CIP DEVIATIONS IN BRICS COUNTRIES AROUND THE 2008 GLOBAL FINANCIAL CRISIS

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ABSTRACT

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Abstract

The covered interest rate parity (CIP) has failed to hold among emerging markets long before the 2008 global financial crisis. The reasons for those CIP deviations range from transaction costs and risk premia demanded by market participants to provide liquidity in an illiquid market and carry out transactions with less credit-worthy counterparties, as well as credit risk, low degree of financial integration, and perceived country risk. This paper examines the effect of the 2008 global financial crisis on CIP deviations among the five largest emerging markets, Brazil, Russia, India, China, and South Africa (BRICS). Additionally, the global and local economic policy uncertainty are tested as potential new explanations for CIP deviations.

In this research, the BRICS countries' CIP deviations are tested against the euro in the period of 2004-2019 to represent the periods before and after the 2008 global financial crisis. With the aid of the Vector Autoregression (VAR) model and the Granger causality tests, the relationships between multiple variables are captured and the predictive power of the variables is tested. In order to capture the negative interest rate era in the eurozone, a dummy variable is estimated to test whether the economic policy uncertainty variables should be treated as an endogenous or exogenous variable.

This research finds for 80% of the cases that the magnitude of CIP deviations for BRICS countries has increased substantially following the 2008 global financial crisis in comparison to the pre-crisis era, while in only 20% of cases, the 2008 financial crisis appears to have not affected the magnitude of the CIP deviations. Furthermore, The results also find that in 30% of the cases, global EPU causes CIP deviations while in 20% of the cases, country-level EPU causes CIP deviations.

Key words
Covered interest rate parity; CIP deviations; Arbitrage; Economic policy uncertainty

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1 INTRODUCTION

1.1 Background

The principle of covered interest rate parity (CIP), which was first developed by Keynes (1923) during the exchange rate turbulence that followed world war I, is the closest thing to a physical law in international finance (Borio et al., 2018). CIP is a theoretical financial condition in which the relationship between interest rates and the spot and forward currency rates of two countries are in equilibrium. The CIP theory suggests that there is no trade-off between investing in a foreign currency in comparison to investing in a local currency since the spot and forward rates should eliminate any additional gains. CIP holds when the interest rate differential between two currencies in the money market equals to the differential between the forward and spot exchange rates. However, history shows that CIP does not always hold. Previous research (Skinner & Mason, 2011; Du, Tepper, & Verdelhan, 2018) suggests that the CIP has not always held, both prior to, and followed by, the 2008 global financial crisis (GFC) in emerging markets. While in developed markets, in contrast, the CIP held rather closely prior to the 2008 GFC. However, since the onset of the GFC, the relationship seems to have been broken down. There are multiple reasons and explanations why CIP fails to hold over time. It is ranging from transaction costs, political risks, capital market imperfections, information costs, regulation-induced or other arbitrage limits, capital control, etc.

The outcome of CIP deviations is covered interest rate arbitrage (CIA). Once CIP collapses, there are new arbitrage opportunities that arbitrageurs are keen to exploit to make seemingly riskless profits. In CIA, an investor is making simultaneous spot and forward market transactions, with an ultimate goal of gaining riskless profit through the combination of currency pairs. In this strategy, the investor uses a forward contract to hedge against exchange rate risk, hence the word arbitrage. The way to measure CIP deviations is by cross-currency basis points. The cross-currency basis is the amount by which the interest paid to borrow one currency by swapping it against another differs from the cost of directly borrowing this currency in the money market. When the cross-currency basis is positive (negative), it suggests that the direct dollar interest rate is higher (lower) than the synthetic dollar interest rate, and when the cross-currency basis is zero, CIP holds and there are no arbitrage opportunities.

This thesis builds on the previous work of Du, Tepper, & Verdelhan (2018) whose empirical results imply significant evidence of the emergence of CIP deviations for G10 currencies following the 2008 GFC. Figure 1. illustrates the effects of the 2008 GFC on the G10 currencies. Prior to the financial crisis, the short-term cross-currency basis for all G10 currencies was around 0 cross-currency basis points. Since the onset of the crisis, the cross-currency skyrocketed to unprecedented new heights, making the GFC a great period of profitable arbitrage. Following the crisis, the cross-currency level remained significantly higher than prior to the crisis, presenting a new era in which also the developed economies provide significant CIP deviations across time.

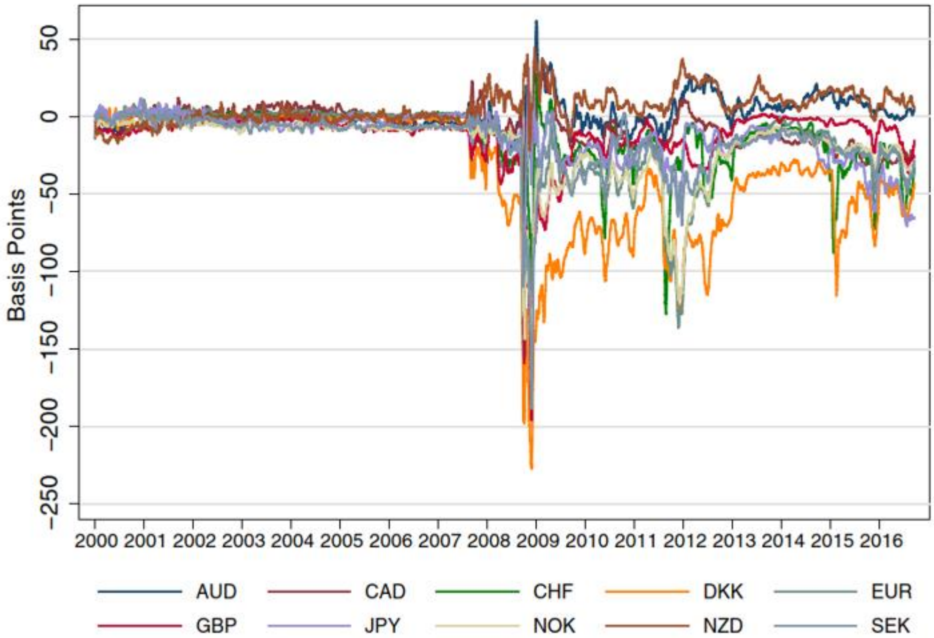

Figure 1. Short-term maturity CIP deviations in G10 currencies (Du, Tepper, & Verdelhan, 2018)

The purpose of this thesis is to test the effect of the 2008 GFC on the CIP deviations for Brazil, Russia, India, China, and South Africa (BRICS) currencies, and to discover whether the magnitudes of the CIP deviations have changed between the two periods. In this research, BRICS' currencies are used to measure for CIP deviations against the euro in the short term, therefore, each BRICS' currency is tested on two different short-term horizons, 1-month, and 3-month maturity. The euro is applied as the currency benchmark since it is at the very top in terms of currency trading. In addition to the effect of the 2008 GFC, this paper puts emphasis on a different potential cause of CIP deviations, that is economic policy uncertainty.

Economic policy uncertainty (EPU) is a concept for the unpredictability of the forthcoming economic state. EPU is affected by both economic variables such as political interventions, economic status, and stochastic events, as well as non-economic variables such as terrorism and natural disasters. Thus, every aspect that might involve decision making and has economic impacts is included in a subcategory of the overall economic uncertainty. The role of economic policy actions is to help prevent economic downfalls, reduce uncertainty, and improve the economic outlook for the future. When turbulences or other concerns in the economy occur, and the impacts of these economic issues or reactions cannot be forecasted, the level of EPU rises. Baker, Bloom, & Davis (2015) developed an economic policy uncertainty index as means to measure EPU. The EPU index is designed to measure economic policy uncertainties by observing the number of headlines of newspapers regarding economic policies. To my knowledge, there are no previous papers investing whether EPU is a potential cause for CIP deviations. Furthermore, at the time of writing these lines, the coronavirus pandemic is driving the worlds' economy towards depression, in which the magnitude is yet unknown, making the economic policy uncertainty topic a timely decision.

In this research, the Vector Autoregression (VAR) model is used as a method for time series forecasting. The VAR model is based on analysing individual time series processes as a stochastic representation of the data and capturing the linear interdependencies among multiple time series. VAR modelling is fairly simple since it requires only a list of variables that can be hypothesized to affect each other intertemporally instead of requiring much knowledge about the forces influencing a variable as do structural models with simultaneous equations do. In order to test whether one time series is useful in forecasting another, the Granger causality test is used. Essentially, "if the prediction of one time series is improved by incorporating the knowledge of a second time series, then the latter is said to have a causal influence on the first" (Bose, Hravnak, & Sereika, 2017). Due to the negative interest rate period in the eurozone in recent years, an additional model with dummy variables is also estimated to observe whether the negative interest rate era has an effect on the results. In the additional model, the negative interest rate period is described with a dummy variable to measure whether global and country-level EPU should be treated as endogenous or exogenous variables. When the Granger causality shows similar results when global and country-level EPU are assumed as exogenous variables and as endogenous variables, it is safe to assume that global and country-level EPU should be treated as endogenous variables because they do not affect the outcome of the results.

1.2 Research questions and objectives

In this paper, the VAR model is applied, and the Granger causality tests are taking place to test for CIP deviations by capturing the relationships between variables over time of the five largest emerging markets, that is the BRICS countries. In addition, this paper focuses on EPU as a potential reason for the CIP deviations in the BRICS countries.

Research questions and hypotheses:

1) What is the effect of the 2008 global financial crisis on CIP deviations in BRICS countries?

H_1. Based on the earlier research, the hypothesis is that CIP deviations in BRICS countries have increased since the onset of the 2008 GFC. This assumption is based on previous research on the effect of the 2008 GFC on the emerging markets where CIP deviations became significantly larger and more consistent than ever before. In addition, also in developed markets, CIP deviations became a norm after being minimal and non-significant prior to the crisis. However, such an increase may not occur for each BRICS country and each time horizon as earlier research suggests no drastic effect of the 2008 GFC on CIP deviations, see Figure 8.

2) Whether global EPU and/or country-level EPU explain part of the CIP deviations?

H_2. Based on the increased level of EPU around the world both during and following the 2008 GFC, and the rising levels of CIP deviations, the hypothesis is that both global and country-level EPU explain part of the CIP deviations in BRICS countries. Furthermore, nations that have an enormous share of international trade, financial assets, and commodities, such as Russia and China are less dependent on global EPU than "small" open countries such as Brazil, India, and South Africa. Thus, in the cases of Brazil, India, and South Africa, global EPU is expected to have a larger impact and for Russia and China, country-level EPU is expected to have a larger impact.

1.3 Main findings

The VAR model and Granger causality tests find that in most cases the 2008 GFC has caused higher levels of CIP deviations and as a result, CIP deviations provide long-lasting arbitrage opportunities ever since. The research finds for 80% of the cases that the magnitude of CIP deviations for BRICS countries has increased substantially following the 2008 GFC in comparison to the pre-crisis era, while in only 20% of cases, the 2008 GFC appears to have not affected the magnitude of the CIP deviations. Furthermore, this paper finds that global EPU appears to have a slightly stronger effect on CIP deviations than country-level EPU. The results find that in 30% of the cases, global EPU causes part of the CIP deviations, while in 20% of the cases, country-level EPU causes part of the CIP deviations. In addition, this study also finds that country-level EPU has stronger explanatory power on the CIP deviations than global EPU. In 20% of the cases, country-level EPU has stronger explanatory power on the CIP deviations than global EPU, while in only 10% of the cases, global EPU has a stronger explanatory power on the CIP deviations than country-level EPU. Finally, this research suggests that also for large economies in terms of international trade of goods, financial assets, and commodities, CIP deviations could be generated more due to global EPU than from country-level EPU.

1.4 Research structure

This study is organized as follows. In chapter one, the principle of covered interest rate parity and the outcome of CIP deviations are presented. The reasons and explanations why CIP fails to hold over time are also discussed, in addition to a brief explanation of EPU as a cause for CIP deviations is introduced. Lastly, the chapter offers the research questions and objectives and its main findings. Chapters 2-4 present the literature review. Where chapter two discusses the benefits and ideas international diversification provides to investors, while chapter three explores arbitrage in financial markets, and chapter four discusses the collapse of CIP around the 2008 global financial crisis. Afterwards, chapter five describes the research method and the data analysis used to collect and analyze the data, and chapter six presents the findings of the analysis performed. Finally, chapter seven concludes the paper and provides the limitations of the study along with suggested avenues for further research.

2 BENEFITS AND IDEAS OF INTERNATIONAL DIVERSIFICATION

Portfolio diversification which was first developed by Tobin (1958) and Markowitz (1959) is a method in which a firm or an investor invests in a range of products or fields of operation. Allocating investments into various financial instruments and industries allows a firm the possibility of reducing its systematic risk. By doing so, only part of, instead of all of the portfolio is exposed to market risk. The extent to which diversification reduces risks depends on the correlations among security returns (Levy & Sarnat, 1970). If the security returns are perfectly correlated, any degree of diversification could not eliminate risk. On the other hand, if security returns are not correlated, diversification could reduce or eliminate risk. In addition, when applying diversification optimally, it may also help to maximize profit while maintaining considerably lower risks in cases of events affecting differently among different industries or sectors.

International diversification is the most useful technique to achieve efficient diversification. During the past several decades, international diversification has become commonplace in international finance. International diversification among developed economies has been ongoing for a considerably longer period of time than among emerging economies, maintaining their position as global leaders financially. Between the years 2000-2005, the growth of market capitalization in emerging markets was 197%, mainly due to the international diversification of firms in developed economies. In emerging markets, in contrast, international diversification has become a common investing method only in the latter years of the 1900s. However, since the beginning of the 21st century, the growth of international diversification among emerging markets has been very rapid (Bodie, Kane, & Marcus, 2009, pp. 868-871).

2.1 Stock market diversification

Stock market diversification is one of the most common methods of international diversification. An international stock portfolio is a selection of stocks across both foreign and domestic markets. A well-designed international stock portfolio provides investors exposure for both developed and emerging markets and may create a vast diversification. Stock market diversification may reduce risk and provide various benefits but also entails its own risks and limitations.

Stock market diversification provides numerous benefits for investors willing to invest in foreign markets. First and foremost, stock market diversification provides risk reduction (Levy & Sarnat, 1970; Rugman, 1976). Stock market diversification allows investors to allocate their total risk into different currencies, industries, markets, and governments. By investing internationally, an investor’s exposure to local economic risk such as recession, changes of rules and regulations by local government or natural disasters is minimized because the other investments are being unaffected or only mildly affected. Furthermore, international stock diversification enables investors from emerging economies to invest in less risky environments. Another major benefit of stock market diversification is profit maximization. By investing in foreign markets, an investor gets access to emerging markets, which potentially generate greater profits than one could possibly earn in local markets. Moreover, having access to emerging markets provides greater chances to locate misprices for long and short positions, as well as arbitrage opportunities (Bodie et al., 2009, pp. 882-889). In addition, a well-diversified portfolio does not require being hedged since currency hedging is not a significant issue in internationally well-diversified portfolios.

Numerous studies are supporting the effect of international stock market diversification on higher stock returns. Yu-Wei, Stewart, & Yermo (2007) explore the Chinese liberalized portfolios in comparison to domestic only portfolios and find that the international portfolios provide higher returns between 1993-2004. Pfau (2011) finds that on average half of emerging market pension fund assets should be allocated to world assets, as limiting them to only domestic markets, will reduce 21% in returns. Liu, Park, & Sohn (2018) find that during the 2008 financial crisis, firms with higher foreign ownership had better stock returns than firms with lower foreign ownership. Asness, Israelov, & Liew (2011) find that during bear markets, over the longer investment horizons, economic performance tends to vary more across markets and diversification generates significant differences in realized returns, and therefore becomes highly beneficial for investors. Figure 2 illustrates the excess returns from international diversification in comparison to investing solely in domestic markets.

Figure 2. Excess returns from international diversification (Fisher, 2012)

Although international stock diversification provides many benefits for investors, it also generates numerous risks and limitations causing such investments to become less profitable and riskier than it might seem at first. By investing in foreign stock exchanges, investors need to bear foreign exchange (FX) risks as they buy and sell stocks in foreign currencies. Appreciation of a local currency against a foreign currency will result in a loss. Another drawback is country-specific risks. As each country may have its own political risks, regulations, or restriction on capital flows across national boundaries, international stock diversification may be transformed into a more costly and risky activity.

International stock diversification may become less beneficial due to its limitations. One of the most important limitations is the level of integration of stock markets with its counterparts because it is directly affecting the level of profitability when investing elsewhere. Liu, Park, & Sohn (2018) argue that diversification benefits are driven by countries with lower global integration. Diversification of funds among perfectly integrated stock markets is essentially worthless since it may not generate higher returns, nor eliminate any risk. Another important limitation of international stock diversification is home and familiarity bias. As most investors and portfolio managers are more familiar with their domestic market or an industry, their investment decisions are often biased towards local or familiar assets that may not be the most ideal international stock diversification for both risk aversion and profit maximization. The phenomena of home and familiarity bias occurs frequently despite the theoretical advantages of international stock diversification. Empirical literature shows that a large number of investors do not optimize their diversification internationally, and instead, allocate more assets into their well-known domestic markets regardless of the benefits of efficient portfolio diversification (Bekaert & Campbell, 2003). Kwabi et al. (2019) argue that one percentage point reduction in home bias, on average, increases the size of the domestic stock market (relative to the size of the economy) by nearly 0.2%. Furthermore, they also find that stock markets with lower degree of home bias tend to be larger, more diversified, liquid, and cost-effective stock markets.

Large-cap bias also limits the use of international stock diversification. A large number of investors tend to invest their funds into familiar and visible large-cap stocks around the globe. There are two main reasons why this phenomenon occurs; the fact that most cross listed firms are large-cap stocks and that institutional investors who often follow national or sector indices, may contribute to the large-cap bias as market indices are dominated by large-cap stocks (Kang & Stulz, 1997). Large-cap stocks are often multinational corporations with a substantial foreign customer and investor base, and therefore, their returns are driven by common global factors. The common exposure to global factors is being reflected by having relatively high correlations with each other. As a result, the gains for large-cap stocks from international diversification may be fairly limited as common global factors affect all of those large-cap firms simultaneously.

In addition, Eun, Huang, & Lai, (2008) find that, for small-cap stocks, international diversification can provide substantially higher profits. Small-cap firms are often more locally oriented with a limited international exposure, causing their returns to be driven by local and idiosyncratic factors which are reflected by having relatively low correlation not only with large-cap firms but also with each other. As a result, investors can achieve significant additional gains from international stock diversification by considering foreign small-cap stocks. Finally, negative local macroeconomic consequences, and loss of capital from domestic markets also limit the use of international stock diversification. Negative macroeconomic consequences such as depreciation of exchange rates or lack of liquidity may be resulted by large capital outflows from international investments. Furthermore, capital outflows from international investments may lead to loss of capital in domestic markets that could have been allocated into social investments such as housing loans or construction of hospitals and schools (International Labour Office, 1997).

2.2 Interest yielding assets and currency market diversification

The world's economy presents a large number of options in which individual investors or investment firms may gain interest on their assets. Financial markets are traditionally segmented into money markets, capital markets, FX markets, in addition to derivative markets for options and futures. Money market instruments include short-term debt, marketable, liquid, low-risk debt securities. Capital markets can be subdivided into bond and equity markets and include longer-term and riskier securities. FX markets are over-the-counter global marketplaces for the trading of currencies (Bodie et al., 2009, p. 23).

The money market is a subsector of the fixed-income market. It consists of very short-term debt securities that usually are highly marketable. Many of these securities trade in large denominations, and therefore, are out of the reach of individual investors. Money market funds, however, are easily accessible to "small" investors as such funds combine a large number of "small" investors resources and purchase a wide variety of money market securities on their behalf. Within the money market, there are different ways in which individual investors and investment firms may earn interest on their assets such as; US treasury bills (also known as T-bills) represent the simplest form of borrowing, in which the government raises money by selling short-term bills to the public; certificate of deposit or CD is a time deposit with a bank, where the time deposits may not be withdrawn on demand and the principal plus interest is paid to the depositor only at the end of the fixed term of the CD; commercial paper is a short-term debt issued by large firms that are not banks to investors; Eurodollars are dollar-denominated deposits at non-American banks or foreign branches of American banks (Bodie et al., 2009, pp. 24-27).

The bond market is composed of longer-term borrowing or debt instruments than those that trade in the money markets. The bond markets are easily accessible to both "small" investors and investment firms as such borrowings and debt instruments are being traded in small or large denominations. These instruments are sometimes said to comprise the fixed-income capital market because most of them promise either a fixed stream of income or a stream of income that is determined according to a specific formula. However, these formulas can result in a non-fixed flow of income, therefore, the term "fixed-income" is most likely not fully appropriate. The bond market consists of instruments such as; treasury notes and bonds represent the form of borrowing, in which the government raises money by selling long-term bills to the public. Treasury notes maturities range up to 10 years, whereas treasury bonds are issued with maturities ranging from 10-30 years; international bonds are simply bonds borrowed and lent internationally, providing access for firms to borrow abroad and to investors to buy bonds from foreign issuers; municipal bonds are bonds issued by state or local governments to investors; corporate bonds are the means by which private firms borrow money directly from the public (Bodie et al., 2009, pp. 28-34).

The equity market (also known as the stock market) is a market in which shares of companies are issued and traded either through exchanges or over-the-counter markets. The equity market provides firms access to capital in order to grow their businesses and to investors a piece of ownership in a firm that potentially will rise in value based on the firm's future performance. Within the equity market, there are different ways in which investors may earn interest on their assets such as; common stock (also known as equity) in ownership shares in a corporation. Common stock owners may earn an annual dividend based on the number of shares owned and the firm's performance, in addition to share value fluctuations (capital gains or loss); preferred stock has features similar to both equity and debt. Preferred stock is similar to a bond in a way that it promises to pay to its holder a fixed amount of income each year. Preferred stock, however, is an equity investment as its owners receive annual dividends based on the firm's performance; American depository receipts (ADR) are certificates traded in US markets that represent ownership in shares of a foreign company. ADRs were created to ease for foreign firms to satisfy US security registration requirements (Bodie et al., 2009, pp. 35-38).

The FX market is a market that determines the exchange rate for currencies around the world. The FX market participants can buy, sell, exchange, and speculate on currencies. Within the FX market, several economic theories link exchange rates, price levels, and interest rates together that are known as international parity conditions. The purchasing power parity (PPP) is a macroeconomic analysis metric to compare economic productivity and standards of living between countries. The PPP helps to compare different countries' currencies through a "basket of goods" approach. The PPP theory forecasts the change in the spot rate based on differences in expected rates of inflation. The PPP theory is subdivided into absolute PPP and relative PPP. In case the law of one price is true for all goods, the absolute PPP exchange rate could be found from any set of prices through price comparison, allowing the determination of individual products' price by using an absolute PPP exchange rate. The relative PPP is a theory that the relative changes in prices between countries over time determine the change in exchange rates. Any change in the differential rate of inflation between two countries tends to be offset over the long run by an equal, but opposite change in the spot rate (Cuthbertson & Nitzsche, 2004, pp. 552-555).

The Fisher effect (FE) is an economic theory developed by economist Irving Fisher that describes the relationship between inflation and both real and nominal interest rates. The FE states that nominal interest rates in each country are equal to the required real rate of return plus compensation for expected inflation. The international Fisher effect (IFE) is an expansion theory of the Fisher effect incorporating the international aspect and applying it cross-border. The IFE states that the spot exchange rate should change in an amount equal to, but in the opposite direction of the difference in interest rates between countries. The justification for the IFE is that investors must be rewarded or penalized to offset the expected change in exchange rates. The IFE predicts that with unrestricted capital flows, an investor should be indifferent between investing in dollar or euro bonds since investors worldwide would see the same opportunity and compete it away (Demirag & Goddard, 1994, p. 76).

