USING COMMODITY PRICE CHANGE TO MODEL EXCHANGE RATE CHANGES IN COMMODITY-DEPENDENT DEVELOPING COUNTRIES

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Using Commodity Price Change to Model Exchange Rate Changes in Commodity-Dependent Developing Countries

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Abstract

A country's exchange rate is a fickle instrument used to stabilize its economic status. The utility and impact of this instrument is amplified for developing countries, as the volatile nature of their exchange rates can have a more profound impact on a fragile economy. Further, developing countries that are export dependent, especially commodity dependent, have proven to respond to limited variables such as inflation and interest. This paper explores the influence of commodity price on commodity-dependent developing countries, and how it may differ for non-commodity-dependent countries. The paper looks at a 65 developing countries and restricts them based on commodity-dependency and then models the change in their exchange rate using commodity price, inflation, and interest as independent variables. The conclusion is that commodity price and inflation has significant explanatory power for modeling exchange rate changes for commodity-dependent countries. The policy implications for the results are discussed.

KEYWORDS: (Exchange Rates, Commodity Prices, Developing Countries, Commodity Dependent, Purchasing Power Parity)
JEL CODES: (F31, F37, G18, O2, O16, O24, O50, Q02)

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Introduction

The modern foreign exchange market began in 1973 when state control of foreign exchange trading ended, and the modern floating rate and free market mentality became nearly ubiquitous. Before 1973, the exchange rate was simply the price of a country's currency, and the foreign exchange market was seen as a means of achieving economic stability by central banks (Chen, 2009). The exchange rate was used internally to manipulate money supply-and-demand in order for a country to meet its preferred economic goals. The exchange rate was an essential feature of a domestic economy; the rate was influential but had minimal financial repercussions outside the country's borders. Today, however, the exchange rate is not simply adjusted by a monetary authority, but it is a number that responds to the shifts and preferences of a foreign exchange (FX) marketplace. In today's economy a country has to keep a keen eye on their currency's price and must constantly maintain a balance between what they want the currency to be worth and what the market says it is worth. The exchange rate has become an instrument—a capricious tool used to combat market pressures and the global economy while maintaining domestic stability.

The exchange rate is a rare case in that its models can be accurate and useful, but an external shock or a mandate from a powerful international organization (like the IMF or the World Bank) could cause an extreme response from the monetary force within a country, thus deeming the model useless. That is, at any moment a country could have to severely depreciate or dramatically appreciate its currency to preserve stability or even qualify for a loan. For example, in 2016 Egypt was asked to devalue the Egyptian pound in order to receive a $12 billion loan from the IMF. Egypt responded by removing the

8.8EGP/USD peg and allowing the pound to float. Within a day the currency depreciated by 50% to nearly 17.6EGP/USD. The float sought to stabilize the dollar-starved economy, encourage an inflow of foreign direct investment, and spur exports (Cohen 2017). Because the exchange rate is so influential to an economy's health it has become an extremely volatile product for speculators, and a carefully monitored instrument for central bankers.

Modeling a variable that is both dependent on market forces, yet heavily regulated by governments can prove to be difficult. In its most basic form, the exchange rate is a function of relative domestic interest and relative domestic inflation. The central bank, or central bank equivalent, adjusts interest rates by increasing or decreasing the money supply. An increase in money supply will decrease interest rates, raise inflation, and then will depreciate the exchange rate (different monetary policies will have distinct impacts on the exchange rate depending on the status of the country within the global economy).

The FX market and speculators can also push a currency's value up or down contingent on market demand. Take the Brazilian Real for example. If the price of the BRL is expected to decrease, speculators will sell their BRL leading to a currency depreciation. In a practical explanation of speculating a BRL price decrease, if no one is buying Brazil's exports or investing in Brazil's domestic economy, then there is little demand for the BRL. There will be an excess of BRLs in the FX market and the price of the BRL will go down. Exchange rates speculating can be a self-fulfilling prophecy.

Developing countries are labeled by the United Nations as either commodity-dependent or non-commodity-dependent. This two-group organization contingent on commodity-dependence provides a control group and a test group. Commodity price for commodity-dependent countries is an essential indicator for their economic health, thus their exchange rate would supposedly respond to a change in commodity price. This study will attempt to establish a set of predictive variables that will indicate a change in a country's nominal exchange rate. Based on theoretical concepts and established exchange rate factors, this study will only look at developing countries and examine their responsiveness to average commodity price conditional on their varying degrees of commodity dependency. This paper is organized with an introduction to exchange rates and their dynamics, basic theory on exchange rate modeling, a literature survey of past studies, an explanation of data, methods, and models, a presentation of the results, and then a discussion that will contain policy implications of accurate exchange rate models for commodity-dependent developing countries.

Theory

Before discussing the past literature on exchange rate dynamics and exchange rate modeling, it is important to define and explain the general economic theories behind exchange rate changes. Prior to discussing the theories, however, it is vital to understand the difference between the real exchange rate (RER) and the nominal exchange rate (NER). The NER is the price of a foreign currency in terms of a home currency. For example, today 1 USD costs 19.23 MXN. The FX market displays a currency's NER. The RER is the nominal exchange rate times the inverse of the relative price levels. The real exchange rate accounts for inflation levels and will explain the relative price of a consumption basket in a foreign country in terms of consumption in a home country. The equations are given below:

Nominal exchange rate equation:

$$E_{USD/MXN} = \frac{1}{E_{MXN/USD}}$$

Real exchange rate equation:

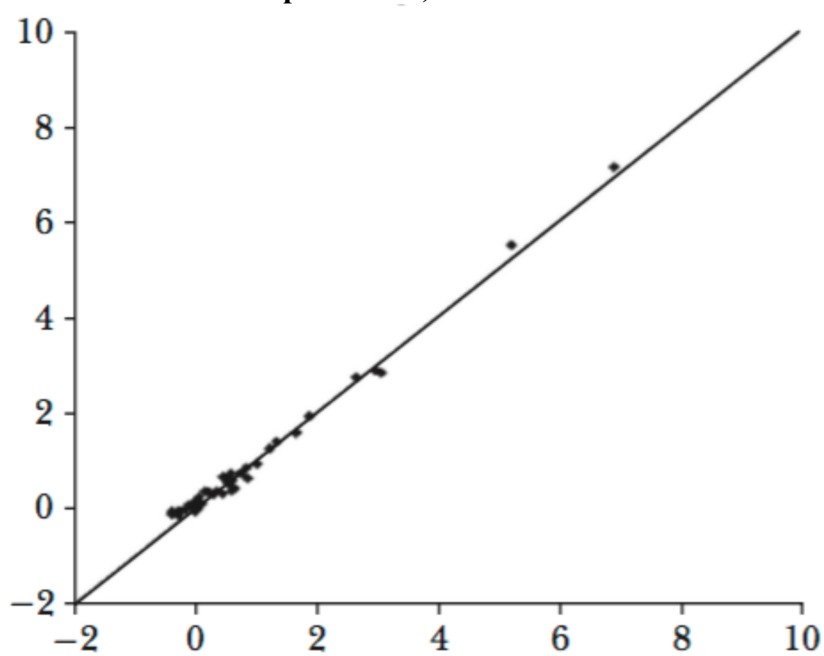
$$e_{USD/MXN} = E_{USD/MXN} \frac{P_{MXN}}{P_{USD}}$$

where $E_{USD/MXN}$ is the US Dollar price of one Mexican Peso, P_{MXN} is the price level in Mexico, P_{USD} is the price level in the United Sates, and $e_{USD/MXN}$ is the relative price of a consumption basket in Mexico in terms of consumption in the United States.

