U.PORTO
FEP FACULDADE DE ECONOMIA
UNIVERSIDADE DO PORTO

Dynamic linkages between Chinese ADRs and underlying stocks returns

Nuno Faustino Loureiro

Dissertation
Master in Finance

Supervised by

Prof. Júlio Fernando Seara Sequeira da Mota Lobão

2022

Acknowledgements

I would like to start by expressing my gratitude to all those, who in some way or another, helped and supported me during the development of this dissertation.

First of all, I would like to thank professor Júlio Lobão, for accepting to be my tutor in the development of this thesis and for all the help and guidance he provided me during the whole process.

Secondly, I would like to thank my colleagues who frequented the Master in Finance with me. They stood with me throughout these two years and it was a pleasure to learn and grow alongside them as future professionals in the world of finance.

Lastly, I would like to thank my family and friends for all the support they provided me during not just the development of my dissertation, but also during these five amazing years I spent at the School of Economics and Management of the University of Porto.

To all of you, a big thank you.

Abstract

American Depository Receipts, or ADRs, are negotiable certificates, issued by US depository banks, that represent a certain number of shares of a foreign company stock. Over the last few decades, the ADR market has grown, both in number and geographical diversification. As such, it becomes important to study this market.

In this dissertation, we propose to analyze the dynamic linkages between American Depository Receipts (ADRs) and the corresponding underlying stocks returns. We will follow the paper by Patel (2015) and apply its methodology to Chinese ADRs currently listed on American stock exchanges, using daily closing prices from as far back as there is data on both ADR and underlying stock of each company, until the 20th of April 2022. In total, the sample is made up of 23 ADRs.

For this study, we resort to the Dickey-Fuller unit root test, Johansen cointegration test, Granger causality test, vector error correction model, impulse response function and variance decomposition.

The results of this study corroborate those of Patel (2015). Both ADRs and underlying stocks are stationary and display long-run equilibrium between the two. In addition, these assets display, in most instances, bidirectional Granger causality, as well as produce a positive effect in one another. Furthermore, a significant portion of each asset's variance is explained by the other. All in all, both ADRs and underlying stocks are found to be major determinants of each other's returns.

Findings of this study could provide some valuable insights, namely for policy makers and investors. For investors, this study could provide some useful inside on whether ADRs allow for international diversification. For authorities, it could help highlight the importance of both markets, since if ADRs and underlying stocks display long-run equilibrium, both markets should be closely monitored.

Keywords: American Depository Receipt, Determinants, VECM, Impulse Response Function and Variance Decomposition.

Table of Contents

List of Tables

Table of Figures

1 Introduction

The depository receipt (DR) market has been experiencing growing importance over the past few years. Just last year, and as published by Citigroup (2022), in 2021 depository receipts raised a total of 35.4 billion globally, trading volume was up by 17% and investors held around 1.1 trillion in DRs.

American Depository Receipts (ADRs) dominate the depository receipt market. In 2021, 49 of the 58 US IPOs came from ADRS. The top ten most liquid securities by trading value and trading volume are exchanged in the US, either in the NYSE or NASDAQ stock exchanges, with a good portion of these representing Chinese companies. Additionally, the majority of the number of equity offerings as well as the capital raised came from Chinese firms.

With this in mind, the theme we are proposing to develop is the dynamic linkages between ADRs and the corresponding underlying stocks returns, based on the paper by Patel (2015).

The main objective of our dissertation is to apply the paper's methodology to Chinese ADRs currently listed on American stock exchanges, using daily closing prices from as far back as there is data on both ADR and underlying stock of each company, until the 20th of April 2022, for a sample of 23 ADRs. We will thus study a different market and update existing information with a more recent time period. Though there have been previous studies addressing Chinese ADRs, my goal here is to update existing information on the relation between ADRs and their underlying stocks, as well as see if the findings of Patel (2015) hold for a different geography.

Given that ADRs end up increasing companies' exposure to investors all around the world, given of course the increased exposure and liquidity of the American stock market, findings of this study could provide some valuable insights for policy makers, researchers, and academia, as well as investors.

For investors, this study could provide some useful inside on whether ADRs allow for international diversification, by the analysis of their correlation and causality.

The results of this study could also provide useful information for authorities. If there is long-run equilibrium between ADRs and underlying stocks, regulatory authorities should monitor both ADR and underlying stock market, since a crisis in one market can impact the other. Furthermore, if ADR and underlying stocks positively affect one another and if ADRs contribute to price discovery and efficiency, ADRs should be supported by local authorities.

The results of this study largely corroborate those of Patel (2015). Both ADRs and underlying stocks are stationary and display long-run equilibrium between the two. In addition, results indicate that these assets display, in most instances, bidirectional Granger causality, as well as produce a positive effect in one another, measured through impulse response functions. Furthermore, a significant portion of each asset's variance is explained by the other, as attested by performing variance decomposition. All in all, both ADRs and underlying stocks are found to be major determinants of each other's returns.

With this said, this study is organized as follows. Chapter 2 contains the literature review. Chapter 3 presents the data and methodology used. Chapter 4 contains the empirical analysis of the results. Finally, chapter 5 provides the study´s conclusion and suggest further research opportunities.

2 Literature Review

2.1 Relevant Definitions

An American Depository Receipt, or ADR for short, is a negotiable certificate that represents a certain number of shares of a foreign company stock (most often they represent one foreign share) and is issued by a US depository bank. These ADRs trade on American stock markets like any other stock and thus allow investors to purchase overseas stock. The way it works is a US financial institution buys foreign stock, which it then keeps in its inventory, and sells the ADR to the public. By doing this, investors do not have to worry about exchanging currency in the market in order to purchase the underlying stock, something which in turn is made by the bank.

An important distinction is needed as to differentiate between ADRs and ADSs. Unlike ADRs, American Depository Shares, or ADSs for short, are the actual shares of the underlying company, owned by the depository bank and quoted in dollars. This way, each individual share is referred to as ADS and the entirety of the issuance is called ADR, reason why ADSs are usually traded as ADRs.

There are two main types of ADRs: sponsored ADRs and unsponsored ADRs. Sponsored ADRs are those where the depository bank issues the ADR on behalf of a foreign company, so there is an agreement between the two entities. On the other hand, unsponsored ADRs are those where the depository bank issues the ADR on its own accord, without partnering with the foreign company.

Furthermore, ADRs can be divided into three different levels, according to level of access foreign companies have to US markets. Level I ADRs are not listed on an exchange and do not allow firms to raise capital. They can, however, be used to establish a trading presence and are traded over-the-counter.

Level II ADRs still do not allow firms to raise capital, though the instruments are quoted on an exchange, meaning they have more requirements from the SEC than previous level ADRs.

Finally, level III ADRs are exchange traded and allow companies to raise capital in the American market. They have more SEC requirements than the previous two levels, but are also the most prestigious one.

There are a number of advantages regarding ADRs. First of all, they provide investors, particularly US investors, with an easier way to invest in foreign companies, or in companies to which they might not otherwise have access to. Secondly, as discussed in a subsequent chapter of this study, ADRs provide investors with a way to internationally diversify their portfolios, without actually having to buy foreign securities. In addition, investors do not have to incur in exchange rate risks, at least directly, since the purchase of the underlying stock is secured by the depository bank. Last but not least, issuing firms benefit from this type of issue since they can get exposure to a new capital market, which is significantly more exposed to global investors than the local market.

There are, however, disadvantages to this type of security. Firstly, ADRs do not necessarily have to comply with SEC standards. Secondly, though they do not need to carry out exchange rate conversion directly, there could be fees associated with this when buying ADRs. Lastly, investors who purchase ADRs could be faced with double taxation.

2.2 Determinants of ADRs and underlying stock returns

Before looking at ADRs' suitability as an international diversification instrument or whether profitable arbitrage opportunities exist, it is important to understand the determinants of both ADRs and underlying stocks' returns.

There have been several authors to study this theme.

One of the more recent studies, by Rodriguez and Toledo (2015), suggests that both domestic market and US market are important determinants of ADRs. The authors use a sample of single-traded Chinese ADRs, meaning these companies are not traded on the domestic exchange, and find the result "consistent with the conjecture that US investors, because they lack precise information about Chinese firms issuing single-listed ADRs, use general information about the country markets to fairly price these instruments" (p. 493).

Esqueda and Jackson (2012) study this theme and suggest that underlying stock, exchange rates and home country market index are all major determinants of ADRs. The authors collect a sample of 74 ADRs from Argentina, Brazil, Chile and Mexico, between 1994 and 2009, and study the behavior of ADR returns during a 300-day period around currency crises in the mentioned countries. With this sample, the authors find that currency depreciations generate significant negative abnormal returns, even after considering the losses derived from the underlying stock, domestic index, exchange rate and US index. As the authors put it, "It appears that controlling for the underlying share captures the economic and transaction exposure, leaving only translation exposure to be carried by ADR holders" (p. 710).

This way, the paper suggests that translation exposure plays a key role in determining ADR prices, so investors should be weary of it and hedge against exchange rate fluctuations, in particular "with ADRs from countries whose currencies are subject to strong market pressures." (p. 710). Furthermore, the paper's results indicate that the major determinants of ADRs' prices are, by order, the underlying stock, exchange rates and home country market index.

In a previous study, Kim et al. (2000) also examine the determinants of ADRs, namely the price of the underlying stock in local currency, exchange rate and US market index, to determine the importance, in relative terms, as well as the speed of adjustment of ADR prices to, these chosen factors. However, unlike Esqueda and Jackson (2012), their chosen sample is from developed markets. Particularly, the authors create a sample of 56 ADRs from Japan, UK, Sweden, Netherlands, and Australia, between 1988 and 1991.

With this sample, the authors find that the price of the underlying stocks is the most relevant factor, though the exchange rate and US market index also play a role in ADR pricing. Furthermore, the authors' analysis allows them to find that changes to the pricing factors are not entirely reflected in the ADR price within the same calendar day, with the pricing adjustment only being complete the following day. There is also evidence of ADR overreaction to US market index and underreaction to both exchange rates and changes in the underlying stock prices, though the deviations from the Law of One Price are not significant enough, after transaction costs, to be profitably exploitable.

Choi and Kim (2000) also study the determinants of ADRs and underlying stock returns, however, their conclusions regarding the importance of exchange rates as determinants of ADRs differs from the previous authors presented. The authors study the period spanning 1990 to 1996, regarding "a firm-specific factor (underlying stock returns), world market factor (world market returns), country factors (local and US market returns), industry factors (world, local, and US industry factors), and finally the exchange rates" (p. 16) as determinants of ADRs.

This study includes ADRs from a variety of different geographies: "three Latin American markets (Argentina, Chile, and Mexico), two Asian markets (Hong Kong and Japan), eight European markets (Denmark, France, Germany, Italy, the Netherlands, Norway, Spain, and the UK) and two Oceanic markets (Australia and New Zealand)" (p. 3).

With this study, the authors find that local factors, both market and industry, have more explanatory power than the world factor for ADRs and their underlying stock returns. All these factors are, however, important determinants of ADRs and underlying stock returns, unlike exchange rates, which the authors find not to be so important. This finding is more acute in emerging markets than in developed markets, though Japan is a noticeable exception. In addition, the authors also find that ADR can be used as a tool for international diversification to investors, in particular ADRs from emerging markets.

2.3 Impact of ADRs on underlying stock and local stock market returns

An important topic worth exploring is the impact that multiple listing by companies has on both underlying stocks and respective local markets. In this section I will thus explore this theme, with a special attention given to the case of dual listed firms, in the form of ADRs.

One of the earlier studies to explore this theme is that of Jayaraman et al. (1993), which study the impact that issuing ADRs has on the underlying stocks. The authors study a sample of 95 firms that had an ADR issued between 1983 and 1988 and find the listing of ADRs leads to abnormal returns and increased volatility of returns for the underlying stock.

These findings support the idea that ADR issuance adds value to companies by providing access to another capital market. Furthermore, the authors find their results consistent with the model by Freedman (1989). Freedman (1989) states that the existence of two markets where the company is traded allows investors to place trades on both, thus taking advantage of any informational differences between them, which in turn increases the creation and development of private information, consequently increasing the volatility of returns of cross-listed securities.

Domowitz et al. (1998) study the consequences of cross-listing by examining the case of the Mexican stock market. The authors analyze 25 equity instruments issued by 16 different companies that had issued ADRs, for the period between 1989 and 1993, and analyze their daily prices and volume.

The authors present three main findings of their study. Firstly, issuance of an ADR seems to lead to "an increase in the variance of public information flows unrelated to the volatility induced by changes in liquidity and trading activity" (p. 25), which in turn is not consistent with the notion of market integration. Secondly, price seems to become more sensitive to volume changes, a manifestation of reduced liquidity and a possible result of foreign investors migrating to the ADR market. Thirdly, the bid-ask spread reduces, possibly explained by an "increased competition among domestic liquidity providers to retain order flow following cross-listing." (p. 26).

In a more recent study, Lang et al. (2003) also studies the consequences of companies cross listing their shares in American stock exchanges, namely regarding their informational environmental and posterior valuation. The sample includes companies from Argentina, Australia, Brazil, Canada, Chile, China, Columbia, Denmark, Finland, France, Germany, Hong-Kong, Ireland, Israel, Italy, Japan, Korea, Mexico, Netherlands, New Zealand, Norway, Peru, Philippines, Portugal, South Africa, Spain, Sweden and UK, during 1996.

In this paper, the authors present four main findings. Firstly, companies which choose to cross list are more exposed to the world, thus earning more coverage from analysts and investors, as well as display a greater forecast accuracy, when compared to companies which do not. Secondly, the authors find that the change in both analyst coverage and forecast accuracy happens around the time during which the cross listing takes place. Thirdly, the authors state that this increased coverage and forecast accuracy leads to higher company valuations. Lastly, they find that "firms with greater improvements in their information environment around cross listing also experience larger increases in valuations" (p. 26), an idea consistent with the possibility of lower cost of capital and/or better corporate governance.

All in all, the authors conclude that the increased exposure of firms following their ADR issuance leads to higher valuations.

Miller (1999) and Howe and Madura (1990) also study the impact of international listing, though unlike previous papers presented, their study is not focused on ADRs alone.

Miller (1999) examines the impact of international dual listing on companies' stock price, in particular the announcement effect of such listings. With a sample of 181 companies from 35 countries, the author finds significant positive price movement, especially in firms listed on the most relevant US exchanges. Thus, the author finds evidence that companies which dual list on the US market can increase shareholder wealth, supporting the idea that dual listing "can mitigate barriers to capital flows, resulting in a higher share price and a lower cost of capital." (pp. 19 and 20).