The interest rate parity (IRP) plays an essential role in FX markets connecting interest rates, spot exchange rates, and foreign exchange rates. The IRP is a theory stating that the difference in the national interest rates for securities of similar risk and maturity should be equal to, but opposite in sign to, the forward rate discount or premium for the foreign currency, except for transaction costs. The IRP is subdivided into covered interest rate parity (CIP) and uncovered interest rate parity (UIP). The CIP is a condition that the relationship between interest rates, spot, and forward currency values of two countries are in equilibrium. Interest rate parity is said to be covered when the use of a forward contract to hedge against exposure to exchange rate risk is applied. Investors shall remain indifferent among the available interest rates between two countries since the forward rate maintains equilibrium such that the dollar return on dollar deposits is equal to the dollar return on the foreign deposit, thereby eliminating the potential for covered interest rate arbitrage profit. The UIP, on the other hand, is a condition that the difference in interest rates between two countries will equal the relative change in currency FX rates over the same period. Interest rate parity is said to be uncovered when the use of a forward contract to hedge against exposure to exchange rate risk is not applied. Risk-neutral investors will be indifferent among the available interest rates in two countries because the exchange rate between those countries is expected to adjust such that the dollar return on dollar deposits is equal to the dollar return on euro deposits, thereby eliminating the potential for uncovered interest rate arbitrage profit. The CIP and UIP are identical when the forward and expected spot rates are equal (Cuthbertson & Nitzsche, 2004, pp. 560-563).

The forward rate unbiasedness (FRU) is an economic theory stating that under conditions of risk neutrality and rational expectations on the part of market agents, the forward rate is an unbiased predictor of the corresponding future spot rate. The FRU theory holds in reality if both CIP and UIP hold simultaneously. Furthermore, if any two of the relationships between the set of CIP, UIP, and FRU are true, the third will also be true. The forward rate as an unbiased predictor of the future spot rate assumption is possible only if the FX markets are thought to be efficient. The prediction level of FRU is in question as it often fails to predict the actual future spot rate, however, its prediction errors are with equal probabilities (directions) and magnitudes (distances) (Cuthbertson & Nitzsche, 2004, p. 562). Figure 3 presents the linkage of exchange rates, price levels, and interest rates which together form the international parity conditions.

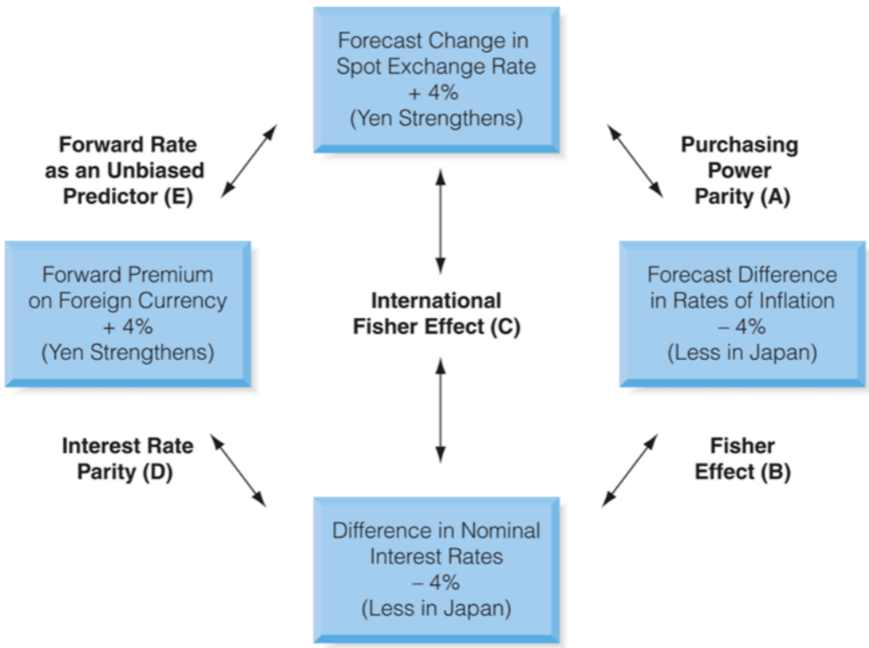

Figure 3. International parity conditions (Moffett, Stonehill, & Eiteman, p.178, 2015)

3 ARBITRAGE IN FINANCIAL MARKETS

The common technique of taking advantage of the difference between two or more markets for profit purposes is called arbitrage. Sharpe & Alexander (1990) define arbitrage as "the simultaneous purchase and sale of the same, or essentially similar, security in two different markets for advantageously different prices". Arbitrage has an important role in the financial markets since it helps to bring asset prices closer to fundamentals and keeps the markets efficient. Based on the efficient market hypothesis by Fama (1970), arbitrage opportunities should not exist. However, financial markets are not always fully efficient due to anomalies, bubbles, and crashes, therefore, arbitrage opportunities are widely available (Burton, 2003).

There are many reasons why there are arbitrage opportunities for different durations and extents, however, most of them can be explained by behavioural finance. The two studies in the field of behavioural finance by Odean (1998); Barber & Odean (1999) are great examples of behavioural biases. Firstly, they argue that investors are reluctant to sell assets when they are at a loss, in contrast, investors are willing to sell when they are in profit. Secondly, overconfidence also causes behavioural biases, as investors tend to trade more than is considered optimal. Furthermore, both professional and amateur investors at times do not operate according to correct analysis results, instead, they are more driven by personal intuition or simply by following the herd. In addition to behavioural biases, also anomalies, bubbles, and crashes may explain why arbitrage opportunities occur. Most of the well-known anomalies split into cross-sectional and time-series anomalies. Momentum investing that was discovered by Asness (1994), being perhaps the most famous cause for cross-sectional anomalies, and the Weekend Effect by Smirlock & Starks (1986) and the January Effect by Keim (1985) are possibly the most well-known time-series anomalies. Anomalies tend to be eliminated since professional arbitrageurs with a large amount of capital often find them relatively quickly, making the arbitrage opportunities for amateur investors harder to find (Shleifer & Vishny, 1995).

In theory, arbitrage entails no risk and capital is unlimited, in reality, however, arbitrage risk varies greatly, and capital is limited. There are different types of risks involved in arbitrage, such as counterparty risk, execution risk, and mismatched items. Counterparty risk is the likelihood that the other party in an agreement will default or fail to live up to its contractual obligation. A large number of arbitrage positions involves two or more parties, making counterparty risk widely available, and therefore riskier. Execution risk is a risk of a financial loss occurring by entering into two or more markets at once and not completing all transactions within the desired time. When arbitrage is not completed at the required speed and a security's price has changed, a potential lower profit or a loss may result. Mismatched items are a risk in which the items bought and sold are not identical and the arbitrage is conducted under the assumption that the prices of the items are correlated.

Mitchell, Pulvino, & Stafford (2002) classify the level of riskiness by riskless arbitrage and risky arbitrage. The level of risk is dependent on the size of the anomalies. Further the prices are from fundamentals, will result in higher risk and higher expected return. In addition, arbitrage may also contain idiosyncratic risk that arbitrageurs must bear in their trading strategies (Shleifer & Vishny, 1995). Riskless arbitrage is the simplest form of arbitrage due to the simultaneous purchase and sale of a security. Several recent papers (Ofek, Richardson, & Whitelaw, 2004; Akram, Rime, & Sarno, 2008) find that there are riskless arbitrage opportunities available, for example, CIP deviations from triangular arbitrage parity, put-call parity, and cross-listed security parity, while other forms of arbitrage are risky.

Arbitrage is practiced not only by professionals but also by amateur arbitrageurs. Most professional arbitrageurs are employed by investment banks and hedge funds. Arbitrage in such firms usually takes place by professionals who are a relatively small number of highly specialized investors who combine their knowledge with resources of outside investors to take large positions. Outside investors include wealthy individuals, banks, endowments, and other investors with only a limited knowledge of the financial markets (Shleifer & Vishny, 1997). In addition to professional arbitrageurs, there are probably millions of individual investors that take smaller positions. Amateur arbitrageurs often have significantly less capital, knowledge, experience, technology access, and information in comparison to professional arbitrageurs.

3.1 Arbitrage theories and models

There are different theories and models in which investors can apply arbitrage for profit purposes, such as arbitrage pricing theory (APT), international arbitrage pricing theory (IAPT), two-fold, triangular, or options arbitrage.

The arbitrage pricing theory (APT) developed by Ross (1976) is an alternative to the widely used capital asset pricing model (CAPM) of Sharpe (1964) Treynor (1961) and Lintner (1965) in determining the expected rate of return on a security. Although capital asset pricing was the main model for empirical work over the past few decades and is the basis of modern portfolio theory, a growing number of researchers has increasingly cast doubt on its ability to accurately determine the expected rate of return given its unrealistic assumptions. The APT, on the other hand, is a great tool for analysing portfolios in order to identify securities that may be temporarily mispriced. Arbitrageurs using the APT are keen to take advantage of any deviation from the fair market value to potentially gain riskless profit. The APT is based on the idea that expected returns of securities can be predicted by using the linear relationship between the asset's expected return and a certain number of macroeconomic variables that capture systematic risk (Robin & Shukia, 1991).

The main difference between the APT and the CAPM is that the APT is a multifactor asset pricing model, whereas the CAPM is a one-factor asset pricing model in which market risk is the lone factor. In the APT there are often common factors, but there are no defined factors that suit most applications. While there is no clear answer about the number of factors available, literature shows that there is at least one factor and that five factors may be sufficient for most applications (Robin & Shukia, 1991). Another important difference between the APT and the CAPM is concerning their underlying assumptions. The CAPM relies on the assumption that the market always ensures all securities at fair value, whereas the APT relies on the assumption that the market sometimes misprices securities and that arbitrage opportunities may occur. In addition, the APT also relies on the assumptions that asset returns are explained by systematic factors and those factors can be eliminated through diversification, as well as, that the well-functioned security markets do not allow for the persistence of arbitrage opportunities (Bodie et al., 2009, pp. 331-332).

Following the emergence of the APT, Solnik (1983) developed an extension for the APT to an international setting, or simply added an "I" in front of "APT", creating the IAPT. Similarly, the IAPT is also a tool for determining the expected rate of return on a security, but the IAPT does not involve only local risks, but also other international risks such as exchange rate or difference in taxation in various countries. However, the IAPT is not free of criticism. One of its major drawbacks in applying pricing theory internationally is arising due to differences in investors' opportunities and perspectives. Kleidon & Pfleiderer (1983) believe that the opportunities might be limited for foreigners investing in the same assets as domestic investors due to substantial restrictions on the capital flow. Furthermore, foreign investors may not have the opportunity to earn the same nominal returns as domestic investors due to differential taxes or transaction costs. In addition, they also raise questions regarding the difference in perspective between domestic and foreign investors. A riskless portfolio for domestic investors may not seem riskless for foreign investors due to additional risks involved such as exchange rate risk.

There are several arbitrage models available in the financial markets. They vary among the length of the positions, the number of players involved, the financial instruments used, among others. The most basic arbitrage models are the two-fold arbitrage and triangular arbitrage. The two-fold arbitrage is a model in which an arbitrageur buys low and sells high assets simultaneously and enjoys the discrepancy of their values in different markets for profit purposes. The buy-sell spread among those markets is the profit one may earn minus any trading costs involved. A simple example of two-fold arbitrage model is when the US dollar price of the British pound sterling is 1.6$ in Frankfurt, but only 1.5$ in Paris, therefore an arbitrageur can buy 1£ in Paris and sell it in Frankfurt and earn a profit of 0.1$ per pound before any transaction costs (Clark & Ghosh, 2004, pp. 1-2). The arbitrage opportunity remains available until either Paris's British pound inventory diminishes or when Paris and Frankfurt adjust their prices to wipe out the opportunity. Triangular arbitrage is a model in which an arbitrageur enjoys the discrepancy between three foreign currencies when the currency's exchange rates do not exactly align. Triangular arbitrage involves three trades, exchanging the initial currency for a second, the second currency for a third, and the third currency for the initial. In order to gain any profit, the final sum should be higher than the initial sum. Triangular arbitrage opportunities are often hard to find and since the price differences between exchange rates are very minimal, a large sum of capital should be involved to gain substantial profits (Clark & Ghosh, 2014, pp. 12-17).

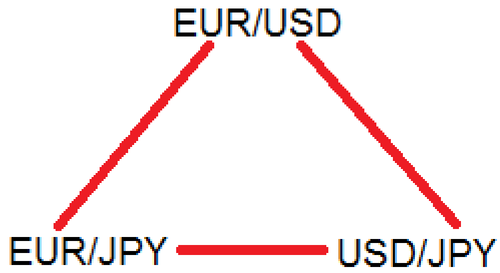

Figure 4. Triangular arbitrage (Overton, 2012)

Arbitrage can also be implemented by applying different financial instruments such as forward contracts or options. Forward arbitrage is available when one market offers a higher return than another and the forward contract guarantees the exchange rate ahead of time. An example of forward arbitrage is spot-forward arbitrage. Spot-forward is a form of arbitrage in which the arbitrageur can gain higher profit by investing elsewhere in comparison to investing in the home country by locking the future exchange rate with a forward contract (Clark & Ghosh, 2004, pp. 132-136). There are a variety of ways in which option arbitrage can be applied by arbitrageurs to gain profit with essentially no risk. Option arbitrage is available when the put-call parity is not correctly preserved or when options are mispriced. Put-call disparity first discovered by Stoll (1969) is a form of arbitrage in which there is either an underpriced call, in relation to a put based on the same underlying security, or an underpriced call compared to another call with a different strike or a different expiration date. Strike arbitrage is a form of arbitrage that can be used when there is a price discrepancy between two option contracts that are based on the same underlying security and have the same expiration date. In addition to Put-call disparity and Strike arbitrage, there are also other forms of arbitrage such as conversion & reversal or box spread arbitrage that involves synthetic options and a higher number of transactions respectively (Options Trading, 2020).

3.2 Limitations of arbitrage

Arbitrage provides a great potential for exploiting the price difference between two or more markets in order to gain profit. However, there are numerous limitations turning arbitrage riskier and less profitable than it may appear. Various factors may discourage arbitrageurs to avoid pushing the asset's value back to its fundamental value and, instead, leave the asset's value mispriced. In theory, arbitrage requires no capital and entails no risk. With those assumptions in mind, arbitrageurs should always enter into arbitrage positions until the markets are fully efficient. However, in reality, arbitrage requires capital and, in most cases entails risk.

The main limitation of arbitrage is the lack of funds. To enter any arbitrage position, there is a need for capital. Even for the simplest forms of arbitrage in which arbitrageurs earn profit instantly, there is an amount of capital invested in the arbitrage position. In order to have access to such funds, investment banks and brokerage firms mainly utilize outside investors' capital or by borrowing from other financial institutions (Shleifer & Vishny, 1997). When depending on outside investors' capital, arbitrageurs may apply suboptimal risk-taking due to fear that the funds may be withdrawn in case of poor performance (Shleifer & Vishny, 1995). Instead of entering into arbitrage positions that may lead to high yields, arbitrageurs may choose to avoid such positions to assure limited losses to guarantee future liquidity. Furthermore, outside investors might consider arbitrageurs' past performance records as an indicator of their abilities and not provide them with sufficient funds to arbitrage. Borrowing funds from other financial institutions might be an easy task for successful arbitrageurs in wealthy investment banks or brokerage firms, however, not all arbitrageurs are successful, and not all investment banks or brokerage firms are financially sound, resulting in higher costs of borrowing and often in smaller scales. In addition, prior research suggests that holding and trading costs may also limit arbitrage. Tuckman & Vila (1992) find that financial constraints that arise from holding costs prevent arbitrageurs from eliminating mispricing, while Dow & Gorton (1994) find that mispricing can arise due to financial constraints from short horizon and trading costs.

The other main limitation is that arbitrage may be risky. The level of risk is dependent on the size of the anomalies. Further the prices are from fundamentals, will result in higher risk and higher expected return. In extreme situations, when the prices are far from their intrinsic value, it is expected that professional arbitrageurs will take advantage and take arbitrage positions. However, arbitrageurs face both fundamental risks, as well as noise trader risk, which increases drastically the expected rate of return to levels that the expected returns do not outweigh the risk when mispricing is extremely large (Shleifer & Vishny, 1995). Another major reason for the limitation of arbitrage is that a large number of professional arbitrageurs are employed by large hedge funds and investment banks. Large hedge funds and investment banks have various investing techniques and strategies which are constrained by agency frictions. Financial institutions and agency frictions are often the sources of non-fundamental demand shocks and as a result, financial institutions do not necessarily correct anomalies, but instead cause them (Gromb & Vayanos, 2010). Finally, arbitrageurs also need to bear in mind of noise traders. There are probably millions of small unprofessional investors with limited resources and knowledge that follow trends or simply do not understand market notions. Millions of small noise traders do not only increase the risk for professional arbitrageurs to operate according to their information and knowledge but may also help to keep asset prices away from their fundamental values.

3.3 Arbitrage in emerging markets

In a well-developed capital market, the market tends to be more efficient in capitalizing on relevant information. The highly efficient markets are attributed to effective legal and regulatory mechanisms, well-established auditing, accounting, and disclosure standards as well as various independent financial intermediaries such as financial analysis and rating agencies. Highly efficient markets leave minimal room for mispricing of assets, therefore, the potential for arbitrage in developed markets is especially limited (Wang, 2019). In emerging markets, in contrast, there are substantially more arbitrage opportunities available. Capital markets in emerging markets are considerably less efficient in comparison to capital markets in developed markets due to the absence of reliable and timely information, enforceable legal and regulatory rules, and well-functioning accounting and auditing systems (Wang & Li, 2018), in addition to weak disclosure, noise trading, liquidity and political risk (Bartram, Brown, & Stulz, 2012). Furthermore, emerging markets are relatively immature due to poor market depth in terms of capitalisation, turnover, and listed companies (Syriopoulos, 2006). The above-mentioned characteristics cause capital markets in emerging markets to contain stock market misvaluation, therefore, more arbitrage opportunities become available.

In different countries, regions, and between developed and emerging economies there are different levels of co-integration. A high level of co-integration appears when different financial markets move together while keeping a constant distance between them over time. Many arbitrageurs seek for low co-integration among markets in order to find arbitrage opportunities (Grubel, 1968; Levy & Sarnat, 1970). The strong correlation among stock returns is an indicator to describe the co-movement. A stronger co-movement phenomenon is likely to diminish arbitrage opportunities while a weaker co-movement phenomenon may offer ample arbitrage opportunities. A stronger co-movement diminishes arbitrage opportunities because once financial markets co-move at the same direction and speed, there are no situations where an asset provides substantially higher returns in one market in comparison to another, whereas a weaker co-movement enables assets' returns to vary among different markets. There has been extended prior research on the co-movement among countries, regions, and between developed, and emerging economies over the past decade. Das & Manoharan (2019) gather prior research on co-movement and discover a pattern on whether there is co-movement within developed markets and emerging markets. According to studies of Rua & Nunes (2009); Graham & Nikkinen (2011); Ranta (2013), there is a relatively high co-movement within developed markets, and according to studies of Aloui & Hkiri (2014); Dima, Dima, & Barna (2015), the co-movement within emerging markets is on the rise in recent years. Prior empirical research about the level of co-movement suggests that in emerging markets there are likely more arbitrage opportunities available than in developed markets.

Although arbitrage appears to be more widely available in emerging markets in comparison to developed markets, there are numerous limits of arbitrage in emerging markets causing them to remain unused by arbitrageurs. First of all, highly integrated markets may limit the arbitrage opportunities among markets. As a result of capital flow from developed to emerging markets that enhances economic integration by inducing a higher degree of stock market co-movements, arbitrage opportunities may diminish (Bekaert & Campbell, 2003). Secondly, low liquidity in emerging markets also may limit the use of arbitrage. After locating mispriced assets in emerging markets, arbitrageurs often seek high liquidity in order to earn a substantial profit. However, emerging markets often experience low liquidity, which leads arbitrageurs to abandon such opportunities, and as a result, mispriced assets may remain available. In addition to co-integration and low liquidity of assets, there are many other limitations for arbitrage in emerging markets. According to Galdi & Lopes (2013); Carrieri, Chaieb, & Errunza (2013), poor property rights protection, frequent noise trading, government expropriation, high transaction costs, lack of information technology, low investor protection, higher corruption rates, and weaker shareholder rights are commonplace in emerging markets which lead to the discouragement of arbitrageurs from actively participating in arbitrage positions.

The most notable emerging markets are Brazil, Russia, India, China, and South Africa, together they form the acronym BRICS. The BRICS countries are large in terms of population and have an abundance of natural resources. On top of that, their relatively underdeveloped financial markets may generate a large number of arbitrage opportunities when the BRICS countries are included in the arbitrage position. Furthermore, due to the BRICS populations size and the high volume of natural resources, the risk of currency devaluation or bankruptcy of a BRICS country is relatively low.

4 THE COLLAPSE OF CIP AROUND THE 2008 GFC

Past experience has demonstrated that CIP held rather closely in recent decades, however, it is no longer the case. Following the 2008 GFC, the frequency and magnitude of CIP deviations have increased substantially, leading to systematic arbitrage opportunities for riskless profits. A common way to measure CIP deviations is by cross-currency basis points. According to Du, Tepper, & Verdelhan (2018), the cross-currency basis is "the difference between the direct dollar interest rate from the cash market and the synthetic dollar interest rate obtained by swapping the foreign currency into US dollars". When the currency basis is positive (negative), it suggests that the direct dollar interest rate is higher (lower) than the synthetic dollar interest rate. When the cross-currency basis is zero, CIP holds and there are no arbitrage opportunities.

4.1 Previous studies on CIP

The principle of CIP, which was first developed by Keynes (1923) during the exchange rate turbulence that followed world war I, is a fundamental building block of international finance. The CIP is a condition that the relationship between interest rates, spot, and forward currency values of two countries are in equilibrium. Interest rate parity is said to be covered when the use of a forward contract to hedge against exposure to exchange rate risk is applied. Investors shall remain indifferent among the available interest rates between two countries since the forward rate maintains equilibrium such that the dollar return on dollar deposits is equal to the dollar return on the foreign deposit, thereby eliminating the potential for CIP arbitrage profits. However, at times CIP collapses. When covered interest rate parity between two countries collapses, an opportunity for CIP arbitrage emerges. The formula of the covered interest rate parity condition is as follows:

$$\frac{F_1}{S_0} = \left(\frac{1 + r}{1 + r_f}\right)$$

Where S is the spot nominal exchange rate, F is the forward exchange rate, r is the interest rate in the base currency and r_f is a foreign currency interest rate on securities that are identical in every respect except for the currency of denomination. It is important to note that this equation ignores any transaction costs in the security and the FX markets.

There has been literature exploring the CIP condition for over a century. Already in Lotz's paper (1889) and later, in a much clearer way, in Keynes's (1923) study, the general idea of the CIP condition was established. In the latter years of the 1900s, numerous researchers, most notably Frenkel & Levich (1975, 1977); Deardorff (1979); Clinton (1988), investigated the CIP condition and tested whether CIP tends to hold over time. Most researchers find that the CIP condition holds well in periods before the 2008 GFC and that arbitrage opportunities are not widely available, therefore, CIP arbitrage may not generate significant profits. However, some studies were able to detect small and transient but economically meaningful departures from CIP. Nonetheless, CIP kept on providing an excellent guide for the relationship of forward and spot exchange rates and interest rates at the macro level. As Akram, Rime, & Sarno (2008) put it, "the lack of predictability of arbitrage and the fast speed at which arbitrage opportunities are exploited and eliminated imply that a typical researcher in international macro-finance using data at the daily or lower frequency can safely assume that CIP holds."

Economic literature has, in the past, widely considered that transaction costs are the main driver for CIP deviations. According to Demsetz (1968), transaction cost can be defined as the cost of exchanging ownership titles, and that, in most cases, a transaction cost is composed of brokerage fees, ask-bid spreads, and transfer taxes. However, numerous studies challenge this belief and find that, in reality, transaction costs create much fewer CIP deviations than academia once believed. Instead, different authors have stressed different reasons and explanations as potential drivers for CIP deviations ranging from regulation-induced or other arbitrage limits (Rime, Schrimpf, & Syrstad, 2017; Du, Tepper, & Verdelhan, 2018), to changes in banks' balance-sheet capacity connected with US dollar appreciation (Avdjiev et al., 2017), to interest-rate differences across currencies and their impact on the swap market (Liao, 2016). Furthermore, several other reasons may explain CIP deviations such as political risk (Aliber, 1973), capital market imperfections (Frenkel, 1973), capital control (McCormick, 1979), and information costs (Clinton, 1988).

