades			
Date	Time	Price$	Vol	Date	Time	Price$	Vol
25-Feb-08	9:01:00	15.1	250				
25-Feb-08	9:01:11	15.1	100				
25-Feb-08	9:01:11	15.1	100				
				25-Feb-08	9:01:34	14.7	1840
				25-Feb-08	9:01:41	14.7	3160
25-Feb-08	9:02:01	15.1	4097				
25-Feb-08	9:02:01	15.1	903				
25-Feb-08	9:02:24	15.1	97				
25-Feb-08	9:02:24	15.1	203				
31-Mar-08	12:19:32	13.8	5000				
31-Mar-08	12:19:32	13.8	3750				
31-Mar-08	12:19:32	13.8	4577				
31-Mar-08	12:19:32	13.8	5000				
31-Mar-08	12:19:32	13.8	3073				
31-Mar-08	12:19:32	13.8	100				
31-Mar-08	12:19:32	13.8	10000				
31-Mar-08	12:19:32	13.8	500				
31-Mar-08	12:19:32	13.8	500				
31-Mar-08	12:19:32	13.8	5000				
31-Mar-08	12:19:32	13.8	62500				
				31-Mar-08	12:19:44	13.5	50000
				31-Mar-08	12:19:45	13.5	2940
				31-Mar-08	12:19:45	13.5	47060
				10-Feb-10	9:58:16	6	2000
10-Feb-10	9:58:17	6.2	600				

10-Feb-10	9:58:34	6.2	1000				
10-Feb-10	9:58:39	6.2	2000				
10-Feb-10	9:58:41	6.2	100				
10-Feb-10	9:58:45	6.2	1000				
10-Feb-10	9:58:48	6.2	1000				
10-Feb-10	9:58:57	6.2	388				
10-Feb-10	9:58:57	6.2	12				
10-Feb-10	9:58:57	6.2	600				
10-Feb-10	9:58:57	6.2	400				
10-Feb-10	9:59:11	6.2	1000				
10-Feb-10	9:59:22	6.2	1000				
10-Feb-10	9:59:22	6.2	600				
10-Feb-10	9:59:23	6.2	4000				
10-Feb-10	9:59:37	6.2	4000				
10-Feb-10	9:59:40	6.2	2000				
10-Feb-10	9:59:49	6.2	40				
				10-Feb-10	10:00:01	6	2000
10-Feb-10	10:00:04	6.240889	484.2				
10-Feb-10	10:00:04	6.240889	1540				
10-Feb-10	10:00:04	6.240889	1975.8				
10-Feb-10	10:00:05	6.240889	222.2				
10-Feb-10	10:00:19	6.240889	100				
10-Feb-10	10:00:23	6.240889	300				
10-Feb-10	10:00:35	6.240889	202				
10-Feb-10	10:00:35	6.240889	460				
10-Feb-10	10:00:45	6.240889	200				
10-Feb-10	10:00:46	6.240889	138				
10-Feb-10	10:00:46	6.240889	62				
				10-Feb-10	10:01:44	6	2000

Orascom Construction Industries OCIC							
Stock Trades				DR Trades			
Date	Time	Price$	Vol	Date	Time	Price$	Vol
				30-Mar-09	10:24:35	24.5	3040
30-Mar-09	10:24:48	24.9	500				
30-Mar-09	10:24:48	24.9	40				
30-Mar-09	10:24:48	24.9	200				
30-Mar-09	10:24:48	24.9	40				
30-Mar-09	10:24:48	24.8	500				
30-Mar-09	10:24:48	24.8	250				
30-Mar-09	10:24:48	24.8	2530				
30-Mar-09	10:24:48	24.8	940				
				30-Mar-09	10:25:29	24.3	3000
				30-Mar-09	10:25:34	24.3	3000
				30-Mar-09	10:25:39	24.3	3000
30-Mar-09	10:25:54	24.8	25				
30-Mar-09	10:25:54	24.8	975				
30-Mar-09	10:26:07	24.8	1000				

30-Mar-09	10:26:08	24.8	2085				
30-Mar-09	10:26:08	24.8	2742				
30-Mar-09	10:26:08	24.8	63				
30-Mar-09	10:26:08	24.8	100				
30-Mar-09	10:26:08	24.8	10				
30-Mar-09	10:26:16	24.8	2000				
30-Mar-09	10:26:18	24.8	490				
30-Mar-09	10:26:18	24.8	20				
30-Mar-09	10:26:18	24.8	100				
30-Mar-09	10:26:18	24.8	390				
30-Mar-09	10:26:35	24.8	3188				

Telecom Egypt ETEL							
Stock Trades				DR Trades			
Date	Time	Price$	Vol	Date	Time	Price$	Vol
5-Feb-08	9:39:02	20.2	985				
				5-Feb-08	9:41:08	19.5	1000
5-Feb-08	9:42:38	20.2	1000				
5-Feb-08	9:43:16	20.2	1050				
5-Feb-08	9:43:41	20.2	450				
5-Feb-08	9:43:41	20.2	2050				
5-Feb-08	9:44:13	20.1	10000				
				5-Feb-08	9:44:53	19.5	1000
5-Feb-08	9:45:11	20.1	25000				
5-Feb-08	9:45:22	20.1	1000				
5-Feb-08	9:46:20	20.1	11950				
5-Feb-08	9:46:20	20.1	3355				
				5-Nov-09	9:53:59	14	20000
				5-Nov-09	9:54:58	14	400
5-Nov-09	9:58:36	15.6	5000				
5-Nov-09	9:58:36	15.6	15000				
				16-Nov-09	9:47:32	15	500
16-Nov-09	9:48:10	16.1	2500				
				16-Nov-09	9:49:37	15	2000
16-Nov-09	9:49:47	16.0	2500				
				16-Nov-09	9:50:06	15	2500

Palm Hills PHDC							
Stock Trades				DR Trades			
Date	Time	Price$	Vol	Date	Time	Price$	Vol
19-Mar-09	11:41:07	5.5	1500				

				19-Mar-09	11:41:08	5.3	1500
				19-Mar-09	11:41:08	5.3	1500
19-Mar-09	11:41:12	5.5	3000				
19-Mar-09	11:41:34	5.5	300				
				19-Mar-09	11:41:46	5.3	1500
23-Jun-09	8:12:40	7.05	200				
23-Jun-09	8:12:40	7.05	1800				
				23-Jun-09	8:12:42	8.3	2000

Banco Macro BMA							
Stock Trades				DR Trades			
Date	Time	Price$	Vol	Date	Time	Price$	Vol
				4-Nov-08	14:31:17	8.4	100
4-Nov-08	14:31:18	9.8	620				
4-Nov-08	14:31:19	9.8	380				
4-Nov-08	14:31:22	9.8	100				
4-Nov-08	14:31:37	9.8	1000				
4-Nov-08	14:31:47	9.8	1000				
				4-Nov-08	14:31:53	8.5	100
				4-Nov-08	14:32:16	8.5	100
				4-Nov-08	14:32:26	8.5	200
4-Nov-08	14:32:46	9.7	536				
4-Nov-08	14:32:46	9.7	9464				
				4-Nov-08	14:32:46	8.6	9500
				4-Nov-08	14:32:46	8.5	100
7-Oct-09	19:27:33	24.7	1.1				
				7-Oct-09	19:27:33	25.1	100
				7-Oct-09	19:29:20	25.0	300
				7-Oct-09	19:29:20	25.2	500
7-Oct-09	19:30:06	24.7	96.4				
7-Oct-09	19:30:07	24.7	500				
7-Oct-09	19:30:07	24.7	20.8				
				7-Oct-09	19:31:07	25.0	100
				11-Nov-09	19:10:32	31.9	200
11-Nov-09	19:11:19	31.1	37.2				
11-Nov-09	19:11:29	31.1	12.4				
11-Nov-09	19:12:00	31.1	24.5				
11-Nov-09	19:12:59	31.2	175.5				
				11-Nov-09	19:14:36	31.9	200
11-Nov-09	19:15:11	31.5	13				
11-Nov-09	19:15:11	31.5	6.1				

11-Nov-09	19:15:28	31.1	4.5				
11-Nov-09	19:22:22	31.2	166				
				11-Nov-09	19:26:01	31.8	400
11-Nov-09	19:26:03	31.2	34				
11-Nov-09	19:26:04	31.2	366				

BBVA Banco Frances FRA							
Stock Trades				DR Trades			
Date	Time	Price$	Vol	Date	Time	Price$	Vol
				10-Mar-08	19:14:47	7.4	200
10-Mar-08	19:14:51	7.6	20.666667				
10-Mar-08	19:14:52	7.6	200				
10-Mar-08	19:14:52	7.6	200				
10-Mar-08	19:14:52	7.6	133.33333				
10-Mar-08	19:14:52	7.6	166.66667				
10-Mar-08	19:14:52	7.6	79.333333				
10-Mar-08	19:14:56	7.6	87.333333				
10-Mar-08	19:14:57	7.6	112.66667				
				10-Mar-08	19:14:59	7.4	800
				23-Oct-08	19:01:16	2.2	300
23-Oct-08	19:02:11	2.5	166.66667				
23-Oct-08	19:02:12	2.5	133.33333				
				23-Oct-08	19:02:14	2.2	600
				23-Oct-08	19:03:18	2.2	600
				23-Oct-08	19:03:21	2.2	200
				23-Oct-08	19:03:23	2.2	100
				23-Oct-08	19:03:25	2.2	100
				23-Oct-08	19:04:21	2.2	400
				23-Oct-08	19:04:21	2.2	100
				23-Oct-08	19:04:57	2.2	5000
				23-Oct-08	19:04:57	2.2	5000
23-Oct-08	19:10:18	2.5	200				
23-Oct-08	19:10:18	2.5	198				
23-Oct-08	19:10:19	2.5	1146.3333				
23-Oct-08	19:10:19	2.5	3333.3333				
				23-Oct-08	19:10:44	2.2	10000
23-Oct-08	19:10:45	2.5	10000				
				23-Oct-08	19:11:02	2.2	100
23-Oct-08	19:11:06	2.5	100				
				3-Apr-09	15:20:03	2.5	100
				3-Apr-09	15:20:05	2.5	100
3-Apr-09	15:20:20	2.6	300				
				3-Apr-09	15:22:02	2.5	100

				3-Apr-09	15:22:13	2.5	100
				3-Apr-09	15:23:06	2.5	1000
3-Apr-09	15:23:18	2.6	36.666667				
3-Apr-09	15:23:19	2.6	522.66667				
3-Apr-09	15:28:06	2.6	540.66667				
				8-Jun-09	19:43:46	4.6	2200
8-Jun-09	19:43:56	4.8	2200				
				8-Jun-09	19:44:23	4.6	8500
8-Jun-09	19:44:35	4.8	7800				
				8-Jun-09	19:44:54	4.6	1400
8-Jun-09	19:45:06	4.8	1400				
				8-Jun-09	19:45:41	4.6	1700
8-Jun-09	19:45:46	4.8	1600				
8-Jun-09	19:46:49	4.8	793				

Edenor EDN							
Stock Trades				DR Trades			
Date	Time	Price$	Vol	Date	Time	Price$	Vol
30-Apr-08	19:01:23	19.2	500				
30-Apr-08	19:01:23	19.2	138				
30-Apr-08	19:01:28	19.2	500				
30-Apr-08	19:01:35	19.2	100				
				30-Apr-08	19:01:50	18.8	500
				30-Apr-08	19:01:50	18.8	500
				30-Apr-08	19:01:51	18.8	100
15-Jan-09	17:43:11	4.8	200				
15-Jan-09	17:44:47	4.8	300				
15-Jan-09	17:44:47	4.8	250				
15-Jan-09	17:44:47	4.8	500				
				15-Jan-09	17:44:54	4.5	700

Grupo Financiero Galicia GFG							
Stock Trades				DR Trades			
Date	Time	Price$	Vol	Date	Time	Price$	Vol
				21-May-08	16:02:35	6.0	800
21-May-08	16:03:36	6.2	1200				
				21-May-08	16:03:49	6.0	100
				21-May-08	16:03:49	6.0	100
				21-May-08	16:03:49	6.0	100
				21-May-08	16:03:49	6.0	100
				3-Jun-08	18:40:58	5.5	100
				3-Jun-08	18:41:23	5.5	100
3-Jun-08	18:41:33	5.8	200				
				3-Jun-08	18:41:39	5.5	100
				3-Jun-08	18:41:46	5.5	500
3-Jun-08	18:41:47	5.8	100				
3-Jun-08	18:41:56	5.8	487.3				
3-Jun-08	18:41:56	5.8	12.7				
				3-Jun-08	18:42:03	5.5	100
3-Jun-08	18:42:11	5.8	100				
				3-Jun-08	18:42:24	5.5	100
				3-Jun-08	18:42:36	5.5	100
				3-Jun-08	18:42:55	5.5	100
3-Jun-08	18:43:16	5.8	100				
3-Jun-08	18:43:24	5.8	200				
24-Apr-09	16:15:46	2.1	500				
24-Apr-09	16:16:28	2.1	3000				
24-Apr-09	16:16:44	2.1	3630				
				24-Apr-09	16:19:13	2.0	5000
24-Apr-09	16:19:19	2.1	1000				
24-Apr-09	16:19:19	2.1	1500				
24-Apr-09	16:19:54	2.1	2500				

IRSA							
Stock Trades				DR Trades			
Date	Time	Price$	Vol	Date	Time	Price$	Vol
8-Jul-08	19:54:28	11.2	21.1				
8-Jul-08	19:54:28	11.2	60.7				

8-Jul-08	19:54:33	11.2	239.3				
8-Jul-08	19:54:33	11.2	184.7				
8-Jul-08	19:54:33	11.2	176				
				8-Jul-08	19:54:41	10.8	300
				8-Jul-08	19:54:46	10.8	100
				8-Jul-08	19:54:48	10.8	100
8-Jul-08	19:55:10	11.2	8.7				
8-Jul-08	19:55:59	11.2	91.3				
3-Nov-08	16:14:04	4.4	500				
				3-Nov-08	16:14:19	3.7	200
				3-Nov-08	16:14:19	3.7	300
				3-Nov-08	16:42:22	3.7	100
				3-Nov-08	16:42:22	3.7	200
				3-Nov-08	16:42:24	3.7	100
				3-Nov-08	16:42:24	3.7	100
3-Nov-08	16:42:42	4.3	17.8				
3-Nov-08	16:43:09	4.3	500				
3-Nov-08	16:43:10	4.3	100				
				3-Nov-08	16:43:17	3.7	100
22-Dec-09	14:57:06	9.5	500				
22-Dec-09	14:57:06	9.5	140				
22-Dec-09	14:57:15	9.5	200				
22-Dec-09	14:57:19	9.6	602.4				
22-Dec-09	14:57:19	9.6	500				
				22-Dec-09	14:57:27	10.0	1000
				22-Dec-09	15:04:06	10.0	200
				22-Dec-09	15:09:29	10.0	300
22-Dec-09	15:09:56	9.6	41				
22-Dec-09	15:12:00	9.7	164				
22-Dec-09	15:12:00	9.7	96				
				22-Dec-09	15:14:48	10.1	100

Metro Gas MET							
Stock Trades				DR Trades			
Date	Time	Price$	Vol	Date	Time	Price$	Vol
22-May-08	15:00:47	5.3	1000				
				22-May-08	15:00:50	5.5	1000
				22-May-08	15:00:51	5.4	100
				22-May-08	15:00:52	5.4	100
22-May-08	15:00:53	5.3	1000				
20-May-08	19:09:40	3.7	500				
				20-May-08	19:09:51	3.4	500
				20-May-08	19:11:29	3.5	1000
20-May-08	19:11:45	3.7	130				
20-May-08	19:18:07	3.7	100				
20-May-08	19:20:52	3.6	85.2				
				20-May-08	19:58:52	3.6	300
				3-Nov-08	14:32:47	1.3	200
3-Nov-08	14:41:08	1.6	200				
				3-Nov-08	14:41:30	1.3	200
				3-Nov-08	14:41:31	1.3	500
3-Nov-08	14:41:41	1.6	700				
3-Nov-08	14:51:11	1.6	400				
3-Nov-08	14:51:16	1.6	469.6				
3-Nov-08	14:51:16	1.7	700				
3-Nov-08	14:52:08	1.7	830.4				
				3-Nov-08	15:02:03	1.3	300
				3-Nov-08	15:02:05	1.3	400
3-Nov-08	15:06:04	1.7	169.6				
3-Nov-08	15:06:04	1.7	430.4				
3-Nov-08	15:09:40	1.7	500				
3-Nov-08	15:25:51	1.7	69.6				
3-Nov-08	15:25:51	1.7	948.4				
				3-Nov-08	15:31:37	1.3	100
3-Nov-08	15:38:01	1.7	51.6				
				3-Nov-08	15:40:02	1.4	600
3-Nov-08	15:40:07	1.7	600				
3-Nov-08	15:46:10	1.7	38.4				
3-Nov-08	15:49:58	1.7	261.6				
				3-Nov-08	15:50:06	1.4	300
				3-Nov-08	15:50:12	1.4	300
3-Nov-08	15:50:18	1.7	300				

TGS2							
Stock Trades				DR Trades			
Date	Time	Price$	Vol	Date	Time	Price$	Vol
26-Jun-08	18:15:45	3.5	400				
26-Jun-08	18:15:46	3.5	20				
26-Jun-08	18:15:46	3.5	200				
26-Jun-08	18:15:47	3.5	150				
26-Jun-08	18:15:47	3.5	230				
				26-Jun-08	18:15:55	3.2	1000
				15-Sep-08	19:22:33	3.0	100
				15-Sep-08	19:22:34	3.0	800
15-Sep-08	19:22:38	3.2	100				
15-Sep-08	19:22:39	3.2	900				
				15-Sep-08	19:22:41	3.0	1000
15-Sep-08	19:22:43	3.2	785.2				
15-Sep-08	19:22:43	3.2	214.8				
15-Sep-08	19:40:07	3.2	100				
15-Sep-08	19:46:07	3.2	100				
15-Sep-08	19:47:27	3.2	500				
				15-Sep-08	19:47:38	3.0	100
				15-Sep-08	19:47:39	3.1	400
				5-Nov-08	15:03:16	2.0	100
				5-Nov-08	15:03:16	2.0	200
5-Nov-08	15:03:22	2.3	1000				
				5-Nov-08	15:03:30	2.0	400
5-Nov-08	15:03:34	2.3	700				
5-Nov-08	15:16:27	2.3	300				
5-Nov-08	15:16:27	2.3	340.8				
5-Nov-08	15:29:20	2.3	100				
5-Nov-08	15:34:20	2.3	59.2				
5-Nov-08	15:34:20	2.3	600				
5-Nov-08	15:34:20	2.3	299.4				
5-Nov-08	15:36:46	2.3	100.6				
5-Nov-08	15:36:54	2.3	155.6				
				5-Nov-08	16:00:57	2.0	100
5-Nov-08	16:05:15	2.3	389.6				
5-Nov-08	16:16:07	2.3	654.8				
5-Nov-08	16:16:07	2.3	3345.2				
				5-Nov-08	16:16:43	2.0	100
				5-Nov-08	16:17:23	2.0	200
				5-Nov-08	16:17:23	2.0	100
5-Nov-08	16:17:28	2.3	1000				

				5-Nov-08	16:17:37	1.9	600
				5-Nov-08	16:17:51	2.0	100
				5-Nov-08	16:17:51	2.0	500
5-Nov-08	16:23:55	2.3	400				
5-Nov-08	16:30:59	2.3	200				
				14-Jul-09	13:57:42	2.1	100
14-Jul-09	14:00:10	2.3	300				
14-Jul-09	14:00:10	2.3	10				
				14-Jul-09	14:01:19	2.1	400
14-Jul-09	14:07:14	2.3	106.4				
14-Jul-09	14:10:06	2.3	293.6				
14-Jul-09	14:10:57	2.3	396.4				
14-Jul-09	14:50:12	2.3	279.4				
14-Jul-09	14:54:35	2.3	3.6				
				14-Jul-09	15:26:55	2.2	100
				14-Jul-09	15:43:55	2.2	100

Cresud CRESY Stock Trades				DR Trades			
Date	Time	Price$	Vol	Date	Time	Price$	Vol
22-Jan-08	15:06:07	16.9	0.9				
22-Jan-08	15:06:07	16.9	199.1				
				22-Jan-08	15:06:31	16.5	300
				22-Jan-08	15:06:46	16.4	200
22-Jan-08	15:06:54	16.9	0.9				
22-Jan-08	15:06:54	16.8	99.1				
				19-Feb-08	14:52:44	18.5	280
				19-Feb-08	14:52:44	18.6	100
19-Feb-08	14:52:51	19.0	380				
				19-Feb-08	14:54:57	18.5	400
				19-Feb-08	14:54:57	18.6	100
				24-Jun-09	17:11:08	9.4	100
				24-Jun-09	17:12:28	9.4	800
				24-Jun-09	17:12:28	9.4	400
				24-Jun-09	17:13:31	9.4	400
				24-Jun-09	17:13:31	9.4	100
				24-Jun-09	17:13:31	9.4	100
				24-Jun-09	17:13:31	9.4	100

				24-Jun-09	17:13:31	9.3	100
				24-Jun-09	17:13:31	9.4	100
				24-Jun-09	17:13:31	9.4	500
				24-Jun-09	17:13:32	9.4	100
24-Jun-09	17:13:36	9.8	1000				
				24-Jun-09	17:14:13	9.4	600
				24-Jun-09	17:14:13	9.4	200
				24-Jun-09	17:14:13	9.4	100
				24-Jun-09	17:14:13	9.4	100
				24-Jun-09	17:14:13	9.4	100
24-Jun-09	17:14:18	9.8	1000				
				24-Jun-09	17:14:26	9.4	200
				24-Jun-09	17:14:26	9.4	100
				24-Jun-09	17:14:26	9.4	100
				24-Jun-09	17:14:26	9.4	100
24-Jun-09	17:14:29	9.8	1000				
				24-Jun-09	17:14:33	9.4	200
				24-Jun-09	17:14:33	9.4	200
				24-Jun-09	17:14:33	9.4	100
				24-Jun-09	17:14:33	9.4	100
24-Jun-09	17:14:39	9.8	400				
24-Jun-09	17:15:08	9.8	600				
				24-Jun-09	17:15:43	9.4	100
				24-Jun-09	17:15:50	9.4	100
				24-Jun-09	17:16:18	9.4	100
				24-Jun-09	17:16:21	9.4	100
				24-Jun-09	17:16:24	9.4	100
				24-Jun-09	17:16:26	9.4	100
				24-Jun-09	17:16:28	9.4	100
				24-Jun-09	17:16:31	9.4	100
				24-Jun-09	17:16:33	9.4	100
				24-Jun-09	17:16:35	9.4	100
24-Jun-09	17:16:45	9.8	1000				

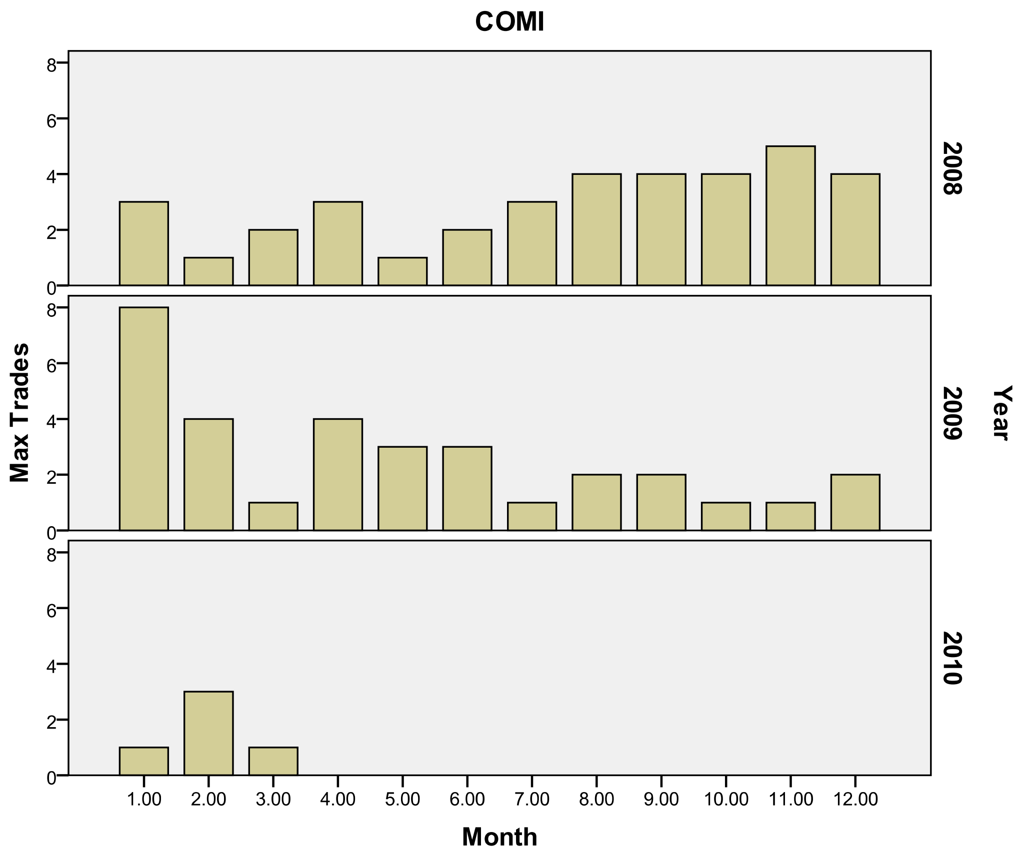
APSA SAM							
Stock Trades				DR Trades			
Date	Time	Price$	Vol	Date	Time	Price$	Vol
				24-Jun-08	18:44:39	11.7	100
				24-Jun-08	18:44:39	11.7	100
				24-Jun-08	18:44:39	11.7	100
				24-Jun-08	18:44:39	11.7	100
24-Jun-08	18:44:54	13.9	50				
24-Jun-08	18:44:54	13.9	350				
				24-Jun-08	18:45:02	11.7	100
24-Jun-08	18:45:10	13.9	100				
				24-Jun-08	18:46:20	11.7	100
				24-Jun-08	18:46:20	11.8	100
				24-Jun-08	18:46:20	11.8	100