Howe and Madura (1990) study the impact of international listing on stock risk using a sample of companies from Australia, Belgium, France, Germany, Japan, the Netherlands, Switzerland and the UK. They conclude that listing does not appear to influence risk, regardless of which risk measures they used. To explain this, the authors put forth two possible explanations: (1) markets are already reasonably well integrated; (2) listing is not effective in reducing segmentation.

Regarding the second explanation, the authors hypothesize that since firms which engage in international listing are typically large, they might have "already mitigated the effects of segmentation through other mechanisms, such as direct foreign investment and/or mergers with foreign firms" (p. 9). Consequently, small firms which are little exposed to foreign investment activity, could benefit more from dual listing.

2.4 International Diversification

The concept of diversification when investing in financial markets is very important. Investors should not worry about returns alone, but risk-adjusted returns. The goal of investors is to obtain the highest level of return for the lowest level of risk, which can be done by diversifying one's portfolio.

There are two main types of risk to consider when investing: systematic risk and unsystematic risk. Systematic risk is the risk common to all securities, and which consists in the relation between the returns of securities and the returns of the market. Unsystematic risk is the firm specific risk, i.e., risk which arises from each security's unique characteristics. Diversification allows investors to eliminate nearly all unsystematic risk, while systematic risk cannot be diversified away. This way, diversification is a good tool in helping to reduce a portfolio's overall risk.

O'Hagan-Luff and Berrill (2019) study the ability of US-traded equity products - including ADRs, multinational corporations, single-country exchange-traded funds, iShares, and closed-end country funds – to provide international diversification benefits to investors. The authors find that, for a sample of products from 22 developed markets and 15 emerging markets, for a period of 15 years, spanning 1996 to 2011, ADRs and multinational corporations offer these international diversification benefits and that these, though weaker in times of crisis, remain robust throughout the time period.

There are also other authors studying the role of ADRs as tools of international diversification. Jiang (1998) studies this theme by examining 113 ADRs from Australia, France, Japan, Netherlands, South Africa, Spain, Sweden, and the UK, between 1980 and 1994, and finds that ADRs are a suitable means with which to internationally diversify. To support this conclusion, Jiang provided three main findings.

Firstly, by comparing two portfolios, one with the US market portfolio and eight ADR portfolios and another with the US market and eight foreign market index portfolios, Jiang (1998) finds that the first outperforms the second, testifying for the effectiveness of ADRs. Secondly, the author finds that, more often than not, both ADRs and respective local market portfolios have an influence on each other, a confirmation on the existence of interrelationships in international markets. As the author puts it, "In general, ADRs are affected by their respective market index portfolios, while the impact of ADRs on local market portfolios is relatively stronger for countries with cointegrated ADR and market portfolios" (p. 15). Lastly, Jiang (1998) finds that though US market returns and ADRs returns are significantly associated, ADRs are still exposed to local market and exchange rates, meaning orthogonal local market return and orthogonal currency return also explain ADRs' returns.

All in all, the author concludes that ADRs provide diversification benefits by means of country diversification, related to industrial structure; and currency diversification, related to different monetary policies in place.

Other authors, including Choi and Kim (2000), already mentioned in this study, and Alaganar and Bhar (2001), have also studied the role of ADRs in international diversification and reach the same conclusions as those mentioned before.

One way investors seek to diversify their portfolios is by looking beyond national markets to do so. However, there are complications when investing internationally. Didia (2015) studies international diversification and whether or not ADRs can be used to pursue it by looking at existing literature on both developed and emerging markets ADRs. The author points out that, when investing internationally, investors usually face a few problems that may hinder their diversification efforts. First of all, investing internationally is often expensive, as it entails high transaction costs and investors are exposed to exchange rates. Secondly, investors can have a hard time collecting dividends due. Lastly, there are marketability issues to worry about, including the difficulty in transferring stock certificates.

However, the author points out ADRs as a suitable option to international diversification, since this type of instrument is able to avoid the aforementioned problems, while carrying the benefits of investing internationally. The author also points out emerging markets ADRs in particular when it comes to international diversification, since "Beyond dividends and share appreciation of ADRs, investors may equally take advantage of arbitrage opportunities in emerging markets which are very likely because of information asymmetries, weak regulatory environment, inadequate infrastructure, transaction costs, investor sentiments, and fluctuations in exchange rates" (p. 2).

Lastly, Schaub (2010) examines the possibility of international diversification using a sample of Chinese ADRs. The results of this study show that Chinese ADRs' performance is in line with that of the S&P 500 index. However, "those [ADRs] trading during the bull market under-performed the market index by over 26% while those trading through the bear market (listed after 1 January 1998) outperformed the S&P 500 by nearly 40%" (p.1). As such, Chinese ADRs provide diversification benefits, given "ADR returns are up when the S&P 500 is down" (p. 3)

All in all, ADRs appear to be a solid instrument for investors efforts to internationally diversify their portfolios.

2.5 Arbitrage strategies with ADRs and the Law of One Price

The Law of One Price states that an asset should have the same price wherever it is quoted. The idea is that, under certain restrictions, in a frictionless market, any price differences that may arise would be eliminated by arbitrage activities, which would force the prices to converge. However, some of the assumptions of frictionless markets, like the inexistence of transaction or transportation costs, do not verify, leading to price differentials that hold throughout time.

Given ADRs represent the underlying share, one would expect the Law of One Price to hold, since the fundamentals are the same for both the ADR and its underlying stock. However, many authors suggest otherwise.

Rabinovitch et al. (2003) study the return distributions of ADR returns and the returns of the locally traded shares between Chile and Argentina and find that significant differences exist for Chilean ADRs, while for Argentinean ADRs do not. All in all, the authors measure the transaction costs which need to be added before arbitrage profit and find arbitrage opportunities between ADRs and underlying share in both Argentina and Chile.

Suarez (2005) uses a high frequency data set of French and American stocks and finds large deviations from the Law of One Price. Though infrequent, these deviations are significant enough to allow for profits should investors decide to try and seize them, thus corroborating the idea that there are untapped arbitrage opportunities in these markets.

Grossman et al. (2007) study the mispricing between ADRs and underlying stocks and the causes for it, using a sample of 74 ADRs from Australia, the UK, Denmark, Finland, France, Germany, Italy, the Netherlands, Spain and Sweden, between 1996 and 2003. The authors find that those that exhibit more mispricing are those that are also more costly to arbitrage. The higher the transactions costs, measured as the bid-ask spread, and the lower the dividend payment of a given ADR, the more its price will deviate from its underlying stock price. Furthermore, the difference is higher when interest rates are higher and both ADRs and underlying stocks seem to be more driven by US sentiment than by the sentiment in the home country. All in all, the results of the authors seem to point to the idea that mispricing is a result of costly arbitrage, with both transaction costs and holding costs being relevant.

Liu and Bogomolov (2012) also attempt to demonstrate whether or not arbitrage profits can be made in dual listed Chinese companies, thus violating the Law of One Price. The authors find that a simple arbitrage strategy could ensure monthly returns between 0.5 and 3.8 per cent, thus violating the Law of One Price. There are, however, risks that the authors point out when attempting to conduct arbitrage, namely the timing aspect. The markets involved in the arbitrage strategy, as is the case here with the Chinese market, can be nonoverlapping ones, so there is a time delay between the time when an opportunity is entered and the time the actual trade is executed. Furthermore, some ADRs might not be as liquid as investors would like, adding to the risks arbitrage entails.

Alsayed and McGroarty (2012) also study the possibility of arbitrage in ADRs by using a sample of 25 ADRs from the UK. However, unlike most literature, the authors find "pairs trading as the main price-correcting mechanism by which arbitrage can maintain stock–ADR parity" (p. 1). The authors find that arbitrage strategies on stock-ADR pairs is possible and earns profits, as mispricing can be exploitable, despite being small and short-lived.

Ansotegui et al. (2013) builds on existing literature regarding arbitrage opportunities in the depository receipts market, with special attention to markets with trading barriers. The authors use a sample of ADRs from Argentina and Egypt and find support for the idea that arbitrage opportunities do exist and profits are possible. Furthermore, the paper also contributes to the support of the idea that arbitrage trades help eliminate arbitrage opportunities in depository receipts, particularly in emerging markets.

Esqueda et al. (2015) study deviations of the Law of One Price between ADRs and underlying stock, namely the impact investor sentiment has on ADRs' premiums. The authors define the premium as "the disparity between the ADR price and the price of the underlying share, after adjusting for the corresponding exchange rate and ADR ratio" (p. 542) and use a sample of 69 ADRs from Argentina, Brazil, Chile, and Mexico, between January 1995 and May 2009. Controlling for transaction costs, local and US stock exchange returns, as well as for liquidity, the authors find deviations from the Law of One Price, which they explain by "the lag of the smoothed volatility index" (p. 541), i.e., investors' fears regarding the outlook of the stock market, measured as changes in the volatility index. Another relevant factor the authors put forth is the US stock market behavior and conclude that "by incorporating the lagged values of the volatility index in determining ADR prices" (p. 543), investors can better improve their hedging strategies.

Ghadhab and Hellara (2015) study this topic by considering companies with multiple foreign listings, specifically focusing on firms with listings in both European and American markets. The authors study three main points in their paper: the Law of One Price, arbitrage and price convergence of cross-listed stocks. All in all, they conclude that the Law of One Price is violated, arbitrage opportunities exist, and investors can earn profits by employing arbitrage strategies, whether on stocks with multiple foreign listing or dual-listed stocks.

Mitra et al. (2019) build on the paper of Alsayed and McGroarty (2012) regarding stock-ADR arbitrage pair trading and find evidence to support the findings of the later, for a data set of 19 UK companies, over a period of 3 years. Furthermore, the authors find substantial asymmetry in returns, a finding which allows them to conclude that the market microstructure of ADR trading influences this type of arbitrage. "Whilst long and short stocks can be easily sourced from the relevant markets, long and short ADR sourcing is less viable due to the market microstructure, but also, ADR's microstructure directly impacts the stock's price" (p. 14).

There are, however, older papers which point in the opposite direction and should not be disregarded, as is the case with Maldonado and Saunders (1983); Kato, Linn and Schallheim (1991); Park and Tavakkol (1994); and Agmon (1972). These authors study this theme and conclude for the validation of the Law of One Price, thus rejecting the idea that arbitrage opportunities exist in the ADR market. Though whether or not the Law of One Price is violated is up for debate, more recent studies do point in the direction that it is.

3 Data and Methodology

As stated, the aim of this report is to study the dynamic linkages between the returns of Chinese ADRs and the returns of their corresponding underlying stocks.

For that purpose, and by resorting to the Refinitiv platform, we compiled a sample of all Chinese ADRs currently traded in the NASDAQ and NYSE stock exchanges and which have a corresponding underlying stock in the Hong Kong and Shanghai stock exchanges. A total of 24 ADRs have been selected, though only 23 have been used, given the low number of observations available for Nio Inc. The sample is presented in the **Table 3.1** below.

Table 3.1 - Sample companies' description

Nº	Name of company	Ticker Symbol		Date of first observation
		ADR	Underlying stock	
1	Alibaba Group Holding Ltd	BABA.N	9988.HK	27/11/2019
2	Aluminum Corp of China Ltd	ACH.N	601600.SS	12/12/2001
3	Autohome Inc	ATHM.N	2518.HK	16/03/2021
4	Baidu Inc	BIDU.ITC	9888.HK	24/03/2021
5	Baozun Inc	BZUN.ITC	9991.HK	30/09/2020
6	Bilibili Inc	BILI.ITC	9626.HK	30/03/2021
7	China Eastern Airlines Corp Ltd	CEA.N	0670.HK	05/01/2000
8	China Life Insurance Co Ltd	LFC.N	2628.HK	19/12/2003
9	China Petroleum & Chemical Corp	SNP.N	0386.HK	20/10/2000
10	China Southern Airlines Co Ltd	ZNH.N	600029.SS	28/07/2003
11	Daqo New Energy Corp	DQ.N	688303.SS	23/07/2021
12	Huaneng Power International Inc	HNP.N	0902.HK	05/01/2000
13	Huazhu Group Ltd	HTHT.ITC	1179.HK	23/09/2020
14	JD.Com Inc	JD.ITC	9618.HK	19/06/2020
15	Li Auto Inc	LI.ITC	2015.HK	13/08/2021
16	NetEase Inc	NTES.ITC	9999.HK	12/06/2020
17	New Oriental Education & Technology Group Inc	EDU.N	9901.HK	10/11/2020
18	PetroChina Co Ltd	PTR.N	0857.HK	17/04/2000
19	Sinopec Shanghai Petrochemical Co Ltd	SHI.N	600688.SS	09/11/1993
20	Trip.com Group Ltd	TCOM.ITC	9961.HK	20/04/2021
21	Xpeng Inc	XPEV.N	9868.HK	08/07/2021
22	Zai Lab Ltd	ZLAB.ITC	9688.HK	29/09/2020
23	ZTO Express (Cayman) Inc	ZTO.N	2057.HK	30/09/2020

Also from the Refinitiv platform, we have collected the daily closing prices of the selected sample from as far back as there is data for both ADR and underlying stock of each company, until the 20th of April 2022.

The first step was then to calculate the returns of both ADRs and underlying stocks, done using the following formula:

$$R_t = \ln\left(\frac{P_t}{P_{t-1}}\right)$$

3.a

Then, we proceeded to calculate the correlation between both series, which allowed us to determine the strength of the relationship that exists between ADRs and underlying stocks. The correlation calculated for this study is Pearson's correlation coefficient, which calculates the linear relationship between two sets of data. The coefficient is presented as a number between -1 and 1, where 1 represents perfect positive correlation, -1 perfect negative correlation and 0 no correlation.

Given we are interested in determining the relationship between ADRs and underlying stocks, we need to apply a Vector Autoregression (VAR) model or a Vector Error Correction Model (VECM), based on whether the variables are stationary and/or cointegrated or not.

Accordingly, the next step is to apply Augmented Dickey-Fuller Unit Root Test (Dickey and Fuller, 1979) to both ADRs and underlying stock returns to test if the time series are stationary or not. A series is said to be stationary if its mean, variance and covariance are constant over time. The test is run as a hypothesis, where the null hypothesis attests for the existence of a unit root, meaning the series is nonstationary, whereas the alternative hypothesis denies the existence of a unit root, meaning the series is stationary.

The reason for using Augmented Dickey-Fuller test and not a simple Dickey-Fuller test is due to the fact that the latter is only appropriate if the time series being considered is an AR(1) process. However, given that is not the case and the series are correlated at higher order lags, the Augmented Dickey-Fuller test becomes necessary, which seeks to correct the problem by adding ρ lagged difference terms to the series.