Once CIP collapses, there are new arbitrage opportunities that arbitrageurs are keen to exploit to gain profits which are known as covered interest rate arbitrage or CIA. In CIA, an investor makes simultaneous spot and forward market transactions, with the ultimate goal of gaining riskless profit through the combination of currency pairs. In this strategy, an investor uses a forward contract to hedge against exchange rate risk, hence the word arbitrage. The CIA consists of four markets: the spot and forward markets for FX and the domestic and foreign securities markets. Arbitrageurs often examine exchange rates and interest rates of international markets to locate CIP deviations for riskless opportunities to gain profit. CIA opportunities are rather uncommon and often small in size because market participants rush in to exploit arbitrage opportunities if one appears, and the resultant demand increase of either currency quickly redresses the imbalance back to equilibrium (Deardorff, 1979).

In textbook arbitrage, an investor may borrow at a low interest rate and lend out at a higher interest rate indefinitely, having hedged currency risk completely, providing opportunities for riskless profits as long as CIP deviations exist. However, in textbooks there are no banks. In practice, on the other hand, CIA entails borrowing and lending through banks, and the assumption that an investor is able to continue earning profits indefinitely is violated due to balance sheet constraints that place limits on the size of the exposure that can be taken by banks. Essentially, for non-banks, their ability to exploit arbitrage opportunities relies on banks to provide leverage.

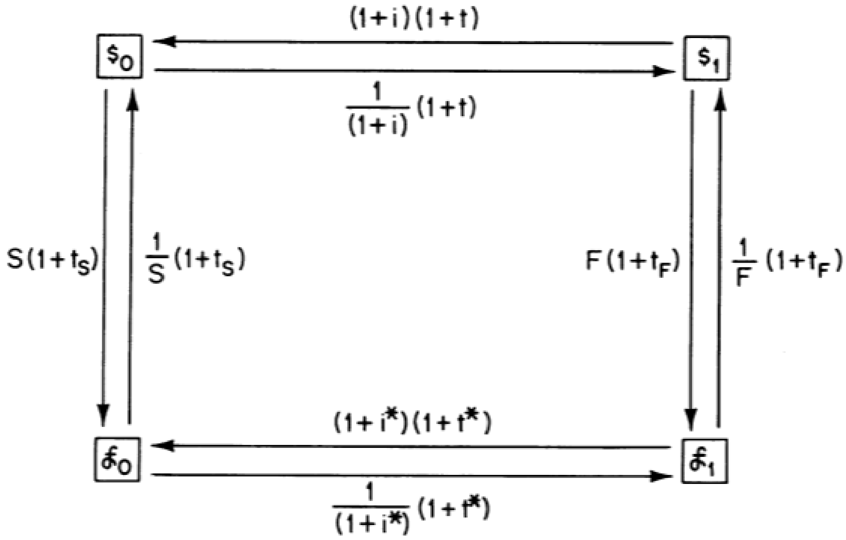

Figure 5. Covered interest rate arbitrage (Deardorff, 1979)

The phenomenon of CIA may be easily understood by examining Figure 5. It is possible to use the four markets together to buy any commodity in exchange for itself since the arrows are heading all around the four markets. There are two ways in which an investor can apply the CIA. One way is following the clockwise arrows starting from the top left corner, by lending dollars, selling them forward, borrowing pounds, and selling them spot, thus effectively exchanging current dollars for current dollars. The current-dollar cost of acquiring a current dollar in this way is found by multiplying the four costs associated with the four clockwise arrows. If that cost is less than unity, then covered interest arbitrage is possible, potentially yielding an instantaneous profit with no out-of-pocket cost. CIA can also be attempted by following the counterclockwise arrows in the figure. Again, if the product of the four counterclockwise costs is less than unity, then a profit can be made.

4.2 The effect of the 2008 global financial crisis on CIP

The 2008 GFC and the following instability in the world's economy have had an enormous impact on international markets. Prior to the financial crisis of 2008, CIP deviations were generally minimal and short-lived (Akram, Rime, & Sarno, 2008). However, this trend has no longer existed since the onset of the 2008 GFC. A number of studies including Coffey, Hrung, & Sarkar (2009); Mancini-Griffoli & Ranaldo (2011); Levich (2012) find failures of the CIP condition during the 2008 financial crisis that resulted in long-lasting CIP deviations.

Figure 6 presents the CIP deviations based on the 3-month maturity for the euro versus the US dollar from January 2000, until April 2012. The period prior to the 2008 GFC appears tranquil with essentially only relatively minor deviations as the basis points being always under 25 and upwards of 95% of all deviations being under 10 basis points of parity. Akram, Rime, & Sarno (2008) find similar results that CIP deviations existed also prior to the 2008 GFC, however in this period, due to high levels of capital mobility between short-term euro and US dollar instruments, significant CIP deviations have historically been rare.

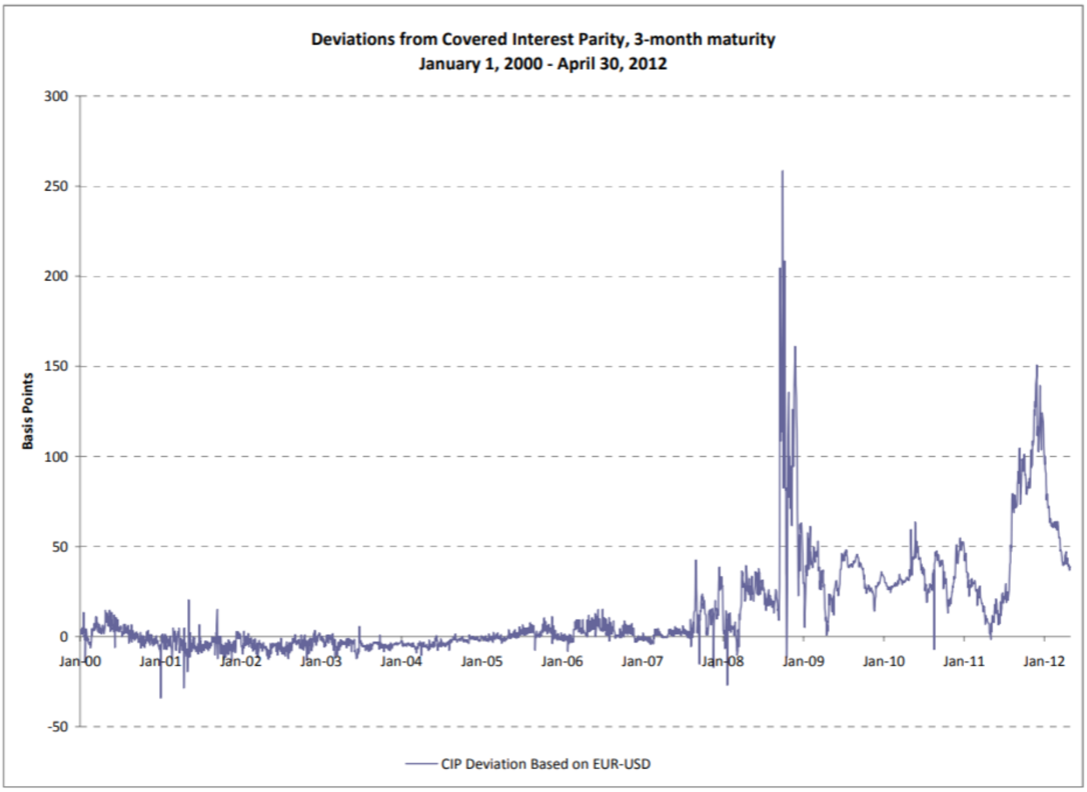

Figure 6. Covered interest rate deviations around the 2008 GFC (Levich, 2012)

The figure above suggests that the first signs of the crisis began in the summer of 2007 when CIP deviations rose from under 10 basis points to around 50 basis points. However, in September 2008, following the bankruptcy of Lehman

Brothers, CIP deviations skyrocketed and reached rates of over 250 basis points, and for the most part remained above 100 basis points for the next three months, providing great opportunities for investors to exploit the situation and to earn riskless profits. In addition to CIP deviations, Levich (2012) also finds that the TED spread, which is the difference between the interest rate on short-term government debt and the interest rate on interbank loans, and the credit default swap rates, suggest that credit risk and counterparty default have increased substantially for large international financial institutions in comparison to their pre-crisis levels.

In the economic literature, numerous reasons are explaining the existence and magnitude of CIP deviations that were generated by the financial crisis of 2008. Coffey, Hrung, & Sarkar (2009); Avdjiev et al. (2017) argue that due to the devaluation of currencies, there was an increased demand for the US dollar that has stemmed higher interest rates for those other currencies. Baba & Packer; Coffey, Hrung, & Sarkar (2009); Mancini-Griffoli & Ranaldo (2011), discover that there was a US dollar shortage since there was lack of US dollar funding liquidity. Ivashina, Scharfstein, & Stein (2015) add that deviations arise when banks shift part of their funding away from wholesale US dollar funding markets due to default risk premia. Furthermore, they also find that CIP deviations can be generated by frictions in the swap market that may complicate the bank's borrowing and lending decisions. Du, Tepper, & Verdelhan (2018) believe that CIP deviations emerge from global demand and supply imbalances arising from differences in countries' net international positions, while Borio et al. (2018) suggest that CIP violations were led by the quantities of FX hedging demand that affected the prices of FX derivatives.

The reasons for CIP violations following the 2008 GFC have several differences from the reasons during the 2008 GFC. Du, Tepper, & Verdelhan; Borio et al. (2018) argue that CIP deviations increase towards the quarter-ends, as banks face tougher balance sheet constraints and FX hedging demand tightens limits to arbitrage, while Ivashina, Scharfstein, & Stein (2015) argue that the reason is due to the capital needed in exploiting arbitrage opportunities in international money markets. In addition, Mancini-Griffoli & Ranaldo (2011); Levich (2012) suggest that the frictions in the international markets prevented arbitrage from eliminating a CIP deviation once it emerges.

Although CIP deviations emerged during the 2008 GFC, deviations continue to persist ever since in different time horizons and magnitudes (Avdjiev et al., 2017; Borio et al., 2018; Cerutti, Obstfeld, & Zhou, 2019), among others. This phenomenon is important for at least two reasons. Firstly, because it may provide evidence of financial market distortions leading to inefficient resource allocation. Second, because it may imply a change in the way macroeconomic policies are transmitted across borders.

Since the onset of the 2008 GFC, when there was a high demand for US dollars that created a shortage of US dollar liquidity, central banks worldwide intervened by applying different methods to maintain their currency's value and help to stabilize the financial markets. During the 2008 GFC, the cross-currency bases were negative for most G10 currency pairs against the US dollar. Following the failure to eliminate those cross-currency bases by domestic liquidity injections, in the spring of 2009, the Federal Reserve and foreign banks supplied US dollars via reciprocal currency arrangements (swap lines). Coffey, Hrung, & Sarkar (2009); Mancini-Griffoli & Ranaldo (2011) argue that the successive rounds of swap lines played a significant role in bringing down CIP deviations and thus, helped to restore greater international capital mobility. Coffey, Hrung, & Sarkar (2009) find that the announcements of the swap lines programme were successful in bringing down the cross-currency by an average of 5 basis points. Furthermore, the auctions of US dollars themselves were also effective in bringing down the basis points. However, they also add that in the post-Lehman Brothers period, the swap lines programmes did not have a significant impact on the basis points. In addition to the swap line programme, Gertler & Kiyotaki (2010) believe that large scale asset purchases by central banks were also effective in mitigating the impacts and helped stabilize the financial markets. Despite the policy initiatives by governments and central banks, Figure 6 shows that CIP deviations are experiencing a new normal.

Although governments and central banks did intervene in order to eliminate CIP deviations, in the post-crisis period, they also implemented regulatory reforms on global banks, as well as country-specific structural factors relative to FX hedging demand, that maintained the cross-currency differences (Du, Tepper, & Verdelhan, 2018). Following the 2008 GFC, a growing number of central banks around the world applied tighter regulations, such as regulations on leverage ratio and risk-weighted capital requirements that increased the cost for banks to expand their balance sheets which resulted in the prevention of arbitraging away CIP deviations. The tighter regulations on banks also impacted other arbitrageurs such as hedge funds, money market funds, foreign currency reserve managers, and corporate issuers as they rely on global banks as their prime brokers.

4.3 Collapse of CIP: developed vs emerging market results

CIP has been explored widely among developed markets for many decades, while in emerging markets there has been minimal research conducted at the same period of time. This may be attributed to the fact that emerging markets have a relatively short history of free-floating exchange rate systems and financial liberalization. Developed markets have developed financial sectors that are characterized by a high degree of market efficiency, high level of liquidity, and daily market activity. Emerging markets, in contrast, have mainly underdeveloped financial sectors that are characterized by asymmetric information, illiquidity, low market activity, and thin daily trading. As a result, financial sectors in emerging markets are imperfect and a weak form of market efficiency. Financial markets with a weak form of market efficiency tend to have multi-layered FX banks such as domestic banks and global bank subsidiaries, with an emphasis on domestic banks which are typically less creditworthy due to limited access to international funds or capital markets and are faced with higher costs for funding global currencies. In addition, financial markets in emerging economies tend to be highly fragmented and segmented, as well as less capable of handling volatility and shocks that are commonly observed in the modern financial world.

Prior to the 2008 GFC, there are contradicting results concerning CIP deviations between developed and emerging markets. Previous research suggests that among developed markets the CIP condition held rather closely in the decades preceding the 2008 GFC with only minor and insignificant CIP deviations. Among emerging markets, on the other hand, the literature suggests that there were large and significant CIP deviations in the period prior to the 2008 GFC. Huang & Guo (2006) find that there are substantial CIP deviations for several East Asian markets, while Fong, Valente, & Fung (2010) discover that the HKD/USD FX market was characterized by a large number of CIP deviations. Furthermore, Skinner & Mason (2011) find that CIP deviations appeared only in emerging markets for longer maturities, while in developed markets the CIP held closely for both shorter and longer maturities. In addition, there is also evidence suggesting that the Chinese market has experienced CIP deviations prior to the 2008 GFC. Cheung & Qian (2010); Chen (2012) discover that CIP deviations appeared before the abandonment of the US dollar peg to the Chinese yuan in 2005.

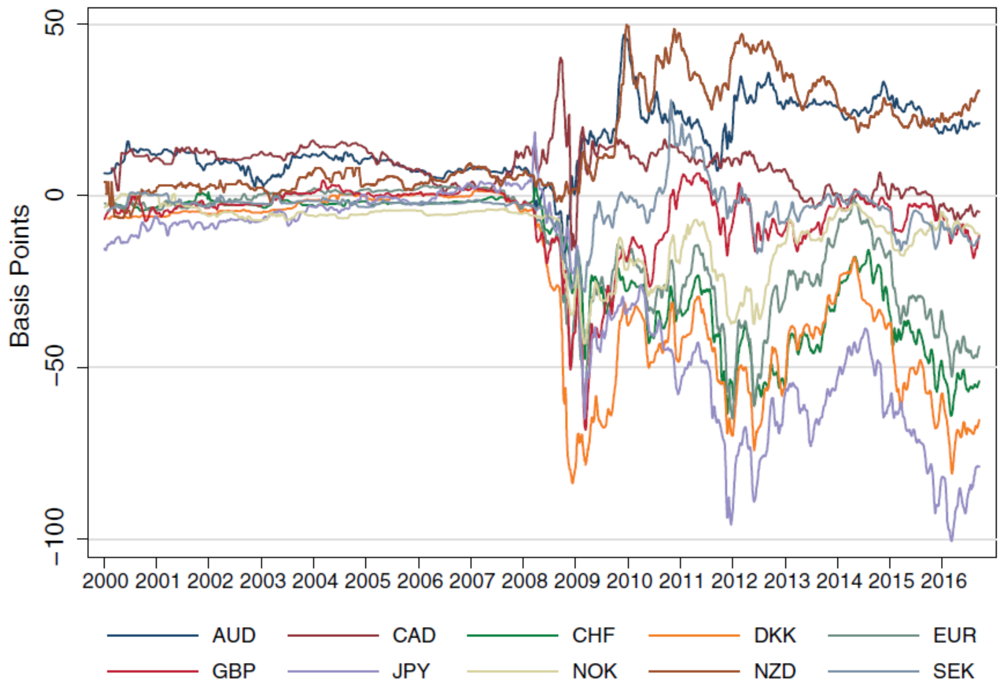

Figure 7. Long-term maturity CIP deviations in G10 currencies (Du, Tepper, & Verdelhan, 2018)

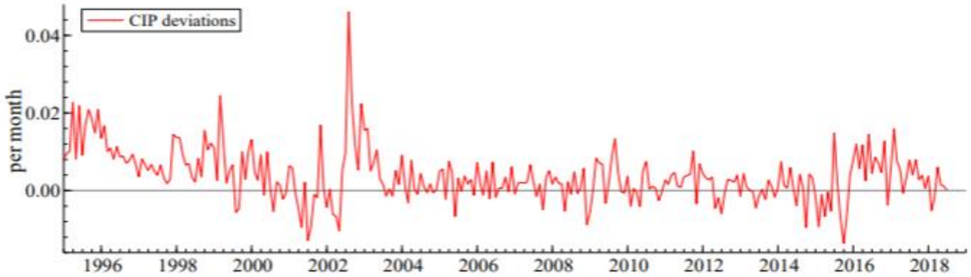

Figure 8. CIP deviations in Brazil around the GFC (Costa & Marçal, 2019)

As Figures 7,8 present, prior to the 2008 GFC, in developed markets, there were no significant CIP deviations as CIP held rather closely, while during and after the 2008 financial crisis, developed markets experienced large and significant CIP deviations which became a new phenomenon. In emerging markets on the other hand, in the pre-crisis period, there were significant CIP deviations, however, during and after the financial crisis, CIP deviations remained at similar levels to the pre-crisis era. Sener, Satiroglu, & Yıldırımm (2012) find that in both developed and emerging markets there were substantial CIP deviations during and after the 2008 GFC, however, the change in deviations was considerably larger among developed markets. Their results suggest that the given risk factors are comparably less relevant in emerging swap markets in comparison to developed swap markets. Rughoo & You (2016) argue that also for emerging markets there are persisting significant CIP deviations in the post-crisis era, however with smaller deviations than during the financial crisis but larger than the pre-crisis era. Suh & Kim (2016) present identical results in which CIP deviations prior to the crisis are substantially smaller than during and post-crisis periods.

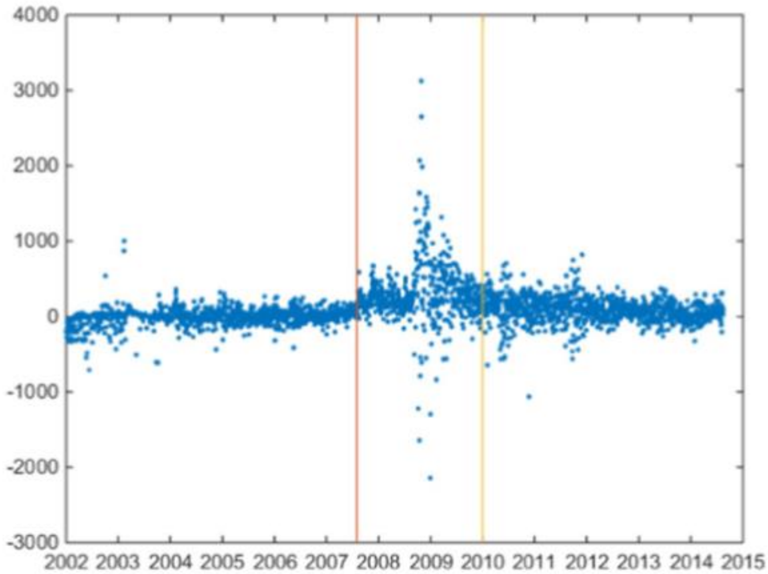

Figure 9. CIP deviations around the GFC in the Korean market (Suh & Kim, 2016)

As can be seen in Figure 9, CIP deviations throughout the three periods are distinct from one another. In the pre-crisis period, there were quite large CIP violations with a standard deviation of 108 basis points. During the financial crisis, there were plenty of extremely large CIP violations with a standard deviation of 392 basis points. And in the period of post-crisis, CIP violations stabilized to standard deviations rates of 160 basis points. Clearly, during the 2008 GFC, there were larger and more significant CIP deviations than during pre- and post-crisis periods. However, it is also clear that the 2008 financial crisis has caused CIP deviations to persist and created a new normal with larger CIP deviations in emerging markets.

The reasons for CIP violations between developed and emerging markets are distinct but also include several similarities. As previously mentioned, prior to the 2008 GFC, there were no significant CIP deviations among developed markets due to their efficient and low-risk financial markets, however, there were CIP deviations among emerging markets during the same time frame. The reasons for CIP deviations in emerging markets in the pre-crisis era were ranging from transaction costs and risk premia due to the increased demand by market participants to provide liquidity in illiquid markets, as well as carrying out transactions with less credit-worthy counterparties (Fong, Valente, & Fung, 2010), to credit risk (Skinner & Mason, 2011), to low degree of financial integration and perceived country risk (Filipozzi & Staehr, 2013).

The reasons for CIP deviations among developed markets during and after the 2008 GFC are associated with changes in banks' balance-sheet capacity connected with US dollar appreciation (Avdjiev et al., 2017), information costs (Clinton, 1988), devaluation of currencies, and frictions in the swap market (Coffey, Hrung, & Sarkar, 2009), among others, while the reasons of CIP deviations in emerging markets are more associated with issues such as changes in federal government total debt, level of reserves, inflation and degree of trade openness (Costa & Marçal, 2019), external and internal economic shocks (Su et al., 2019), increased global risks and repressed financial system (Filipozzi & Staehr, 2013), and capital control policy imposed by governments that prohibits free capital flow between countries (Cheung & Qian, 2010), among others. Furthermore, Sener, Satiroglu, & Yıldırımm (2012) argue that developed swap markets are more sensitive to global systemic shocks while emerging swap markets are more sensitive to regional biases. In addition, some of the CIP deviation reasons are also similar between developed and emerging markets during and after the 2008 GFC. They include flawed transaction costs, increased political risk, capital market imperfections, and the US dollar shortage during the financial crisis (Frenkel; Aliber, 1973; Frenkel & Levich, 1975; Baba & Packer, 2009; Fong, Valente, & Fung, 2010; Filipozzi & Staehr, 2013).

5 EMPIRICAL DATA ANALYSIS

5.1 Stationarity/non-stationarity: The Augmented Dickey-Fuller test

Unit root tests examine stationarity in a time series. When a time series has a unit root, it shows a systematic pattern that is unpredictable. Therefore, a time series is stationary when a shift in time does not cause a change in the shape of the distribution (Glen, 2016). A stationary time series is one whose statistical properties such as mean, variance, autocorrelation, etc. are all constant over time, causing the series to be predicted relatively easily because the statistical properties should be the same in the future as they were in the past. Determining stationarity in a time series is a key step before running any analysis. In most business and economic time series, the presence of a trend component results in the series being non-stationary when expressed in its original units of measurement. A series that contains a unit root, hence, the mean, variance, and autocorrelations are not constant over time, could eliminate the unit root by differencing the series; such a series is said to be difference stationary (Kwiatkowski et al., 1992). In this study, the Augmented Dickey-Fuller is carried out to test for stationarity.

The Augmented Dickey-Fuller (ADF) developed by Dickey & Fuller (1979), is one of the most commonly used statistical tests for detecting unit roots in a series. The ADF test is based on linear regression and it can be used to test for serial correlation. The ADF uses a parametric autoregression to approximate the structure of errors. The null hypothesis in this test is α=1 in the following model equation when alpha is the coefficient of the first lag on Y.

$$y_t = c + \beta t + \alpha y_{t-1} + \phi \Delta Y_{t-1} + e_t$$

where,
$y(t-1) = \ lag\ 1\ of\ time\ series$
$\Delta Y(t-1) = first\ difference\ of\ the\ series\ at\ time\ (t-1)$

When the null hypothesis is accepted, there is a unit root, hence the series is non-stationary and when the null hypothesis is rejected, the time series is stationary (or trend-stationary).

