DETERMINANTS OF EXCHANGE RATES: THE CASE OF THE CHILEAN PESO

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ABSTRACT

In this study, we analyzed the relationship between the exchange rate movements of two countries, Chile and the United States, by studying the underlying fundamentals given by the modern exchange rate theory. In this context, we included in our regression analysis three main economic factors. Monetary policy interest rate, money supply and inflation rates were considered for both countries since January 1990.

We also included a fourth variable in our model; Copper Price. The evolution of this commodity's price played an important role in our study as we will discover that a significant portion in exchange rates variation is explained by this variable. Copper was considered because of the increasing importance of this commodity in the Chilean economy.

The results show that the determinants of the exchange rate may vary over time. The independent variables that have an effect on the exchange rate may lose their explanatory power when economic conditions change or a switch in the foreign exchange rate policy dictated by central banks or, as we proved, when variations on certain markets takes place.

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INTRODUCTION

Since the early seventies, several theories concerning exchange rates determination have evolved. At this time, it was common to emphasize international trade flows as primary determinants of exchange rates. This was due, in part, to the fact that governments maintained tight restrictions on international flows of financial capital. The role of exchange rate changes in eliminating international trade imbalance suggest that we would expect countries with current trade surpluses to have an appreciating currency, whereas countries with trade deficits should have depreciating currencies.

These different models developed mainly in the 70's led to testable propositions in which the changes in the exchange rate are linearly related to the news in the fundamental variables, such as money stocks, prices, output, current accounts, etc. Among these models, we find the monetary model, Dornbush model, and the portfolio balance model.

We can consider this as the first stage in exchange rate determination theory. Unfortunately, these first generation models were rejected by the data, at least for countries where the levels of inflation where relatively low. Three anomalies were detected.

- First, the random walk forecast typically outperforms a forecast based on the first generation models. The study conducted by Meese and Regoff (1983 – 1988) demonstrated that the theory behind these models can't be confirmed by the results of the study. Random walk theory states that currencies take a random and unpredictable path.
- Second, since the start of the floating exchange rate regime, variability of exchange rates increased dramatically. At the same time, there is no evidence to be found that the variability of the fundamentals identified by the theoretical models has increased compared to the fix exchange rates period. First generation models implied that the variability of exchange rates can only increase when the variability of the underlying fundamentals increases
- Third, the first stage models assume that exchange rates can only change at a certain point in time as a result of "news" in the fundamentals. A study directed by De Boeck (2000) and Altavilla (2000) find that unanticipated shocks in the fundamental variables explain only a small fraction of the unanticipated changes in exchange rates.

Typically they find that news on inflation, output and interest rates explain about 5% in the variation of exchange rates.

At this point, where theory has been proven wrong, researchers are driven to alternatives to this first stage models. Some studies introduce non-linearities into the model (see De Grauwe and Dewatcher, 1993; Frankel and Frot, 1990; Kilian and Taylor, 2003; Kurz and Motolese, 1999). These models are characterized by the existence of several agents using different information sets and/or by the existence of transaction costs. The insight provided by these models is that they predict frequent structural breaks in linear exchange rate equations, and that they allow for changes in the exchange rates that are unrelated to news about the underlying fundamentals.

It is also worth mentioning and considering the contribution of Nelson C. Mark (1995) where he investigates the extent to which deviations of the exchange rate from a fundamental value suggested by economic theory are useful in predicting exchange rates over long horizons. The study presents evidence that there is an economically significant component in long horizon changes in log nominal exchange rates. This was made by testing regressions of multiple-period changes in the log exchange rate on the deviation of the log exchange rate from its “fundamental value”. The results of the study show that while short horizons changes tend to be dominated by noise, this noise tend to be averaged out over time. The so called “Noise” refers to exchange rates fluctuations in the market that can confuse one’s interpretation of market direction. The study reveals systematic exchange rate movements that are determined by economic fundamentals. This was one of the first studies that proved with empirical results that exchange rate changes can be forecasted.

The objective of this project is, considering previous studies on the field, to analyze the nature of the relationship between exchange rate changes and the variations in the underlying fundamentals, looking at the historic development of two currencies, the US dollar and Chilean Peso.

Besides testing the Chilean currency against the fundamental variables, a new test will be performed taking into consideration the impact that commodity prices may have in foreign exchange determination, in view of the high impact of copper in the Chilean economy.

