New Perspectives on Commodity and Currency Risk

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Pusilla res mundus est, nisi in illo quod quaerat omnis mundus habeat.

Declarations

There are no known conflicts as it relates to the undertaking and findings of this research. All findings and opinions are those of the author's alone.

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Abstract

This thesis proposes new frameworks and methodologies for understanding commodity price co-movements with national currencies. The body of work is organized into three self-contained research papers and are thus referred to throughout the thesis corresponding to each chapter. Throughout the work, 'chapter' and 'paper' may be used interchangeably, though for ease of reference all page numbers are ordered sequentially as one body of work while figure, equation and table numbers are ordered corresponding to chapter.

The first chapter proposes a novel framework for interpreting currency-commodity correlations: indirect relationships. Direct, or 'traditional' currency-commodity effects, enjoy a wide literature base where such relationships assert themselves via a trade link: where a significant proportion of national product is linked to a specific commodity, variation in demand for that commodity will have a substantial impact on demand for national currency. Indirect relationships are proposed, where currency-commodity correlations will assert themselves during times of crisis, or in cases where there is no explicit import-export channel in the stated commodity market.

The second chapter contributes a crisis-state definition framework based on currency volatility-acceleration as a means of implementing the conceptual framework for detecting indirect currency-commodity relationships in Emerging Market (EM) countries. Instances of direct and indirect currency-commodity relationships are identified under the frameworks and are subjected to statistical robustness testing. The currency volatility acceleration tool is shown to be a potent 'early-warning' detection system for defining crisis-states in certain EM countries, and the indirect currency-commodity framework is shown to produce significant results and validate the methodology.

The third chapter contributes a pricing-power detection framework based on currency-commodity relationships, generalizing findings that demonstrate a statistically significant relationship between the British pound and European sugar import prices arising from a single UK firm dominating refined sugar exports to the Continent.

Keywords: exchange rates, currency risk, equity returns, equity risk, commodities, commodity returns, emerging markets, carry trade, commodity-currency, crisis-state definition, volatility acceleration, pricing power, sugar, British pound, sterling, EU, Brexit, trade

General Introduction

Currency risk is a substantial contributor to portfolio return, especially in emerging market (EM) economies where high local interest rates tend to compensate investors for tolerating higher volatility relative to developed markets (DM). The growing size and complexity of investable EM products coincides with larger investment appetite for international equity managers in an era of low DM interest rates and a concurrent search for high-yielding assets. This trend, however, is met with a gap in the available literature that deals with EM currency risk mitigation. EM equity allocations are still shown to be small in size relative to well-established DM capital tranches, and a combination of illiquidity and relatively poor data quality until recent years has produced a paucity of interest from both practitioners and academic researchers in investigating new currency hedging frameworks. The growing importance of EM as an asset class, and the underperformance of unhedged exposure to EM relative to pre-financial crisis history (Figure 2.1) are providing new impetus for focus on the field (Corominas & Scott, 2014).

This thesis investigates natural hedges for EM currency risk. Currency hedging is an important area of study in EM given the sizeable contribution of currency to equity returns, though hedging costs have historically been perceived as prohibitively expensive when using foreign exchange instruments. A conceptual framework for identifying commodities as natural hedges for currency risk is proposed. Techniques leveraging acceleration in currency volatility, a methodology previously limited to equity market analysis (He & Narayanamoorthy, 2019) and currency options pricing theory (Baaquie & Cao, 2014), provide new tools to define crisis-states that are specific to EM countries with independence from global macro factors.

This work ties together three strands of literature in addressing a specific gap: broad-based analysis of commodities as currency hedging tools specific to crisis-state periods for EM equity portfolios. The available literature as it stands discusses each of these area in great depth, though combination of such factors has been limited to cases of direct commodity-currency instances and to single-commodity instances largely in the case of oil (due in no small part to oil's role as a manufacturing input). Elements of these branches of the literature are discussed in Chapter 1 as part of the establishment of the indirect currency-commodity conceptual framework. A fourth strand of literature, that of pricing power in the field of industrial organization, is drawn in following the accidental discovery of a particularly strong indirect currency-commodity effect. This literature base and its applications is discussed in Chapter 3. Following statistical verification of the phenomenon, a generalized framework for efficiently detecting future instances of relationships of this nature is proposed as a contribution to the field.

This thesis is organized as follows: the first chapter contributes a conceptual framework for detecting indirect currency-commodity relationships. Indirect currency-commodity relationships are instances where a substantial correlation between commodity and currency prices asserts itself during times of financial market stress in the absence of significant external demand for the commodity (a 'traditional,' or direct currency-commodity relationship). The second chapter implements this framework using a broad selection of commodities, derived from the entire universe of International Monetary Fund (IMF) commodity price baskets, and a representative sample of dominant EM countries. As a component of implementation, the volatility-acceleration methodology for crisis-state identification is proposed and delivered with success in various EM countries as an 'early warning signal' for in-sample equity market downturn. Where a currency volatility acceleration signal is detected, the following three months coincide with negative equity market average return in all tested EM markets, with the exception of India. These return averages are significantly lower than in-sample total series average positive returns for the EM series' (Figure 2.3). The lower post-volatility acceleration currency signal returns in local equity markets both demonstrate the virtue of leveraging currency insights to mitigate equity risk and validate this novel approach to define crisis states that are country-specific as opposed to arbitrary time-series segmentation around macro events such as the global financial crisis (Forbes & Rigobon, 2002). These frameworks serve to expand the field of literature in both crisis-state definition tools and with commodity-currency research.

The third chapter relates to the discovery of a specific instance of high long-run correlation between commodity and DM currency prices. This instance, detected via the indirect currency-commodity framework, is statistically significant and appears idiosyncratic to the industrial framework surrounding the commodity series, European refined sugar imports, and the currency, the British pound in pre-Brexit prices. Figure 3.1 displays logarithmic prices of the British currency and European refined sugar import prices (left), along with the same price levels along with free market and US sugar import prices (right) to demonstrate that the phenomenon is limited to European import prices as opposed to the broader sugar markets.

A system of pricing power appears to be responsible for the relationship, and a generalized framework to describe the fundamental conditions behind this market structure is contributed. This generalized framework is applied under simple conditions for demonstrative purposes. The framework is offered to expand the field of literature to further investigate such relationships, and to explore means of more efficiently detecting instances of pricing power in commodity-exporting companies in future research.

0.1 Contributions

0.1.1 Indirect Currency-Commodity Effects

This chapter makes a substantial contribution in proposing relationships that assert themselves between currency and commodity prices outside of a traditional import-export framework at the national level. The established literature, including the influential works of Chen & Rogoff (2003), has focused on 'direct' currency-commodity correlations that appear when a large share of country output, and thus demand for national currency, is tied to a specific commodity.

Currency risk is of special interest for EM studies, where it is well established in the available literature that foreign exchange fluctuation is a dominant contributor to local market equity returns (Phylaktis & Ravazzolo, 2004; Corominas & Scott, 2014). The increasing size of EM as relative to DM, where leading members of the former are expected to become the dominant economic bloc by the mid-21st century (Cheng, Gutierrez, Mahajan, Shachmurove, & Shahrokhi, 2007), lends urgency to the study of currency risk as it applies to the market segment. Studies in EM currency risk mitigation, however, are relatively lacking due to previously identified structural features. A perceived disinterest from practitioners as it relates to EM currency hedging may partially explain the gap in literature related to risk mitigation. Xin (2011) identifies various disincentives for investors to hedge away currency risk in EM, including high trading costs associated with illiquid foreign exchange markets and the inherent yield, or 'carry' attractiveness of local market interest rates. Where there is a strong base of literature, it has tended to focus on return-generation as opposed to risk-mitigation as with fundamental and technical-based studies (De Zwart, Markwat, Swinkels, & Van Dijk, 2009; Pojarliev, 2005) and on correlation between local market variation and carry trade features (Burnside, Eichenbaum, & Rebelo, 2007; Menkhof, Sarno, Schmeling, & Schrimpf, 2012).

The framework proposed addresses a gap in the literature that covers a broad representative spectrum of both EM countries and commodity baskets. Where commodity prices have been incorporated into EM risk studies, these works tend to bias towards global macro risk such as the aftermath of the 2008 financial crisis (Bova, 2012) or towards direct currency-commodity frameworks (Pedersen, 2019).

Where direct commodity-currency relationships assert via an import-export channel where demand for a commodity impacts demand for national currency, indirect currency-commodity relationships conceptually operate outside of traditional trade channels. Indirect relationships that do not assert during normal time-periods as the result of demand for exports denominated in local currency are scanned for during periods of stress where commodity prices still behave predictably in relation to currency fluctuations but as a result of local market conditions. A testing framework for indirect relationships is proposed in order to both account for crisis-period specific analysis as well as non-spuriousness by way of evaluating commodity correlation to currency as well as to local equity market. As local equity market returns are of primary interest in investigating currency hedging vehicles, commodity-equity co-movements are a natural avenue to validate economic indirect relationships between commodities and currency. A framework is proposed relating correlation coefficients (h) between commodities (c) and country currency (cy) so as to specify commodity-currency relationships during crisis periods in time series (i) analysis. The relevant crisis-state factor ($ø$) is further defined in Chapter 2. In order to identify indirect currency-commodity effects, both crisis-state correlation coefficients in currency-commodity and currency-equity measures must have the same sign as per equation (1.1), where positive or negative correlations may imply a relationship where economic asset and currency prices are affected in a similar manner. Several economic conditions that would give rise to such indirect relationships are discussed, and applications of such frameworks for EM currency risk are further detailed as contributions to the literature and practitioner fields.

Two instances of indirect currency-commodity effects are identified, arising from idiosyncratic economic conditions as expected per the conceptual framework: banana prices as they relate to the Brazilian real (Chapter 2), and sugar prices as they relate to the British pound (Chapter 3). The existence of two instances of indirect currency-commodity effects that exist absent a trade-based currency demand dynamic should promote further interest in identifying more of such relationships and their applications.

0.1.2 Crisis State Definition Methodology

Chapter 2 contributes a volatility-acceleration based methodology to crisis-state definition in the currency and commodity literatures as a means of detecting indirect currency-commodity relationships as proposed with Chapter 1's (*ø*) factor (equation 1.1). The practice of splitting time-series data into 'crisis' and 'non-crisis' periods for separate analysis is common in the currency and commodity fields, defining the turmoil period as beginning at a visible crisis-point and defining "the 'stable' period as [the preceding year], to the start of the turmoil period" (Forbes & Rigobon, 2002, p. 2238). The volatility-acceleration framework builds on previous use of such tools in future return estimations, though these methods have largely been confined to equity markets (He & Narayanamoorthy, 2019) or have appeared as proposals in currency option pricing theory (Baaquie & Cao, 2014) and long-term EM economic development indicators (Hausmann, Pritchett, & Rodrik, 2005).

A simple forward-looking acceleration function is proposed with (a^t) representing acceleration at monthly interval (t), and (v) representing monthly volatility price observations. Volatility acceleration is defined as the second derivative of volatility. As currency volatility enters a period of upward acceleration in excess of a stated sample average extremity, the signal implies periods of heightened local equity market drawdown risk over the following three months. As noted in equation (2.1), the framework disallows for downward acceleration 'false positive' signals, though in practice these false signals are not regularly observed as would be expected from well-established market insights on volatility derivative of the Leverage Effect (Black, 1976; Candelon & Straetmans, 2006). The acceleration function is tested against an extremity constant, Ψ^c, equal to twice the standard deviation of the entire in-sample monthly acceleration readings. For observations where $a^t > \Psi^c$, that month's observations are tagged as the beginning of a 'market stress' period, Ψ^1, defined as including the signal month and the following three months of data, or $\Psi^{t,t+1,t+2,t+3}$. The Ψ^1 signals form a data point, where the 'market stress' periods comprise a split of the time series. Where $a^t \leq \Psi^c$, observations are marked as 'normal,' or Ψ^0.

Acceleration in currency volatility is shown to provide an in-sample early warning signal of the onset of periods of negative equity return (Figure 2.3). In deploying this methodology, Chapter 2 demonstrates that indirect currency-commodity relationships, asserting themselves during times of stress, can be detected leveraging the volatility-acceleration based dual-state framework. This currency volatility-acceleration framework expands the field of literature to provide new tools to investigate crisis-period behaviour in financial instruments beyond arbitrary macro event timeframe definitions, and further informs market practitioners with validated risk-mitigation early-warning signals that have application in a wide range of instruments.

0.1.3 Pricing Power Detection Framework

A pricing power detection schematic, the *C-score*, is proposed following the investigation of a long-run stable correlation (pre-Brexit) between the British pound and European Union (EU) refined sugar import prices (Figure 3.1). This correlation was detected by accident as part of the indirect currency-commodity framework, though the strength of the relationship immediately identified it as warranting further investigation. Upon robust statistical evaluation, and after eliminating other causal direct and indirect currency-commodity channels, it is determined that this correlation is the result of an instance of pricing power being achieved by a single United Kingdom (UK) firm dominating sugar refining exports to the EU, where imported prices are a function of the British currency.

The proposed pricing-power detection framework is contributed as a means of more efficiently detecting such instances in future research. The framework is embedded in an industrial organization literature base that relates corporate consolidation measures to stability in profit margin, or variability in earnings before interest and taxes (EBIT) (Beyer, Kottmann, & von Blanckenburg, 2020; Brennan, Canning, & Mcdowell, 2007; Bresnahan, 1989; Cotterill, Egan, & Buckhold, 2001; Porter, 1985; Shinjo & Doi, 1989; Tichbourne, 2018, Round, 1983). This paper contributes to the literature in extending such industrial organizational frameworks to currency-commodity trade channels, and in developing a generalizable framework built off of established pricing power detection methodologies like low margin variability.

A *C*-score (C_g) is proposed, composed of (h) return correlation of commodity price (p) to producer/importer region currency (f), corporate consolidation measure (e) and normalization factor (*g*) for a sample of *C* scores among industry peers. A commodity-exporting company that demonstrates low profit margin, or EBIT, variability in a country with a high said commodity to national currency correlation will score highly under the framework. If the company scores highly relative to a basket of comparable companies, the framework suggests a higher likelihood of an instance of pricing-power. This framework is demonstrated in various forms of complexity, in graphical representation of base components as well as in a combined generalized methodology score as a means of broadening the field of research. Consolidation in the sugar industry specifically has been noted within the literature base (Benešová, Řezbová, Smutka, Tomšík, & Laputková, 2015), though the extension of currency-commodity correlation to such analysis has not as yet been demonstrated to the author's knowledge. The further addition of the British pound to the field of study within commodity currencies is intended to spur new investigations outside of heavily supply-chain oriented commodity baskets such as oil (Basher, Haug, & Sadorsky, 2012; Dauvin, 2014) where existing research has been concentrated.

Chapter 1
Indirect Currency-Commodity Effects

Abstract

Currency returns are significant contributors both to emerging market (EM) equity investment risk and EM investment performance. Currency hedging vehicles exist, but they are prohibitively expensive and hedge out performance. This paper proposes a conceptual framework to evaluate commodity prices as a natural hedging vehicle against EM currency drawdown risk by differentiating between direct, or trade linked, and indirect, or non-trade linked currency-commodity relationships. This framework addresses a gap in the literature, applying extensive research on direct demand for exported commodity materially impacting demand for national currency to cases of indirect currency-commodity effects where no import-export channel is present.

1.1 Introduction

This paper proposes a generalized conceptual framework to detect causal relationships during periods of financial stress in price changes between currency and commodities that assert themselves in instances of no direct import-export external demand links. It is well established that the investigation of currency risk is particularly important in emerging markets (EM), where following the works of Phylaktis & Ravazzolo (2004) currency risk is known to be a dominant contributor to local market equity returns. The study of currency-commodity correlation as a significant forecasting and risk-mitigation tool in the modern economy has been the subject of much investigation following the works of Chen & Rogoff (2003), where ‘direct’ currency-commodity correlation is observable in instances where a large share of country output (and concurrently, external demand for national currency) is related to the purchase or sale of commodity product. Emerging market economies where currency risk is pronounced entice foreign investment with high local interest rates as an offset against exchange rate volatility, making direct currency hedging prohibitively expensive for international investors seeking to mitigate currency-drawdown risk. The proposed conceptual framework seeks to address this problem by evaluating commodities as a natural hedge against emerging market currency risk, and by broadening the universe of potential commodity instruments to include instances where a commodity may provide a natural hedging exposure via an ‘indirect’ channel that is not related to import-export demand for currency.

This work should be of interest for policymakers looking to attract international investment and to investors attempting to mitigate local currency risk in a cost-effective manner. The EM focus is a result of both a gap in literature and a continued realignment of international growth in equity markets away from developed markets (DM). International financial investment allocations to EM are increasing in size along with rapid development that has put the countries of Brazil, Russia, India, and China (BRICs) on course to become the largest economic group by the mid-21st century (Cheng, Gutierrez, Mahajan, Shachmurove, & Shahrokhi, 2007). The higher prominence of EM in investment portfolios as a result of this growth combined with the significance of currency performance contribution to EM equity returns, as much as 45% in Morgan Stanley Capital International (MSCI) EM aggregate investment from 1998 to 2013 (Corominas & Scott, 2014, p. 3609), should lead to more focus around EM currency risk. There has been little previous investigation into EM currency hedging relative to DM peers, with disincentives to investor appetite for such work including the heavy costs associated with illiquid currency strategy implementation as well as the inherent yield, or 'carry' attractiveness of EM currency exposure (Xin, 2011, p. 6655). Commodity prices are a key link in appraising EM investment risk; due to historical economic dependence on the export of natural resources, "it is generally recognized that commodity prices can be a source of macroeconomic instability in developing countries" (Bodart, Candelon, & Carpantier, 2012, p. 1483). The growing importance of EM investment allocations with under-investigated associated risks pose a threat to international investment portfolios and deserve new priority as such.

There is a large amount of literature detailing the relevance of commodity prices to the currencies of commodity-linked economies, but even in EM markets that do not have typically strong economic dependence on commodity exports (Chen, Rogoff, & Rossi, 2010, p. 1181), the investigation into commodity market links to equity asset and currency prices has relevance. Previously demonstrated varying correlations between currency and asset markets in DM analyses (Antonakakis & Kizys, 2015; Creti et al., 2013) and rising EM commodity consumption (Basher, Haug, & Sadorsky, 2012, p. 228) suggest potentially significant linkages to be explored. These links may be either 'direct,' where the production of one commodity may be so central to the local economy or where a country has sufficient market power over a single commodity that variations in the price of said commodity would have a tangible economic effect observable via the domestic currency market, or they may be 'indirect' where a currency-commodity correlation may be observed as an effect of idiosyncratic economic phenomena.

Section 1.2 reviews the state of the field of currency-commodity research, and section 1.3 proposes the generalized indirect currency-commodity conceptual framework and discusses the nature of these relationships. Section 1.2.1 discusses currency research as delineated by forecasting versus risk mitigation. Sections 1.2.2 and 1.2.3 review the literature base of direct and indirect currency-commodity frameworks respectively. Section 1.2.4 reviews literature in equity-commodity linkages, and Section 1.2.5 discusses the literature's focus on EM relative to DM. The lack of generalized indirect currency-commodity evaluations and of EM risk mitigation research in the literature is identified as a motivating factor for the conceptual framework's proposal and applications.

1.2 Literature Review

1.2.1 Alpha Generation versus Risk Mitigation

A good deal of effort devoted to EM currency research centers on alpha generation, or on extending various DM currency management practices to EM to increase investment portfolio value via currency speculation. Though there have been efforts to extend DM fundamental and technical-based practices into EM with the aim to produce stronger returns for investors (De Zwart, Markwat, Swinkels, & Van Dijk, 2009; Pojarliev, 2005), structural differences including heightened 'carry' costs, political-risk impact and smaller market size relative to DM make this a niche-area within currency alpha-generation literature. Strong linkages between EM currency alpha-generation strategy performance and that of the carry trade, sensible considering the higher yield of EM compared to DM, make such strategies attractive to investors during times of low currency volatility, particularly given low observed correlations between carry returns and those of major DM equity indices (Burnside, Eichenbaum, & Rebelo, 2007). While such works may indeed provide researchers with additional analytical tools and findings to inform currency hedging work, an emphasis on currency risk-mitigation is important in highlighting the inherent dangers of such strategies given "significantly negative co-movement of high interest rate currencies…with global FX volatility innovations" (Menkhof, Sarno, Schmeling, & Schrimpf, 2012, Conclusion para 3). Investors embracing EM alpha generation strategies should be wary of increased susceptibility to financial shocks.

1.2.2 The 'Direct' Currency-Commodity Link

The initial observation of stable long-run relationships between commodity prices and currency markets in countries that have substantial economic dependencies on commodity exports followed the collapse of Bretton Woods in 1970 and the subsequent abandonment of pegged-exchange rates by developed commodity-export economies in the mid-1980s. Initial research into currency-commodity links tended to focus on three main examples of *commodity currencies*, with Australia, Canada, and New Zealand having a sufficiently long history of floating-rate currencies and being most directly identifiable as commodity economies with a "large share of their production and exports accounted for by primary commodity products" (Chen & Rogoff, 2003, p. 136). There is a wide and continually expanding base of literature on the ability of commodity prices to predict exchange rate movements in such known DM commodity currencies (Liu, Tan, & Wang, 2020; Roy & Bhar, 2020).

Prominent 'direct' commodity-currency links are frequently treated with skepticism given the observed economic volatility associated with resource-dependent economies. In EM, this harsh view of resource proximity is in part due to an increased vulnerability of small economies to large downside commodity price shocks. Bova (2012) demonstrates that shocks have been the subject of much discussion following the particularly vivid example of the 2008 global financial crisis and direct-effects for commodity (in this case copper) exporting EM countries such as Zambia:

> *"Following years of commodity price increases, the price fall caused a sudden reversal in the trade balance of many commodity exporting economies which had accumulat[ed] trade surpluses in the years of the boom…In economies with floating exchange rates and inflation-focused monetary policies, the reversal in the trade balance (aggravated by capital outflows) led the currency to depreciate. As a consequence, domestic prices increased, moving monetary indicators well beyond the targets for monetary policy. As the price fall occurred after the boom, depreciation followed a period of currency appreciation, dramatically intensifying instability and uncertainty for exporters and investors." (p. 768)*

Similar work has been done in the case of Chile, also heavily economically exposed to swings in copper prices (Pedersen, 2019). These examples demonstrate the practical necessity to further understand direct commodity-currency effects, as these can have long-lasting implications for monetary policy and economic activity.

This traditional commodity currency approach, however, implies only one direction of influence, and further investigation by Clements and Fry (2008) "suggested that commodity-currency models failing to account for endogeneity between currency and commodity returns may be misspecified" (p. 71). Clements and Fry's (2008) proposed theoretical framework posits that countries with pricing power over commodity markets may exhibit the reverse directionality, in currency influencing the price of commodities, and also supports the forward-looking informational view that "exchange rates should be useful in forecasting future economic variables" (Engel & West, 2005, p. 512). This particular directionality has been corroborated, with Chen et al. (2010) finding "strong and robust evidence that exchange rates can Granger-cause and forecast out-of-sample future commodity prices" (p. 1168), but not the reverse. The observation of multiple-directions of currency-commodity causality is key in that it admits the existence of correlations outside of a traditional *commodity currency* narrative framework tied specifically to the economic dominance of a particular article of trade.

1.2.3 Other Currency-Commodity Links

Currency hedging using alternative methodologies does indeed have a base of literature, though the applications to commodity-currency links in EM on a broad-enough basis are quite limited. Previous research has discussed using alternative hedging instruments to mitigate currency risk where 'Direct' vehicles are unavailable, employing financial tools such as futures contracts tied to local assets with high correlations to currency movements (Broll & Eckwert, 1999), though such examples are corporate-entity specific as opposed to an investment-portfolio level application.

Furthermore, investigation of correlations outside of traditional 'direct' frameworks encounter a structural disincentive related to complexity. Virtually all forms of economic activity impact the price of a currency, making it difficult for fundamental analysis to establish causality beyond easily observable commodity currencies. Furthermore, predictive tools as to currency forecasting are not static where "the predictability of fundamentals varies not only across countries, models and predictors, but also over time" (Rossi, 2013, p. 1066). Currency hedging offers challenges, particularly in EM, where "the complexity of the information required to assess economic exposure may involve different areas [and] its long-term nature makes it difficult to identify and measure economic exposure" (Fornes & Cardoza, 2009, p. 9). The difficulty of analysis has been cited as a contributing factor in the perception of a high cost-to-benefit ratio for currency hedging, leaving excessive economic exposures vulnerable to currency volatility (Martin & Mauer, 2003). The importance of currency to corporations is so central to cash-flow analysis that despite any lack of hedging activity it is still considered a core business function, where "the most important aspect of foreign exchange risk management is to incorporate currency change expectations into all basic corporate decisions" (Shapiro, 2003, p. 377).

It has also been observed that different types of firms respond differently to currency shocks, where firm size and status as a net importer or exporter can have significant impacts on sensitivity of returns to currency fluctuations (Solakoglu, 2005). Similar to crisis-event related studies in EM, however, these works tend to be country specific. A broadening of analysis to incorporate a basket of EM countries and a larger representation of commodity effects would be of great assistance to researchers looking to apply currency hedging frameworks to investment portfolios.

1.2.4 The Equity-Commodity Link

The effects of commodity price fluctuations would not only be expected to have influence over a country's currency, but also over various macro-economic factors and company-specific fundamentals. In addition to obvious commodity-linked stock implications, there is a robust literature related to the impact of commodities on broader country stock market performance. Creti et al. (2013), citing the increased use of commodities as a component of portfolio asset allocation and the financialization of commodity markets, employ a dynamic conditional correlation GARCH methodology to demonstrate various state-based correlations between commodities and the US stock market:

> *"First, the correlations between commodity and stock returns evolve through time, being highly volatile…the highest correlations are observed during the financial turmoil, showing increased links between stock and commodity markets. Second, some commodities are characterized by a speculation phenomenon, especially oil, coffee and cocoa: while their correlations with S&P 500 returns grow in times of increasing stock prices, they diminish in times of bearish financial markets. Third, the safe-haven role of gold is evidenced, as its correlations with stock returns are mostly negative and diminish in times of declining stock prices." (Conclusion section, para. 2)*

Specific commodities, oil in particular, have received much investigative attention in this respect due not only to their prominence in a wide array of manufacturing chain processes but also due to their broader macro-economic implications. For companies that are not involved with commodity import or export, rises in oil prices "increase the cost of doing business and…reduce profits. Rising oil prices are often seen as inflationary by policy makers, and central banks respond to inflationary pressures by raising interest rates which affects the discount rate used in the stock pricing formula" (Basher et al., 2012, Section 2, para. 1). In both DM and EM, it has been shown that changes in oil prices have impact on index-level stock prices, and similar levels of scrutiny with regards to broader commodity baskets have tended to focus on the United States and other advanced economies. Multi-directionality in correlational causality has also been investigated in this context (Ahmed, 2020), particularly in relation to the 2008 global financial crisis (Caporale, Hunter, & Ali, 2014), but these analyses are concentrated in DM economies with extensions to EM found wanting. Studies that jointly analyze the implications of currency, commodity and equity price fluctuations have covered both DM and EM cases, but have still been contained to well-known single-commodity instances such as oil (Lin & Chang, 2020) and gold (Aftab, Shah, & Ismail, 2018).