5.2 Vector Autoregression: The Granger causality test

The Vector Autoregression (VAR) is a statistical model used to capture the linear interdependencies among multiple time series. It is a natural extension of the univariate autoregressive model to dynamic multivariate time series. The VAR is a successful tool in explaining past and causal relationships among multiple variables, predicting future observations, as well as describing the dynamic behaviour of economic and financial time series (Zivot & Wang, 2006). The different VAR models describe the joint generation process of a set of variables over time in order to investigate relationships between variables. The Granger causality is one type of relationship between time series variables.

The concept of causality was first introduced by Wiener in 1956 and later reformulated and formalized by Granger in the context of bivariate linear stochastic autoregressive models in 1969. The Granger causality test is a statistical hypothesis test for determining whether one time series is useful in forecasting another. The basic idea of Granger causality can be stated as "if the prediction of one time series is improved by incorporating the knowledge of a second time series, then the latter is said to have a causal influence on the first" (Bose, Hravnak, & Sereika, 2017). The Granger causality test can be performed only with stationary series, therefore stationarity testing such as the ADF test is a requirement in order to test for the linear interdependencies in a series. In the case the series is non-stationary, the first (or higher) difference should be applied instead of the original series. The number of lags to be included is chosen by applying an information criterion. In this study, the Bayesian information criterion (BIC) is applied. In the Granger causality test, the null hypothesis that Y does not cause X is rejected when the coefficients for the lagged values of X are significant. In order to test whether Y has a causal effect on X, the following formula can be used for hypothesis testing:

$$Prob(X_{t+1} \in A|\Omega_t) \neq Prob(X_{t+1} \in A|\Omega_{(-Y)t})$$

where,

"Prob" refers to probability, "t" is time, "A" is a non – empty set, and "Ω" and "$\Omega_{(-Y)t}$" denote the available information in time t with Y as known and unknown variables, respectively.

Four possible causal directions between two variables X and Y are possible:

- Feedback, H_0: X ↔ Y (bidirectional)
- Independent, H_1: X ⊥ Y
- Y causes X but X does not cause Y, H_2: Y → X (unidirectional)
- X causes Y but Y does not cause X, H_2: X → Y (unidirectional)

5.3 Data

BRICS is a group composed of the five major emerging markets: Brazil, Russia, India, China, and South Africa. Goldman Sachs economist Jim O'Neill coined the term BRIC (without South Africa) in 2001, claiming that by 2050 the four BRIC economies would come to dominate the global economy alongside the United States. In 2003 O'Neill's Goldman Sachs colleagues claimed that the BRIC economies may grow to a size larger than the G7, which is composed of the seven largest developed economies: Canada, France, Germany, Italy, Japan, the United Kingdom, and the United States. Later on, in 2010 South Africa was added to the BRIC countries forming the current acronym: the BRICS countries. As of 2019, the BRICS countries together represent about 42% of the world population, 23% of the world GDP, 30% of the world territory, and 18% of the global trade. The BRICS countries ranked among the world's fastest-growing emerging market economies for the past few decades. They have enormous growth potential as a result of low labour costs, favourable demographics, and abundant natural resources at a time of a global commodities boom (BRICS, 2020). In the following figure, the real GDP growth rate of BRICS countries in comparison to the global growth rate is presented.

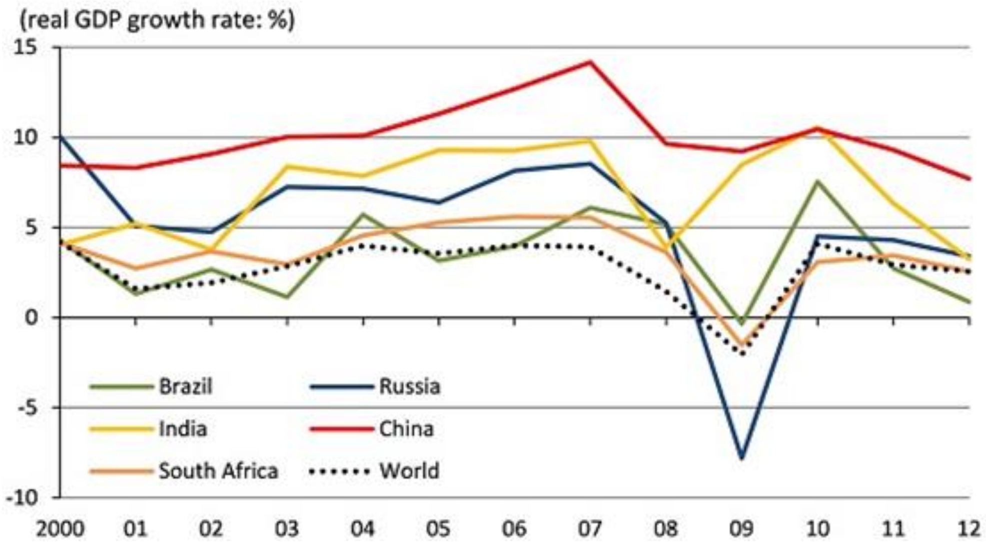

Figure 10. BRICS gross domestic product growth (Egawa, 2014)

In this study, monthly data from the period of 2004-2019 is used. This particular period is chosen because prior data for some BRICS countries are not available. Furthermore, prior to the 2008 GFC, there were far fewer CIP deviations available worldwide, therefore, a period that combines pre- during and post-crisis, captures CIP deviations from each period separately. In addition, other frequencies are not used since some datasets exist only as monthly data.

The data are obtained from DataStream and Economic Policy Uncertainty Index website and consists of spot exchange rates between BRICS currencies and the euro, 1-month and 3-month forward rates of the euro/BRICS currencies, 1-month and 3-month interest rates of the BRICS countries, as well as the Euribor, global EPU, and BRICS country-level EPU indices. Due to the fact that the South African EPU does not exist, the United States EPU is applied instead. Relatively "small" open economies such as the South African economy, are strongly dependent on the "big" country such as the United States uncertainty because of global trade of goods, financial assets, commodities, among others.

The above-mentioned variables are used in RATS, a statistical package for time series analysis and econometrics to apply the analysis. The variables are used to be able to measure whether there are CIP deviations between the BRICS currencies against the euro in the period of 2004-2019 and to find which variables cause those CIP deviations. In order to test for CIP deviations two variables are needed: the interest rate difference which consists of the difference between each BRICS countries' interest rates versus the Euribor at the same time horizon, and forward premium which is defined as the logarithmic difference between each BRICS currency's forward rate and its own spot rate. Furthermore, global and BRICS country-level EPU are also converted into logarithmic forms and are used to measure whether they have an impact on CIP deviations in the BRICS countries. In addition, a dummy variable is also estimated in order to test whether the negative interest rate era in the eurozone has an impact on the results. In case the negative interest rate era has an effect on the results, the variables of global or country-level EPU are treated as exogenous. Once all these datasets are found to be stationary (in some cases the first difference is applied due to non-stationary data series), the cross-currency basis is calculated by subtracting the difference between the interest rate difference and the forward premium from the Euribor at the same time horizon. Following that, finding the optimal lag structure for the VAR model is needed for the purpose of applying the Granger causality test to locate which of the variables cause CIP deviations in the BRICS currencies against the euro.

The following table presents the descriptive statistics of the variables used to measure CIP deviations for each of the BRICS currencies at 1-month and 3-month maturity. The table indicates that the interest rate difference ranges between 1-2 in the case of the Chinese yuan against the Euribor, and between 6-8 in the cases of the other four currencies against the Euribor. The forward premium remains relatively low across the whole dataset, having a mean ranging between 0.05-0.92. The global EPU in a logarithmic form has a mean of 4.97, while the maximum and minimum are 5.83 and 4.41, respectively. And finally, the BRICS country-level EPU in a logarithmic form has a mean ranging between 4.55-5.32.

Table 1. Descriptive Statistics

	Interest Rate Difference	Forward Premium	Log of Global EPU	Log of Russian EPU
Russia 1M				
Mean	7.52	0.92	4.97	5.05
Std. Error	4.22	2.01	0.33	0.53
Maximum	25.06	11.59	5.83	6.07
Minimum	-1.22	-9.37	4.41	3.48
Observations	147	190	136	136
Russia 3M				
Mean	7.17	0.67	4.97	5.05
Std. Error	4.72	0.86	0.33	0.53
Maximum	28.23	4.98	5.83	6.07
Minimum	0.51	-2.40	4.41	3.48
Observations	177	190	136	136
	Interest Rate Difference	Forward Premium	Log of Global EPU	Log of Brazilian EPU
Brazil 1M				
Mean	8.10	0.60	4.97	5.06
Std. Error	7.12	1.58	0.33	0.56
Maximum	46.03	4.64	5.83	6.52
Minimum	-50.89	-7.14	4.41	3.10
Observations	162	190	136	136
Brazil 3M				
Mean	7.80	0.69	4.97	5.06
Std. Error	2.79	0.57	0.33	0.56
Maximum	13.85	2.29	5.83	6.52
Minimum	2.87	-1.99	4.41	3.10
Observations	147	190	136	136
	Interest Rate Difference	Forward Premium	Log of Global EPU	Log of Chinese EPU
China 1M				
Mean	1.47	0.11	4.97	5.32
Std. Error	5.35	0.92	0.33	0.77
Maximum	16.86	2.90	5.83	6.88
Minimum	-14.51	-3.00	4.41	3.26
Observations	162	190	136	136
China 3M				
Mean	2.58	0.05	4.97	5.32
Std. Error	2.11	0.40	0.33	0.77
Maximum	5.72	1.14	5.83	6.88
Minimum	-1.50	-1.06	4.41	3.26
Observations	190	190	136	136

(continues)

Table 1. (continues)

	Interest Rate Difference	Forward Premium	Log of Global EPU	Log of Indian EPU
India 1M				
Mean	6.27	0.52	4.97	4.55
Std. Error	2.29	0.98	0.33	0.48
Maximum	11.50	3.75	5.83	5.65
Minimum	2.05	-3.35	4.41	3.49
Observations	190	190	136	136
India 3M				
Mean	6.22	0.47	4.97	4.55
Std. Error	2.23	0.36	0.33	0.48
Maximum	10.96	1.73	5.83	5.65
Minimum	1.71	-0.72	4.41	3.49
Observations	190	190	136	136
	Interest Rate Difference	Forward Premium	Log of Global EPU	Log of USA EPU
South Africa 1M				
Mean	6.27	0.36	4.97	4.57
Std. Error	1.25	1.60	0.33	0.37
Maximum	10.01	4.12	5.83	5.38
Minimum	3.95	-8.21	4.41	3.84
Observations	190	190	136	136
South Africa 3M				
Mean	6.30	0.48	4.97	4.57
Std. Error	1.29	0.54	0.33	0.37
Maximum	9.98	1.83	5.83	5.38
Minimum	3.92	-2.23	4.41	3.84
Observations	190	190	136	136

6 RESULTS

In this research, the variable interest rate difference is found to be non-stationary in 60% of the cases. In theoretical terms, the interest rate difference should be stationary as the variable is composed of the difference between each BRICS countries' interest rate and the Euribor at the same time horizon. In a search for structural change that may cause the unit root property, tests for subsamples are applied, however, the tests have not revealed any clear structural changes. Therefore, in this research, the interest rate difference variable is assumed to be stationary for all datasets.

Russian ruble at 1-month maturity results

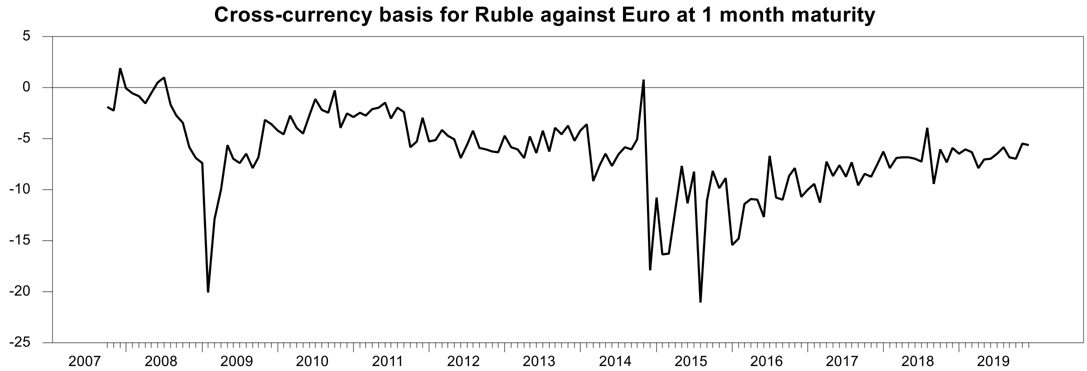

Figure 11. Cross-currency basis for the Russian ruble against the euro at 1-month maturity

As can be seen in Figure 11, there are significant long-lasting CIP deviations between the Russian ruble against the euro at 1-month maturity. Due to lack of data, there is only a short period prior to the 2008 GFC, resulting in a very limited ability to compare between pre-, during, and post-crisis results. In the short period prior to the 2008 financial crisis, there were minor and insignificant CIP deviations, while at times there were no deviations at all. Following the crisis on the other hand, and especially at the end of 2014 where the price of crude oil dropped at a high speed, CIP deviations increased drastically, therefore, profitable arbitrage opportunities have been occurring ever since. This suggests that the 2008 GFC has caused CIP deviations to reach new heights. Furthermore, as a result of having a negative cross-currency basis throughout the period, the direct euro interest rate was lower than the Russian ruble interest rate at 1-month horizon.

According to table 2, the interest rate difference and the forward premium explain part of the CIP deviations. The Granger causality test shows that the interest rate difference causes CIP deviations in the basic model at 5% risk level and in the model with global EPU at 10% risk level. Due to the fact that in the model with Russian EPU the interest rate difference Granger causes forward premium results have changed when assuming Russian EPU as an exogenous variable, Russian EPU should be treated as an exogenous variable. Therefore, the interest rate difference is found to Granger cause the forward premium at 1% risk level. This suggests that not only Russian EPU is an exogenous variable in this model, but it has stronger explanatory power on the role of the interest rate difference on these deviations than global EPU. The forward premium, on the other hand, causes CIP deviations in all three models at 1% risk level. This suggests that in the models with global and Russian EPU, the forward premium retains the Granger-causality towards the interest rate difference. Therefore, both global and Russian EPU have explanatory power on the role of forward premium in these CIP deviations. Although Russian EPU is also found capturing CIP deviations at 10% and 1% risk levels, Russian EPU does not capture part of these CIP deviations since it is found and treated as an exogenous variable.

Table 2. Granger causality – Russian ruble at 1-month maturity

Variables	**Level (Endogenous)**	**First difference**	**Level (Exogenous)**
	Significance level	**Significance level**	**Significance level**
Russian ruble 1M			
Model 1: Without EPU			
INTDIFF ---> FWP	**0.032****	**0.000*****	
FWP ---> INTDIFF	**0.000*****	**0.002*****	
Model 2: With Global EPU			
INTDIFF ---> FWP	**0.060***	**0.000*****	**0.005*****
INTDIFF ---> LGEPU	0.714	**0.043****	
FWP ---> INTDIFF	**0.000*****	**0.002*****	**0.000*****
FWP ---> LGEPU	0.261	0.123	
LGEPU ---> INTDIFF	0.331	0.623	
LGEPU ---> FWP	0.995	0.991	
Model 3: With Russian EPU			
INTDIFF ---> FWP	0.172	**0.000*****	**0.007*****
INTDIFF ---> LRUEPU	0.279	0.707	
FWP ---> INTDIFF	**0.000*****	**0.003*****	**0.000*****
FWP ---> LRUEPU	0.591	0.835	
LRUEPU ---> INTDIFF	**0.059***	0.420	
LRUEPU ---> FWP	**0.007*****	**0.006*****	

Note: *, **, *** shows significance at 10 %, 5 %, and 1 % risk level.

Russian ruble at 3-month maturity results

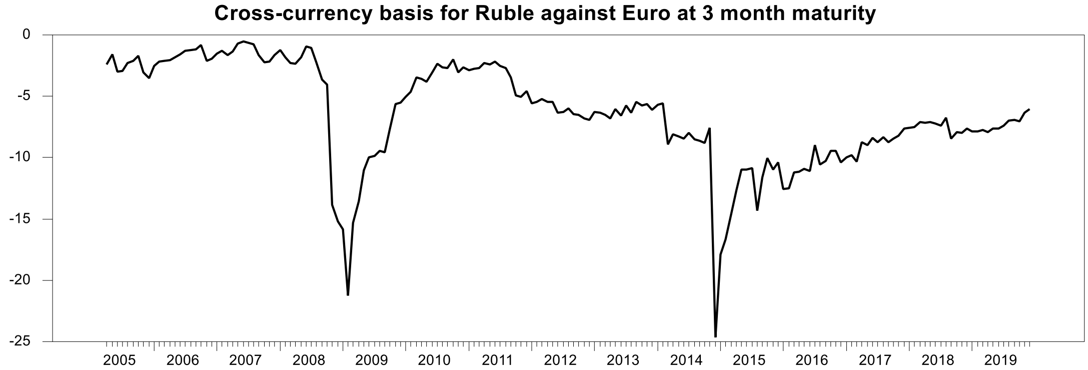

Figure 12. Cross-currency basis for the Russian ruble against the euro at 3-month maturity

Figure 12 shows that there are significant long-lasting CIP deviations between the Russian ruble against the euro at 3-month maturity. In the period prior to the 2008 GFC, there were minor and insignificant CIP deviations. Following the crisis, on the other hand, CIP deviations increased drastically, therefore, the CIP deviations have been providing persistent arbitrage opportunities ever since. This suggests that the 2008 GFC has caused CIP deviations to reach new heights. Furthermore, as a result of having a negative cross-currency basis throughout the whole period, the direct euro interest rate was lower than the Russian ruble interest rate at 3-month horizon.

According to table 3, the interest rate difference, forward premium, and Russian EPU explain part of the CIP deviations. The Granger causality test shows that the interest rate difference causes CIP deviations in all three models at 5% risk level. Similarly, the forward premium also causes CIP deviations, however at 1% risk level in all three models. This suggests that in the models with global and Russian EPU, both the interest rate difference retains the Granger-causality towards the forward premium, and the forward premium retains the Granger-causality towards the interest rate difference. Therefore, both global and Russian EPU have explanatory power on the role of the interest rate difference and the forward premium in these CIP deviations. In addition, Russian EPU also captures CIP deviations at 5% and 1% risk levels.

Table 3. Granger causality – Russian ruble at 3-month maturity

Variables	Level (Endogenous)	First difference	Level (Exogenous)
	Significance level	Significance level	Significance level
Russian ruble 3M			
Model 1: Without EPU			
INTDIFF ---> FWP	**0.024****	0.189	
FWP ---> INTDIFF	**0.000*****	**0.016****	

(continues)

Table 3. (continues)

Model 2: With Global EPU			
INTDIFF ---> FWP	**0.017****	**0.000*****	**0.003*****
INTDIFF ---> LGEPU	0.672	**0.040****	
FWP ---> INTDIFF	**0.000*****	**0.025****	**0.000*****
FWP ---> LGEPU	0.260	**0.089***	
LGEPU ---> INTDIFF	0.236	0.400	
LGEPU ---> FWP	0.685	0.755	
Model 3: With Russian EPU			
INTDIFF ---> FWP	**0.028****	**0.000*****	**0.005*****
INTDIFF ---> LRUEPU	0.329	0.267	
FWP ---> INTDIFF	**0.000*****	**0.040****	**0.000*****
FWP ---> LRUEPU	0.503	0.678	
LRUEPU ---> INTDIFF	**0.042****	0.219	
LRUEPU ---> FWP	**0.006*****	**0.003*****	

*, **, *** shows significance at 10 %, 5 %, and 1 % risk level.

Brazilian real at 1-month maturity results

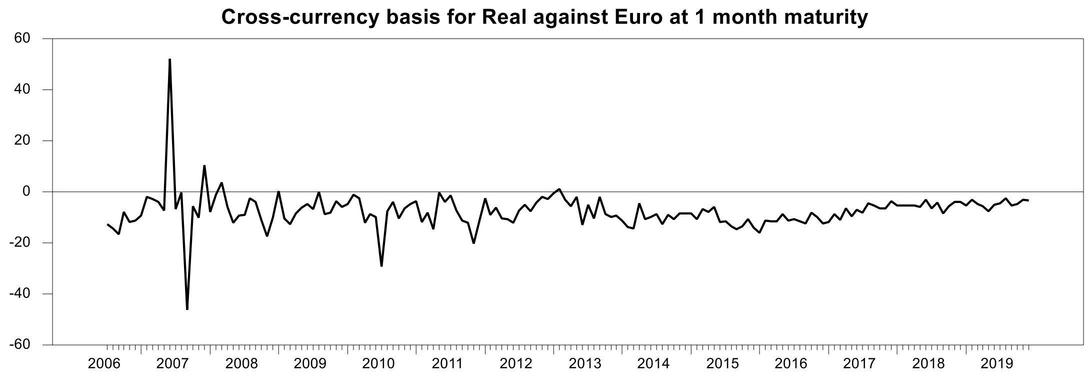

Figure 13. Cross-currency basis for the Brazilian real against the euro at 1-month maturity

Figure 13 indicates that there are significant long-lasting CIP deviations between the Brazilian real against the euro at 1-month maturity. In the period prior to the 2008 GFC, there were significant CIP deviations almost constantly, while at times there were no deviations at all. In addition, there were two massive increases in CIP deviations in 2007. After the crisis, CIP deviations fluctuated between -5 to -20 basis points, therefore, the CIP deviations have been providing profitable arbitrage opportunities throughout the period. In this case, however, the 2008 GFC did not cause CIP deviations to reach new heights. Furthermore, as a result of having a negative cross-currency basis for most of the period, the direct euro interest rate was mainly lower than the Brazilian real interest rate at 1-month horizon.

According to table 4, the interest rate difference and the forward premium explain part of the CIP deviations. The Granger causality test shows that the interest rate difference causes CIP deviations only in the basic model at 1% risk level, while not causing CIP deviations in the models with global EPU and Brazilian EPU. Similarly, the forward premium also captures CIP deviations only at the basic model at almost 1% risk level, while not causing CIP deviations in the models with global and Brazilian EPU. This suggests that in the case of the Brazilian real at 1-month maturity, in both models with global and Brazilian EPU, the interest rate difference and the forward premium do not retain the Granger-causality towards the forward premium and interest rate difference, respectively. Therefore, both global and Brazilian EPU do not have explanatory power on the role of the interest rate difference and forward premium in these CIP deviations.

Table 4. Granger causality – Brazilian real at 1-month maturity

Variables	**Level (Endogenous)**	**First difference**	**Level (Exogenous)**
	Significance level	**Significance level**	**Significance level**
Brazilian real 1M			
Model 1: Without EPU			
INTDIFF ---> FWP	**0.000*****	0.736	
FWP ---> INTDIFF	**0.012****	0.543	
Model 2: With Global EPU			
INTDIFF ---> FWP	0.214	0.984	0.711
INTDIFF ---> LGEPU	0.146	0.162	
FWP ---> INTDIFF	0.106	**0.041****	0.103
FWP ---> LGEPU	0.141	0.167	
LGEPU ---> INTDIFF	0.246	0.924	
LGEPU ---> FWP	0.999	0.882	
Model 3: With Brazilian EPU			
INTDIFF ---> FWP	0.294	0.997	0.181
INTDIFF ---> LBREPU	0.107	0.491	
FWP ---> INTDIFF	0.151	**0.037****	0.182
FWP ---> LBREPU	0.896	0.930	
LBREPU ---> INTDIFF	0.581	0.320	
LBREPU ---> FWP	0.404	0.282	

*, **, *** shows significance at 10 %, 5 %, and 1 % risk level.