THEORIES BEHIND EXCHANGE RATE DETERMINATION, BRIEF REVIEW

1. Purchasing Power Parity (PPP): Based on 'no arbitrage argument' or 'law of one price', PPP is a flow model of the 'inflation theory of exchange rates' vis-a-vis the balance of trade. Only relative PPP seems to hold in the long run. Shifts in technology, tastes, commercial policies or labor force growth will structurally change national *productivity* and hence will permanently change the real exchange rate.
2. Monetary Approach: These stock models are based on IS/LM/Phillip Curve paradigm. Basically the theories are based on finding the exchange rate which the available amount of currency supply is equal to the demand to hold the currency.

2.1 Mundell-Fleming Model: The theory considers three markets: money, asset and goods markets under perfect *price flexibility* in long run. One implication is devaluation may lead to further devaluation if fiscal discipline, inflation and balance of payments are not well managed. Another is that the higher the degree of re-export processing industry the country has, the lower the impact of devaluation for current account improvement.

2.2 Monetarist Model: This concept implies that the exchange rate level is perfectly correlated with the level of the *relative money supply* in long run. In a *stationary* economy, the relative money growth rate would be zero and the exchange rate expectation would play a trivial role. Postulated in an inflationary and/or high growth economy, this model explains why a foreign exchange rate market may be characterized by a *self-fulfilling prophecy*. When the money supply becomes stochastic, *rational expectation* and accuracy of market *information* play an important role in *inter temporal* analysis.

2.3 'Sticky Price' Model : When a currency is devalued and the price of goods remains fixed in the short run, but not in the long run, the currency value may 'overshoot'. A balance of payment crisis, extended from the model, is the equilibrium outcome of maximizing behavior by rational agents faced with a fundamental *in*consistency between monetary and exchange rate policies. One implication can be in a *game-theoretic* perspective in policy implementation. In a non-cooperative and uncoordinated game with many players, each individual player has little information on other players' payoffs. There is no reason to believe everyone would act together to reach the desired outcome in a single step. Good government *coordination* as a signal to the financial market becomes essential to achieve effective monetary policy for currency stabilization.

2.4. Portfolio-Balance Approach: This theory determines the exchange rate *as the relative price of monies* in short run. The asset substitution effects and the nature of expectations formation places more emphasis on short run capital flows rather than the trade balance. In general, the short run impact of policies can be quite different from the long run impact, depending on the nature of the *expectations*. Exchange rates should implicitly behave like the behavior of asset prices in speculative markets.

BACKGROUND ON CHILE AND THE UNITED STATES – ECONOMY AND CURRENCIES

The U.S. Dollar

The US dollar accounts for about 70% of all foreign-exchange reserves and over one-half of global private financial wealth. About two-thirds of world trade is invoiced in US dollars and three-quarters of international bank lending is denominated in dollars.[1] The dollars importance has, however, decreased since the mid-1970s, when it was responsible for 80% of official reserves in foreign countries. Investors would start diversifying their portfolios as the world moves towards a multiple currency system. A legitimate rival of the USD is the Euro, especially after its introduction in 2000-2004, and in recent years many countries have announced that they are increasing their euro reserves as it has an increasing role in the world's economy.

Exchange Rate Movements and Economic Performance

The 1990s was a period of unprecedented economic growth in the US, and in February 2000 the economy surpassed the previous record for the longest sustained expansion of 107 months. The main feature of the expansion was a steady improvement in productivity, owing partly to wider use of computers and other advanced technology. Real GDP grew by almost 40% between 1991 and 2001, equivalent to an annual average of 3.4%. This economic prospect allowed the US dollar to appreciate throughout the nineties and beginning of the new century against most trading partners. The Federal Reserve's index of

[1] www.eiu.com, country profile USA

the US dollar's effective exchange rate against other major currencies rose from an average of 94.06 in 1998 (March 1973=100) to 107.66 in 2001. The long appreciation of the dollar reflected the strong underlying performance of the US economy and the prospect of high investment returns.

The first indication that the long expansion was coming to an end came with the collapse in the value of high-tech stocks that began in March 2000. Investments slowed down dramatically, while slow growth in the US.s major trading partners contributed to a deteriorating trade balance. Growth slowed further during 2001, especially in the immediate aftermath of the September 11th terrorist attacks. This was also a bad time for financial markets, which were rocked by a number of major scandals. Most of these can be traced back to the excesses of the stock market boom of the 1990s, when some high-profile companies resorted to dubious accountancy practices to boost their profits and share prices.