1.2.5 EM Applications

Within the commodity-currency literature, there has been a tendency to focus on DM examples given both the size of these markets and the relatively longer history of flexible exchange-rate regimes (Chen & Rogoff, 2003). There are some exceptions to this. For example Chen et al. (2010) include South Africa and Chile in their analysis of currency forecasting-power for commodities, and Cashin et al. (2004) use the International Monetary Fund's (IMF) seasonally-adjusted Consumer Price Index (CPI) based Real Effective Exchange Rate (REER) indicator to expand their sample of commodity-sensitive markets to 53 developing and 5 developed countries. In Cashin et al.'s (2004) analysis of long-run currency-commodity co-movement, 19 out of 58 countries showed evidence of being commodity currencies. Coudert et al. (2008) and Dauvin (2014) both include developing countries in their analyses, but both use a similar REER-based methodology and make the distinction between oil and commodity-exporting countries. The commodity-currency link literature additionally tends to exclude state-based analysis in long-run cointegration study, with the most notable exception being Antonakakis and Kizys' (2015) use of Diebold and Yilmaz's (2012) generalized VAR spillover index framework to conduct dynamic testing. This work, however, has previously mentioned constrictions in data sample scope in both currencies (limited to major DM pairs) and commodities (limited to precious metals and oil), making it difficult to apply to a wider range of equity portfolios.

There are recent EM-specific commodity market spillover investigations into currency factors, though these still tend to be regionally focused on major resource-linked economies such as Nigeria and South Africa on the African continent with (Fasanya & Awodimila, 2020), or focus on a wider group of DM and EM countries but with a narrow range of primarily metals commodities that would restrict results to mining-exporting economies as with Belasen & Demirer (2019).

Similar knowledge gaps exist in the commodity-equity link literature, where analysis has tended to focus on major developed economies and on oil impact rather than on broader commodity baskets. There is generally a more integrated state-based approach to identifying commodity-equity links. However, as in the case of Creti et al. (2013), where there is broad commodity-basket analysis it is usually only applied to large developed stock markets such as that of the U.S. In other words, there are robust investigations into long-run commodity-currency and commodity-equity ties, but there is little literature on a state-based, flexible commodity-basket approach with EM specific applications of all of these themes. There has been work done in currency-commodity causality testing within EM, but as previously mentioned is limited to direct currency-commodity relationships as defined by a limited range of country exports in the analysis (Belasen & Demirer, 2019).

One possible explanation for the dearth of research in this field is the perception that currency hedging is prohibitively expensive in EM (Kim, 2012; Martin & Mauer, 2003; Xin, 2011). Another layer of complexity is added when considering the fragmentation of various dominant EM currency markets between deliverable and non-deliverable forward (NDF) products arising from anti-speculative trading regulations:

> *"An NDF is similar to a deliverable forward. The difference is that no physical delivery of the local currency takes place at maturity, but that the contract is settled by making a net payment in US dollar or another convertible currency. This payment is proportional to the difference between the agreed forward rate and the realised spot rate (fixing). Additionally, NDFs trade in offshore markets outside the direct jurisdiction of the authorities of the corresponding currencies. The pricing of NDFs is not constrained to the domestic interest rates. In fact the NDF-implied offshore yields often differ from the onshore interest rates because NDF prices are also affected by supply and demand, liquidity, perceived probability of changes in the foreign exchange regime, and speculative positions."* (De Zwart, Markwat, Swinkels, & Van Dijk, 2009, para. 13)

The current widespread use of NDFs and similar products should provoke further investigation into use of alternative hedging assets, given the global financial systems' demonstrated willingness to embrace a diverse set of trading vehicles in the navigation of currency risk.

Previous investigation of alternative hedging vehicles, however, opens up extensions of 'Direct' currency-commodity links to 'Indirect' currency-commodity links in the pursuit of more economic downturn-protection vehicles. Such vehicles should be considered from a broad EM view, as not only is this more relevant to the international investment community but EM economies have exhibited tendencies to move in tandem in response to commodity or currency shocks. Such symmetrical responses to broad economic shocks (Eichler & Karmann, 2011), as well as similar studies into volatility transmission between geographically linked EM currency markets (Bubák, Kočenda, & Žikeš, 2011) demonstrate the significance of maintaining a broad-based view of EM, though incorporating individual economy characteristics to capture 'Indirect' effects is still important for further analysis.

1.3 Indirect Conceptual Framework

Indirect currency-commodity relationships are here defined as crisis-specific correlations between currency and commodity returns that are derivative of local market conditions absent an import-export external currency demand link. Where direct currency-commodity links follow a known causal channel of currency demand resulting from trade in commodity output, indirect relationships are unconnected to trade but are statistically observable as the result of unknown local economic conditions. Indirect currency-commodity relationships require a novel detection framework in order to test for suitability as a hedging vehicle for EM currency risk. Direct currency-commodity relationships assert via an import-export channel separate from other economic areas, whereas indirect relationships will arise from economic phenomena separate from import-export channels. As such, a framework for detection is developed that analyzes currency and commodity co-movement in conjunction with local equity prices. The indirect relationship must definitionally be observable between exchange rate and commodity prices but be detectable in an economic field additional to the supply and demand for national currency. An indirect relationship is conceptually stated to become visible specifically during times of financial stress; for a commodity to exhibit long-run positive correlation to currency would imply a direct relationship where supply and demand for one inform the other, while an indirect relationship is the result in changes of supply and demand. The appearance of an indirect relationship specifically during stress periods relates to expected disruptions in supply chains during crises where prices of commodities without explicit international trade links are linked to supply conditions (Dauvin, 2014, Section 2.1 para 3). Periods of financial stress that coincide with disruptions in supply-chains thus are expected to not only show currency distortion, but also those in domestic commodities.

Market shifts that produce a situational correlation between commodity and currency are useful from a currency hedging perspective, where if a commodity can be shown to co-move with currency during a time of stress it can then be applied to a portfolio in a manner that would re-create expected currency return by proxy during a time of crisis. Given the previously discussed expensive nature of EM currency hedging, such alternative natural hedge candidates that assert co-movement during periods when hedges are expected to perform is of great interest to researchers and practitioners alike.

A crisis-state factor (*ø*) is applied to correlation coefficients (h) between commodities (c) and country currency (cy) so as to specify commodity-currency relationships during crisis periods versus non-crisis periods in time series analysis. Separating time-series into 'crisis' and 'non-crisis' states is required so as to capture indirect currency effects, though discussion of existing approaches and nominal methodology is out of scope for this paper.

A robustness measure by way of local market equity price correlation is introduced into the framework. There is a high likelihood of spuriousness in conducting scans of commodity prices for correlation to emerging market currency prices, particularly during times of financial stress, given the established literature around the rise of co-movements for 'risky' assets. Globalization and the distortive effects of worldwide shocks akin to the global financial crisis have been shown to impact resource-sensitive economies (Bova, 2012), and as such false-positives are expected in performing broad screenings of commodity prices against national currency for relevant correlations. As local equity market returns are of primary interest in investigating currency hedging vehicles, commodity-equity co-movements are a natural avenue to narrow economic indirect relationships between commodities and currency. A correlation coefficient between commodity and country equity (e) time series during crisis-state periods is measured according to the same methodology as with currencies and commodities:

$$(1.1) \qquad (h^{\text{\o}}c,cy \,/\, h^{\text{\o}}c,e) > 0$$

The same-sign correlation restriction is added in order to identify economically significant relationships, where a commodity's relationship between an asset class, in this case equity markets, will be expected to have the same sign of relationship to currency markets where there is an economic causal channel between the two. A commodity with significant positively signed correlation to equity and currency markets, an example of a direct commodity-currency relationship, would potentially serve as a traditional alternative and less-costly hedging instrument ('carry' cost are avoided in shorting a synthetic commodity product as opposed to negative-yield accrued from directly shorting EM currency). Negatively signed correlation coefficients imply the existence of a natural hedge to local currency risk, where accumulating commodity exposure would provide synthetic protection against local equity and currency downturn without needing to employ a shorting contract.

This research is interested in screening for indirect currency-commodity relationships that assert themselves during times of crisis so as to be useable as natural hedging vehicles for crisis-state currency drawdown risk. As the underlying economic conditions defining such indirect relationships are unknown yet statistically identifiable, the identification tools are statistical in nature. There are several speculative economic situations that would give rise to indirect currency-commodity effects in EM. Such a situation may arise where a commodity is relevant to national output but is entirely domestically consumed and produced, where no import-export effects are observable. Manufacturing-input commodities such as oil, which enjoy a substantial literature in direct currency-commodity effects, do not fit this definition where if an energy self-sufficient economy experiences a period of financial stress the price of energy is not expected to rise absent a significant supply shortage. Commodities that relate to internal food supply-chains are likely avenues to observe indirect relationships, as small changes in supply during market-disruptive events are known to create large price swings of demand-inelastic products. Exported food products demonstrating a relation to currency price movements would fall under a direct commodity-currency relationship, though supply-chain disruptions in food networks that are not linked to trade may still produce economically significant links to currency that can be exploited for hedging purposes: an EM economy encountering periods of severe financial instability has been shown to exhibit hoarding-behaviors or supply-chain disruption in modern food networks. In the cases of the Philippines and Mexico, it has been demonstrated that a combination of low public food reserves-to-demand margins and increases in speculative financial capital has generated "rising prices and greater market volatility" (Rosset, 2009, p. 190). Particularly in cases of inelastic demand conditions where relatively small changes in supply have pronounced effects on price (Chadwick & Nieuwoudt, 1985), crisis periods can be expected to produce indirect currency-commodity effects where market stress that impacts demand for national currency coincides with stress in home markets surrounding commodity prices. Following the identification of such a food-based commodity that may exhibit indirect currency-commodity relationships, for example, food price return replication may be applied to an equity portfolio via a market-based hedging instrument during times of stress to offer synthetic protection against local currency downturn. Congruent to the definition of indirect currency-commodity relationships, such food prices would provide positive returns that are negatively correlated to currency returns during periods of stress, effectively mitigating negative portfolio performance without applying uneconomical currency hedge vehicles. Idiosyncratic currency-commodity correlations where equity indices are linked to commodity prices via abnormal channels may also be detected, such as instances of monopolistic pricing control over exported commodities. Further idiosyncratic relationships may arise in course of analysis for which causal economic explanations need to be elaborated, though this is a subject of future research as the indirect currency-commodity framework is further applied. This framework is parameterized chiefly as a means of expanding the field of literature beyond commodity-currency relationships that follow a trade channel.

1.4 Conclusions

This paper not only addresses the state of the field in commodity-currency research to incorporate equity price inputs as a core component, a previously lacking extension, it also illuminates the distinction between direct and indirect currency links as it relates to a body of research that has been primarily concerned with direct commodity-currency relationships. The importance of EM currency risk, a relatively under-studied field given a small market size compared to DM and practitioner hedging disincentives, is of particular importance in discussions of commodity risk transmission due to the sensitivity of these economies to global price shocks and a tendency towards export reliance in developing nations (Fornes & Cardoza, 2009; Burnside et al., 2007). Investment into EM equity markets is becoming an increasingly large component of global allocations alongside the relative outperformance of emerging economies versus developed counterparts, and brings with it a myriad of risks to portfolio managers. Significant linkages between commodity price fluctuations and those of currencies and equities have been independently established in the existing literature with indirect qualities, but these findings have yet to be applied to EM assets in a way that would provide better understanding for investors looking to manage the risks in investing in these markets. Given the prominence of currency as a contributor to equity returns in EM and the rising integration of commodities to financial portfolios, the existing literature is in varying capacities either too specific in scope, either related to the focus on developed markets or on specific commodities, or too general in avoidance of state-based analysis to address these concerns with sufficient urgency. The here-proposed conceptual framework builds on efforts to unify direct commodity-currency and commodity-equity research to EM, and in establishing a generalized indirect commodity detection framework expands the field of research in commodities using EM currency and equity market indices. Testing for indirect currency-commodity effects and evaluating potential candidate phenomena under statistical robustness testing and economic analysis is an important next-step to validate the framework under both traditional direct conditions as well as those that would provide new hedging avenues to mitigate currency risk.

Chapter 2

Going Bananas in Brazil: Indirect Currency-Commodity Links in Emerging Market Risk Reduction Analysis

Abstract

This paper asks whether there are naturally occurring hedges to mitigate currency risk for investors in emerging markets (EM). A novel crisis-definition tool, currency volatility acceleration, is used to identify country-specific commodity effects that exist absent a national trade-link and provide a non-synthetic performance hedge relative to currency movements. The crisis-definition framework identifies a direct (or 'traditional' long run trade-linked) currency-commodity effect in Mexico and an indirect effect (crisis-based and absent a trade link) in Brazil, the latter of which is demonstrated to provide risk-mitigation benefits for equity investments in and out of sample using a volatility acceleration-based hedging strategy.

2.1 Introduction

This paper is interested in mitigating currency drawdown risk in emerging market (EM) equity investment portfolios. Commodity prices are investigated as a natural hedge against currency risk. Indirect currency-commodity effects, defined as commodities that do not have an established external trade link to national currency yet demonstrate correlations to currency and asset markets during times of crisis, are the focus of the efforts. A novel crisis-detection framework is defined using currency volatility acceleration to isolate economy-specific periods of stress for analysis and more effectively detect indirect currency-commodity relationships. The analysis that follows contains five discrete functions as discussed in Section 2.3 to identify commodity indices for potential use as synthetic currency hedges: (1) defining the crisis-detection framework, (2) detecting direct and indirect currency-commodity effects, (3) explaining how the identified currency-commodity-equity correlations change in and out of crisis periods, (4) robustness testing and (5) hedge framework application. Traditional direct currency-commodity effects are demonstrated in Mexico, and Bananas are identified as creating an indirect currency-commodity effect in Brazil. The economic value of a hedging strategy for Brazilian equities based on these results is detailed in Section 2.6, and further validates the extension of commodity price signals to currency hedging products in EM (Eaker & Grant, 1987).

Acceleration in volatility is employed as a crisis-definition tool to take advantage of the relationship between higher-volatility and associated lower returns, as well as the higher-volatility profile of EM currency risk. Volatility acceleration is a strong crisis definition tool as it does not rely on arbitrary time series breaks and effectively identifies the onset of stress periods. In applying volatility acceleration methodologies to EM, the problem of heightened sensitivity to currency-effects is addressed through a currency-drawdown early-warning signal that is specific to country investments. The crisis-state definition tool is shown to be effective in predicting extended periods (one to three months) of currency market distress in various EM countries and provides researchers and practitioners with a new mechanism to investigate state-based relationships and forecast periods of market stress that are aligned to specific country risks as opposed to broad-based global market factors. The focus on commodities as an alternative currency hedging vehicle is employed so as to broaden the field of research in making portfolio 'currency insurance' effectively more affordable for international equity investors, where hedging local currency exposure via traditional foreign exchange instruments incurs negative carry costs that significantly diminish investment returns (Xin, 2011, p. 6655). Though specific commodity instruments may require additional practitioner-market analysis for cost effectiveness screening, the virtue of investigating commodity prices as a natural hedge against currency devaluation risk is well understood through examples such as gold and other precious metals following the global financial crisis (Bedoui et al., 2020). This methodology's implementation serves to expand the field of literature to extend new currency-commodity correlation analyses beyond traditional direct import-export demand channels and into investigation of further indirect instances of economic commodity relationship to currency and equity markets absent such a 'commodity currency' trade framework. The application of these findings to an EM currency hedging framework is intentional in addressing a gap in the literature in broad-based currency-commodity-equity studies, as well as in providing investors and policymakers new tools to promote international investment into EM with reduced currency drawdown risk.

Data used for analysis is detailed in Section 2.4. The analysis in Section 2.5 suggests that such indirect relationships do exist in the case of banana prices and the Brazilian economy. In the absence of a substantial export market, the country's major world producer status and close proximity to large US dollar-based exporter economies creates an environment where banana prices can be used to hedge against Brazilian real depreciation. A further discussion of these results, and of applications in a currency-hedging framework, follows the analysis in Section 2.6.

2.2 Literature Review

Hedging EM currency risk via direct currency products is not only prohibitively expensive given higher volatility and interest rates as compared to developed markets, it is also detrimental to portfolios in that it reduces return by eliminating higher interest rate yield that is implemented to entice foreign investment in the first place. The use of alternative products to mitigate currency risk is especially urgent in EM localities such as Brazil where market regulators have capital controls in place. As Brazil trades under a 'non-deliverable forward' regime for overseas investors, hedging currency risk using currency products includes interest rate differentials. Interest rate yield cannot be separated from forward currency hedges under this scheme, and thus identifying an object that correlates with currency without hedging away interest rate yield is novel and valuable to EM investors and researchers. Alternative hedging vehicles that mitigate currency-related drawdowns without eliminating upside currency risk premium entirely is desirable for investors in this asset class as for EM "the currency risk premium is substantial and forms a big part of the total risk premium, dominating it at times" (Phylaktis & Ravazzolo, 2004, Section 5 para 5). The indirect currency-commodity framework posits that commodities exhibiting strong correlation patterns to currency and equity markets during stress periods, in spite of a lack of a traditional 'commodity currency' relationship where demand or supply of a commodity would have material impact on demand for national currency, will function as valid natural hedges against currency risk should an indirect relationship exist.

This field of study is significant in that an EM investor is by near definition a currency investor, beset by relatively high volatility. Local currency performance has been shown to contribute as much as 45% of returns in Morgan Stanley Capital International (MSCI) EM aggregate investment from 1998 to 2013 (Corominas & Scott, 2014, p. 3609). EM currency is furthermore a cumbersome beast to manage, given a higher historical volatility profile as compared to Developed Market (DM) currencies and less liquidity available to investors (Xin, 2011, p. 6655). The increased prevalence of EM economies in global investment (Cheng, Gutierrez, Mahajan, Shachmurove, & Shahrokhi, 2007), concurrent with the modernization of regional powerhouse economies such as Brazil, creates new urgency in the search for alternative currency hedging methodologies to make asset allocation more sustainable, or to avoid traditionally distortive effects of currency drawdown on EM portfolios where, continuing with the example of Brazil, currency crises have had "debilitating effects" (Campa, Chang, & Refalo, 2002, Section II, para 1). Currency hedging in EM is historically prohibitively expensive, a problem exacerbated by the high dependence on currency risk in such products to portfolio return (Corominas & Scott, 2014). Commodity prices, enjoying an established literature around currency ties to commodity-concentrated export economies, are a natural venue for further alternative currency hedging exploration in EM as "it is generally recognized that commodity prices can be a source of macroeconomic instability in developing countries" (Bodart, Candelon, & Carpantier, 2012, p. 1483). Though there has been study of currency-commodity correlation in EM during periods of volatility, research has tended to focus on either highly inflation-linked commodities such as oil (Basher, Haug, & Sadorsky, 2012) or on the effects of exogenous shocks like the global financial crisis on highly resource-sensitive economies (Bova, 2012) as opposed to local-currency specific effects where indirect effects may assert themselves on regional supply chains.

There is additional need to study new hedging avenues for EM currency risk given recent underperformance of local currency index returns. This phenomenon, as seen in the underperformance of the MSCI EM unhedged versus MSCI EM 100% hedged to US Dollar series over the same analysis window despite a stronger recovery following a deep underperformance in the 2008 global financial crisis (Figure 2.1) has been a particularly important development to the international investment community. Annual return outperformance of the 100% currency hedged to US Dollar series has averaged 2.54% over the unhedged series in the 2010-2020 period at the <1% significance level. Though 100% currency hedging vehicles are unlikely to be taken up in-large by the community, with associated carry incentives of local currency investment being a core contributor to EM investment return (Corominas & Scott, 2014), alternative products that provide protection against sharp currency-related drawdown will be of increasing interest to equity market investors as EM regions continue to modernize and attract capital inflows. The recent relative outperformance of 100% currency-hedged vehicles may suggest that global investors already have access to risk-reduction vehicles. Reliance on such US-dollar specific hedging vehicles, however, exposes non-US investors to fluctuations in the US dollar and US monetary policy shifts in their EM allocations. Non-US investors would benefit from country-specific hedging vehicles to avoid compounding currency risk by relying on US-dollar products. Commodity-based natural hedging vehicles can help investors avoid compounding currency risk while employing country-specific strategies. Country-specific currency hedging products retain the criticisms of high-fee and high interest-rate penalty costs (Xin, 2011), and thus alternative measures at the country level such as economy-specific commodity prices are of interest.

Indirect relationships that assert themselves on national currency via non-traditional direct import-export channels are detected by establishing a dual-state volatility framework, constricting the time series to crisis and non-crisis periods where acceleration in volatility is used to mark periods of turmoil. Acceleration in volatility provides an early warning signal of the onset of periods of heightened downside return risk as EM products with local currency exposure and concomitant high yield, or 'carry,' risk factors typically underperform in periods of stress (Roussanov, Verdelhan, & Lustig, 2014). Allocations to EM in spite of higher volatility risk have historically been justified by a stronger recovery due to a combination of that very carry factor driven by local central bank investment-incentive generation, and by a front-loaded currency drawdown effect where the largest losses occur in the immediate aftermath of a downside market trigger. The latter is derivative of the leverage effect (Black, 1976), though leveraging volatility acceleration may enable investors to avoid front-loaded losses and better predict drawdowns. This acceleration methodology builds on previous work in applying acceleration frameworks to future quarterly return estimations (He & Narayanamoorthy, 2019), though these methods have largely been confined to stock market analysis. Related to the leverage effect, where acceleration in volatility may be seen as a precursor to market negative events, the use of volatility acceleration has been previously proposed in currency options pricing theory (Baaquie & Cao, 2014) where in periods of crisis "[options] traders have less confidence in the market," (Baaquie & Cao, 2014, p. 348) though this research has yet to be extended to practical applications in EM. There are examples in EM research of applying long-term economic growth acceleration as it relates to development (Hausmann, Pritchett, & Rodrik, 2005), but to the best of the author's knowledge this is the first attempt to apply acceleration frameworks to EM currency volatility analysis. Volatility measures are employed specific to each country series' as opposed to a synchronous multi-country crisis definition tool, where the literature on equity market contagion suggests "no evidence for a clear relationship between excess co-movement and commonly used crisis samples" (Mierau & Mink, 2013, para. 4).

Commodity prices are often referenced in economic surveys of EM's from a fundamental analysis perspective, and in cases where a direct currency-commodity effect exists (Chen & Rogoff, 2003) these may certainly already be said to be viable to investors as hedging instruments in markets where a single commodity is so central to economic output in a heavily export-sensitive economy (Dauvin, 2014) that demand for said commodity may directly impact the demand for the relevant national currency (Clements & Fry, 2008). Many existing studies focus on the oft-studied relationship between oil exportation and risk of Dutch disease symptoms, particularly in EM (Kutan & Wyzan, 2005). This paper includes such commodity relationships in comparable analysis of correlation to Mexican direct equity and currency market returns (Coudert, Couharde, & Mignon, 2008), but the bulk of the analysis is dedicated to applying indirect commodity links where there is an underlying valid economic tie between commodity and equity-currency markets that is not explained by a direct commodity export or import dynamic. The goal of this analysis is to investigate as-yet unexplored economic relationships surrounding indirect currency-commodity effects, and to expand existing research into economies that would benefit from newly available currency hedging instruments as a method of making inbound equity investment more sustainable in the face of currency-drawdown risk.

This paper expands the area of research to include more such questions of indirect causal relationships between non-trade linked yet observably correlated commodity-currency markets where negative correlations only exist in certain defined states as opposed to asserting themselves continuously. Such relationships have been observed in cases of non-economic factors such as political turmoil impacting local market and commodity prices (Melvin & Sultan, 1990), as well as in cases of financialization of commodities as collateral where higher capital controls in emerging economies are associated with higher global commodity prices (Tang & Zhu, 2016). Continuous observation of strong correlations is rare even in cases of established direct currency-commodity relationships, as the importance of global macro factors (Belvisi et al., 2016) is well documented as a contributor to portfolio returns where periods of broad investor-behaviour alignment during crisis periods can create instances of contagion (Forbes & Rigobon, 2002) in equity markets with little economic overlap (Dungey, Fry, González-Hermosillo, & Martin, 2006).

2.3 Methodology

The indirect currency-commodity implementation methodology is comprised of the following four stages: crisis definition via volatility acceleration, candidate verification, crisis-state correlation change estimation, robustness testing and then application. Initially screening commodity series' candidates for EM currency hedging vehicles is first done through a joint currency-commodity-equity analysis, where relationship validation and robustness testing are performed on the currency-commodity level. As the hedging methodology is concerned with equity investment portfolio risk reduction, equity prices are re-introduced during a final volatility-acceleration based hedge application experiment. Equity prices are not a component of the substantive analysis, however, as commodity prices are employed in order to hedge currency risk. This hedging methodology could be applicable to a wide range of asset portfolios beyond equity investments, though for demonstrative purposes the paper focuses on equity investments.

2.3.1 Crisis Definition via Volatility Acceleration

Currency, commodity and equity time series are split into crisis and non-crisis states in order to analyze commodity series' explicitly in a crisis context where they would be expected to act as a hedge against market-downturn risk. The screening mechanism employed to such ends is derived from acceleration signals in volatility pricing. Monthly measurements are used so as to maintain consistency with IMF commodity basket inputs, which are available on a monthly basis (International Monetary Fund [IMF], 2017). A simple forward-looking acceleration function, (a), the product of the velocity of the previous-to-current month's indexed volatility change versus that of the previous month's, is constructed. With (a^t) representing acceleration at monthly interval (t), and (v) set to monthly volatility price observations, the framework is illustrated as follows:

$$(2.1)\ a^{t} = \left[\left((v^{t} - v^{t-1}) / v^{t-1} \right) - (v^{t-1} - v^{t-2}) / v^{t-2} \right] \ / \ \left[(v^{t-1} - v^{t-2}) / v^{t-2} \right] ;\ (v^{t} - v^{t-1}) > 0$$

Acceleration signals are only observed in cases where the second derivative of volatility is positively signed in the numerator (i.e. removing downward-acceleration events). While the acceleration signals' basic equation disallows for downward acceleration 'false-positives,' in practice this is not regularly observed and occurs in fewer than 25% of total observations across all country currency series' in the 2004-2014 period. This finding is in line with established market observations around the behavior of volatility as a predominately price-negative event (Black, 1976; Candelon & Straetmans, 2006).