The simple DF test and the ADF test are presented in equations 3.b and 3.c*3.c,* respectively:

$$\Delta y_t = \alpha y_{t-1} + x_t'\delta + \epsilon_t$$

3.b

$$\Delta y_t = \alpha y_t + x_t'\delta + \beta_1 \Delta y_{t-1} + \beta_2 \Delta y_{t-2} + \cdots + \beta_\rho \Delta y_{t-\rho} + v_t$$

3.c

Following this, we applied the Johansen Cointegration Test, which allows to test for the long-run relationship between ADRs and underlying stocks, by determining whether the time series are cointegrated or not. The null hypothesis is that there are no cointegrating equations and the alternative is that the number of cointegrating equations is at least one. The number of cointegrating equations is discovered sequentially, from r = 0 to r = k - 1, until the point we do not reject the null.

This test performs trace test statistic and maximum eigenvalue test statistic. The trace statistic tests the null hypothesis under which there are r cointegrating relations, against the alternative under which there are k cointegrating relations, k being the number of endogenous variables. The test is performed as follows:

$$Trace\ (r, k) = -T \sum_{i=r+1}^{k} \ln(1 - \lambda_i)$$

3.d

The maximum eigenvalue tests the null hypothesis under which there are r cointegrating relations, against the alternative under which there are r + 1 cointegrating relations. The test is performed as follows:

$$\lambda_{max}(r, r+1) = -T \ \ln(1 - \lambda_{r+1})$$

3.e

Next, if ADRs and underlying stocks are found to be cointegrated, VECM can be applied to study both the short and long-run relationship between the two.

A Vector Autoregressive (VAR) model is a statistical method employed to study the relationship between different time series, often employed in economics given its flexibility and simplicity. A VECM is a special case of the VAR model, a multivariate time series model, used when the series considered in the study are found to be cointegrated, given it accounts for short-term relationships between the variables.

In this model, any deviations to the long-run equilibrium are corrected through short-term adjustments, represented by the error correction term.

The VECM can be presented as follows:

$$\Delta Z = \Gamma_1 \Delta Z_{t-1} + \cdots + \Gamma_{k-1} \Delta Z_{t-k-1} + \alpha(\beta \mu_1 \delta_1)(Z_{t-1} 1t) + \mu_2 + \delta_2 t + \mu_t$$

3.f

In the above equation, Z is a vector of k cointegrating variables, while α is the error correction term, i.e., the speed of adjustment to equilibrium coefficient.

μ_1, β and δ_1 are constant, coefficient of variable and coefficient of trend of the cointegrating equation, respectively, while μ_2, Γ and δ_2 are constant, coefficient of variables and coefficient of trend of the VAR, respectively.

Then, we applied the Granger Causality Test to determine the direction of causality between both types of assets. This method attempts to determine if one variable, X, causes another, Y, by uncovering how much of the current value of Y can be explained by the past values of Y, and how much can be explained by lagged values of X. This way, a variable is said to Granger-cause another if it helps in predicting it.

The test is run as bivariate regressions:

$$Y_t = \alpha_0 + \sum_{i=1}^{m} \alpha_i Y_{t-i} + \sum_{j=1}^{n} \beta_j X_{t-1} + \varepsilon_{t1}$$

3.g

$$X_t = \delta_0 + \sum_{i=1}^{m} \delta_i Y_{t-i} + \sum_{j=1}^{n} \theta_j X_{t-1} + \varepsilon_{t2}$$

3.h

The null hypothesis states that X does not Granger-cause Y in the first regression and that Y does not Granger-cause X in the second regression.

Since the Granger Causality Test and the VECM do not allow us to understand whether one variable positively or negatively affects the other and how long the system will take to absorb the change, the next step is to calculate impulse response function and variance decomposition.

Impulse response functions attempt to determine the impact of a one-time shock to the endogenous variable on the other variables in the VECM, allowing to understand whether that shock is positive or negative and how long the change takes to be absorbed.

Variance decomposition on the other hand, attempts to separate the variance of the endogenous variable caused by the shock from other variables and from the variable itself.

4 Empirical Analysis

As a means to characterize the variables, descriptive statistics for the returns of ADRs and underlying stocks were calculated and are presented in **Table 4.1**, **Table 4.2**, **Table 4.3** and **Table 4.4**.

From the tables, we can see that 12 out of the 23 ADRs present negative mean returns, while 15 out of the 23 underlying stocks, from which the 12 corresponding underlying stocks, also present negative mean returns. Of these securities that present negative mean returns, most only contain a little over a year's worth of data, so the negative values can partly be explained by the recent crash of Chinese stocks.

From the ADRs, only one is negatively skewed, New Oriental Education & Technology Group Inc, while from the underlying stocks eight are negatively skewed. Furthermore, all ADRs and underlying stocks follow a leptokurtic distribution as showed by their Kurtosis values.

We can also conclude, by conducting the Jarque-Bera statistic tests, that for all ADRs and underlying stocks, except the ADR of Daqo New Energy Corp., the null hypothesis is rejected, concluding that these do not follow a normal distribution.

Table 4.1 – ADR's descriptive statistics (1)

Ticker Symbol	BABA	ACH	ATHM	BIDU	BZUN	BILI	CEA	LFC	SNP	ZNH	DQ	HNP
Mean	-0.0012	0.0001	-0.0038	-0.0028	-0.0034	-0.0055	0.0003	0.0003	0.0004	0.0003	-0.0016	0.0003
Median	-0.0027	-0.0005	-0.0058	-0.0041	-0.0058	-0.0072	0.0000	-0.0006	0.0004	-0.0012	-0.0088	0.0000
Maximum	0.3131	0.2205	0.2214	0.3308	0.3003	0.3891	0.5049	0.2126	0.1870	0.3373	0.1715	0.1558
Minimum	-0.1432	-0.2228	-0.1060	-0.1563	-0.1838	-0.1883	-0.2708	-0.1297	-0.1691	-0.1938	-0.1489	-0.1751
Std. dev.	0.0317	0.0336	0.0388	0.0385	0.0476	0.0613	0.0338	0.0244	0.0240	0.0333	0.0511	0.0257
Skewness	1.5075	0.4093	0.9891	2.2978	0.7473	1.1056	1.1605	0.4121	0.2072	0.4829	0.3970	0.1440
Kurtosis	20.6162	6.8474	7.6908	25.0519	9.5418	9.4209	21.8721	8.3567	9.0447	9.3568	3.9504	7.2292
Jarque-Bera	7652.777	3107.446	284.000	5433.489	697.956	486.157	79825.550	5386.313	7959.870	7434.530	11.055	3995.901
Probability	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0040	0.0000
Sum	-0.7117	0.5628	-0.9989	-0.7110	-1.2812	-1.3956	1.4214	1.4453	2.1074	1.1540	-0.2766	1.7294
Sum sq. dev.	0.5782	5.4442	0.3945	0.3790	0.8400	0.9484	6.0492	2.6169	2.9944	4.7825	0.4487	3.5302
Observations	575	4820	263	257	372	253	5299	4401	5204	4316	173	5337

Table 4.2 – ADR's descriptive statistics (2)

Ticker Symbol	HTHT	JD	LI	NTES	EDU	PTR	SHI	TCOM	XPEV	ZLAB	ZTO
Mean	-0.0003	0.0004	-0.0018	0.0003	-0.0080	0.0003	0.0001	-0.0021	-0.0024	-0.0015	-0.0002
Median	-0.0019	-0.0022	-0.0068	-0.0004	-0.0071	0.0000	-0.0005	-0.0028	-0.0035	-0.0020	-0.0003
Maximum	0.2963	0.3936	0.2769	0.2286	0.2348	0.1441	0.4915	0.2498	0.2589	0.2089	0.1803
Minimum	-0.2006	-0.1583	-0.2308	-0.1467	-0.7813	-0.1490	-0.2274	-0.1453	-0.1607	-0.2271	-0.1293
Std. dev.	0.0376	0.0381	0.0516	0.0327	0.0693	0.0230	0.0323	0.0387	0.0534	0.0492	0.0282
Skewness	0.6346	2.4458	0.3673	0.6667	-4.3834	0.0569	0.8358	0.6184	0.4735	0.1970	0.1907
Kurtosis	16.3575	28.9690	10.2615	9.7034	50.2049	8.1738	16.4753	11.0480	5.7557	7.0255	9.2900
Jarque-Bera	2828.018	12831.610	361.780	868.091	33328.720	5879.694	50857.970	665.767	66.865	254.261	615.497
Probability	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Sum	-0.1141	0.1627	-0.2852	0.1314	-2.7880	1.7712	0.3846	-0.5002	-0.4607	-0.5441	-0.0621
Sum sq. dev.	0.5307	0.6371	0.4314	0.4755	1.6607	2.7815	6.9213	0.3601	0.5362	0.9011	0.2956
Observations	377	441	163	446	347	5269	6620	241	189	373	372

Table 4.3 - Underlying stocks descriptive statistics (1)

Ticker Symbol	9988.HK	601600.SS	2518.HK	9888.HK	9991.HK	9626.HK	0670.HK	2628.HK	0386.HK	600029.SS	688303.SS	0902.HK
Mean	-0.0013	-0.0001	-0.0044	-0.0027	-0.0037	-0.0059	0.0000	0.0003	0.0004	0.0003	-0.0005	0.0004
Median	-0.0016	0.0000	-0.0063	-0.0035	-0.0045	-0.0025	0.0000	0.0000	0.0000	0.0000	-0.0041	0.0000
Maximum	0.2414	0.1331	0.2664	0.1856	0.2652	0.3424	0.3460	0.1630	0.1664	0.1563	0.1278	0.2040
Minimum	-0.1270	-0.3168	-0.1695	-0.2761	-0.2251	-0.2673	-0.3711	-0.1741	-0.1797	-0.1058	-0.1106	-0.1537
Std. dev.	0.0315	0.0291	0.0413	0.0381	0.0462	0.0566	0.0317	0.0225	0.0226	0.0286	0.0364	0.0253
Skewness	0.8181	-0.2432	0.7823	-0.6438	0.3063	0.4595	0.1546	0.2242	0.1322	0.0158	0.3085	0.2297
Kurtosis	10.3625	8.9869	10.7222	15.3016	8.9482	9.5498	12.6308	8.3471	7.9685	5.7721	4.5058	7.6365
Jarque-Bera	1362.825	7246.002	680.294	1638.251	554.223	461.143	20500.180	5279.906	5367.798	1382.119	19.089	4827.407
Probability	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000
Sum	-0.7604	-0.4319	-1.1529	-0.7015	-1.3863	-1.4908	0.1784	1.2710	1.9751	1.1196	-0.0883	2.0852
Sum sq. dev.	0.5711	4.0779	0.4461	0.3711	0.7905	0.8061	5.3197	2.2199	2.6658	3.5304	0.2275	3.4081
Observations	575	4820	263	257	372	253	5299	4401	5204	4316	173	5337

Table 4.4 - Underlying stocks descriptive statistics (2)

Ticker Symbol	1179.HK	9618.HK	2015.HK	9999.HK	9901.HK	0857.HK	600688.SS	9961.HK	9868.HK	9688.HK	2057.HK
Mean	-0.0001	-0.0001	-0.0013	0.0002	-0.0082	0.0003	0.0002	-0.0017	-0.0024	-0.0020	-0.0004
Median	0.0000	-0.0007	-0.0009	-0.0011	-0.0037	0.0000	0.0000	-0.0009	-0.0016	-0.0006	-0.0009
Maximum	0.2763	0.3048	0.2970	0.2103	0.3151	0.2637	0.3105	0.3038	0.2805	0.2255	0.1825
Minimum	-0.3211	-0.1598	-0.4165	-0.1427	-0.6353	-0.1625	-0.2102	-0.3061	-0.3603	-0.2228	-0.1604
Std. dev.	0.0421	0.0371	0.0560	0.0318	0.0664	0.0222	0.0266	0.0446	0.0566	0.0488	0.0285
Skewness	-0.3760	1.3035	-1.5975	0.4050	-3.5855	0.4866	0.7202	-0.1189	-0.7068	-0.1394	0.2932
Kurtosis	18.5613	14.6254	24.7230	9.0753	36.9018	11.7875	14.4279	19.9743	13.3005	7.8297	9.8350
Jarque-Bera	3812.733	2608.258	3274.234	698.091	17360.900	17161.050	36594.960	2893.853	851.277	363.737	729.447
Probability	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Sum	-0.0494	-0.0529	-0.2126	0.1034	-2.8596	1.5497	1.0633	-0.4199	-0.4443	-0.7465	-0.1402
Sum sq. dev.	0.6658	0.6053	0.5085	0.4494	1.5258	2.6039	4.6681	0.4780	0.6028	0.8875	0.3010
Observations	377	441	163	446	347	5269	6620	241	189	373	372

Table 4.5 contains the correlation coefficients of ADRs and underlying stocks. As presented, all ADRs and respective underlying stocks are positively correlated and under 0.8, meaning there is no possibility of multicollinearity between the two.

Table 4.5 - Asset pairs correlation coefficient

Ticker Symbol		Correlation Coefficient
ADR	**Underlying stock**	
BABA.N	9988.HK	0.52
ACH.N	601600.SS	0.35
ATHM.N	2518.HK	0.27
BIDU.ITC	9888.HK	0.40
BZUN.ITC	9991.HK	0.26
BILI.ITC	9626.HK	0.34
CEA.N	0670.HK	0.75
LFC.N	2628.HK	0.67
SNP.N	0386.HK	0.66
ZNH.N	600029.SS	0.41
DQ.N	688303.SS	0.29
HNP.N	0902.HK	0.73
HTHT.ITC	1179.HK	0.39
JD.ITC	9618.HK	0.53
LI.ITC	2015.HK	0.22
NTES.ITC	9999.HK	0.46
EDU.N	9901.HK	0.45
PTR.N	0857.HK	0.62
SHI.N	600688.SS	0.22
TCOM.ITC	9961.HK	0.31
XPEV.N	9868.HK	0.27
ZLAB.ITC	9688.HK	0.20
ZTO.N	2057.HK	0.41

The results of the Augmented Dickey-Fuller Unit Root Test are presented in **Table 4.6** and **Table 4.7**, for ADRs and underlying stocks respectively.

The null hypothesis is rejected for all assets in the sample, ADRs and underlying stocks alike, for both constant and constant and trend test values. As such, there is no unit root and returns of both series are stationary at level or integrated of order zero, I(0), a result which is in line with that of Patel (2015).

Table 4.6 – ADRs' results for Augmented Dickey-Fuller unit root test

ADRs return at level		
Ticker Symbol	**Constant ADF test value**	**Constant and trend ADF test value**
BABA	-26.00*	-26.10*
ACH	-68.80*	-68.80*
ATHM	-15.01*	-15.03*
BIDU	-15.30*	-15.28*
BZUN	-18.82*	-18.89*
BILI	-15.95*	-15.94*
CEA	-72.46*	-72.46*
LFC	-72.21*	-72.25*
SNP	-77.96*	-77.97*
ZNH	-66.24*	-66.24*
DQ	-12.21*	-12.17*
HNP	-76.90*	-76.93*
HTHT	-15.11*	-15.13*
JD	-20.29*	-20.31*
LI	-9.76*	-9.75*
NTES	-21.43*	-21.42*
EDU	-14.40*	-14.38*
PTR	-76.43*	-76.46*
SHI	-81.85*	-81.85*
TCOM	-14.68*	-14.65*
XPEV	-14.26*	-14.26*
ZLAB	-18.57*	-18.72*
ZTO	-13.60*	-13.59*

For constant model and constant and trend model, critical values at 5% level of significance are -2.87 and -3.42, respectively.