There are two main theories that are used to explain exchange rate interactions in the market and their supposed equilibrium levels. The first theory is called purchasing power parity, or PPP. Purchasing power parity is based on the "Law of One Price," which states that because of arbitrage, prices should be the same across markets. Thus, absolute

PPP states that the real exchange rate should be one-to-one because if an item costs more in one currency than it does in the other then one of two things would happen: the item would be consumed in the cheaper currency until market forces raised the item's price to be equal to the price in the more expensive currency, or the nominal exchange rate would adjust to balance the purchasing power. Both situations would eliminate the price discrepancy. Absolute PPP should hold true if all goods are instantly tradeable. In summary, absolute PPP says that a change in exchange rate is proportional to the change

Graph 1- Consumer Price Inflation Relative to the U.S. versus Dollar Exchange Rate Depreciation, 1970-1998



Source: Taylor and Taylor, 2004

in price levels.

Relative PPP is similar to absolute PPP except that relative PPP assumes no expected movements in the RER, thus the change in exchange rate is proportional to the relative change in price levels. Relative PPP is understood to not hold in the short-run, but there is evidence of relative PPP holding in the long-run (Taylor and Taylor 2004).

The graph above shows consumer price inflation versus exchange rate depreciation over 29 years. The high correlation demonstrates how the theory of relative PPP holds in the long-run because as consumer price inflation increased, the exchange rate depreciated accordingly. Regarding exchange rates, PPP is only useful for economies with a high volume of tradeable goods. PPP could not be applied in the long-run for certain countries because untradeable goods, such as restaurant meals and haircuts, can make up over half of a country's GDP (Arkolakis 2014). Countries whose economies are service oriented or have closed economies would have exchange rates that are unresponsive to PPP models.

The other prevalent theory of exchange rate determination is called uncovered interest rate parity (UIP). UIP is a condition that says that the interest rate differential is equal to the expected change of the interest rate. It assumes the efficient market will not allow for exchange rates to be arbitraged by means of varying foreign interest rates to make a profit. For example, if the interest rate in South Africa is 7% and the interest rate in the United States is 3%, the exchange rate should reach an equilibrium where a return on a foreign investment in ZAR post-repatriation would equal the return on domestic investment in USD. The equation for UIP is given below:

$$1 + i_t = (1 + r^*) \frac{E_{t+1}^e}{E_t}$$

where $1 + i_t$ is the return on a domestic bond, $(1 + r^*)$ is the return on a foreign bond, and E_t^e is the expected nominal exchange rate at time t + 1. Uncovered interest rate parity has limited evidence because of how difficult it is to estimate the expected nominal exchange rate in the model, but is generally used as a theoretical device for rational expectations models; that is, UIP is used as an input for equations yielding expected values (Arkolakis 2014).

Literature Review

This section segments the literature review into three parts. The first discusses relevant basic macroeconomic exchange rate dynamics that serve as a foundation for exchange rate modeling. The next sub-section describes exchange rate models and relationships between inflation, interest rates, current accounts, and exchange rates. The final sub-section explores the nuances around emerging markets/developing economies monetary policy and exchange rate regimes. Like most economic instruments, exchange rates are complex, and prior theory is expanded upon in order to arrive at a more cohesive postulate.

The most popular theories for exchange rate modeling utilize asset-pricing models, monetary models, or build on the theory of uncovered interest parity acting as an efficient market instrument. More recently, models have come out treating exchange rates like assets that appreciate and depreciate in accordance with country-specific economic fundamentals (like relative price of tradeable goods or output). The inclusion of fundamentals in an exchange rate model results in an increase in accuracy as well as a tendency to treat the foreign exchange market like a securities market with bubbles and dramatic dips.

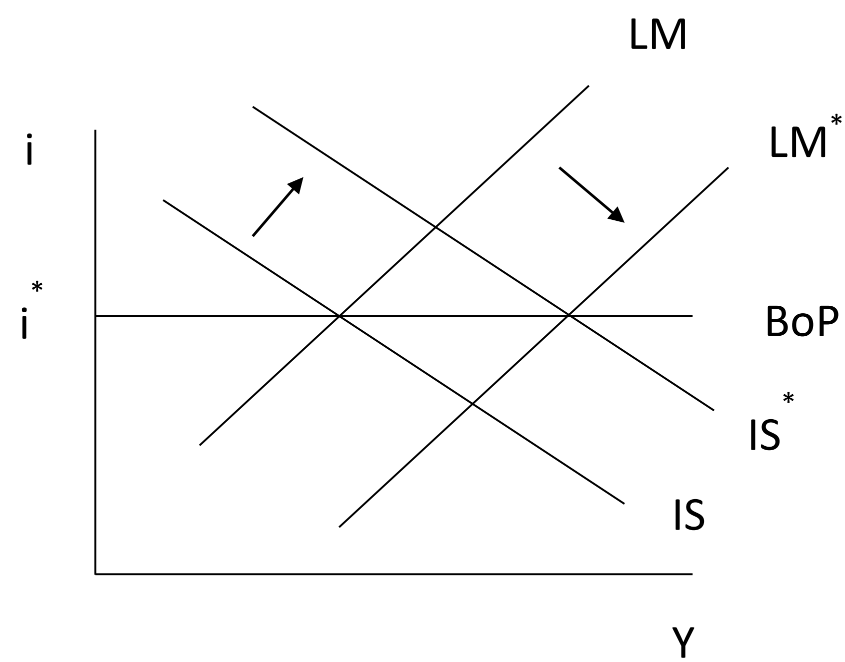
i. Exchange rate dynamics

Exchange rates are unique in that they are vital concepts of macroeconomic policy, while also being measurements and instruments of international finance. In their 1995 paper entitled *Exchange Rate Dynamics Redux*, Obstfeld and Rogoff summarize past theory that is paramount to analyzing exchange rates in a macroeconomic context. They connect the intertemporal approach of a flexible-price model provided by Frenkel (1976) with the classic Mundell-Fleming IS-LM-BoP model to explain the complex relationships between variable exchange rates, current accounts, and monetary policy. The Frenkel flexible-price model, assuming that prices are flexible and that PPP holds across economies, assesses the impact of exogenous or endogenous variables on endogenous variables only—an estimation of exchange rate movements between two currencies. The model assumes that a change in real income does not cause a change in money supply—changes in real income and changes in the money supply occur exogenously. The model theorizes that the exogenous variables *moneysupplydifferential*, *realincomedifferential*, and *interestratedifferential* determine the foreign exchange rate between two currencies (Wang 2009).

$$d\ RER = f(\ d\ moneysupply, d\ realincome, d\ interest\ rate\ )$$

The Keynesian IS-LM model (investment saving liquidity and money) only considers the interest rate and output of an economy in autarky. The Mundell-Fleming model expands upon the Keynesian model by introducing the nominal exchange rate of a small open economy; however, the exchange rate impacts are implicit in the model. Assuming perfect capital mobility, the BoP curve is horizontal at the world interest rate. If there is an increase in money supply the LM curve shifts out (right) and the interest rate decreases causing an increase in outflow of capital, increasing the exchange rate (currency depreciation). The IS curve follows by shifting out to reach world interest rate equilibrium because low rates spur investment. The IS curve follows the LM curve to ensure that the interest rate rises from below the world interest rate to become equal to the world interest rate. Increases in spending shift the IS curve out, increasing the interest rate and decreasing the exchange rate (currency appreciation). The LM curve shifts out because the appreciation of the currency causes capital inflows, and then the world interest rate equilibrium is reached.