Even as the US economy weakened and US interest rates fell during 2001, the US dollar held its value against most currencies. Poor investments returns elsewhere in the world contributed to the US dollar to maintain its value for that time.

However, the US dollar dropped in value significantly against most major currencies during 2002, with the pace quickening in 2003-04, primarily against the euro and the Chinese yen. This was also the case for the Chilean peso.

The central banks exchange-rate index against major currencies averaged 93.o4 in 2003 and 85.42 in 2004, or nearly 21% below its 2001 average.[2] The depreciation reflected concern about the widening current-account deficit and the rapid deterioration in the federal government's fiscal position. In 2005 the US dollar regained some strength, propelled by a combination of rising short-term interest rates in the US and the weakness of other economies, notably those in the euro zone.

The US dollar reached a one-year low of US $1.27 against the euro in May 2006, a 28-year low of US$1.12 against the Canadian dollar, and also retreated significantly against the yen. G7 finance ministers made it clear at a meeting in April 2006 that they would welcome an appreciation of currencies of emerging economies with big trade surpluses with the US, such as China and South Korea.

Economic Background and exchange rate regime in Chile

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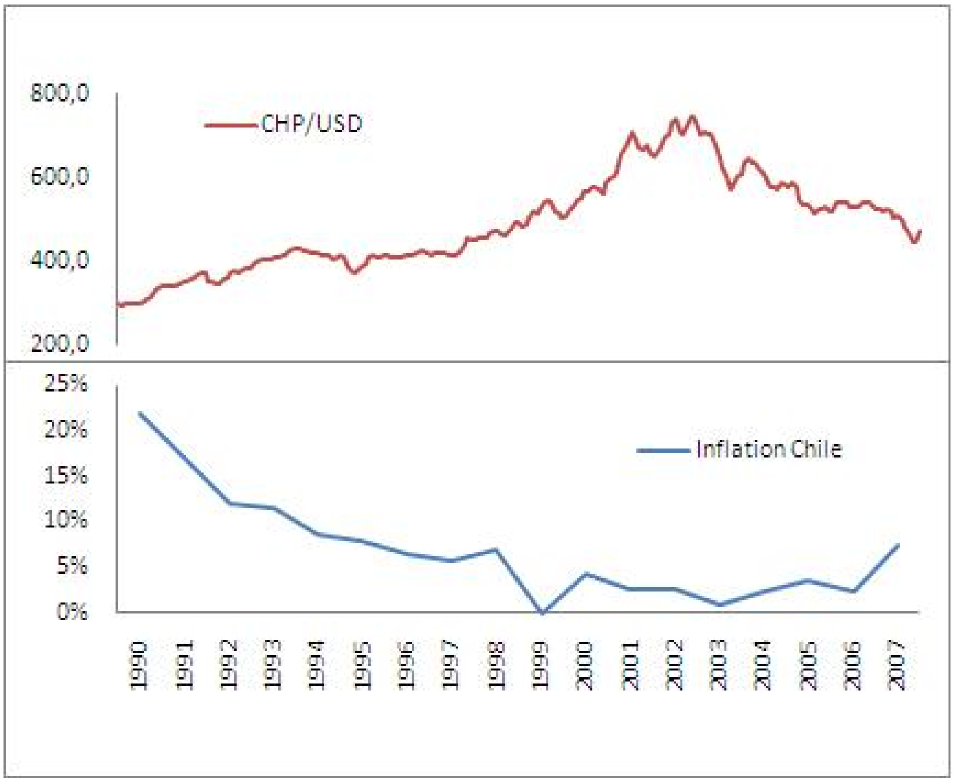
[2] www.eiu.com, country profile USA

The Chilean peso trend had a remarkable inflexion point in the beginning of year 2003, where it reached its maximum value of 745.21 pesos per US dollar. The appreciation of the CLP is evident after that date.

Starting in 1990, the Central Chilean Bank (CCB) adopted an inflation target regime. An inflation objective was set every year and gradually adjusted so as to allow for an ongoing reduction of inflation. In fact, in 1990, the target for the following year was set at 27%, whereas in 2001 the target was 3%.