This acceleration function is then tested against an extremity constant Ψ^c set as twice the standard deviation of the entire in-sample monthly acceleration readings (2004-2014) where $\Psi^c = 2*\sigma(a)$. For observations where $a^t > \Psi^c$, that month's observations are tagged as the beginning of a 'market stress' period, Ψ^1, defined as including the signal month and the following three months of data, or $\Psi^{t,t+1,t+2,t+3}$. The Ψ^1 signals form a data point, where the 'market stress' periods comprise a split of the time series. Where $a^t \leq \Psi^c$, observations are marked as 'normal,' or Ψ^0. This methodology reflects the standard practices in financial market crisis-definition literature of defining the turmoil period as beginning at a visible crisis-point and defining "the 'stable' period as [the preceding year], to the start of the turmoil period" (Forbes & Rigobon, 2002, p. 2238). Observations within the Ψ^1 market-stress periods are isolated and analyzed independently of normal Ψ^0 periods. A volatility-gating structure provides the benefit of capturing distortive moves in currency markets, where sharp moves relevant to recent history give more context in the distortive nature of currency drawdown. The methodology has the added benefit of expanding on research that time-dummy variables are significant in specifying cross-market correlation models (Büyüksahin & Robe, 2014) and time-varying analysis states (Wen, Wei, & Huang, 2012) yet separating itself from such efforts that rely on arbitrary crisis-state definitions around large global events such as the 1997 East Asian Crises (Forbes & Rigobon, 2002) or the 2008-9 global financial crisis which will "generally…cause asset prices to plunge across markets and will create speculative runs and capital flight, leading to considerable market instability" (Wen et al., 2012, p. 1435). Alternatively relying on a nominal volatility threshold to discern states of volatility may create a number of false-positives should currency markets remain in elevated-volatility environments, a common feature of EM currency where volatility tends to be more elevated compared to DM currencies (De Zwart, Markwat, Swinkels, & Van Dijk, 2009). There is a known limitation to the methodology, where in the case of volatility starting from a low base a small rise will trigger a large acceleration signal. There are cases where this 'low base' effect is observable, such as with the first such observed acceleration signal in South Korea (Figure 2.2), but this does not become a pronounced factor in the analysis as EM currencies tend to exhibit high levels of base volatility.

The volatility acceleration methodology provides an alternative analysis tool to a percentile-based or similar state definition for the simple reason that EM volatility is sensitive to global systemic risk, as evidenced by the large impact in-sample of the global financial crisis where analysis would be heavily skewed given the well-analyzed commodity-to-equity market spillover effects of the Lehman crisis where "cross-market correlations increase in globally bad economic times" (Büyüksahin & Robe, 2014, p. 64). Furthermore, volatility acceleration gives a more economy-specific view of abnormal events, where otherwise analysis would be tainted by the prevalence of common volatility factors. This can be visually articulated by comparing individual country Ψ^1 signals to series of signals marking the top 5% of indexed volatility levels (Figure 2.2), and reflects the preference of this paper in siding with a turmoil-period marker methodology as described by (Forbes & Rigobon, 2002) as opposed to a quantile-of-return extremity threshold based methodology (Bae, Karolyi, & Stulz, 2003, p. 726).

2.3.2 Candidate Verification

Commodity price correlation coefficients are measured against country equity and currency series in crisis states so as to determine the manner in which they may be used as a synthetic hedge against currency downturn risk. In measuring correlation coefficients (*h*) between commodities (*c*) and country currency (*cy*), and between commodity and country equity (*e*) time series during volatile post-Ψ^1 signal periods, both correlation coefficients must be of the same sign to be considered valid for currency hedging potential. The same-sign requirement is imposed as a means of eliminating spurious relationships from the analysis.

A commodity with a positively signed correlation to equity and currency markets, an example of a direct currency-commodity relationship, would potentially serve as a traditional alternative and less-costly hedging instrument (it would potentially be cheaper, by accruing less 'carry' cost, to short a synthetic commodity product than to short EM currency). Negatively signed correlation coefficients, evidence of indirect currency-commodity relationships, imply the existence of a natural hedge to local currency risk, where accumulating commodity exposure would provide synthetic protection against local equity and currency downturn without needing to employ a shorting contract.

2.3.3 Crisis-State Change Estimation

After testing for cointegration (Engle & Granger, 1987),[1] an Ordinary Least Squares (OLS) regression of currency and commodity series returns under CAPM specifications (Demirer, Kutan & Chen, 2010, p. 286) is executed in STATA™ using the crisis-period data using both a restricted crisis-period-only time series set as well as a full sample time series set including a dummy variable for periods of crisis. This is done in order to both test for spuriousness and to determine whether the relationship between currency and commodity change during crisis, as well as whether or not the relationship during crises is significant. Various base currencies are used to ensure the results are not dependent on US dollar effects. The chosen variable base currencies are the euro, Swiss franc and Japanese yen. These monthly logarithmic returns in variable base currency exchange

[1] It was concluded that it is difficult to find a robust cointegrating relationship, leading to the implementation of methodology section 2.3.4

rates set against EM currencies are derived from spot and forward prices in the same forward-tenor as the US Dollar-based testing series.

In order to validate the volatility-acceleration methodology and to clarify the state-based nature of the relationship between selected currency (*Currency*) and commodity (*Commod*) time series returns, under OLS regression a dummy variable (D; $1 = \Psi^1$, $0 = \Psi^0$) is used to separate Ψ^1 signal *t* periods versus non-signal periods:

$$(2.2) \quad \text{Currency}_t = \alpha + \beta\text{Commod}_t + \gamma\text{DCommod}_t + \varepsilon_t$$

For significant readings where commodity returns will either demonstrate increased positive correlation to currency returns (direct relationship) or more severe negatively signed coefficients (indirect relationship) during crisis periods as relative to non-crisis states, the volatility acceleration methodology can be seen to correctly identify both crisis periods as well as potential hedging vehicles. Following hedging vehicle identification, a sample US dollar portfolio of relevant EM equity exposure hedged with commodity prices over the sample period and out of sample is described. Leveraging the formulation of equation (2.2), commodity exposure is added to monthly portfolio returns during the three months following an in-sample derived Ψ^1 signal.

2.3.4 Robustness Testing

Following the verification of potential synthetic hedging vehicles, the full-sample relationships between commodity and currency series' are further defined. An optimal-lag Autoregressive Distributed Lag Model (ARDL) is implemented in STATA^{TM}, where currency (*Currency*) level time series returns (*r*) are described by lagged currency, commodity (*Commod*) and crisis-state commodity (*DCommod*) returns. Dependent variable lags (*p*) and for (*i*) number of exogenous variables, variable lags (*q*) are selected via an Akaike information criterion (AIC). A constant (α) and (ε) is a vector of error terms are tested for significance. The crisis-state (*DCommod*) commodity returns are dummy-variable (*D*) specified as in equation (2.2):

$$(2.3)\ r\text{Currency}_t = \alpha + \sum_{i=1}^{p} \lambda_i\, r\text{Currency}_{t-i} + \sum_{i=1}^{q1} \beta_i\, r\text{Commod}_{t-i} + \sum_{i=1}^{q1} \gamma_i\, r\text{DCommod}_{t-i} + \varepsilon_t$$

Where return variables are not found to be significant, the ARDL model is re-run with non-significant variables excluded. Residual autocorrelation is tested for under Breusch-Godfrey (1978) parameters, as is heteroscedasticity under a White test implemented in STATA™. As the relationships between currency and commodity prices are designed so as to be useable in equity-portfolio hedging applications, an additional ARDL model is specified to include non-contemporaneous (*LagEquity*) equity returns, conditional on the exclusion of previously stated non-significant (*Commod)* or (*DCommod)* return variables. Though the objective is to hedge the currency component, the inclusion of equities in the model must be tested so as to ensure that a higher model R^2 explanatory power does not alter the relationship between currency and commodities. Contemporaneous equity returns are excluded as significant equity-currency relationships "are not contemporaneous but occur in a lead-lag fashion from equities to currencies" (Turkington & Yazdani, 2020, p. 71):

$$(2.4)\ r\mathrm{Currency}_t = \alpha + \sum_{i=1}^{p} \lambda_i\, r\mathrm{Currency}_{t-i} + \sum_{i=1}^{q1} \beta_i\, r\mathrm{Commod}_{t-i} + \sum_{i=1}^{q1} \gamma_i\, r\mathrm{DCommod}_{t-i} + \sum_{i=1}^{q2} \eta_i\, r\mathrm{LagEquity}_{t-i} + \varepsilon_t$$

The equity-inclusive results are anticipated to increase model explanatory power and are implemented with Huber/White/sandwich (White, 1980) robust standard errors in STATA™.

2.4 Data

The economies in scope for this analysis are Brazil, India, Mexico, South Korea, South Africa and Taiwan. The six-country basket representatives offer a testing ground for the volatility acceleration analysis, while Mexico is employed to test the volatility-acceleration framework for correct identification of direct relationships as a traditional 'commodity-currency,' and Brazil is introduced to test indirect currency-commodity hedging applications. The indirect and direct frameworks are tested in the Latin American regional sphere of Mexico and Brazil. As Mexico is a traditional commodity-currency, the IMF all commodity price index is used for direct relationship analysis. For Brazil, bananas were selected as a major agricultural product with no explicit trade link. This group has been selected by isolating the top 80% by market-capital weighting of the MSCI EM basket. The six-country grouping comprises Asian, African and Latin American regional economic exposures, making it a valid field of study for broader EM applications. The principal exclusion from this group, notably, is China. Up until 2019, Chinese representation in the MSCI EM basket was comprised exclusively of equity shares denominated in Hong Kong dollar. Though such Chinese H-Class shares are a significant component in the MSCI EM basket, due to Hong Kong's maintenance of a currency board system these shares bear little to no foreign exchange risk (Jao, 2002). There is as yet not enough long-run data either within the MSCI series or in alternative series' with independently verifiable quality to analyze local Chinese equity-currency markets. The expansion of the MSCI EM to include direct Chinese mainland exposure certainly provides a new avenue of analysis for future researchers but is out of scope for the purposes of this paper.

The inclusion of South Korea in the EM basket, though in keeping with MSCI standards, may be described as contentious given that the Republic of Korea ranks 5th in the world in terms of economic complexity (Simoes & Hidalgo, 2011). This also differs from World Bank definitions, where South Korea is classified as a 'High Income' country (The World Bank, 2021). These criticisms are valid from a developmental perspective, and it is likely in future research that such definitions will change as standard practice. For this paper's purposes, the Korean won is included in the analysis due to investor/market standard as well as due to similarity in top 5% volatility readings (Table 2.2) to other EM countries in sample. The rest of the EM sample is in-line with both market and policymaker definitions as Brazil, Mexico, South Africa, Taiwan and India all fall into 'Low & Middle Income' brackets (The World Bank, 2021).

Table 2.2

Volatility Acceleration Ψ^1 Signal Versus Top 5% Volatility Signal Cross Correlation Analysis

Ψ^1	Brazil	South Africa	Taiwan	South Korea	India
South Africa	0.340				
Taiwan	0.270	0.397			
South Korea	-0.031	-0.022	0.270		
India	-0.022	-0.015	-0.019	-0.022	
Mexico	0.428	0.625	0.236	-0.035	-0.024

Top 5%	Brazil	South Africa	Taiwan	South Korea	India
South Africa	0.849				
Taiwan	0.849	1.000			
South Korea	0.698	0.849	0.849		
India	0.548	0.548	0.548	0.548	
Mexico	0.849	0.849	0.849	0.849	0.548

Note. Top "Ψ1" results refer to currency volatility acceleration signals in each country series, and Bottom "Top 5%" results refer to 95th percentile threshold of in-sample currency volatility signals in each country series.

Data used in this analysis are a combination of market currency prices and external source equity and commodity indices, as listed in Table 2.1. Currency spot, forward, non-deliverable forward and volatility prices are sourced via Bloomberg and Reuters, while equity and commodity returns are proxied via the relevant MSCI country indices and IMF commodity baskets respectively. Descriptive statistics for time series logarithmic returns over the full dataset history are listed in Table 2.3.

Currency volatility is measured via the 3-month US Dollar / local currency at-the-money option volatility instrument as the Ψ1 state is defined as a quarterly period. This also conforms to aforementioned market practice, where 3-month option prices enjoy greater trading liquidity over standard International Money Market (IMM) maturation windows. As the analysis is limited to monthly returns given the restrictions on available data for the IMF commodity baskets, currency price inputs use market 1-month forward prices. Non-deliverable forward market prices are used for Brazilian Real, Indian Rupee, and the New Taiwan Dollar as these are hedging instruments available to offshore investors and are thus relevant for risk-mitigation analysis. Data used in the first-round volatility screening analysis is taken 'in-sample' over the 2004-2014 period, where out of sample hedge applications data for Brazil is added over the 2010 – 2020 period.

The construction of this dataset is unique not just in terms of comparing a broad basket of commodity prices to non-traditional commodity-currency economies and local equity markets, but also because it uses market-based hedging instruments such as non-deliverable forward outrights to evaluate asset correlations as opposed to currency spot prices. Direct currency spot prices are not accessible to international investors in the case of three of the observed EM economies. Currency spot prices additionally do not appeal directly to market participants with risk-mitigation priorities in that spot prices are not widely useable as forward hedging instruments, and forward term risk premia is excluded. Despite offshore forward exchange rate variability as a store of future exchange rate information (Froot & Frankel, 1989) and historically observed deviation from onshore interest rate sources (Ma, Ho, & McCauley, 2004), forward risk premia in EM should be included in analysis given interest in international investor exposure to currency excess return (Gilmore & Hayashi, 2011) and relative less bias (Frankel & Poonawala, 2010), or more predictive qualities in forward rates given the high concentration of carry risk compared to DM.

Further expansion of the out of sample period is out of scope for this paper, as inclusion of 2019 data would have to include additional considerations for Chinese A-share MSCI basket inclusion and would materially impact the long-run analysis format. Analysis of the post-2020 period, particularly as it relates to the normalization of DM monetary policy and impacts on EM, are important avenues of further exploration in the field as the unwinding of extraordinary central bank measures post 2008 financial crisis and recovery from the global COVID-19 pandemic continues to take form.

2.5 Results

2.5.1 Volatility Acceleration-Based Crisis-State Definition

A cross-correlation comparison between countries of the Ψ^1 signals and top 5% volatility level time series' reveals a distinct advantage for the volatility acceleration methodology. There is a strong cross-correlation in a simple volatility level reading, to the extent that in the case of South Africa and Taiwan the top 5% readings are identical, while the Ψ^1 series' enjoy much more differentiation (Table 2.2). As the goal of the analysis is to evaluate country-specific hedging instrument validity, a minimization of common risk factors greatly favours the volatility acceleration-based framework over more straightforward analysis methods, though the framework does not produce universally strong results across EM: India, for example, demonstrates an upwardly trended volatility regime over the sample period that would defy a variety of crisis-definition methodologies (Figure 2.2). This is illustrated by comparing the volatility acceleration signals to the average monthly equity returns over varying time horizons post-signals, where currency volatility events in India on average produce larger than total-sample average returns across all observed windows (Figure 2.3). The results of the methodology are able to successfully define volatility periods in Mexico, South Africa, South Korea and Brazil, where the Ψ^1 signals capture a large number of upward volatility-anticipatory identifier periods and indeed coincide with periods of lower-than-average returns in equity market indices versus total series average (Figure 2.3).

As for the results of Taiwan, an established anti-volatility mandate by the Central Bank of Taiwan (Park & Kim, 2019), visible in the low sample currency volatility data (Table 2.3, Row 8 Column 3) versus all other currency standard deviations, may explain the relatively muted 2 and 3-month impact of currency volatility events (Figure 2.3).

2.5.2 Direct and Indirect Results

Mexico appears to exhibit direct currency-commodity-equity correlations, while Brazil evidences indirect correlations. In both cases of Mexico and Brazil, currency and commodity variables demonstrate one order of integration though do not evidence cointegration (Tables 2.5, 2.6). Dummy-variable regression evidence for Mexico would appear to affirm a direct currency-commodity relationship, as verified under robustness testing. The results of Brazil demonstrate a statistically significant indirect currency-commodity relationship where: banana prices are long-run insignificant to currency prices but crisis-state significant with a negative coefficient. These findings offer further scope for analysis of indirect currency-commodity phenomena under variable-state volatility acceleration frameworks.

2.5.2.1 Mexico – Direct Currency-Commodity Framework

Mexico's currency demonstrates a high currency correlation to the All Commodity Price Index (including Fuel) (Figure 2.4), but this is not unusual given the country's role as a global exporter and traditional observations of oil as an input in the manufacturing process (Antonakakis & Kizys, 2015, p. 304). The correlation is positively signed, which fits in with a traditional direct currency-commodity correlation framework where increased price and/or demand for an exported product will increase demand for the national currency abroad as well as have positive effects in the local economy (Clements & Fry, 2008, p. 55).

The Mexico currency, equity and commodity series' all exhibit significant lags, explained primarily by one lag of autocorrelation and none reject the null hypothesis of a presence of a unit root during Dickey-Fuller (DF) testing, though returns are stationary (Table 2.5). Though currency and commodity series' demonstrate one order of integration, Engel-Granger (1987) testing does not reveal cointegration (Table 2.5).

The framework identifies in Mexico an example of an established direct currency-commodity link that appears robust during cross-currency screening checks, with little variation across the three alternative base currencies between the 30-50% range (Figure 2.4). An OLS return regression of commodity onto currency with dummy variables for Ψ^1 signal dates included produces an R^2 of 0.188 with commodity series' and γ dummy variable significance levels of 1% and 10% respectively (Table 2.7). The commodity series β factor of 0.178 and dummy variable correlation coefficient γ of 0.167 are both positively signed with overall coefficient impact increasing 94% with the addition of the dummy during stress periods, suggesting that the volatility acceleration methodology is capturing periods of genuine stress where commodity prices are positively correlated to currency in normal times but exhibit even more significant relationships to currency prices during stress periods.

Table 2.7

Volatility Acceleration Ψ[1] State Dummy Return Analysis by Least Squares Regression for Mexico

Model Parameters (MX_C)	
Total Observations	131
Filtered Observations	131
R^2	**0.188**
Standard Error	0.028

	DF	Sum of Squares	Mean Squares	F	P>F
Regression	2	0.023	0.012	14.843	<0.001
Residual	128	0.100	0.001		
Total	130	0.123			

Variable	Coefficient	Standard Error	t	P>|t|	Lower Bound (95%)	Upper Bound (95%)
α	-0.002	0.003	-0.756	0.451	-0.007	0.003
β	**0.178*** **	**0.060**	**2.949**	**0.004**	**0.059**	**0.298**
γ	**0.167***	**0.101**	**1.666**	**0.098**	**-0.031**	**0.366**

Note. ***, **, * represents significance at the 1%, 5% and 10% levels respectively. β representing commodity series significant impact on currency, with γ crisis-state dummy period variable also significant and demonstrating increased impact of commodities onto currency during crisis periods.

ARDL optimal lag lengths for currency (two lags) commodity (three lags) and equity (four lags) variables are specified via AIC (Table 2.8). The results show that in contrast to the crisis-state change estimation methodology, the crisis-dummy return variable does not show significance but full-series commodity returns are significant at the 1% level (Table 2.9). After excluding the crisis-dummy variable, full-series commodity returns are still significant at the 1% level and demonstrate a positive coefficient of 0.25 with R^2 of 0.24 (Table 2.10). It is implied that a 1% increase in commodity returns will coincide with a 0.25% increase in Mexican peso returns. The first commodity lag coefficient of 0.10 is also significant at the 10% level. The residuals do not evidence autocorrelation, though there is evidence of residual heteroscedasticity (Table 2.11). Implementation of the heteroscedasticity-robust equity-inclusive ARDL model with crisis-state commodities still excluded (Table 2.12) still demonstrate a positive commodity return coefficient of 0.28, significant at the 1% level with a model R^2 of 0.26.

Table 2.9

Mexico ARDL ˜Currency, Commod, DCommod Short Run Model

Model Parameters ARDL(2,3,3)†	
Total Observations	128
Prob > F	<0.001
R^2	**0.259**
Root MSE	0.028
Log Likelihood	282.628

Variable	Coefficient	Standard Error	t	P>|t|	Lower Bound (95%)	Upper Bound (95%)
λ_1	-0.229**	0.098	-2.33	0.021	-0.424	-0.035
λ_2	-0.192*	0.099	-1.94	0.055	-0.389	0.004
β_0	**0.200*** **	**0.063**	**3.17**	**0.002**	**0.075**	**0.325**
β_1	0.082	0.067	1.23	0.222	-0.230	0.022
β_2	0.063	0.067	0.95	0.345	-0.121	0.058
β_3	0.061	0.066	0.93	0.357	-0.070	0.192
γ_0	0.197	0.132	1.49	0.139	-0.065	0.458
γ_1	-0.043	0.157	-0.28	0.781	-0.355	0.267
γ_2	0.053	0.150	0.35	0.728	-0.245	0.350
γ_3	-0.042	0.127	-0.33	0.741	-0.293	0.209
α	-0.004	0.003	-1.29	0.201	-0.010	0.002

Note. ***, **, * represents significance at the 1%, 5% and 10% levels respectively. ˜represents dependent variable. †. Variable coefficient readings with subscripts refer to lags of dependent and exogenous variables as corresponding to ARDL(#) lag lengths in respective order of model variable definition.

Table 2.10

Mexico ARDL ˜Currency, Commod Short Run Model

Model Parameters	
ARDL(2,3)	
Total Observations	128
Prob > F	<0.001
R^2	**0.240**
Root MSE	0.028
Log Likelihood	281.005

Variable	Coefficient	Standard Error	t	P>|t|	Lower Bound (95%)	Upper Bound (95%)
λ_1	-0.194**	0.095	-2.05	0.043	-0.381	-0.006
λ_2	-0.203*	0.094	-2.16	0.033	-0.389	-0.017
β_0	**0.251*** **	**0.055**	**4.56**	**<0.001**	**0.142**	**0.359**
β_1	0.102*	0.061	1.69	0.093	-0.017	0.222
β_2	0.081	0.057	0.43	0.157	-0.032	0.194
β_3	0.046	0.053	0.08	0.386	-0.059	0.152
α	-0.005*	0.003	-1.95	0.053	-0.010	0.000

Note. ***, **, * represents significance at the 1%, 5% and 10% levels respectively. ˜represents dependent variable. †. Variable coefficient readings with subscripts refer to lags of dependent and exogenous variables as corresponding to ARDL(#) lag lengths in respective order of model variable definition.

Table 2.12

Mexico ARDL ˜Currency, Commod, LagEquity Short Run Model with Robust Standard Errors

Model Parameters	
ARDL(2,3,4)	
Total Observations	126
Prob > F	<0.001
R^2	**0.260**
Root MSE	0.028

Variable	Coefficient	Robust Standard Error	t	P>|t|	Lower Bound (95%)	Upper Bound (95%)
λ_1	-0.100	0.181	-0.55	0.583	-0.459	0.259
λ_2	-0.130	0.118	-1.10	0.273	-0.364	0.104
β_0	**0.276*** **	**0.074**	**3.71**	**<0.001**	**0.129**	**0.423**
β_1	0.099	0.062	1.61	0.110	-0.023	0.222
β_2	0.052	0.062	0.84	0.401	-0.070	0.175
β_3	0.051	0.064	0.80	0.426	-0.076	0.178
η_0	-0.060	0.061	-0.98	0.327	-0.182	0.061
η_1	-0.030	0.058	-0.52	0.606	-0.146	0.085
η_2	0.032	0.039	0.80	0.425	-0.047	0.110
η_3	-0.005	0.051	-0.09	0.928	-0.106	0.097
η_4	-0.031	0.039	-0.79	0.431	-0.108	0.046
α	-0.003	0.003	-1.19	0.236	-0.009	0.002

Note. ***, **, * represents significance at the 1%, 5% and 10% levels respectively. ˜represents dependent variable. †. Variable coefficient readings with subscripts refer to lags of dependent and exogenous variables as corresponding to ARDL(#) lag lengths in respective order of model variable definition.

The short-run model demonstrates a positive direct commodity-currency relationship as fitting with Mexico's treatment as a traditional 'commodity-currency' in the established literature, validating the detection framework as it relates to known currency-commodity effects. The lack of crisis-state short run significance diminishes the applicability of potential risk-reduction mechanisms.

2.5.2.2 Brazil – Indirect Currency-Commodity Framework

In the case of Brazil and banana prices, currency, equity and commodity series' all exhibit significant lags, explained primarily by one lag of autocorrelation and none reject the null hypothesis of a presence of a unit root during Dickey-Fuller (DF) testing (with the exception of banana prices that have some evidence of level stationarity), though returns are stationary (Table 2.5). Engel-Granger (1987) testing does not reveal cointegration (Table 2.6).

In state-based validation based on equation (2.2), the commodity onto currency dummy-variable time series OLS regression analysis (R^2 of 0.071) demonstrates a negatively signed coefficient for both commodity prices β and dummy-modification γ that is only significant during crisis periods at the 1% level (Table 2.13). In non-crisis times, there is no meaningfully observable relationship with a β coefficient -0.009 reading that is insignificant, but during crisis periods the negatively signed correlation substantially increases in intensity with a γ coefficient of -0.235 that is significant at the 1% level, evidence of an indirect currency-commodity effect that becomes significant during times of stress.

The indirect bananas correlation to Brazilian currency appears to be consistent across all currency cross-pairs during crisis-state robustness checks. The currency-commodity correlations all fall in the -75% to -80% range for varying base currency crosses (Figure 2.5), and the commodity-equity correlation is negative as well at -55%. Following dummy-regression evidence of an indirect relationship and with cointegration verified the first differenced OLS error correction model regression produces significant coefficients for adjustments on the banana commodity series. The implication that banana prices are an indirect function of currency prices validates their potential as a currency hedging mechanism.