Graph 2- Mundell-Fleming IS-LM-BoP Model



Both the Mundell-Fleming model and the Frankel flexible-price model are derived from the Keynesian Cross (Obstfeld Rogoff 1995). Obstfeld and Rogoff integrate the Mundell-Fleming model and the Frankel flexible-price model and introduce consumption, a function of real income increases or decreases. Their model yields the conclusion that "consumption [expressed via the current account], rather than output, enters the money supply." This conclusion puts more emphasis on consumption and recommends further monitoring and altering of consumption rather than output. Policy allows for consumption shocks and consumption smoothing via trade policies, taxes, subsidies, lending, and borrowing. The implication is that a country that has the ability to control consumption, through foreign borrowing and lending, could initiate consumption shocks. The consumption shocks can become the new base level of consumption through intense smoothing, and because of new levels of consumption the exchange rate changes. The consumption shocks thus become exchange rate effects (Obstfeld and Rogoff 1995). In conclusion, the exchange rate can be manipulated by consumption. Their theory is that predictable money supply (a function of interest rates) and consumption will stabilize an exchange rate, equalizing the short-run and long-run rate. They propose the long-run exchange rate equation:

$$\hat{E} = \left(\widehat{M} - \widehat{M^{*}}\right) - \frac{1}{\pi}\left(\hat{C} - \widehat{C^{*}}\right)$$

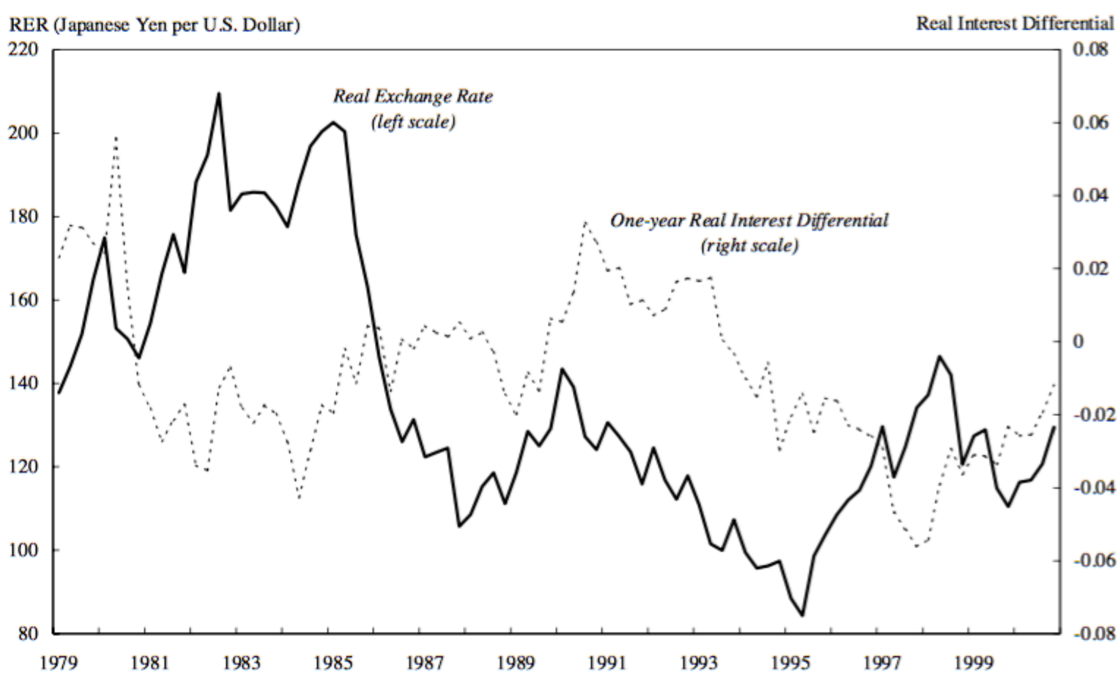
The above equation explains constant exchange rate, $\hat{E}$, as a function of money supply differential and consumption differential subject to inflation (denoted by π). In accordance with their hypothesis, the short-run exchange rate will become the long-run exchange rate because money supply and consumption shocks become constant. The Frenkel flexible-price model and Mundell-Fleming's IS-LM-BoP relationships are meshed by Obstfeld and Rogoff to provide the framework in which future exchange rate models are built.

ii. Interest, inflation, current account, and exchange rate relationships

The literature on exchange rates and their impact on economic fundamentals is wide and deep. Engel and West (2005) argue that, in accordance with past literature, nominal exchange rates are unpredictable by fundamental economic variables (like money supply, outputs, inflation, and interest rates), yet they find that the nominal exchange rate can help predict these fundamentals. They utilize Granger causality tests to explain how "exchange rates should be useful in forecasting future economic variables such as money, income, and interest rates" (Engel and West 2005). They conclude that nominal exchange rates and economic fundamentals have a relationship that is most consistent with asset-pricing models of the exchange rate.

Rao (2000) expands upon the relationship between business cycles and exchange rates citing that fluctuations in economic activity are inherent behavioral features of most economies, so the exchange rate, or price of a country's currency, must follow the cycle. The author lays out the goals of macroeconomic policy as recession avoidance and, in turn, economic stability. He finds that "a current account surplus…will increase the supply of assets denominated in foreign currency, tending to reduce the risk premium and causing the currency to appreciate" (Rao 2000). Rao determines that the real exchange rate (RER) and the current account deficit ratio (CAD/GDP) are inversely related.

Graph 3- Japan RER and One-year Interest Differential



Source: Rogoff, 2001

The graph above illustrates how an increasing interest rate differential is associated with an appreciation of the RER while a decreasing interest rate differential is associated with a depreciation of the RER, using the Japanese Yen as an example.

Rao acknowledges that most exchange rate theories are based on the nexus of interest rate differentials and exchange rates, but that the current account relationship is incontrovertible. At the conclusion of his paper, Rao explains that advanced economies are not as responsive to net exports; his model of current account and money supply impacting a change in the real exchange rate is custom-fitted for developing economies.

Macdonald (1995) gives a general equation that summarizes how the exchange rate, balance of payments, current account, and capital account interact. The author concludes that the exchange rate works to offset any discrepancy in the relationship between the balance of payments and the current and capital accounts. The exchange rate "ensures that the sum of the current and capital accounts…is equal to zero" (Macdonald 1995). I summarize his equation:

$$E + BoP = \sum CA + \sum CAP$$

Where:

$$E = f(current\ account, capital\ account, balance\ of\ payments)$$

The author concludes that the equilibrium equation is intrinsically flawed because a long-run equilibrium would require current accounts to be zero and thus capital flows would be zero. He contends that in a floating exchange rate period long-term capital flows would not be zero because they reflect inflation and productivity, thus it is incorrect to assume that exchange rates are a function of relative prices. His exchange rate models statistically perform better than the random-walk theories, encouraging further research in economic fundamentals as indicators of exchange rate variability.

iii. Emerging economy nuances and theories

Emerging economies are inherently unique in that most of their growth and economic health is contingent on their exports. Exports (tradeable goods) are very responsive to exchange rates, thus an emerging economy would like to keep their currency depreciated (Gervais, Lawrence, and Suchanek 2015). The desire to maintain a depreciated currency incentivizes developing countries to employ managed exchange rate regimes. In their study, Gervais, Schembri, and Suchanek dive into the effects of real exchange rates' roles in domestic current account imbalances. The authors conclude that the real exchange rate, which is a function of the nominal rate, has the ability to reverse a current account imbalance and help an emerging economy avoid a financial crisis or a loss of output. The exchange rate's ability to stabilize a current account comes from the capital inflows that follow a depreciated currency as well as the attractiveness of inexpensive exports to foreign trade partners. They recommend that emerging economies should allow for flexible nominal rates (managed floating rates) instead of a fixed peg because when a country wants to rebalance its current account, a fixed rate change would be very costly in terms of output and could result in a domestic financial crisis.