Figure 1. Evolution CHP/USD compared to the Chilean Inflation



From the mid eighties to September 7, 1999, the CCB adopted a crawling exchange rate band, where the rate is allowed to fluctuate in a band around a central value, which is adjusted periodically. The main objectives of the band were to maintain international competitiveness and reduce excessive exchange rate volatility.

However, since the start of the band, many of its features, including its width, rate of crawl, reference currency basket, degree of symmetry and central parity were modified. Since September 2, 1999, the CCB has embraced a fully- flexible exchange rate regime, with the possibility of the CCB intervening in the market only in the case that "the exchange rate does not reflect the real value of the foreign currency."

However, the elimination of the band in September 1999 did not imply the absence of foreign exchange interventions. In fact, in response to large exchange rate depreciation and volatility, the CCB announced and carried out a temporary policy of sterilized interventions between July 2001 and January 2002. The stated objectives of the interventions were to reduce excessive exchange rate volatility and provide a hedge against future devaluations, without affecting exchange rate trends.

COMMODITY CURRENCIES

Commodity currencies are those of countries which depend heavily on the export of certain raw materials or commodities for income.

Different studies have been performed in this area to determine if such commodities exporting countries see their currencies affected by variations on internationally traded commodity prices. The study by Yu-Chin Yen and Rogoff (2002) analyzed the relationship between the exchange rate movements and commodity prices for Canada, New Zealand and Australia. These countries were chosen because they constitute open economies and are highly integrated to global capital markets and are dynamic participants in international trade. All of them have been operating under a freely floating exchange rate regime. Commodity exports account for 60% of Australia's total exports and 50% for New Zealand. Canada has a stronger industrial base, but still continues to rely more than a quarter of its exports on commodities. The authors find that world prices of commodity exports, expressed in American dollars, have a firm and stable influence on the exchange rates for Australia and New Zealand. For Canada the influence is not as strong, but fairly significant. Even though these countries have open capital markets and free floating exchange rate regimes, a real explanatory variable was found for determining exchange rate movements.

Indeed, the study performed by Cashin, Céspedes, and Sahay (2002) based on the assumption that fluctuations in real commodity prices have the potential to explain changes in real exchange rates, given that many countries are highly dependent on commodities for their exports revenues. They also studied the relationship between commodity prices and currency determination, but expanded their study to all the commodities exporting countries. 58

commodity exporting countries were included in the sample. 53 of those are developing countries[3]. “Commodity exports typically exceeded 50 percent of the total exports of several sub-Saharan African countries, especially Burundi (97 percent), Madagascar (90 percent), and Zambia (88 percent). The share of primary commodity exports in total exports was quite high even for the industrial countries (Australia, 54 percent; Iceland, 56 percent).”[4]

The results obtained by their study showed that 22 out of these 58 countries present a surprisingly strong relationship that remains over time between commodity price shifts and the currency determination. Half of these commodity-currency countries belong to the sub-Saharan African countries, due to their strong dependence to commodities. In many cases they rely on the exports of only one commodity. For these countries their commodities exports usually account for more than 90% of their total exports. That is the case for Dominica (bananas), Ethiopia (coffee), Mauritius (sugar), Niger (uranium), and Zambia (copper).

Over 80% of the variation in the real exchange rate can, on average, be explained by movements in real commodity prices alone. Measuring the impact of price variations, they found that the elasticity typically ranged between 0.2 and 0.4, with a median of 0.38. Thus, a 10 percent drop in the real price of the commodity exports of countries with commodity currencies is typically associated with a 3.8 percent depreciation of their real exchange rate. Further analysis also indicated that, when deviations from the relationship between exchange rates and commodity prices occurred in countries with commodity currencies, they were caused primarily by changes in real commodity prices. Following a movement in commodity prices, it is typically the real exchange rate that then adjusts to restore its long-run relationship with real commodity prices. [5]

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[3] (classified by the IMF's *World Economic Outlook* as exporters of nonfuel primary products and those with diversified export earnings)

[4] Paul Cashin, Luis Céspedes, and Ratna Sahay (2002)

[5] Paul Cashin, Luis Céspedes, and Ratna Sahay (2002)