ARDL optimal lag lengths for currency (one lag). commodity (one lag) and equity (two lags) variables are specified via AIC (Table 2.14). The results (Table 2.15) yield a model R^2 of 0.08 and show the crisis-dummy variable as on the cusp of significance, but the full-series commodity variable as insignificant. Eliminating the full-series commodity variable produces a significant crisis-state commodity coefficient of -0.21 with a model R^2 of 0.08 (Table 2.16). It is implied that a 1% increase in commodity returns will coincide with a 0.21% decrease in Brazilian currency returns, as expected from the identified indirect currency-commodity relationship. No other variables in the model are significant, and the model verifies the results of the crisis-change estimation. The lack of long-run crisis state commodity significance is in line with expectations. The residuals do not evidence autocorrelation, though there is evidence of residual heteroscedasticity (Table 2.17). Implementation of the heteroscedasticity-robust equity-inclusive ARDL model with full-series commodities still excluded (Table 2.18) still demonstrate a negative crisis-state commodity return coefficient of -0.24, significant at the 1% level with a model R^2 of 0.14. This is indicative of an indirect currency-commodity relationship where short-run crisis-based hedging applications may require additional specification, but the indirect currency-commodity relationship is not observable outside of crisis-states.

Table 2.13

Volatility Acceleration Ψ1 State Dummy Return Analysis by Least Squares Regression for Brazil

Model Parameters (BR_C)	
Total Observations	131
Filtered Observations	131
R^2	**0.071**
Standard Error	0.042

	DF	Sum of Squares	Mean Squares	F	P>F
Regression	2	0.017	0.009	4.884	0.009
Residual	128	0.229	0.002		
Total	130	0.247			

Variable	Coefficient	Standard Error	t	P>|t|	Lower Bound (95%)	Upper Bound (95%)
α	0.002	0.004	0.466	0.642	-0.006	0.000
β	**-0.009**	**0.037**	**-0.231**	**0.818**	**0.082**	**0.065**
γ	**-0.235*** **	**0.087**	**-2.716**	**0.008**	**-0.406**	**-0.064**

Note. ***, **, * represents significance at the 1%, 5% and 10% levels respectively. β representing commodity series non-significant impact on currency, with γ crisis-state dummy period variable significant and demonstrating impact of commodities onto currency only during crisis periods.

Table 2.15

Brazil ARDL ˜Currency, Commod, DCommod Short Run Model

Model Parameters	
ARDL(1,1,1)	
Total Observations	130
Prob > F	0.056
R^2	**0.082**
Root MSE	0.043
Log Likelihood	228.504

Variable	Coefficient	Standard Error	t	P>|t|	Lower Bound (95%)	Upper Bound (95%)
λ_1	0.091	0.089	1.01	0.314	-0.087	0.268
β_0	-0.011	-0.038	-0.29	0.770	-0.087	0.065
β_1	-0.020	0.038	-0.53	0.599	-0.095	0.055
γ_0	-0.196	0.119	-1.65	0.102	-0.430	0.039
γ_1	0.094	0.118	0.80	0.427	-0.140	0.328
α	0.002	0.004	0.48	0.631	-0.006	0.009

Note. ***, **, * represents significance at the 1%, 5% and 10% levels respectively. ˜represents dependent variable. α are variable coefficients, and *p,q* refer to lags of dependent and exogenous variables respectively.

Table 2.16

Brazil ARDL ˜Currency, DCommod Short Run Model

Model Parameters	
ARDL(1,1)	
Total Observations	130
Prob > F	0.015
R^2	**0.079**
Root MSE	0.043
Log Likelihood	228.292

Variable	Coefficient	Standard Error	t	P>|t|	Lower Bound (95%)	Upper Bound (95%)
λ_1	0.090	0.089	1.01	0.313	-0.086	0.266
γ_0	**-0.210***	**0.109**	**-1.93**	**0.056**	**-0.425**	**0.005**
γ_1	0.070	0.111	0.63	0.527	-0.149	0.290
α	0.002	0.004	0.39	0.694	-0.006	0.009

Note. ***, **, * represents significance at the 1%, 5% and 10% levels respectively. ˜represents dependent variable. α are variable coefficients, and *p,q* refer to lags of dependent and exogenous variables respectively.

Table 2.18

Brazil ARDL ˜Currency, DCommod, LagEquity Short Run Model with Robust Standard Errors

Model Parameters	
ARDL(1,1,2)	
Total Observations	128
Prob > F	<0.001
R^2	**0.138**
Root MSE	0.042

Variable	Coefficient	Robust Standard Error	t	P>|t|	Lower Bound (95%)	Upper Bound (95%)
λ_1	-0.173	0.199	-0.87	0.388	-0.567	0.222
γ_0	**-0.237*** **	**0.036**	**-6.50**	**<0.001**	**-0.309**	**-0.165**
γ_1	0.005	0.052	0.09	0.928	-0.098	0.108
η_0	0.129	0.079	1.64	0.103	-0.026	0.285
η_1	**0.085** **	**0.040**	**2.11**	**0.037**	**0.005**	**0.164**
η_2	0.008	0.037	0.22	0.823	-0.065	0.081
α	-0.001	0.004	-0.17	0.868	-0.009	0.007

Note. ***, **, * represents significance at the 1%, 5% and 10% levels respectively. ˜represents dependent variable. α are variable coefficients, and *p,q* refer to lags of dependent and exogenous variables respectively.

2.6 Economic Framework and Applications

Brazil evidences a robust indirect currency-commodity relationship that, due to its crisis-state dependency, can serve as a hedge against currency risk. In evaluating the potential for banana prices to serve as an alternative currency hedging instrument for local Brazil equity investment, the causal economic framework of the phenomenon must first be investigated before application. While it might be argued that in this case, given the homogeneity and centralized nature of banana production, there might be an explanatory factor in the impact of severe weather on both crop yields (a supply disruption leading to an increase in price) and economic activity, it should be noted that Brazil is nearly "entirely free from tropical hurricanes" (Shaw, 1947, p. 18) with the 2004 Hurricane Catarina being the first such reported South Atlantic event (Pezza & Simmonds, 2005). Though further investigation of this specific link is warranted, there are important economic reasons to believe the relationship has causal validity, mainly drawn from the prominent regional position of the Brazilian economy at over 50% of 2018 South American GDP (International Monetary Fund [IMF], 2018) and the highly concentrated and supply-shock sensitive nature of the banana trade (Chadwick & Nieuwoudt, 1985). That this particular link is understudied is perhaps unsurprising given the almost complete lack of any channel for direct currency-commodity effect: Brazil is a leading producer of bananas, yet the national banana product is almost entirely domestically consumed (Simoes & Hidalgo, 2011). Various idiosyncrasies, such as a historically non-diverse genetic strain of banana, a heavily concentrated regional supply chain (Soluri, 2005, p. 109), and a demand-inelastic consumer market (Chadwick & Nieuwoudt, 1985) make the banana industry a case study ripe for indirect currency effects. This subject is to be further explored, but while the underlying economic channels that lend this statistically robust indirect relationship weight are out of scope for this paper, they nonetheless are compelling enough to warrant additional scrutiny from future researchers on this and other indirect commodity-equity-currency phenomena.

By constructing a sample US dollar portfolio of MSCI Brazil exposure hedged with banana prices over the sample period, the practical applicability of these findings for currency drawdown protection can be demonstrated. The sample portfolio, comprised of OLS residuals of MSCI Brazil returns regressed onto banana price returns and indexed to 100 at January 2004, does appear to provide drawdown protection when compared to naked (unhedged) MSCI Brazil returns over the same period and reduce volatility (Figure 2.8), where Ψ^1-hedged returns only imply banana hedging exposure added to portfolio returns in the three months following the Ψ^1 signal and the rest of the series remains un-hedged during all other periods. Under this framework, MSCI Brazil returns 100% hedged with banana prices return 150% over the sample period versus 128% naked local equity returns, while a Ψ^1-hedged banana portfolio offers 431% returns. Interestingly, in-sample while the hedging methodology does provide superior returns to Brazil equity exposure, it does not reduce volatility. The 100% hedged series returns have a standard deviation of 0.177, the returns of the Ψ^1-hedged banana portfolio have a standard deviation of 0.111 and those of the unhedged portfolio read 0.093. Taking the series' out of sample to cover the 2010 to 2020 time-horizon for comparison, indexed to 100 at September 2010, the returns of the banana-hedged strategy demonstrate great value in both mitigating portfolio loss and reducing volatility. The 100% hedged portfolios generate 30% returns and the Ψ^1-hedged portfolio produces -49% returns versus -55% returns for naked local MSCI Brazil exposure (Figure 2.9). The Ψ^1-hedged returns continue to protect the portfolio from currency drawdown during periods of volatility acceleration marked using the same in-sample extremity constant and outperforms the unhedged exposure. The hedging methodology provides volatility protection on top of superior return, where the unhedged series' returns have a standard deviation of 0.096 while the Ψ^1-hedged returns have a standard deviation of 0.089 (the 100% hedged series, unsurprisingly, has a much lower volatility profile with a standard deviation of 0.033).

Table 2.19

Brazil In-Sample Banana-Hedged Portfolio Return Descriptive Statistics (Figure 2.8)

Statistic	100% Hedged MXBR Returns	Ψ1 Hedged MXBR Returns	MXBR Returns
Nbr. of observations	132	132	132
Minimum	-0.340	-0.340	-0.324
Maximum	0.759	0.703	0.243
Median	-0.004	0.016	0.010
Mean	0.020	0.019	0.011
Skewness (Pearson)	1.665	1.350	-0.250
Kurtosis (Pearson)	4.773	10.712	0.798

Note. In-sample implied banana-hedged MXBR (MSCI Brazil) returns versus un-hedged MXBR returns where Ψ^1 Hedged returns imply banana hedging exposure added to portfolio returns in the three months following the Ψ^1 currency volatility-acceleration signal

Table 2.20

Brazil Out-of-Sample Banana-Hedged Portfolio Return Descriptive Statistics (Figure 2.9)

Statistic	100% Hedged MXBR Returns	Ψ1 Hedged MXBR Returns	MXBR Returns
Nbr. of observations	118	118	118
Minimum	-0.107	-0.383	-0.383
Maximum	0.121	0.193	0.303
Median	0.000	-0.004	-0.007
Mean	0.003	-0.002	-0.002
Skewness (Pearson)	0.222	-0.433	-0.131
Kurtosis (Pearson)	2.739	1.978	1.719

Note. Out-of-sample implied banana-hedged MXBR (MSCI Brazil) returns versus un-hedged MXBR returns where Ψ^1 Hedged returns imply banana hedging exposure added to portfolio returns in the three months following the Ψ^1 currency volatility-acceleration signal

Though the ARDL short-run estimations validate the applicability of the volatility acceleration tool, where out of sample returns do provide performance enhancement and volatility reduction over unhedged exposure, the application of the indirect currency-commodity framework in the 100% hedged series appears to provide a natural hedge to local currency exposure. Though hedging strategies can generally be expected to offer return incentives during an extended period of market underperformance, the apparent success of inclusion of a commodity hedge in mitigating portfolio drawdown risk is not only attractive from a relative hedging cost perspective (where alternative currency vehicles would be prohibitively expensive for investors) but also for an opening of the field to further investigate indirect currency-commodity relationships. This methodology assumes constant hedging in the sample portfolio, as well as no transaction cost, and thus further qualification research that includes product-specific applications such as futures market contracts or Exchange Traded Fund (ETF) vehicles is warranted. Such investigations are likely to be undertaken given the potential portfolio out-performance suggested by methodology results, as well as the cost-attractiveness of alternatively expensive direct currency-product risk mitigation tools.

2.7 Conclusions

The successful identification of statistically significant direct and indirect currency-commodity effects in Mexico and Brazil is an important demonstration of both the volatility-acceleration crisis-state identification tool and the indirect commodity correlation framework. These findings contribute new risk-mitigation and economic crisis-evaluation frameworks for policymakers, investors and researchers. Evidence of statistically relevant indirect commodity price ties to Brazilian currency and equity market returns suggests that commodity prices deserve renewed attention as vehicles for currency-drawdown protection in EM equity portfolios. In the cases of established traditional commodity-export economies such as South Africa and Mexico (Chen & Rogoff, 2003; Chen et al., 2014), the relevance of commodities to the study of currency risk is clear. In the cases of other EM countries, and with additional commodities in Brazil and Mexico, study into possible new cases of indirect currency-commodity effects should be encouraged to further evaluate the relevance of using financialized products in these cases to mitigate risk for investors. Additional robustness-checks are also encouraged as a further refinement of the concepts discussed, which are presented in simple terms here for ease of introduction of novel crisis-detection and conceptual currency-commodity frameworks. The continued growth of EM economies and inclusion of new entrants like China in the MSCI EM basket should prompt additional study in the field. Future research may focus on optimal post-volatility event time-horizon analysis for individual country volatility acceleration series, as the equity market underperformance in volatile states under this analysis is not uniformly patterned across the sample EM country basket, but for the purposes of this paper and in keeping with market standards around liquidity of available hedging instruments the three-month return window forms the basis for crisis-state definition.

This paper further expands the literature by exploring new avenues of currency-commodity correlation as well as by applying a new generation of statistical analysis and verification technology to long-run commodity correlation analysis. Direct commodity-currency effects have been observed in both DM and EM spaces previously (Bodart et al., 2012; Cashin et al., 2004; Chen & Rogoff, 2003; Clements & Fry, 2008; Hatzinikolaou & Polasek, 2005), though the additional inclusion of equity market factors, previously limited to single-commodity studies such as oil (Antonakakis & Kizys, 2015; Dauvin, 2014), adds another layer of economic explanation to observed market price trends. The expansion of the analysis to investigate indirect commodity-equity-currency effects also opens the field further by expanding traditional commodity-currency analysis to areas where such correlations were previously left out of studies due to the absence of a direct export-import effect channel. Applying currency-commodity correlation research to new EM economies where such relationships are not obvious has indeed been suggested (Clements & Fry, 2008, p. 71). This paper serves as one step in the process of opening up the field of EM correlation analysis, and future researchers should feel emboldened to apply these techniques to other EM economies that are out of scope of this paper. EM economies that would benefit from such analysis in particular are smaller-tier Asian, African, Latin American and Eastern European economies, though in these cases data quality may be a barrier to long-run study.

This paper presents a new opportunity for global equity investors to strengthen portfolios against negative currency swings while avoiding historically uneconomic direct currency hedging products. Discussions of investor applications are limited here to risk reduction, though studies in indirect commodity-equity-currency correlations certainly do have alpha-generation implications that could be expanded by further study. An ‘early warning’ application of volatility acceleration signals in alerting investors to heightened risk of currency drawdown, as demonstrated in the case of Brazil where Ψ^1 signals tend to lead automatically selected impulse indicators, should be the subject of future research. The applicability of future hedging tool applications may benefit from alternative construction methodologies around the volatility acceleration signals such as rolling extremity windows.

Local policymakers looking to increase investment into emerging economies have great incentive to embrace further study of both indirect commodity-equity-currency effects and of alternative currency hedging vehicles. In terms of indirect currency-commodity relationships, greater understanding of various commodities and the effects that large price swings may have on consumer demand, regardless of causal direction, are certainly quite relevant to policymakers seeking to project impact of commodity-based supply chain policy proscriptions. In terms of alternative currency hedges, local governments have a continued interest in maintaining fully functioning markets where investors are able to safely invest and promote growth of corporate equity financing. In cases where local currency risk is both expensive to hedge and susceptible to global macro factor risks (Fratzscher, 2012), policymakers are wary of 'hot money' (Edison & Reinhart, 2001) inflows that may quickly exit equity markets should global investor sentiment turn sour. Making investment into EM safer by adding new hedging venues for investors would reduce the risk of such outflows, as decreased currency drawdown risk typically associated with such global macro events (Sarno & Taylor, 1999) would be reduced, as would the urgency for investors to exit such investments during periods of stress.

Policymakers should not just encourage increased market stability through the further exploration of alternative hedging vehicles, they should also act to make such alternative hedging markets more robust in terms of the ability of international investors to access them. There already exist a variety of policy disincentives around direct currency hedging, a response in part to aggressive speculative activity on the part of active global investors with the most extreme being the implementation of pegged exchange rates (Mishkin, 1999, Chapter 2.3), yet the existence of commodity-based alternative hedging vehicles would give policymakers scope to navigate around currency speculation while still promoting healthy investment into local markets. Commodity futures are an obvious portfolio-level application of such research, but these markets are often small in size compared to currency markets. Further opening of commodity futures markets or the use of derivative products such as ETFs to create liquid asset classes based on commodity price movements would help to deliver additional access to such instruments as hedging vehicles and make currency-drawdown avoidance strategies based around this papers' conclusions more commercially viable.

2.8 Appendix

Table 2.1

List of Variables Used in the Empirical Analysis

Variable ID	Variable Short ID	Asset Class	Country	Name	(Source) Ticker
brl3m_v	BR_V	Volatility	Brazil	Brazil 3-Month At The Money (ATM) Volatility	(Bloomberg) USDBRLV3M Curncy
1sBRL	BR_C	Currency	Brazil	Brazilian Real 1-Month Forward Outright (FO) Currency	(Bloomberg) BCN+1M Curncy
mxbr	BR_E	Equity	Brazil	MSCI Brazil Index	(Bloomberg) MXBR Index
zar3m_v	SA_V	Volatility	South Africa	South Africa 3-Month ATM Volatility	(Bloomberg) USDZARV3M Curncy
1sZAR	SA_C	Currency	South Africa	South African Rand 1-Month FO Currency	(Bloomberg) ZAR+1M Curncy
mxsa	SA_E	Equity	South Africa	MSCI South Africa Index	(Bloomberg) MXZA Index
twd3m_v	TW_V	Volatility	Taiwan	Taiwan 3-Month ATM Volatility	(Bloomberg) USDTWDV3 M Curncy
1sTWD	TW_C	Currency	Taiwan	New Taiwan Dollar 1-Month FO Currency	(Bloomberg) NTN+1M Curncy
mxta	TW_E	Equity	Taiwan	MSCI Taiwan Index	(Bloomberg) MXTA Index
krw3m_v	SK_V	Volatility	South Korea	South Korea 3-Month ATM Volatility	(Bloomberg) USDKRWV3 M Curncy
1sKRW	SK_C	Currency	South Korea	South Korean Won 1-Month FO Currency	(Bloomberg) KWN+1M Curncy
mxkr	SK_E	Equity	South Korea	MSCI South Korea Index	(Bloomberg) MXKR Index
inr3m_v	IN_V	Volatility	India	India 3-Month ATM Volatility	(Bloomberg) USDINRV3M Curncy

1sINR	IN_C	Currency	India	Indian Rupee 1-Month FO Currency	(Bloomberg) IRN+1M Curncy
mxin	IN_E	Equity	India	MSCI India Index	(Bloomberg) MXIN Index
mxn3m_v	MX_V	Volatility	Mexico	Mexico 3-Month ATM Volatility	(Bloomberg) USDMXNV3 M Curncy
1sMXN	MX_C	Currency	Mexico	Mexican Peso 1-Month FO Currency	(Bloomberg) MXN+1M Curncy
mxmx	MX_E	Equity	Mexico	MSCI Mexico Index	(Bloomberg) MXMX Index
1sEUR	EUR	Currency	Europe	Euro 1-Month FO Currency	(Bloomberg) EUR1M Curncy
1sGBP	GBP	Currency	United Kingdom	British Pound 1-Month FO Currency	(Bloomberg) GBP1M Curncy
1sCHF	CHF	Currency	Switzerland	Swiss Franc 1-Month FO Currency	(Bloomberg) CHF1M Curncy
1sJPY	JPY	Currency	Japan	Japanese Yen 1-Month FO Currency	(Bloomberg) JPY1M Curncy
PALLFNF	Commods	Commodity		All Commodity Price Index (Fuel and Non-Fuel)	(IMF) PALLFNF
PBANSOP	Bananas	Commodity		Bananas, Central American and Ecuador	(IMF) PBANSOP

Note. A full list of IMF commodity baskets can be found at https://www.imf.org/en/Research/commodity-prices.

Table 2.3

Descriptive Statistics of Market Returns

Variable	Mean (%)	St Dev (%)	Min (%)	Max (%)	Skewness (%)	Kurtosis (%)
BR_V	0.015	0.179	-0.254	0.939	1.973	5.837
BR_C	0.000	0.045	-0.157	0.123	-0.448	1.360
BR_E	0.009	0.096	-0.324	0.303	-0.003	0.687
SA_V	0.007	0.147	-0.314	1.042	3.048	17.078
SA_C	-0.003	0.046	-0.154	0.116	-0.422	0.320
SA_E	0.010	0.042	-0.127	0.112	-0.014	-0.013
TW_V	0.015	0.170	-0.302	0.655	1.352	2.621
TW_C	0.001	0.016	-0.057	0.052	0.255	0.944
TW_E	0.004	0.053	-0.175	0.145	-0.392	1.007
SK_V	0.015	0.193	-0.281	0.978	2.498	8.990
SK_C	0.001	0.033	-0.108	0.123	-0.128	2.731
SK_E	0.008	0.053	-0.210	0.143	-0.376	1.537
IN_V	0.017	0.169	-0.385	0.688	1.272	2.652
IN_C	-0.002	0.025	-0.089	0.078	-0.344	1.585
IN_E	0.012	0.067	-0.248	0.287	-0.144	2.693
MX_V	0.015	0.202	-0.261	1.801	4.853	37.828
MX_C	-0.002	0.031	-0.152	0.077	-1.021	4.211
MX_E	0.009	0.065	-0.307	0.167	-0.768	2.974
EUR	0.000	0.030	-0.101	0.100	-0.262	1.781
GBP	-0.001	0.026	-0.099	0.095	-0.331	2.472
CHF	0.000	0.027	-0.078	0.073	-0.202	0.069
JPY	0.002	0.032	-0.113	0.134	0.210	2.691
Commods	0.004	0.052	-0.211	0.117	-0.958	1.875
Bananas	0.011	0.102	-0.273	0.511	1.782	8.178

Note. Please refer to Table 2.1 for Variable Short ID listings.

Table 2.4

Sample Correlations in Market Returns

	BR_V	BR_C	BR_E	SA_V	SA_C	SA_E	TW_V	TW_C	TW_E	SK_V	SK_C	SK_E	IN_V	IN_C	IN_E	MX_V	MX_C	MX_E	Commods
BR_C	-0.259																		
BR_E	-0.227	0.894																	
SA_V	0.690	-0.107	-0.187																
SA_C	-0.340	0.530	0.193	-0.070															
SA_E	0.070	-0.333	0.046	-0.289	-0.885														
TW_V	0.724	0.022	0.051	0.706	-0.196	-0.017													
TW_C	-0.371	0.399	0.514	-0.396	-0.129	0.418	-0.154												
TW_E	-0.360	-0.139	0.183	-0.548	-0.385	0.654	-0.364	0.296											
SK_V	0.763	0.056	0.027	0.742	-0.209	-0.063	0.804	-0.153	-0.547										
SK_C	-0.556	0.235	0.180	-0.541	0.400	-0.141	-0.578	0.082	0.436	-0.734									
SK_E	-0.150	0.135	0.473	-0.410	-0.595	0.844	-0.097	0.705	0.666	-0.135	-0.001								
IN_V	0.525	0.302	0.323	0.445	-0.255	0.116	0.470	0.212	-0.413	0.753	-0.514	0.196							
IN_C	-0.232	0.624	0.359	0.058	0.900	-0.839	-0.064	-0.232	-0.290	-0.103	0.438	-0.551	-0.186						
IN_E	0.020	-0.172	0.231	-0.332	-0.790	0.957	-0.009	0.430	0.736	-0.090	-0.080	0.890	0.081	-0.697					
MX_V	0.766	-0.088	-0.060	0.694	-0.380	0.134	0.707	-0.056	-0.425	0.870	-0.752	0.047	0.723	-0.345	0.075				
MX_C	-0.406	0.560	0.253	-0.161	0.868	-0.778	-0.342	-0.093	-0.283	-0.298	0.582	-0.525	-0.197	0.869	-0.713	-0.537			
MX_E	-0.294	0.338	0.601	-0.532	-0.413	0.696	-0.268	0.704	0.586	-0.245	0.238	0.885	0.226	-0.333	0.742	-0.140	-0.199		
Commods	-0.303	0.718	0.791	-0.287	-0.007	0.243	-0.123	0.801	0.132	-0.048	0.139	0.608	0.428	0.018	0.296	-0.055	0.162	0.761	
Bananas	0.187	0.023	0.326	-0.052	-0.662	0.763	0.274	0.592	0.334	0.249	-0.357	0.799	0.422	-0.625	0.749	0.386	-0.671	0.638	0.465

Note. Please refer to Table 2.1 for Variable Short ID listings.

Table 2.5

Dickey-Fuller (ADF stationary, k:5) unit root test results for Mexico

DF Test	MX_C	MX_E	Commods
Test statistic (level)	-1.375	-1.905	-1.932
p-value (level)	0.594	0.330	0.317
Test statistic (returns)	-10.105***	-9.866***	-7.087***
p-value (returns)	<0.001	<0.001	<0.001

MX_C & Commods Engle-Granger test for cointegration, N (1st step) = 131, N (test) = 130

	Test Statistic	1% Critical Value	5% Critical Value	10% Critical Value
Z(t)	-1.528	-3.982	-3.384	-3.077

Note. Please refer to Table 2.1 for Variable Short ID listings. ***, **, * represents Dickey-Fuller significance at the 1%, 5% and 10% critical value levels respectively.

Table 2.6

Dickey-Fuller (ADF stationary, k:5) unit root test results for Brazil

DF Test	BR_C	BR_E	Bananas
Test statistic (level)	-1.818	-1.982	-2.880**
p-value (level)	0.372	0.295	0.048
Test statistic (returns)	-10.975***	-9.736***	-11.404***
p-value (returns)	<0.001	<0.001	<0.001

BR_C & Bananas Engle-Granger test for cointegration, N (1st step) = 131, N (test) = 130

	Test Statistic	1% Critical Value	5% Critical Value	10% Critical Value
Z(t)	-2.217	-3.982	-3.384	-3.077

Note. Please refer to Table 2.1 for Variable Short ID listings.

Table 2.8

Lag selection order criteria –Mexican price levels (127 observations)

Currency

Lag	LL	LR	df	p	FPE	AIC	HQIC	SBIC
0	-461.311				84.996	7.281	7.290	7.303
1	-311.799	299.02*	1	0.000	8.198	4.942	4.960	4.987*
2	-309.924	3.748	1	0.053	8.086*	4.928*	4.955*	4.995
3	-309.840	0.170	1	0.681	8.203	4.942	4.979	5.032
4	-308.782	2.116	1	0.146	8.196	4.941	4.987	5.053

Equity

Lag	LL	LR	df	p	FPE	AIC	HQIC	SBIC
0	-735.836				6411.49	11.604	11.613	11.626
1	-541.561	388.55	1	0	305.559	8.560	8.578*	8.605*
2	-541.004	1.113	1	0.291	307.702	8.567	8.594	8.634
3	-540.906	0.198	1	0.657	312.104	8.581	8.618	8.671
4	-538.524	4.763*	1	0.029	305.394*	8.559*	8.605	8.671

Commodity

Lag	LL	LR	df	p	FPE	AIC	HQIC	SBIC
0	-686.356				2941.34	10.825	10.834	10.847
1	-489.234	394.24	1	0.000	134.033	7.736	7.764	7.781
2	-470.372	37.723*	1	0.000	101.171	7.455	7.482*	7.522*
3	-469.212	2.3207	1	0.128	100.917*	7.452*	7.489	7.542
4	-468.608	1.2087	1	0.272	101.55	7.459	7.504	7.570

Note. (*) representing optimal lag length. Endogenous = price level, exogenous = constant.