Policies and theories for emerging economies go hand in hand as they have served as a testing ground for monetary policy and exchange rate regimes. Given that developing nations want a somewhat depreciated currency, especially relative to their major trading partners, it is vital to have an efficient and effective central banking system to respond to exogenous shocks. Khan (1986) summarizes the different strategies of emerging economies' responses to shocks based upon their geographic region from 1977 to 1984, when worsening terms of trade, falling growth rates for industrialized countries, and less available foreign financing caused heavy stress for macroeconomic management (Khan 1986). Flexible exchange rate regimes became more and more popular to combat the difficult trade environment and heavy borrowing became the norm. Latin American countries' borrowing increased from $17 billion in 1977 to over $56 billion in 1981 (Khan 1986). He stresses the importance of policy that actively depreciates the emerging market currency and notes its popularity, "of the 106 developing countries…nearly one half had adopted policies that resulted in depreciating effective exchange rates" (Khan 1986).

Bettendorf and Chen (2013) looked for bubble trends in exchange rates and found that the foreign exchange markets do not exhibit bubble trends; however, the authors found that exchange rates do respond to the relative price of traded goods. Their initial asset-price tests, which are standard in international economic theory, showed little evidence of bubbles, thus they concluded that "it is crucial to take the underlying fundamentals into account when identifying rational bubble asset prices" because asset price equations alone are not sufficient (Bettendorf and Chen 2013). Hu and Oxley (2017) expanded on the work of Bettendorf and Chen and applied their asset-price models with fundamentals to emerging market economies. Emerging market economies are found to exhibit exchange rate bubbles because of loose monetary policy and the existence of unmonitored parallel exchange rates (an exchange rate black market). They concluded that industrialized economies were more stable and less responsive relative price in an asset-price model than emerging economies. The authors suggest that the changes in exchange rates for developing countries comes from the change in relative price of traded goods.

Data, Methods, and Model

The intention of this research is to explore the variables that change a commodity-dependent developing country's exchange rate, and then discuss the policy implications of a useful strategy for predicting those exchange rate changes. The research is specific in that it focuses on developing countries, particularly commodity-dependent developing countries, and tests if the average commodity price has any nominal impact on their currency fluctuation. This section describes the data, methods, and model that are used for this study.

In order to get an appropriate and balanced sample, the United Nations list of developing countries was used, as well as their specification list of commodity-dependent developing countries. In total 65 developing countries were selected; 28 countries are commodity-dependent, 22 countries are not commodity-dependent, and 15 are oil-dependent. The official nominal exchange rate relative to the USD for the selected countries was taken from OANDA, a private financial services company. The exchange rates used are the annual rates from 1995 to 2016.

The variables included in the regression are the average commodity price (excluding price of oil), current account to GDP ratio, inflation rate, and interest rate. For comparison purposes I included and ran regressions for the average commodity price including the price of oil as well as the commodity price of just food and beverage related commodities. The data come from The IMF and The World Bank. All of the data is public and available back through year 1995 from their respective sources. The data is in panel data form and it is strongly balanced. However, for some countries, such as Gabon and Togo, there is not complete data for current account to GDP ratio because it is self-reported information. In the summary statistics in Figure 1 is is clear that several observations lack the natural log of current account to GDP ratio data.

The method of testing is a standard fixed-effects regression model. A Hausman specification test is used to determine the appropriateness of random or fixed effects in the model. The model is estimated with robust standard errors to address heteroscedasticity. The natural log of each variable is ran in the regression to test the hypothesis: that a change in exchange rate is driven by changes in commodity price, interest rate, and some measure of inflation. The natural log of the exchange rate makes the unit tested a percent instead of a currency unit number. A difficult task is selecting which variables are appropriate measures for commodity price, interest rate, and inflation rate. The IMF average annual commodity price, excluding the price of oil, is used to represent commodity price. The real interest rate as indicated by The World Bank is used as a measure of interest rate. Inflation has many measures, but in accordance with past models and theories The World Bank purchasing power parity conversion factor of private consumption is used as the proxy for inflation. The conversion factor says how many units of one currency would be necessary to purchase the same goods and services in the domestic market as the USD would buy in the United States. Every variable is specific to each country over the time period 1995-2016. This is the regression:

$$\ln(exchange\ rate) = \beta_0 + \beta_1 \ln(average\ commodity\ price) + \beta_2 \ln(real\ interest\ rate) + \beta_3 \ln(purchasing\ power\ parity) + \beta_4 \ln(current\ account\ to\ GDP\ ratio) \quad (1)$$

To accurately test the hypothesis of this paper, the 65 developing countries are split into three groups: commodity-dependent, non-commodity-dependent, and oil-dependent. The 'developing country' classification comes from the United Nations annual categorization of developing countries versus fully developed countries and countries in transition. Within the 'developing country' list there are subsections that label countries commodity-dependent, non-commodity-dependent, and oil-dependent. Oil-dependent countries are "fuel-exporters" which means that fuel exports are greater than 20 percent of total exports and their total fuel exports is 20 percent higher than that of a country's fuel imports (WESP 2014). The countries chosen represent every sub-region of the world as denoted by the United Nations, such as East Africa and South-Eastern Asia.

Some variables are self-reported and are thus not always available if a county doesn't have the infrastructure to collect the appropriate data, or if they chose to withhold information. Thus, the observation total goes from 1,430 to 851 when the model is tested. Moreover, the current account to GDP ratio is only available for 283 of the 851 testable observations. The robustness of a result is significantly decreased when a sample shrinks by over 66 percent. Accordingly, the natural log of the current account to GDP ratio variable is removed in some regressions. The regressions being run becomes:

$$\ln(exchange\ rate) = \beta_0 + \beta_1 \ln(average\ commodity\ price) + \beta_2 \ln(real\ interest\ rate) + \beta_3 \ln(purchasing\ power\ parity) \quad (2)$$

Given the three different average commodity price variables (average commodity price without oil, average commodity price with oil, and average commodity price of only food and beverage) a few different regressions are run in order to determine the best measure of commodity price. At the onset of testing, a full regression is run containing all three commodity prices, and then three separate regressions are run with each individual commodity price. The additional regressions run are listed below:

$$\ln(exchange\ rate) = \beta_0 + \beta_1 \ln(average\ commodity\ price) + \beta_2 \ln(average\ price\ of\ food\ and\ beverage\ commodities) + \beta_3 \ln(average\ commodity\ price\ including\ oil) + \beta_4 \ln(real\ interest\ rate) + \beta_5 \ln(purchasing\ power\ parity) \quad (3)$$

$$\ln(exchange\ rate) = \beta_0 + \beta_1 \ln(average\ price\ of\ food\ and\ beverage\ commodities) + \beta_2 \ln(real\ interest\ rate) + \beta_3 \ln(purchasing\ power\ parity) \quad (4)$$