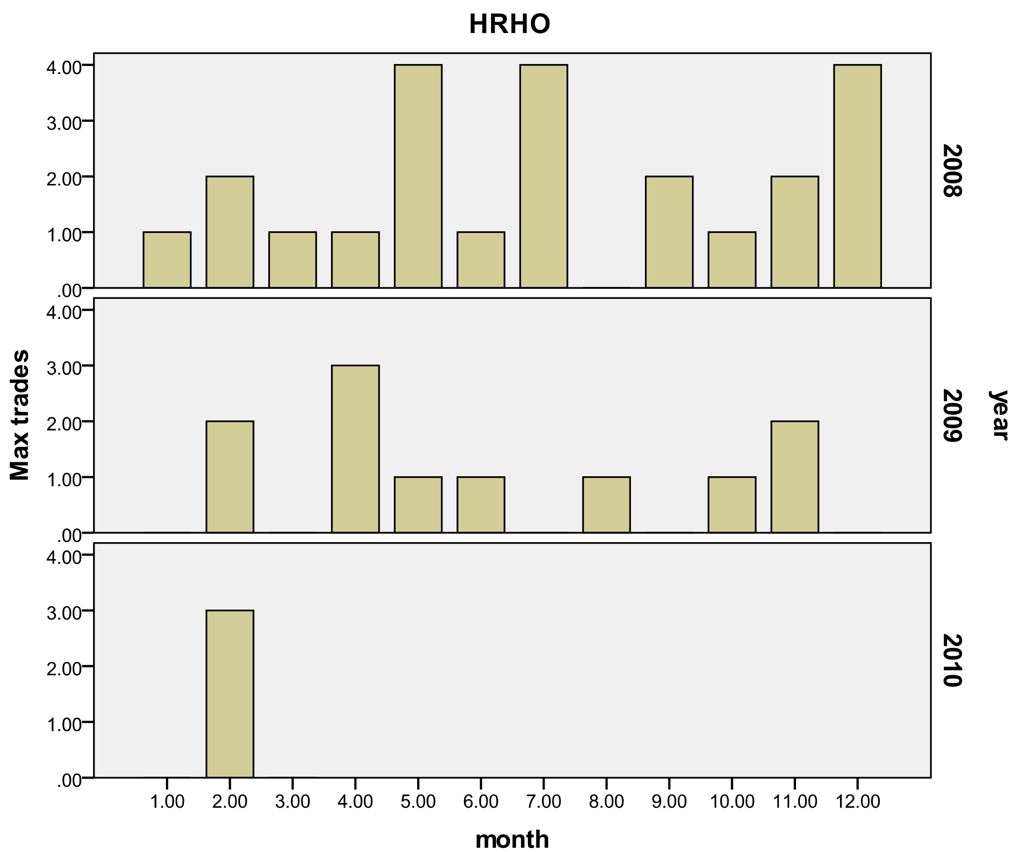
				24-Jun-08	18:46:20	11.8	100
24-Jun-08	18:46:26	13.9	400				
24-Jun-08	19:13:01	14.1	87.5				
24-Jun-08	19:13:01	13.9	112.5				
24-Jun-08	19:21:32	13.9	287.5				
24-Jun-08	19:21:44	13.9	12.5				
24-Jun-08	19:22:45	13.9	12.5				
				24-Jun-08	19:25:13	12.0	300
				24-Jun-08	19:25:27	12.0	400
				24-Jun-08	19:30:52	12.1	200
24-Jun-08	19:35:45	13.9	50				
24-Jun-08	19:35:46	13.7	12.5				
				24-Jun-08	19:46:10	12	400
24-Jun-08	19:46:14	13.9	125				
				24-Jun-08	19:49:13	12	200

YPF							
Stock Trades				DR Trades			
Date	Time	Price$	Vol	Date	Time	Price$	Vol
				23-Jun-08	18:10:30	47.7	500
23-Jun-08	18:10:58	50.4	500				
				23-Jun-08	18:11:02	47.7	500
23-Jun-08	18:11:05	50.4	500				
				23-Jun-08	18:11:10	47.7	500
23-Jun-08	18:11:28	50.4	500				
				23-Jun-08	18:11:31	47.7	500
23-Jun-08	18:15:38	50.4	1000				
				23-Jun-08	18:15:47	47.7	500
				23-Jun-08	18:15:47	47.7	500
23-Jun-08	18:16:07	50.4	1000				
				23-Jun-08	18:16:12	47.7	500
				23-Jun-08	18:16:12	47.7	500
23-Jun-08	18:18:04	50.4	2182				
				23-Jun-08	18:18:06	47.7	500
				23-Jun-08	18:18:06	47.7	500
				23-Jun-08	18:18:06	47.7	500
				23-Jun-08	18:18:06	47.7	500
				23-Jun-08	18:57:34	47.7	100
				23-Jun-08	19:09:00	47.7	100
				23-Jun-08	19:17:49	47.7	100
23-Jun-08	19:40:23	51.3	18				
14-Oct-09	14:47:04	39.3	100				
				14-Oct-09	14:47:14	40.5	100
14-Oct-09	14:52:08	39.5	100				
				14-Oct-09	14:52:16	40.5	100
14-Oct-09	14:55:43	39.8	22				
14-Oct-09	14:55:44	39.8	100				

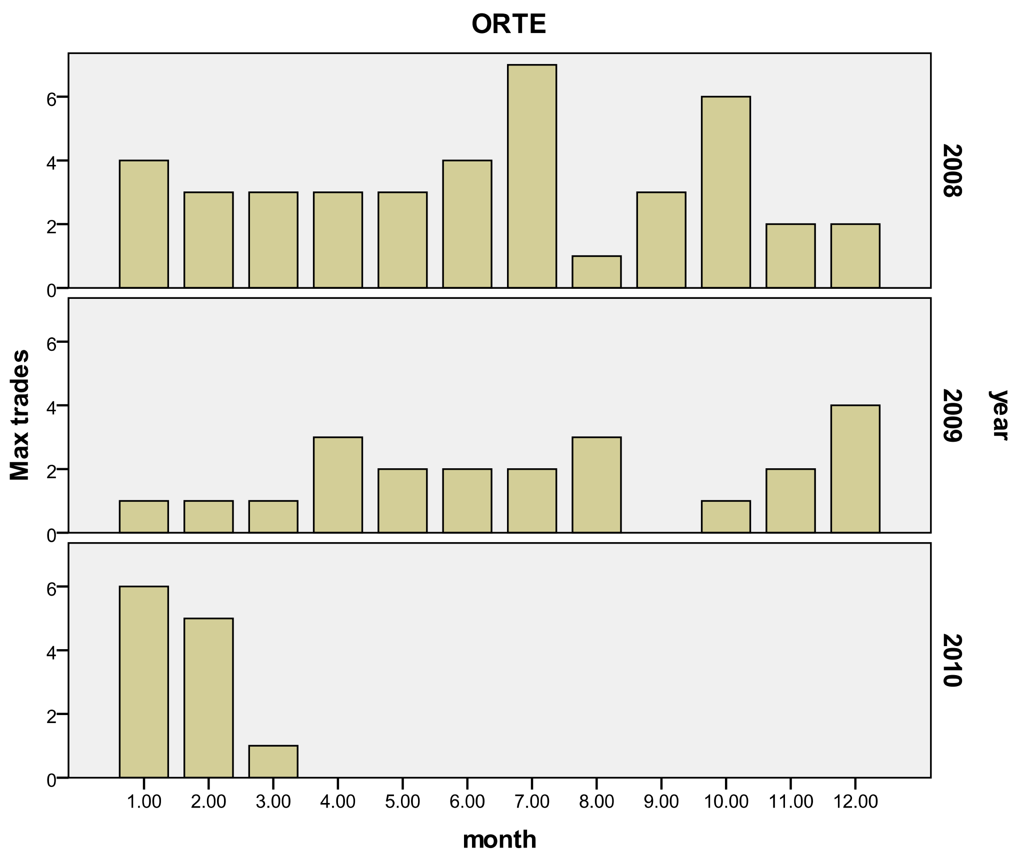
14-Oct-09	15:07:05	39.8	45				
				14-Oct-09	15:12:42	40.5	100
14-Oct-09	15:12:49	39.8	100				
7-Nov-08	19:16:00	55.4	100				
				7-Nov-08	19:16:03	47.8	100
7-Nov-08	19:20:19	55.4	100				
7-Nov-08	19:20:29	55.4	100				
7-Nov-08	19:20:36	55.4	100				
7-Nov-08	19:20:47	55.4	100				
7-Nov-08	19:20:55	55.4	100				
				7-Nov-08	19:21:11	47.5	100
7-Nov-08	19:22:05	55.4	300				
				7-Nov-08	19:22:08	47.3	100
7-Nov-08	19:22:31	55.7	14				
7-Nov-08	19:27:49	55.4	386				
				7-Nov-08	19:27:55	47.1	100
				7-Nov-08	19:29:10	47.5	200
				7-Nov-08	19:29:10	47.5	100
				7-Nov-08	19:32:13	47.5	100
7-Nov-08	19:38:34	55.4	163				
7-Nov-08	19:40:48	55.4	100				
				7-Nov-08	19:40:52	47.5	100

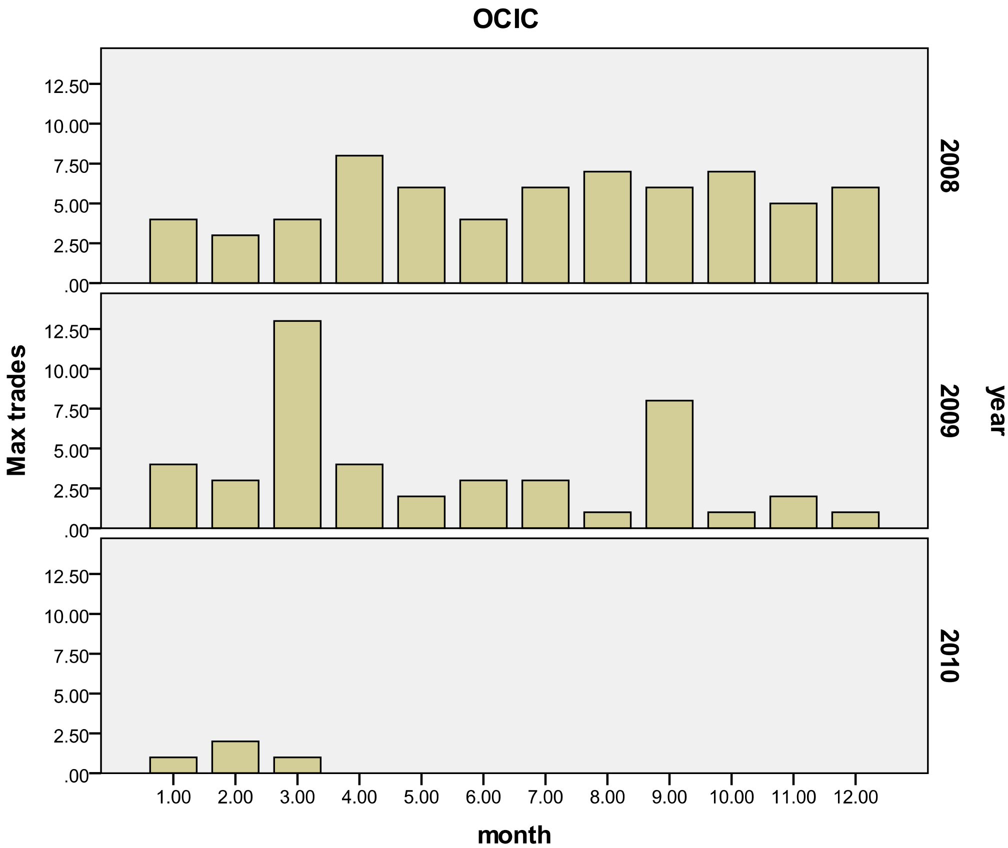
10.7 Appendix 7 Maximum Number of Trades to Converge

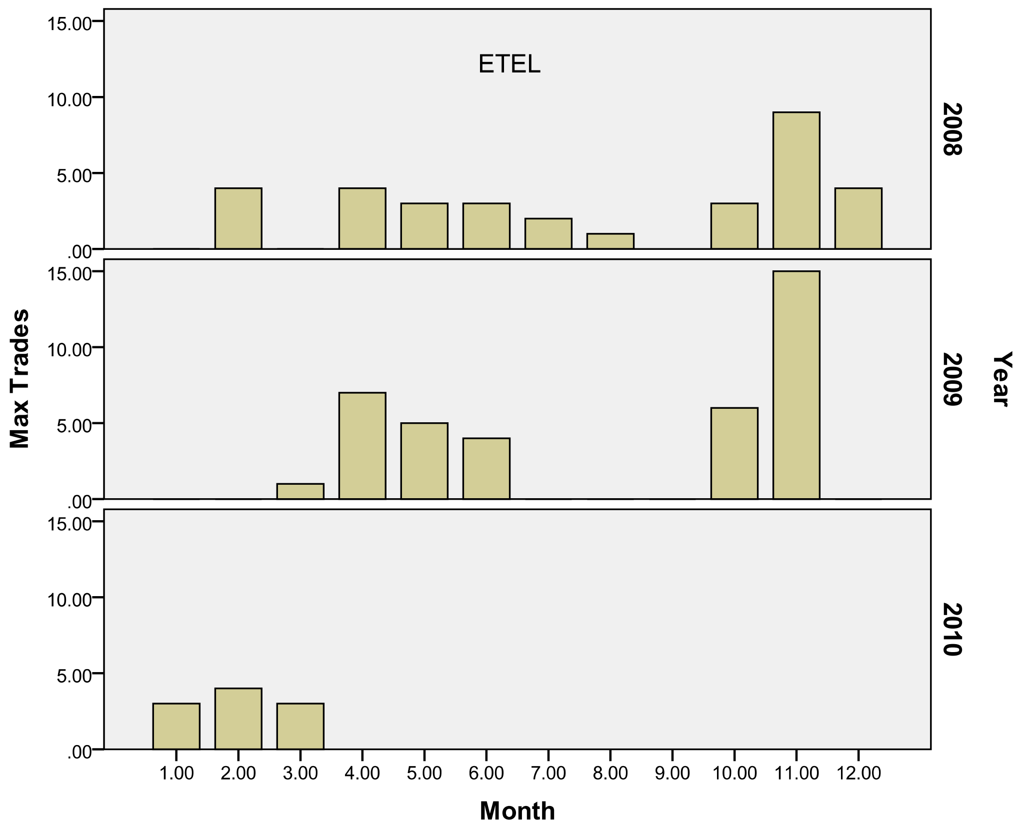


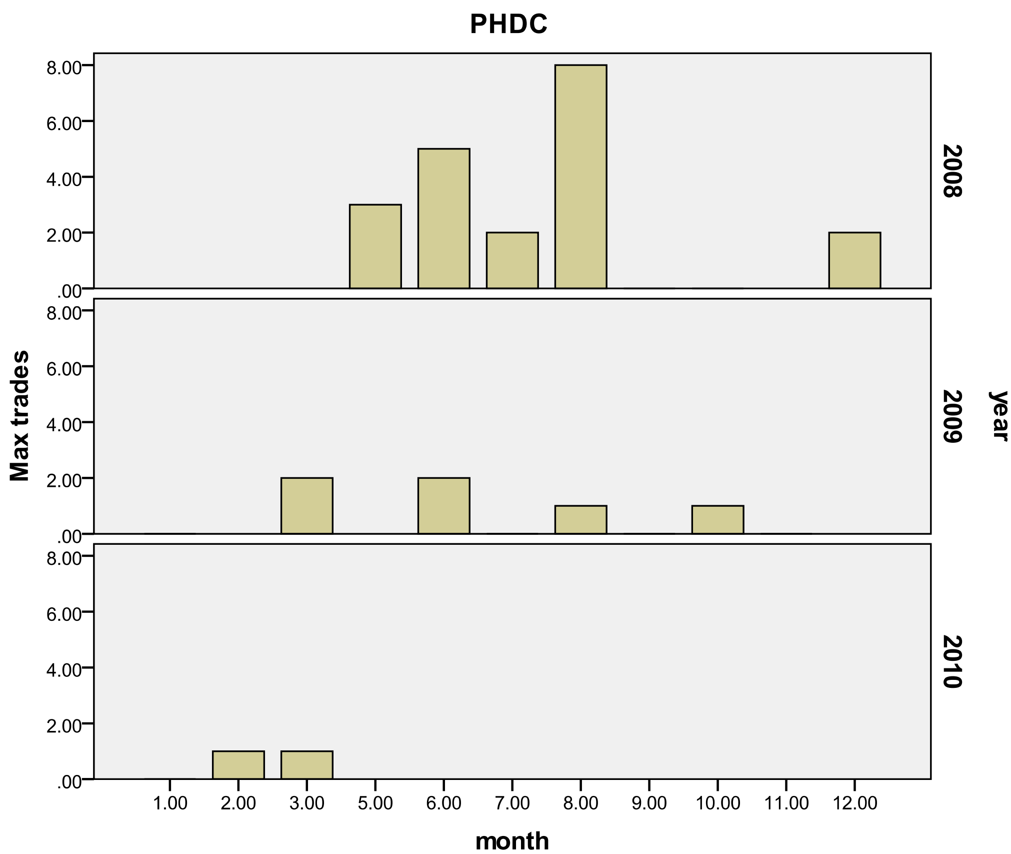


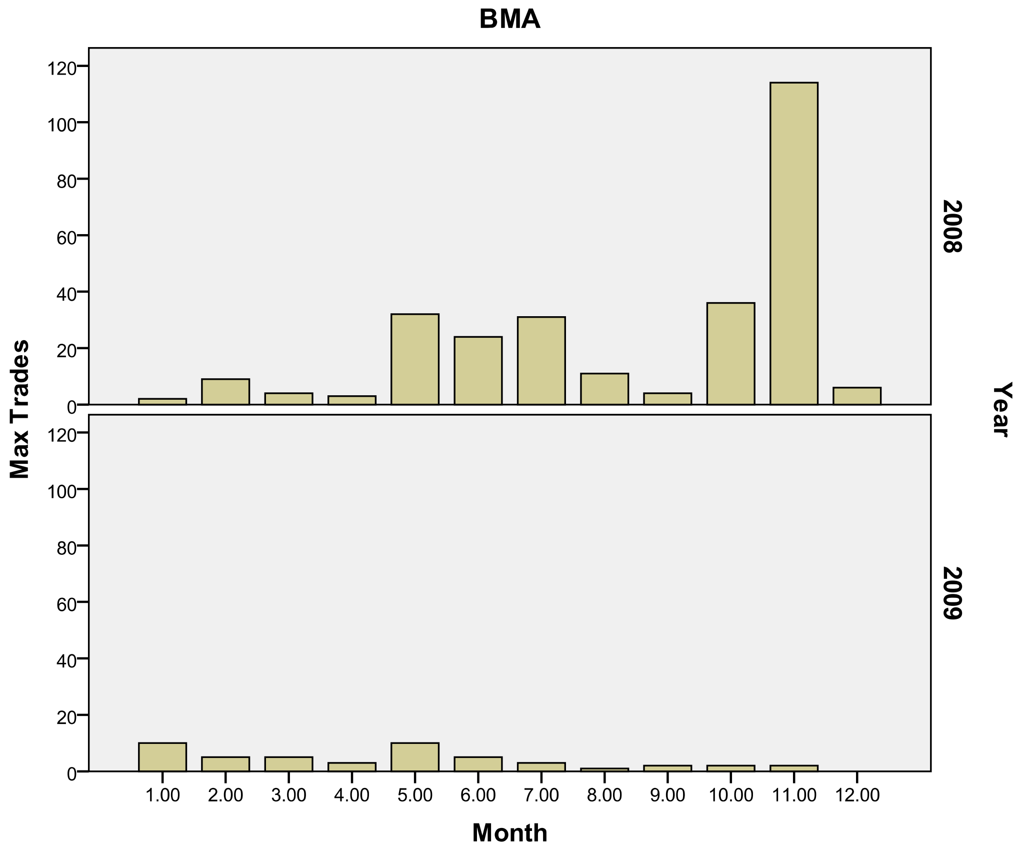
HRHO
4.00
3.00
2.00
1.00
.00
Max trades
2008
2009
2010
year
1.00
2.00
3.00
4.00
5.00
6.00
7.00
8.00
9.00
10.00
11.00
12.00
month


ORTE
Max trades
2008
2009
2010
year
0
2
4
6
1.00
2.00
3.00
4.00
5.00
6.00
7.00
8.00
9.00
10.00
11.00
12.00
month

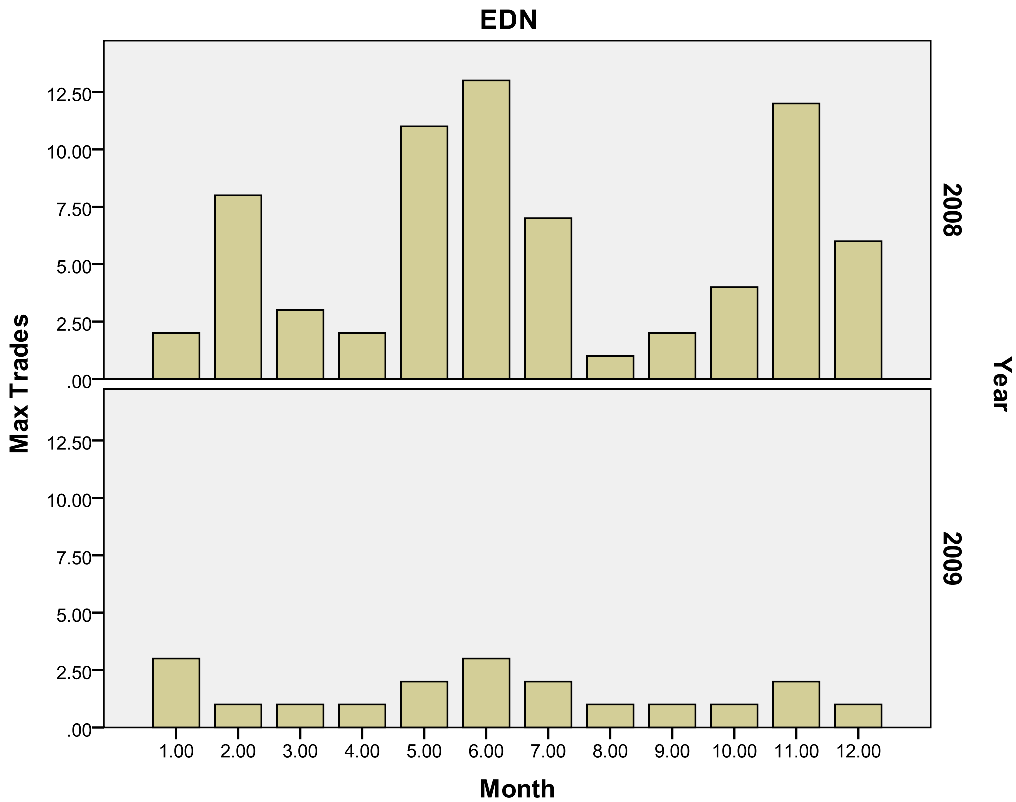

OCIC
Max trades
12.50
10.00
7.50
5.00
2.50
.00
2008
2009
2010
year
1.00
2.00
3.00
4.00
5.00
6.00
7.00
8.00
9.00
10.00
11.00
12.00
month