Brazilian real at 3-month maturity results

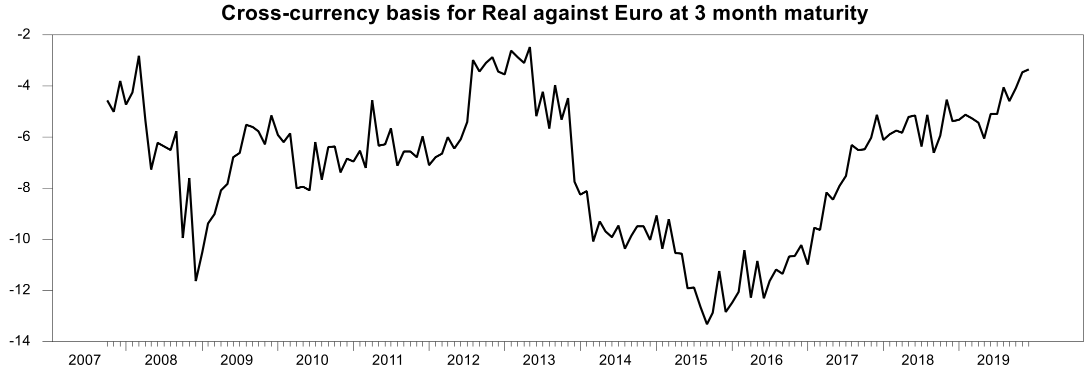

Figure 14. Cross-currency basis for the Brazilian real against the euro at 3-month maturity

Figure 14 shows that there are significant long-lasting CIP deviations between the Brazilian real against the euro at 3-month maturity. In the very short period prior to the 2008 GFC, there were significant CIP deviations constantly. Following the crisis, on the other hand, CIP deviations fluctuated at higher rates between -3 to -13 basis points, and at times reached significantly higher levels of CIP deviations than prior to the crisis, suggesting that the Brazilian real at 3-month maturity have been providing persistent arbitrage opportunities throughout the period. This suggests that the 2008 GFC has caused CIP deviations to reach new levels. Furthermore, as a result of having a negative cross-currency basis throughout the whole period, the direct euro interest rate was lower than the Brazilian real interest rate at 3-month horizon.

According to table 5, the interest rate difference and global EPU explain part of the CIP deviations. The Granger causality test shows that the interest rate difference causes CIP deviations at 1% risk level in all three models. This suggests that in the models with global and Brazilian EPU, the interest rate difference retains the Granger-causality towards the forward premium. Therefore, global, and Brazilian EPU have explanatory power on the role of the interest rate difference in these CIP deviations. In addition, global EPU also captures CIP deviations at 5% risk level.

Table 5. Granger causality – Brazilian real at 3-month maturity

Variables	**Level (Endogenous)**	**First difference**	**Level (Exogenous)**
	Significance level	**Significance level**	**Significance level**
Brazilian real 3M			
Model 1: Without EPU			
INTDIFF ---> FWP	**0.000*** **	0.250	
FWP ---> INTDIFF	0.959	**0.000*** **	
Model 2: With Global EPU			
INTDIFF ---> FWP	**0.000*** **	0.109	**0.011** **
INTDIFF ---> LGEPU	0.382	0.264	
FWP ---> INTDIFF	0.453	0.287	0.616
FWP ---> LGEPU	0.146	0.175	
LGEPU ---> INTDIFF	**0.031** **	**0.031** **	
LGEPU ---> FWP	0.814	0.549	
Model 3: With Brazilian EPU			
INTDIFF ---> FWP	**0.001*** **	0.106	**0.000*** **
INTDIFF ---> LBREPU	**0.015** **	**0.025** **	
FWP ---> INTDIFF	0.659	0.544	0.776
FWP ---> LBREPU	0.851	0.306	
LBREPU ---> INTDIFF	0.896	0.522	
LBREPU ---> FWP	0.553	**0.029** **	

*, **, *** shows significance at 10 %, 5 %, and 1 % risk level.

Chinese yuan at 1-month maturity results

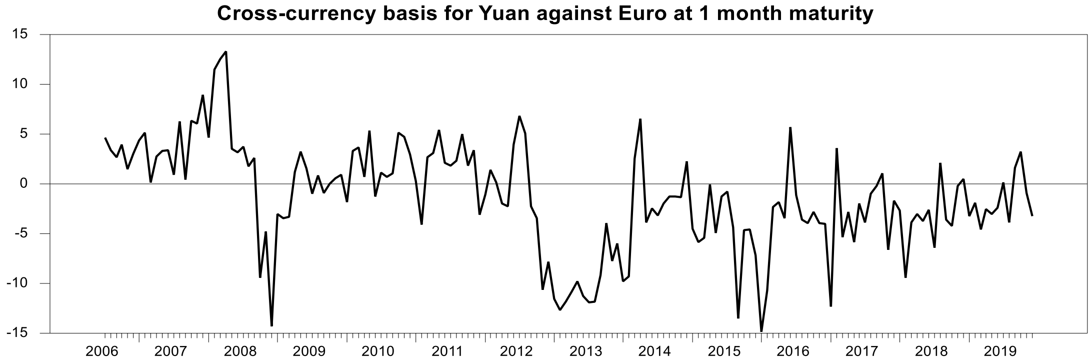

Figure 15. Cross-currency basis for the Chinese yuan against the euro at 1-month maturity

As can be seen in Figure 15, there are significant long-lasting CIP deviations between the Chinese yuan against the euro at 1-month maturity. In the short period prior to the 2008 GFC, there were significant CIP deviations almost constantly, ranging between 3 to 13 basis points, while at times there were no deviations at all. Following the crisis, CIP deviations fluctuated very irregularly between -15 to 6 basis points, therefore, profitable arbitrage opportunities have been occurring for the most part. This figure suggests that the 2008 GFC, has not only caused CIP deviations to reach considerably higher levels but has also made CIP deviations to fluctuate between positive and negative basis points. Furthermore, as a result of having a positive cross-currency basis prior to the crisis, the direct euro interest rate was higher than the Chinese yuan interest rate at 1-month horizon. Following the crisis, on the other hand, it could be divided into two periods. The first ranging from 2009 to the end of 2012 and the second from the end of 2012 until 2020. The first period is characterized by minor positive CIP deviations, while the second period is characterized by larger negative CIP deviations, suggesting that at the first period the direct euro interest rate was higher than the Chinese yuan interest rate, and in the second period, the direct euro interest rate was lower than the Chinese yuan interest rate at 1-month horizon.

According to table 6, the interest rate difference, forward premium, and global EPU explain part of the CIP deviations. The Granger causality test shows that the interest rate difference causes CIP deviations only in the basic model, while not causing in the models with global EPU and Chinese EPU. This suggests that in models with global and Chinese EPU, the interest rate difference does not retain the Granger-causality towards the forward premium. Therefore, both global and Chinese EPU do not have explanatory power on the role of the interest rate difference in these CIP deviations. The forward premium, on the other hand, causes CIP deviations in the models with global and Chinese EPU, while not causing in the basic model, as the null hypothesis is barely accepted at 10% risk level. Furthermore, in the model with global EPU, the forward premium Granger-causes the interest rate difference at almost 5% risk level, while in the model with Chinese EPU, the forward premium Granger-causes the interest rate difference only at 10% risk level. This suggests that both global and Chinese EPU are crucial to the role of forward premium in the CIP deviations. Moreover, global EPU has stronger explanatory power on the role of forward premium in these CIP deviations than Chinese EPU. In addition, global EPU also captures CIP deviations at 10% risk level.

Table 6. Granger causality – Chinese yuan at 1-month maturity

Variables	Level (Endogenous)	First difference	Level (Exogenous)
	Significance level	Significance level	Significance level
Chinese yuan 1M			
Model 1: Without EPU			
INTDIFF ---> FWP	**0.073***	0.194	
FWP ---> INTDIFF	0.105	0.980	
Model 2: With Global EPU			
INTDIFF ---> FWP	0.754	0.867	0.552
INTDIFF ---> LGEPU	0.318	**0.037****	
FWP ---> INTDIFF	**0.055***	**0.062***	**0.066***
FWP ---> LGEPU	0.402	0.386	
LGEPU ---> INTDIFF	0.639	0.828	
LGEPU ---> FWP	**0.072***	**0.070***	
Model 3: With Chinese EPU			
INTDIFF ---> FWP	0.600	0.412	0.714
INTDIFF ---> LCHEPU	0.541	0.629	
FWP ---> INTDIFF	**0.074***	0.626	**0.062***
FWP ---> LCHEPU	0.581	**0.010*****	
LCHEPU ---> INTDIFF	0.811	0.916	
LCHEPU ---> FWP	0.376	0.159	

*, **, *** shows significance at 10 %, 5 %, and 1 % risk level.

Chinese yuan at 3-month maturity results

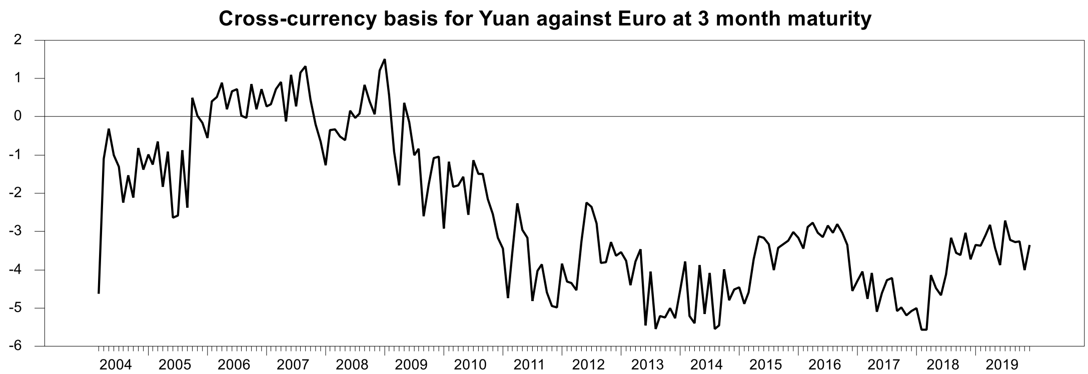

Figure 16. Cross-currency basis for the Chinese yuan against the euro at 3-month maturity

Figure 16 indicates that there are significant long-lasting CIP deviations between the Chinese yuan against the euro at 3-month maturity. In the period prior to the 2008 GFC, minor CIP deviations were ranging between -5 to 1 basis points. Following the crisis, CIP deviations increased drastically up to -5.5 basis points, therefore, profitable arbitrage opportunities have been occurring mainly post-crisis. This suggests that the 2008 GFC has caused CIP deviations to increase substantially. Furthermore, as a result of having both positive and negative cross-currency bases, the pre-crisis period could be subdivided into two periods. The first ranging from 2004 to 2005 and the second from 2006 until the 2008 GFC. The first period is characterized by minor negative basis points, while the second period is characterized by minor positive basis points, suggesting that at the first period the direct euro interest rate was lower than the Chinese yuan interest rate, and in the second period, the direct euro interest rate was higher than the Chinese yuan interest rate at 3-month horizon. Following the crisis, the cross-currency basis was always negative, suggesting the direct euro interest rate was lower than the Chinese yuan interest rate at 3-month horizon.

According to table 7, the interest rate difference and Chinese EPU explain part of the CIP deviations. The Granger causality test shows that the interest rate difference causes CIP deviations in the basic model, as well as in the model with Chinese EPU, at 1% risk level, while not causing in the model with global EPU. This suggests that Chinese EPU has explanatory power on the role of the interest rate difference on these CIP deviations but global EPU does not. In addition, global EPU also captures CIP deviations at 1% risk level.

Table 7. Granger causality – Chinese yuan at 3-month maturity

Variables	**Level (Endogenous)**	**First difference**	**Level (Exogenous)**
	Significance level	**Significance level**	**Significance level**
Chinese yuan 3M			
Model 1: Without EPU			
INTDIFF ---> FWP	**0.000*** **	0.516	
FWP ---> INTDIFF	0.623	0.255	
Model 2: With Global EPU			
INTDIFF ---> FWP	0.283	0.187	0.231
INTDIFF ---> LGEPU	0.475	0.902	
FWP ---> INTDIFF	0.248	0.116	0.318
FWP ---> LGEPU	0.532	0.599	
LGEPU ---> INTDIFF	0.779	0.951	
LGEPU ---> FWP	**0.004*** **	**0.002*** **	
Model 3: With Chinese EPU			
INTDIFF ---> FWP	**0.009*** **	**0.000*** **	**0.087* **
INTDIFF ---> LCHEPU	0.635	**0.000*** **	
FWP ---> INTDIFF	0.411	0.735	0.382
FWP ---> LCHEPU	0.555	**0.000*** **	
LCHEPU ---> INTDIFF	0.325	0.889	
LCHEPU ---> FWP	0.843	**0.000*** **	

*, **, *** shows significance at 10 %, 5 %, and 1 % risk level.

Indian rupee at 1-month maturity results

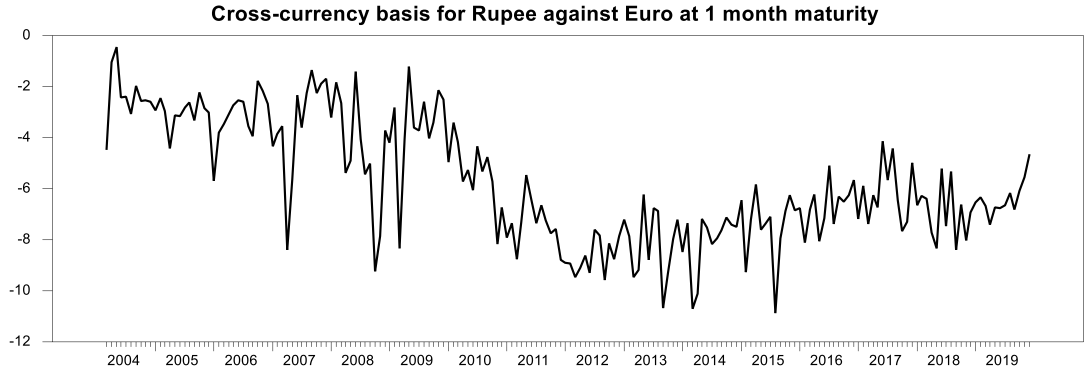

Figure 17. Cross-currency basis for the Indian rupee against the euro at 1-month maturity

As can be seen in Figure 17, there are significant long-lasting CIP deviations between the Indian rupee against the euro at 1-month maturity. In the period prior to the 2008 GFC, there were significant CIP deviations constantly with an average of about -4 basis points. Following the crisis, the cross-currency basis points remained negative the whole period, however, at higher rates. Therefore, profitable arbitrage opportunities have been occurring ever since, suggesting that the 2008 GFC has caused CIP deviations to skyrocket. Furthermore, as a result of having a negative cross-currency basis throughout the whole period, the direct euro interest rate was lower than the Indian rupee interest rate at 1-month horizon.

According to table 8, only the interest rate difference explains part of the CIP deviations. The Granger causality test shows that the interest rate difference causes CIP deviations in the models with global and Indian EPU at 5% risk level, while not causing in the basic model. This suggests that both global and Indian EPU are crucial to the role of the interest rate difference in these CIP deviations.

Table 8. Granger causality – Indian rupee at 1-month maturity

Variables	**Level (Endogenous)**	**First difference**	**Level (Exogenous)**
	Significance level	**Significance level**	**Significance level**
Indian rupee 1M			
Model 1: Without EPU			
INTDIFF ---> FWP	0.246	0.168	
FWP ---> INTDIFF	0.938	0.567	
Model 2: With Global EPU			
INTDIFF ---> FWP	**0.040****	0.312	**0.034****
INTDIFF ---> LGEPU	0.624	**0.017****	
FWP ---> INTDIFF	0.680	0.390	0.765
FWP ---> LGEPU	0.552	0.550	

(continues)

Table 8. (continues)

LGEPU ---> INTDIFF	0.850	0.786	
LGEPU ---> FWP	0.914	0.864	
Model 3: With Indian EPU			
INTDIFF ---> FWP	**0.037****	0.309	**0.029****
INTDIFF ---> LINEPU	0.778	0.369	
FWP ---> INTDIFF	0.736	0.407	0.859
FWP ---> LINEPU	0.494	0.552	
LINEPU ---> INTDIFF	0.328	0.537	
LINEPU ---> FWP	0.722	0.834	

*, **, *** shows significance at 10 %, 5 %, and 1 % risk level.

Indian rupee at 3-month maturity results

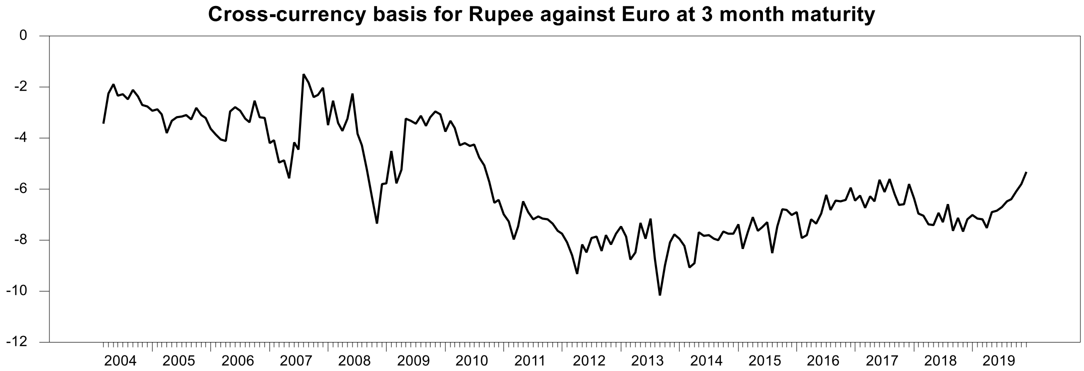

Figure 18. Cross-currency basis for the Indian rupee against the euro at 3-month maturity

Figure 18 shows that there are significant long-lasting CIP deviations between the Indian rupee against the euro at 3-month maturity. In the period prior to the 2008 GFC, there were significant CIP deviations constantly with an average of about -3 basis points. Following the crisis, the cross-currency basis points remained negative during the whole period, however, at higher rates. Therefore, the CIP deviations have been providing more profitable arbitrage opportunities, suggesting that the 2008 GFC has caused CIP deviations to reach new heights. Furthermore, as a result of having a negative cross-currency basis throughout the period, the direct euro interest rate was lower than the Indian rupee interest rate at 3-month horizon.

According to table 9, only the interest rate difference explains part of the CIP deviations. The Granger causality test shows that the interest rate difference causes CIP deviations in all three models at 1% risk level. This suggests that in the models with global and Indian EPU, the interest rate difference retains the Granger-causality towards the forward premium. Therefore, global, and Indian EPU have explanatory power on the role of the interest rate difference in these CIP deviations.

Table 9. Granger causality – Indian rupee at 3-month maturity

Variables	Level (Endogenous)	First difference	Level (Exogenous)
	Significance level	**Significance level**	**Significance level**
Indian rupee 3M			
Model 1: Without EPU			
INTDIFF ---> FWP	**0.000*****	0.210	
FWP ---> INTDIFF	0.852	0.244	
Model 2: With Global EPU			
INTDIFF ---> FWP	**0.000*****	0.615	**0.000*****
INTDIFF ---> LGEPU	0.506	0.636	
FWP ---> INTDIFF	0.162	**0.030****	0.233
FWP ---> LGEPU	0.442	0.619	
LGEPU ---> INTDIFF	0.696	0.609	
LGEPU ---> FWP	0.998	0.516	
Model 3: With Indian EPU			
INTDIFF ---> FWP	**0.000*****	0.592	**0.000*****
INTDIFF ---> LINEPU	0.814	0.433	
FWP ---> INTDIFF	0.240	**0.038****	0.308
FWP ---> LINEPU	0.310	0.342	
LINEPU ---> INTDIFF	0.157	0.345	
LINEPU ---> FWP	0.318	0.757	

*, **, *** shows significance at 10 %, 5 %, and 1 % risk level.

South African rand at 1-month maturity results

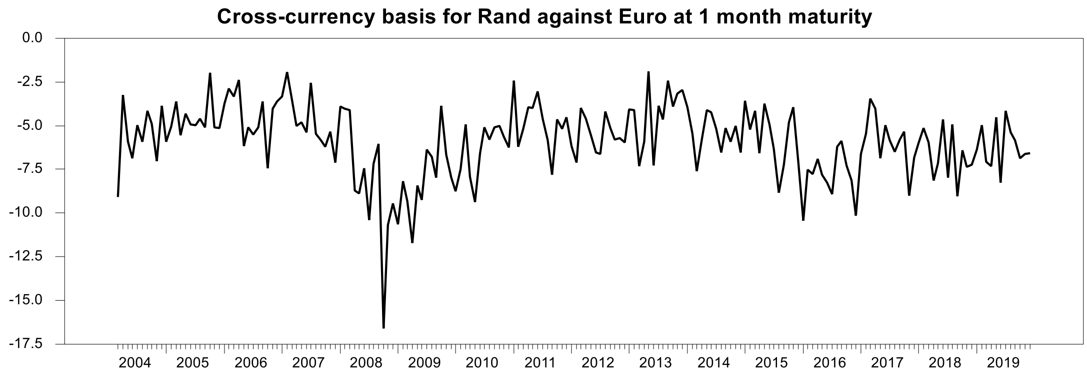

Figure 19. Cross-currency basis for the South African rand against the euro at 1-month maturity

Figure 19 indicates that there are significant long-lasting CIP deviations between the South African rand against the euro at 1-month maturity. Both in the period prior to the 2008 GFC and the period of post-crisis, there were significant CIP deviations. In Both periods the cross-currency basis points fluctuated in the range of -2.5 to -10. The only time where there were substantially higher rates of CIP deviations was during the crisis when basis points reached a rate of -17. Therefore, the constant CIP deviations have been providing persistent arbitrage opportunities throughout the period. In this case, the 2008 GFC did not cause CIP deviations to reach new heights in the post-crisis period. Furthermore, as a result of having a negative cross-currency basis throughout the whole period, the direct euro interest rate was lower than the South African rand interest rate at 1-month horizon.

According to table 10, only US EPU explains part of the CIP deviations. The Granger causality test shows that the US EPU causes CIP deviations at 10% risk level.

Table 10. Granger causality – South African rand at 1-month maturity

Variables	Level (Endogenous)	First difference	Level (Exogenous)
	Significance level	Significance level	Significance level
South African rand 1M			
Model 1: Without EPU			
INTDIFF ---> FWP	0.435	**0.000*** **	
FWP ---> INTDIFF	0.876	0.750	
Model 2: With Global EPU			
INTDIFF ---> FWP	0.501	0.501	0.620
INTDIFF ---> LGEPU	0.735	0.735	
FWP ---> INTDIFF	0.701	0.701	0.959
FWP ---> LGEPU	0.337	0.337	
LGEPU ---> INTDIFF	0.146	0.146	
LGEPU ---> FWP	0.238	0.238	
Model 3: With USA EPU			
INTDIFF ---> FWP	0.365	0.365	0.939
INTDIFF ---> LUSEPU	0.600	0.600	
FWP ---> INTDIFF	0.949	0.949	0.910
FWP ---> LUSEPU	0.961	0.961	
LUSEPU ---> INTDIFF	0.400	0.400	
LUSEPU ---> FWP	**0.062***	**0.062***	

*, **, *** shows significance at 10 %, 5 %, and 1 % risk level.

South African rand at 3-month maturity results

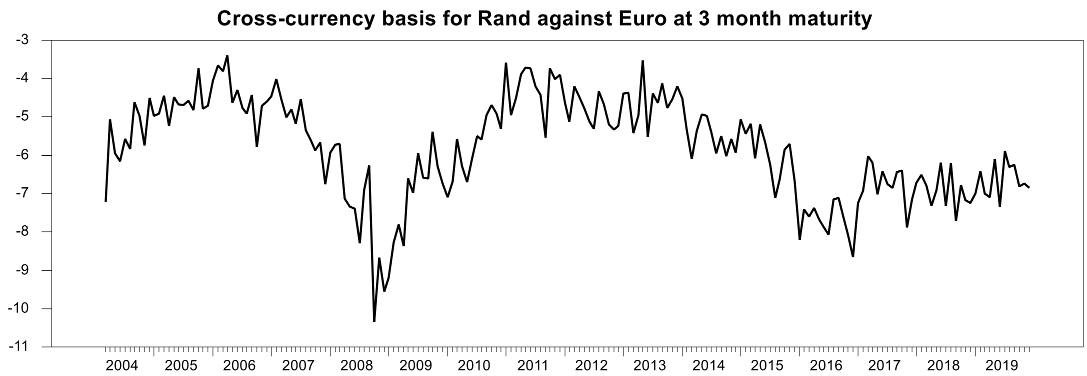

Figure 20. Cross-currency basis for the South African rand against the euro at 3-month maturity

As can be seen in Figure 20, there are significant long-lasting CIP deviations between the South African rand against the euro at 3-month maturity. Both in the period prior to the 2008 GFC and the period of post-crisis, there were significant CIP deviations, however, after the end of 2015, the CIP deviations increased substantially in comparison to the pre-crisis era. In the pre-crisis period, the basis point averaged about -5 while the post-crisis period averaged at about -7 basis points, therefore, the CIP deviations have been providing more profitable arbitrage opportunities throughout the latter years. This figure suggests that the 2008 GFC has caused CIP deviations to reach new levels. Furthermore, as a result of having a negative cross-currency basis throughout the whole period, the direct euro interest rate was lower than the South African rand interest rate at 3-month horizon.