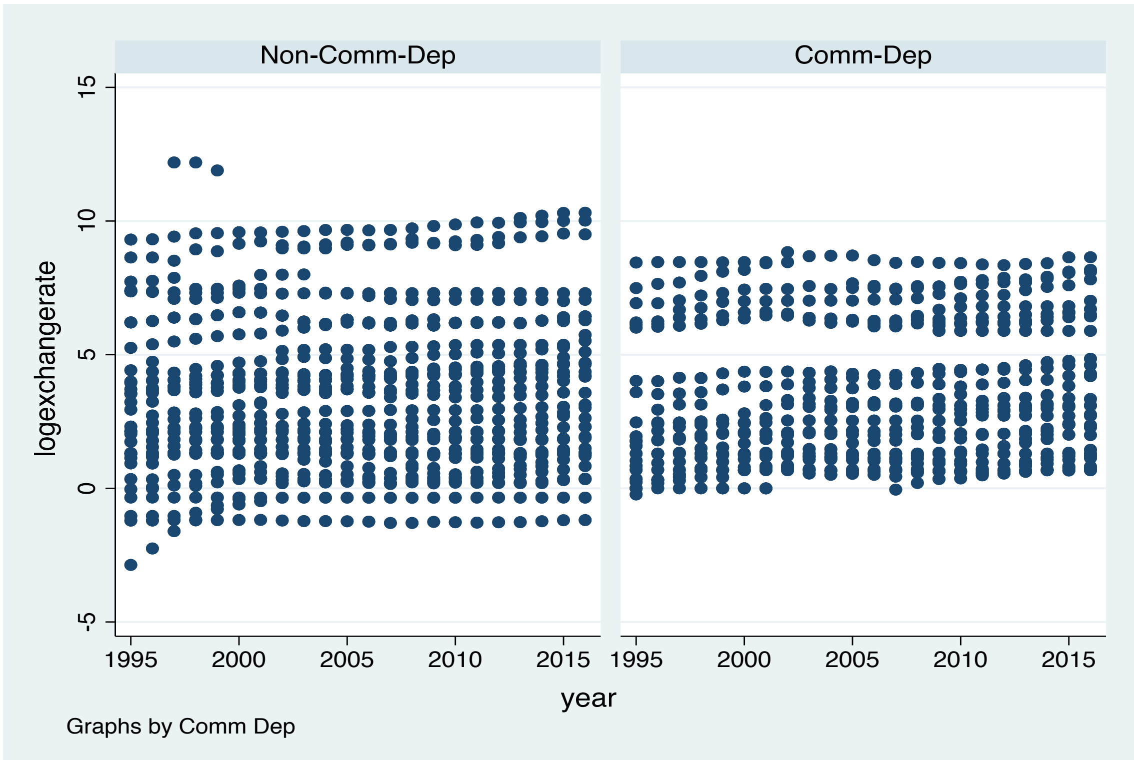
$$\ln(exchange\ rate) = \beta_0 + \beta_1 \ln(average\ commodity\ price\ including\ oil) + \beta_2 \ln(real\ interest\ rate) + \beta_3 \ln(purchasing\ power\ parity) \quad (5)$$

$$\text{natural log}(exchange\ rate) = \beta_0 + \beta_1\ \text{natural log}(average\ commodity\ price) + \beta_2\ \text{natural log}(real\ interest\ rate) + \beta_3\ \text{natural log}(purchasing\ power\ parity) + \beta_4 comminteract \quad (6)$$

Equation (3) includes all three average commodity prices and equations (4) and (5) are modifications of equation (2) with different commodity prices. This process is simply a cross-check to ensure that results are robust to commodity price substitutions. The next step after running regressions for the restricted samples is creating an interaction term. Commodity price is interacted with the commodity dependency dummy variable. The interaction term will show the variability in the natural log of exchange rate caused by commodity dependency. Regressions are run for the full sample and then for the sub-groups labeled commodity dependency and non-commodity dependency. Oil-dependent countries are grouped with non-commodity-dependent countries because in all prior tests and analyses commodity-dependent countries are tested as a different category as non-commodity-dependent countries. A reason they are tested differently is because of the relationship that their economies have with the price of oil: when the price of oil goes up, their economies are stimulated. In many commodity-dependent countries, the price of oil makes the cost of living increase and can hinder growth. Thus, for the estimations in this paper, oil-dependent countries are categorized as non-commodity-dependent.

The summary statistics for the full sample point out that the natural log of the exchange rate is the most volatile measurement, only rivaled by natural log of purchasing power parity. When the summary statistics are sorted by commodity dependency, a similar picture is painted except that the changes in commodity-dependent exchange rates are slightly more concentrated. However, the commodity-dependent countries' exchange rates are insignificantly less volatile than the rates of non-commodity-dependent countries. Below, Graph 4 presents the natural log of exchange rates for non-commodity-dependent developing countries versus commodity-dependent countries over the time period 1995-2016.

Graph 4- Summary Natural log of Exchange Rate, Comparing Restricted Samples



The summary statistics for the full sample and both restricted samples are shown in Figure 1, Figure 2, and Figure 3. It is interesting to note that the means of *lnexchangerate* are very close across the subsets of countries. Further, the standard deviations are very similar. The expectation is that commodity-dependent countries would have a more variable exchange rate, thus their exchange rate changes would be greater and there would be more variability. More surprising is the similarity in the inflation and interest rate measures. Regardless of commodity dependency, developing countries' inflation and interest rates seem to move at the same rate and have similar variability. It is important to remember that the natural log is the percent change and that the percent change can mean a greater change in a country with a seven percent interest rate versus a country with a two percent interest rate. The commodity prices are standard across all countries and sample types because they are global measures published by the IMF. Perhaps in a future and more in-depth study a country's model could contain not the natural log average commodity price, but the natural log of its top or top three commodity export prices. A country and commodity specific model could give more insight into how an exchange rate is influenced by a domestic economy's top commodity export prices, versus grouping all countries together and all commodities together. The bold numbers in the figures are either significant or will be referenced.

Figure 1- Summary Statistics All Variables, Full Sample

Summary Statistics All Variables – Full Sample (n=1,430)			
Variable	Obs	Mean	Std. Deviation
lnexchangerate	1,333	**3.535**	**2.767**
lncommprice	1,430	4.722	2.999
lncommfood	1,430	4.760	.2750
lncommoil	1,430	4.537	.4661
lnrealint	939	2.077	1.007
lnPPP	1,296	2.651	2.635
lncagdp	434	1.428	1.444

Figure 2- Summary Statistics Relevant Variables, Commodity-Dependent

Summary Statistics Relevant Variables – ComDependent (n=616)			
Variable	Obs	Mean	Std. Deviation
lnexchangerate	540	**3.521**	**2.590**
lncommprice	616	4.722	.3001
lncommfood	616	4.760	.2751
lncommoil	616	4.540	.4663
lnrealint	428	**2.278**	**.9981**
lnPPP	524	**2.743**	**2.580**

Figure 3- Summary Statistics Relevant Variables, Non-Commodity-Dependent

Summary Statistics Relevant Variables – NonComDependent (n=814)			
Variable	Obs	Mean	Std. Deviation
lnexchangerate	793	**3.543**	**2.883**
lncommprice	814	4.722	.3001
lncommfood	814	4.760	.2751
lncommoil	814	4.540	.4663
lnrealint	511	**1.909**	**.9848**
lnPPP	772	**2.589**	**2.672**

Results and Analysis

This section first discusses the tests done on all 65 countries and their results and then explains the restricted test groups: commodity-dependent group and non-commodity-dependent group. The final part of the section discusses findings when an interaction term is interjected to estimate exchange rate variability.