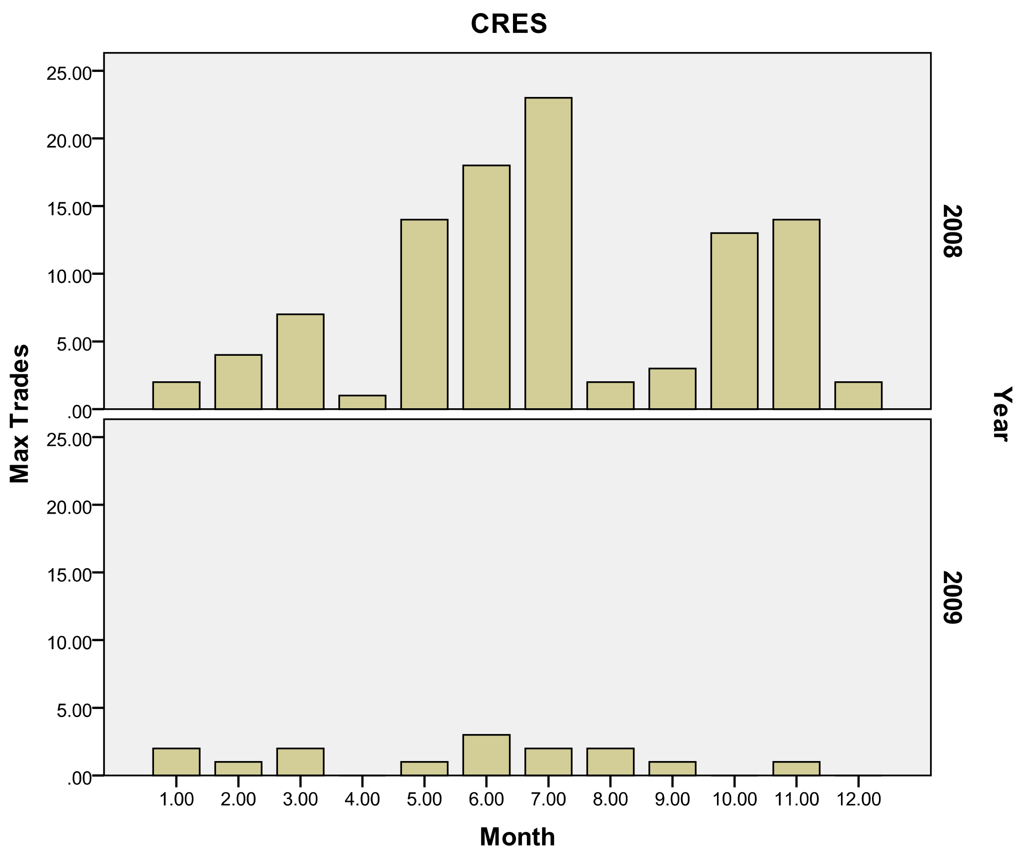

ETEL
Max Trades
Month
Year
2008
2009
2010
15.00
10.00
5.00
.00
1.00
2.00
3.00
4.00
5.00
6.00
7.00
8.00
9.00
10.00
11.00
12.00


PHDC
Max trades
8.00
6.00
4.00
2.00
.00
2008
2009
2010
year
1.00
2.00
3.00
5.00
6.00
7.00
8.00
9.00
10.00
11.00
12.00
month

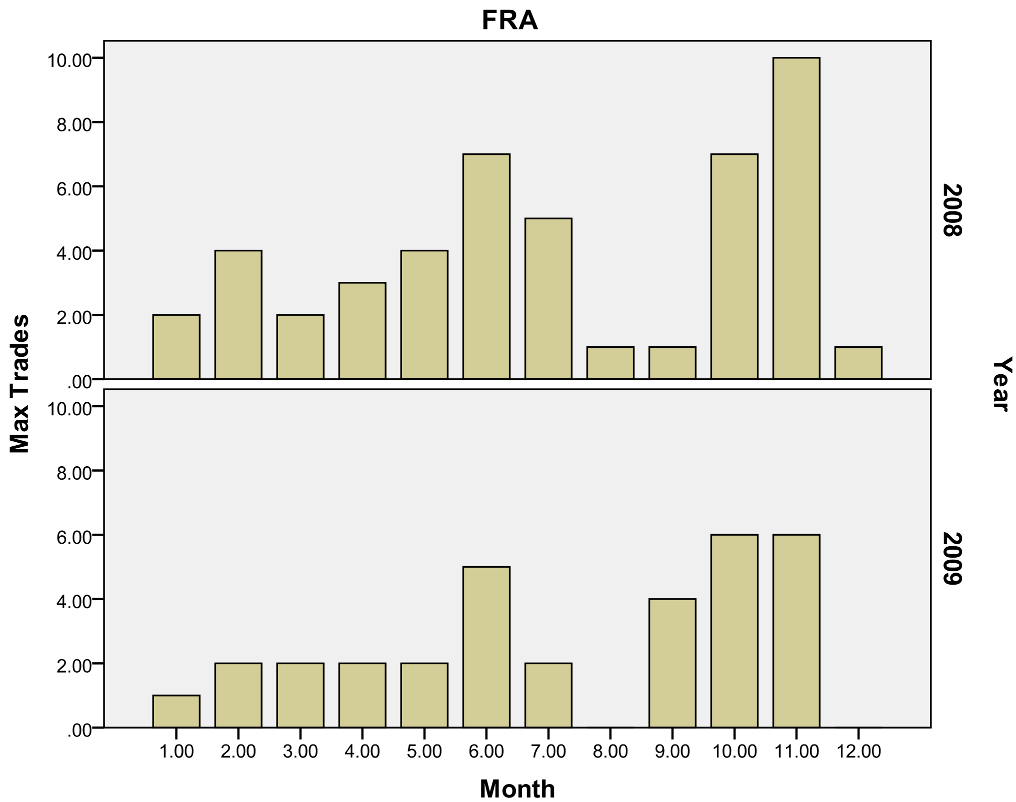


BMA
Max Trades
120
100
80
60
40
20
0
120
100
80
60
40
20
0
2008
2009
Year
1.00
2.00
3.00
4.00
5.00
6.00
7.00
8.00
9.00
10.00
11.00
12.00
Month

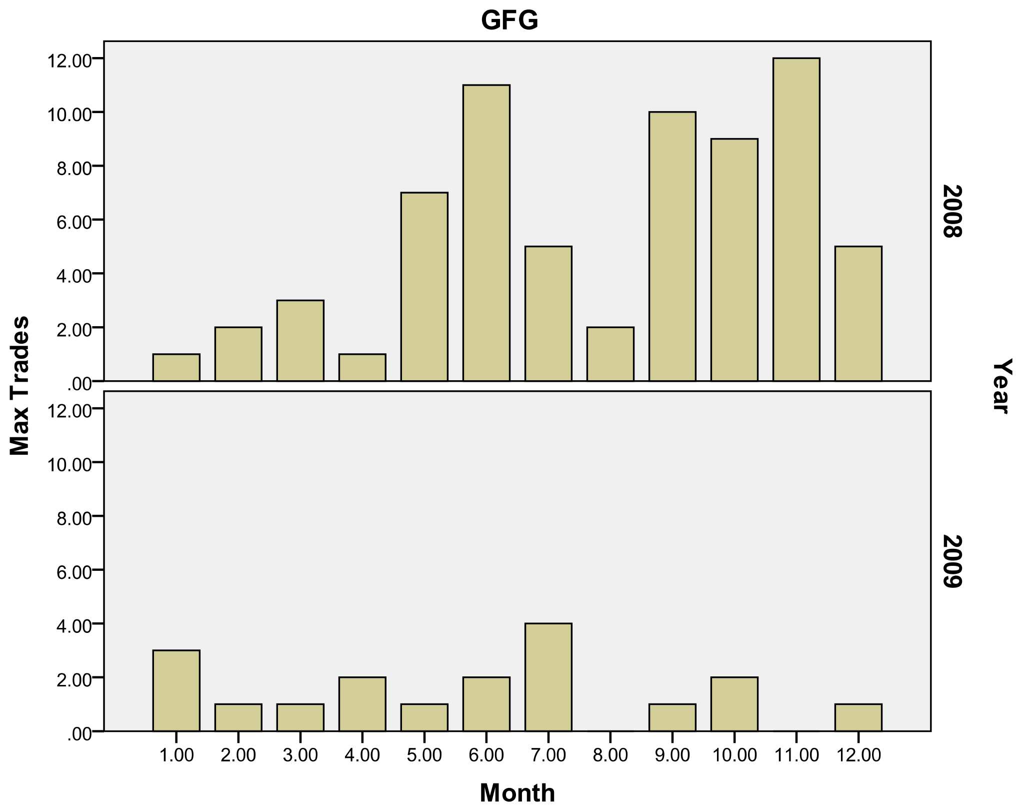

EDN
Max Trades
12.50
10.00
7.50
5.00
2.50
.00
2008
2009
Year
1.00
2.00
3.00
4.00
5.00
6.00
7.00
8.00
9.00
10.00
11.00
12.00
Month



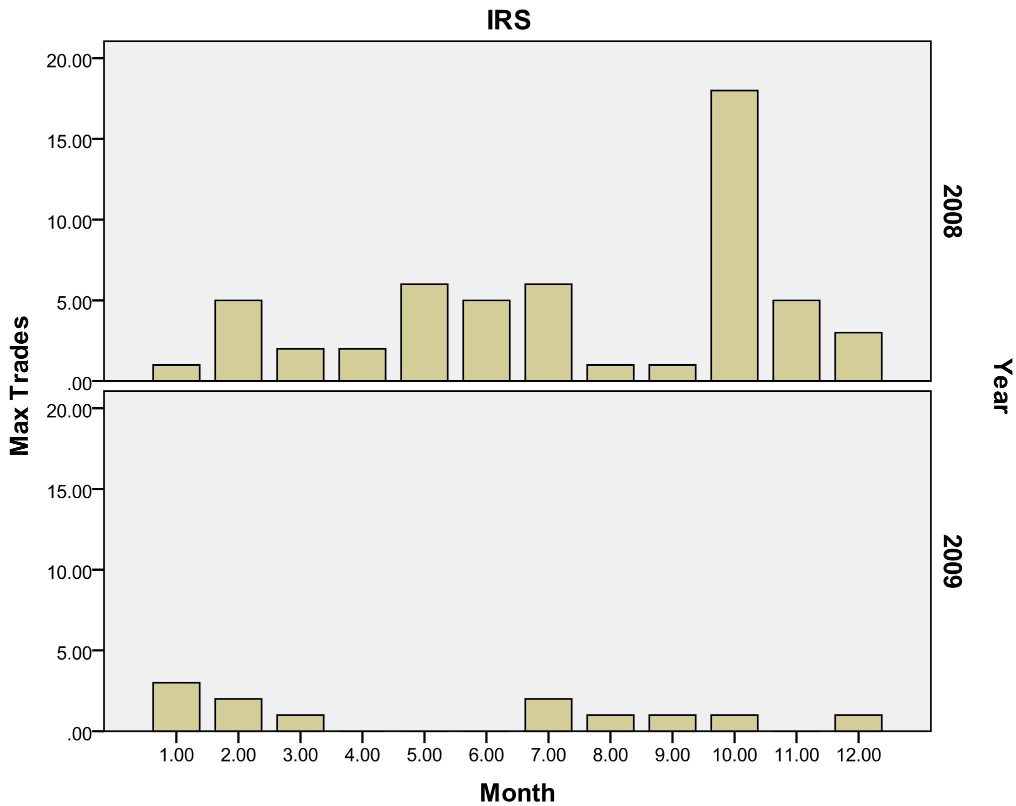
CRES
25.00
20.00
15.00
10.00
5.00
.00
25.00
20.00
15.00
10.00
5.00
.00
Max Trades
2008
2009
Year
1.00
2.00
3.00
4.00
5.00
6.00
7.00
8.00
9.00
10.00
11.00
12.00
Month



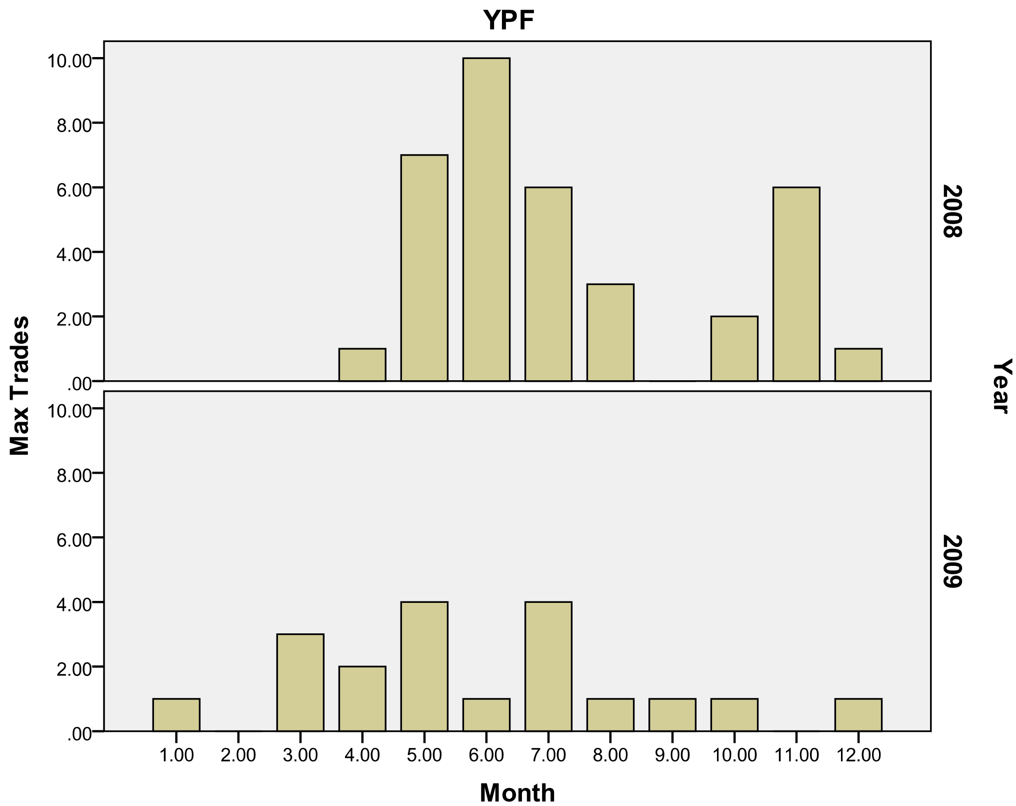
FRA
Max Trades
10.00
8.00
6.00
4.00
2.00
.00
1.00
2.00
3.00
4.00
5.00
6.00
7.00
8.00
9.00
10.00
11.00
12.00
Month
Year
2008
2009

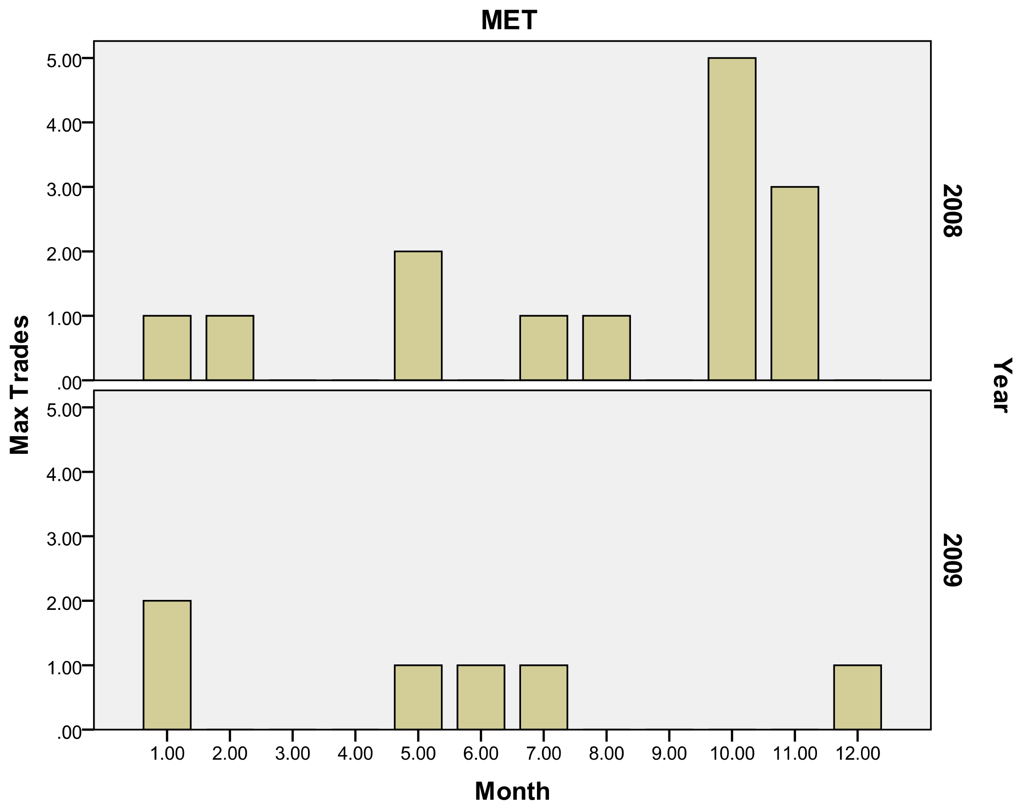


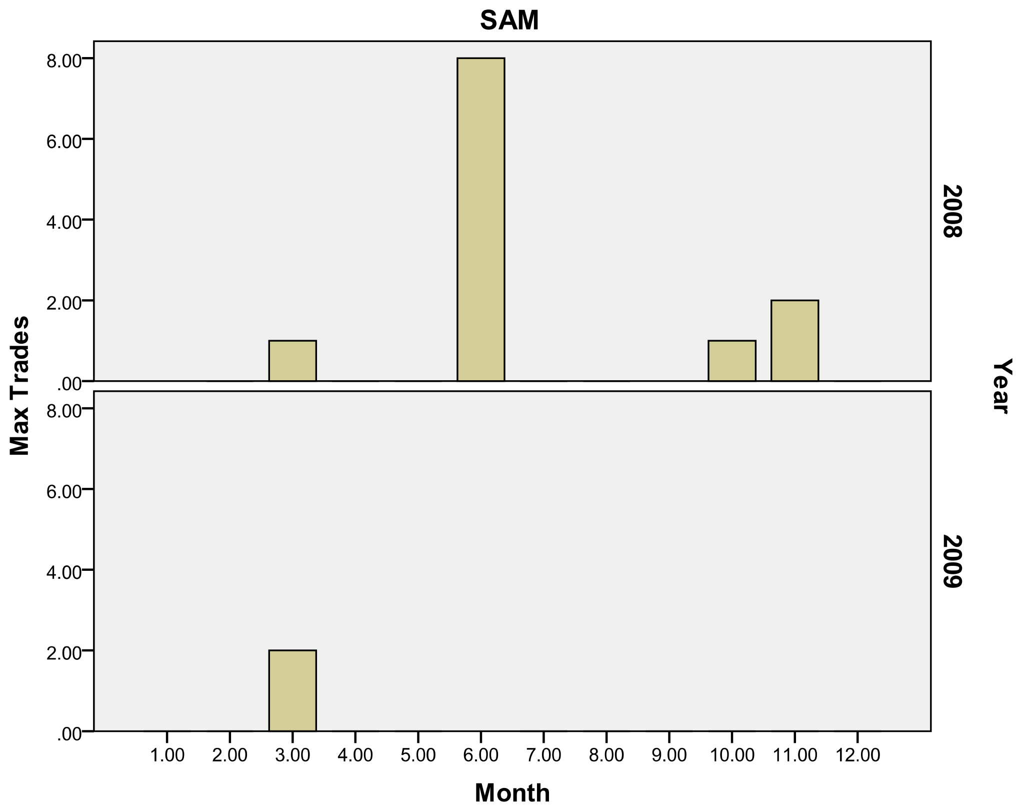
GFG
12.00
10.00
8.00
6.00
4.00
2.00
.00
Max Trades
2008
2009
Year
1.00
2.00
3.00
4.00
5.00
6.00
7.00
8.00
9.00
10.00
11.00
12.00
Month

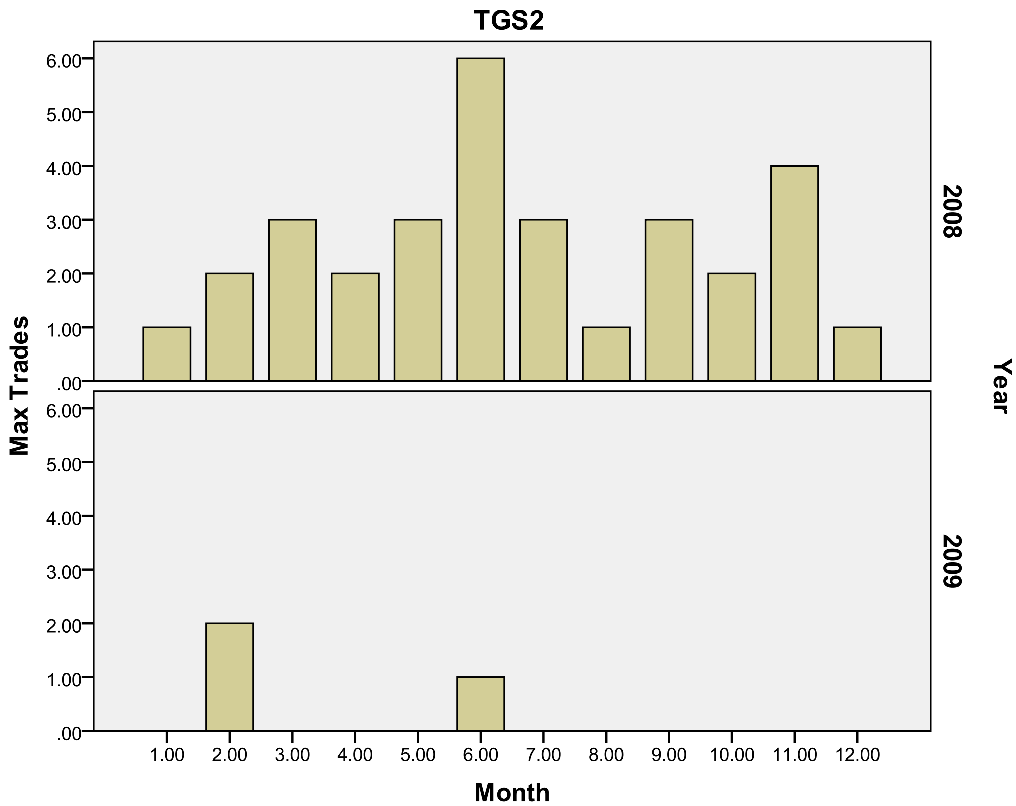


IRS
20.00
15.00
10.00
5.00
.00
20.00
15.00
10.00
5.00
.00
Max Trades
2008
2009
Year
1.00
2.00
3.00
4.00
5.00
6.00
7.00
8.00
9.00
10.00
11.00
12.00
Month

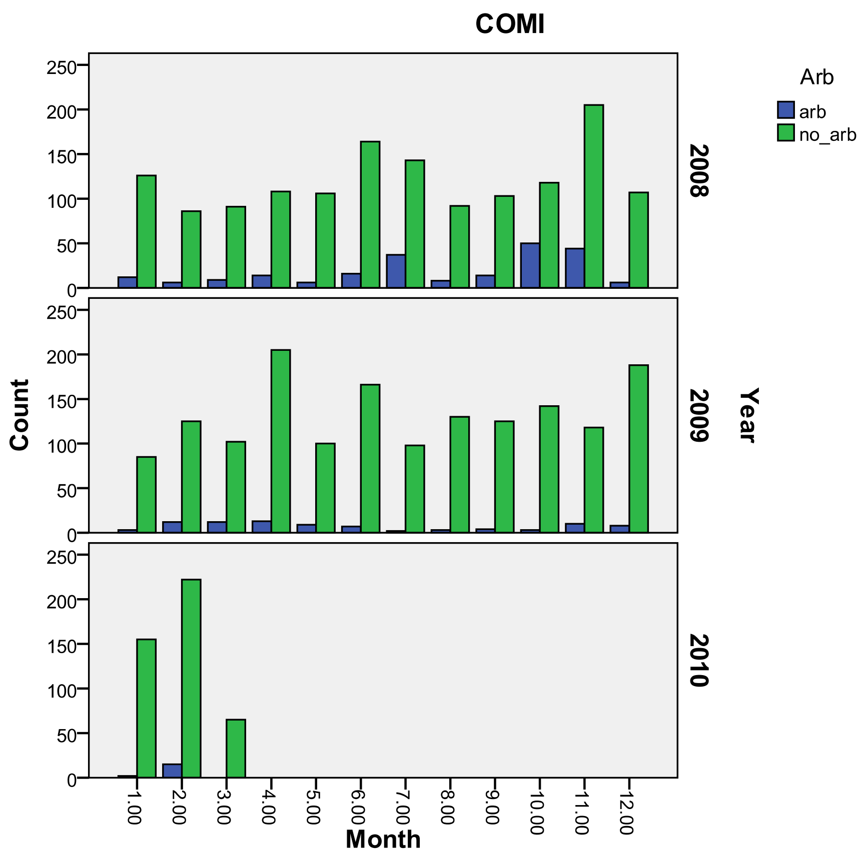

YPF
Max Trades
10.00
8.00
6.00
4.00
2.00
.00
2008
2009
Year
1.00
2.00
3.00
4.00
5.00
6.00
7.00
8.00
9.00
10.00
11.00
12.00
Month