Table 2.11

Mexico ARDL ˜Currency, Commod Short Run Model Breusch-Godfrey LM test for autocorrelation

lags (p)	chi2	df	Prob>chi2
1	0.008	1	0.929

White's test for unrestricted heteroscedasticity

chi2(9) =	44.08
Prob > chi2 =	0.020*

Note. Breusch-Godfrey H0 = no serial autocorrelation. White's test for H0: homoscedasticity, against * Ha: unrestricted heteroscedasticity

Table 2.14

Lag selection order criteria –Brazilian price levels (127 observations)

Currency

Lag	LL	LR	df	p	FPE	AIC	HQIC	SBIC
0	-661.400				1985.49	10.4315	10.441	10.454
1	-559.043	204.71*	1	0.000	402.402*	8.835*	8.854*	8.880*
2	-559.028	0.030	1	0.861	408.694	8.851	8.878	8.918
3	-557.493	3.070	1	0.08	405.271	8.842	8.879	8.932
4	-556.896	1.194	1	0.274	407.858	8.849	8.894	8.961

Equity

Lag	LL	LR	df	p	FPE	AIC	HQIC	SBIC
0	-778.788				12610.1	12.280	12.289	12.303
1	-614.129	329.32*	1	0.000	958.086	9.703	9.721	9.748*
2	-612.253	3.752	1	0.053	944.97*	9.689*	9.716*	9.756
3	-611.384	1.738	1	0.187	946.937	9.691	9.727	9.781
4	-611.121	0.526	1	0.468	958.011	9.703	9.748	9.815

Commodity

Lag	LL	LR	df	p	FPE	AIC	HQIC	SBIC
0	-661.400				1985.490	10.432	10.441	10.454
1	-559.043	204.710*	1	0.000	402.402*	8.835*	8.854*	8.880*
2	-559.028	0.030	1	0.861	408.694	8.851	8.878	8.918
3	-557.493	3.070	1	0.080	405.271	8.842	8.879	8.932
4	-556.896	1.194	1	0.274	407.858	8.849	8.894	8.961

Note. (*) representing optimal lag length. Endogenous = price level, exogenous = constant.

Table 2.17

Brazil ARDL ˜Currency, DCommod Short Run Model Breusch-Godfrey LM test for autocorrelation

lags (p)	chi2	df	Prob>chi2
1	1.924	1	0.165

White's test for unrestricted heteroscedasticity

chi2(9) =	19.15
Prob > chi2 =	0.024*

Note. Breusch-Godfrey H0 = no serial autocorrelation. White's test for H0: homoscedasticity, against * Ha: unrestricted heteroscedasticity

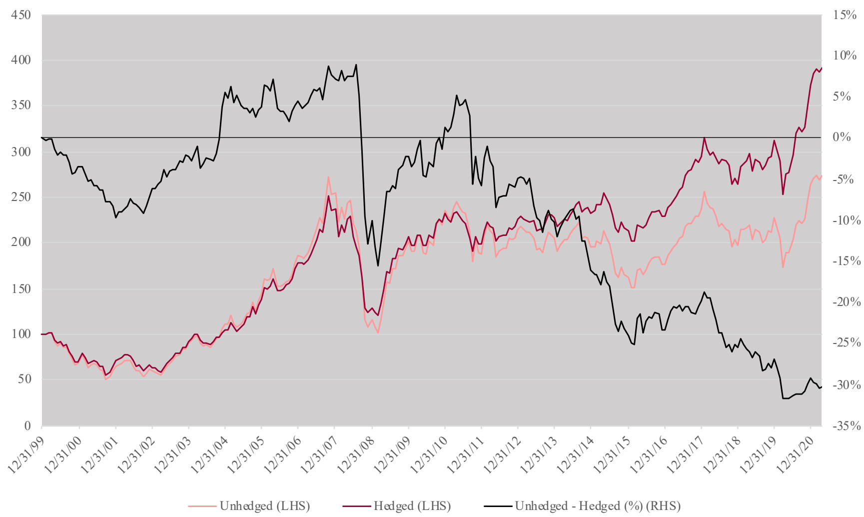

Figure 2.1. MSCI EM Unhedged (MXEF Index ticker) versus MSCI EM 100% Currency Hedged to US Dollar (M1EFHUS Index ticker). Note: Both series' are indexed to 100 at Dec 31, 1999. Data Source: Bloomberg

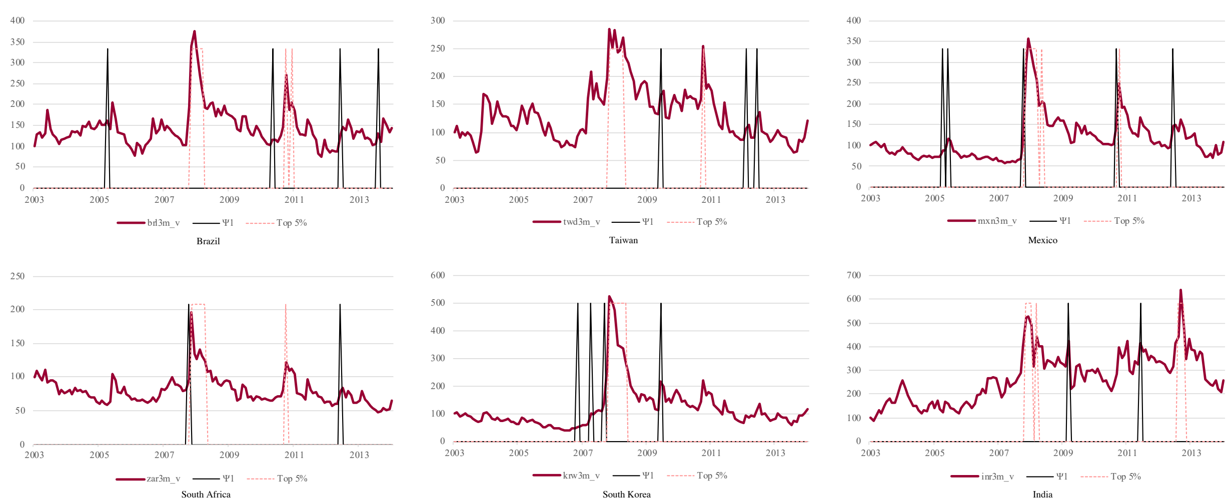

Figure 2.2. Country 3-month volatility series along with volatility acceleration $\mathbf{\Psi^1}$ signals and monthly top 5% volatility level signals

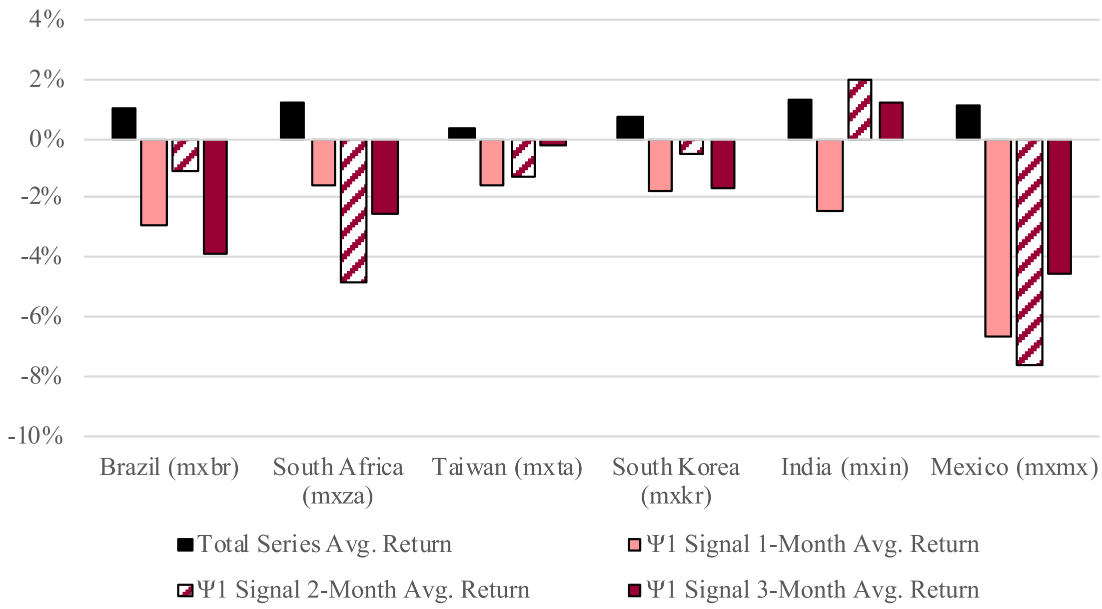

Figure 2.3. Country equity return series' averages over varying crisis-state windows following volatility acceleration Ψ^1 signals (2004-2014)

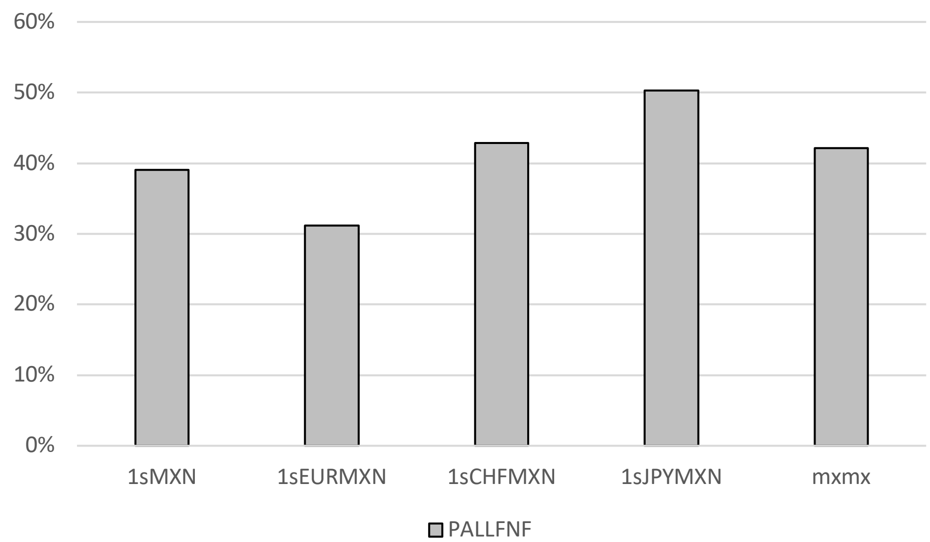

Figure 2.4. Mexico Currency Cross-Screening Correlations of All Commodity and Fuel (PALLFNF) to Variable Base Currency Time Series and MSCI Mexico Equity Series (MX_E)

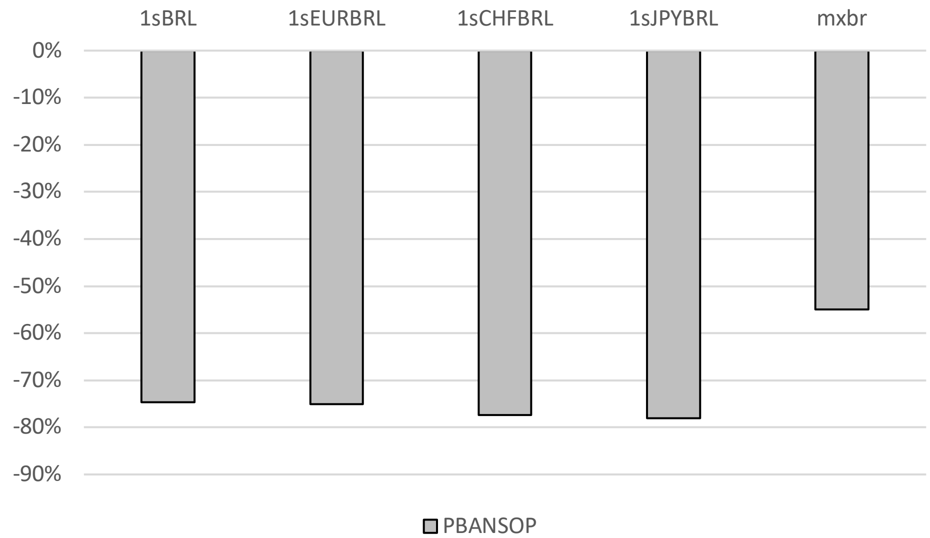

Figure 2.5. Brazil Currency Cross-Screening Correlations of Banana Commodity (PBANSOP) to Brazilian Real in Variable Base Currency Time Series' and MSCI Brazil Equity Series (BR_E)

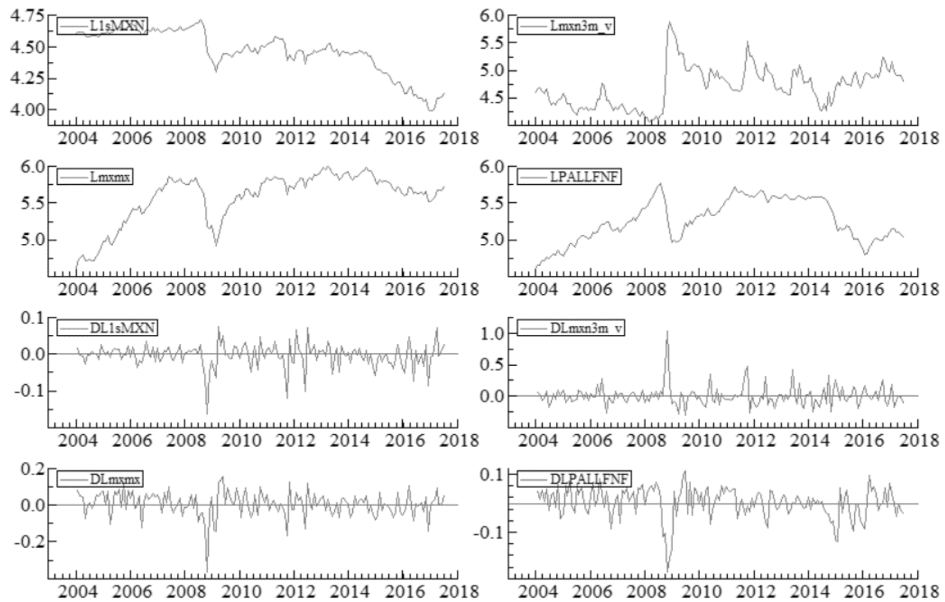

Figure 2.6. Log Mexico Price Data used in Empirical Analysis. Note that D_headed series denote first difference of time series.

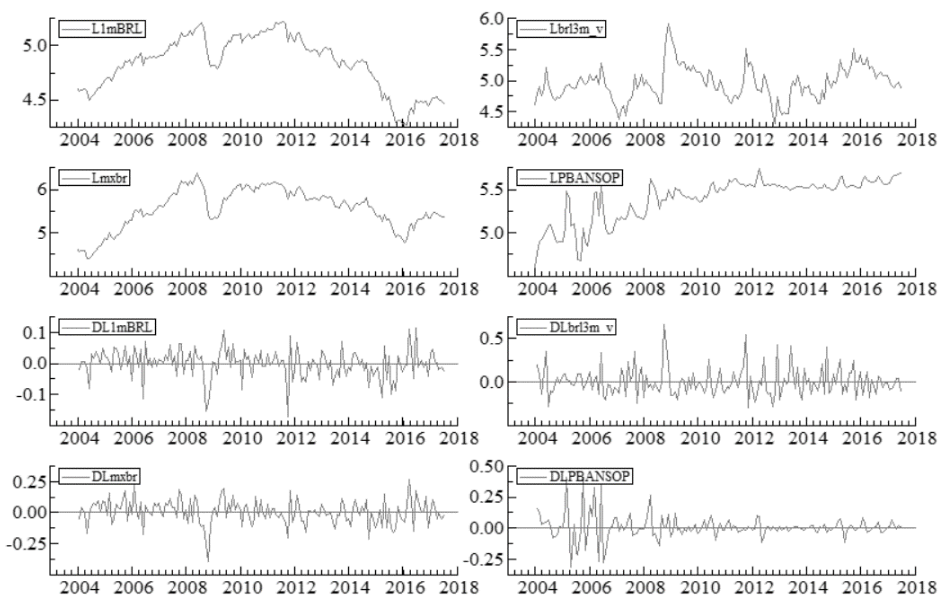

Figure 2.7. Log Brazil Price Data used in Empirical Analysis. Note that D_headed series denote first difference of time series.

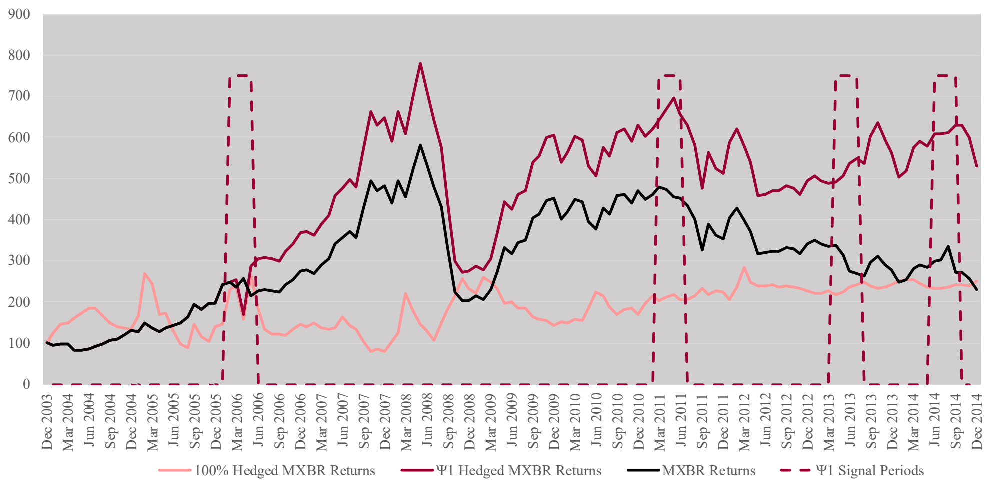

Figure 2.8. In-sample implied banana-hedged MXBR returns versus un-hedged MXBR returns where Ψ^1 Hedged returns imply banana hedging exposure added to portfolio returns in the three months following the Ψ^1 currency volatility-acceleration signal

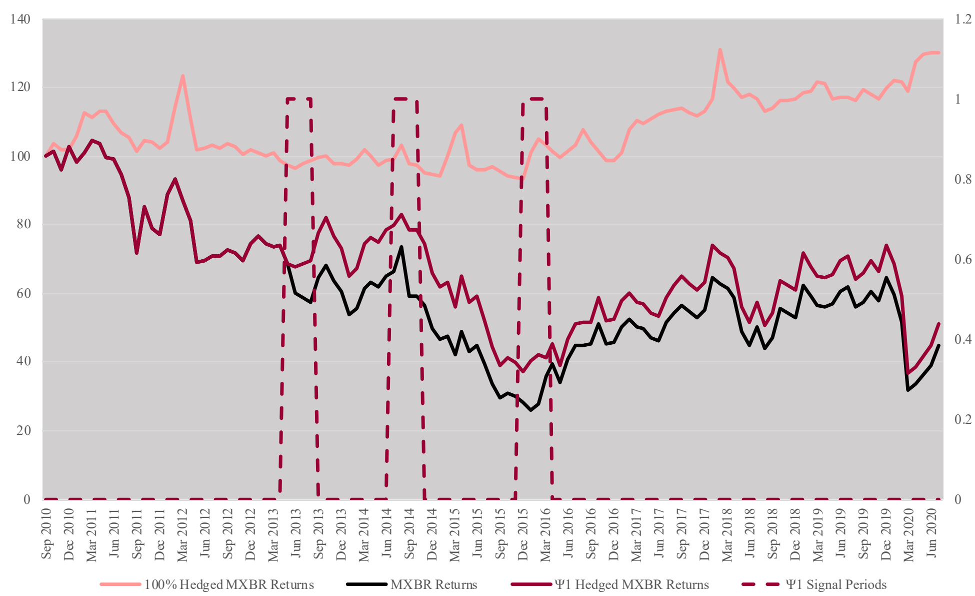

Figure 2.9. Out-of-sample implied banana-hedged MXBR returns versus un-hedged MXBR returns where Ψ^1 Hedged returns imply banana hedging exposure added to portfolio returns in the three months following the Ψ^1 currency volatility-acceleration signal

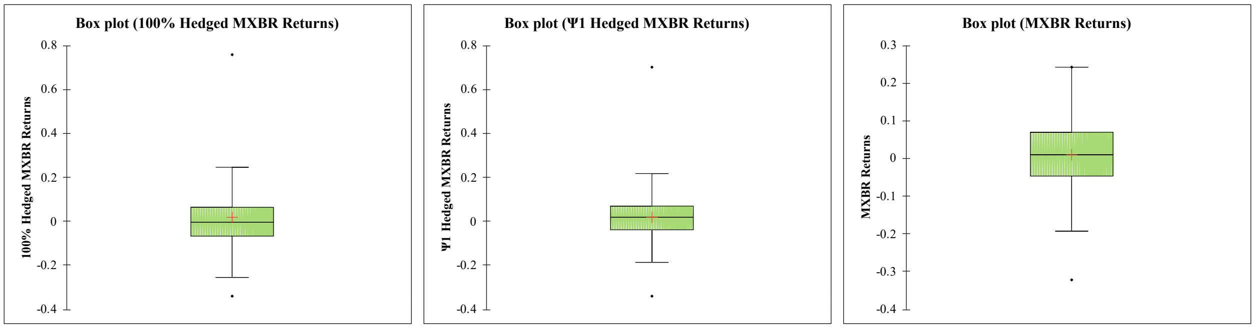

Figure 2.10. Box-plot of in-sample implied banana-hedged MXBR returns versus un-hedged MXBR returns where Ψ^1 Hedged returns imply banana hedging exposure added to portfolio returns in the three months following the Ψ^1 currency volatility-acceleration signal

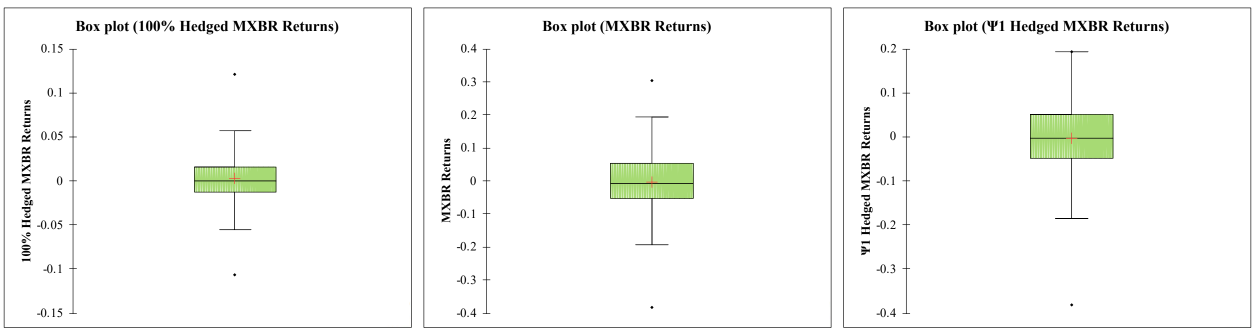

Figure 2.11. Box-plot of out-of-sample implied banana-hedged MXBR returns versus un-hedged MXBR returns where Ψ^1 Hedged returns imply banana hedging exposure added to portfolio returns in the three months following the Ψ^1 currency volatility-acceleration signal

Chapter 3

Sweetness by the Pound: A Currency-Commodity Pricing Power Detection Schematic

Abstract

In observing British pound spot prices and European sugar import prices over the 2004-2016 period, an unusually strong currency-commodity correlation is detected and statistically validated. This correlation is the result of a single firm dominating European refining, effectively fixing the import price to sterling. Based on these findings, this paper proposes a generalized pricing-power detection framework based on currency-commodity correlation and corporate consolidation is offered as a means of efficiently detecting additional instances, and to inform future industrial organization and currency-commodity research.

3.1 Introduction

Analysis of the price of the British pound to US dollar and of the International Monetary Fund's (IMF) EU Sugar import basket US dollar price over the 2004 – 2016 period reveals a remarkably stable correlation (Figure 3.1). It was by chance that in conducting broad-based correlation studies of currencies and commodity markets for the purpose of evaluating natural hedges against foreign exchange risk, the extremely robust pre-Brexit relationship between the British Pound and EU Sugar Import prices was detected; it's significance at a social and economic level, however, was immediately recognized. This phenomenon appears indicative of a direct currency-commodity relationship due to the positively signed correlation and the existence of a defined commodity export channel, though the causal factor is unlikely to be traditional commodity-currency demand effects due to the spuriousness of a classical economic framework. This paper validates the correlation by demonstrating cointegration in the first order of both series' and establishing via error correction model that EU sugar import prices significantly adjust back to long-run equilibrium with UK currency prices, though currency prices do not adjust. A probable causal explanation is rooted in the achievement of pricing power by a single UK sugar refiner, Tate & Lyle, where price of EU sugar imports, absent competitive pressure, is a function of the exporter's currency. A discussion of economic links demonstrates that such a relationship falls outside the bounds of established trade treaty under UK-EU relations during the sample period, indicative of pricing power as opposed to officially sanctioned relationship. Analysis of global sugar-exporting company stock returns show an exposure to British currency fluctuations, suggesting this relationship is not broadly priced in by the industry at large. Currency-commodity effects in this case can be shown to detect such instances of pricing power, and this paper proposes a tool to demonstrate how to replicate such investigations efficiently. This framework is generalized so as to expand the field of industrial organization literature to leverage commodity-currency relationships in detecting future instances of such pricing power structures, and to give researchers and policymakers new avenues for understanding such market conditions. Policymakers, researchers and market practitioners stand to gain important new insights from this research not only in that it offers another example of currency-commodity effects that exist outside traditional, or direct trade relationships, but also that it expands the literature of industrial organization with currency as a new detection mechanism for pricing power.