* Indicates that ADF test value is significant at 1 % level of significance

Table 4.7 - Underlying stocks' results for Augmented Dickey-Fuller unit root test

Underlying stocks return at level		
Ticker Symbol	**Constant ADF test value**	**Constant and trend ADF test value**
9988.HK	-18.69*	-18.81*
601600.SS	-65.63*	-65.62*
2518.HK	-15.82*	-15.79*
9888.HK	-16.25*	-16.24*
9991.HK	-16.06*	-16.19*
9626.HK	-15.46*	-15.47*
0670.HK	-69.56*	-69.55*
2628.HK	-65.94*	-66.00*
0386.HK	-71.60*	-71.61*
600029.SS	-60.17*	-60.16*
688303.SS	-14.15*	-14.18*
0902.HK	-72.45*	-72.48*
1179.HK	-16.49*	-16.50*
9618.HK	-15.40*	-15.50*
2015.HK	-15.24*	-15.20*
9999.HK	-15.12*	-15.14*
9901.HK	-15.99*	-15.97*
0857.HK	-71.52*	-71.56*
600688.SS	-76.55*	-76.55*
9961.HK	-17.95*	-17.91*
9868.HK	-16.26*	-16.28*
9688.HK	-18.69*	-18.86*
2057.HK	-14.01*	-14.01*

For constant model and constant and trend model, critical values at 5% level of significance are -2.87 and -3.42, respectively.

* Indicates that ADF test value is significant at 1 % level of significance

Next, the Johansen Cointegration Test has been applied by calculating both trace statistic and maximum eigen value statistic. In order to apply the test, the optimal lag length (p) was calculated for every asset by means of the Akaike Information Criterion (AIC) in all but one asset, DQ, whose optimal lag length did not allow for the conduction of the test. This is so because the VECM is applied with a lag length of p-1. As such, given DQ presented a lag length of 1 under the AIC, VECM with be run with a p value of zero, making it impossible to run the model. In this case, sequential modified LR test statistic was applied. The results of the optimal lag lengths are presented in **Table 4.8**, and Johansen Cointegration Tests are presented in **Table 4.9** and **Table 4.10**.

Table 4.8 - Optimal Lag Length

Ticker Symbol		Optimal Lag Length				
ADR	**Underlying stock**	**LR**	**FPE**	**AIC**	**SC**	**HQ**
BABA	**9988.HK**	6	6	6	2	4
ACH	**601600.SS**	5	5	5	1	2
ATHM	**2518.HK**	2	3	3	2	2
BIDU	**9888.HK**	8	8	8	2	2
BZUN	**9991.HK**	7	7	7	2	4
BILI	**9626.HK**	8	8	8	2	4
CEA	**0670.HK**	8	8	8	3	5
LFC	**2628.HK**	7	8	8	4	6
SNP	**0386.HK**	6	8	8	5	6
ZNH	**600029.SS**	8	8	8	1	2
DQ	**688303.SS**	4	1	1	0	0
HNP	**0902.HK**	6	6	6	4	6
HTHT	**1179.HK**	5	6	6	2	3
JD	**9618.HK**	4	4	4	3	4
LI	**2015.HK**	6	3	3	2	3
NTES	**9999.HK**	4	4	4	4	4
EDU	**9901.HK**	3	3	3	2	3
PTR	**0857.HK**	8	8	8	5	6
SHI	**600688.SS**	6	6	6	1	1
TCOM	**9961.HK**	7	7	7	2	2
XPEV	**9868.HK**	3	3	3	2	2
ZLAB	**9688.HK**	3	5	5	2	3
ZTO	**2057.HK**	6	4	4	2	2

Table 4.9 - Results of Johansen's cointegration test (1)

Ticker Symbol		Optimal Lag Length	H0	Trace Statistic	5% critical value	Maximum eigen statistic	5% critical value
ADR	Underlying stock						
BABA	9988.HK	6	r = 0	253.34	15.49	174.09	14.26
			r ≤ 1	79.25	3.84	79.25	3.84
ACH	601600.SS	5	r = 0	1534.65	15.49	821.14	14.26
			r ≤ 1	713.50	3.84	713.50	3.84
ATHM	2518.HK	3	r = 0	136.57	15.49	93.28	14.26
			r ≤ 1	43.29	3.84	43.29	3.84
BIDU	9888.HK	8	r = 0	76.95	15.49	47.81	14.26
			r ≤ 1	29.13	3.84	29.13	3.84
BZUN	9991.HK	7	r = 0	117.35	15.49	78.26	14.26
			r ≤ 1	39.09	3.84	39.09	3.84
BILI	9626.HK	8	r = 0	64.17	15.49	38.01	14.26
			r ≤ 1	26.17	3.84	26.17	3.84
CEA	0670.HK	8	r = 0	1408.64	15.49	841.08	14.26
			r ≤ 1	567.56	3.84	567.56	3.84
LFC	2628.HK	8	r = 0	1245.39	15.49	760.97	14.26
			r ≤ 1	484.42	3.84	484.42	3.84
SNP	0386.HK	8	r = 0	1485.68	15.49	911.24	14.26
			r ≤ 1	574.44	3.84	574.44	3.84
ZNH	600029.SS	8	r = 0	1012.48	15.49	589.19	14.26
			r ≤ 1	423.30	3.84	423.30	3.84
DQ	688303.SS	4	r = 0	77.20	15.49	46.67	14.26
			r ≤ 1	30.53	3.84	30.53	3.84
HNP	0902.HK	6	r = 0	1935.86	15.49	1135.15	14.26
			r ≤ 1	800.72	3.84	800.72	3.84

Table 4.10 - Results of Johansen's cointegration test (2)

Ticker Symbol		Optimal Lag Length	H0	Trace Statistic	5% critical value	Maximum eigen statistic	5% critical value
ADR	Underlying stock						
HTHT	1179.HK	6	r = 0	175.55	15.49	113.05	14.26
			r ≤ 1	62.50	3.84	62.50	3.84
JD	9618.HK	4	r = 0	263.66	15.49	173.70	14.26
			r ≤ 1	89.96	3.84	89.96	3.84
LI	2015.HK	3	r = 0	116.78	15.49	72.25	14.26
			r ≤ 1	44.53	3.84	44.53	3.84
NTES	9999.HK	4	r = 0	251.75	15.49	156.24	14.26
			r ≤ 1	95.51	3.84	95.51	3.84
EDU	9901.HK	3	r = 0	223.54	15.49	155.71	14.26
			r ≤ 1	67.83	3.84	67.83	3.84
PTR	0857.HK	8	r = 0	1468.00	15.49	902.31	14.26
			r ≤ 1	565.68	3.84	565.68	3.84
SHI	600688.SS	6	r = 0	1946.10	15.49	1054.12	14.26
			r ≤ 1	891.98	3.84	891.98	3.84
TCOM	9961.HK	7	r = 0	92.92	15.49	68.45	14.26
			r ≤ 1	24.47	3.84	24.47	3.84
XPEV	9868.HK	3	r = 0	118.63	15.49	77.95	14.26
			r ≤ 1	40.68	3.84	40.68	3.84
ZLAB	9688.HK	5	r = 0	149.28	15.49	107.40	14.26
			r ≤ 1	41.88	3.84	41.88	3.84
ZTO	2057.HK	4	r = 0	188.79	15.49	121.31	14.26
			r ≤ 1	67.48	3.84	67.48	3.84

As we can see from **Table 4.9** and **Table 4.10**, for a 5% level of significance, and for both r = 0 and r = 1, trace statistic and maximum eigen value are higher than the corresponding critical values for all companies, thus rejecting the null hypothesis and attesting that the number of cointegrating equations is at least one. All in all, the study finds two cointegrating vectors to all pairs of ADRs and underlying stocks, which again is in line with the results of Patel (2015).

The use of a vector autoregressive (VAR) model to study the relationship between the series is dependent on whether they are cointegrated or not. Given the Johansen Cointegration Tests concluded, for all ADRs and underlying stocks', cointegration of order 1, Vector Error Correction Model (VECM) should be used, as VAR is unfit for these situations since it loses consistency in longer timeframes.

Lag selection has been chosen automatically for each asset and the results of the VECM are shown in **Table 4.11**, **Table 4.12** and **Table 4.13**.

Table 4.11 - Results of vector error correction model (1)

Asset	Coint. Eq. (1)	Und. Stck lag 1	Und. Stck lag 2	ADR lag 1	ADR lag 2	Constant
BABA	0.3956* (0.1836)	0.0254 (0.1365)	-0.1582* (0.0605)	-0.9475* (0.1596)	-0.2406* (0.0866)	-0.0001 (0.0015)
9988.HK	2.1458* (0.1245)	0.4551* (0.0926)	0.0497 (0.0410)	-1.0639* (0.1082)	-0.2877* (0.0587)	0.0000 (0.0010)
ACH	-0.8337* (0.0292)	-0.4578* (0.0218)	-0.2170* (0.0170)	-0.0776* (0.0239)	-0.0466* (0.0166)	0.0000* (0.0005)
601600.SS	0.3953* (0.0261)	-0.4700* (0.0194)	-0.2587* (0.0152)	-0.1517* (0.0214)	-0.0532* (0.0148)	0.0000 (0.0005)
ATHM	-0.0899 (0.2406)	-0.3937* (0.1649)	-0.2577* (0.0651)	-0.5099* (0.2315)	0.0045 (0.1361)	-0.0003 (0.0027)
2518.HK	1.7479* (0.1276)	0.1826* (0.0875)	0.0261 (0.0345)	-0.7574* (0.1228)	-0.1869* (0.0722)	-0.0003 (0.0014)
BIDU	-0.2323 (0.2117)	-0.7576* (0.1408)	-0.3840* (0.0660)	-0.1921 (0.1998)	0.2529* (0.1130)	0.0000 (0.0025)
9888.HK	1.7042* (0.1273)	-0.0091 (0.0847)	-0.0406 (0.0397)	-0.7066* (0.1202)	-0.0911 (0.0680)	0.0007 (0.0015)
BZUN	-0.0600 (0.2230)	-0.3023 (0.1598)	-0.3031* (0.0613)	-0.5579* (0.2096)	-0.1367 (0.1218)	-0.0003 (0.0028)
9991.HK	1.6717* (0.1030)	0.2889* (0.0738)	0.0038 (0.0283)	-0.7260* (0.0968)	-0.1909* (0.0562)	0.0003 (0.0013)
BILI	-0.7804* (0.2504)	-0.8460* (0.1657)	-0.3210* (0.0750)	0.1436 (0.2244)	0.3215* (0.1267)	-0.0009 (0.0045)
9626.HK	1.4133* (0.1419)	-0.1133 (0.0939)	-0.0846* (0.0425)	-0.4966* (0.1271)	-0.0405 (0.0718)	-0.0003 (0.0025)
CEA	-0.9607* (0.0533)	-0.5490* (0.0417)	-0.2803* (0.0254)	-0.0631 (0.0410)	-0.0679* (0.0246)	0.0000 (0.0005)
0670.HK	0.7454* (0.0501)	-0.2105* (0.0392)	-0.1678* (0.0239)	-0.3701* (0.0385)	-0.1622* (0.0231)	0.0000 (0.0005)
LFC	-0.8668* (0.0662)	-0.5835* (0.0476)	-0.2955* (0.0257)	-0.1046* (0.0513)	-0.0495 (0.0280)	0.0000 (0.0004)
2628.HK	1.3162* (0.0561)	-0.0477 (0.0404)	-0.1133* (0.0218)	-0.6342* (0.0435)	-0.2164* (0.0237)	0.0000 (0.0004)

* Indicates that ADF test value is significant at 5% level of significance

Table 4.12 - Results of vector error correction model (2)

Asset	Coint. Eq. (1)	Und. Stck lag 1	Und. Stck lag 2	ADR lag 1	ADR lag 2	Constant
SNP	-0.8338*	-0.5366*	-0.2455*	-0.1178*	-0.0694*	0.0000
	(0.0611)	(0.0444)	(0.0239)	(0.0474)	(0.0260)	(0.0004)
0386.HK	1.3807*	0.0494	-0.0500*	-0.6682*	-0.2496*	0.0000
	(0.0529)	(0.0385)	(0.0207)	(0.0410)	(0.0225)	(0.0003)
ZNH	-0.8869*	-0.4580*	-0.2399*	-0.0718*	-0.0439*	0.0000
	(0.0331)	(0.0246)	(0.0187)	(0.0267)	(0.0180)	(0.0005)
600029.SS	0.3759*	-0.4511*	-0.2779*	-0.1441*	-0.0450*	0.0000
	(0.0293)	(0.0218)	(0.0166)	(0.0237)	(0.0160)	(0.0005)
DQ	-0.7886*	-0.7545*	-0.4310*	0.0113	0.0755	-0.0006
	(0.1405)	(0.1294)	(0.1045)	(0.1183)	(0.0860)	(0.0042)
688303.SS	0.3717*	-0.5616*	-0.2768*	-0.1001	-0.0328	0.0001
	(0.0996)	(0.0918)	(0.0741)	(0.0839)	(0.0609)	(0.0029)
HNP	-0.6247*	-0.4084*	-0.1991*	-0.2489*	-0.1407*	0.0000
	(0.0607)	(0.0442)	(0.0249)	(0.0469)	(0.0268)	(0.0004)
0902.HK	1.3596*	0.0500	-0.0525*	-0.6778*	-0.2627*	0.0000
	(0.0559)	(0.0407)	(0.0230)	(0.0431)	(0.0246)	(0.0004)
HTHT	-0.1730	-0.3239*	-0.2867*	-0.2963	-0.0567	-0.0001
	(0.1979)	(0.1468)	(0.0619)	(0.1824)	(0.1093)	(0.0022)
1179.HK	1.9281*	0.3843*	0.0245	-0.8204*	-0.2733*	0.0003
	(0.1193)	(0.0885)	(0.0373)	(0.1099)	(0.0659)	(0.0013)
JD	0.9524*	0.3856*	-0.0603	-1.2959*	-0.4610*	-0.0002
	(0.1908)	(0.1506)	(0.0672)	(0.1732)	(0.0991)	(0.0021)
9618.HK	2.1432*	0.6414*	0.1460*	-1.1097*	-0.3774*	-0.0001
	(0.1119)	(0.0883)	(0.0394)	(0.1016)	(0.0582)	(0.0012)
LI	-0.3773	-0.7660*	-0.3366*	-0.1270	0.3083	-0.0002
	(0.2889)	(0.2079)	(0.0813)	(0.2932)	(0.1705)	(0.0046)
2015.HK	1.8710*	0.2515*	0.0528	-0.9376*	-0.2320*	-0.0001
	(0.1447)	(0.1041)	(0.0407)	(0.1468)	(0.0854)	(0.0023)
NTES	0.3473	-0.0210	-0.1755*	-0.8545*	-0.2981*	-0.0001
	(0.2082)	(0.1517)	(0.0654)	(0.1827)	(0.1009)	(0.0018)
9999.HK	2.0587*	0.4437*	0.0821*	-1.0126*	-0.2934*	-0.0001
	(0.1223)	(0.0891)	(0.0384)	(0.1074)	(0.0593)	(0.0011)