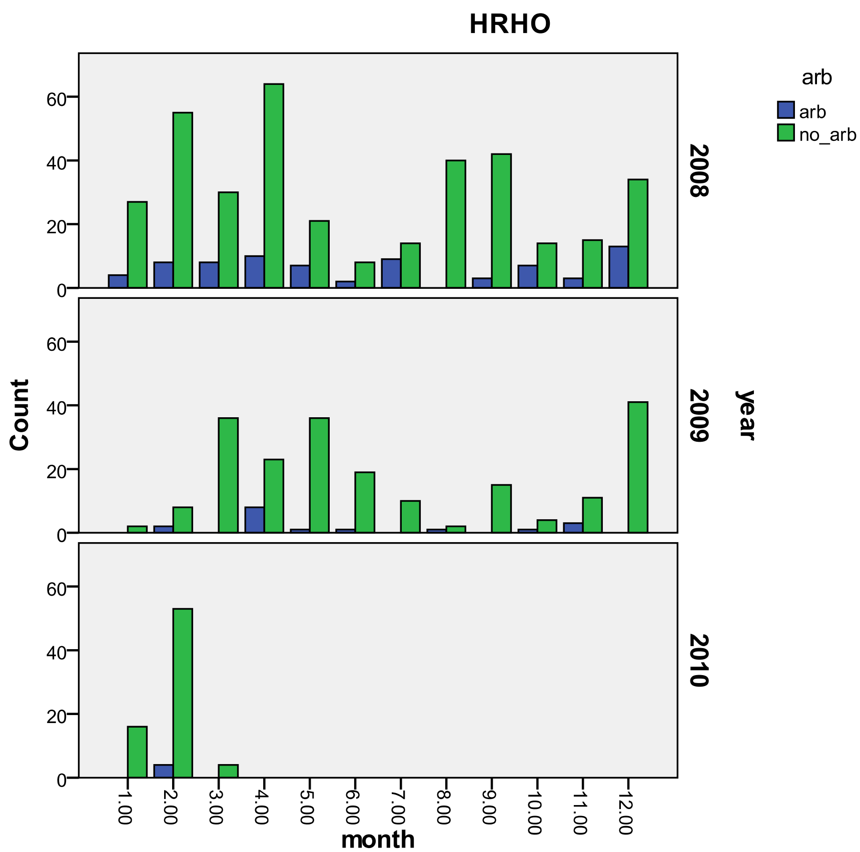

MET
5.00
4.00
3.00
2.00
1.00
.00
5.00
4.00
3.00
2.00
1.00
.00
Max Trades
2008
2009
Year
1.00
2.00
3.00
4.00
5.00
6.00
7.00
8.00
9.00
10.00
11.00
12.00
Month

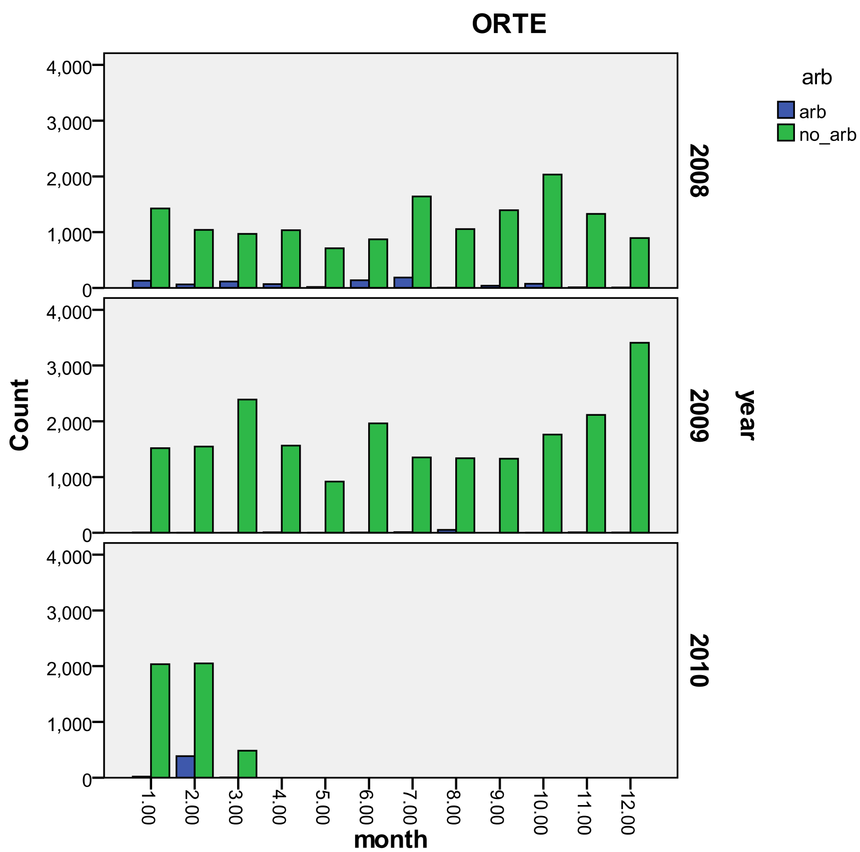

SAM
Max Trades
8.00
6.00
4.00
2.00
.00
8.00
6.00
4.00
2.00
.00
1.00 2.00 3.00 4.00 5.00 6.00 7.00 8.00 9.00 10.00 11.00 12.00
Month
2008
2009
Year

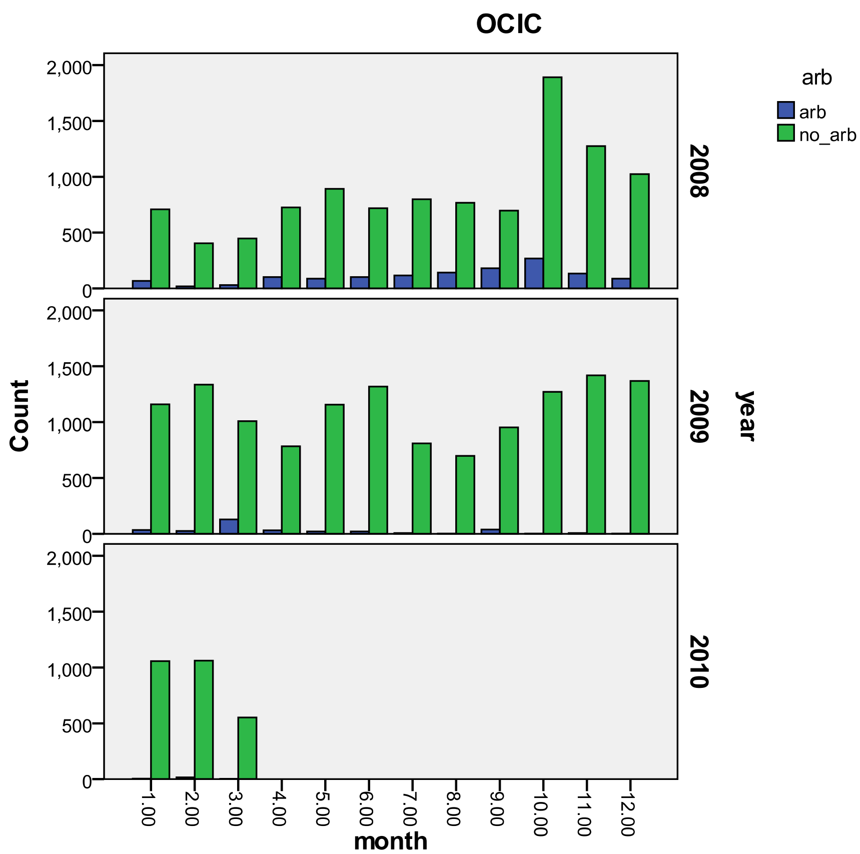


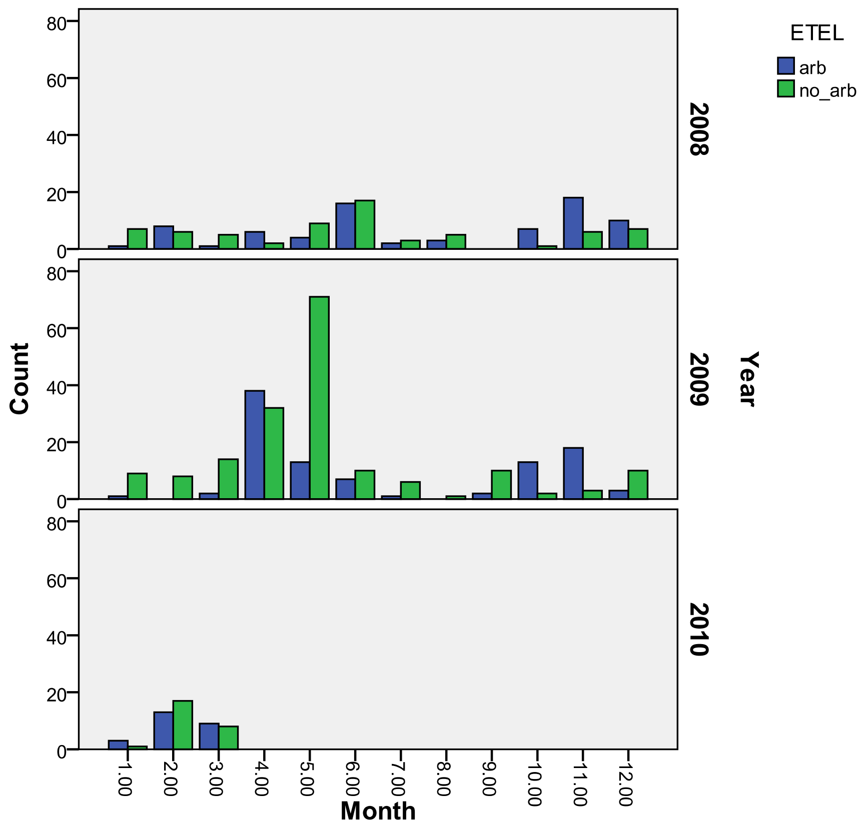
10.8 Appendix 8 Frequency of Arbitrage Opportunities by Month in Sample

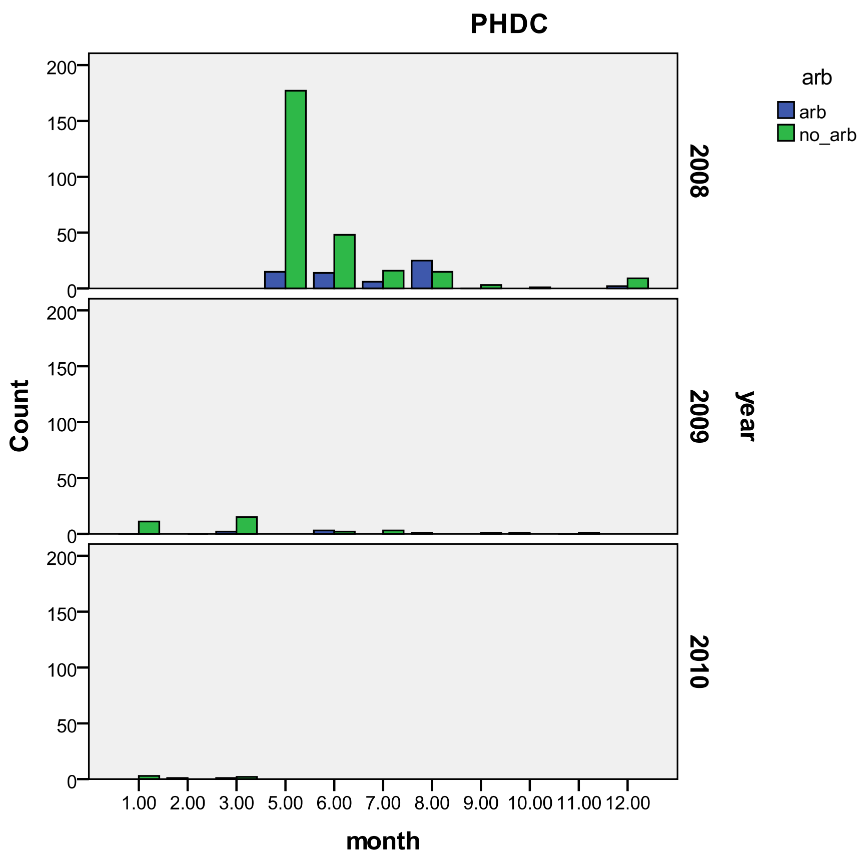

COMI
Arb
arb
no_arb
Count
Year
2008
2009
2010
0
50
100
150
200
250
1.00
2.00
3.00
4.00
5.00
6.00
7.00
8.00
9.00
10.00
11.00
12.00
Month

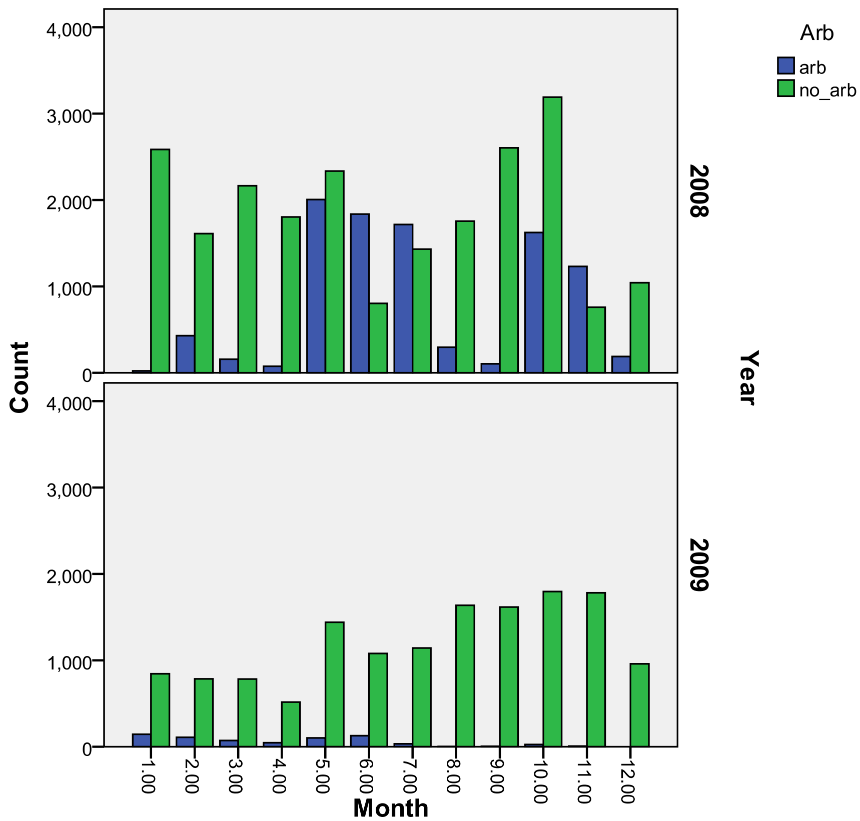

HRHO
arb
arb
no_arb
Count
2008
2009
2010
year
month
1.00
2.00
3.00
4.00
5.00
6.00
7.00
8.00
9.00
10.00
11.00
12.00


ORTE
arb
arb
no_arb
Count
4,000
3,000
2,000
1,000
0
2008
2009
2010
year
1.00
2.00
3.00
4.00
5.00
6.00
7.00
8.00
9.00
10.00
11.00
12.00
month

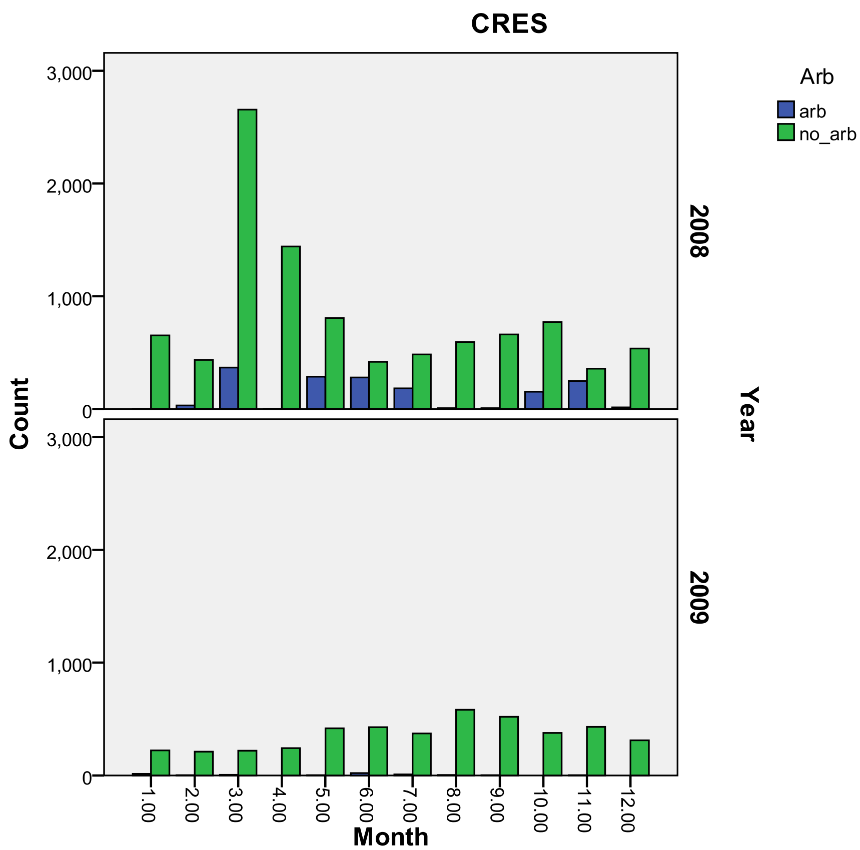

OCIC
arb
arb
no_arb
Count
year
2008
2009
2010
2,000
1,500
1,000
500
0
1.00
2.00
3.00
4.00
5.00
6.00
7.00
8.00
9.00
10.00
11.00
12.00
month

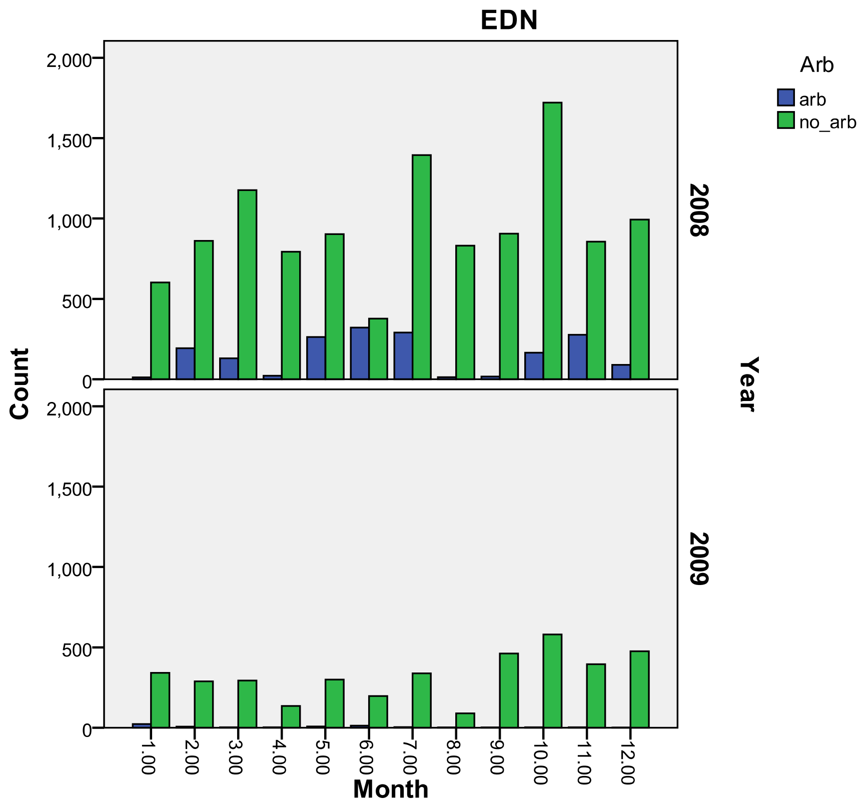

ETEL
arb
no_arb
Count
Year
2008
2009
2010
Month
0
20
40
60
80
1.00
2.00
3.00
4.00
5.00
6.00
7.00
8.00
9.00
10.00
11.00
12.00


PHDC
arb
arb
no_arb
2008
2009
2010
year
Count
0
50
100
150
200
1.00
2.00
3.00
5.00
6.00
7.00
8.00
9.00
10.00
11.00
12.00
month

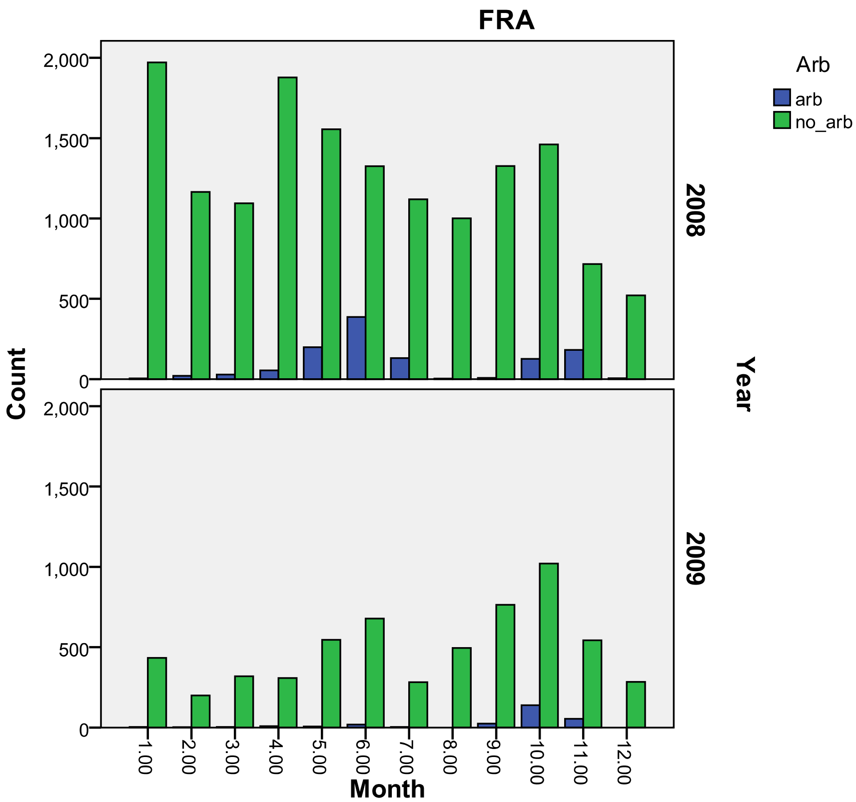


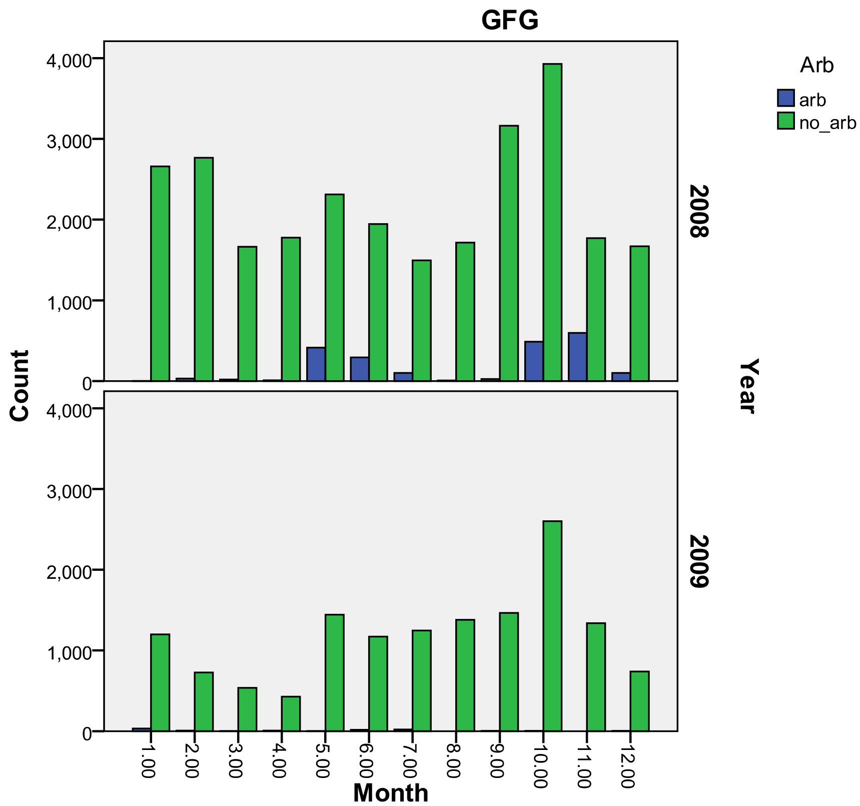
Arb
arb
no_arb
Count
Year
2008
2009
4,000
3,000
2,000
1,000
0
1.00
2.00
3.00
4.00
5.00
6.00
7.00
8.00
9.00
10.00
11.00
12.00
Month