Of all the industries that have been upended by the 2016 popular electoral decision for the United Kingdom to leave the European Union, sugar may be one of the most impactful in modern society. Sugar is one of the most pervasive substances in the modern diet, making its way into 68% of packed food and beverages (Popkin & Hawkes, 2016) with EU consumption second only to India (United States Department of Agriculture, 2019). The sugar industry self-reports that in the UK, 85% of sugar demand is from food and drink manufacturers, with retail making up only 15% (AB Sugar website, 2016, figure 1). The United Kingdom and the EU sugar industries enjoyed over five decades of controlled market access relations through a Common Market Organization (CMO) quota system that carefully managed imports and exports until 2017. While this has not been a free-market system, it has enjoyed political popularity from local farmers and few sustained threats from corporate interests. Sugar, however, has still seen consolidated control as "multinational alliances (especially German and French one[s]) are also taking control over the production capacities of their subsidiaries. In most countries…the given quota is controlled by one or two producers only" (Benešová, Matysik-Pejas, Rovný, & Smutka, 2015, para. 1). In this context of consolidated control that would provide conditions for superior pricing power of a few large industry players, further statistical validation is sought. The impact of non-economic factors on commodity prices has been previously explored in cases such as South African political unrest in oil and gold markets; company pricing power that is outside of stated national trade regulation may certainly qualify as "empirical proxies for political factors that can move the markets" (Melvin & Sultan, 1990, p. 110) in a case where national currency is having an observable and significant impact on imported commodity price.

The relationship between currency and commodity price appears just as strong under alternative cross-currency comparisons, validating that there is a pure sugar to British pound direct relationship as opposed to country terms-of-trade effects. This relationship, assuming non-spuriousness, can arise under one of two imagined conditions: (1) a dominant pricing-power country trade structure between the UK and the European market area exists, with the realized import price fluctuating according to the currency exchange rate, or (2) sugar prices are extremely impactful on the UK economy, where variations in the price of sugar would materially impact demand for British currency. Scenario (1) is likely given the CMO-controlled nature of the sugar market, but it does not fully explain the extremely high correlation to the British pound. For this to be the case, the United Kingdom would have to enjoy principal producer status; while the

European Economic Zone accounts for 94% of global sugar beet exports and 95% of imports, the UK makes up only 2.6% and 5.3% respectively (Simoes & Hidalgo, 2011). Thus, for the UK to be a principal producer the control over sugar price would have to extend beyond its domestic industry. Alternatively, pricing power would be a function of control at a level above raw sugar imports, mainly in the refining capacity where sugar imported into the EU passes through a UK-dominant secondary trade channel that does not observe competitive price pressure. This trade channel, detailed in Section 3.5.1, is the result of Tate & Lyle importing raw sugar cane from former colonial Everything But Arms (EBA) and Economic Partnership Agreements (EPA) states and exporting refined sugar to the EU. This appears most likely following the elimination of scenario (2) as a possibility and is anti-competitive in both potentially circumventing EU treaties regarding sugar tariffs as well as subjecting developing-nation sugar exports to artificial profit-margin absorption on behalf of sugar refiners. The anti-competitiveness of the channel is observable in the stability of company earnings margins over time and provides a generalizable extension of the findings to more effectively identify future similar instances of exported-commodity pricing power.

Scenario (2) would follow a traditional ‘commodity currency’ model similar to countries where “when the value of the currency of a commodity-exporting country moves in sympathy with world commodity prices, it is said to be a ‘commodity currency’” (Clements & Fry, 2008, para. 1). The assertion of the relationship via a US dollar cross-rate would fit within the established literature, given that “commodity trading is conducted mostly in a few global exchange markets using US dollars” (Chen & Rogoff, 2003, Section 4.2). Extensive testing of various classical economic channels does not reveal this scenario to be probable.

This paper first uses an error correction model framework to define the correlation as per methodologies previously employed in commodity currency analysis (Cashin, Céspedes, & Sahay, 2004; Chen, Rogoff, & Rossi, 2010; Chen, Turnovsky, & Zivot, 2014), after which a means to determine the economic value implied by the relationship (i.e. the difference in prices between the IMF sugar import series and the treaty-level sugar reference rate and its value relative to actual sugar import quantities) is stated. A CAPM-based OLS regression between sugar exporting company equity and British currency returns is used to determine the degree of market awareness of the observed phenomenon. A framework for detecting pricing-power architectures is then proposed, drawing on past examples of direct price impact in the sugar industry and intended for use by commodity market regulatory entities and market practitioners. Following insights gleaned from the pricing-power framework results, this paper draws on structural and market-practitioner evidence to demonstrate that the relationship is far more likely to be one of pricing-power achievement rather than that of a UK commodity currency state. Evidence to support Scenario (2) is evaluated against this conclusion, both in the analysis of statistical impact of sugar prices on the British pound and vice versa as well as in the relationship of sugar to short-term UK inflation expectations.

As this study is based primarily in currency-commodity relationships, additional measures traditionally used in the field of industrial organization to detect instances of pricing power are employed for generalization of the findings. Following the works of (Bourlakis, 1997; Cowling & Waterson, 1976; Eckard, 1982; Qualls, 1974; Qualls, 1979; Setiawan, 2019; Slade, 2004), price-cost margin is a central metric in the study of instances of high barriers to entry and high industrial concentration. As is common practice in the literature around price-cost margins (Beyer, Kottmann, & von Blanckenburg, 2020; Brennan, Canning, & Mcdowell, 2007; Bresnahan, 1989; Cotterill, Egan, & Buckhold, 2001; Porter, 1985; Shinjo & Doi, 1989; Tichbourne, 2018), earnings before interest and taxes (EBIT) variability is the primary tool used for analysis, where in a pricing power situation such a price-cost margin figure will display stability relative to a situation of high price competition. Commodity-exporting firms where there potentially exists pricing power, as evidenced by a strong domestic currency-to-commodity correlation, are expected to exhibit low levels of EBIT variability as it implies a level of industry concentration and protectionism (i.e. the absence of competitive threats on profit margin) through a low-differentiation channel. Though prices may change, in this case related to changes in the exchange rate, a low variability in profit margin implies that the changes in prices are being passed on to consumers. Under such conditions, exchange rate fluctuations for a UK entity that affect the cost of exporting sugar into the EU, where the costs in a non-competitive environment are entirely passed on to the importing party, make the relative cost of that fluctuation visible in the sugar price while the exporter company profit margin remains stable. Industrial organization studies on pricing power as such have tended to focus on domestic instances, while this paper's main focus on currency correlation adds in an international component. This means of internationalizing pricing-power detection is intended to expand the field of research into such currency-commodity situations, and to promote the further exploration and refinement of the analytical methodologies that are proposed following these empirical findings.

Investigation of this relationship is important for the following reasons: increasing understanding of currency risk for global investors, investigating historical market practices and their ancillary effects as the EU experiences Brexit and moves away from CMOs, and exploring potential (and to my knowledge as yet un-scrutinized) sugar-based ramifications of Brexit on the UK economy. This paper will expand the literature of direct currency-to-commodity effects, where known commodity currencies including the Australian dollar, New Zealand dollar, Canadian dollar, and Emerging Markets (EM) with heavy commodity exposures have tended to dominate focus. The addition of the British pound to the field of study within commodity currencies will spur new investigations outside of heavily supply-chain oriented commodity baskets such as oil (Basher, Haug, & Sadorsky, 2012; Dauvin, 2014) and into more regionally focused import-export markets. This paper will also shed additional light on the sugar industry which, through either market-distortive consolidation or unappreciated market impact on the UK economy, deserves fresh observation. In detailing persistent colonial-era trading architectures, this paper has policy applications for the UK as it contemplates post-EU integration models.

3.2 Literature Review

The existing body of literature as it relates to sugar trade and the EU deals with concentration in the production market as well as the ongoing effects of the CMO's quota system. While sugar cane is present in the EU market, 96 out of 100 sugar factories in the shared market "specialize in sugar beet processing," (Maitah, Řezbová, Smutka, & Tomšík, 2016, p. 237) making this particular form the most relevant to the purposes of these studies. Though the UK made up 7-8% of the CMO's quota share, combined with the economies of Germany, France and Poland this bloc "operate[s] about 67 sugar factories located in the EU and produce over 61.8% of the EU sugar quota" (Maitah et al., 2016, p. 238). Consolidation in the industry has been credited to the application of the CMO, where "the profile of the EU sugar market has become very limited…these plants are operated by only a few International alliances and the number of independent sugar plants is constantly decreasing" (Benešová, Řezbová, Smutka, Tomšík, & Laputková, 2015, p. 1826). The sugar industry has clearly gone through a period of consolidation, which would lend itself to centralized pricing mechanisms that could certainly have cross-border trade impacts.

Industry sector consolidation is commonly measured through the Herfindahl-Hirschman index (HHI), which analyzes participant market share relative to the number of participants. This measure has limitations in practical application, including completeness of measured market-share, though the work of Krivka (2016) provides an excellent overview of various adaptations and alternative methodologies implemented in a wide variety of developed and emerging market industries. For the purposes of this paper, a novel methodology must be introduced for the simple reason that due to the lack of any competitors in the UK sugar refining industry, Tate & Lyle would receive a HHI of 100%. The presence of concentration in this case is undisputed, and focus is shifted to detection mechanisms that observe the effects of pricing power in margin stability.

Though there is certainly some debate as to the stability of margins in oligopolistic pricing conditions, such as the frequency of price wars as a part of cooperation-enforcement, the aspects of commodity industries that have dedicated export market channels (observable in export commodity to-currency correlation) lend themselves to those factors which would be expected to depress margin variability:

> *"Profit margin variability may be affected by the extent of product differentiation, which is undertaken to produce stability in market demand by winning customer allegiance and by protecting firms from current and potential rivals…product differentiation should thus be negatively related to profit margin variability. Profit margin variability will also be affected by factors not under a firm's direct control, in particular by government action designed to protect domestic markets from foreign competition. Other things being equal, markets enjoying high levels of protection (whether for infant industry or employment reasons) should experience one less source of intertemporal profit margin variability than those with less protection, as one of the main reasons for protection is to make domestic firms less subject to competition from imports, whose source, quantity, price and availability can vary substantially over time. In contrast, the greater the variability of actual import competition over time, the more variable are the likely (and expected) effects of foreign competition and hence the greater the uncertainty facing firms, and so actual import variability should be linked positively with intertemporal profit margin variability." (Round, 1983, p. 193)*

This paper contributes to the literature in extending such industrial organizational frameworks to currency-commodity trade channels, and in developing a generalizable framework built off of established pricing power detection methodologies like low margin variability.

Further literature explores sugar beets from an environmental, production and consumer health perspective, but outside of production cost / industry competitiveness analysis (Řezbová, Belová, & Škubna, 2013) there is little literature that links sugar to currency effects outside of broad commodity panel analysis (Chen et al., 2010, appendix I; Chen & Rogoff, 2003, table A.2.1; Dauvin, 2014) or secondary transmission effects as with products such as oil (Carpio, 2019).

One strand of literature more deeply embedded in financial analysis focuses on attempts to "search for predictable patterns in commodity markets [that are] of obvious importance to farm policy" (Chatrath, Adrangi, & Dhanda, 2002, p. 124), though such studies rarely focus on sugar specifically and instead target dominant agricultural products with large futures markets such as corn, soybeans and cotton. There are no major studies, to my knowledge, of correlation analysis relating to sugar and the UK in the modern era, nor of targeted analysis between sugar and currency. The UK's reliance on external food producers, with 30% coming from the EU (The House of Lords, 2018, p. 3), is itself an area of great interest post-Brexit but has yet to attract a notable literature base.

With regards to the distinction between currency translation and economic exposure, this paper addresses a gap in the literature where national financial risk from foreign currency fluctuations, most commonly studied in debt markets, coincides with risks related to trade. Previous research has shown the destabilizing effects that unhedged banking system exchange rate vulnerabilities can have on economies during times of crisis (Özsöz, Rengifo, & Kutan, 2015). The prevalence of financialization relative to strategically important commodities that may be used for collateral purposes has been noted as a source of "'excess volatility' in commodity prices beyond economic fundamentals" (Tang & Zhu, 2016, p. 2115), and in cases where regulators are not aware of company pricing power over commodity price channels there may be instances where perceived translation risk overlaps with economic risk. For an imported commodity to not only have economic importance as a food staple but also to provide currency risk in terms of exposure to another countries exchange rate movements represents such a case. There are no studies, to the author's knowledge, that propose a detection mechanism for cases of pricing power where stability between currency translation in commodity import-export markets has basis in economic channels related to exporting companies.

This paper will contribute to the existing body of literature both in illuminating the consolidation of the EU sugar industry specifically through a historical currency-impact channel that has as yet gone unobserved as well as to develop correlation and causality-analysis on single-commodity and currency effects in a non-traditional commodity currency situation, and in proposing a framework to detect such instances.

3.3 Methodology & Data

After demonstrating a robustness in the correlation between European sugar import prices and British pound by comparing cross-correlations to other sugar price baskets and base currency pairs, the relationship is statistically validated with cointegration testing and definition in a traditional error correction model. First difference variables are created from the time-series of market price inputs, after which an error correction model is built to include the variables in first difference and variable levels lagged by one period excluding time *t* variables. The error correction model after testing for cointegration via XLSTAT™ is demonstrated following the methodology of (Engle & Granger, 1987), where for the value of $\beta < 0$ in the error correction term is the difference between the lag of last month's level of exchange rate and last month's level of sugar price for SugEU variable *y* and GBP/\$ variable *x*:

$$(3.1)\quad \begin{pmatrix} \Delta y_t \\ \Delta x_t \end{pmatrix} = \alpha + \beta\ (y_{t-1} - x_{t-1})\ + \delta \begin{pmatrix} \Delta y_{t-1} \\ \Delta x_{t-1} \end{pmatrix} + \varepsilon_t$$

where α is a two by one vector, β is a two by one vector, and δ is a two by two matrix. This is then repeated with the natural log time series for SugEU and GBP/\$ for comparison. Level SugEU prices are estimated under the same parameters against alternative currencies (x) euro and Japanese yen so as to determine the uniqueness of the British pound's relationship.

In order to quantify the economic value *EV* of the pricing-power effect, the IMF EU sugar price series is compared to the monthly implied EU reference price *EURef* series derived by multiplying the EU reference price by the euro-to-US dollar monthly exchange rate (Figure 3.3). The deviation in price changes between the two series are then cumulatively applied to the monthly implied EU reference price series' and multiplied by total EU-external monthly refined white sugar European import quantity S and price P, both measured in euro per ton, so as to give an estimation of the economic value of the difference between the two series:

$$(3.2) \quad EV = \sum^{n}_{i} [(SugEU_n / EURef_n) - 1] * S_n * P_n$$

An additional verification step is to determine the market awareness of the observed phenomenon is employed, where exposure to UK currency fluctuations are measured against sugar-exporting companies under CAPM specifications (Demirer, Kutan & Chen, 2010, p. 286). Deviations in British pound spot rates are modeled via OLS regression against company stock returns. The degree to which variations in currency prices explain company stock returns is not subjected to further evaluation, though significance of the British pound to global sugar exporting company returns would imply that the industry at-large is not broadly aware of the dominant Tate & Lyle relationship; were European and Japanese exporters aware of or possibly included in this pricing power relationship, a degree of exposure hedging or price adjustment against British pound would be expected to mitigate this currency impact. A one factor model is formulated for β_{GBP} natural log British pound sensitivity readings where currency returns will demonstrate adjustments to expected returns $E_t(\bullet)$ of company natural log stock prices r_{CO} at time t including intercept α and error term ε:

$$(3.3) \; E_t(r_{CO}) = \alpha + \beta_{GBPt} + \varepsilon_t$$

Once a non-trivial cointegrated relationship has been specified, economic scope of the pricing-power effect defined and non-market awareness demonstrated, this in turn presents the challenge of generalizing such insights so as to be relevant to future investigation of similar currency and commodity price relationships building on the established direct commodity-currency literature. Drawing on the industrial organization literature to further qualify likely situations involving pricing power, a measure of corporate consolidation is invoked to double-sort firms in the analysis. In keeping with previous observations of sugar pricing-power, where in the absence of competitive pressure a change in cost is passed on to consumers via the price (Cotterill et al, 2001) and thus a stable margin is maintained for the manipulating party, e is stated to be the five-year EBIT return variance (Equation 3.5). This is in keeping with established literature around monopoly price detection, where "in a pure monopoly…the firm has a great deal of discretion over price" (Brennan, Canning, & Mcdowell, 2007, p. 214), and the selection of EBIT as the unit of measurement for price discretion follows the influential (Porter, 1985) studies of late-19th century railroad cartel pricing power; in application, "outside the perfectly competitive model, firms do not have supply curves. Instead, price or quantity-setting conduct follows more general supply relations" where market price less a demand function times firm equals the perceived marginal economic cost (Bresnahan, 1989, p. 1016). This measure has additionally been used in deadweight welfare loss models estimating monopoly profits as a function of operating profit (EBIT) less competitive profit rate times total firm assets (Shinjo & Doi, 1989, p. 247), as well as more recently in the analysis of European trucking cartel pricing power (Beyer, Kottmann, & von Blanckenburg, 2020). EBIT continues to be a popular measure in contemporary economic studies as a determinant of economic value added based on a "perpetual but informal promise to shareholders to make returns appropriate given capital projects level of risk," (Tichbourne, 2018, Section 5.1) and a measure of company terms of trade in its output markets (Higson, 2012, p. 173).

Firms relevant to the sugar situation in question as well as other commodity-exporter sample groups are selected, then plotted with currency-commodity correlation h on the horizontal and corporate consolidation e on the vertical axis so as to visually identify likely situations of pricing power. Companies that exhibit low margin variability and high local currency correlation to exported commodities are expected to fall on the lower right quartile of the plot.

This form of analysis may be applied further so as to produce a direct mechanism for the purposes of focusing of future areas of suspected pricing-power. In this effort to expand the field of research, a *C-score* mechanism is proposed as a demonstrative example of a ratio that is informative about pricing power. A *C-score* (C_g) is composed of h return correlation of commodity price p to producer/importer region currency f, corporate consolidation measure e and normalization factor g for a sample of *C-scores* among industry peers:

$$h_{pf} = n\sum p_i f_i - \sum p_i \sum f_i \,/\, [\sqrt{(n(\sum p)^2{}_i - (\sum p_i)^2)}\ \sqrt{(n(\sum f)^2{}_i - (\sum f_i)^2)}\,] \quad (3.4)$$

$$e = \sum^n{}_i (EBIT_i - \overline{EBIT})^2 \,/\, (n - 1) \quad (3.5)$$

$$C = h / e \quad (3.6)$$

$$g = (\sum^n{}_{i=1} C_n) / n \quad (3.7)$$

$$C_g = C / g \quad (3.8)$$

A larger correlation between product/commodity price and currency combined with a lower margin variability will result in a higher *C-score*. All relevant inputs are measured in US dollars for ease of comparability and in keeping with global commodity transaction practice. The normalizing *g* factor reflects an average *C-score* of top relevant producer country companies so as to give the results industry context; this would be particularly relevant in a globally managed commodity industry such as oil. Note that the proposed *C-score* framework may not be useable in cases of pricing-power specific to domestic markets, as the proposed structure invokes commodity price correlation to national currency as a primary input; in such a case where there is no specific export or import channel, the corporate EBIT score comparison to correlation will deliver a result divorced from fundamental economic principle.

In applying the plotting and *C-score* frameworks, the only relevant and available data at our disposable specific to the sugar-to-pound phenomenon is that for Tate & Lyle, where that of ASR Group is private data with no publicly available income information. This is still taken to be a reasonable proxy for UK pricing-power as Tate & Lyle operates their EUS holdings on a licensed basis and maintains membership with global sugar refinery trade groups. So as to provide a representative sample of industry peers, the g group companies and results are listed in Table 3.10 over the 2011-2015 time period. Using European and Japanese sugar exporting companies along with two different examples of known commodity export-economies with traditional direct currency-commodity effects, the C score is applied to determine effectiveness in various industries. Five sugar companies, including Tate & Lyle, five gold companies and five oil companies are selected for the demonstrative comparison.

As Tate & Lyle is the only exporter of refined sugar in the UK, four other sugar exporting companies from Europe (two) and Japan (two) are selected for analysis so as to provide a robustness check that the correlation of sugar to exporting-company local currency and EBIT variability is not a feature common to the global sugar market. In the cases of South Africa and Canada, the relevant commodities (gold and oil) have been selected for demonstrative comparison due to their common regard as having direct commodity-currency relationships where fluctuation in demand for exported commodities will have observable effects on demand for national currency. Canada serves as a developed market ‘commodity currency’ instance (Clements & Fry, 2008), while South Africa provides an emerging market example (Arezki et al., 2014) where in both cases the availability of EBIT and commodity-currency data is supported by the presence in the relative industries of multiple publicly traded exporting companies. Commodities that occupy significant components of total country exports, so as to ensure adequate comparability with the high UK sugar-to-sterling correlation, were selected for South African and Canadian with gold and oil commodity exports accounting for 16% and 14% of country exports respectively as of 2017 (Simoes & Hidalgo, 2011).

Price series' and their calculated returns, including currency spot prices, commodity series' and inflation series are measured monthly over the period of 30th June 2004 to 31st March 2016. Currency prices for the British pound against both a US dollar cross, Japanese yen and a euro cross are measured for cross-currency comparison purposes. The monthly format matches that of sugar prices taken at the EU import level, US import level, and Free Market level (International Monetary Fund [IMF], 2017). Due to the closing of the CMO system, data past 2016 is not available for EU sugar import prices. Company EBIT measurements are derived from income statement US dollar values for reporting years 2011-2015. Variables are listed in (Table 3.1), with descriptive statistics for market variables listed in (Table 3.2).

3.4 Empirical Results

Robustness tests find that British pound exhibits lower correlation to alternative sugar (US and Free Market prices) indices (Figure 3.4). The relationship appears idiosyncratic to EU import prices, which considering the controlled nature of the CMO quota system over the time period is to be expected. Further analysis of the correlations under different cross-currency comparison reveal that this relationship is stable in the 60-90% range (Figure 3.5), suggesting that exogenous effects from a US dollar base currency are minimal.

Results of Augmented Dickey-Fuller (ADF) testing reveals that the GBP/$ and SugEU time series' are non-stationary (Table 3.4), but the first differences GBP$_D and SugEU_D (Figure 3.6) are stationary with the same order I(1) of integration implied by both max eigenvalue and trace testing (Table 3.5). With cointegration verified, the error correction model estimated by first differenced Ordinary Least Squares (OLS) regression produces significant coefficients for adjustments on the SugEU series, with an R^2 of 0.58 and significant t-statistic in the error correction term (Table 3.6). It appears that the exchange rate does not significantly adjust, which would verify the relationship as SugEU being a function of currency price. An error correction model produced using the natural log time series of GBP/$ and SugEU yields the same results with an R^2 of 0.56 and significant t-statistic in the error correction term for adjustments on the SugEU series, yet no significance in adjustment on the exchange rate (Table 3.7). The estimated β coefficient (Equation 3.1) in this case implies that one logged GBP/$ currency deviation from the equilibrium relationship results in an average log change of 1.27 in EU Sugar import prices at the <1% significance level (Table 3.7, Model Parameters (LSugEU) Variable 2), where the positively signed β error correction coefficient does not show significance for adjustments from sugar prices onto currency. Under both level (Table 3.6) and natural log (Table 3.7) regression analysis, no other coefficients are significant at the 10% level. The only significant adjustments in error correction model analysis are currency impacting sugar, or that EU Sugar Import Price changes are statistically significantly (positively) affected by changes in British Pound prices. The positive correlation between GBP/$ and SugEU is verified as non-spurious over the sample period, with SugEU changing as a result of fluctuations in GBP/$. The results tested under alternative base currency analysis show the β error correction coefficient lacking significance and show that these results are unique to the British pound (Table 3.8).

In applying the economic value model (Equation 3.2) inputs this pricing power amounts to a potential economic value of more than €430 million over the 2012-2015 period for which European import data is available; this is equivalent to a 36.44% difference in premium between SugEU and EURef over the 2012-2015 period (Figure 3.3). This shows the effect to not only be statistically, but also economically significant.

In implementing the awareness-test in competitor stock-to-currency sensitivity analysis, (Equation 3.3), for four out of the five sugar-exporting companies (including Tate & Lyle) the British pound is shown to have a significant effect on company monthly stock returns (Table 3.9). The only company that does not show a significant exposure to pound fluctuations is Meiji Holdings Co., Ltd (MHC), which has a smaller sample size due to lack of available data over the same sample period as other companies in the analysis. The coefficient is positively signed for the other four companies where currency fluctuation exposure is significant and validates that the impact of the phenomenon and the pound's relationship to profit in the European sugar market is not being actively hedged by companies.

Table 3.6

Vector Error Correction Model by Least Squares Regression for Level Time Series

Model Parameters (GBP/$)	
Total Observations	140
Filtered Observations	140
R^2	0.015
Standard Error	0.043

	DF	Sum of Squares	Mean Squares	F	P>F
Regression	3	0.004	0.001	0.708	0.549
Residual	136	0.254	0.002		
Total	139	0.258			

Variable	Coefficient	Standard Error	t	P>|t|	Lower Bound (95%)	Upper Bound (95%)
α	-0.003	0.004	-0.766	0.445	-0.010	0.004
β	0.346	0.365	0.947	0.345	-0.377	1.068
δ (Δx_{t-1})	-0.172	0.255	-0.672	0.503	-0.676	0.333
δ (Δy_{t-1})	0.009	0.009	0.968	0.335	-0.010	0.028

Model Parameters (SugEU)	
Total Observations	140
Filtered Observations	140
R^2	0.575
Standard Error	0.409

	DF	Sum of Squares	Mean Squares	F	P>F
Regression	3	30.758	10.253	61.340	<0.0001
Residual	136	22.732	0.167		
Total	139	53.489			

Variable	Coefficient	Standard Error	t	P>|t|	Lower Bound (95%)	Upper Bound (95%)
α	-0.051	0.035	-1.462	0.146	-0.120	0.018
β	22.181***	3.458	6.414	<0.0001	15.343	29.020
δ (Δx_{t-1})	-2.663	2.416	-1.102	0.272	-7.441	2.116
δ (Δy_{t-1})	0.130	0.089	1.456	0.148	-0.047	0.306

Note. ***, **, * represent significance at the 1%, 5% and 10% levels respectively. β representing error-correction coefficient, significant for SugEU model parameters but not for GBP/$ and implying that currency prices produce significant corrections for sugar prices (but not vice versa).