Chile and Copper

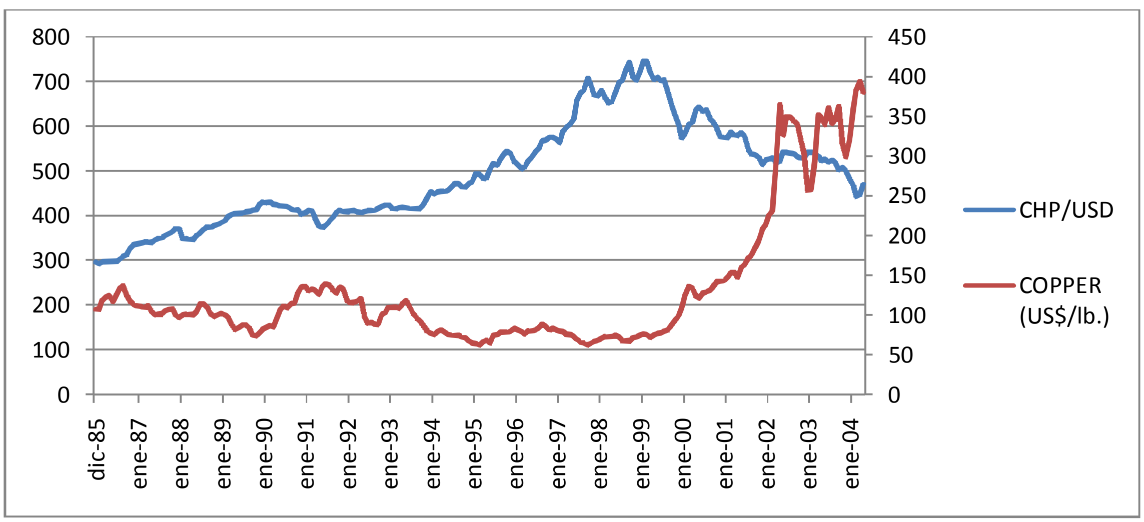
Chile is the largest producer and exporter of copper in the world, followed by Peru, USA and Indonesia. Utilized primarily in the construction industry, it is also widely used as a conductor for electronic devises, house hold products, coinage, biomedical applications, and chemical applications among others. Copper stands for 45% of Chilean exports and accounts for 13.9% of Chile's Nominal GDP. Chile produces 35.6% of the worlds copper production and represents 30% of the world's reserve of copper.[6]

The study by Cashin, Céspedes, and Sahay (2002) does not consider Chile to be a commodity currency country, but this may be explained because historic prices for copper remained stable for the period studied. After 2003, copper prices started increasing at a very quick pace due to growing world demand and a large drop in international inventories levels.

Our latter analysis is focused to determine if the relationship between copper price and currency determination is stable and significant.

The following graph shows the evolution of CLP against the increase in price of a pound of copper.

Figure 2. Evolution CHP/USD compared to the Evolution of Copper Price



Three commodity exchanges provide the facilities to trade copper: The London Metal Exchange (LME), the Commodity Exchange Division of the New York Mercantile Exchange (COMEX/NYMEX) and the Shanghai Metal Exchange (SHME). In these exchanges, prices

[6] COCHILCO (Chilean Copper Commission)

are settled by bid and offer, reflecting the market's perception of supply and demand of a commodity on a particular day. On the LME, copper is traded in 25 tons lots and quoted in US dollars per ton; on COMEX, copper is traded in lots of 25,000 pounds and quoted in US cents per pound; and on the SHME, copper is traded in lots of 5 tons and quoted in Renminbi per ton. More recently, mini contracts of smaller lots sizes have been introduced at the exchanges. Exchanges also provide for the trading of futures and options contracts. These allow producers and consumers to fix a price in the future, thus providing a hedge against price variations. In this process the participation of speculators, who are ready to buy the risk of price variation in exchange for monetary reward, gives liquidity to the market. A futures or options contract defines the quality of the product, the size of the lot, delivery dates, delivery warehouses and other aspects related to the trading process. Contracts are unique for each exchange. The existence of futures contracts also allows producers and their clients to agree on different price settling schemes to accommodate different interests. Exchanges also provide for warehousing facilities that enable market participants to make or take physical delivery of copper in accordance with each exchange's criteria. [7]

DATA SOURCES AND COLLECTION METHODS

Data Description

Data on monthly and daily exchange rates was gathered from the Central Bank of Chile's database. The daily dollar price denominated in Chilean pesos is calculated based on transactions of financial institutions that took place the previous working day. Weekends and holidays are excluded.

The sample considered in this study contemplates information on exchange rates starting in January 1990 until in March 2008.