* Indicates that ADF test value is significant at 5% level of significance

Table 4.13 - Results of vector error correction model (3)

Asset	Coint. Eq. (1)	Und. Stck lag 1	Und. Stck lag 2	ADR lag 1	ADR lag 2	Constant
EDU	-1.1407* (0.2500)	-0.7254* (0.1643)	-0.3349* (0.0685)	0.4176* (0.2090)	0.1343 (0.1195)	-0.0002 (0.0042)
9901.HK	1.3981* (0.1507)	-0.0005 (0.0991)	-0.0727 (0.0413)	-0.4047* (0.1260)	-0.1368 (0.0721)	0.0001 (0.0026)
PTR	-0.6892* (0.0579)	-0.4389* (0.0413)	-0.2276* (0.0218)	-0.2022* (0.0454)	-0.1059* (0.0250)	0.0000 (0.0004)
0857.HK	1.5294* (0.0492)	0.1146* (0.0351)	-0.0394* (0.0186)	-0.7470* (0.0387)	-0.2727* (0.0213)	0.0000 (0.0003)
SHI	-0.9917* (0.0228)	-0.3253* (0.0152)	-0.1618* (0.0135)	0.0069 (0.0184)	-0.0092 (0.0129)	0.0000 (0.0004)
600688.SS	0.1901* (0.0207)	-0.5719* (0.0138)	-0.2774* (0.0123)	-0.0798* (0.0168)	-0.0374* (0.0117)	0.0000 (0.0004)
TCOM	-0.0127 (0.2452)	-0.5176* (0.1812)	-0.3453* (0.0686)	-0.4574 (0.2439)	0.1107 (0.1425)	-0.0003 (0.0027)
9961.HK	1.8990* (0.1361)	0.2393* (0.1006)	0.0458 (0.0381)	-0.8318* (0.1353)	-0.1542 (0.0791)	-0.0004 (0.0015)
XPEV	-0.3829 (0.2824)	-0.7461* (0.1948)	-0.3311* (0.0790)	-0.2158 (0.2718)	0.2470 (0.1529)	-0.0005 (0.0043)
9868.HK	1.8263* (0.1533)	0.1121 (0.1058)	0.0147 (0.0429)	-0.8152* (0.1476)	-0.1456 (0.0830)	0.0003 (0.0024)
ZLAB	-0.6055* (0.2496)	-0.5639* (0.1644)	-0.3742* (0.0552)	-0.0834 (0.2328)	0.0566 (0.1347)	-0.0001 (0.0029)
9688.HK	1.7050* (0.1044)	0.1990* (0.0688)	-0.0295 (0.0231)	-0.7122* (0.0974)	-0.2049* (0.0564)	0.0001 (0.0012)
ZTO	0.1133 (0.1866)	-0.3231* (0.1361)	-0.3199* (0.0603)	-0.5471* (0.1756)	-0.0002 (0.1028)	0.0000 (0.0017)
2057.HK	1.6440* (0.1100)	0.1547 (0.0802)	0.0035 (0.0355)	-0.6779* (0.1035)	-0.0959 (0.0606)	0.0000 (0.0010)

* Indicates that ADF test value is significant at 5% level of significance

The error correction term, ECT(-1), given by CointEq1, indicates the percentage of the past deviation from equilibrium that will be adjusted in the next day, i.e., the speed of adjustment. This value should be between 0 and -1 and significant.

For all ADRs except BABA, JD, NTES, ZTO and EDU, ECT(-1) is negative and indicates that between 1.27% and 99.17% of the "past deviation from equilibrium will be adjusted within the next day". EDU presents itself as an exception, presenting a ECT(-1) lower than -1, which does not make sense, while BABA, JD, NTES and ZTO present positive ECT(-1), meaning a chock to the system will not be followed by an adjustment in the long-run, making the system unstable. The opposite is reported by all underlying stocks, which present positive ECT(-1).

A different situation is reported by Patel (2015), where the ADRs under study present positive ECT(-1), meaning that any disturbance will cause the system to become unstable, whereas the underlying stocks present negative ECT(-1).

Next, the Granger Causality Test has been applied in order to determine the causality's direction and its results are displayed in **Table 4.14** and **Table 4.15**.

Lag selection has been chosen automatically by Eviews for each asset. The test reveals that the ADRs of Aluminum Corp of China Ltd, Baozun Inc, NetEase Inc, New Oriental Education & Technology Group Inc, NIO Inc and Zai Lab Ltd granger cause their corresponding underlying stocks, while the ADRs of Daqo New Energy Corp does not. All other companies in the sample display bidirectional causality, meaning both the ADRs and underlying stocks explain one another.

These results support the findings of the VECM, as short-term movements between the time series imply both ADRs and underlying stocks are affected by one another.

Table 4.14 - Results of Granger's causality test (1)

Null Hypothesis	F-Statistic	p-value	Conclusion
9988.HK does not Granger Cause BABA	2.97789	0.0045	Reject H0
BABA does not Granger Cause 9988.HK	71.5391	2.00E-73	Reject H0
601600.SS does not Granger Cause ACH	1.70865	0.1147	Do not reject H0
ACH does not Granger Cause 601600.SS	21.5804	4.00E-25	Reject H0
2518.HK does not Granger Cause ATHM	2.7258	0.03	Reject H0
ATHM does not Granger Cause 2518.HK	150.54	2.00E-65	Reject H0
9888.HK does not Granger Cause BIDU	6.28313	6.00E-08	Reject H0
BIDU does not Granger Cause 9888.HK	51.6019	3.00E-50	Reject H0
9991.HK does not Granger Cause BZUN	1.33074	0.2269	Do not reject H0
BZUN does not Granger Cause 9991.HK	121.151	1.00E-95	Reject H0
9626.HK does not Granger Cause BILI	3.03224	0.0019	Reject H0
BILI does not Granger Cause 9626.HK	39.3088	2.00E-41	Reject H0
0670.HK does not Granger Cause CEA	13.0899	7.00E-21	Reject H0
CEA does not Granger Cause 0670.HK	17.0351	5.00E-28	Reject H0
2628.HK does not Granger Cause LFC	3.11237	0.001	Reject H0
LFC does not Granger Cause 2628.HK	82.8541	2.00E-142	Reject H0
0386.HK does not Granger Cause SNP	5.5892	1.00E-07	Reject H0
SNP does not Granger Cause 0386.HK	93.9865	6.00E-163	Reject H0
600029.SS does not Granger Cause ZNH	3.93185	5.00E-05	Reject H0
ZNH does not Granger Cause 600029.SS	12.6901	4.00E-20	Reject H0
688303.SS does not Granger Cause DQ	2.50542	0.0326	Reject H0
DQ does not Granger Cause 688303.SS	2.23229	0.0537	Do not reject H0

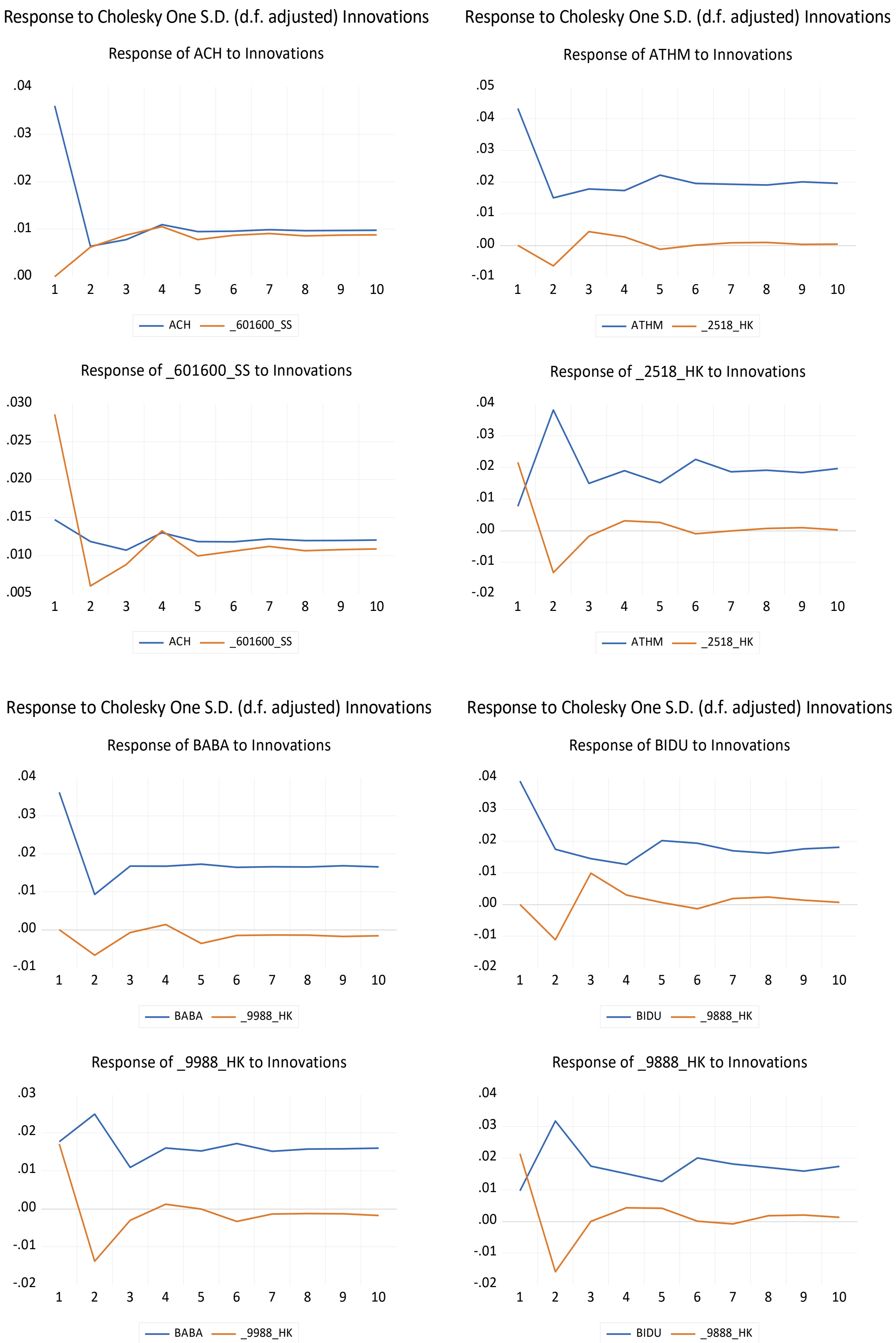
Table 4.15 - Results of Granger's causality test (2)

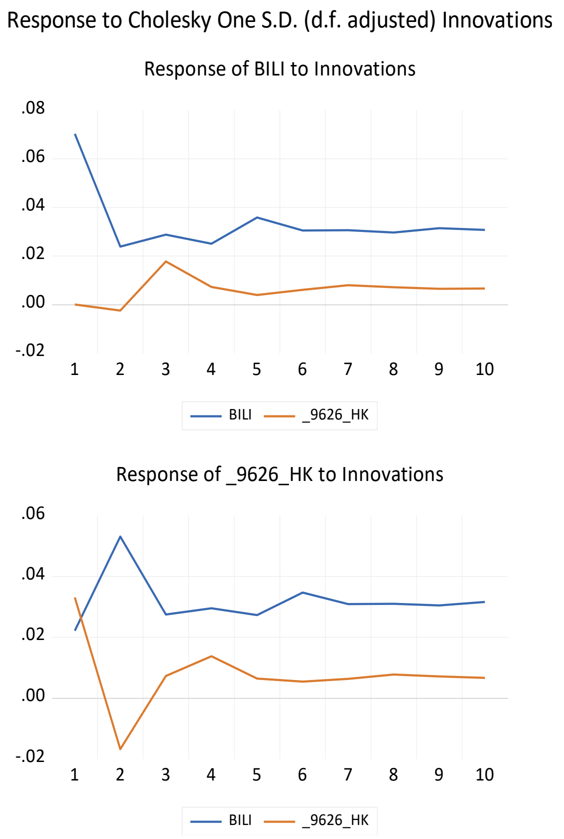
Null Hypothesis	F-Statistic	p-value	Conclusion
0902.HK does not Granger Cause HNP	3.25513	0.0019	Reject H0
HNP does not Granger Cause 0902.HK	77.2207	5.00E-107	Reject H0
1179.HK does not Granger Cause HTHT	2.59658	0.0127	Reject H0
HTHT does not Granger Cause 1179.HK	103.307	1.00E-81	Reject H0
9618.HK does not Granger Cause JD	7.1732	2.00E-06	Reject H0
JD does not Granger Cause 9618.HK	105.913	2.00E-72	Reject H0
2015.HK does not Granger Cause LI	4.96115	0.0009	Reject H0
LI does not Granger Cause 2015.HK	102.15	8.00E-42	Reject H0
9999.HK does not Granger Cause NTES	2.01711	0.0751	Do not reject H0
NTES does not Granger Cause 9999.HK	102.362	6.00E-71	Reject H0
9901.HK does not Granger Cause EDU	1.64076	0.1636	Do not reject H0
EDU does not Granger Cause 9901.HK	117.354	2.00E-62	Reject H0
0857.HK does not Granger Cause PTR	3.81802	8.00E-05	Reject H0
PTR does not Granger Cause 0857.HK	140.914	6.00E-239	Reject H0
600688.SS does not Granger Cause SHI	4.1716	0.0155	Reject H0
SHI does not Granger Cause 600688.SS	13.522	1.00E-06	Reject H0
9961.HK does not Granger Cause TCOM	4.70611	2.00E-05	Reject H0
TCOM does not Granger Cause 9961.HK	80.8155	1.00E-60	Reject H0
9868.HK does not Granger Cause XPEV	5.23236	0.0005	Reject H0
XPEV does not Granger Cause 9868.HK	99.6779	4.00E-44	Reject H0
9688.HK does not Granger Cause ZLAB	0.92916	0.4739	Do not reject H0
ZLAB does not Granger Cause 9688.HK	218.717	8.00E-116	Reject H0
2057.HK does not Granger Cause ZTO	3.8516	0.0021	Reject H0
ZTO does not Granger Cause 2057.HK	99.7271	2.00E-65	Reject H0

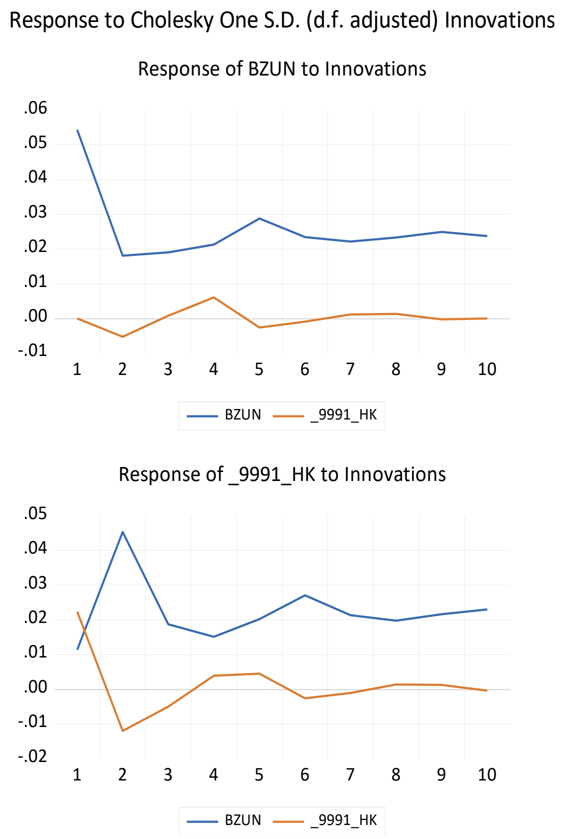
Finally, from applying impulse response functions we can understand that both ADRs and underlying stocks positively affect one another. Furthermore, we can also see that the effect is approximately equal on ADRS when impulse is given to underlying stocks and underlying stocks when impulse is given to ADRs.