Table 3.7

Vector Error Correction Model by Least Squares Regression for Natural Log Time Series

Model Parameters (LGBP/$)	
Total Observations	140
Filtered Observations	140
R^2	0.014
Standard Error	0.026

	DF	Sum of Squares	Mean Squares	F	P>F
Regression	3	0.001	0.000	0.659	0.578
Residual	136	0.092	0.001		
Total	139	0.093			

Variable	Coefficient	Standard Error	t	P>|t|	Lower Bound (95%)	Upper Bound (95%)
α	-0.002	0.002	-0.740	0.461	-0.006	0.003
β	0.245	0.370	0.661	0.510	-0.488	0.977
δ (Δx_{t-1})	-0.132	0.256	-0.514	0.608	-0.639	0.375
δ (Δy_{t-1})	0.166	0.158	1.049	0.296	-0.147	0.479

Model Parameters (LSugEU)	
Total Observations	140
Filtered Observations	140
R^2	0.558
Standard Error	0.015

	DF	Sum of Squares	Mean Squares	F	P>F
Regression	3	0.038	0.013	57.156	<0.0001
Residual	136	0.030	0.000		
Total	139	0.069			

Variable	Coefficient	Standard Error	t	P>|t|	Lower Bound (95%)	Upper Bound (95%)
α	-0.002	0.001	-1.428	0.156	-0.004	0.001
β	1.268***	0.213	5.964	<0.0001	0.848	1.689
δ (Δx_{t-1})	-0.127	0.147	-0.861	0.391	-0.418	0.164
δ (Δy_{t-1})	0.126	0.091	1.384	0.169	-0.054	0.306

Note. ***, **, * represent significance at the 1%, 5% and 10% levels respectively. β representing error-correction coefficient, significant for SugEU model parameters but not for GBP/$ and implying that currency prices produce significant corrections for sugar prices (but not vice versa).

Table 3.8

Alternative Base Currency Vector Error Correction Model by Least Squares Regression for Level Time Series

Model Parameters (SugEU)		
Total Observations	140	
Variable	Euro Base	Japanese Yen base
Model R^2	0.218	0.097
β Coefficient	-0.453	-17.843
β Standard Error	0.471	37.695
β Significance (P>|t|)	0.338	0.637

Note. β representing error-correction coefficient, non-significant for SugEU model parameters under EUR/$ and JPY/$ alternative base-currency testing.

Table 3.9

Natural Log Company Return and Currency Analysis by Least Squares Regression

Model Parameters (by Company)					
Total Observations	141				
Variable	TATE	SZU	AGR	MSC	MHC†
Model R^2	0.141	0.071	0.186	0.049	0.016
α Coefficient	0.003	0.001	0.001	0.002	0.005**
α Standard Error	0.003	0.003	0.002	0.002	0.002
α Significance (P>|t|)	0.409	0.818	0.506	0.361	0.020
β Currency Coefficient	0.283***	0.162***	0.185***	0.116***	0.043
β Standard Error	0.059	0.049	0.033	0.043	0.037
β Significance (P>|t|)	<0.0001	0.001	<0.0001	0.009	0.255

Note. ***, **, * represent significance at the 1%, 5% and 10% levels respectively. β representing British pound fluctuation exposure coefficient, significant for all company models at the 1% level except for MHC. † representing reduced sample size due to lack of data availability (Total Observations = 84).

Table 3.10

C-Scores relating pricing power to margin variability (e) and currency-commodity correlation (h)

Company	C	C_g	e	h
TATE	7.372	2.355	0.087	0.641
SZU	1.488	0.475	0.264	0.393
AGR	1.646	0.526	0.239	0.393
MSC	2.336	0.746	0.062	0.146
MHC	2.813	0.898	0.052	0.146
ANG	0.322	0.152	0.958	0.309
GFI	6.450	3.051	0.048	0.309
HAR	0.000	0.000	2493.677	0.309
PAF	1.747	0.826	0.177	0.309
SSW	2.051	0.970	0.151	0.309
ENB	1.150	0.569	0.555	0.638
SU	2.303	1.140	0.277	0.638
IMO	3.575	1.770	0.179	0.638
CNQ	1.571	0.778	0.406	0.638
CVE	1.499	0.742	0.426	0.638

Note. A C-score is composed of h return correlation of commodity price to producer/importer regional currency divided by corporate consolidation measure e and normalization factor g for a sample of C-scores among industry peers. A high C-score implies strong probability of pricing power, and a high C_g score reflects a strong probability of pricing power taking industry context into account.

Implementing the proposed pricing-power detection framework (Figure 3.9), income statement data for five South African gold mining companies and correlation of gold prices to South African rand spot prices (Table 3.3) are entered into the equation along over the 2011-2015 time horizon. The same is done for Canadian oil companies and oil prices, as well as two European and two Japanese sugar exporting companies and respective country currency and IMF commodity prices (EU Sugar Import prices for European firms, and Free Market Sugar Import prices for Japan). Visual analysis confirms Tate & Lyle (TATE) in the lower-right quadrant (Figure 3.9) as most likely to demonstrate pricing power behaviour in the sample group given the established currency-commodity link and low margin variability. Visual analysis would additionally suggest that Canadian oil companies (ENB, SU, IMO, CNQ, CVE) might be an area for further investigation, though this is largely due to the strength of the currency-commodity correlation of 0.638 over the sample period (Table 3.10, column 5 rows 11-15); the dispersion in margin variability suggests if there is pricing-power, it is far from coordinated in the group sample.

In the applied parametric framework, Tate & Lyle receives a *C-score* of 2.355 (Table 3.10). This would indicate a very strong degree of potential pricing-power dominance, as is already claimed in the above empirical analysis and economic pricing-framework. Further *C-score* analysis demonstrates that in spite of the strong currency-commodity return correlation in the respective markets (60.15% Canadian dollar to oil, and 35.59% South African rand to gold) there is relative low probability of pricing-power have been achieved with the exception of Gold Fields Limited. The margin variability of Tate & Lyle, in other words, is unusually low in the context of a very strong British pound to EU sugar import price correlation even when compared to other country direct commodity-currency export relationships and indicates achievement of superior pricing power of the UK in the sugar market. Within the sugar exporting company bloc, Tate & Lyle occupies a demonstrably high ranking relative to European and Japanese firms and affirms that the position of the UK entity is unusual relative to its peer group. Further research should be applied to validate the conditions under which Gold Fields Limited (GFI) exhibits a strong *C-score* in range of Tate & Lyle and a group-weighted C_g score of 3.051 (Table 3.10, column 3 row 7), larger than Tate & Lyle's, as it may imply similar pricing power instance in the South African gold mining industry. Investigation into this specific channel and company instance is out of scope for this paper, though further refinement and application of the demonstrated framework is encouraged as an expansion of the field of research.

3.5 Discussion on Economic Link

The establishment of the non-triviality of the statistical relationship between British pound and EU sugar import prices, the strong indications of likely pricing-power achievement in the UK and the potential >€400mio value of such a structure motivate the investigation into an economic link behind the correlation. The positively signed relationship would imply a direct currency-commodity link, though this occurs absent a traditional demand framework where an exported commodity represents a significant portion of demand for national currency. Section 3.5.1 evaluates the necessary versus existing conditions to explain such a direct framework state, followed by Section 3.5.2 which discusses indirect currency-commodity conditions. In both cases, the economic channels proposed are spurious and are eliminated as probable causes in favour of the pricing power state as generalized in the *C-score* framework.

3.5.1 Direct Currency-Commodity Economic Arguments

The highly interrelated nature of the sugar-to-currency relationship, in spite of the strength of level correlation observed (Figure 3.1), would appear to be attributable to a near-mechanical translation that runs contrary to EU import policy. The IMF affirms the series, and that as sugar prices were managed via fixed reference rates "the fluctuation of EU sugar price in USD (PSUGAEEC series) was mainly driven by exchange rate" (IMF Commodities Team, personal communication, January 23, 2020). For EU sugar import prices to be a function of the British pound, it would practically imply that price levels were at a constant and then multiplied by the currency price. That such a state is observed not via euro, but via the pound implies either British dominance over both former colonial agriculture markets as well as global producer markets where a small number of UK companies control the entire margin of EU sugar import prices, or a system where the EU import price has been completely stable but is entirely accessed via the UK and passes through an effective secondary import channel with encountered British pound currency translation rates. These conditions in the former case might well have been in place earlier in the British trade relationship with the EU, where as late as 2000 former colonies under the ACP designation made up the entire negotiated EU sugar import price series "under the Sugar Protocol" (Cashin, Liang, & McDermott, 2000, appendix I). The list of countries that export sugar to the EU, however, has grown following numerous trade challenges and market reforms over the years, Brazil and Central America accounting for ~16% of imports in the 2016/2017 period (Flint and The European Centre for International Political Economy, 2018, graph 4). The UK's trade relationship channel in other words should not be dominant enough to completely account for the observed import prices. The British pound should also not observe a mechanical relationship to import prices under an access system, as the majority EPA and EBA price channels are "duty free and quota free" (Commission Regulation Laying Down Detailed Rules of Application for the Marketing Years 2009/2010 to 2014/2015 for the Import and Refining of Sugar Products of Tariff Heading 1701 Under Preferential Agreements, 2009) over the observation period. Even in assuming total import access control, the observable variability in prices from exporter countries disallows a static price channel where a mechanical translation would alter the series to conform to British pound prices.

The EU sugar import basket is not reflective of global market providers, but rather favours nations with preferential terms of trade where EBA and EPA make up over 50% of supply duty-free (Flint and The European Centre for International Political Economy, 2018, graph 4). Import prices themselves have historically been managed with various exporters via treaty, where in the spirit of international development the African, Caribbean and Pacific (ACP) countries have enjoyed market access to the EU following the Lomé Convention in 1975. The guaranteed prices that ACP and other countries would have realized during the pre-reform time period would have under strict interpretation of the EU-ACP Sugar Protocols been subject to negotiation, "although in practice this obligation has been unilaterally determined by the EU which is (arguably) allowable as the language in Article V approximates the price that can be negotiated to a price 'within the price range obtaining in the Community'" (Gillson, Hewitt, & Page, 2005, p. 9). In such conditions where dominant pricing-power is achieved, and thus where competitive price-fluctuations are very low, pass-through in prices should indeed be observable at the consumer level. Such pass-through happens via a channel where producer costs, absent competitive threats, are borne by consumers and thus observable as either inflationary pressure in prices or in currency on exports. An export case with pricing-power through local British pound currency pricing, as it appears with EU sugar imports, follows the established on pass-through channels "since the profit function is linear with respect to the exchange rate, the expected profit is the same as the profit with the actual exchange rate" (Oi, Otani, & Shirota, 2004, p. 33).

The pass-through channel suggested here for sugar itself has been observed previously in the United States during a similar period of challenges to monopolistic price practices in sugar-related industry. The prevalence of sugar and industry abuses with regards to anti-competitive price fixing were both crystalized during the ADM high fructose corn syrup price fixing case of the 1990's, and produced models for determining "whether a cost increase due to price fixing in an input market is passed on by direct purchasers to intermediaries and ultimately to consumers" (Cotterill, Egan, & Buckhold, 2001, p. 45). The existence of similar model conditions, where the UK enjoys pricing-power in the European sugar import market, suggests validity to the statistical observations of British pound impact on the sugar price.

The UK has been shown to not have pricing-power in raw sugar imports by itself, but in evaluating potential secondary trade channels a reasonable path of inquiry is to evaluate country dominance in sugar refining that would facilitate such pricing-power. Unfortunately, there is a tremendous lack of transparency in the refinery industry with regards to market share and pricing practices, but in observing market composition and refinery capacity there is a clear bias towards the UK that would confirm such dominance. According to the European Sugar Refineries Association (ESRA) trade body, membership that "represents the majority of the EU cane refining sector" (European Sugar Refineries Association [ESRA], 2019, p. 3) consisted of the following member companies as of 2016: Agrana Romania, Rar Açúcar, Sfir Raffineria Di Brindisi, Sidul Açúcares, Zaharni Zavodi and Tate & Lyle Sugars (European Sugar Refineries Association [ESRA], 2016). Of these six companies, Tate & Lyle Sugars is the clear industry leader where their London refinery alone represents "production capacity of 1.2 million metric tons of sugar per year" ("Our Companies," n.d., para. 4); this capacity would have accounted for over 90% of the EU total sugar imports of 2017/18 (European Commission [EC], 2020, Slide 15). With refinery presences in both the UK and Portugal (Tate & Lyle, 2010, para. 3), Tate & Lyle's EU Sugar Refining (EUS) operations have functioned under a license agreement with American Sugar Refining (ASR) Group since 2010. ASR Group, in addition to their EUS acquisitions, also controls Sidul (AB Sugar website, 2016), demonstrating the form of consolidation that would make pricing-power viable at the local currency denomination level as described by (Oi et al., 2004), though the purchase via license and existing dominance of the EUS operations would explain the persistence of the currency relationship to the import series in the sample period. With the statistical validity of the SugEU to GBP/$ relationship established and the relevant conditions in place to support an economic pricing-power explanation at the sugar refinery level, the only alternative explanation (being a direct or indirect commodity-currency effect) for the relationship must be explored.

3.5.2 Indirect Currency-Commodity Economic Arguments

In a case where sugar has a material directional impact on the British pound, pass-through of import prices to the currency would have either a positive (direct) or negative (indirect) correlation effect with regards to inflation expectations, and thus currency. Though the stated phenomenon is a positively-signed correlation, indirect effects that assert themselves absent and import-export trade relationship may conceivably be positively signed where demand for a systemically important commodity will have a significant effect on local economic conditions. The argument for an indirect relationship between sugar and the British economy, and likewise the national currency, can be related to the demand inelasticity of sugar and controlled nature of the market. The SugEU series reflects import prices, and with a demand-inelastic product an increase in production cost does not necessarily get reflected to consumers as would be captured by official statistics. If demand is inelastic under a monopolized market scheme where no competitor threats would incentivize price changes, as "price transmission does not change consumer behaviour. All firms will maintain their prior profit level and continue any sales or loss leader strategies that were in play" (Cotterill, 1998, p. 4). Furthermore, given demand inelasticity one can see possibilities for a deflationary effects of a rise in sugar import prices where either domestic surplus production is unleashed onto the economy (a result of European production quotas) or prices elsewhere in the supply chain are reduced so as to offset consumer-facing increases. In the absence of competitive price pressures and in the context of a heavily controlled and monopolistic market, it is difficult to determine either the exact level of demand elasticity or the degree of consumer pass-through.

On the arguments for the positive side, where with sugar's known prevalence in the UK (and global) food supplies, the suggestion that prices could be influencing the currency would follow a known transmission mechanism between commodities and inflation where "rising commodity prices leads to cost push inflation from rising manufacturing prices and rising wages. In the industrialized countries with floating exchange rates…this typically leads to a tightening of national monetary policy, [and] a rise in interest rates," (Ussher, 2009, p. 415) which is positive for a currency. This would produce a positive-correlation similar to what we observe between GBP/$ and SugEU, where a price increase in sugar would lead to higher prices for consumers in official inflation statistics and thus an increase in the currency.

The British pound exhibits only a small correlation to interest rate returns. To illustrate this under a separate dataset of returns under the 1 January1999 to 14 March 2012 period and comparing British pound spot rates to UK Government 10 year yields, the correlation is only 8.3% (Belvisi, Pianeti, & Urga, 2016, table 3). The Belvisi et al. (2016) dataset does, however, reveal a much stronger relationship between currency and more short-term inflation-sensitive instruments such as corporate debt. Corporate debt in the UK is pronounced in terms of its influence on currency prices by virtue of market size and ownership structure, where investment-grade non-financial corporate bonds make up around 50% of business investment but the majority of assets (60%) are held by bank dealers and investors outside of the UK (Baranova, Douglas, & Silvestri, 2019, p. 7-8). This inflation-sensitive market channel indeed has a heavy impact on currency rates in the country, with UK corporate debt market return correlations to British pound at 83.3% over the 1 January1999 to 14 March 2012 period (Belvisi et al., 2016, table 3). The size of the market and international makeup of capital flows can be seen to have a marked effect on the British pound, so in terms of searching for a valid channel to link sugar import prices to currency performance, some form of short-term inflation measure would appear to be favourable.

The 5-year, 5-year GBP inflation swap rate is a market-based measure used by both dealers and the central bank to look at expectations of future inflation and should thus be a suitable channel to attempt to observe inflation expectation pass-through from sugar to the British currency. The return series itself is highly correlated to that of the currency at +62.4% (Table 3.3) and displays a strong degree of positive correlation to sugar EU import prices on the return level at +35.8% (Figure 3.8). With an observable positive relationship between sugar prices and a known currency-sensitive inflation channel, a direct commodity-currency relationship between European sugar import prices and the British pound could be possible, though it is unlikely that inflation expectations would be the sole driver of foreign exchange risk.

This currency-impact effect is predictably seen in the euro as well with a return correlation of 38.9% (Table 3.3), albeit to a lesser degree where the domestic economy accounts for much more of a share of consumption relative to the UK and overproduction based surpluses would not have as direct an impact. EU sugar imports according to the industry's statistics itself are heavily tilted towards the UK, "which imports the most from EPA-EBA countries at preferential rates…in the marketing year 2016-2017 (as of July 2017), it represented 39% of applications for import licenses for sugar from EPA-EBA countries, up from 34% the year before, demonstrating that international supply with the preferential quota is reasonably responsive to changes in UK demand. This contrasts with France and Germany, at 10% and 8% respectively" (Flint and The European Centre for International Political Economy, 2018, p. 9). It would follow that the EU import series' is more heavily impactful on the British pound given the larger exposure the basket has to the UK versus European recipients. Furthermore, while the euro is more deeply correlated to the European corporate bond short-term inflation proxy, these bonds are less sensitive than their counterparts in the UK to interest rate changes (Belvisi et al., 2016, tables 3 & 4). That said, the observation of positive correlation in the euro to both EU sugar import prices and the same UK5y5y inflation channel strengthens the case for non-spuriousness as relates to the pound's correlation to sugar prices. A sugar effect would not likely be observable in the United States, as the US dollar's function as a global reserve currency sets its trading patterns apart from the pound and the US the sugar market structure is quite different from that of Europe or the UK, having undergone competitive re-alignment following the North American Free Trade Agreement and previous experience with sugar-monopoly-based consumer pass-through litigation.

While an economic argument exists via an inflation expectations pass-through channel, the strong known relationships between the British pound and other factors such as EU corporate bonds and UK equities with 61.6% and 50.2% market return correlations respectively (Belvisi, Pianeti, & Urga, 2016, table 3) would suggest it to not be the sole driver. Sugar prices are not expected to have impact on currency prices, given the UK is a developed market economy that is not heavily dependent on import or export commodity markets with only 29.9% of Gross Domestic Product (GDP) linked to exports of goods and services (The World Bank Group, 2019). These effects could perhaps observable in other economies where a dominant group of producers account for the overwhelming majority of supply, such as in Brazil where country exports account for ~57% of global raw sugar cane supply (Simoes & Hidalgo, 2011), and present an area of further study. The lack of decisive economic evidence of a direct commodity-currency relationship, however, brings us back to the secondary-channel argument for the UK enjoying pricing-power over EU sugar imports.

3.6 Conclusions

This paper seeks to better understand the unusually strong correlation between the British pound, a non-traditional commodity-currency, and European sugar import prices. In this effort, generalized contributions to the field in proposing an efficient framework for evaluating such instances are presented. This research builds on long-established direct commodity-currency link frameworks (Chen et al., 2014; Dauvin, 2014; Clements & Fry, 2008; Cashin et al., 2004) to extend analysis to a country where such a relationship is not expected given the relatively small size of imports and exports in the particular commodity basket, but highlights the applicability of such research to new fields where currency transmission mechanisms can be used to isolate pricing-power situations in international trade.

The sugar industry has attracted several criticisms around concentration and multinational corporate consolidation around key production states (Benešová et al., 2015; Maitah et al., 2016), but the relationship that can be observed from the British pound spot rate on European import prices during the period of 2004-2016 suggests that the price control relationship has an even higher consumer impact than previously estimated. The condition for such a control channel are perhaps unsurprising given the sheer level of consolidation, as "seven dominant alliances: Su¨dzucker, Nordzucker, Tereos, ABF (Associated British Foods), Pfeifer and Langen, Royal Cosun and Cristal Union…control nearly 90% of the total EU sugar quota production while sharing the protection from imports due to the high duties and taxes" (Maitah et al., 2016, p. 240). Such concerns have been echoed from within recent European Commission Sugar High-Level Group proceedings:

> *"one Member State…stressed that the current situation of cane sugar refineries may also have socioeconomic repercussions. One Member State…is concerned about a further concentration in the EU sugar sector and its economic and social consequences" (European HLG Sugar, 2019, p. 39).*

With a transmission mechanism and a causal relationship established, in the context of a tightly controlled market that limits exogenous factors such as non-influence of foreign competitive price pressures and the lack of a "reasonably competitive environment in any [EU] member state" with "only a limited number of companies/alliances operat[ing] in the sugar beet quota system in EU-countries" (Benešová et al., 2015, p. 1834), the high impact of the pound through likely import dominance transmission mechanisms reveals the effective control of such a network on local prices.

It is perhaps not surprising that the UK-EU sugar price channel underwent sincere changes following the Brexit referendum, with myriad new competitive demand factors posing a challenge to a heavily controlled framework that has had predictable consumer-facing impacts. It is possible that trade negotiations between the UK and EU produce new changes to sugar imports, or that new protection measures for domestic sugar beet producers in both the UK and EU secure novel incentives as part of a separation agreement that impacts Europe's chief source of refined cane sugar. Reorganization of ASR Group's EUS holdings under new ownership may even shift control over the refining operation away from Tate & Lyle towards operators without a British pound incentive. Considering the move away from the quota price system and the de-listing of concurrent European sugar import prices in the IMF databases, alternative measures using direct-market sources or commodity futures should be employed to monitor the continued relationship between sugar and the British pound as the sugar market itself liberalizes. Sugar, with its well documented addictive properties, is likely to continue to play a heavy role in the UK and EU food supplies and monitoring of its pervasiveness should be of extreme interest to both policymakers and to international financial portfolio analysts looking to understand the driving forces of commodities trading. To this end, and as it relates to similar suspected practices in other commodity export/import markets, frameworks to estimate the likelihood of pricing-power relationships using the combined inputs of currency-commodity correlation and anticompetitive corporate margin stability should be further explored in future research. Competitor awareness of the British-pound-to-sugar relationship has been implemented as a means to direct further research in the impact of this work. The *C-score* has also been designed and implemented in this paper with a limited data-set for the purposes of demonstrating such an approach to determine the economic likelihood of such a specific pricing-power instance, and while it is certainly applicable to evaluation of investments or entities from an Environment, Sustainability and Governance (ESG) perspective, further evaluation of currency-commodity correlations as such should be a subject of future industrial organizational research.

There may be applications for out-of-sample forecasting of currency returns based on insights from pricing power relationships. These extensions are out of scope of this paper for structural and data-availability reasons: firstly, the important of non-economic factors in asset price modeling has previously been signaled as areas of investigation, where political unrest has been demonstrated to have a significant impact on commodity markets in developing nations. This work is intended to continue in this vein, and to broaden the literature to explore where pricing power has impact on commodity and currency markets. This is important as it expands the field of research here commodity-currency relationships can be known to arise from instances of pricing power, which not only has implications for research in financial markets but also industrial organization. Secondly, the relevant data series from which this paper draws its insights has been discontinued by the IMF following the Brexit referendum, and thus out of sample forecasting is impossible without the identification of a new price series'. Such a novel series will additionally need to be evaluated for similar properties of pricing power, where it is conceivable that the conditions that created the phenomenon related to Tate & Lyle's control over EU sugar imports may have changed following the UK's exit from the EU. Forecasting methodologies that might leverage these insights are expected to be based on alternative series' and potentially new trading conditions, and thus are proposed as avenues for future research.