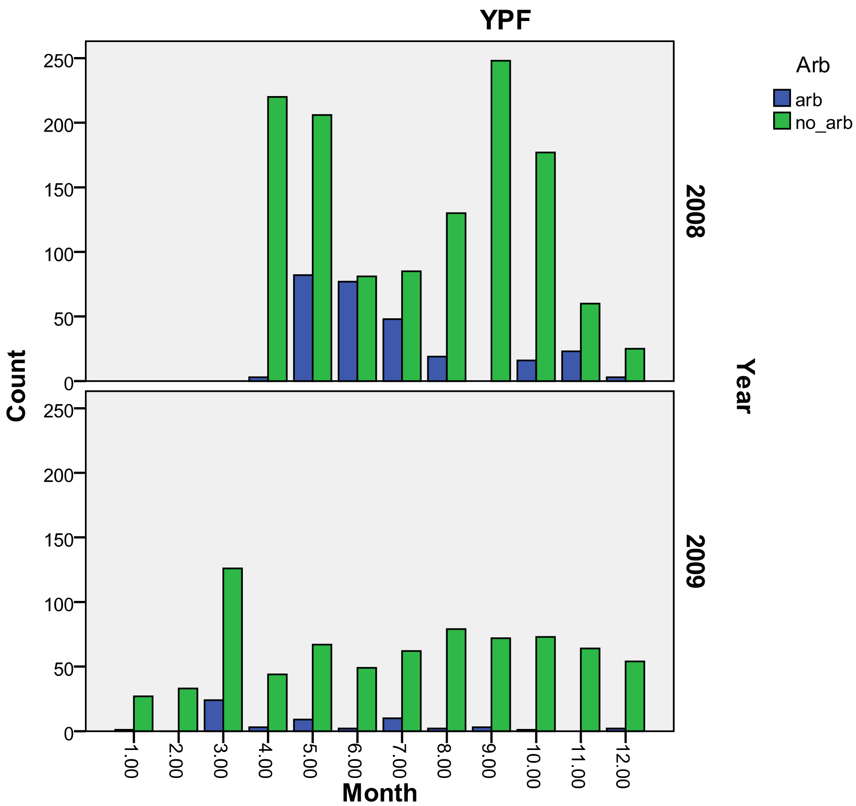

CRES
Arb
arb
no_arb
Count
Year
2008
2009
3,000
2,000
1,000
0
1.00
2.00
3.00
4.00
5.00
6.00
7.00
8.00
9.00
10.00
11.00
12.00
Month

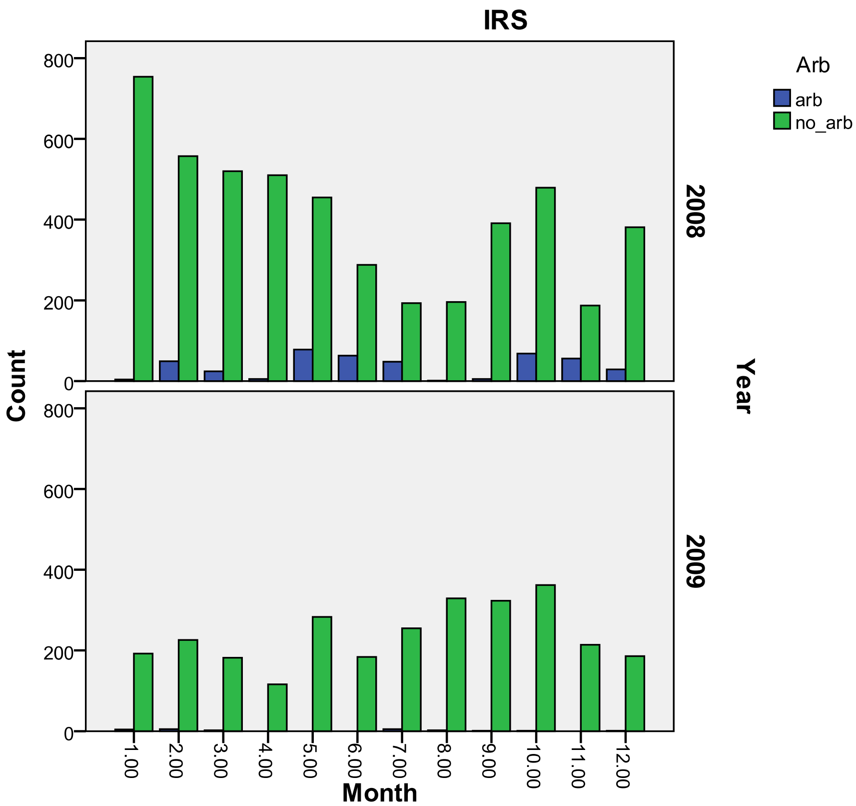


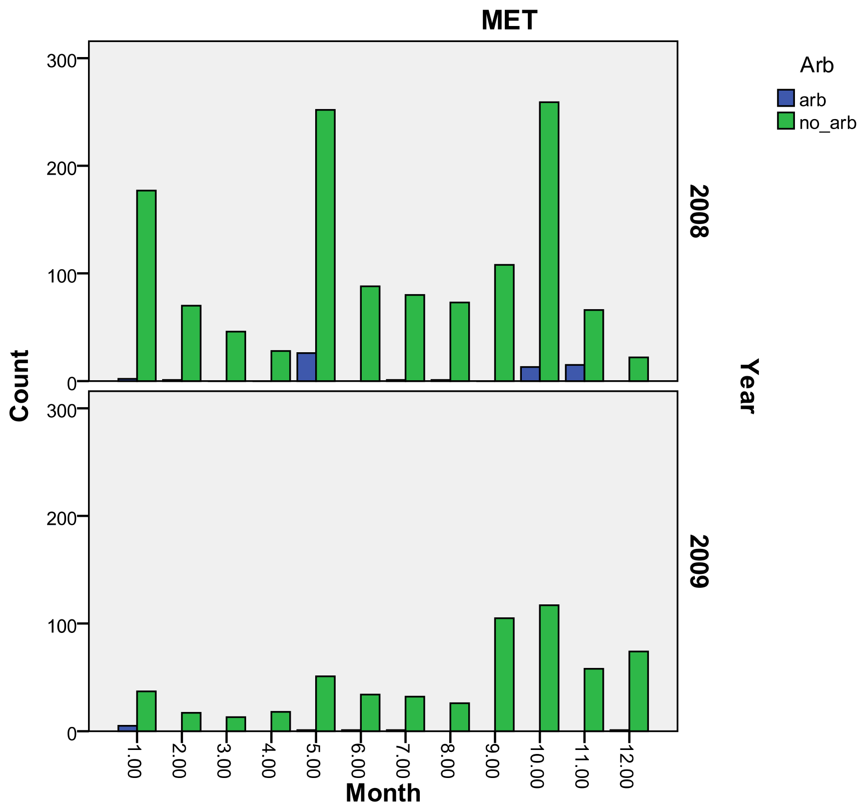
EDN
Arb
arb
no_arb
Count
2,000
1,500
1,000
500
0
2008
2009
Year
1.00
2.00
3.00
4.00
5.00
6.00
7.00
8.00
9.00
10.00
11.00
12.00
Month

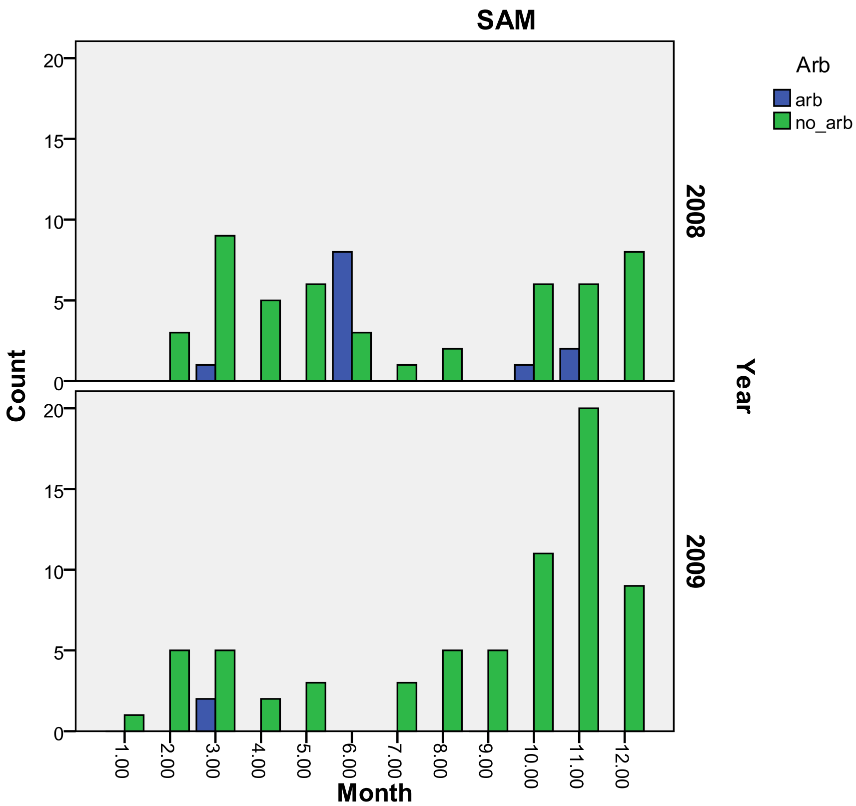

FRA
Arb
arb
no_arb
Count
2,000
1,500
1,000
500
0
2008
2009
Year
1.00
2.00
3.00
4.00
5.00
6.00
7.00
8.00
9.00
10.00
11.00
12.00
Month

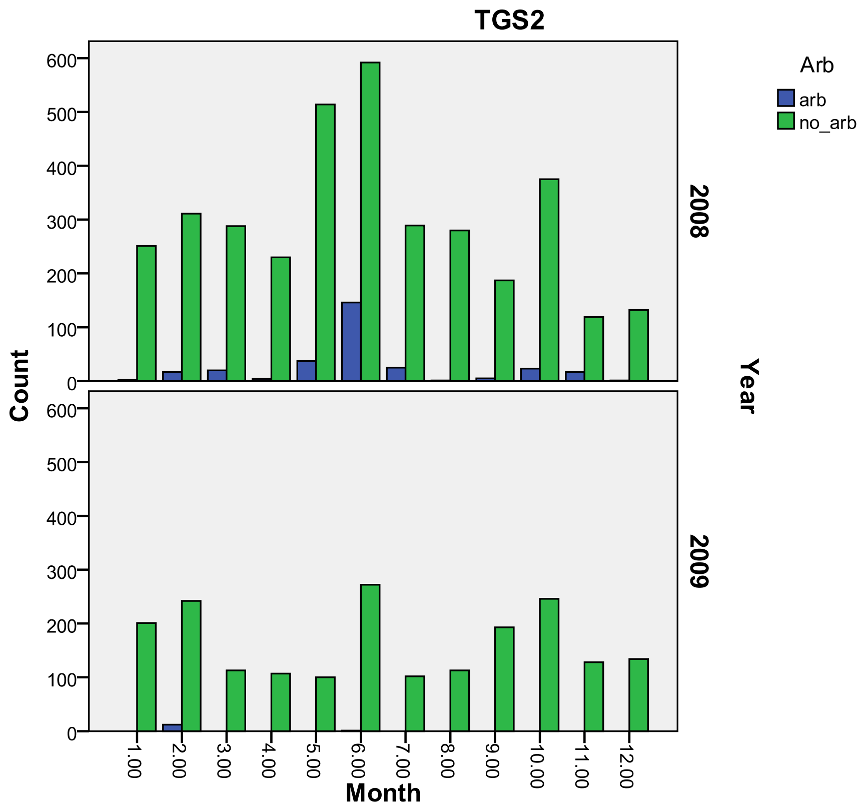

GFG
Arb
arb
no_arb
Count
4,000
3,000
2,000
1,000
0
2008
2009
Year
1.00
2.00
3.00
4.00
5.00
6.00
7.00
8.00
9.00
10.00
11.00
12.00
Month


YPF
Arb
arb
no_arb
2008
2009
Year
Count
Month
0
50
100
150
200
250
1.00
2.00
3.00
4.00
5.00
6.00
7.00
8.00
9.00
10.00
11.00
12.00

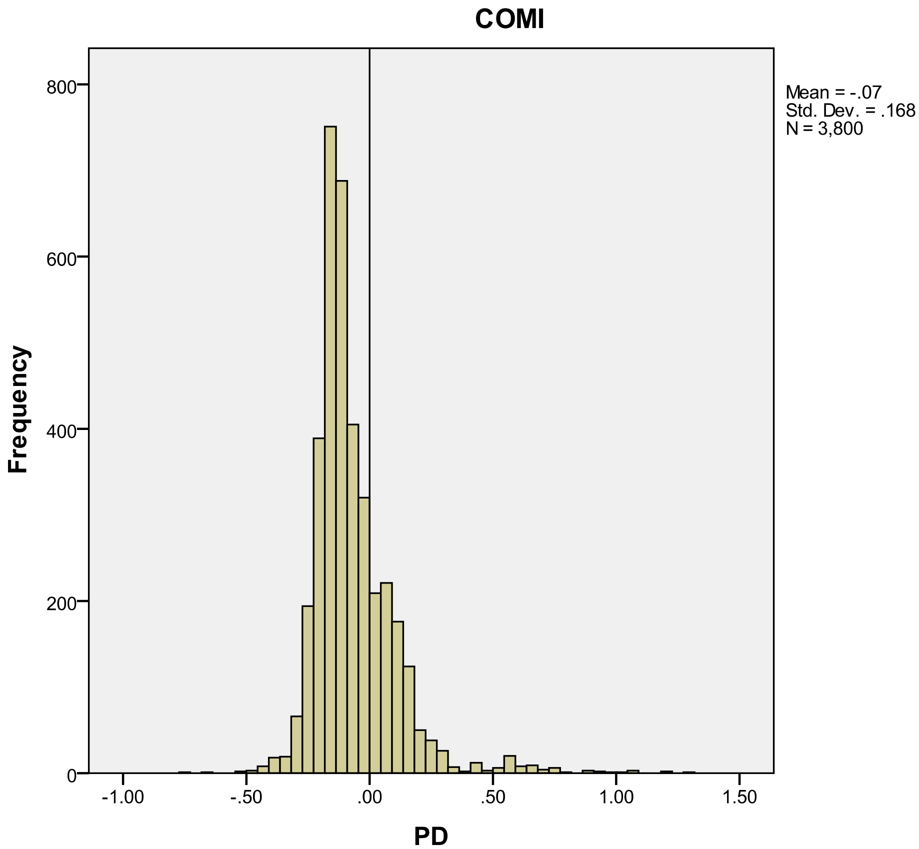

IRS
Arb
arb
no_arb
Count
800
600
400
200
0
2008
2009
Year
1.00
2.00
3.00
4.00
5.00
6.00
7.00
8.00
9.00
10.00
11.00
12.00
Month

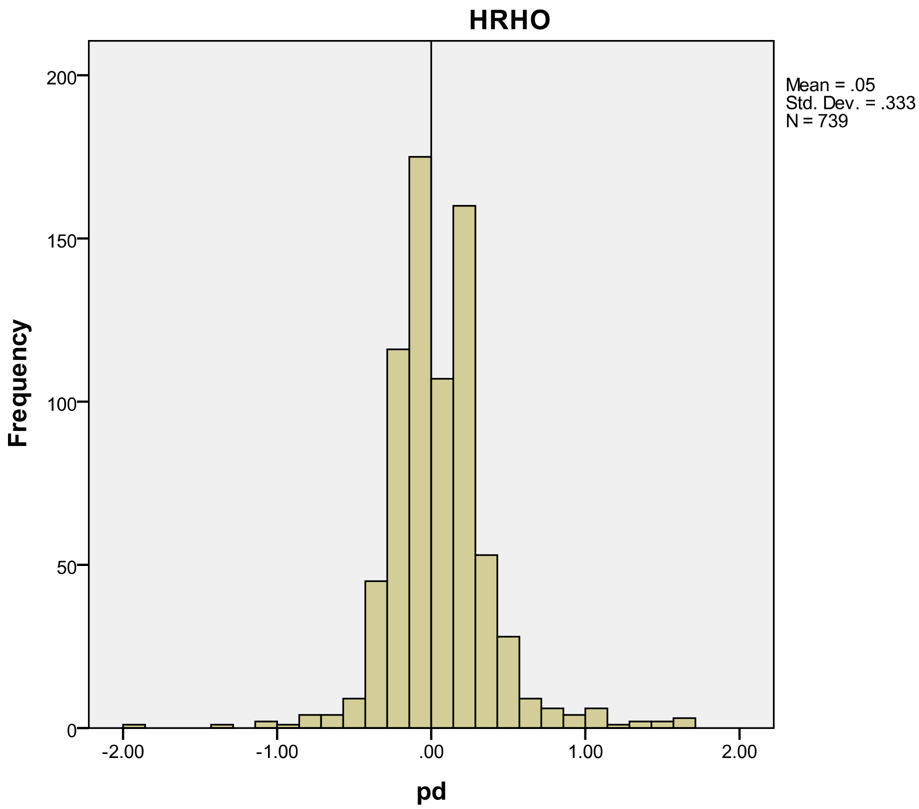

MET
Arb
arb
no_arb
Count
300
200
100
0
2008
2009
Year
1.00
2.00
3.00
4.00
5.00
6.00
7.00
8.00
9.00
10.00
11.00
12.00
Month

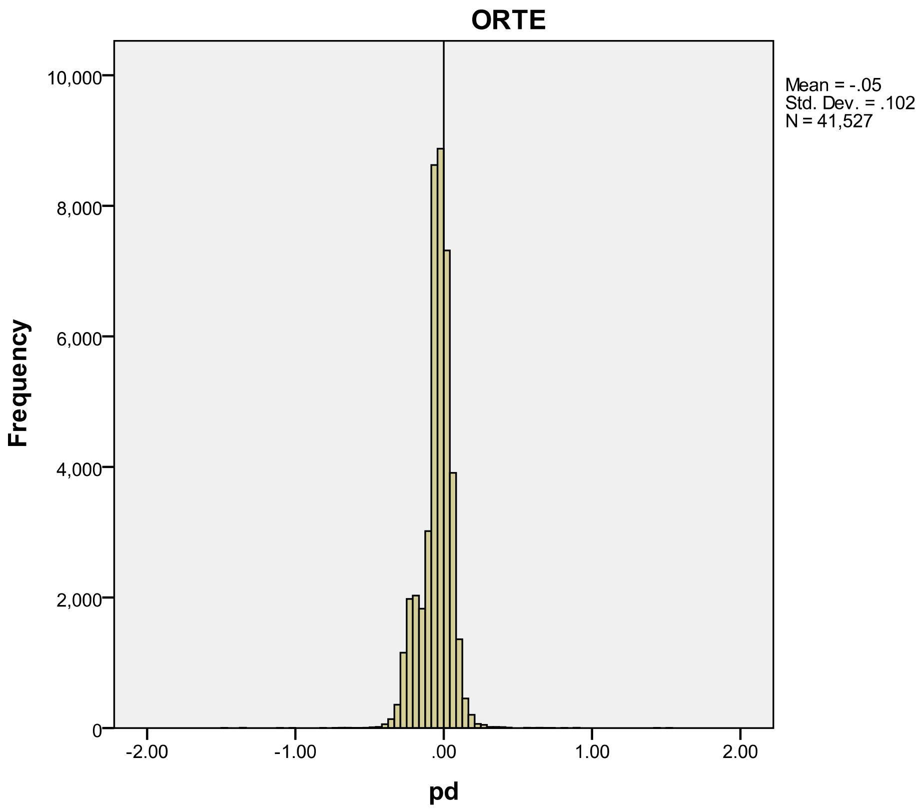

SAM
Arb
arb
no_arb
Count
Year
2008
2009
Month
1.00
2.00
3.00
4.00
5.00
6.00
7.00
8.00
9.00
10.00
11.00
12.00
0
5
10
15
20

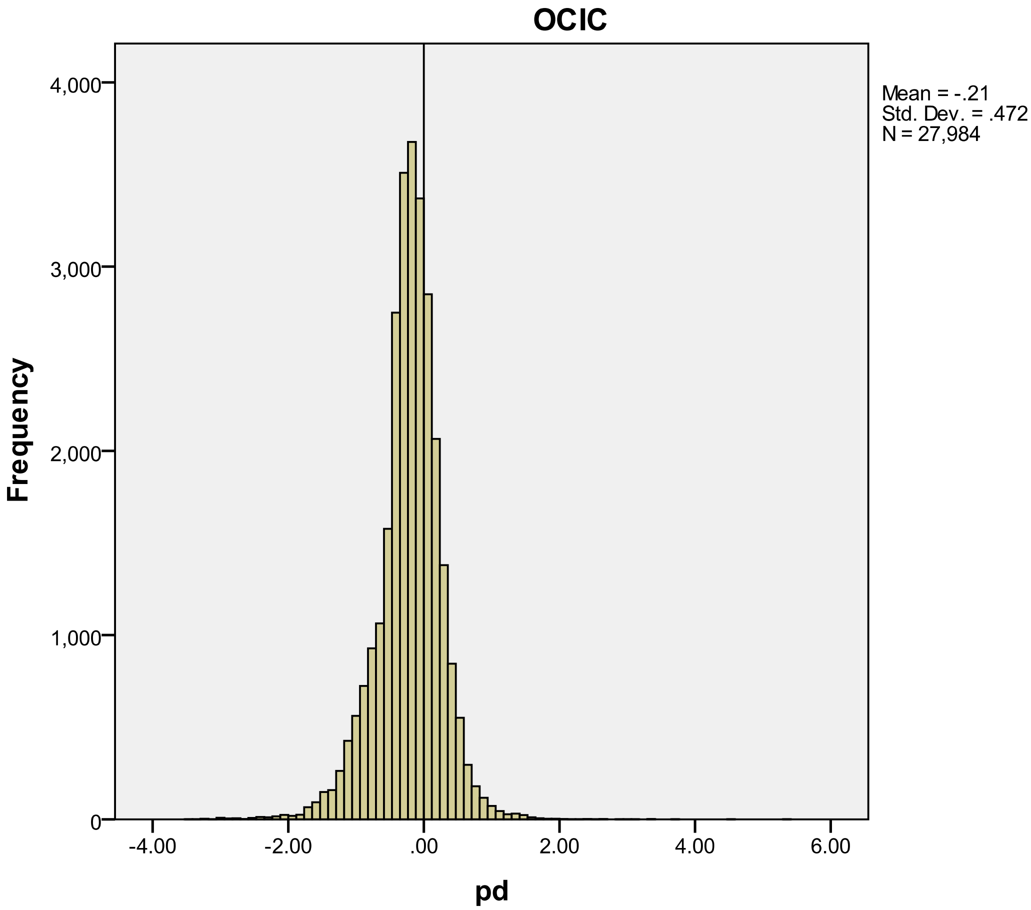


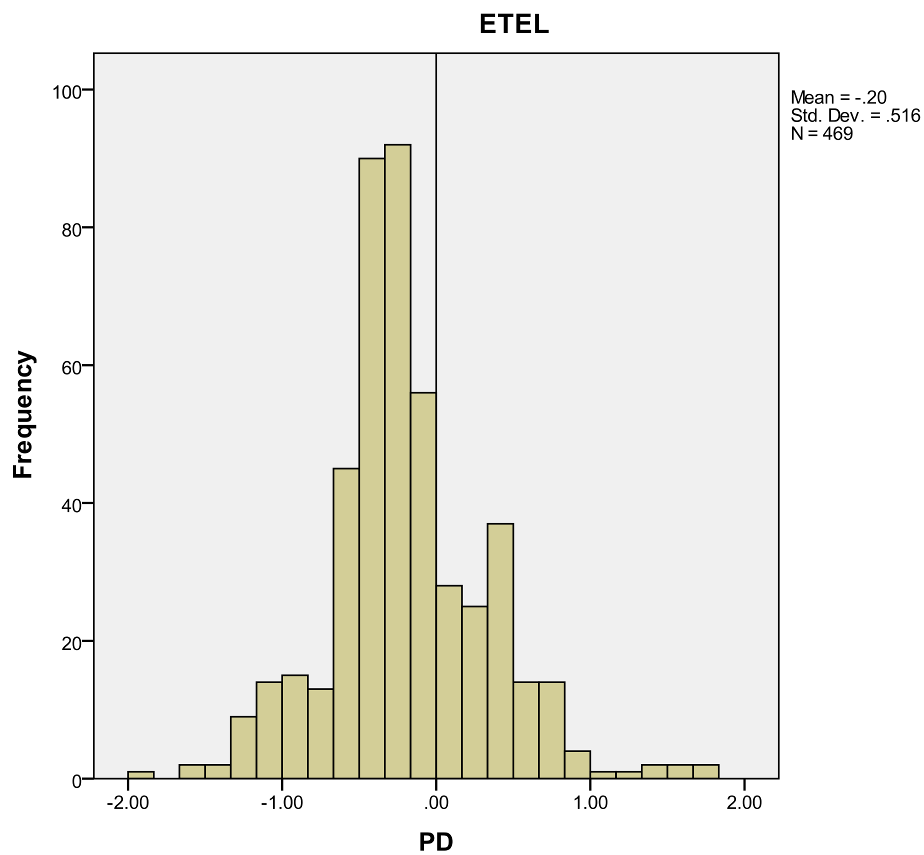
10.9 Appendix9 Histogram of Price Deviations