According to table 11, only the interest rate difference explains part of the CIP deviations. The Granger causality test shows that the interest rate difference causes CIP deviations only at the basic model at 1% risk level. Due to the fact that in the models with global and US EPU, the interest rate difference Granger causes forward premium results have changed when assuming US EPU as an exogenous variable, US EPU should be treated as an exogenous variable. Therefore, the interest rate difference is found to not Granger cause the forward premium in the models with global and US EPU. Although US EPU is also found capturing CIP deviations at 10% and 5% risk levels, US EPU does not capture part of these CIP deviations since it is found and treated as an exogenous variable.

Table 11. Granger causality – South African rand at 3-month maturity

Variables	Level (Endogenous)	First difference	Level (Exogenous)
	Significance level	Significance level	Significance level
South African rand 3M			
Model 1: Without EPU			
INTDIFF ---> FWP	**0.009*****	0.199	
FWP ---> INTDIFF	0.851	0.268	
Model 2: With Global EPU			
INTDIFF ---> FWP	**0.039****	0.212	0.618
INTDIFF ---> LGEPU	0.433	0.536	
FWP ---> INTDIFF	0.583	0.570	0.960
FWP ---> LGEPU	0.336	0.206	
LGEPU ---> INTDIFF	0.433	0.876	
LGEPU ---> FWP	0.301	**0.070***	
Model 3: With USA EPU			
INTDIFF ---> FWP	**0.016****	0.303	0.358
INTDIFF ---> LUSEPU	0.655	0.471	
FWP ---> INTDIFF	0.975	0.947	0.936
FWP ---> LUSEPU	0.973	0.938	
LUSEPU ---> INTDIFF	**0.073***	0.158	
LUSEPU ---> FWP	**0.043***	**0.039****	

*, **, *** shows significance at 10 %, 5 %, and 1 % risk level.

6.1 Robustness

For robustness, the I(2) series, that is, processes that require to be differenced twice to become stationary are applied and compared with the original results. In addition, for extra validity, the same research method is implemented for several G10 currencies in order to compare the results of Du, Tepper, & Verdelhan (2018) with their research method.

As previously mentioned, in 40% of the cases, the interest rate difference is found to be stationary, while in 60% of the cases it is found to be non-stationary. Among the 40% of the cases with the interest rate difference being stationary, the results using I(2) series are fairly identical to the original results. The causes of deviations for the Russian ruble at 1- and 3-month maturity, as well as the Chinese yuan at 1-month maturity, remained identical to the ones in the original results. Only in the case of the Brazilian real at 1-month maturity, the causes of deviations changed between the original results and the I(2) series results. Furthermore, in all of those cases, the explanatory power of global and country-level EPU changed between the original results and the I(2) series results. In addition, in the cases of the Russian ruble at both 1- and 3-month maturity, the confidence level changed when the I(2) series is applied, while the causes of the deviations did not change. As a result of these changes, the explanatory power of global and country-level EPU altered between the two sets of results.

Among the 60% of cases with the interest rate difference being non-stationary, the results using the I(2) series are different from the original results. The causes of deviations remained identical to the original results only for the Indian rupee at 1-month maturity, while the South African rand at both 1- and 3-month maturity, as well as the Brazilian real, Chinese yuan, and Indian Rupee at 3-month maturity have different causes for deviations between the original results and the I(2) series results. In both cases of the Brazilian real and the Chinese yuan at 3-month maturity, the causes of CIP deviations changed from being interest rate difference and global EPU into being all four causes, that is, interest rate difference, forward premium, global EPU, and country-level EPU. In the cases of the South African rand at 1- and 3-month maturity, as well as the Indian rupee at 3-month maturity, on the other hand, there are different cause changes. Furthermore, in the cases of the Brazilian real and the Chinese yuan at 3-month maturity, as well as the Indian rupee at 1-month maturity, the explanatory power of global and country-level EPU changed between the original results and the I(2) series results, while in the cases of the South African rand at 1- and 3-month maturity, as well as the Indian rupee at 3-month maturity the explanatory power did not change.

Du, Tepper, & Verdelhan (2018) paper found that during the pre-crisis period, the G10 currencies were presenting minimal and mainly not profitable CIP arbitrage opportunities when the cross-currency bases were not significantly different from zero. During and post-crisis, on the other hand, their results were changed drastically. During the 2008 financial crisis, the cross-currency bases skyrocketed, especially around the Lehman Brothers bankruptcy announcement. The deviations from CIP did not disappear when the crisis abated, instead, since then, the deviations have been persistently different from zero. This paper tries to replicate Du, Tepper, & Verdelhan (2018) paper's results by testing CIP deviations in the periods of pre-, during, and post-crisis. The currencies of Japan, Norway, and Switzerland are selected as G10 currencies and are measured against the euro at 3-month maturity, similarly to the original time horizon. As it is shown in the figures below, this method is unable to replicate their results. This method found that there were significant CIP deviations existing already prior to the 2008 GFC, where the original paper did not find substantial CIP deviations during the same period of time. Furthermore, also the magnitude of the CIP deviations in terms of cross-currency basis is not similar to the original results. Potential explanations why this paper is unable to replicate the same results may be due to the use of the euro as the benchmark currency instead of the US dollar, as well as that the measurement of the interest rate difference variable is not identical.

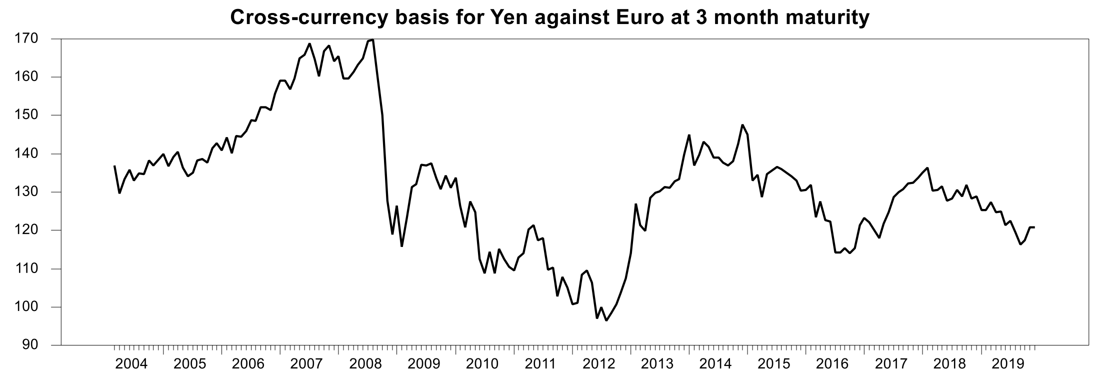

Figure 21. Cross-currency basis for the Japanese yen against the euro at 3-month maturity

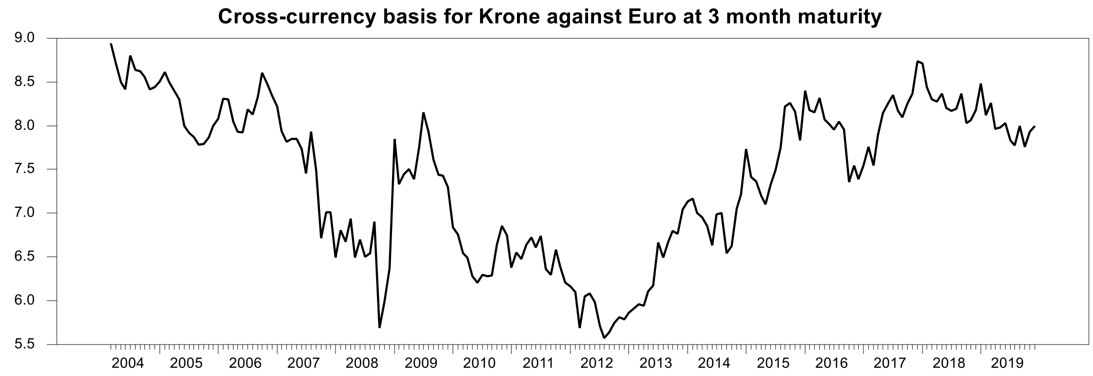

Figure 22. Cross-currency basis for the Norwegian krone against the euro at 3-month maturity

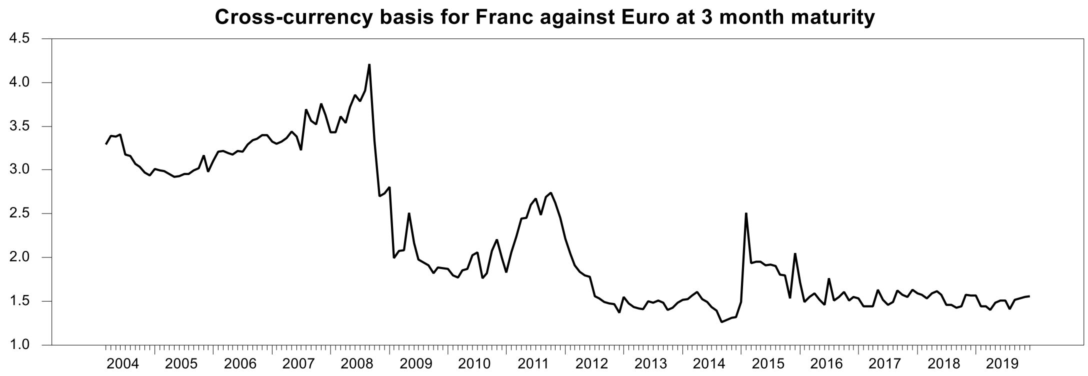

Figure 23. Cross-currency basis for the Swiss franc against the euro at 3-month maturity

7 CONCLUSIONS

The focus of this thesis is discovering whether the 2008 GFC has caused changes in CIP deviations in the BRICS currencies against the euro and whether the concept of EPU explains part of the deviations.

Earlier research suggests that prior to the 2008 GFC, in emerging markets there were significant CIP deviations that provided profitable CIP arbitrage opportunities. After the 2008 financial crisis, emerging economies continued to provide large CIP deviations, however at a higher magnitude, resulting in more profitable arbitrage opportunities. The results of this paper support earlier findings for the most part. This research finds that in most cases the 2008 GFC has caused a higher level of CIP deviations in the BRICS countries and as a result, provides long-lasting arbitrage opportunities, thus the first hypothesis is accepted. In the majority of cases, the magnitude of CIP deviations for the BRICS countries has increased substantially following the 2008 GFC in comparison to the pre-crisis era. In the cases of the Russian ruble, Chinese yuan, and Indian rupee at both 1- and 3-month maturity, as well as the Brazilian real and the South African rand at 3-month maturity, this research finds that following the 2008 GFC, CIP deviations are in substantially higher rates than during the pre-crisis era. In the cases of the Brazilian real and the South African rand at 1-month maturity, on the other hand, the 2008 GFC appears to have not affected the magnitude of CIP deviations. In both cases, the magnitude of CIP deviations remained at relatively similar levels to the levels they were before the crisis began.

Interestingly, only in the cases of the Russian ruble at both 1- and 3-month maturity, the research did not find evidence of significant CIP deviations prior to the 2008 GFC. After the crisis, however, there are significant CIP deviations, providing constant arbitrage opportunities. The results of the Russian ruble at both maturities appear very similar to the ones of Du, Tepper, & Verdelhan (2018) where they tested for the influence of the 2008 GFC on the G10 currencies and argue that developed markets started to present CIP deviations only following the 2008 financial crisis. It is puzzling why in Russia, a clear emerging market, CIP held rather closely prior to the 2008 GFC whereas not in the other BRICS countries. One potential explanation for it might be the high reserves the Russian central bank accumulated prior to the crisis acting as insurance against foreign exchange risk.

The level of EPU was relatively stable prior to the 2008 GFC. The 2008 financial crisis has caused EPU to grow considerably and it has remained extraordinarily high ever since. Earlier research suggests that when EPU grows, interest rates change and as a result of the interest rate change, CIP deviations may occur. The results of this paper find that in some cases global EPU and in some cases country-level EPU explain part of the CIP deviations. Global EPU appears to have a slightly stronger effect on CIP deviations than country-level EPU, thus the second hypothesis is mostly accepted. The results suggest that at the Brazilian real at 3-month maturity, as well as the Chinese yuan at both 1- and 3-month maturity, global EPU is causing CIP deviations and that at the Russian ruble at 3-month maturity and the South African rand at 1-month maturity, country-level EPU is causing CIP deviations. These results are slightly surprising since a large nation that has an enormous share of international trade and financial assets such as China is expected to be less dependent on global EPU than Chinese EPU. For Russia, another international trade of goods, and financial assets owner giant, the results are as expected. The Russian EPU was at considerably higher rates, and in a significantly more volatile state than the global EPU since its economy is highly dependent on a sector that at times is in distress. This is in line with the enormous spike of its CIP deviations in the latter half of 2014 during the collapse of crude oil price. Similarly, also the results for Brazil are excepted since it is a "small" open country with a heavy dependency on global trade of goods.

Another apparent detail that is interesting is in the case of the South African rand at 1-month maturity, where the US EPU is found to be a main cause of the CIP deviations, while global EPU is not. That is puzzling because US EPU is by far the most dominant factor in determining global EPU rates. The surprising results might be explained by the extensive exposure that the US economy has on the South African economy and that the US EPU is not a major factor of the global EPU as it is believed to be.

Global and country-level EPU, in addition to causing CIP deviations, also demonstrate explanatory power on the CIP deviations. The results of the models with EPU variables show that country-level EPU has stronger explanatory power on CIP deviations than global EPU. In the cases of the Russian ruble at 3-month maturity and the South African rand at 1-month maturity, country-level EPU is found to have stronger explanatory power on CIP deviations than global EPU, where only in the case of the Chinese yuan at 1-month maturity, global EPU is found to have stronger explanatory power than country-level EPU, while in the rest of the datasets, either country-level EPU or global EPU are not found to be more relevant. This is interesting results not only because country-level EPU appears to be more relevant to these CIP deviations than global EPU, but also because the results for the Chinese yuan and the South African rand exhibit opposing results than hypothesized. However, the results for the South African rand may be explained by applying US EPU and their strong dependency on US uncertainty because of the global trade of goods, financial assets, and commodities.

Another interesting result is that in the in cases of the Chinese yuan and the Indian rupee at 1-month maturity, the interest rate difference and forward premium in the models without any EPU variables, are found not causing CIP deviations, but in the models with global and country-level EPU variables, the interest rate difference and forward premium are found causing CIP deviations. These results show the crucial relevance of EPU variables in CIP deviations.

Limitations and future research

The main limitation of this research is the inability to replicate Du, Tepper, & Verdelhan (2018) results. This paper tried to replicate their results by testing the currencies of Japan, Norway, and Switzerland as G10 currencies against the euro at 3-month maturity. The same test using this method finds that there were existing CIP deviations before the 2008 GFC, where the original paper finds that there were not significant CIP deviations prior to the 2008 financial crisis. In addition, also the magnitude of the CIP deviations in terms of cross-currency basis is not identical with the original results. However, the inability to replicate their results may be due to the use of the euro as the benchmark currency instead of the US dollar, and that the measurement of the interest rate difference variable is not identical.

Another limitation is using non-stationary datasets. In this research, the variable of interest rate difference is found to be non-stationary in 60% of the cases. In theoretical terms, the interest rate difference should be stationary as the variable is composed of the difference between each BRICS countries' interest rate and the Euribor at the same time horizon. Therefore, the interest rate difference variable is assumed to be stationary also when the Augmented Dickey-Fuller test showed otherwise. However, when the I(2) series is applied for robustness in order to measure whether the same CIP deviations causes remain, the results changed drastically.

Finally, having a relatively short data frame prior to the 2008 GFC is also a limitation. Since the financial markets in BRICS countries only began applying and recording the necessary datasets for this research in the 2000s, the length of the period prior to the crisis might be too short to create fully reliable results, especially in the case of the Russian ruble at 1-month maturity in which the dataset found began only during 2007.

Future research can take many different paths. One of those can be testing for the effect of COVID-19 on CIP deviations on BRICS currencies. Similarly to the effect of the 2008 financial crisis, also COVID-19 has caused the EPU index to skyrocket and potentially causes numerous excellent CIP arbitrage opportunities that may provide great profit to investors. Although at the time of writing, the coronavirus pandemic is yet to end, in future years such research could take place.

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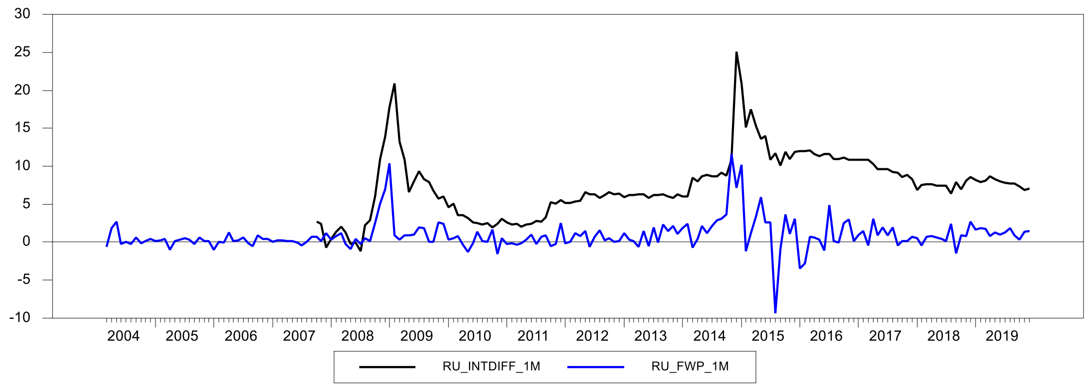
APPENDIX 1: ADF UNIT ROOT TESTS

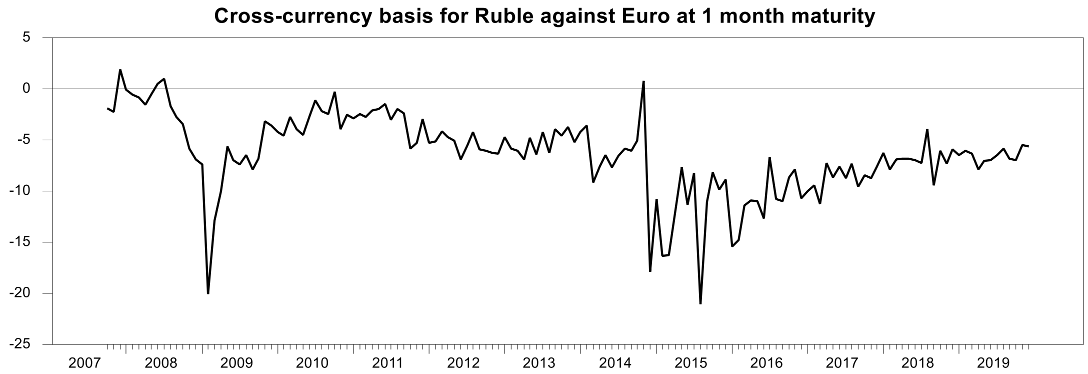
Table 12. ADF unit root tests

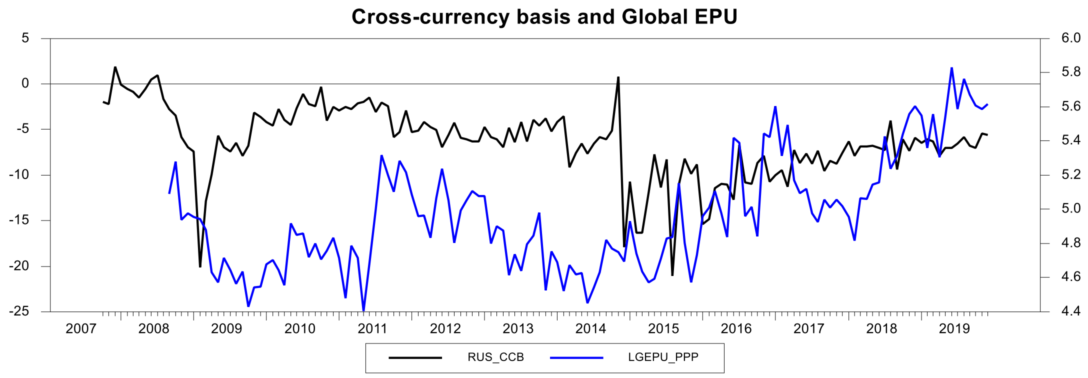
Variables	Level				First difference			
	T-Statistic	1% Crit. Value	5% Crit. Value	10% Crit. Value	T-Statistic	1% Crit. Value	5% Crit. Value	10% Crit. Value
Russia 1M								
Interest Rate Difference	**-2.861***	-3.476	-2.881	-2.577	**-11.657*****	-3.476	-2.881	-2.577
Forward Premium	**-9.309*****	-3.466	-2.877	-2.575				
Russia 3M								
Interest Rate Difference	**-2.677***	-3.468	-2.878	-2.575	**-12.291*****	-3.469	-2.878	-2.575
Forward Premium	**-6.969*****	-3.466	-2.877	-2.575				
Brazil 1M								
Interest Rate Difference	**-7.793*****	-3.472	-2.880	-2.576	**-10.838*****	-3.473	-2.880	-2.576
Forward Premium	**-14.423*****	-3.466	-2.877	-2.575				
Brazil 3M								
Interest Rate Difference	-1.829	-3.476	-2.881	-2.577	**-14.705*****	-2.577	-2.881	-3.476
Forward Premium	**-12.706*****	-3.466	-2.877	-2.575				
China 1M								
Interest Rate Difference	**-3.959*****	-3.472	-2.879	-2.576	**-12.463*****	-3.473	-2.880	-2.576
Forward Premium	**-12.992*****	-3.466	-2.877	-2.575				
China 3M								
Interest Rate Difference	-1.334	-3.466	-2.877	-2.575	**-13.907*****	-3.466	-2.877	-2.575
Forward Premium	**-4.280*****	-3.466	-2.877	-2.575				
India 1M								
Interest Rate Difference	-2.275	-3.466	-2.877	-2.575	**-13.153*****	-3.466	-2.877	-2.575
Forward Premium	**-13.986*****	-3.466	-2.877	-2.575				
India 3M								
Interest Rate Difference	-1.994	-3.466	-2.877	-2.575	**-12.892*****	-3.466	-2.877	-2.575
Forward Premium	**-11.877*****	-3.466	-2.877	-2.575				
South Africa 1M								
Interest Rate Difference	-1.951	-3.466	-2.877	-2.575	**-14.777*****	-3.466	-2.877	-2.575
Forward Premium	**-11.901****	-3.466	-2.877	-2.575				
South Africa 3M								
Interest Rate Difference	-1.467	-3.466	-2.877	-2.575	**-11.860*****	-3.466	-2.877	-2.575
Forward Premium	**-11.617*****	-3.466	-2.877	-2.575				
EPU								
Global EPU	**-3.054****	-3.479	-2.883	-2.578				
Russian EPU in	**-5.161*****	-3.480	-2.883	-2.578	**-11.560*****	-3.480	-2.883	-2.578
Brazilian EPU in	**-4.079*****	-3.480	-2.883	-2.578	**-10.492*****	-3.480	-2.883	-2.578
Chinese EPU	-1.125	-3.480	-2.883	-2.578	**-15.208*****	-3.480	-2.883	-2.578
Indian EPU	**-4.400*****	-3.479	-2.883	-2.578	**-11.454*****	-3.480	-2.883	-2.578
USA EPU	**-4.231*****	-3.479	-2.883	-2.578	**-9.628*****	-3.480	-2.883	-2.578