The explanatory variables included in the model are:

[7] http://www.icsg.org/

Money Stock (M2)

Consists of the total amount of money held by the nonbank public at a point in time in an economy.

M0= Cash or assets that could quickly be converted into currency.

M1= M0 + Demand deposits, which are checking accounts.

M2= M1 + small time deposits (less than $100,000), savings deposits, and non-institutional money-market funds.

Money supply monthly observations for Chile were also taken from the central bank of Chile´s database, whereas the US money supply figures were taken from the Federal Reserve's database.

Inflation

Monthly changes in the Consumer Price Index represent the rate of inflation. CPI is a measure of the average price level of a fixed basket of goods and services purchased by consumers as determined by the Bureau of Labor Statistics for the US and the National Institute of Statistics (INE) for Chile.

The Consumer Price Index (CPI-U) is compiled by the Bureau of Labor Statistics and is based upon a 1982 Base of 100.[8] For Chile, CPI variations are gathered by the National Institute of Statistics (INE).

The basket of goods, and the weight of every item in it, may differ from country to country. For example, in developing countries, the weight that is given to food products tends to be higher than for the developed countries, where technological goods have a higher portion of the basket. This is one of the distortions of comparing inflation between two countries, but for our analysis we will not address this problem since those distortions are not extraordinarily considerable.

Monthly observations on the Chilean CPI were taken from the Chilean national institute of statistic's database. For the US consumer price index, this information was gathered from the Federal Reserve's database. After compiling the historical consumer's

[8] www.inflationdata.com

price index for both countries, Inflation was calculated by establishing the differential between one period and the previous one.

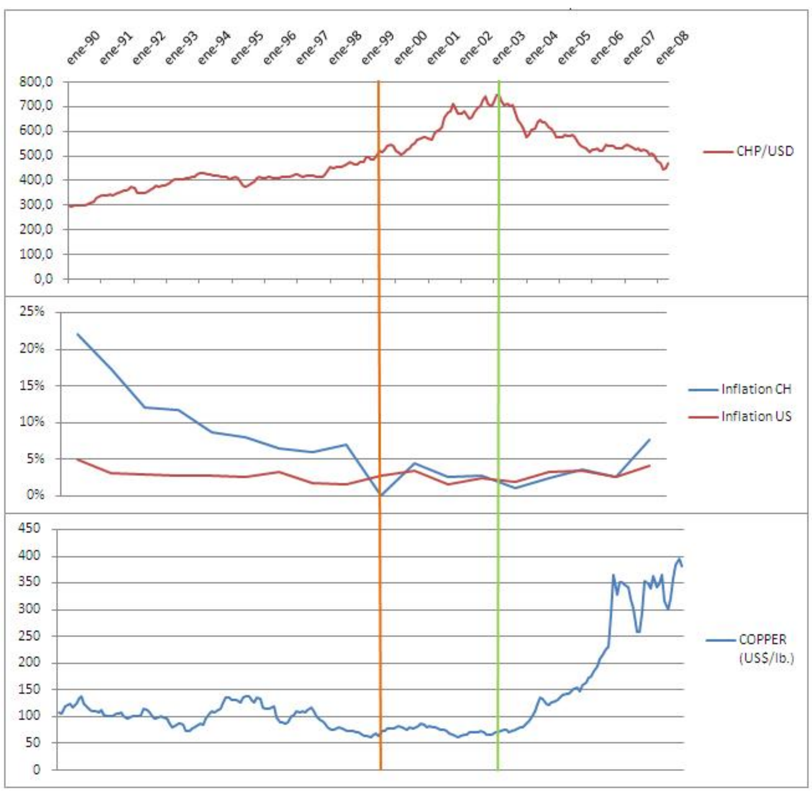
Monetary Policy Interest Rate

Also called Federal Funds Rate, corresponds to the interest rate at which a depository institution lends immediately available funds (balances at the Federal Reserve) to another depository institution overnight.

Data on the federal funds rate was collected from the federal funds database. The Chilean monetary policy interest rate was taken from the CCB database. Observations are again on a monthly basis.