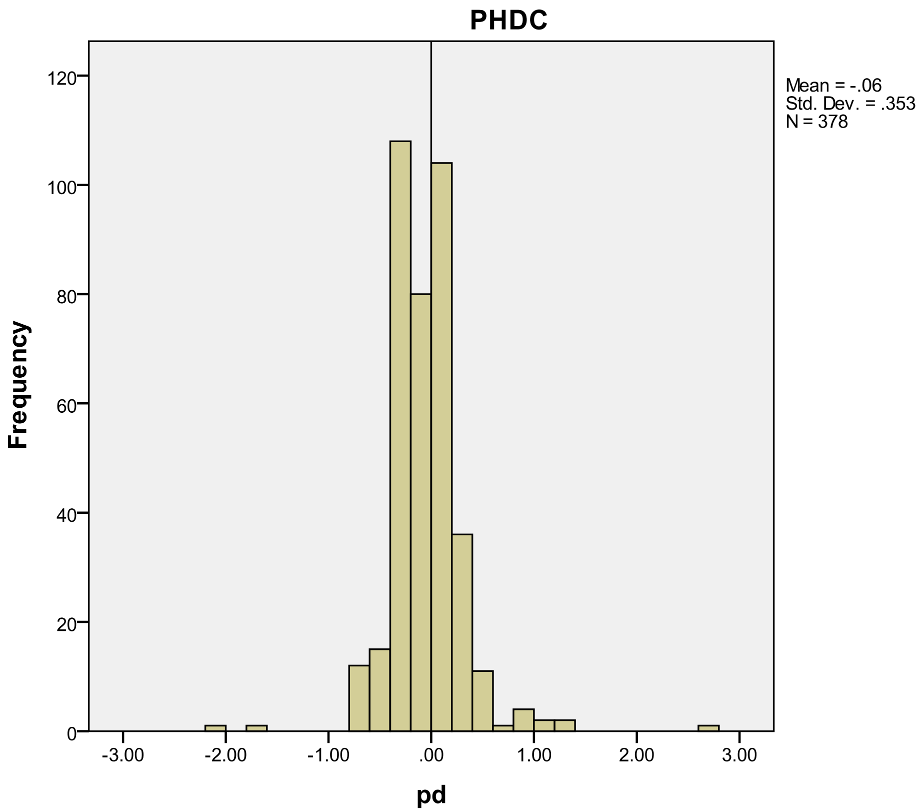

COMI
Mean = -.07
Std. Dev. = .168
N = 3,800
Frequency
800
600
400
200
0
-1.00
-.50
.00
.50
1.00
1.50
PD

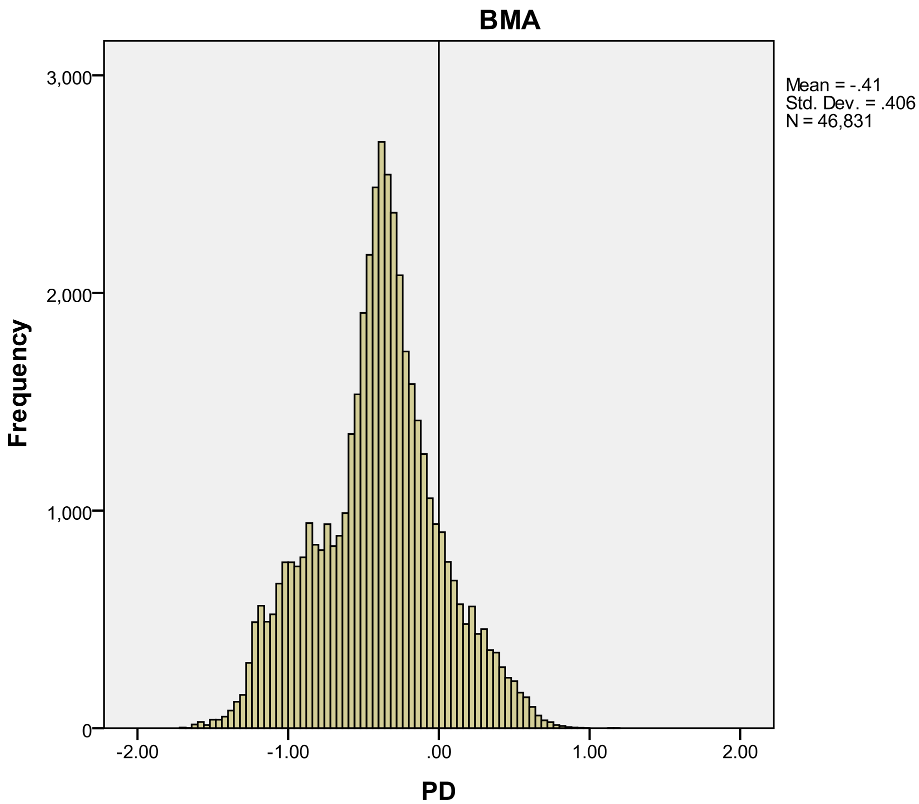

HRHO
Mean = .05
Std. Dev. = .333
N = 739
Frequency
200
150
100
50
0
-2.00
-1.00
.00
1.00
2.00
pd


ORTE
Frequency
10,000
8,000
6,000
4,000
2,000
0
-2.00
-1.00
.00
1.00
2.00
pd
Mean = -.05
Std. Dev. = .102
N = 41,527

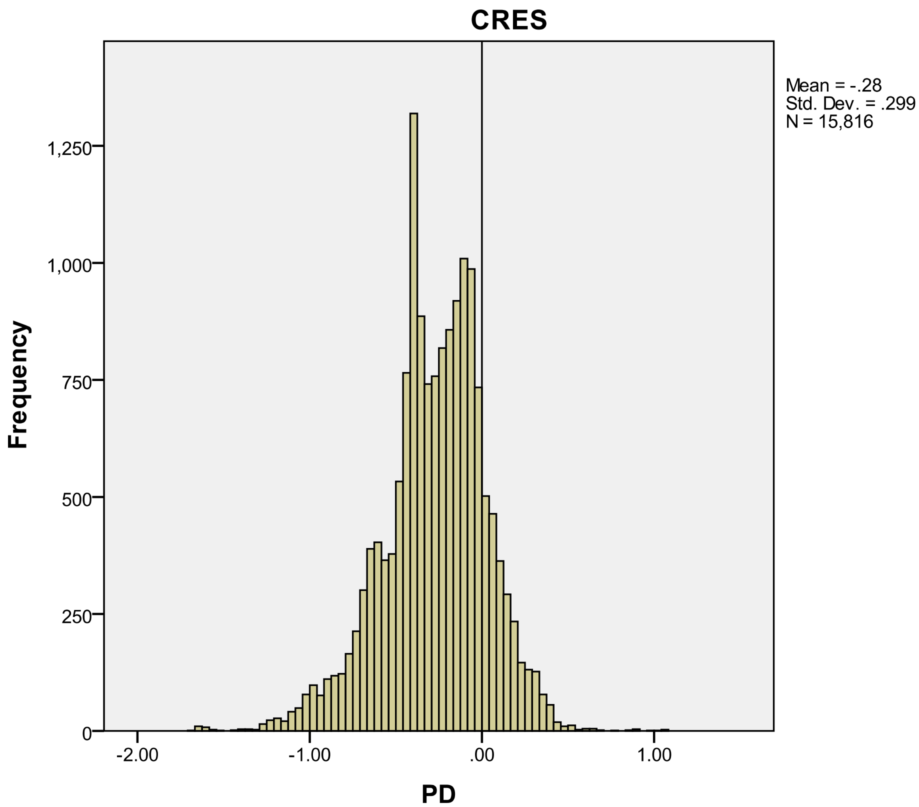

OCIC
Frequency
4,000
3,000
2,000
1,000
0
-4.00
-2.00
.00
2.00
4.00
6.00
pd
Mean = -.21
Std. Dev. = .472
N = 27,984

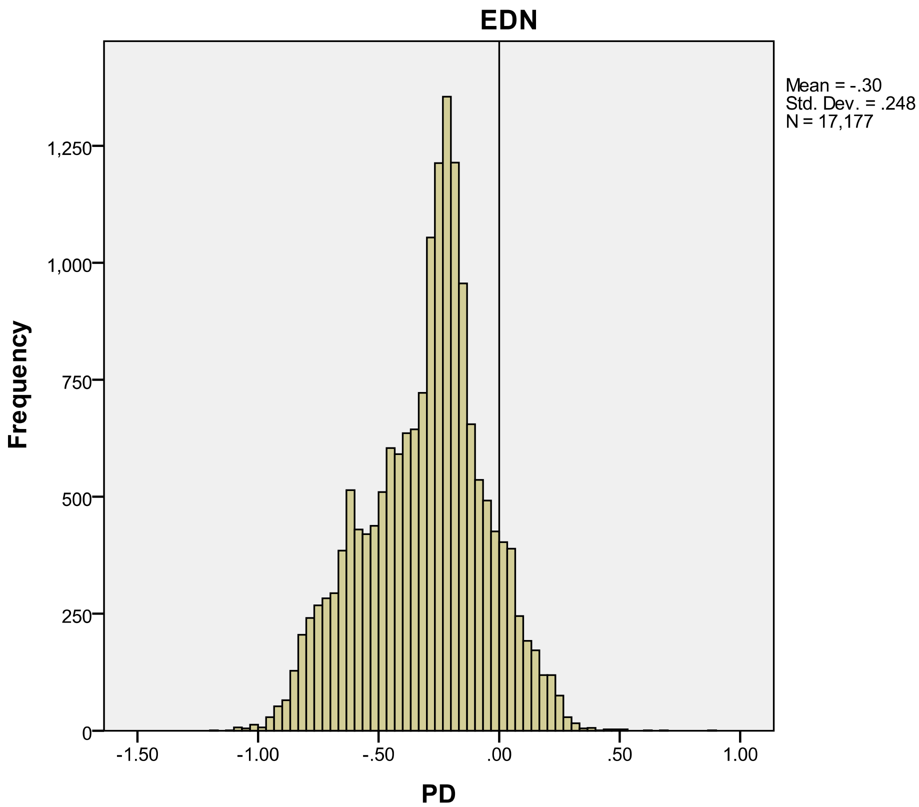

ETEL
Mean = -.20
Std. Dev. = .516
N = 469
Frequency
100
80
60
40
20
0
-2.00
-1.00
.00
1.00
2.00
PD

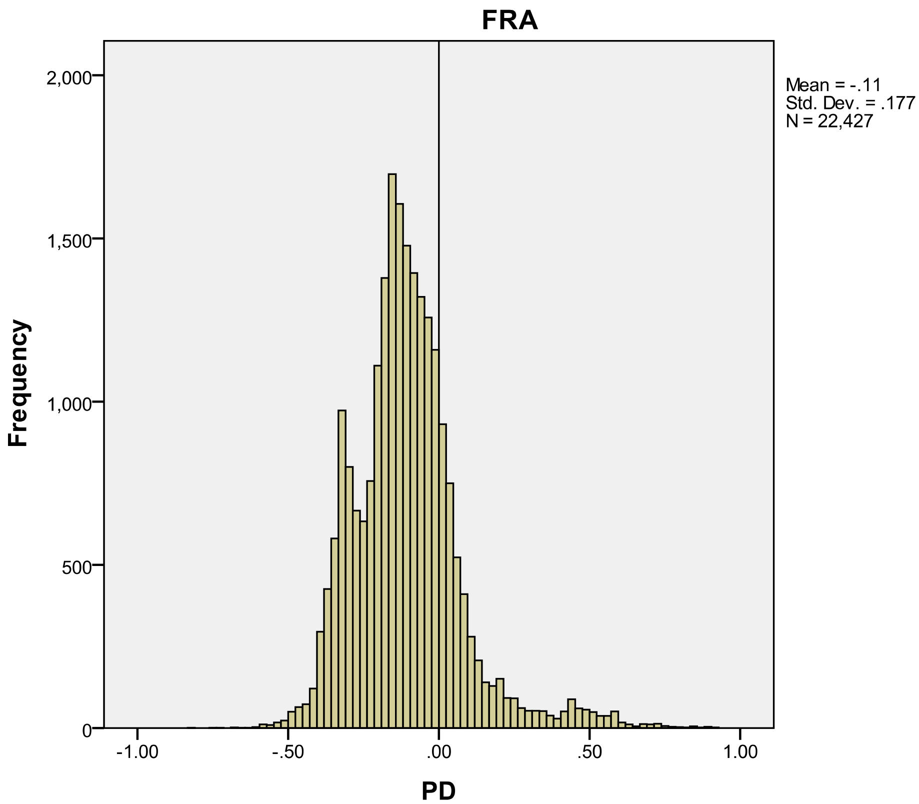

PHDC
Mean = -.06
Std. Dev. = .353
N = 378
Frequency
120
100
80
60
40
20
0
-3.00
-2.00
-1.00
.00
1.00
2.00
3.00
pd

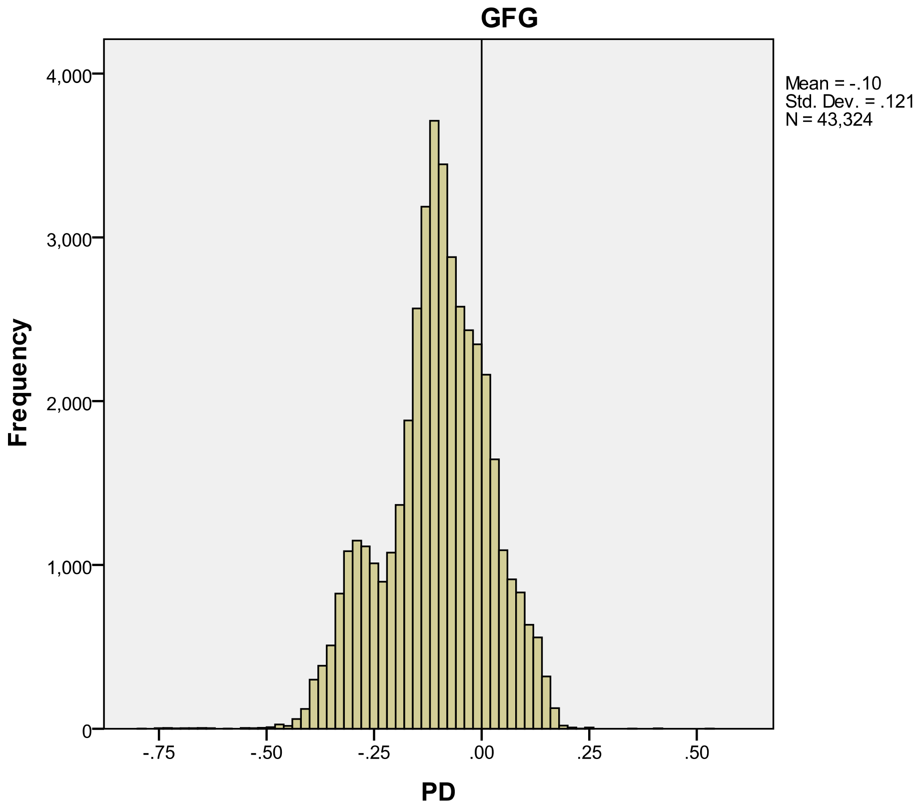


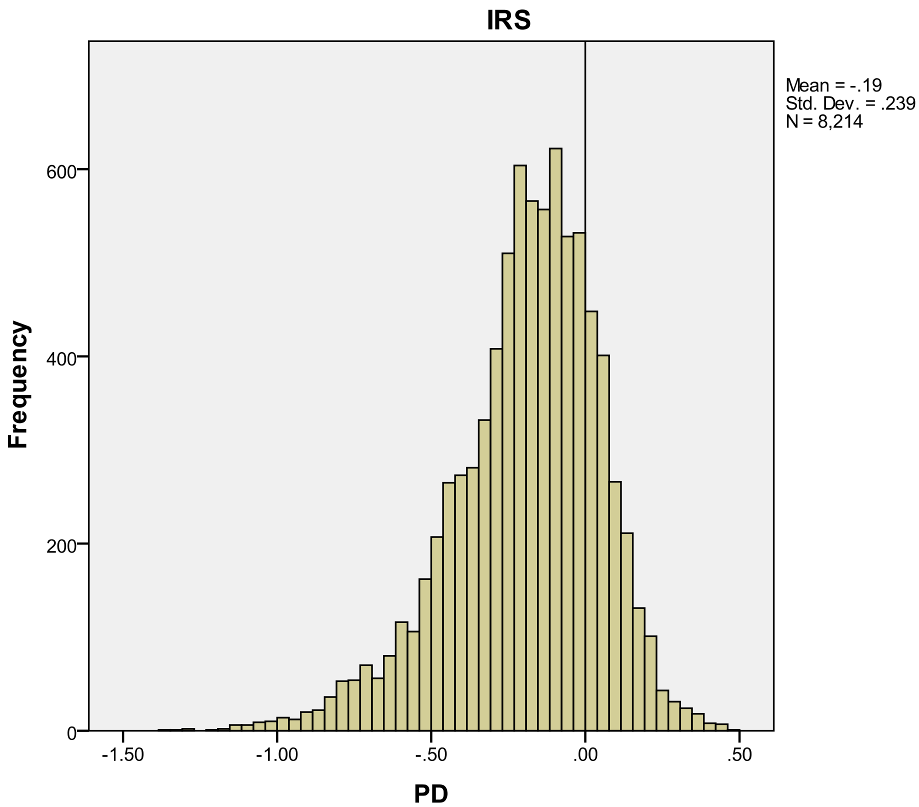
BMA
Mean = -.41
Std. Dev. = .406
N = 46,831
3,000
2,000
1,000
0
Frequency
-2.00
-1.00
.00
1.00
2.00
PD

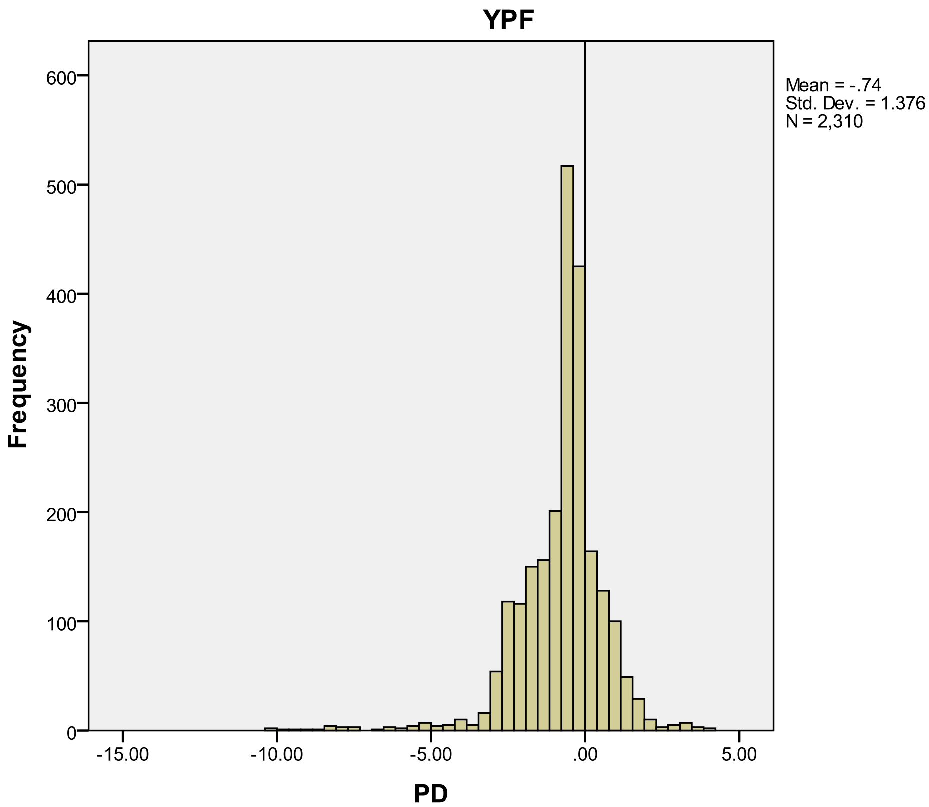

CRES
Mean = -.28
Std. Dev. = .299
N = 15,816
Frequency
1,250
1,000
750
500
250
0
-2.00
-1.00
.00
1.00
PD

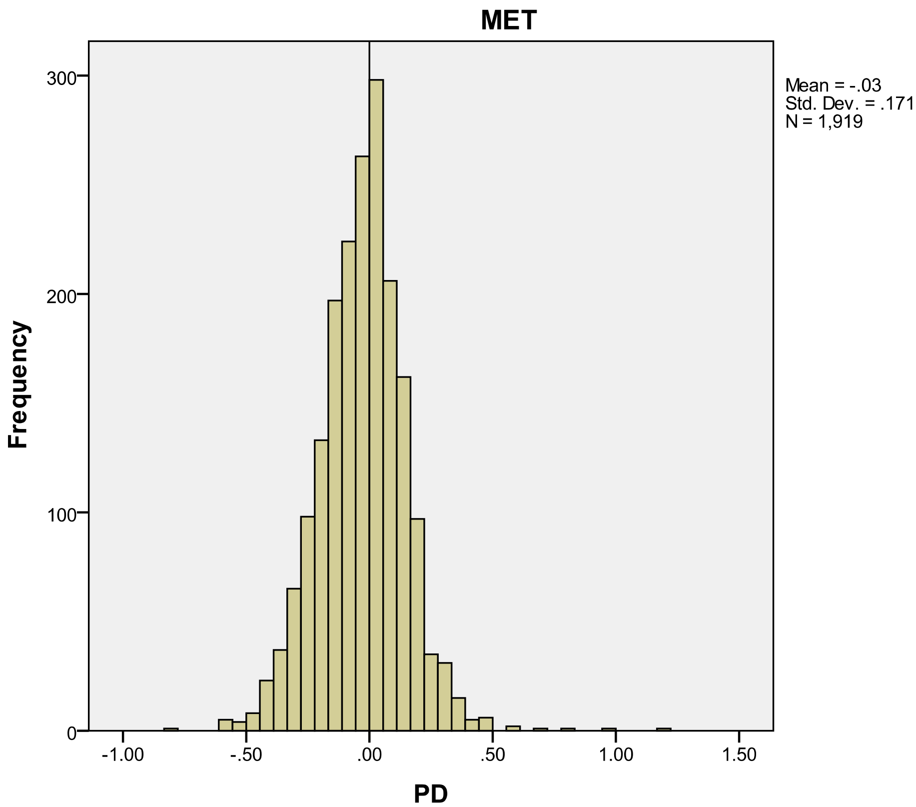

EDN
Mean = -.30
Std. Dev. = .248
N = 17,177
Frequency
1,250
1,000
750
500
250
0
-1.50
-1.00
-.50
.00
.50
1.00
PD

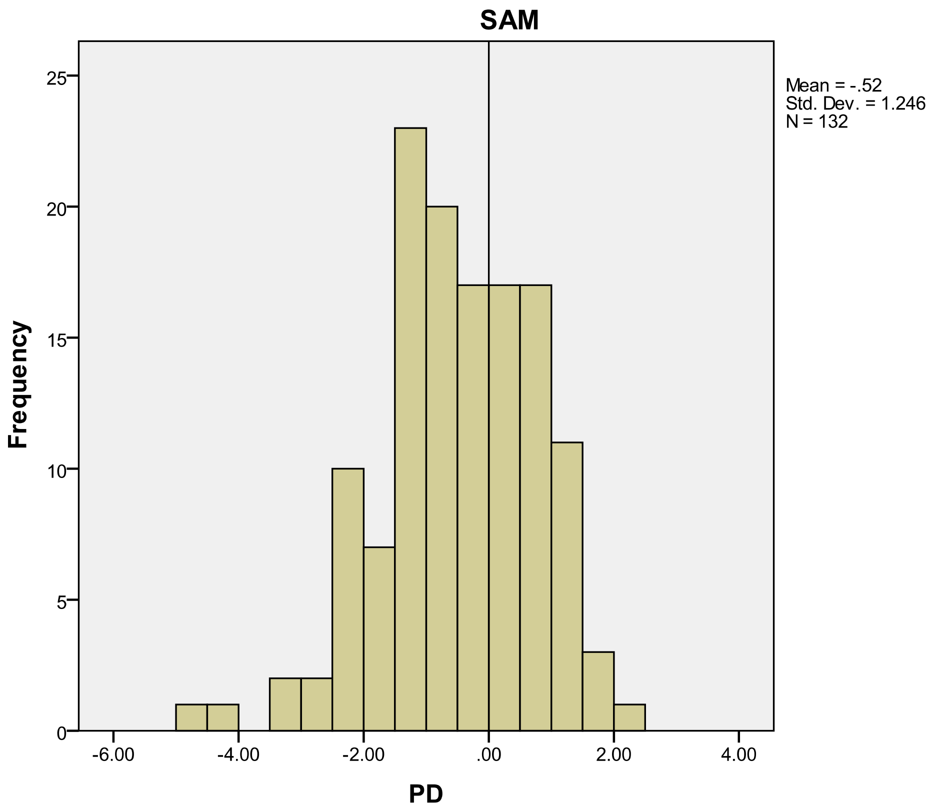

FRA
Mean = -.11
Std. Dev. = .177
N = 22,427
Frequency
2,000
1,500
1,000
500
0
-1.00
-.50
.00
.50
1.00
PD