Before the results are discussed, it is important to note that diagnostics tests showed that the data may be subject to multicollinearity, as well as the errors of the regression not having a normal distribution. The multicollinearity of the data is expected because the selected variables move together and affect each other. The abnormal distribution is due to outliers, but when outliers are removed the results do not change, thus the outliers were kept in the model.

The first model (1) has natural log of exchange rates, again for all 65 countries over a 22-year period (1995-2016), as the dependent variable and natural log of average commodity price, natural log of real interest rate, natural log of PPP, and natural log of current account to GDP ratio as independent variables. The fixed effects command is determined by a Hausman test and the command 'robust' addresses heteroscedasticity in the errors. The natural log is used to regress all models to show if a one percent change in an independent variable will appreciate or depreciate a currency and by what percent. Natural log is also a better fit for the model.

The estimation of model (1) yields an R^2 value of .9856 and an F-stat significant at the 99 percent level. The first model (1) is a solid fit and the variables of interest, *lncommprice* and *lnPPP*, are significant at the .05 level, while *lnrealinterest* is significant at the .10 level. The signs of the coefficients *lncommprice* and *lnrealinterest* are negative, meaning that a one percent increase in commodity price or real interest rate will decrease the exchange rate, implying a currency appreciation. *LnPPP* has a positive coefficient, meaning that a one percent increase will increase the exchange rate, depreciating the currency. Figure 4 presents the results of this initial regression; however, the number of observations decreases by over 66 percent when the regression is run with variable *lncagdp*. In addition, *lncagdp* is only significant at 78 percent confidence. As mentioned in the Data, Methods, and Models section, the natural log of current account to GDP ratio is removed for the rest of the models in order to have more robust results. A difficult variable to track will eliminate all observations that lack that variable, decreasing the sample size. The results of the modified model (2) without the natural log of current account to GDP ratio are presented in Figure 5.

Figure 4- Fixed Effects Regression, Model 1-Full Sample

lnexchangerate—Fixed Effects Regression R^2 = **.9856** (n=283)				
Variable	Coefficient	Robust Std Err	t-value	P value
lncommprice	-.3531	.0425	-8.30	**.000**
lnrealinterest	-.0118	.0069	-1.71	.096
lnPPP	.7667	.0749	10.23	**.000**
lncagdp	.0077	.0062	1.24	.221

Figure 5- Fixed Effects Regression, Model 2-Full Sample

lnexchangerate—Fixed Effects Regression R^2 = **.6376** (n=851)				
Variable	Coefficient	Robust Std Err	t-value	P value
lncommprice	.1676	.3040	.55	.584
lnrealinterest	**-.0429**	.0175	-2.45	**.018**
lnPPP	-.0382	.5531	-.07	.945

The results in Figure 5 tests the full testable sample as observations increase to 851. A lower R^2 is expected as only three independent variables are included to explain the exchange rate change. Surprisingly, the *lnrealinterest* is the only significant variable at the .05 level, while neither of the variables that were significant in model (1), *lncomm* or *lnPPP*, are significant in model (2). The coefficient for *lnrealinterest* of -.0429 means that a one percent increase in real interest will appreciate a currency by .0429 percent—it could be noted that four basis points can be considered economically small. The null hypothesis that commodity price does not have an impact on exchange rates is cannot be rejected.

Before moving on to testing both commodity-dependency groups in their restricted samples, the use of average commodity price must be confirmed statistically as the best price proxy. The regression is run using model (3). The regression is run with the full sample. All three commodity prices are used: average commodity price, average price of food and beverage commodities, and average price of commodities including the price of oil. Recall Figures 1 through 3 describing the summary statistics for the three prices. The natural log of price of commodities including the price of oil has the largest standard deviation at .4611 while the standard deviation of the natural log of average price of food and beverage commodities is .2750. The graph below layers the three correlated commodity price natural logs. The estimation results for model (3) are presented in Figure 6.

Graph 5- Natural log of Commodity Prices from 1995 to 2016

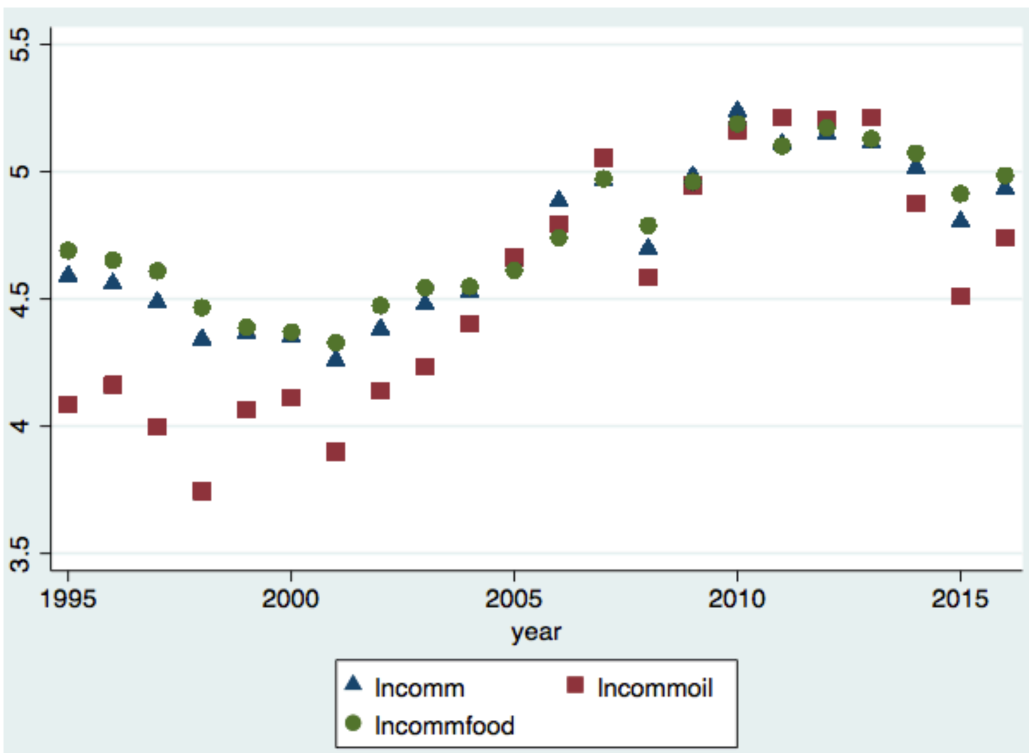


Figure 6- Fixed Effects Regression, Model 3-Full Sample

lnexchangerate—Fixed Effects Regression R^2 = **.7385** (n=851)				
Variable	Coefficient	Robust Std Err	t-value	P value
lncommprice	**-1.146**	.4817	-2.38	**.021**
lncommfood	.8711	.6791	1.28	.205
lncommoil	**.3733**	.1323	2.82	**.007**
lnrealinterest	**-.0412**	.0198	-2.08	**.042**
lnPPP	-.0726	.5618	-.13	.898

The regression in Figure 6 shows the influence of the natural log of average commodity price and natural log of commodity price including the price of oil. The *lncommprice* is significant at the .05 level with a P value of .021, as is the *lncommoil* with a P value of .007; however, the coefficient of the *lncommprice* is much greater than the *lncommoil*. Further, the *lncommprice* is related to the exchange rate change as expected, whereas the *lncommoil* is inversely related to the exchange rate change. The way to read the sign in front of the coefficient is that a one percent increase in commodity price will lead to a -1.146 percent change in the exchange rate; a negative exchange rate change is an appreciation of a currency. The regression shows that an increase in the *lncommoil* will depreciate a country's currency—when looking at the full sample. The natural log of real interest is also significant at the .05 level with a P value of .042. A one percent increase of the real interest rate will appreciate a currency by .0412 percent—a small increase in terms of magnitude, as well as an intuitive and proven result (Engel and West 2005).