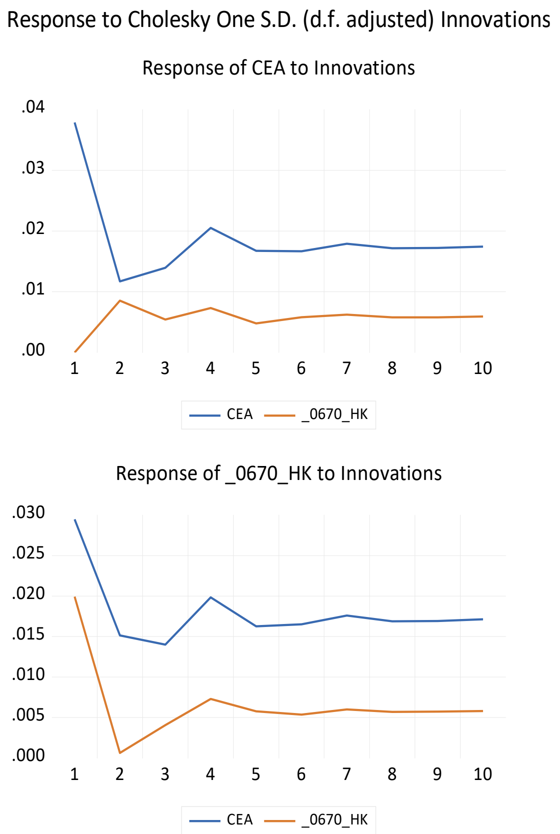
Overall, by observing the charts presented in **Figure 1**, and in line with the results of Patel (2015), we can conclude that the responses in both cases are continuing between three and five days.

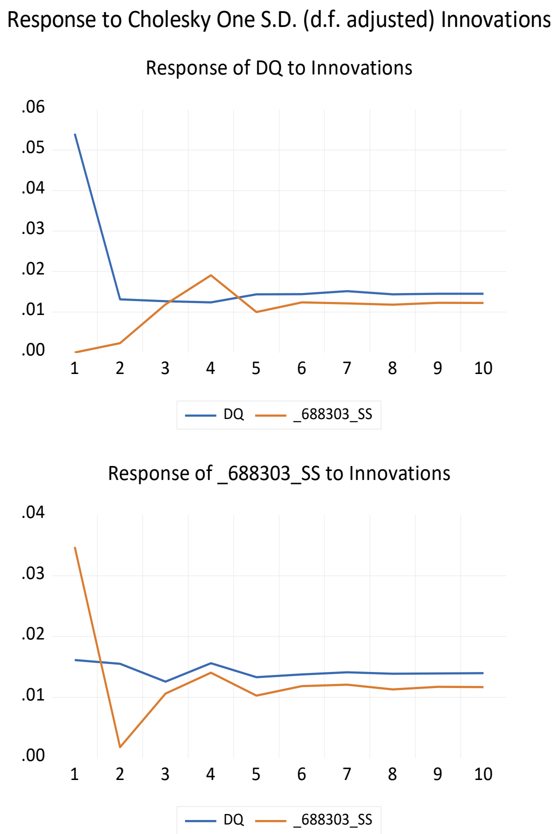
Figure 1 - Impulse Response Functions

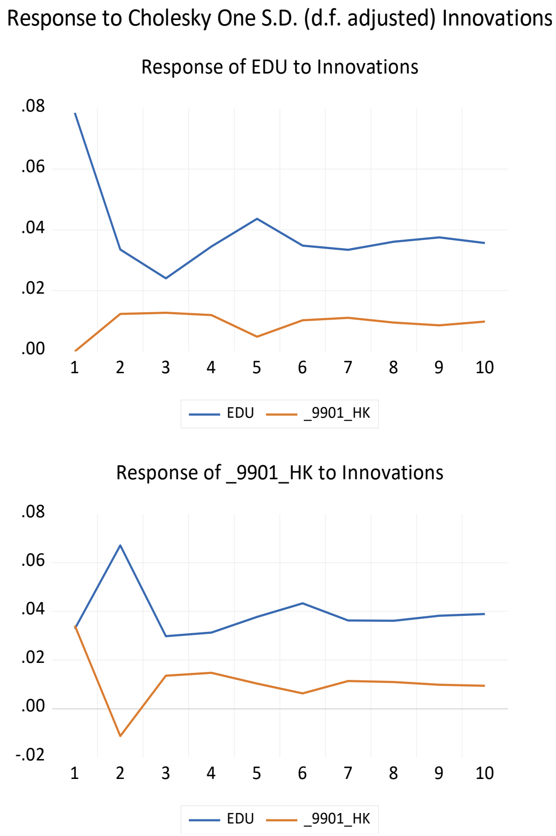


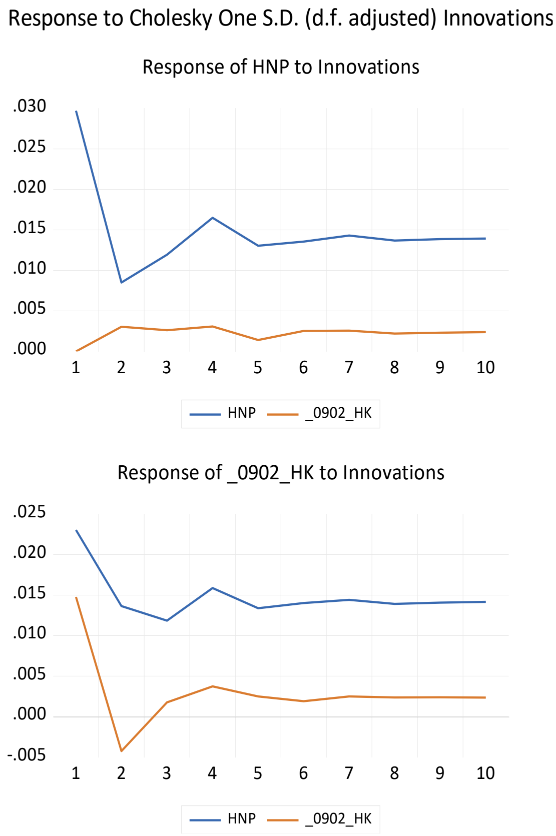

Response to Cholesky One S.D. (d.f. adjusted) Innovations
Response of BILI to Innovations
.08
.06
.04
.02
.00
-.02
1 2 3 4 5 6 7 8 9 10
BILI _9626_HK
Response of _9626_HK to Innovations
.06
.04
.02
.00
-.02
1 2 3 4 5 6 7 8 9 10
BILI _9626_HK

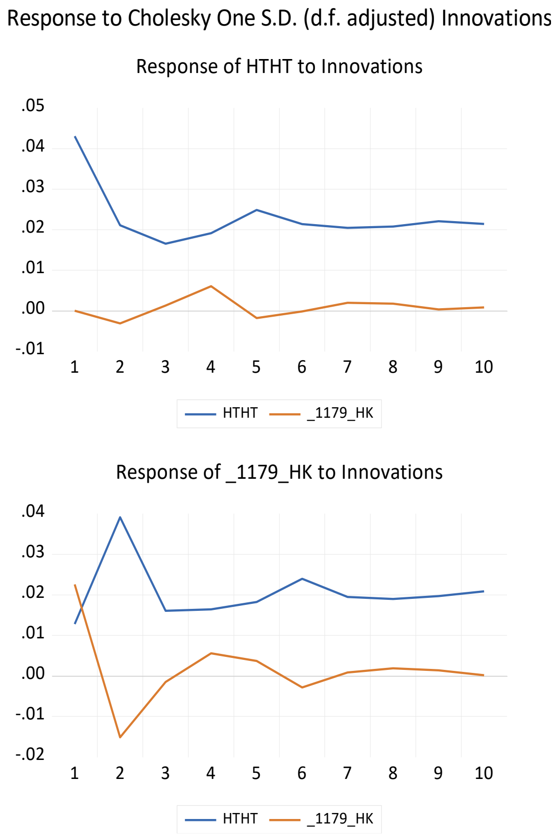

Response to Cholesky One S.D. (d.f. adjusted) Innovations
Response of BZUN to Innovations
.06
.05
.04
.03
.02
.01
.00
-.01
1 2 3 4 5 6 7 8 9 10
BZUN _9991_HK
Response of _9991_HK to Innovations
.05
.04
.03
.02
.01
.00
-.01
-.02
1 2 3 4 5 6 7 8 9 10
BZUN _9991_HK

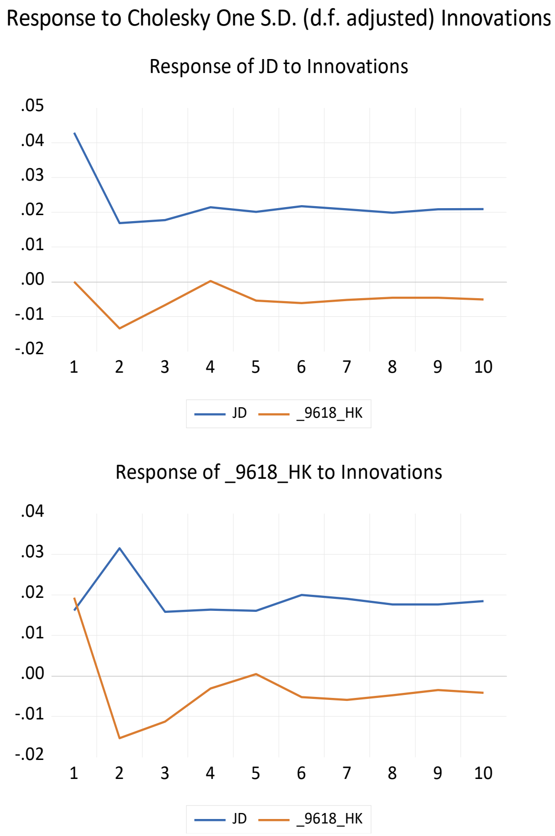

Response to Cholesky One S.D. (d.f. adjusted) Innovations
Response of CEA to Innovations
.04
.03
.02
.01
.00
1 2 3 4 5 6 7 8 9 10
CEA _0670_HK
Response of _0670_HK to Innovations
.030
.025
.020
.015
.010
.005
.000
1 2 3 4 5 6 7 8 9 10
CEA _0670_HK

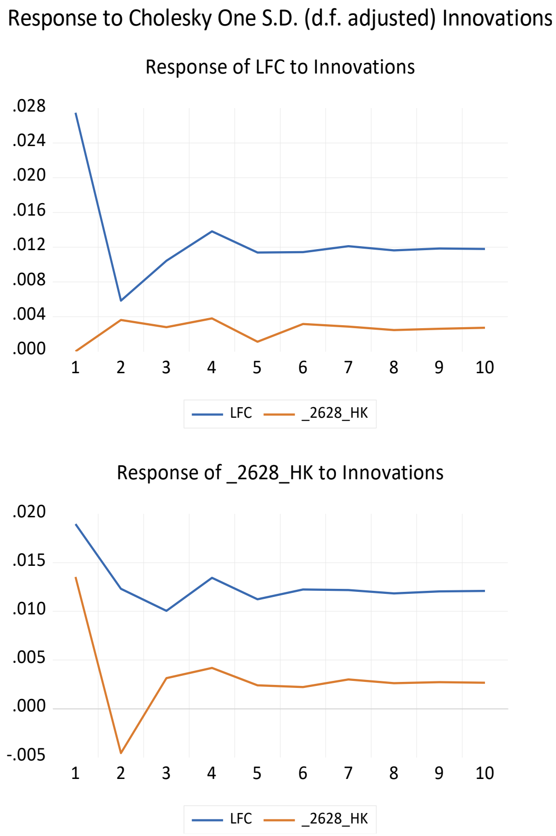

Response to Cholesky One S.D. (d.f. adjusted) Innovations
Response of DQ to Innovations
.06
.05
.04
.03
.02
.01
.00
1 2 3 4 5 6 7 8 9 10
DQ _688303_SS
Response of _688303_SS to Innovations
.04
.03
.02
.01
.00
1 2 3 4 5 6 7 8 9 10
DQ _688303_SS