Data Split

Figure 3. CHP/USD – Inflation Us and Chile – Copper Price Evolution



The data were first analyzed as one complete sample, and later separated into two different groups to better explain the exchange rates determinants. Looking at the graphs shown below, we can see that there are two possible breaking points. The first one occurred in September 1999 when the Central Bank of Chile changed the foreign exchange regime to a complete floating policy. The second break noticed in the data was when the Chilean peso reached its lower level in March 2003. This event broke a long trend of a depreciating currency. The complete set of regressions were performed to both sets of samples, meaning that we first separated the data in the observation number 117 (Sept 1999) and then we separated the data in the observation number 158 (March 2003). The results obtained by splitting the data when the exchange rate regime was modified (Sept 1999) gave us better results in our search for the determinants of the exchange rate; therefore we focused our analysis in that event. Summary statistics for the regressions performed splitting the data in year 2003 are provided in tables 10, 11, 12 and 13.

[9]

EMPIRICAL ANALYSIS

Variables and Models

The variables considered are:

- Money Stock differential (M2).

  $(MS^{US\$} - MS^{CLP})$

- Inflation differential

  $(I^{US} - I^{CL})$

- Federal Funds Interest Rate differential.

  $(r^{US} - r^{CL})$

These are the main fundamental variables used in many regression models and were tested in a conventional multiple regression model shown below.

$$\Delta e_t = \alpha + \beta_1 (MS^{US\$} - MS^{CLP}) + \beta_2 (I^{US} - I^{CL}) + \beta_3 (r^{US} - r^{CL}) + \varepsilon$$

Where $\Delta e_t = \dfrac{\Delta CLP}{\Delta USD}$, MS represent Money Stocks differential, the error term is noted as ε.

[9] The perpendicular line to the left (orange) denotes a Split in the data where a change in the Chilean foreign currency policy took place. The perpendicular line on the right (green) denotes a break in the depreciating tendency of the CLP.

Also, this model was used in the study conducted by Paul de Grawke and Isabel Vansteenkiste (2007) where the authors developed a non-linear model based on the existence of transaction costs. They performed their analysis using samples of both high and low inflation countries. The empirical analysis shows that for the high inflation countries the relationship between news in the fundamentals and the exchange rate changes is stable and significant. This is not the case, however for the low inflation countries, where frequent regime switches occur.

Correlation Analysis

A preliminary test was made to establish the correlation between the variables. As in all the following tests, the analysis contemplates a test using the full sample, and two consecutives ones utilizing the first and second periods separately. As we mentioned earlier, the split point was established when the central bank of Chile decided to modify the exchange rate policy in September 1999. The results of the correlation test are shown in the following table.

Table 1. Correlation Analysis

Full Sample					
	et	*(I US - I Ch)*	*(MS US - MS Ch)*	*(r US - r Ch)*	*% Change COPPER*
et	1				
(I US - I Ch)	-0.21720268	1			
(MS US - MS Ch)	0.006527779	0.000337447	1		
(r US - r Ch)	0.012682794	0.085201824	-0.0017249	1	
% Change COPPER	-0.26398336	0.189467543	0.03996015	0.107563922	1
First Period					
	et	*(I US - I Ch)*	*(MS US - MS Ch)*	*(r US - r Ch)*	*% Change COPPER*
et	1				
(I US - I Ch)	-0.22101799	1			
(MS US - MS Ch)	0.089704954	0.022637297	1		
(r US - r Ch)	0.05990003	0.088942881	-0.03288607	1	
% Change COPPER	-0.0984901	0.096864671	-0.0046928	0.175329971	1
Second Period					
	et	*(I US - I Ch)*	*(MS US - MS Ch)*	*(r US - r Ch)*	*% Change COPPER*
et	1				
(I US - I Ch)	-0.1890756	1			
(MS US - MS Ch)	-0.12711475	-0.04958071	1		
(r US - r Ch)	-0.02133903	0.239124111	0.034159938	1	
% Change COPPER	-0.34262285	0.299720935	0.155370445	0.091477354	1

Where et= Δe_t

As we can see in the table, for the full sample, the strongest correlation between our dependant and independent variables can be found in the inflation differential and the copper price change. The other independent variables do not show a strong correlation. Let's notice that for both variables, (I US – I CH) and % Change Copper, the correlation shows a negative sign, meaning that if any of these variables increases, the Chilean peso will appreciate.

For the first period, inflation showed the highest correlation, -0.22, and the copper price change was weaker than in the full sample analysis. This variable showed a much stronger correlation when analyzing the second period. Copper price influence in exchange rate determination seems to be much higher after 1999, reaching -0.34 correlation coefficient.