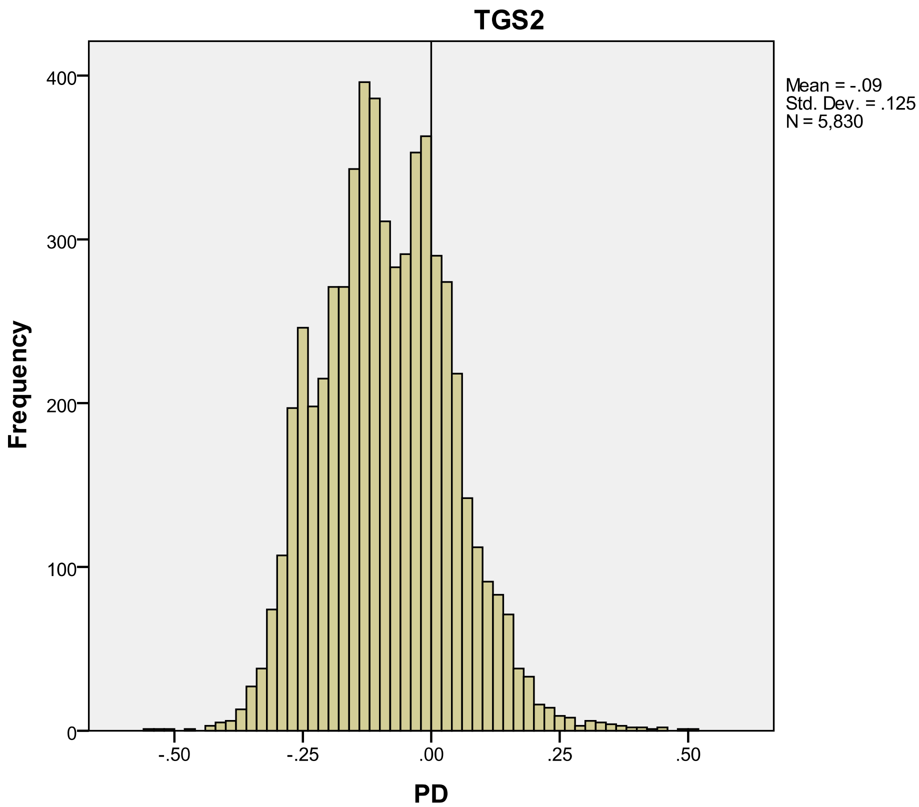

GFG
Mean = -.10
Std. Dev. = .121
N = 43,324
Frequency
4,000
3,000
2,000
1,000
0
-.75
-.50
-.25
.00
.25
.50
PD


IRS
Mean = -.19
Std. Dev. = .239
N = 8,214
Frequency
600
400
200
0
-1.50
-1.00
-.50
.00
.50
PD


YPF
Mean = -.74
Std. Dev. = 1.376
N = 2,310
Frequency
600
500
400
300
200
100
0
-15.00
-10.00
-5.00
.00
5.00
PD

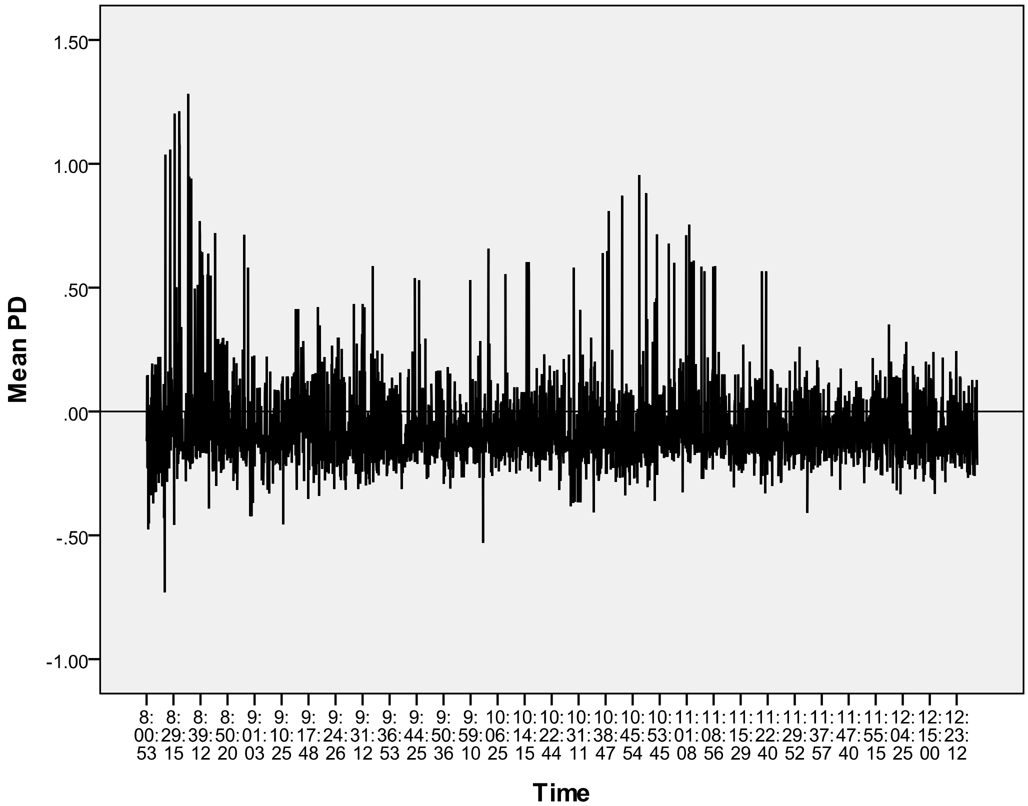

MET
Mean = -.03
Std. Dev. = .171
N = 1,919
Frequency
300
200
100
0
-1.00
-.50
.00
.50
1.00
1.50
PD


SAM
Mean = -.52
Std. Dev. = 1.246
N = 132
Frequency
25
20
15
10
5
0
-6.00
-4.00
-2.00
.00
2.00
4.00
PD

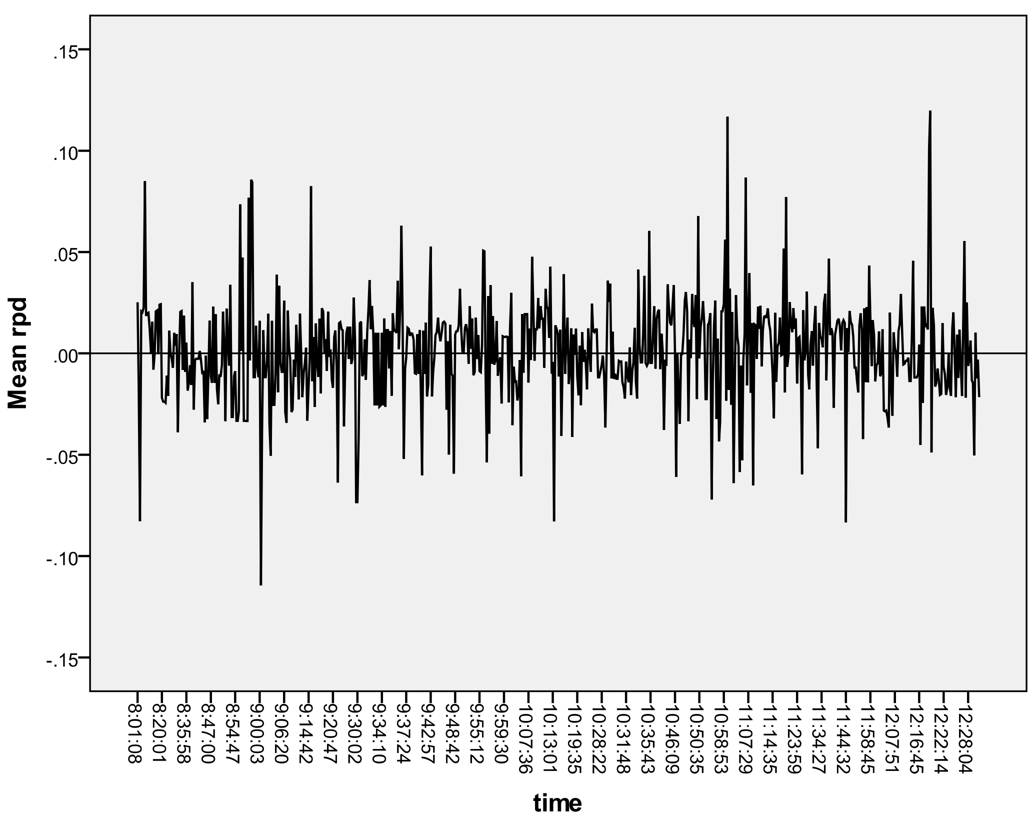


10.10 Appendix 10 Price Deviation by Hour of Overlap

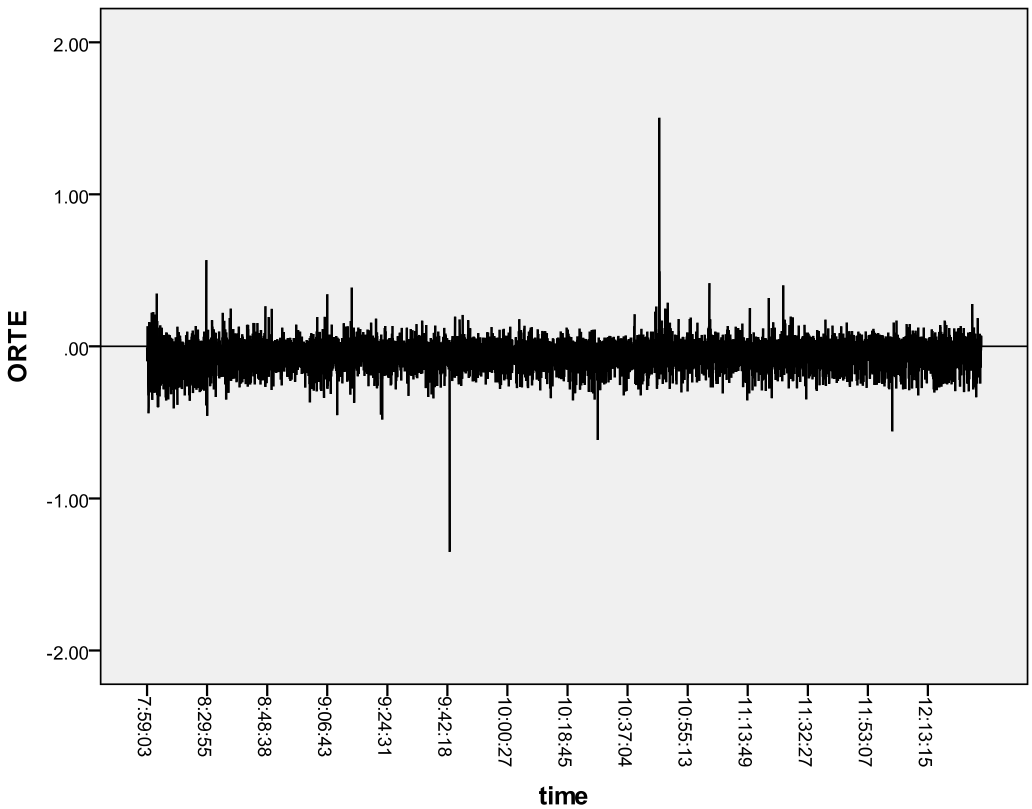
COMI


1.50
1.00
.50
.00
-.50
-1.00
Mean PD
8:00:53
8:29:15
8:39:12
8:50:20
9:01:03
9:10:25
9:17:48
9:24:26
9:31:12
9:36:53
9:44:25
9:50:36
9:59:10
10:06:25
10:14:15
10:22:44
10:31:11
10:38:47
10:45:54
10:53:45
11:01:08
11:08:56
11:15:29
11:22:40
11:29:52
11:37:57
11:47:40
11:55:15
12:04:25
12:15:00
12:23:12
Time

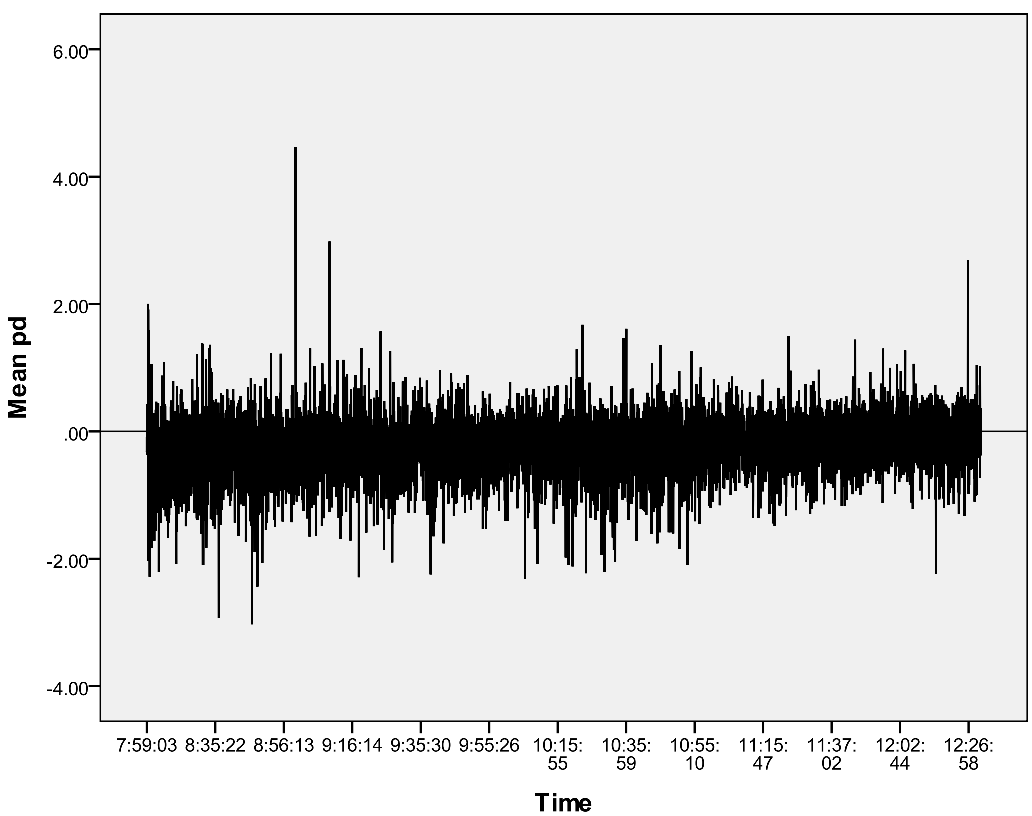
HRHO

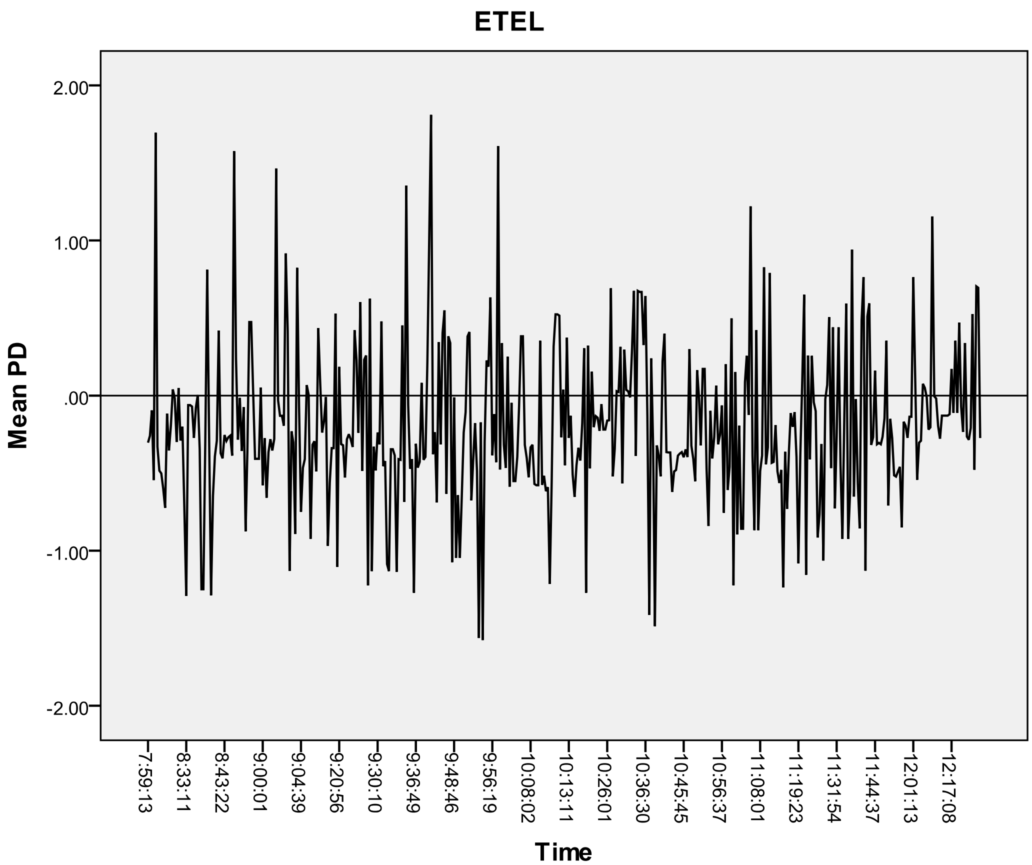

.15
.10
.05
.00
-.05
-.10
-.15
Mean rpd
8:01:08
8:20:01
8:35:58
8:47:00
8:54:47
9:00:03
9:06:20
9:14:42
9:20:47
9:30:02
9:34:10
9:37:24
9:42:57
9:48:42
9:55:12
9:59:30
10:07:36
10:13:01
10:19:35
10:28:22
10:31:48
10:35:43
10:46:09
10:50:35
10:58:53
11:07:29
11:14:35
11:23:59
11:34:27
11:44:32
11:58:45
12:07:51
12:16:45
12:22:14
12:28:04
time

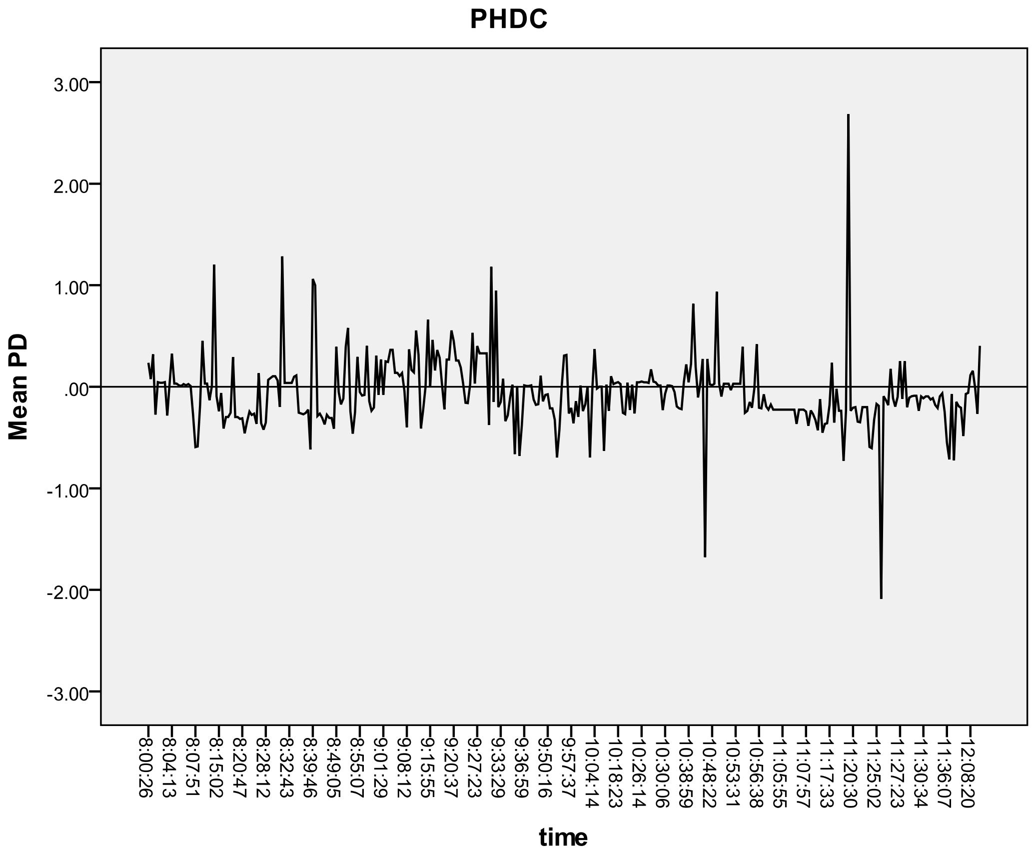
ORTE


2.00
1.00
.00
-1.00
-2.00
ORTE
7:59:03
8:29:55
8:48:38
9:06:43
9:24:31
9:42:18
10:00:27
10:18:45
10:37:04
10:55:13
11:13:49
11:32:27
11:53:07
12:13:15
time

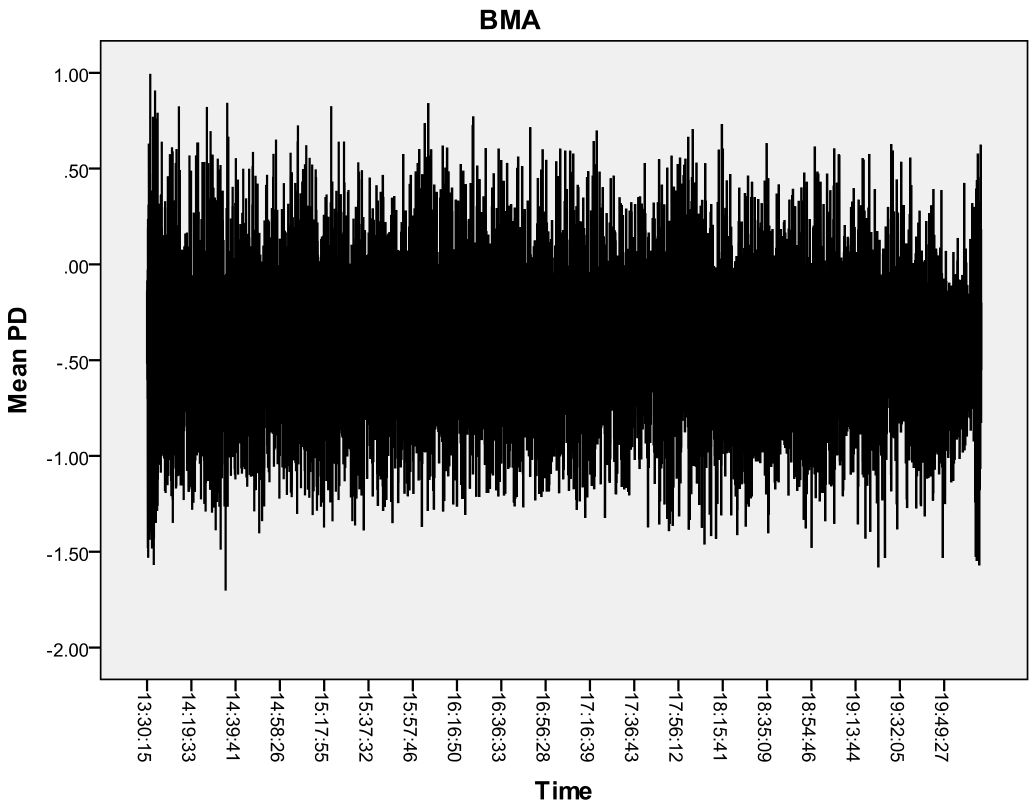
OCIC

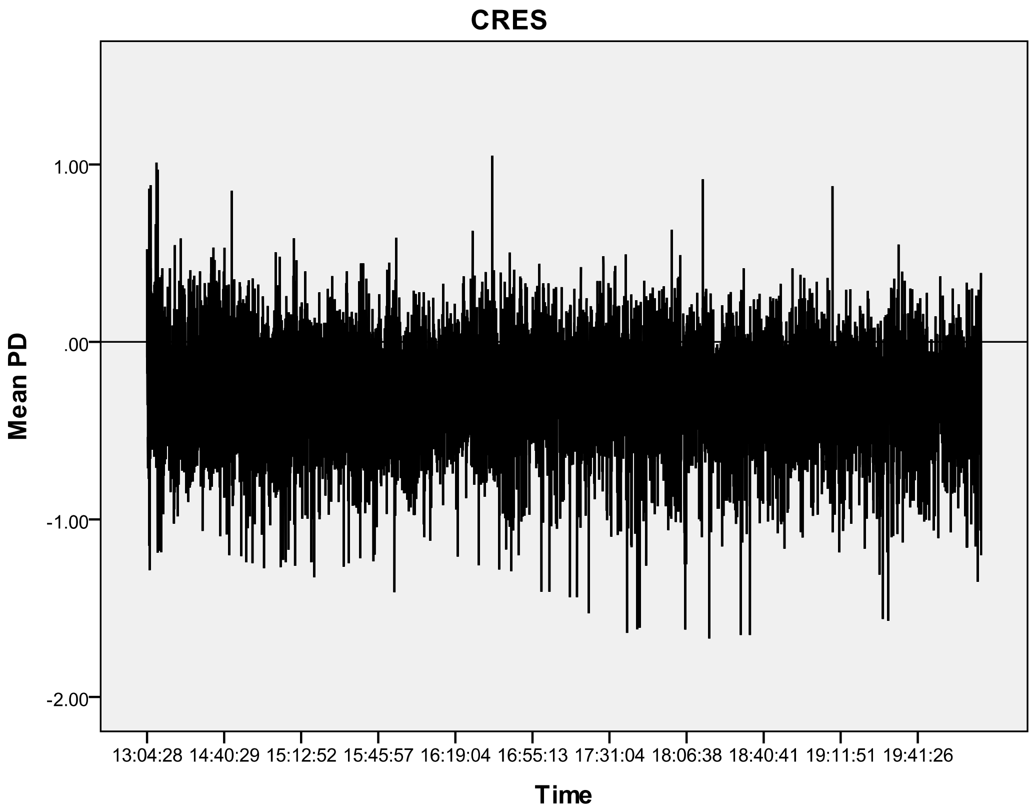

6.00
4.00
2.00
.00
-2.00
-4.00
Mean pd
7:59:03
8:35:22
8:56:13
9:16:14
9:35:30
9:55:26
10:15:55
10:35:59
10:55:10
11:15:47
11:37:02
12:02:44
12:26:58
Time