3.7 APPENDIX

Table 3.1

List of Variables Used in Empirical Analysis

Variable ID	Variable Short ID	Variable Type	Country	Description	(Source) Ticker
GBP/USD	GBP/$	Currency	UK	British Pound	(Bloomberg) GBPCurncy
EUR/USD	EUR/$	Currency	EU	Euro	(Bloomberg) EURCurncy
USD/JPY	JPY/$	Currency	Japan	Japanese Yen	(Bloomberg) JPYCurncy
*USD/CAD	CAD/$	Currency	Canada	Canadian Dollar	(S&P Capital IQ) $CADUSD
*USD/ZAR	ZAR/$	Currency	South Africa	South African Rand	(S&P Capital IQ) $ZARUSD
Sugar EU Import	SugEU	Commodity	EU	EU Sugar Import Price	(IMF) PSUGAEEC
Sugar US Import	SugUS	Commodity	US	US Sugar Import Price	(IMF) PSUGAISA
Sugar FM Import	SugFree	Commodity	All	Free Market Sugar Import Price	(IMF) PSUGAUSA
*Sugar EU Reference	EURef	Commodity	EU	Implied Monthly EU Sugar Reference Price in USD	(European Commission, Bloomberg)
*Gold	Gold	Commodity	All	Generic physical gold price	(S&P Capital IQ) GC
*Crude Oil - Light	Oil	Commodity	All	Cushing, Oklahoma generic contract	(S&P Capital IQ) CL

GBP Inflation Swap Forward 5y5y	UK5y5y	Inflation	UK	5-year, 5-year GBP inflation swap rate	(Bloomberg) FWISBP55 Index
**EU(28) Sugar White Import; Partner Extra EU(28)	S	Commodity Volume	EU	Volume in tonnes of white sugar imported to EU from all non-EU sources	(European Commission)
Average Price for Industrial White Sugar within the Community	P	Commodity Industrial Price / Volume	EU	Price in tonnes of white sugar imported to EU from all non-EU sources	(European Commission)
Tate & Lyle plc	TATE_S	Company	UK	Stock Price	(S&P Capital IQ) LSE:TATE
Südzucker AG	SZU_S	Company	EU	Stock Price	(S&P Capital IQ) XTRA:SZU
AGRANA Beteiligungs-Aktiengesellschaft	AGR_S	Company	EU	Stock Price	(S&P Capital IQ) WBAG:AGR
Mitsui Sugar Co., Ltd.	MSC_S	Company	Japan	Stock Price	(S&P Capital IQ) TSE:2109
***Meiji Holdings Co., Ltd.	MHC_S	Company	Japan	Stock Price	(S&P Capital IQ) TSE:2269
*Tate & Lyle plc	TATE	Company	UK	Company Profitability (EBIT)	(S&P Capital IQ) LSE:TATE
*Südzucker AG	SZU	Company	EU	Company Profitability (EBIT)	(S&P Capital IQ) XTRA:SZU
*AGRANA Beteiligungs-Aktiengesellschaft	AGR	Company	EU	Company Profitability (EBIT)	(S&P Capital IQ) WBAG:AGR

*Mitsui Sugar Co., Ltd.	MSC	Company	Japan	Company Profitability (EBIT)	(S&P Capital IQ) TSE:2109
*Meiji Holdings Co., Ltd.	MHC	Company	Japan	Company Profitability (EBIT)	(S&P Capital IQ) TSE:2269
*AngloGold Ashanti Limited	ANG	Company	South Africa	Company Profitability (EBIT)	(S&P Capital IQ) JSE:ANG
*Gold Fields Limited	GFI	Company	South Africa	Company Profitability (EBIT)	(S&P Capital IQ) JSE:GFI
*Harmony Gold Mining Company Limited	HAR	Company	South Africa	Company Profitability (EBIT)	(S&P Capital IQ) JSE:HAR
*Pan African Resources PLC	PAF	Company	South Africa	Company Profitability (EBIT)	(S&P Capital IQ) AIM:PAF
*Sibanye Stillwater Limited	SSW	Company	South Africa	Company Profitability (EBIT)	(S&P Capital IQ) JSE:SSW
*Enbridge Inc.	ENB	Company	Canada	Company Profitability (EBIT)	(S&P Capital IQ) TSX:ENB
*Suncor Energy Inc.	SU	Company	Canada	Company Profitability (EBIT)	(S&P Capital IQ) TSX:SU
*Imperial Oil Limited	IMO	Company	Canada	Company Profitability (EBIT)	(S&P Capital IQ) TSX:IMO
*Canadian Natural Resources Limited	CNQ	Company	Canada	Company Profitability (EBIT)	(S&P Capital IQ) TSX:CNQ
*Cenovus Energy Inc.	CVE	Company	Canada	Company Profitability (EBIT)	(S&P Capital IQ) TSX:CVE

Note. All data is monthly from 30th June 2004 to 31st March 2016, except for * series where only data from 31st January 2011 onward is used and ** from 31st January 2012 to 31st March 2016 and *** from 31st Marc 2009 to 31st March 2016

Table 3.2

Descriptive Statistics of Market Returns from 30th June 2004 to 31st March 2016

Variable	Mean	St Dev	Min	Max	Skewness	Kurtosis
GBP/$	-0.001	0.026	-0.097	0.095	-0.229	2.046
EUR/$	0.000	0.031	-0.097	0.101	-0.237	1.334
JPY/$	0.000	0.027	-0.078	0.078	-0.055	0.426
*CAD/$	-0.004	0.025	-0.087	0.046	-0.519	1.115
*ZAR/$	-0.012	0.038	-0.127	0.073	-0.617	0.807
*EURef	-0.002	0.026	-0.068	0.047	-0.473	0.112
SugEU	-0.002	0.022	-0.092	0.061	-0.409	1.948
SugUS	0.008	0.079	-0.181	0.220	0.424	0.231
SugFree	0.003	0.039	-0.106	0.136	0.262	0.863
*Gold	-0.001	0.054	-0.122	0.122	0.151	-0.227
*Oil	-0.010	0.085	-0.208	0.253	0.133	0.940
UK5y5y	0.000	0.049	-0.167	0.195	0.223	2.824
TATE_S	0.006	0.082	-0.279	0.211	-0.458	1.227
SZU_S	0.004	0.095	-0.252	0.245	-0.130	0.652
AGR_S	0.004	0.071	-0.232	0.298	0.209	2.960
MSC_S	0.008	0.083	-0.190	0.336	0.639	1.947
***MHC_S	0.020	0.068	-0.140	0.205	0.358	0.440

Note. All data is monthly from 30th June 2004 to 31st March 2016, except for * series where only data from 31st January 2011 onward is used and ** from 31st January 2012 onward and *** from 31st Marc 2009 onward

Table 3.3

Sample Correlations in Market Returns from 30th June 2004 to 31st March 2016

	GBP/$	EUR/$	JPY/$	CAD/$	ZAR/$	EURef	SugEU	SugUS	SugFree	Gold	Oil	UK5y5y	TATE	SZU	AGR	MSC
EUR/$	0.630															
JPY/$	0.035	0.175														
*CAD/$	0.647	0.657	0.091													
*ZAR/$	0.537	0.506	0.008	0.646												
*EURef	0.678	1.000	-0.039	0.657	0.506											
SugEU	0.640	0.389	-0.009	0.250	0.248	0.389										
SugUS	0.250	0.226	0.121	0.258	0.271	0.152	0.115									
SugFree	0.156	0.061	0.121	0.003	-0.040	-0.022	0.152	0.524								
*Gold	0.210	0.304	0.391	0.274	0.296	0.304	0.057	0.111	0.250							
*Oil	0.529	0.558	0.048	0.646	0.418	0.558	0.292	0.072	0.061	0.266						
UK5y5y	0.624	0.344	-0.190	0.508	0.265	0.538	0.358	0.202	0.134	-0.091	-0.091					
TATE	0.343	0.331	0.057	0.125	0.079	0.184	0.212	0.212	0.069	-0.011	0.159	0.140				
SZU	0.235	0.432	0.013	0.363	0.309	0.396	0.073	0.254	-0.052	0.094	0.272	0.205	0.184			
AGR	0.382	0.372	0.000	0.406	0.277	0.409	0.212	0.310	0.053	-0.072	0.315	0.350	0.134	0.372		
MSC	0.235	0.221	0.142	0.064	0.151	0.271	0.180	0.199	0.172	0.051	0.041	0.127	0.114	0.039	0.100	
***MHC	0.109	-0.009	0.139	-0.227	0.002	-0.131	0.090	0.074	0.098	0.081	-0.186	0.086	0.020	-0.083	0.024	0.330

Note. All data is monthly from 30th June 2004 to 31st March 2016, except for * series where only data from 31st January 2011 onward is used and ** from 31st January 2012 to 31st March 2016 and *** from 31st March 2009 to 31st March 2016

Table 3.4

Dickey-Fuller (ADF stationary, k:5) and Phillips-Perron (no intercept, short lag) unit root test results for British pound currency (GBP/$) and IMF EU Sugar Import prices (SugEU)

DF Test	GBP/$	SugEU
Tau (Observed value)	-2.717	-2.911
Tau (Critical value)	-3.410	-3.410
p-value (one-tailed)	0.220	0.152
alpha	0.05	0.05

PP Test	GBP/$	SugEU
Tau (Observed value)	-0.932	-0.747
Tau (Critical value)	-1.943	-1.943
p-value (one-tailed)	0.311	0.391
alpha	0.05	0.05

Table 3.5

VAR order estimation and Johansen test results

Number of lags	AIC	HQ	BIC	FPE
·1	-17.163	-17.111	-17.035	0.000
2	-17.129	-17.042	-16.916	0.000
3	-17.109	-16.988	-16.811	0.000
4	-17.061	-16.905	-16.677	0.000
5	-17.056	-16.866	-16.588	0.000

Max Eigenvalue Test

No. of cointegrating equations	Eigenvalue	Statistic	Critical value	p-value
None	0.493	95.157	15.892	<0.0001***
At most 1	0.019	2.727	9.164	0.633

Trace Test

No. of cointegrating equations	Eigenvalue	Statistic	Critical value	p-value
None	0.493	97.883	20.262	<0.0001***
At most 1	0.019	2.727	9.164	0.633

Note. (·) representing VAR order estimate according to AIC, and ***, **, * indicating 1 cointegrating relation(s) at the 1%, 5% and 10% significance levels, respectively.

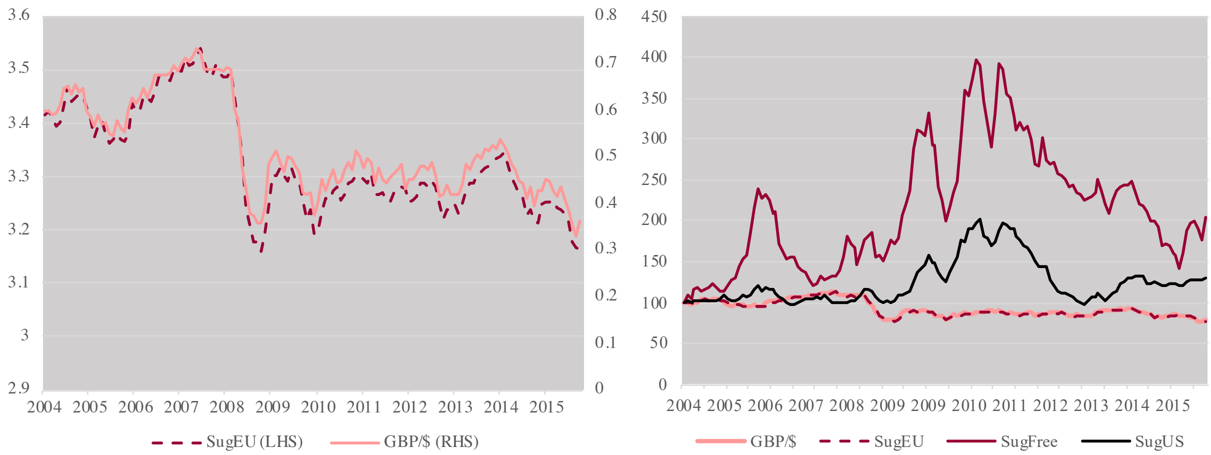

Figure 3.1. (Left) Natural Log of GBP/$ Exchange Rate and IMF EU Sugar Import Price Levels from 30th June 2004 to 31st March 2016, (Right) GBP/$ Exchange Rate and IMF Sugar (Free Market, US and EU) Price Levels Indexed to 100 at January 2004

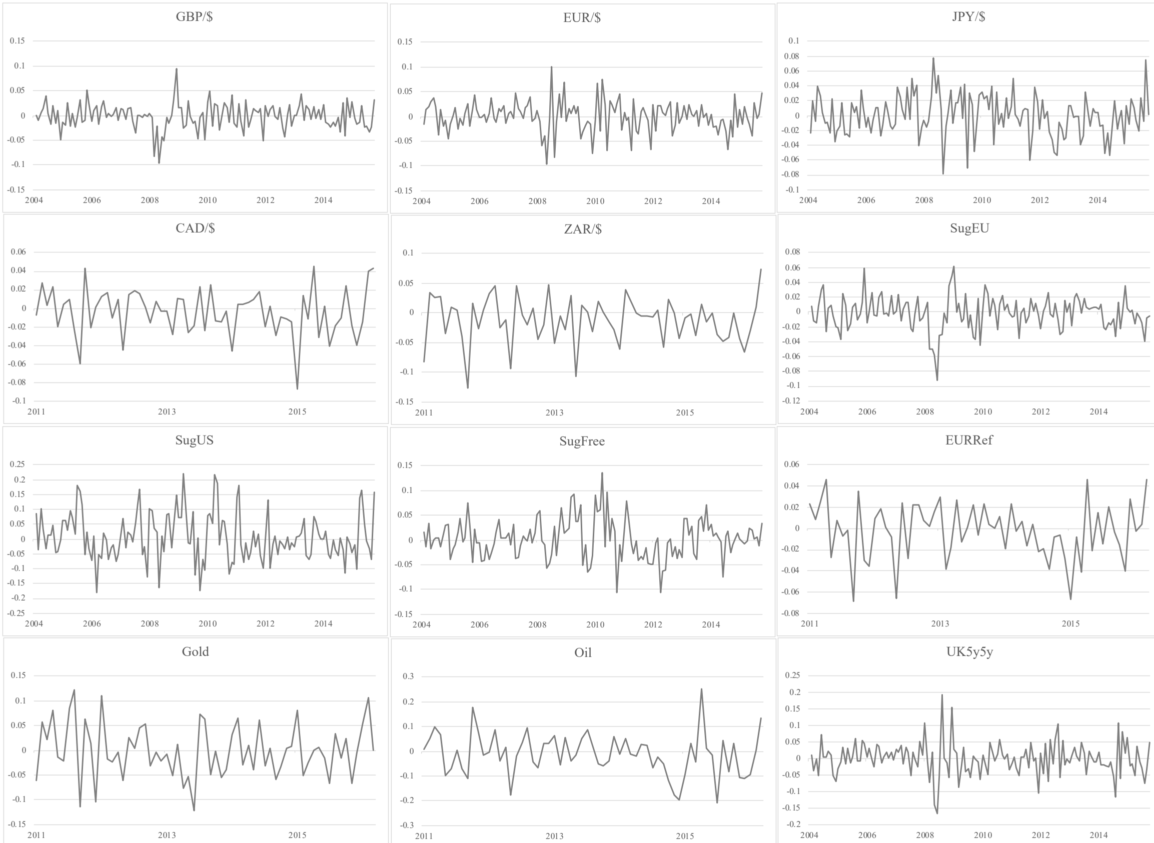

Figure 3.2. Price Data Used in Empirical Analysis

Figure 3.3. EURef (Synthetic EU Sugar Import Rate based on Treaty Reference Level and GBP/EUR) Level Time Series Comparison to GBP/EUR Exchange Rate and SugEU (IMF EU Sugar Import Prices). Note: Indexed to 100 at 31st July 2006

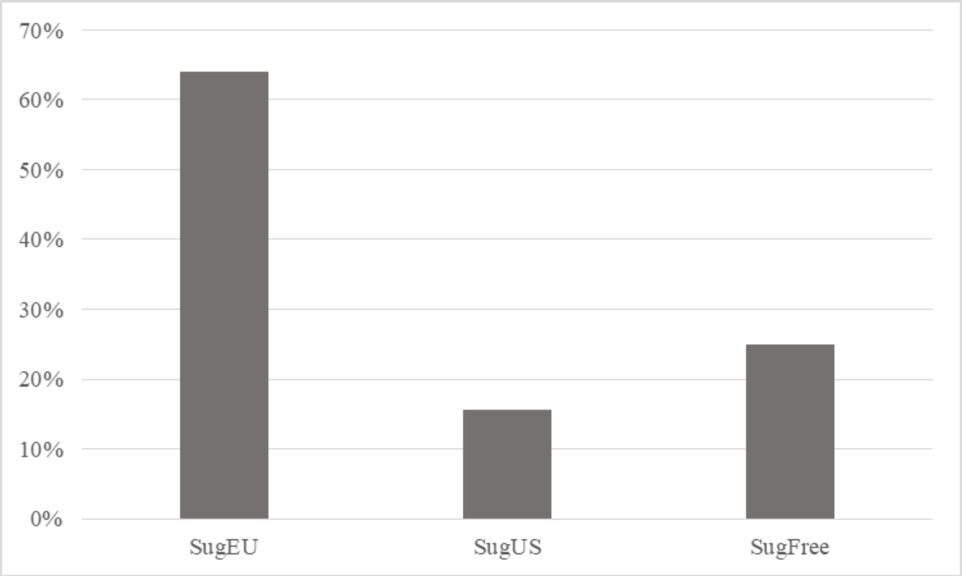

Figure 3.4. IMF EU, US and Free Market Sugar Price Return Correlations to GBP/$ Exchange Rate Returns

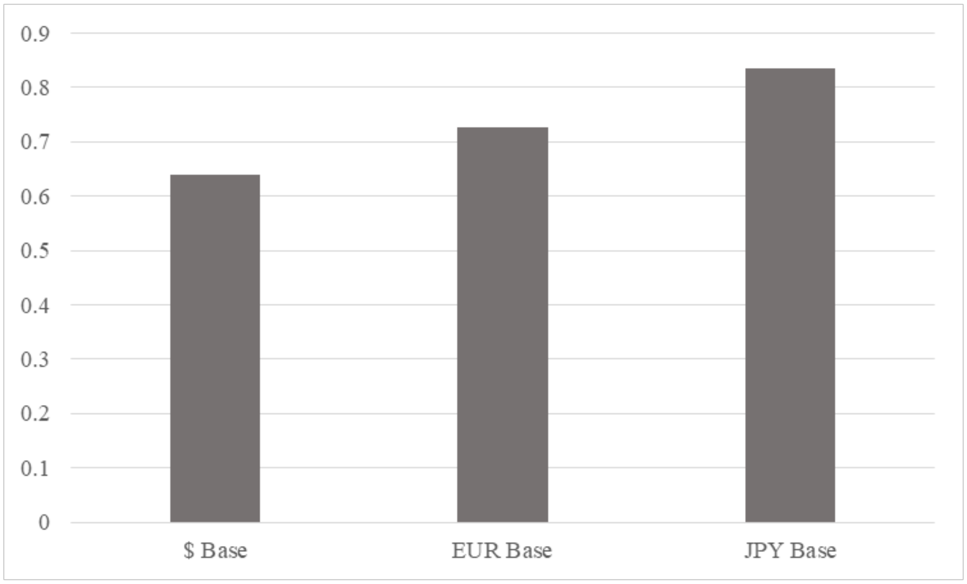

Figure 3.5. GBP Currency and IMF EU Sugar Import Price Return Correlation Robustness Analysis Under US$, EUR and JPY Variable Base Currency

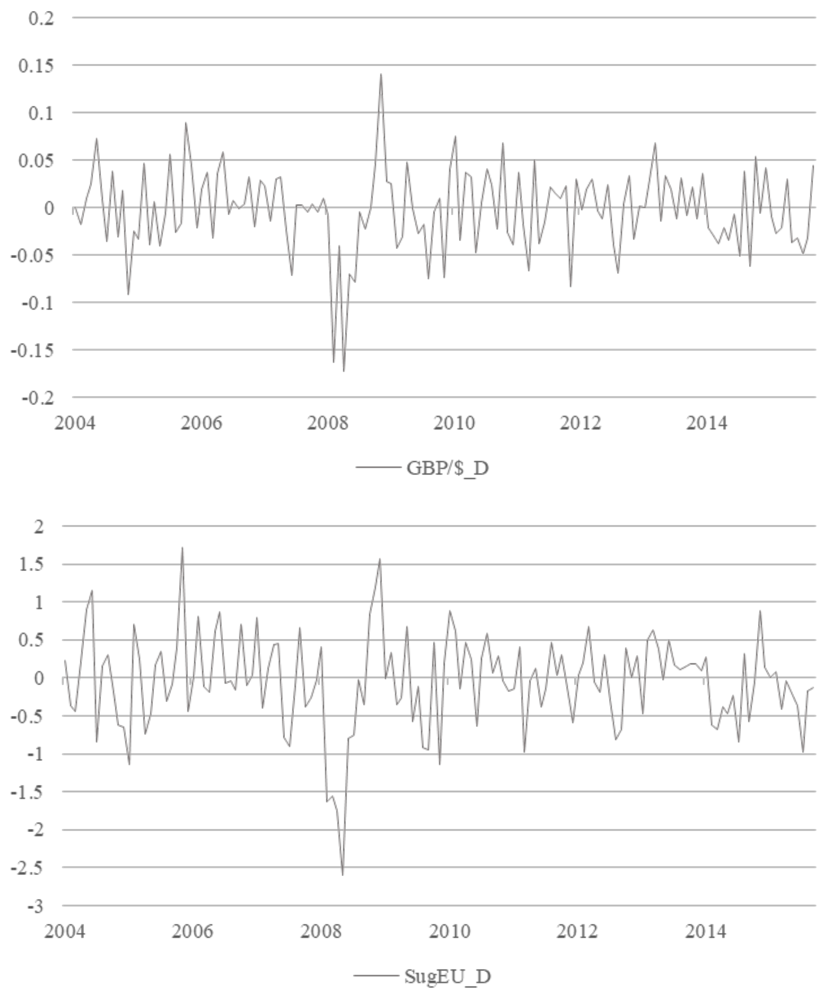

Figure 3.6. First differences of time series' GBP/$ Currency and IMF EU Sugar Import Prices (SugEU)

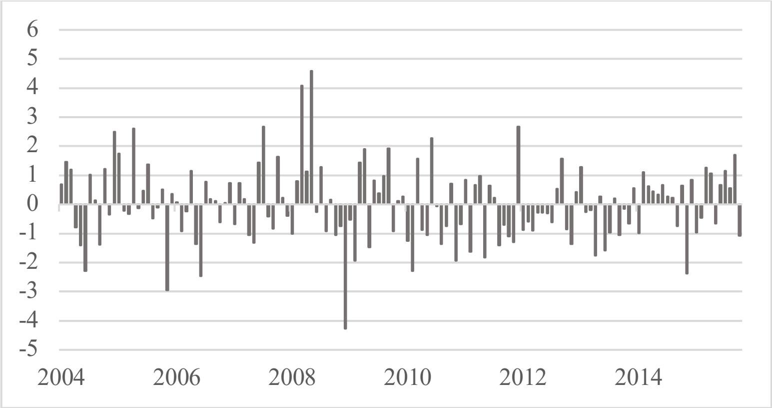

Figure 3.7. Residuals from linear regression of GBP/$ Currency and IMF EU Sugar Import Prices

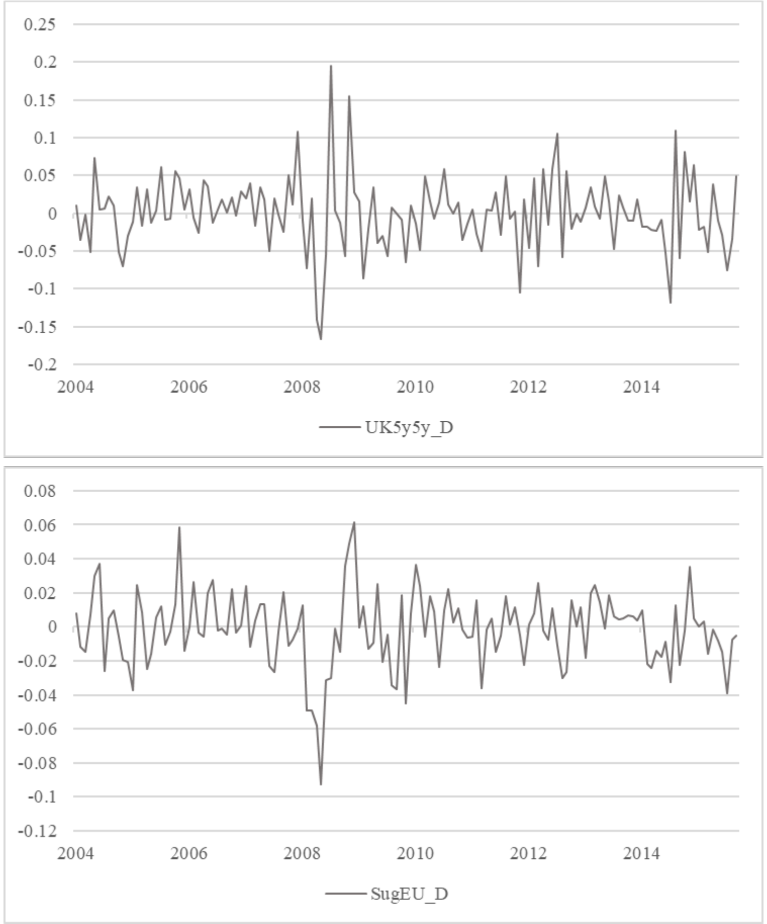

Figure 3.8. First differences of time series' UK5y5y Inflation Expectations and IMF EU Sugar Import Prices

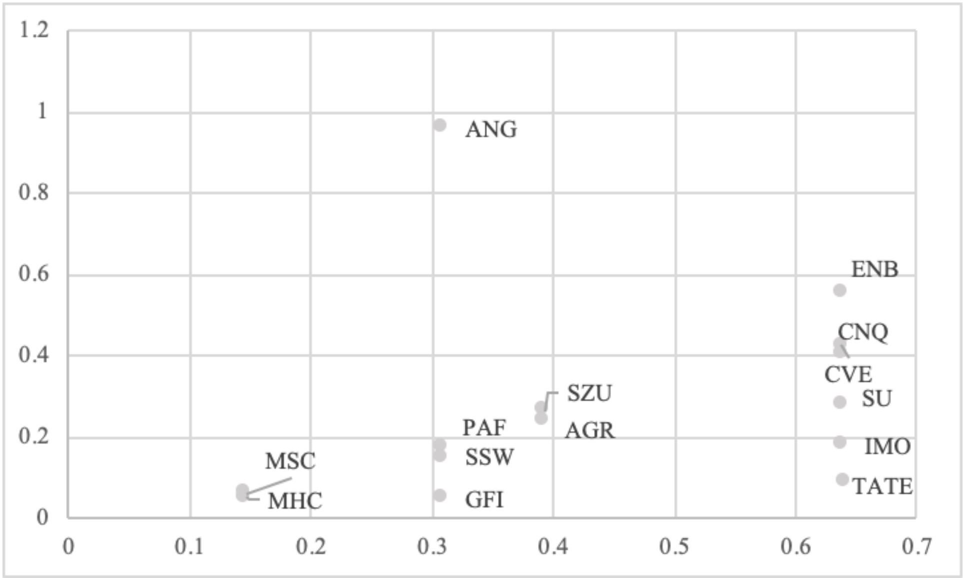

Figure 3.9. Non-parametric visual analysis plot of corporate consolidation *e* (vertical) versus currency-commodity correlation *h* (horizontal) for pricing power detection *excludingHAR, where lower right quadrant indicates probable pricing-power instances of low margin variability (high corporate consolidation) and high currency-commodity correlation

General Conclusions

The search for natural hedges against Emerging Market (EM) currency risk in international equity allocations is necessitated by the significance of currency to returns, as well as by the expensiveness of hedging against currency directly using foreign exchange products. Investors, simply put, are there for the currency risk in the first place. If one were taking an ocean voyage, however, and were told that the risk of drowning is roughly the same as the risk of shipwrecking, could one imagine making the attempt with no life preservers because the risk of drowning 'is inherent in any trek?' This work attempts to provide investors and researchers with new life preservers to evaluate, making currency risk more manageable via commodity exposure. Applying commodity risk to an EM equity portfolio, with the expectation that in times of financial stress the commodity will counteract a currency drawdown effect, has the benefit of retaining the positive effects of local high-yielding currency exposure while reducing the risk of substantial loss resulting from currency volatility.

The contributions of this work are to provide investors, researchers and policymakers with new perspectives, and new tools, to answer these questions. Indirect currency-commodity effects, as proposed in Chapter 1, broaden the existing literature to include new commodities and countries in currency correlation analysis that fall outside the bounds of traditional import-export linked 'commodity-currency' research. Currency volatility acceleration frameworks, as implemented in Chapter 2 to define crisis states, offer new means of investigating correlations during periods of stress that are relevant to local markets. The examples of direct and indirect currency-commodity effects, as discussed in Chapter 2, demonstrate proof-of-concept of these methodologies. The additional contribution in Chapter 3 of a new framework to detect instances of pricing-power in commodity exporting industries provides new avenues to perceive currency-commodity effects and the various causal channels that they can assert themselves through that are as yet undefined in the literature. This work is designed to offer these tools up for further evaluation, refinement, and implementation in a broad range of applications, and to make international equity allocations to EM and beyond a more informed and protected endeavour.

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