To further confirm the use of average commodity price, the restricted samples are tested with each commodity price, individually. Figure 7 and Figure 8 present the three regressions run with each individual commodity price. The models being run are models (2), (4), and (5). These models are run and presented for the restricted samples: commodity-dependent countries and non-commodity dependent countries, as dictated by the commodity-dependent dummy variable. The figures only show the commodity price results and R^2 values to demonstrate that the model is robust to alternative substitutions. The R^2 values for both samples are nearly identical, as are the P values. The coefficients for the commodity-dependent sample are all inversely related to the exchange rate change, as expected, and the coefficients for the non-commodity-dependent sample are directly related to the exchange rate change but are insignificant. Because of the similarities between the influence of the three commodity prices and the consistent robustness of the tests, it is appropriate to select the average commodity price as the proxy for commodity price.

Figure 7- Fixed Effects Regression, Model 2, 4, and 5-Commodity-Dependent

Model	Variable	Coefficient	Robust Std Err	t-value	P value	R^2
(2)	lncommprice	-.3388	.0832	-4.07	**.001**	**.9853**
(4)	lncommfood	-.3983	.0988	-4.03	**.001**	**.9855**
(5)	lncommoil	-.1655	.0445	-3.72	**.001**	**.9849**

Figure 8- Fixed Effects Regression, Model 2, 4, and 5-Non-Commodity-Dependent

Model	Variable	Coefficient	Robust Std Err	t-value	P value	R^2
(2)	lncommprice	.2962	.3100	0.96	**0.346**	**.9262**
(4)	lncommfood	.3581	.3588	1.00	**0.326**	**.9257**
(5)	lncommoil	.1871	.1768	1.06	**0.298**	**.9262**

Figure 4 and Figure 5 test the regression against all countries—the full sample. The next step is refining results and properly testing the hypothesis by running the final regression, model (2), on the restricted samples. The restricted samples are created by splitting the data into commodity-dependent and non-commodity-dependent countries. Oil-dependent countries are grouped in the Non-Commodity-Dependent sample. The summary statistics are available in Figure 2 and Figure 3 for the two country groups. As a measure of variance, the exchange rate standard deviation for commodity-dependent countries is slightly below the full sample standard deviation and the exchange rate standard deviation for non-commodity-dependent countries is slightly above the sample standard deviation. A test of equality of standard deviation was run comparing the standard deviations for the two samples to determine if there was a difference in variance. The F-value of 1.239 allows the rejection of the null hypothesis that the variances are the same. The results are given for $lnexchangerate_{commodity\text{-}dependent}$ and for $lnexchangerate_{non\text{-}commodity\text{-}dependent}$ in Figure 9 and Figure 10, respectively.

Figure 9- Fixed Effects Regression, Model 2-Commodity-Dependent

lnexchangerate—Fixed Effects Regression R^2 = **.9853** (n=367)				
Variable	Coefficient	Robust Std Err	t-value	P value
lncommprice	**-.3388**	.0832	-4.07	**.001**
lnrealinterest	-.0067	.0110	-0.61	.551
lnPPP	**.9288**	.0970	9.57	**.000**

Figure 10- Fixed Effects Regression, Model 2-Non-Commidty-Dependent

lnexchangerate—Fixed Effects Regression R^2 = **.9262** (n=484)				
Variable	Coefficient	Robust Std Err	t-value	P value
lncommprice	.2962	.3100	.96	.346
lnrealinterest	-.0370	.0291	-1.27	.212
lnPPP	-.3691	.5657	-.65	.519

The restricted sample tests present significant results. The R^2 value for the commodity-dependent sample is .9853 and the R^2 value for the non-commodity-dependent sample is .9262. The R^2 values say that 98.53 percent of the variation in *lnexchangerate* for commodity-dependent countries can be explained by the independent variables, and 92.62 percent of the variation in *lnexchangerate* for non-commodity-dependent countries can be explained by the independent variables, but with less significant values. In the commodity-dependent sample, the *lncommprice* is significant at the .05 level with a P value of .001. The *lncommprice* coefficient explains that a one percent increase in average commodity price will result in a .3388 percent appreciation of a commodity-dependent country's currency. The *lnPPP* is also significant at the .05 level with a P value of .000. The real interest rate is found to be insignificant for commodity-dependent country exchange rates.

The restricted sample of non-commodity-dependent countries has no significant values, despite a high R^2 value of .9262. This result is expected and in accordance with the hypothesis. The change in commodity price has little significance or influence on the change in exchange rate for non-commodity-dependent countries. The change in commodity price does significantly influence the change in exchange rate for commodity-dependent countries. The null hypothesis that commodity price does not have an impact on exchange rates can be rejected for the commodity-dependent restricted sample, but cannot be rejected for the non-commodity-dependent sample. Despite the results, it is important to note that a Chow Test is run to determine whether or not there are structural breaks in the model. The Chow Test results do not allow for the rejection of the null that there are no structural breaks in the data. Thus, there is little statistical significance that there are quantitative differences in the data set, yet there are qualitative differences in the data organization.

The final step is testing the whole sample with an interaction term. The regression with an interaction term will test if the variability in the exchange rate can be explained by the commodity price change and by being commodity dependent. The dummy variable *commdep*, which indicates whether a country is in the commodity-dependent sample or the non-commodity-dependent sample, is interacted with the *lncommprice*. The interaction term created is *comminteract*. The results of the fixed-effects estimation (6) are presented in Figure 11. The results have a dismal R^2 of .0287, meaning that the model explains very little of the change in exchange rates. The results show that the *comminteract* has no significance with a P value of .227. *Lncommprice* is also not significant with a P value of .773. The only significant variable at the .05 level is *lnrealinterest* with a P value of .012. Model (6) cannot reject the null that that commodity price does not have an impact on exchange rates.

Figure 11- Fixed Effects Regression, Model 6-Full Sample

lnexchangerate—Fixed Effects Regression R^2 = **.0287** (n=851)				
Variable	Coefficient	Robust Std Err	t-value	P value
lncommprice	.0757	.2610	.29	**.773**
lnrealinterest	-.0454	.0176	-2.58	**.012**
lnPPP	-.0393	.5492	-.07	.943
comminteract	.2091	.1712	1.22	**.227**

It is interesting to note that *lnrealinterest* is only significant in model (6) (Figure 11) and model (3) (Figure 6). Further, lnrealinterest and *lnPPP* are never significant in the same model and *lnPPP* and *lncommprice* are always significant together. According to the correlation table they are not correlated. There are two samples being tested and both have distinct results. The regression on the full sample with an interaction term yields insignificant results, fails to reject the null hypothesis, and says that *lnrealinterest* is a strong explanatory variable. The interaction term tests if the variability in exchange rates are a function of commodity price for commodity dependent countries. The model fails that test.