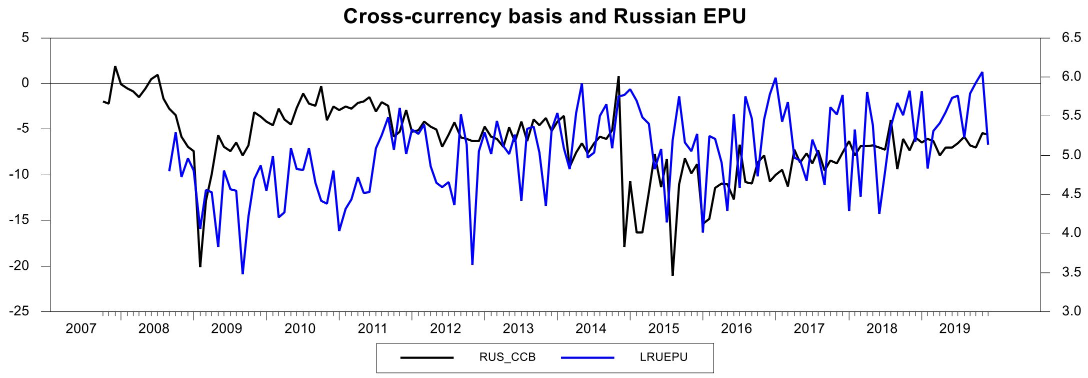
APPENDIX 2: GRAPHS OF THE VARIABLES AND CROSS-CURRENCY BASES

Russian ruble at 1-month maturity:

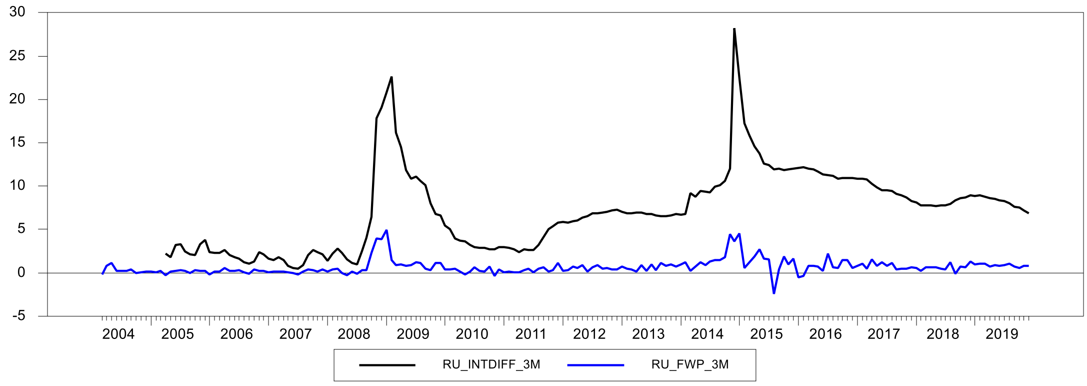


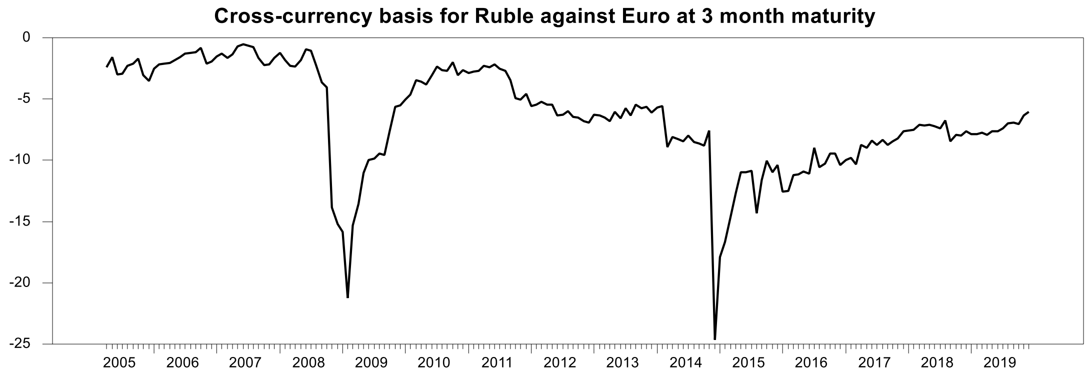


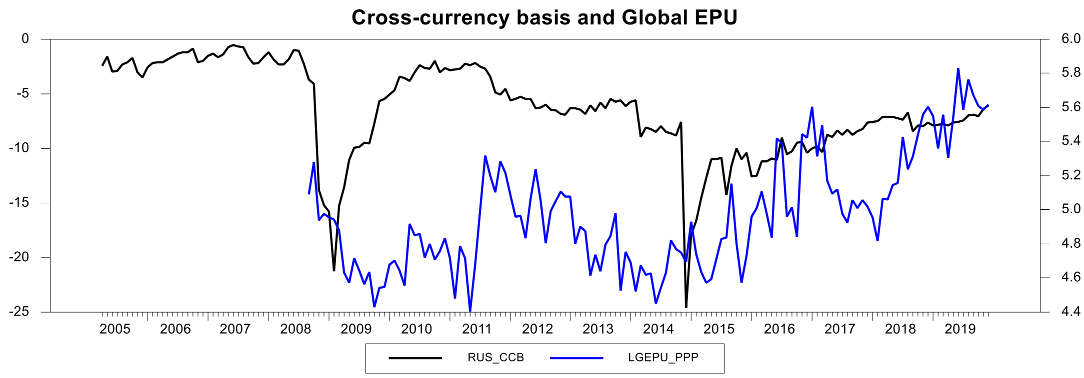


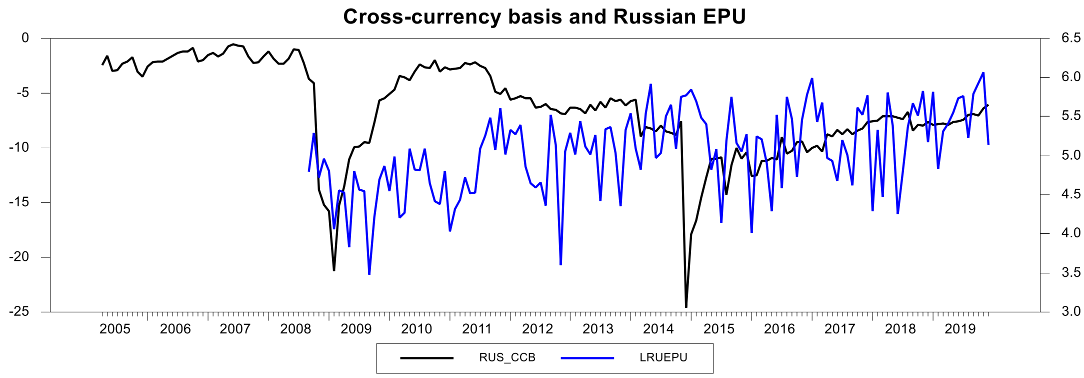


Russian ruble at 3-month maturity:

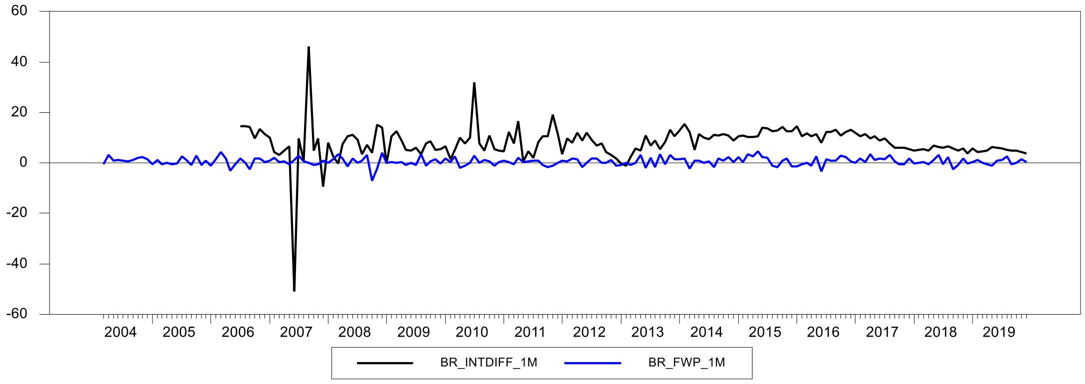


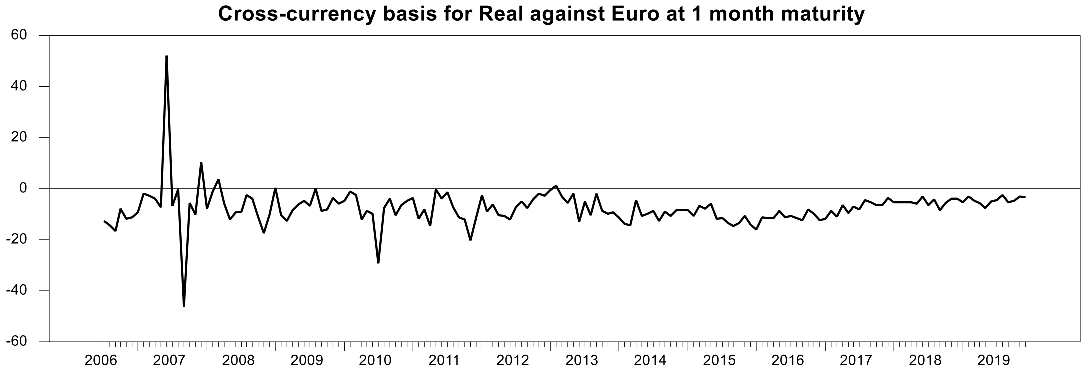


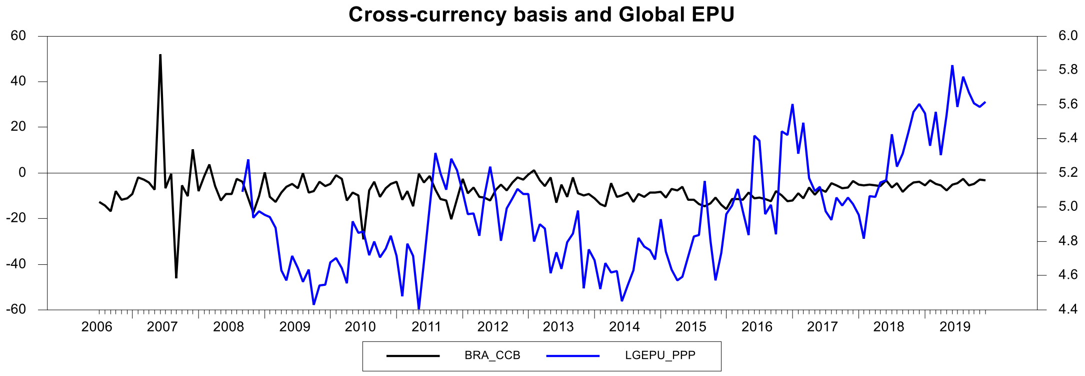


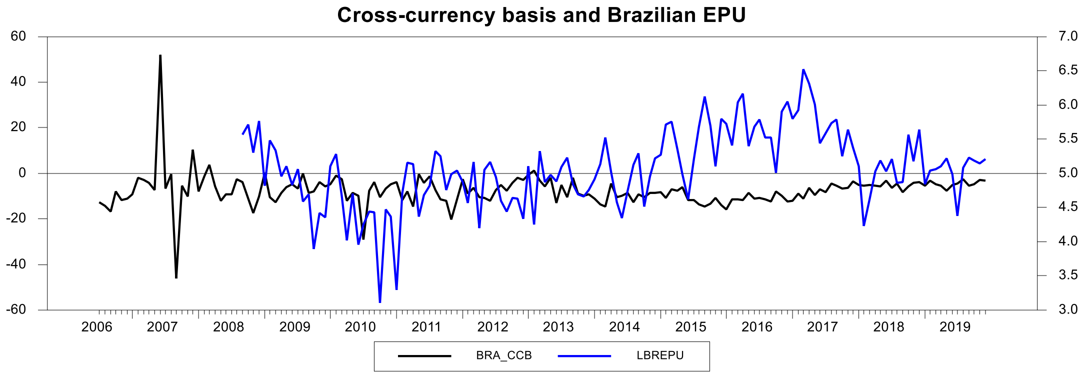


Brazilian real at 1-month maturity:

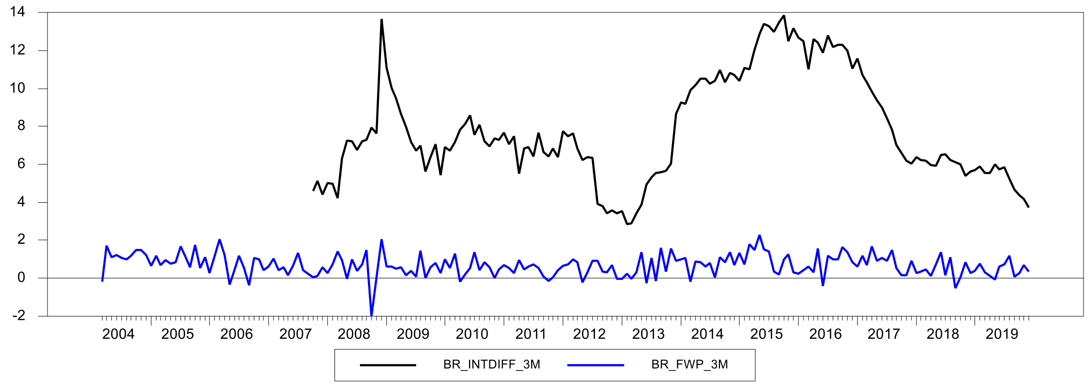


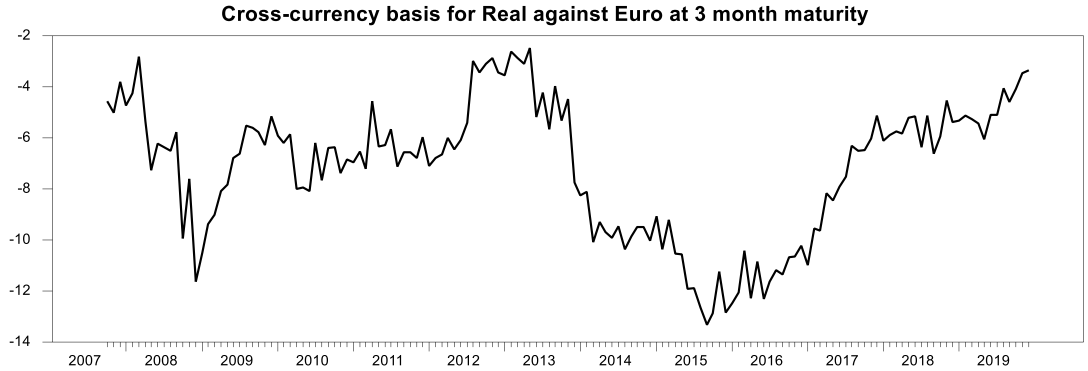


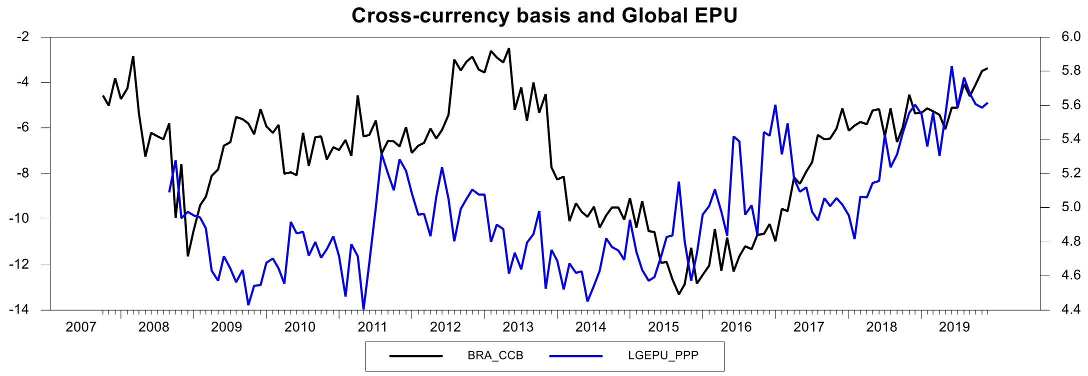


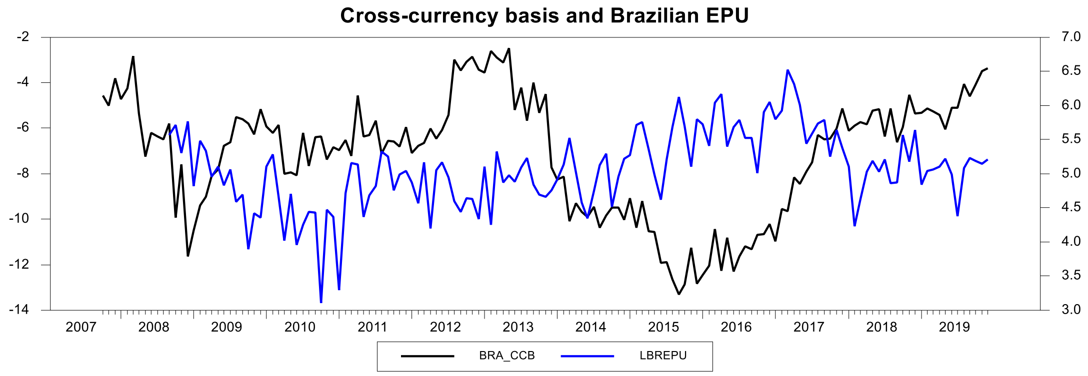


Brazilian real at 3-month maturity:

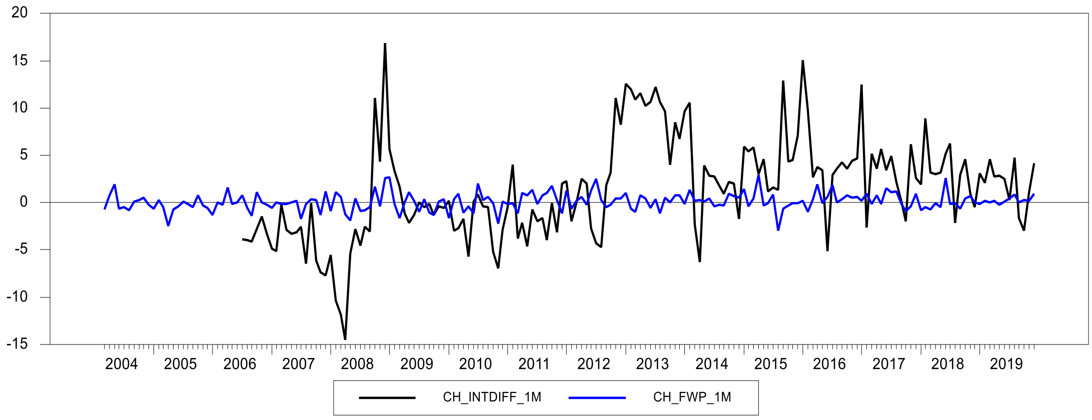


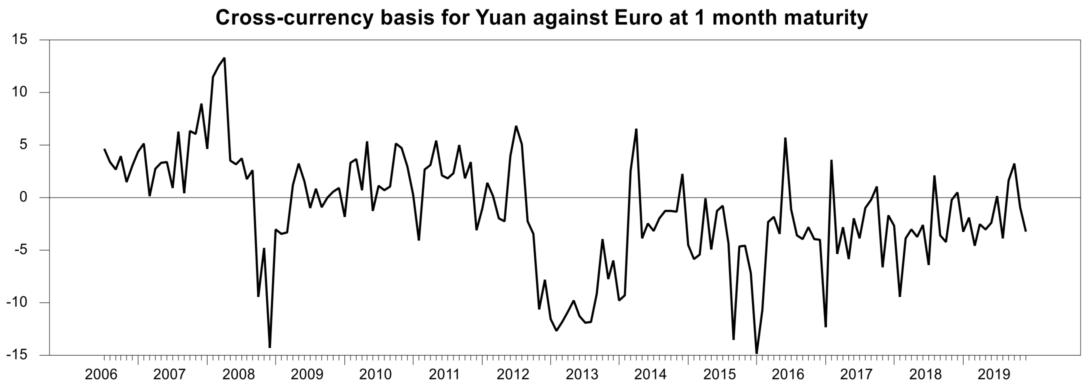


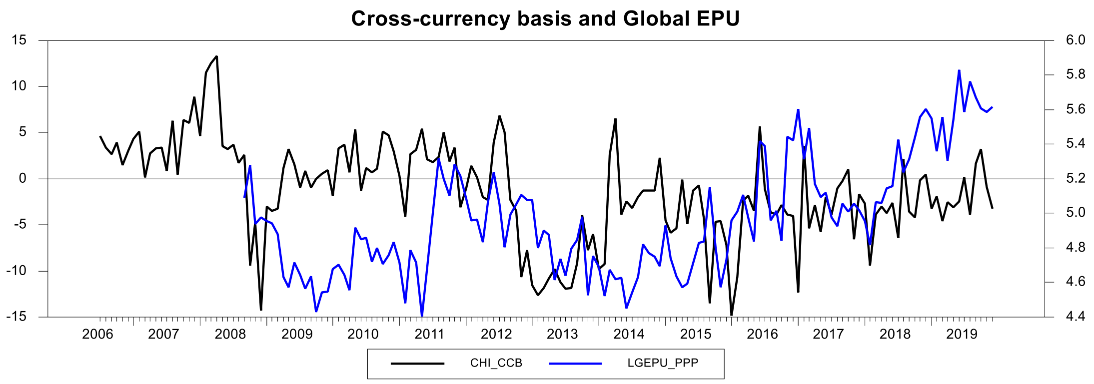


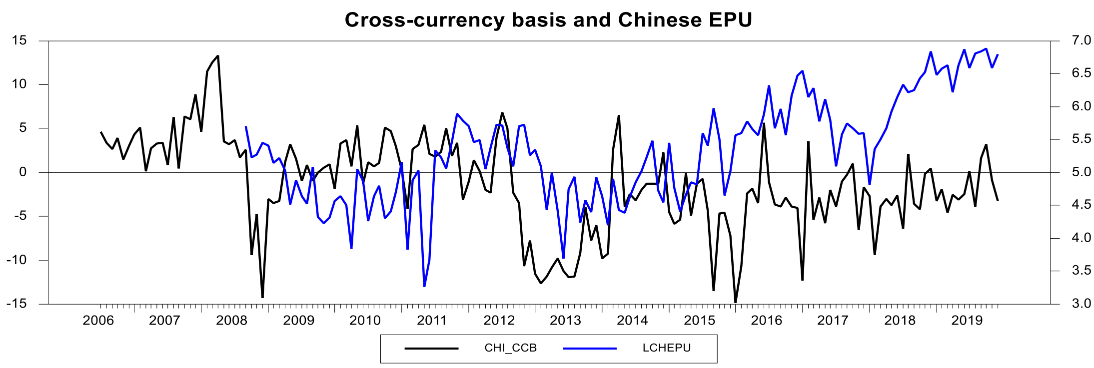


Chinese yuan at 1-month maturity:

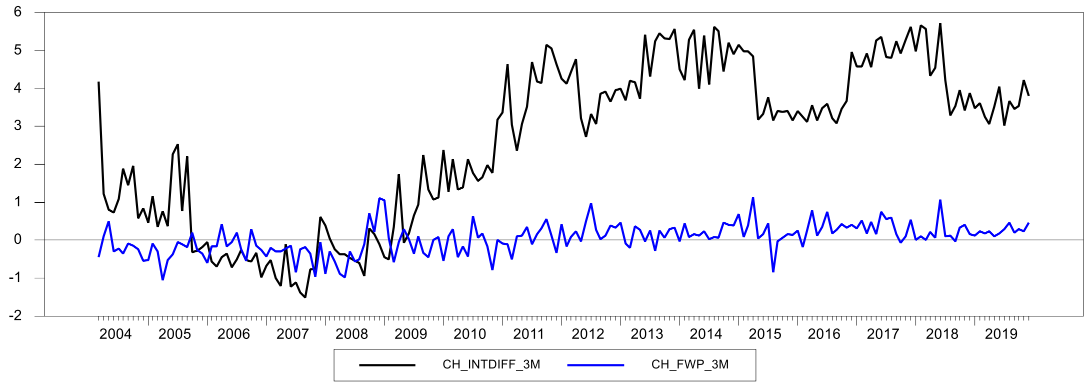


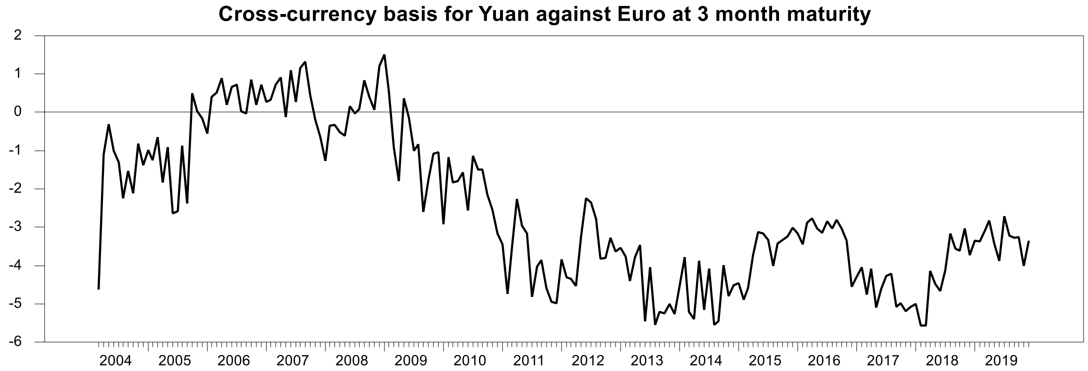


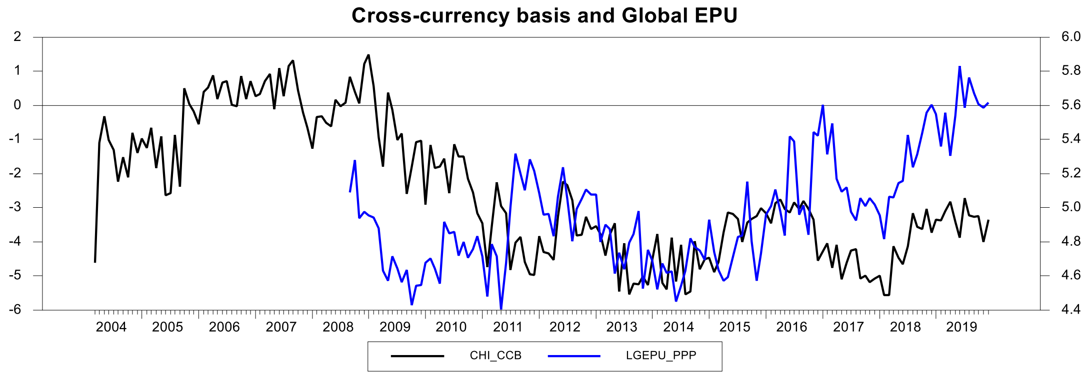


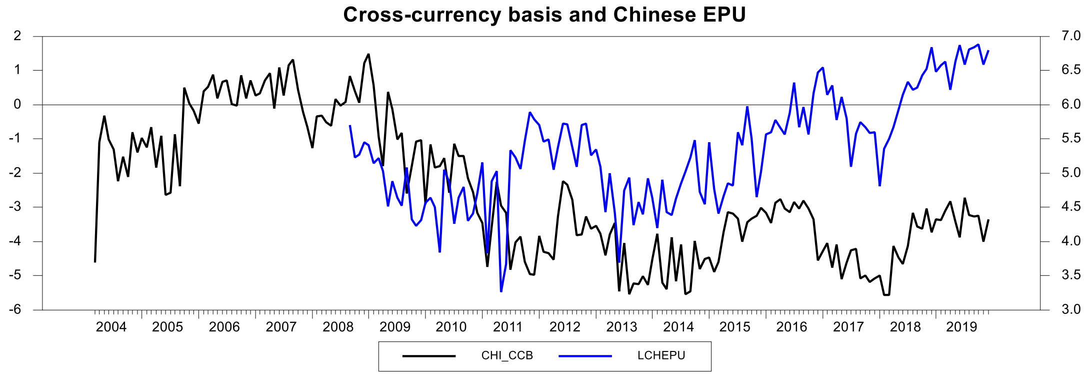


Chinese yuan at 3-month maturity:

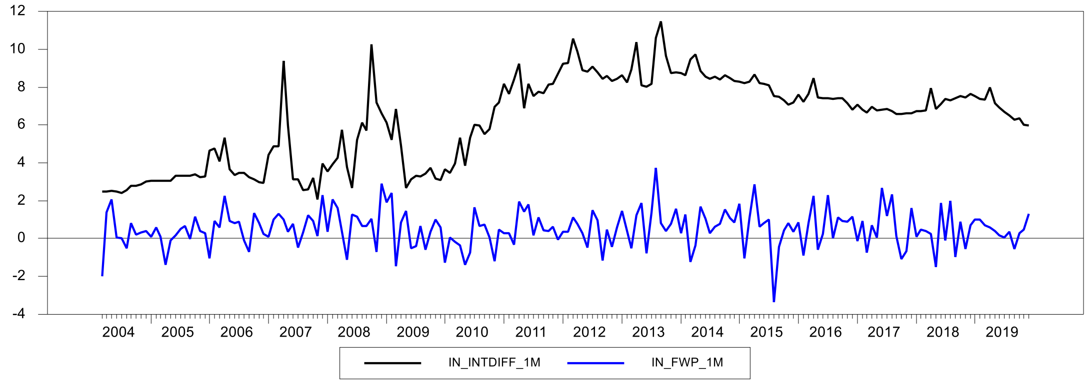




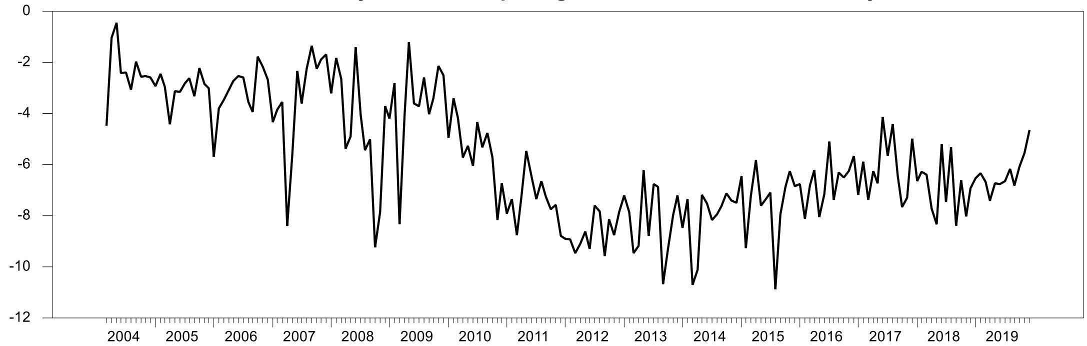




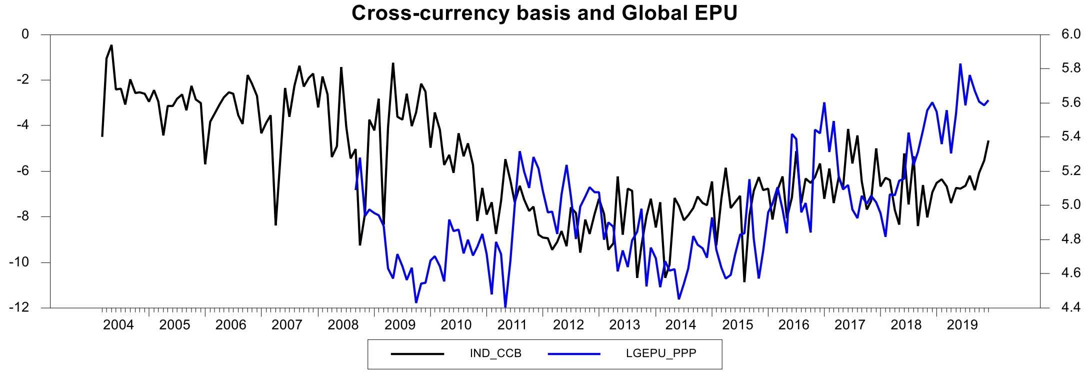
Indian rupee at 1-month maturity:



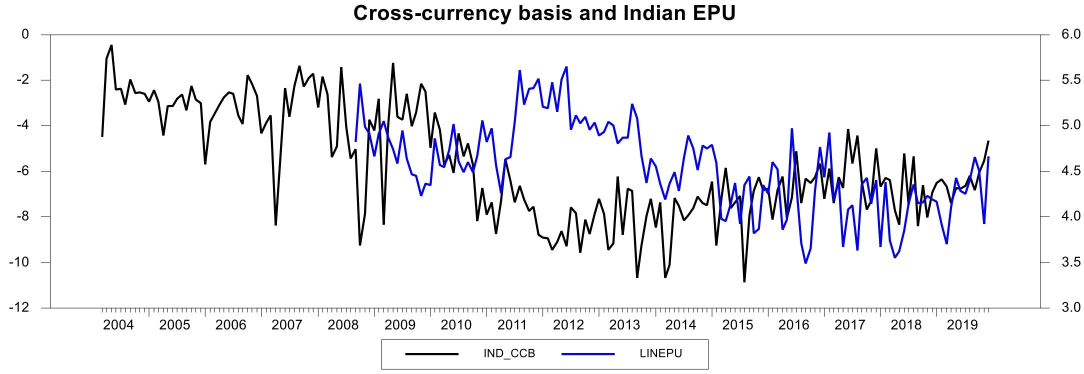
Cross-currency basis for Rupee against Euro at 1 month maturity



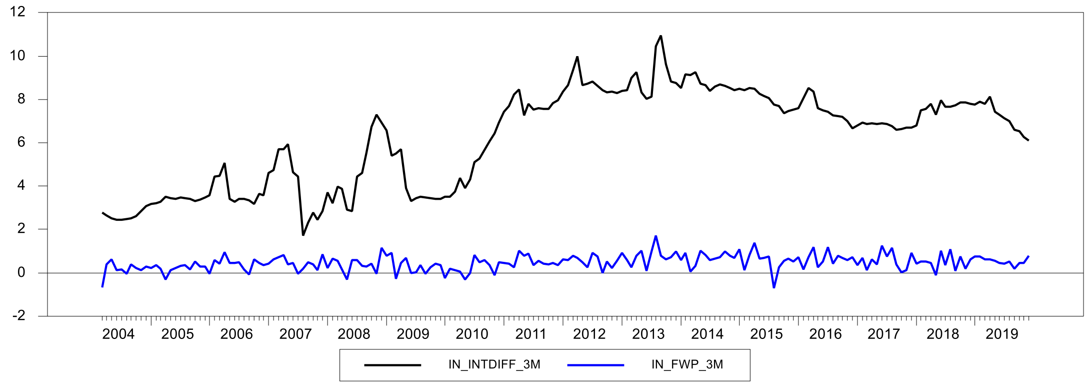
Cross-currency basis and Global EPU



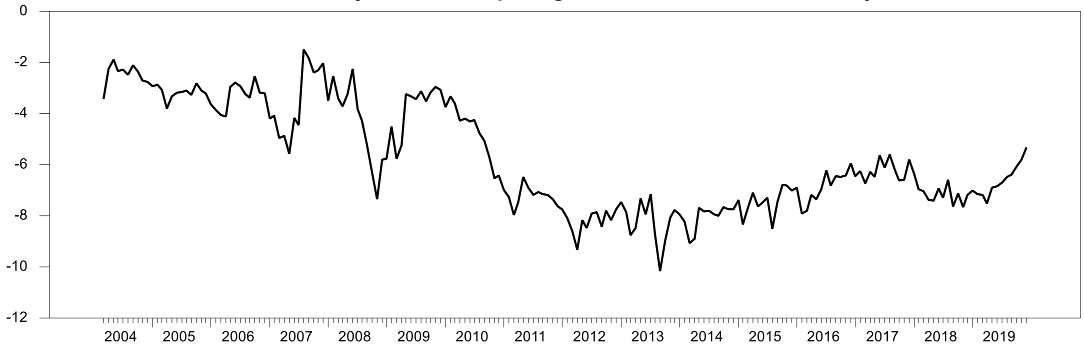
Cross-currency basis and Indian EPU



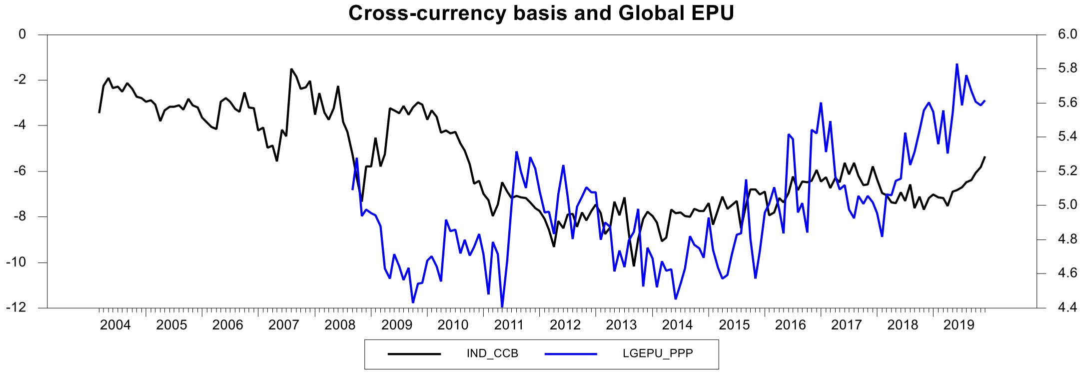
Indian rupee at 3-month maturity:



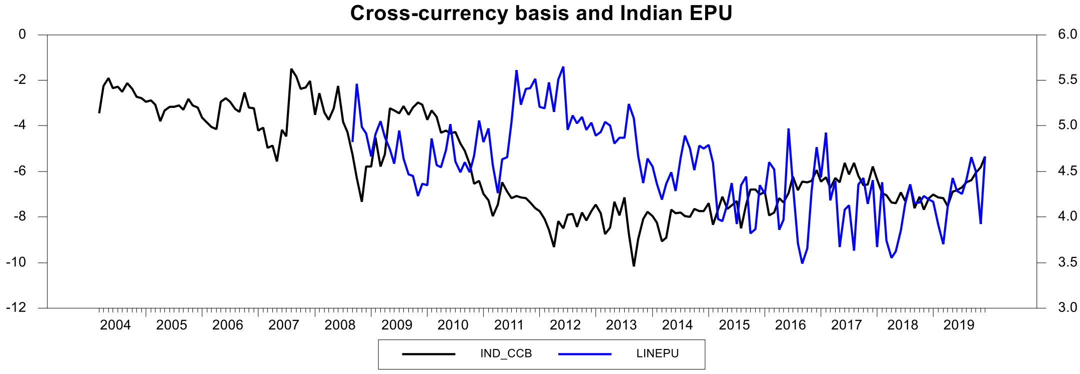
Cross-currency basis for Rupee against Euro at 3 month maturity



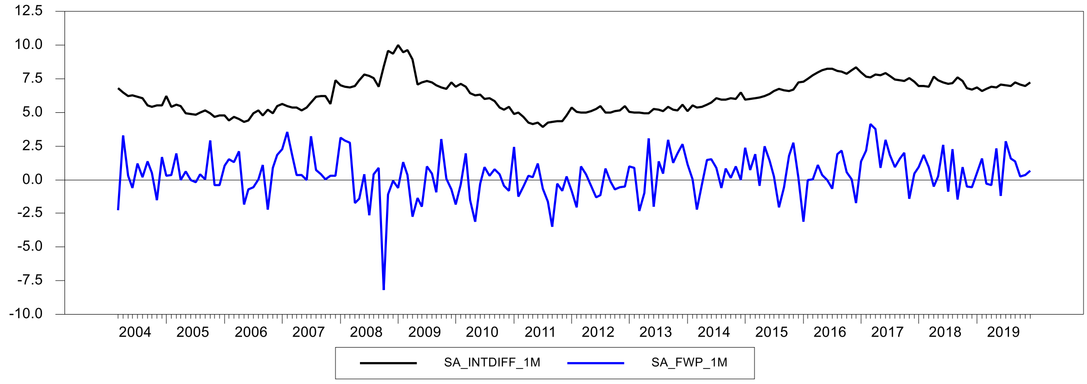
Cross-currency basis and Global EPU



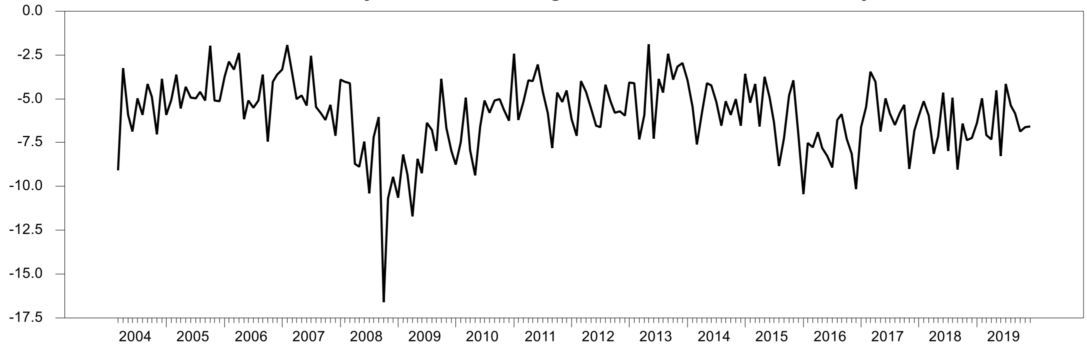
Cross-currency basis and Indian EPU



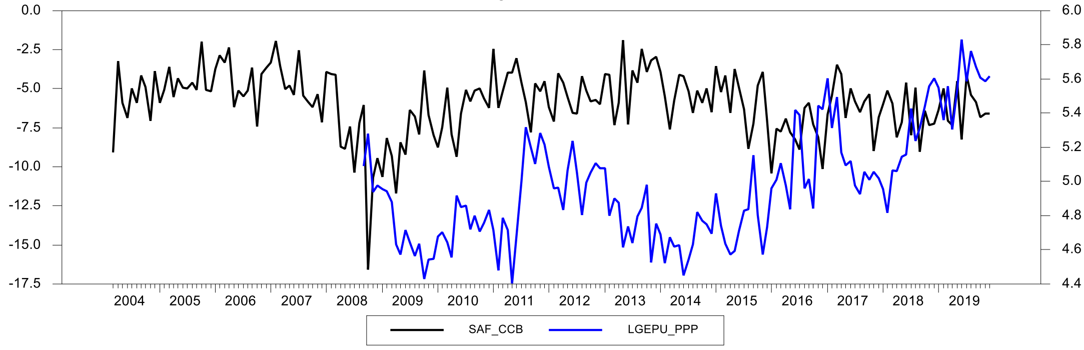
South African rand at 1-month maturity:



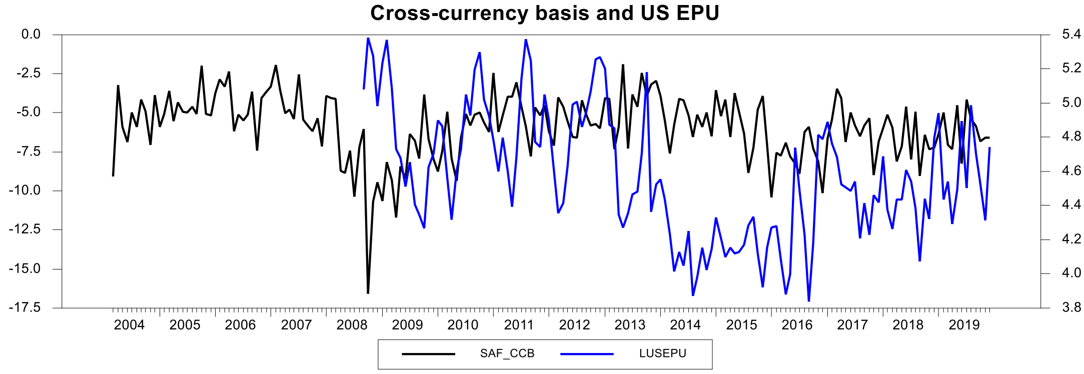
Cross-currency basis for Rand against Euro at 1 month maturity



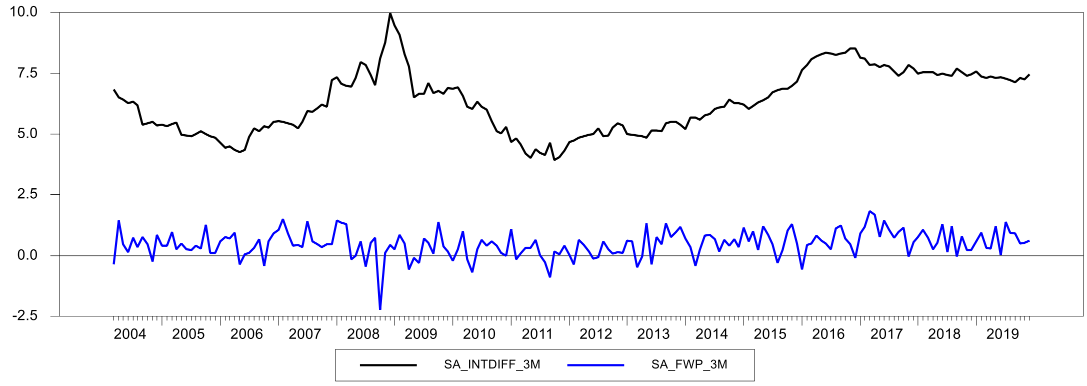
Cross-currency basis and Global EPU



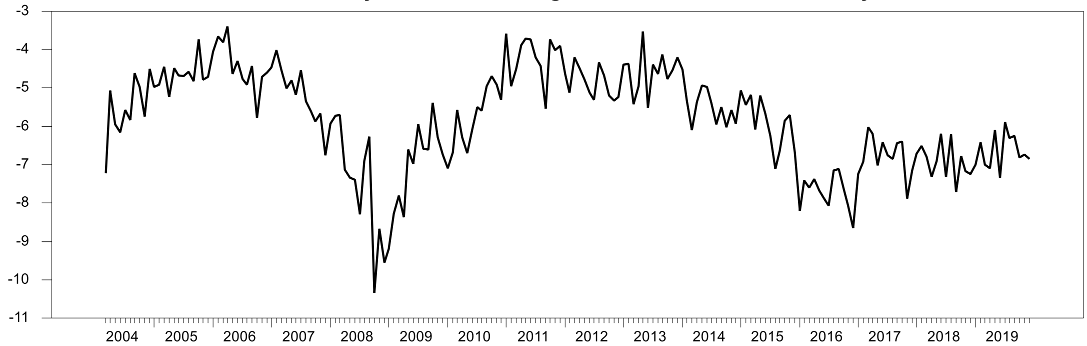
Cross-currency basis and US EPU



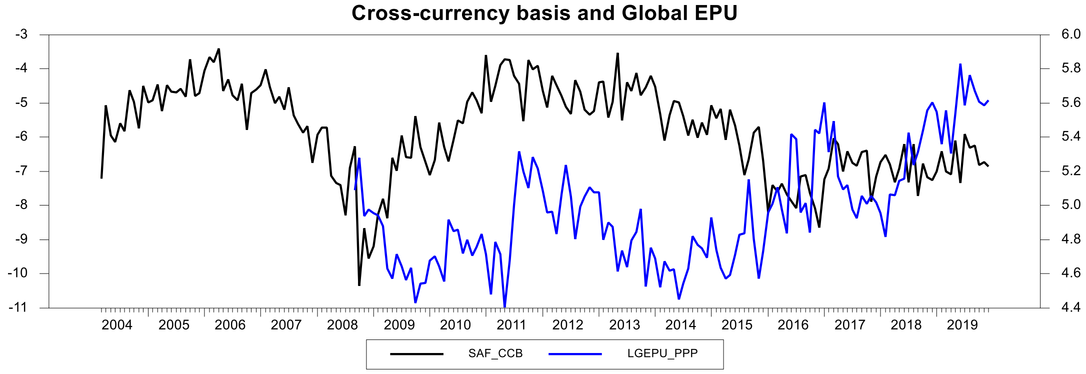
South African rand at 3-month maturity:



Cross-currency basis for Rand against Euro at 3 month maturity



Cross-currency basis and Global EPU



Cross-currency basis and US EPU