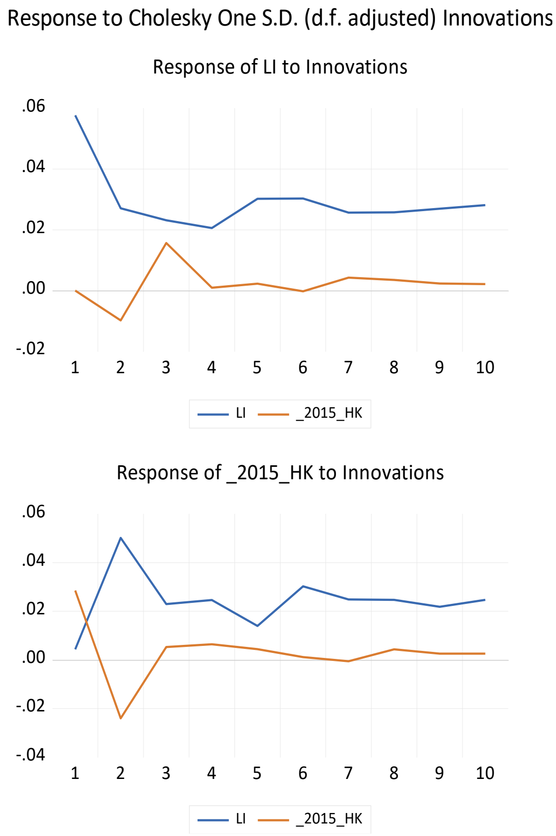

Response to Cholesky One S.D. (d.f. adjusted) Innovations
Response of EDU to Innovations
.08
.06
.04
.02
.00
1 2 3 4 5 6 7 8 9 10
EDU
_9901_HK
Response of _9901_HK to Innovations
.08
.06
.04
.02
.00
-.02
1 2 3 4 5 6 7 8 9 10
EDU
_9901_HK

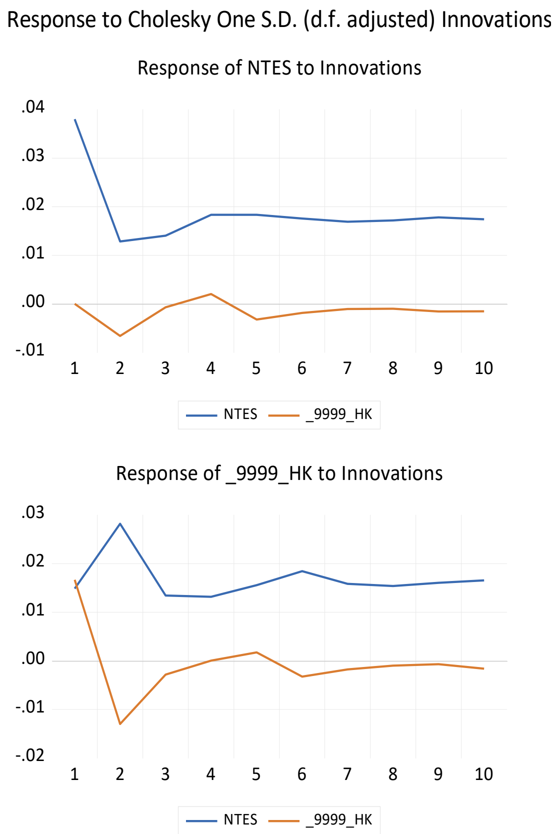

Response to Cholesky One S.D. (d.f. adjusted) Innovations
Response of HNP to Innovations
.030
.025
.020
.015
.010
.005
.000
1 2 3 4 5 6 7 8 9 10
HNP
_0902_HK
Response of _0902_HK to Innovations
.025
.020
.015
.010
.005
.000
-.005
1 2 3 4 5 6 7 8 9 10
HNP
_0902_HK

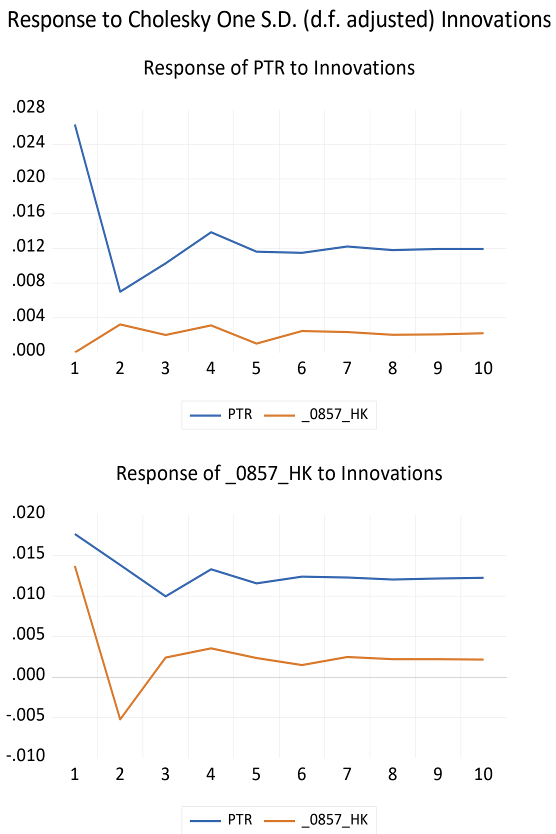

Response to Cholesky One S.D. (d.f. adjusted) Innovations
Response of HTHT to Innovations
.05
.04
.03
.02
.01
.00
-.01
1 2 3 4 5 6 7 8 9 10
HTHT
_1179_HK
Response of _1179_HK to Innovations
.04
.03
.02
.01
.00
-.01
-.02
1 2 3 4 5 6 7 8 9 10
HTHT
_1179_HK

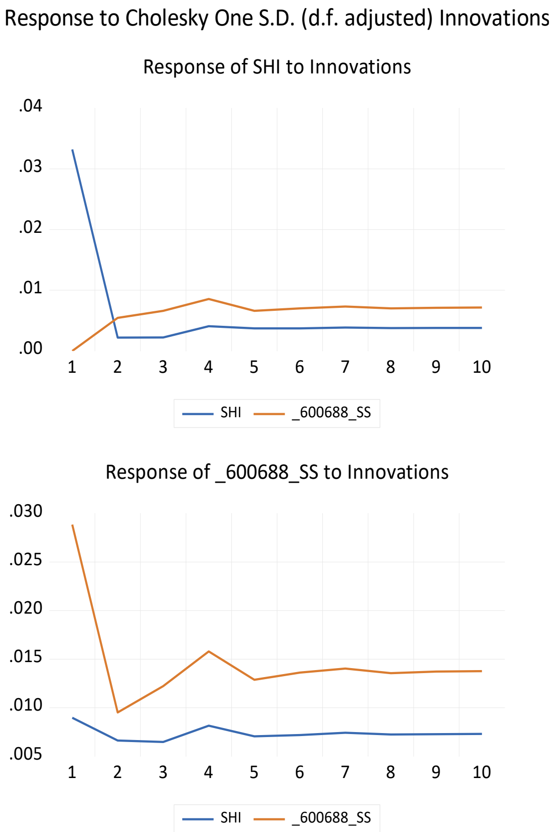

Response to Cholesky One S.D. (d.f. adjusted) Innovations
Response of JD to Innovations
.05
.04
.03
.02
.01
.00
-.01
-.02
1 2 3 4 5 6 7 8 9 10
JD
_9618_HK
Response of _9618_HK to Innovations
.04
.03
.02
.01
.00
-.01
-.02
1 2 3 4 5 6 7 8 9 10
JD
_9618_HK

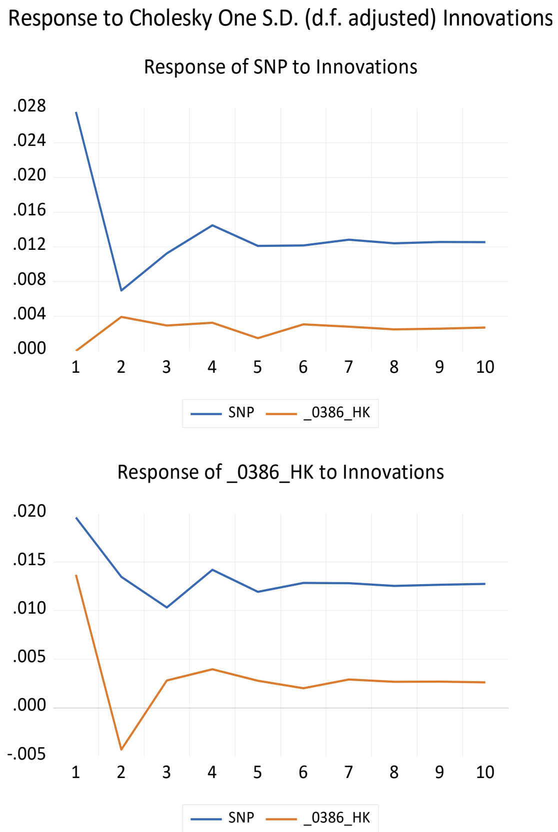

Response to Cholesky One S.D. (d.f. adjusted) Innovations
Response of LFC to Innovations
.028
.024
.020
.016
.012
.008
.004
.000
1 2 3 4 5 6 7 8 9 10
LFC _2628_HK
Response of _2628_HK to Innovations
.020
.015
.010
.005
.000
-.005
1 2 3 4 5 6 7 8 9 10
LFC _2628_HK

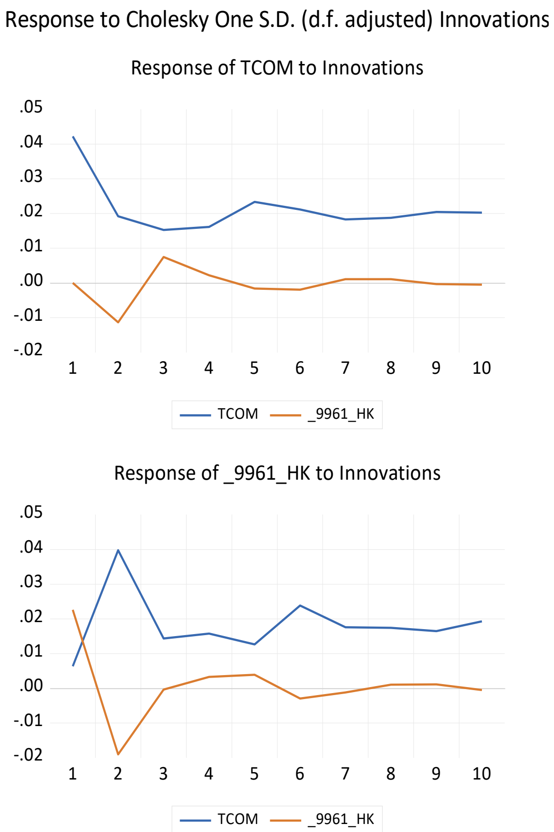

Response to Cholesky One S.D. (d.f. adjusted) Innovations
Response of LI to Innovations
.06
.04
.02
.00
-.02
1 2 3 4 5 6 7 8 9 10
LI _2015_HK
Response of _2015_HK to Innovations
.06
.04
.02
.00
-.02
-.04
1 2 3 4 5 6 7 8 9 10
LI _2015_HK

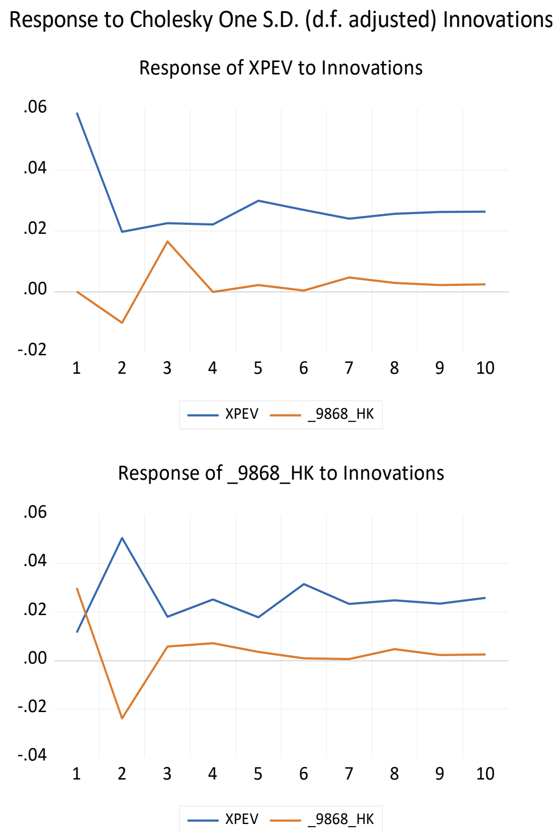

Response to Cholesky One S.D. (d.f. adjusted) Innovations
Response of NTES to Innovations
.04
.03
.02
.01
.00
-.01
1 2 3 4 5 6 7 8 9 10
NTES _9999_HK
Response of _9999_HK to Innovations
.03
.02
.01
.00
-.01
-.02
1 2 3 4 5 6 7 8 9 10
NTES _9999_HK


Response to Cholesky One S.D. (d.f. adjusted) Innovations
Response of PTR to Innovations
.028
.024
.020
.016
.012
.008
.004
.000
1 2 3 4 5 6 7 8 9 10
PTR _0857_HK
Response of _0857_HK to Innovations
.020
.015
.010
.005
.000
-.005
-.010
1 2 3 4 5 6 7 8 9 10
PTR _0857_HK

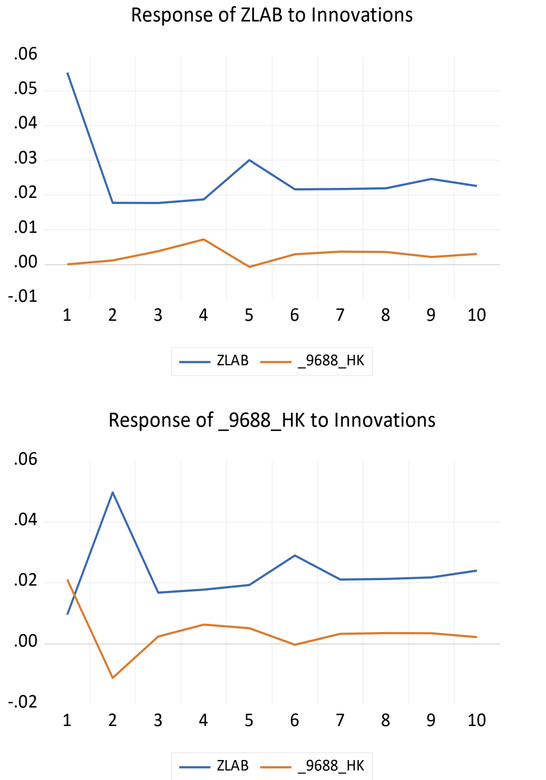

Response to Cholesky One S.D. (d.f. adjusted) Innovations
Response of SHI to Innovations
SHI
_600688_SS
Response of _600688_SS to Innovations
SHI
_600688_SS


Response to Cholesky One S.D. (d.f. adjusted) Innovations
Response of SNP to Innovations
SNP
_0386_HK
Response of _0386_HK to Innovations
SNP
_0386_HK