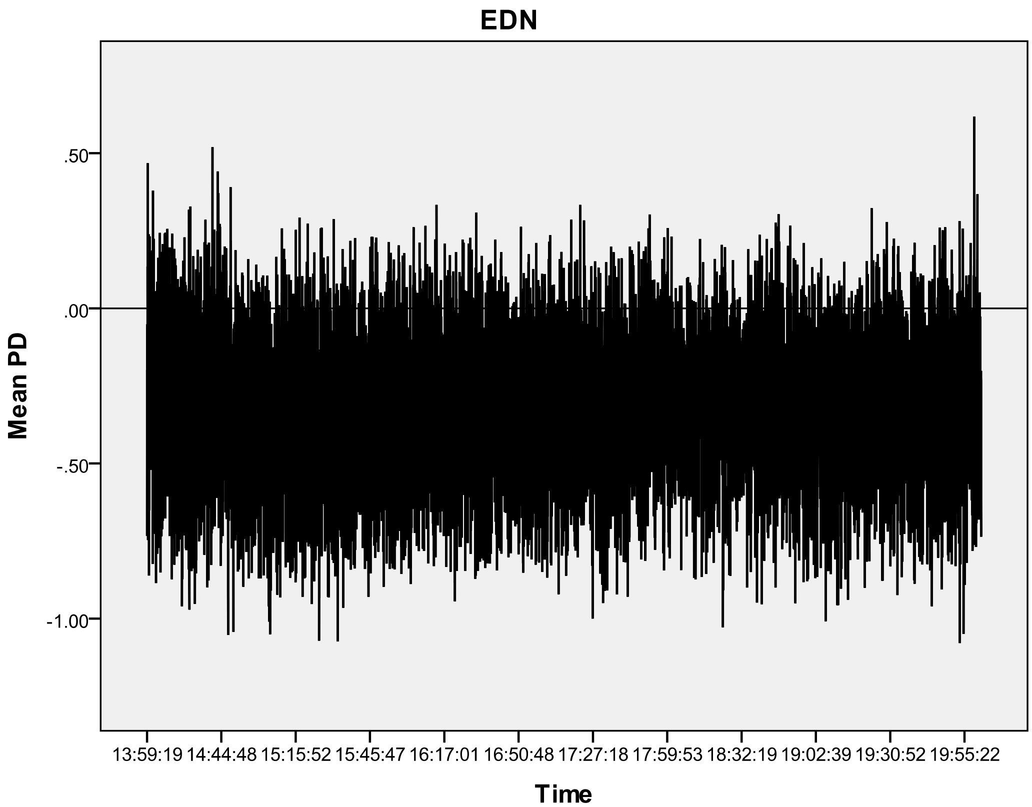

ETEL
2.00
1.00
.00
-1.00
-2.00
Mean PD
7:59:13
8:33:11
8:43:22
9:00:01
9:04:39
9:20:56
9:30:10
9:36:49
9:48:46
9:56:19
10:08:02
10:13:11
10:26:01
10:36:30
10:45:45
10:56:37
11:08:01
11:19:23
11:31:54
11:44:37
12:01:13
12:17:08
Time

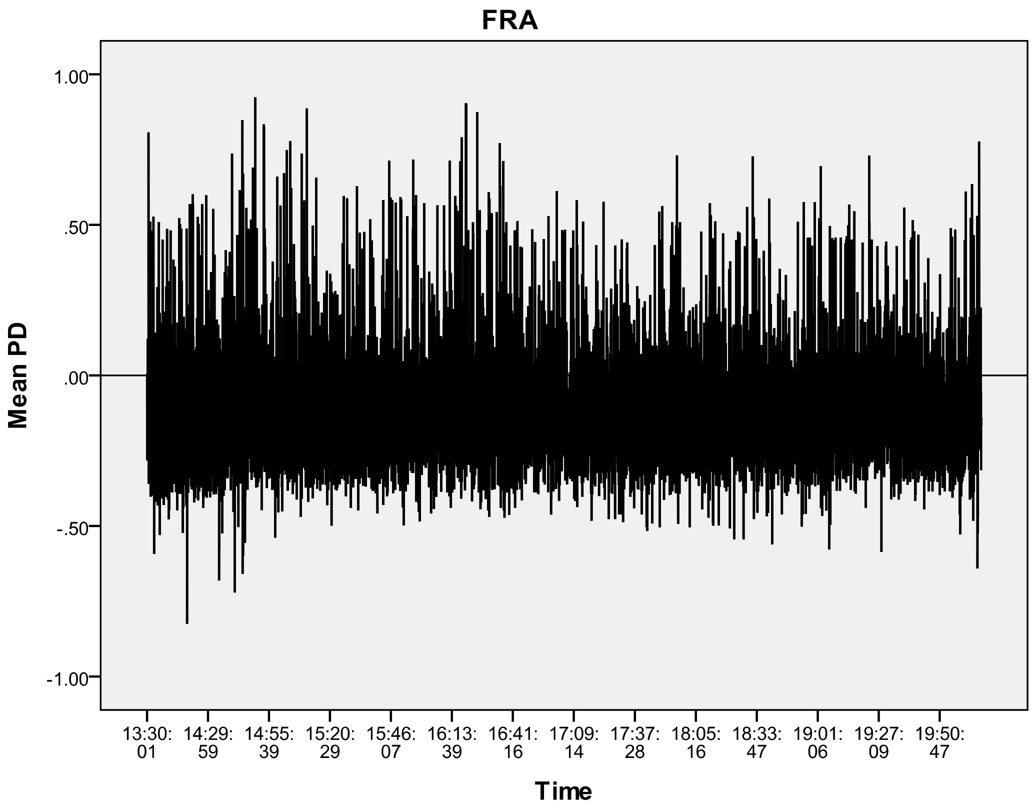


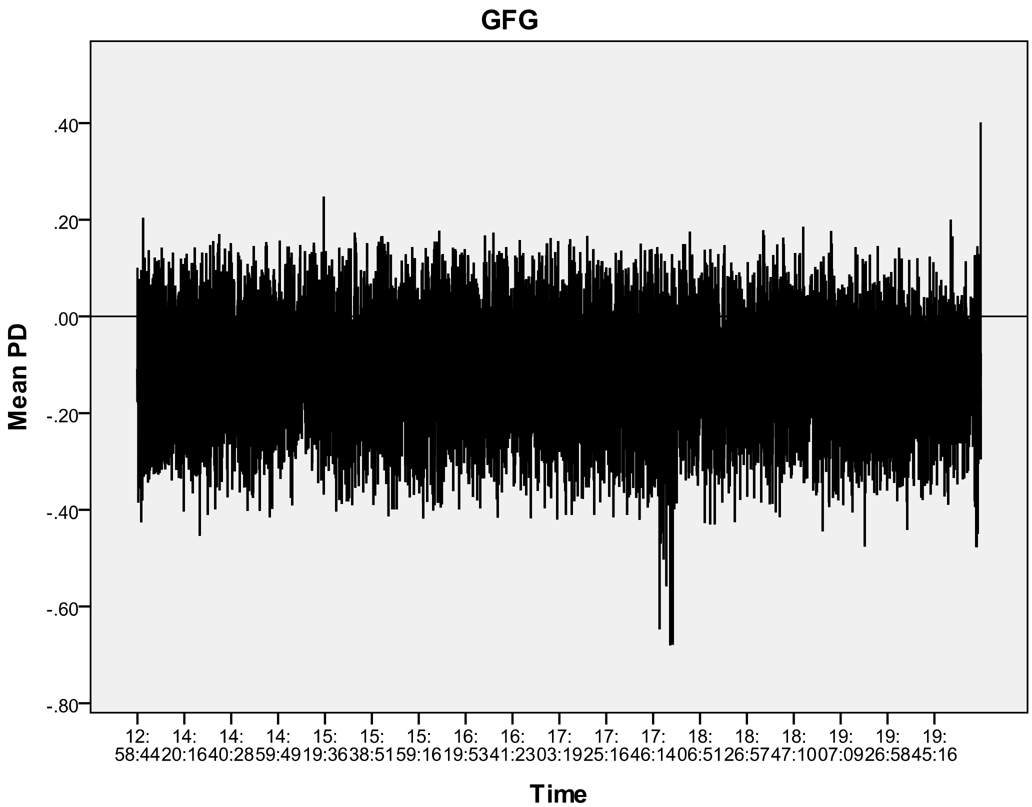
PHDC
3.00
2.00
1.00
.00
-1.00
-2.00
-3.00
Mean PD
8:00:26
8:04:13
8:07:51
8:15:02
8:20:47
8:28:12
8:32:43
8:39:46
8:49:05
8:55:07
9:01:29
9:08:12
9:15:55
9:20:37
9:27:23
9:33:29
9:36:59
9:50:16
9:57:37
10:04:14
10:18:23
10:26:14
10:30:06
10:38:59
10:48:22
10:53:31
10:56:38
11:05:55
11:07:57
11:17:33
11:20:30
11:25:02
11:27:23
11:30:34
11:36:07
12:08:20
time

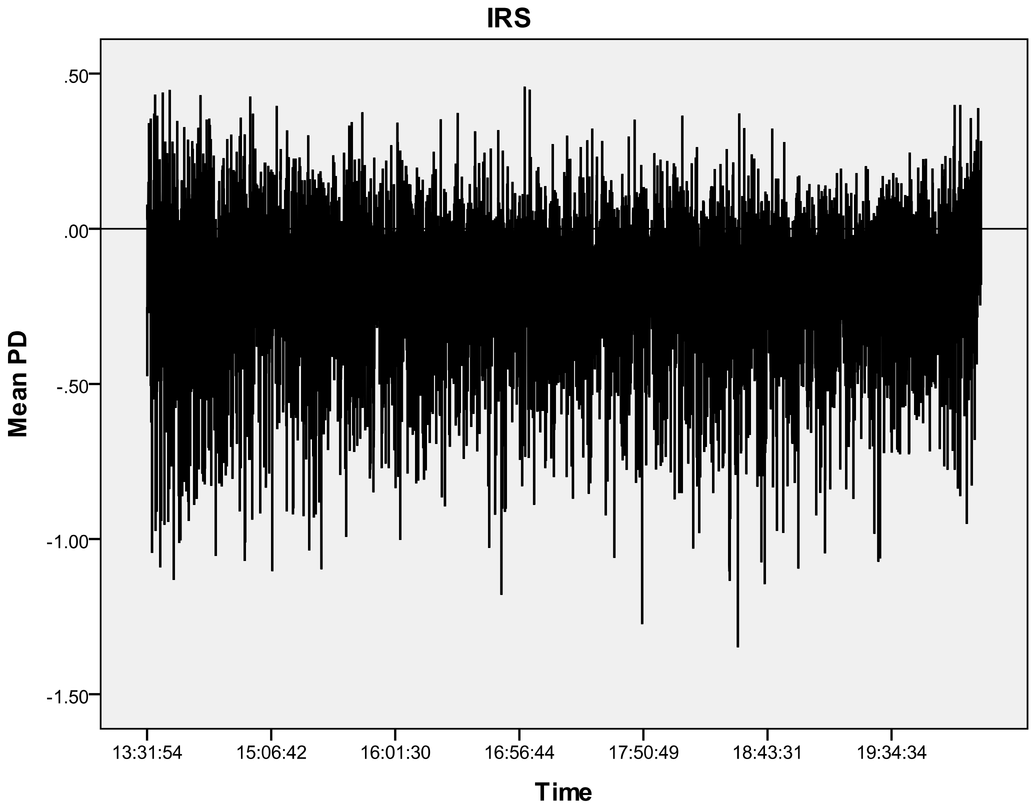

BMA
1.00
.50
.00
-.50
-1.00
-1.50
-2.00
Mean PD
13:30:15
14:19:33
14:39:41
14:58:26
15:17:55
15:37:32
15:57:46
16:16:50
16:36:33
16:56:28
17:16:39
17:36:43
17:56:12
18:15:41
18:35:09
18:54:46
19:13:44
19:32:05
19:49:27
Time

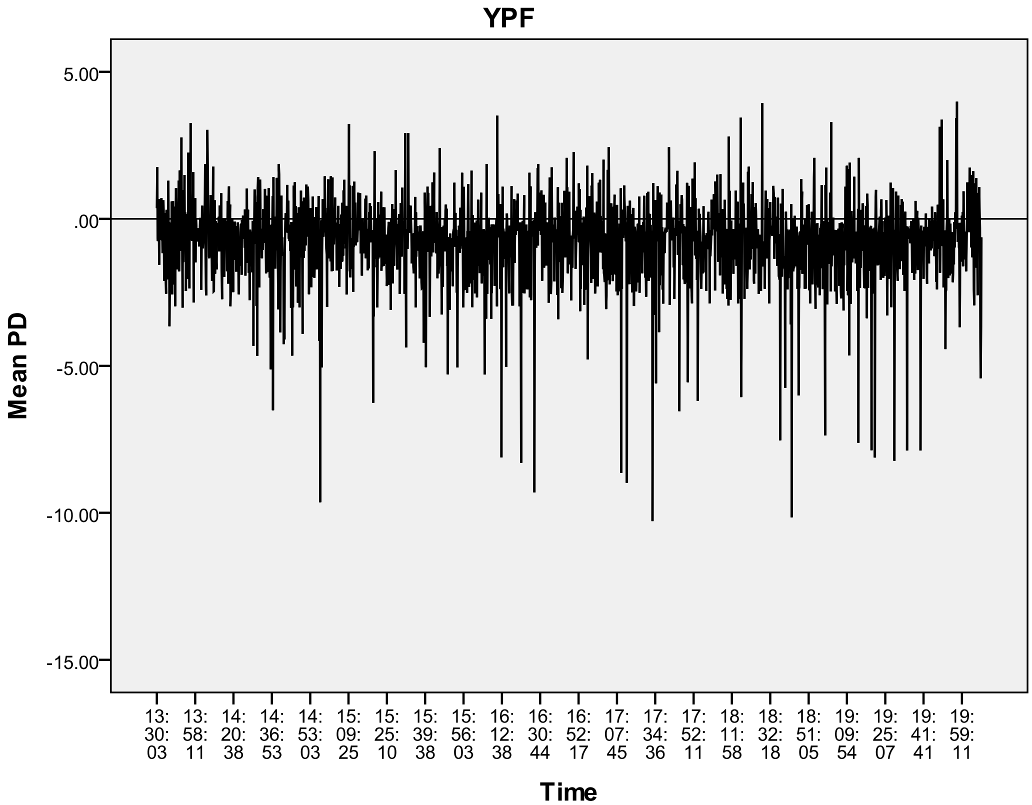

CRES
1.00
.00
-1.00
-2.00
Mean PD
13:04:28
14:40:29
15:12:52
15:45:57
16:19:04
16:55:13
17:31:04
18:06:38
18:40:41
19:11:51
19:41:26
Time


EDN
.50
.00
-.50
-1.00
Mean PD
13:59:19 14:44:48 15:15:52 15:45:47 16:17:01 16:50:48 17:27:18 17:59:53 18:32:19 19:02:39 19:30:52 19:55:22
Time

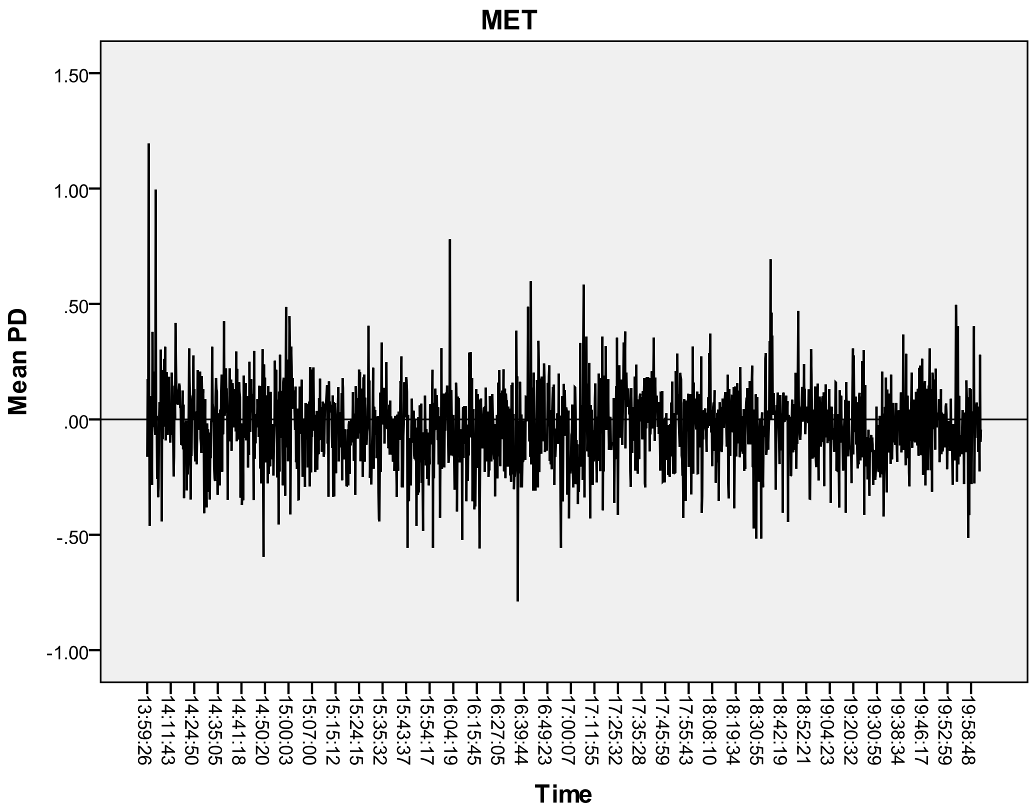

FRA
1.00
.50
.00
-.50
-1.00
Mean PD
13:30: 01
14:29: 59
14:55: 39
15:20: 29
15:46: 07
16:13: 39
16:41: 16
17:09: 14
17:37: 28
18:05: 16
18:33: 47
19:01: 06
19:27: 09
19:50: 47
Time

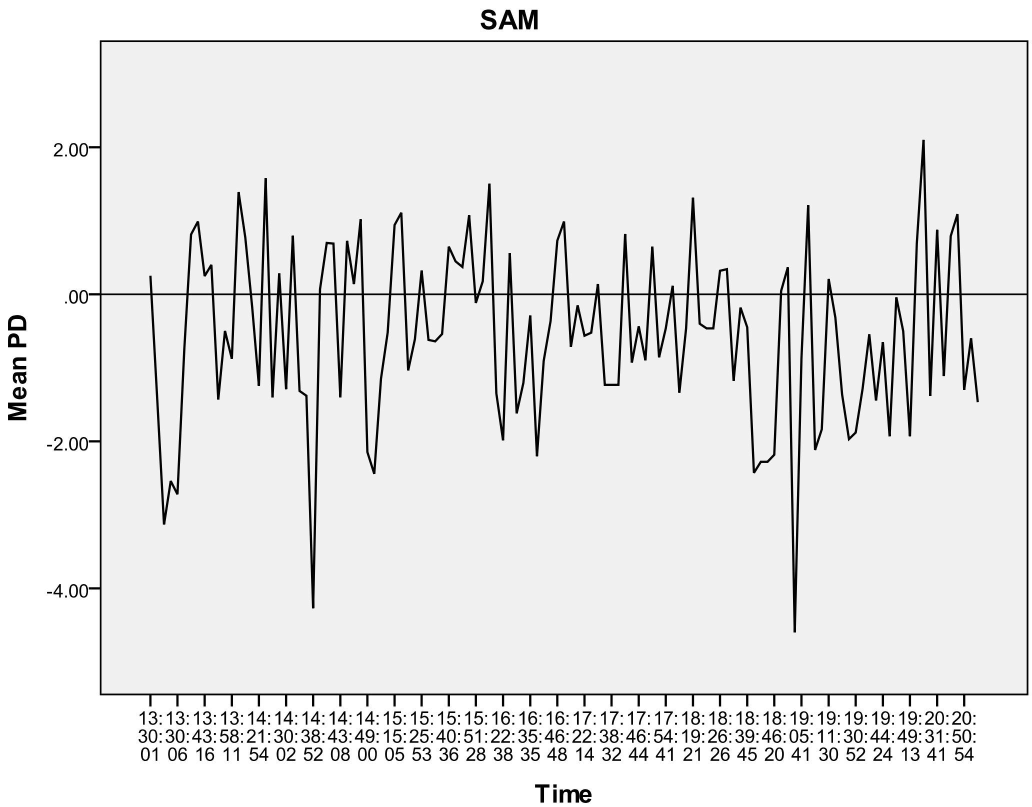

GFG
Mean PD
.40
.20
.00
-.20
-.40
-.60
-.80
12: 58:44
14: 20:16
14: 40:28
14: 59:49
15: 19:36
15: 38:51
15: 59:16
16: 19:53
16: 41:23
17: 03:19
17: 25:16
17: 46:14
18: 06:51
18: 26:57
18: 47:10
19: 07:09
19: 26:58
19: 45:16
Time

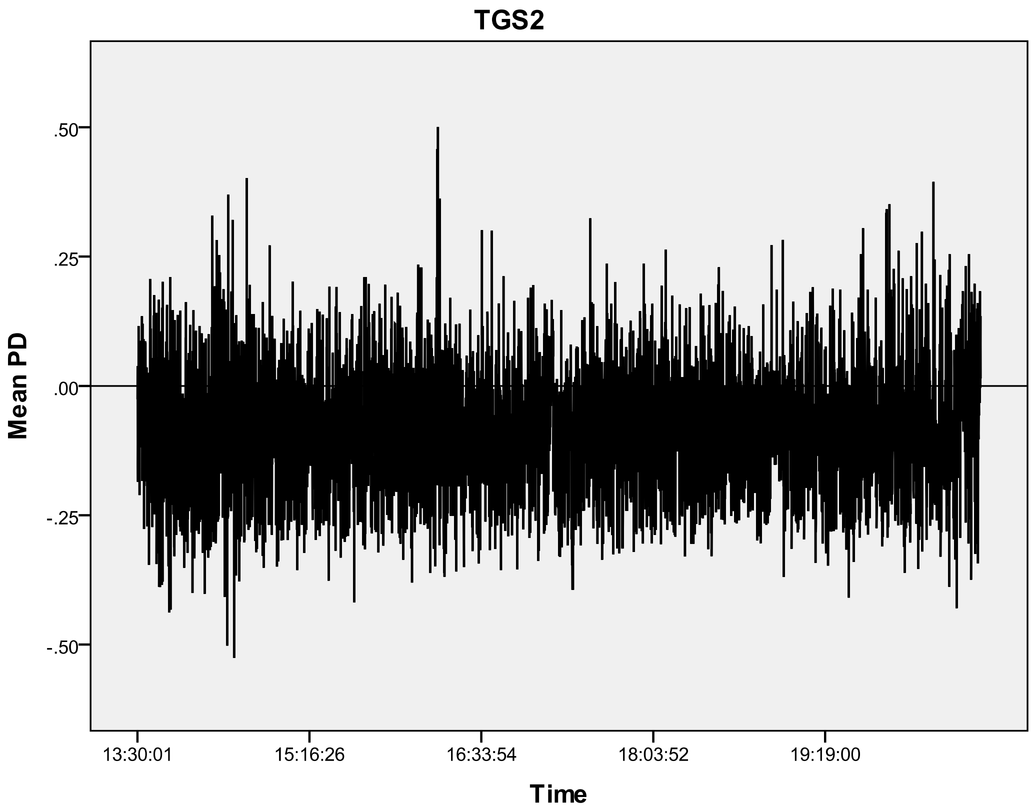

IRS
.50
.00
-.50
-1.00
-1.50
Mean PD
13:31:54
15:06:42
16:01:30
16:56:44
17:50:49
18:43:31
19:34:34
Time



YPF
Mean PD
5.00
.00
-5.00
-10.00
-15.00
Time
13:30:03
13:58:11
14:20:38
14:36:53
14:53:03
15:09:25
15:25:10
15:39:38
15:56:03
16:12:38
16:30:44
16:52:17
17:07:45
17:34:36
17:52:11
18:11:58
18:32:18
18:51:05
19:09:54
19:25:07
19:41:41
19:59:11


MET
Mean PD
1.50
1.00
.50
.00
-.50
-1.00
13:59:26
14:11:43
14:24:50
14:35:05
14:41:18
14:50:20
15:00:03
15:07:00
15:15:12
15:24:15
15:35:32
15:43:37
15:54:17
16:04:19
16:15:45
16:27:05
16:39:44
16:49:23
17:00:07
17:11:55
17:25:32
17:35:28
17:45:59
17:55:43
18:08:10
18:19:34
18:30:55
18:42:19
18:52:21
19:04:23
19:20:32
19:30:59
19:38:34
19:46:17
19:52:59
19:58:48
Time


SAM
Mean PD
2.00
.00
-2.00
-4.00
13:30:01
13:30:06
13:43:16
13:58:11
14:21:54
14:30:02
14:38:52
14:43:08
14:49:00
15:15:05
15:25:53
15:40:36
15:51:28
16:22:38
16:35:35
16:46:48
17:22:14
17:38:32
17:46:44
17:54:41
18:19:21
18:26:26
18:39:45
18:46:20
19:05:41
19:11:30
19:30:52
19:44:24
19:49:13
20:31:41
20:50:54
Time


TGS2
Mean PD
.50
.25
.00
-.25
-.50
13:30:01
15:16:26
16:33:54
18:03:52
19:19:00
Time