The regression on the restricted samples yields significant results (R^2 of 98.53 percent on the commodity-dependent and 92.62 percent on the non-comodity-dependent), rejects the null hypothesis, and confirms that *lncommprice* has measurable and significant influence on the change of exchange rates for commodity-dependent countries. The restricted sample tests commodity-dependent currencies' reactions to commodity price change versus non-commodity-dependent currencies' reactions to commodity price change. The model shows that commodity price change can explain some change in commodity-dependent currency values.

Discussion and Policy Implications

Developing countries are constantly working to achieve economic development, the reason being that an increase in development leads to an increase in domestic quality of life. A major factor of economic development is stability. This paper's intention is to isolate the exchange rate, an indicator of economic stability, and identify a means to forecasting its variability. This section will explain what the results mean in a practical application and give recommendations to countries' central organizations to promote internal economic stability. At the end of this section there will be an explanation of the paper's limitations and steps to improve a similar study in the future.

The sample of interest is commodity-dependent country currencies because their currencies, though freely floating, can typically loosely follow a G10 currency or their export prices. Some non-commodity-dependent developing countries, such as Singapore, India, and Mexico, have sophisticated financial centers, leverage influential central banks, and enjoy large corporate banking presences. Complex financial centers indicate transactions beyond exports and imports, deliberate central banks are conducive to stability, and big banking presences develop human capital and can stimulate economies by means of loans. Many commodity-dependent developing countries are devoid of the financial institutions that encourage stability.

Monitoring the exchange rate and being aware of how and why it moves can be a powerful preventative measure for external shocks, lack of export demand, or diminishing export supply. The results in the restricted sample (Figure 9) showed that some change in the exchange rate of a commodity-dependent country's currency can be explained by the change in average commodity price. Additionally, the change in purchasing power parity heavily influences the change in the exchange rate of a commodity-dependent country's currency. Both variables were significant at the 99 percent confidence level and the R^2 is over 98 percent. This test confirms that a commodity-dependent country should actively track the average commodity price and the consumer price purchasing power parity. In a practical application, capital inflow from an increase in commodity price can appreciate a country's currency. The central bank should desire to keep a steady exchange rate because the country is commodity-export dependent, meaning that the foreign price of their exports matters. Avoiding the Dutch Disease, an inflow of foreign reserves appreciating currency beyond competitive export price levels, should be a priority for developing nations. The central bank could issue a sell-off of local currency and stabilize foreign currency reserves, a smart move in terms of building a steady foundation for future currency buy-backs in case of an average commodity price decrease. Monetary policy for commodity-dependent countries can be, for lack of a better term, sticky.

The full sample regression (Figure 6) showed that for developing countries, regardless of commodity dependency, the natural log of average commodity prices as well as the natural log of average commodity prices including oil were significant at the .05 and the .01 level, respectively. Both prices could explain some change in developing country exchange rates. Interestingly, the natural log of average commodity price with oil is inversely related with the exchange rate, meaning that an increase of price of oil would lead to a depreciation of a developing country's currency. Additionally, the natural log of real interest is significant at the .05 level and directly related with a developing country currency appreciation. In order to brace for a currency depreciation in response to speculative commodity price (including oil) increases, a central bank could raise interest rates mildly by 20-30 basis points. When grouped together, 73.85 percent of a developing country's exchange rate change can be explained by the natural log of average commodity price and natural log of real interest.

Policy measures can be put in place as a reactionary tool to mitigate a significant change in the market. With the information from this paper, a commodity-dependent developing nation can follow commodity prices and the consumer price conversion factor and issue currency buy-backs and sell-offs accordingly. This paper suggests that a central bank can be confident in the effectiveness of controlling domestic inflation (measured by PPP) to stabilize its exchange rate. As far as stability goes, it is important to recall that the countries of interest are export-dependent, and many of them are commodity-export dependent. As the results show, a one percent change in the commodity price would change their currency value by .33 percent—that is an economically large, crucial number. A country that is commodity-export dependent, the change in commodity price has a direct change in government revenue and could hinder the ability to import essential goods. Beyond economic stability, careless monetary policy as a result of incomprehensive commodity price monitoring could result in a lack of political stability or obstruct human development.

A more audacious recommendation would be to not augment reactionary tools, rather control the dictating price. The Organization of Petroleum Exporting Countries took it upon themselves to control the price of oil by increasing or decreasing production, that is supply control. Commodity-dependent countries that share similar exports and export partners could organize to create a supply control through quotas, thus having increased authority over the commodity price. If the commodity price is predictable, then the central bank can more effectively manipulate the exchange rate, leading to stability and hopefully economic development.

This study has several limitations that must be acknowledged. The first and most important limitation is the data itself. The sample is large and representative, but it could have been a more cohesive paper if all 1,430 observations were tested. The *lncagdp* was not available for many observations, and as the summary statistics (Figure1) show, the *lnrealinterest* was not available for all observations. Only having testable data for countries that report all the required information could explain bias in the results. Further, the variables chosen to be proxies for exchange rate inputs may not be the best options. Inflation rate could be chosen over PPP, and nominal or discounted interest could be chosen instead of real interest. Further, the decision to add oil-dependent countries into the non-commodity-dependent group may have skewed the results. Exchange rates as well as their inputs are also relatively correlated, which could mean that they move together in real time or even instantaneously.

Conclusion

The purpose of this study is to explore the inputs of developing country exchange rates and estimate how much the inputs may vary, in their type and magnitude, contingent on whether or not the developing country is commodity-dependent or non-commodity-dependent. The hypothesis is that a change in commodity price can explain a change in the exchange rate of a developing country that is commodity-dependent more than it can explain the change in the exchange rate of a developing country that is non-commodity-dependent. Though the results differed when the test sample was full and when it was restricted, some results were significant and could inspire further examination of exchange rates of developing countries. When the sample is restricted by commodity-dependency, the natural log of average commodity price and natural log of purchasing power parity are very significant for commodity dependent countries and no variables are significant for non-commodity-dependent countries. This finding expands on the conclusion of Hu and Oxley (2017) that all developing countries' exchange rate changes respond to the price of traded goods, and explains that the responsiveness varies by commodity dependency. Beyond the intentions of this paper, inflation, represented by change in purchasing power parity, is found to be a reliable indicator of exchange rate change; this conclusion has been theorized and assumed in the past by MacDonald (1995), and this paper further suggests its legitimacy. The results suggest that the natural log of average commodity price and the natural log of purchasing power parity explain the exchange rate changes in commodity-dependent developing countries, while the natural log of average commodity price, natural log of average commodity price including oil, and natural log of real interest rate help explain exchange rate changes for all developing countries.

A study could build upon this research to include a greater number of variables or different proxies for interest, inflation, or commodity price. Further, the study could have a greater number of data taken for the observations that lacked current account to GDP ratios. It would also be interesting to run the model by region, or to custom-fit the model to include the prices of each country's greatest commodity exports. Countries do exhibit varying degrees of responsiveness to commodity price conditional on their commodity-dependency, but the variability in the exchange rate change cannot be explained by whether or not a country is commodity-dependent. Further research could attempt to identify a means to a cohesive understanding of developing country exchange rates, and hopefully prescribe the foreign exchange stability that a developing country needs in order to advance in the fast-paced globalized economy.

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