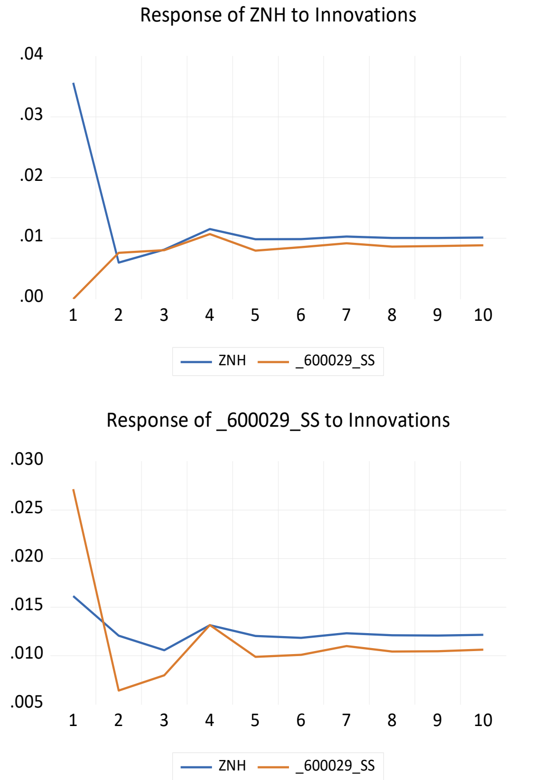

Response to Cholesky One S.D. (d.f. adjusted) Innovations
Response of TCOM to Innovations
TCOM
_9961_HK
Response of _9961_HK to Innovations
TCOM
_9961_HK


Response to Cholesky One S.D. (d.f. adjusted) Innovations
Response of XPEV to Innovations
XPEV
_9868_HK
Response of _9868_HK to Innovations
XPEV
_9868_HK

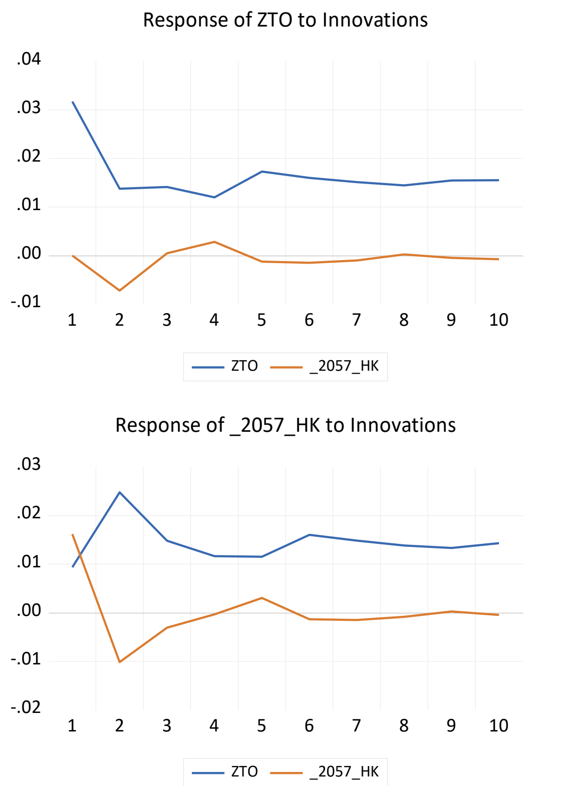
Response to Cholesky One S.D. (d.f. adjusted) Innovations



Response to Cholesky One S.D. (d.f. adjusted) Innovations



Response to Cholesky One S.D. (d.f. adjusted) Innovations



The results of variance decomposition are presented in **Table 4.16** and **Table 4.17**.

Table 4.16 - Results of variance decomposition (1)

Cholesky ordering (at lag 10)	ADR (%)	Und. Stck (%)
Variance decomposition of **BABA**	98.05796	1.94204
Variance decomposition of **9988.HK**	84.62729	15.37271
Variance decomposition of **ACH**	75.58225	24.41775
Variance decomposition of **601600.SS**	45.60354	54.39646
Variance decomposition of **ATHM**	98.61983	1.380165
Variance decomposition of **2518.HK**	86.53057	13.46943
Variance decomposition of **BIDU**	94.46714	5.53286
Variance decomposition of **9888.HK**	81.68767	18.31233
Variance decomposition of **BZUN**	99.01921	0.980793
Variance decomposition of **9991.HK**	88.92358	11.07642
Variance decomposition of **BILI**	95.38781	4.612189
Variance decomposition of **9626.HK**	85.06406	14.93594
Variance decomposition of **CEA**	91.81846	8.181536
Variance decomposition of **0670.HK**	83.64835	16.35165
Variance decomposition of **LFC**	96.25726	3.742738
Variance decomposition of **2628.HK**	85.84429	14.15571
Variance decomposition of **SNP**	96.55121	3.448786
Variance decomposition of **0386.HK**	87.09387	12.90613
Variance decomposition of **ZNH**	75.45601	24.54399
Variance decomposition of **600029.SS**	48.45614	51.54386
Variance decomposition of **DQ**	77.63493	22.36507
Variance decomposition of **688303.SS**	46.98519	53.01481
Variance decomposition of **HNP**	97.80235	2.197648
Variance decomposition of **0902.HK**	88.87476	11.12524

Table 4.17 - Results of variance decomposition (2)

Cholesky ordering (at lag 10)	ADR (%)	Und. Stck (%)
Variance decomposition of **HTHT**	98.99539	1.004612
Variance decomposition of **1179.HK**	85.44465	14.55535
Variance decomposition of **JD**	93.35188	6.648123
Variance decomposition of **9618.HK**	81.39238	18.60762
Variance decomposition of **LI**	96.15153	3.848472
Variance decomposition of **2015.HK**	82.40517	17.59483
Variance decomposition of **NTES**	98.30218	1.697822
Variance decomposition of **9999.HK**	86.20416	13.79584
Variance decomposition of **EDU**	94.71915	5.280854
Variance decomposition of **9901.HK**	87.79965	12.20035
Variance decomposition of **PTR**	97.39197	2.608031
Variance decomposition of **0857.HK**	86.36729	13.63271
Variance decomposition of **SHI**	73.2465	26.7535
Variance decomposition of **600688.SS**	18.38796	81.61204
Variance decomposition of **TCOM**	96.27908	3.720922
Variance decomposition of **9961.HK**	81.63138	18.36862
Variance decomposition of **XPEV**	95.55186	4.448141
Variance decomposition of **9868.HK**	82.10041	17.89959
Variance decomposition of **ZLAB**	98.48231	1.517688
Variance decomposition of **9688.HK**	90.29879	9.701207
Variance decomposition of **ZTO**	97.86266	2.137343
Variance decomposition of **2057.HK**	85.23445	14.76555

The results reveal that ADRs explain between 18% and 90% of the variance of underlying stocks, while the remaining variance is explained by the underlying stocks themselves. Similarly, underlying stocks explain between 73% and 99% of ADRs variance, while the remaining is explained by the ADRs themselves.

From this we conclude that underlying stocks are a significant determinant of ADRs.

5 Conclusion

With this study we sought to analyze the dynamic linkages between American Depository Receipts (ADRs) and their corresponding underlying stocks returns. To do so, we followed the methodology of Patel (2015) in an attempt to replicate his study for the Chinese market. We used a sample of 23 ADRs, from as far back as there is data on both ADR and underlying stock of each company, until 20th April 2022. We applied the Dickey-Fuller unit root test, Johansen cointegration test, Granger causality test, vector error correction model, impulse response function and variance decomposition to reach our conclusions.

The results of this study largely support the study of Patel (2015). First, given positive correlation was found between all ADRs and corresponding underlying stocks, investors should be wary when seeking portfolio diversification by investing in the two assets.

Second, the existence of long-run equilibrium between the returns of ADRs and underlying is supported. Thus, market participants, regulatory bodies and governmental institutions should track both markets, as any negative run in one can impact the other's performance.

Third, both ADRs and underlying stocks returns explain one another, as bidirectional Granger causality is found in 16 out of the 23 companies. In five companies the ADRs Granger cause the corresponding underlying stocks, while in one the underlying stock Granger causes the ADR. As such, we can conclude for the importance of the ADR market in the price discovery of the underlying stocks, though the affect appears to be two-way.

Fourth, this study provides evidence of the causality and interdependence between ADRs and underlying stocks, thus contributing to existing literature.

Fifth, given both ADRs and underlying stocks positively affect one another, as indicated by the results of impulse response functions, cross-listing in US markets should be supported and encouraged by Chinese authorities.

Sixth, forecasting models for both ADRs and underlying stocks should include the other as important determinants, as a significant portion of each asset's variance is explained by the other.

As a suggestion for futures studies into this theme, it might be worth exploring if these results hold in different markets, with a particular focus on developed markets, given their bigger worldwide exposure to investors and market agents, when compared to developing markets.

6 References

Alaganar, V. T., & Bhar, R. (2001). Diversification gains from American depositary receipts and foreign equities: evidence from Australian stocks. *Journal of International Financial Markets, Institutions and Money, 11(1)*, 97-113. https://doi.org/10.1016/S1042-4431(00)00038-X

Alsayed, H., & McGroarty, F. (2012). Arbitrage and the Law of One Price in the market for American depository receipts, *Journal of International Financial Markets, Institutions and Money, 22(5)*, 1258-1276. https://doi.org/10.1016/j.intfin.2012.07.002

Ansotegui, C., Bassiouny, A., & Tooma, E. (2013). The proof is in the pudding: Arbitrage is possible in limited emerging markets. *Journal of International Financial Markets, Institutions and Money, 23*, 342-357. https://doi.org/10.1016/j.intfin.2012.11.001

Cao-Alvira, J.J. and Rodríguez, J. (2017). IPO and Aftermarket Performance of Single-Listed Chinese ADRs. *Journal of International Financial Management & Accounting, 28 (1)*, 5-26. https://doi.org/10.1111/jifm.12051

Choi, Y. K., & Kim, D. (2000). Determinants of American Depositary Receipts and their underlying stock returns: Implications for international diversification. *International Review of Financial Analysis, 9(4),* 351-368. https://doi.org/10.1016/S1057-5219(00)00041-7

Citigroup. (2022, Fabruary). *Year End 2021 Report*. Retrieved from Citigroup Depository Receipts Services.

Didia, D. O. (2015). Emerging Markets, American Depository Receipts and International Diversification. *Journal of International Business and Economics, 3(2),* 43-50. http://dx.doi.org/10.15640/jibe.v3n2a3

Dickey, D. A., & Fuller, W. A. (1979). Distribution of the Estimators fo Autoregressive Time Seies With a Unit Root. *Journal of the American Statistical Association, 74*, 427-431. https://www.jstor.org/stable/2286348

Domowitz, I., Glen, J., & Madhavan, A. (1998). International Cross-Listing and Order Flow Migration: Evidence from an Emerging Market. *The Journal of Finance, 53,* 2001-2027. https://doi.org/10.1111/0022-1082.00081

Esqueda, O.A., & Jackson, D.O. (2012). Currency depreciation effects on ADR returns: evidence from Latin America. *Journal of Economics and Finance, 36,* 691–711. https://doi.org/10.1007/s12197-010-9144-9

Esqueda, O.A., Luo, Y., & Jackson, D.O. (2015). The linkage between the U.S. "fear index" and ADR premiums under non-frictionless stock markets. *Journal of Economics and Finance*, 39, 541–556. https://doi.org/10.1007/s12197-013-9265-z

Ghadhab, I., & Hellara, S. (2015). The law of one price, arbitrage opportunities and price convergence: Evidence from cross-listed stocks. *Journal of Multinational Financial Management, 31,* 126-145. https://doi.org/10.1016/j.mulfin.2015.05.002

Grossmann, A., Ozuna, T., & Simpson, M. W. (2007). ADR mispricing: Do costly arbitrage and consumer sentiment explain the price deviation? *Journal of International Financial Markets, Institutions and Money, 17(4)*, 361-371. https://doi.org/10.1016/j.intfin.2006.02.001

Howe, J. S., & Madura, J. (1990). The impact of international listings on risk: Implications for capital market integration. *Journal of Banking & Finance, 14(6),* 1133-1142. https://doi.org/10.1016/0378-4266(90)90004-L

Jayaraman, N., Shastri, K., & Tandon, K. (1993). The impact of international cross listings on risk and return: The evidence from American depository receipts. *Journal of Banking & Finance, 17(1)*, 91-103. https://doi.org/10.1016/0378-4266(93)90081-N

Jiang, C.X. (1998). Diversification with American Depository Receipts: The Dynamics and the Pricing Factors. *Journal of Business Finance & Accounting, 25,* 683-699. https://doi.org/10.1111/1468-5957.00207

Kim, M., Szakmary, A. C., & Mathur, I. (2000). Price transmission dynamics between ADRs and their underlying foreign securities. *Journal of Banking & Finance, 24(8),* 1359-1382. https://doi.org/10.1016/S0378-4266(99)00076-XLang, M.H., Lins, K.V., & Miller, D.P. (2003). ADRs, Analysts, and Accuracy: Does Cross Listing in the United States Improve a Firm's Information Environment and Increase Market Value? *Journal of Accounting Research, 41,* 317-345. https://doi.org/10.1111/1475-679X.00106

Liu, L. X., & Bogomolov, T. (2012). The law of one price and arbitrage on China's dual-listings. *International Journal of Banking and Finance, 9 (2),* 58-76. https://researchonline.jcu.edu.au/52972/

Mark Schaub (2010). A note on the performance of Chinese American Depository Receipts, *Applied Economics Letters, 17(5),* 431-435. https://doi.org/10.1080/13504850701842850

Miller, D. P. (1999). The market reaction to international cross-listings: evidence from Depositary Receipts. *Journal of Financial Economics, 51(1),* 103-123. https://doi.org/10.1016/S0304-405X(98)00045-2

O'Hagan-Luff, M., & Berrill, J. (2018). The international diversification benefits of U.S.-traded equity products. *International Journal of Finance & Economics, 24,* 1238–1253. https://doi.org/10.1002/ijfe.1714

Rabinovitch, R., Silva, A. C., & Susmel, R. (2003). Returns on ADRs and arbitrage in emerging markets. Emerging Markets Review, 4(3), 225-247. https://doi.org/10.1016/S1566-0141(03)00038-4

Rodríguez, J. & Toledo, W. (2017). Chinese single-listed ADRs: returns and volatility. *International Journal of Managerial Finance, 11(4)*, 480-502. https://doi.org/10.1108/IJMF-07-2014-0103

Sovan Mitra, S., Chinthalapati, V. L. R., Clark, E., & McGroarty, F. (2019). Stock-ADR Arbitrage: Microstructure Risk. *Journal of International Financial Markets, Institutions and Money, 63*, Article 101132. https://doi.org/10.1016/j.intfin.2019.08.004

Suarez, E. D. (2005). Arbitrage opportunities in the depositary receipts market: Myth or reality? *Journal of International Financial Markets, Institutions and Money, 15(5)*, 469-480. https://doi.org/10.1016/j.intfin.2004.11.001