Next, we describe the tests performed utilizing simple multiple regression analysis.

The following regressions were performed:

I. The first sets of regressions were performed utilizing the model described earlier that includes the fundamental variables. The first test considers the complete sample consisting of 220 monthly observations. The second regression was performed utilizing the first period, from January 1990 until September 1999, where the exchange rate regime changed. The third regression consists of the second period, from Sept 1999 to March 2008.

The results for the first test are shown in Table 1 in the appendix.

In this case, for both change in monetary policy interest rates and change in money stock coefficients, the null hypothesis has to be accepted. There is no statistical evidence that the slope of these coefficients is significantly different from zero. However, for the differential in Inflation, the P-value is 0.001129498 at a 5% confidence level.

The coefficients are:

$$\Delta e_t = 0.0002521117 - 0.6042205554(I^{US\$} - I^{CLP})$$

If the American inflation differential is higher than the Chilean inflation differential, the Chilean currency will appreciate. The adjusted R square for this test is 3.4981737%

For the second test performed we used 115 observations, where we do not have a change in the monetary policy. Let´s remember that for this period the regime of the CCB was inflation targeting.

The summary statistics for this test can be found in Table 2 in the appendix.

Once again, for both change in monetary policy interest rates and money stock change, there is no statistical evidence that the slope of these coefficients is significantly different from zero therefore the null hypothesis has to be accepted.

The P-value for $(I^{US\$} - I^{CLP})$ is 0.007445252, meaning that it's statistically significant at a 5% confidence level.

In this case, the coefficients are:

$$\Delta e_t = 0.001994857 - 0.442222329(I^{US\$} - I^{CLP})$$

The adjusted R square for this regression is 4.9446156% and it is the highest in this first set of tests performed.

The third test performed considers the second period, after September ′99 and consists of 105 observations. The summary statistics for this test are in Table 3.

We still do not find evidence that either the change in interest rates or money stocks are significant determinants of the exchange rate, but MS has improved as an explanatory variable.

The coefficients are:

$$\Delta e_t = -0.000539375 - 1.289662897(I^{US\$} - I^{CLP})$$

Even if the coefficient for $(I^{US\$} - I^{CLP})$ is the highest, the p-value is the less significant (0.051925028, significant at a 6% confidence level) and the adjusted R square is also the lowest (2.4737736%).

The results of these tests shows us that for the first half of the period studied, where the objective of the central bank of Chile was to target and lower inflation, the inflation differential had the greatest impact in the exchange rate determination, out of all variables considered. In any of these regressions the other variables showed statistical significance in the analysis.

A final regression was performed utilizing a Dummy variable for representing the regime change occurred in 1999, but it does not add any statistical significance to the model. The results for this regression can be found in Table 7 in the appendix.

II. For the second set of regressions, testing the second period, the change in copper prices was added to the model to determine the influence that the commodity price may have in foreign exchange determination. Copper is traded in the London Mercantile Exchange. The data also consists in monthly observations and will be separated just as in the tests performed previously. As mentioned earlier, copper prices increased dramatically due to international inventory drops and increasing international demand.

The model used this time is the following.

$$\Delta e_t = \alpha + \beta_1(MS^{US\$} - MS^{CLP}) + \beta_2(I^{US\$} - I^{CLP}) + \beta_3(r^{US\$} - r^{CLP}) + \beta_4(\Delta\%_{Copper\,Price})$$

The summary statistics for the first set of tests can be found in Table 4 in the appendix.

In this case, as we found in the first set of regressions, changes in the monetary policy interest rate and changes in the money stock are not significant at a 5% confidence level. There is no statistical evidence that the slope of these coefficients is significantly different from zero, therefore the null hypothesis has to be accepted.

The coefficients are as follows,

$$\Delta e_t = 0.001263161 - 0.48602805(I^{US\$} - I^{CLP}) - 0.08042013(\Delta\%_{Copper\,Price})$$

The P-value for $(I^{US\$} - I^{CLP})$ is 0.00791446 at a 5% confidence level, while for $(\Delta\%_{Copper\,Price})$ the P-value is 0.000426143, making it statistically significant at a 5% level.

An increasing copper price would result in an appreciating currency, which is consistent with our expectations.

Looking at the inflation effect, the results are similar to the ones obtained in the previously tested regressions. If the change in the American inflation is higher than the change in the Chilean inflation, the Chilean currency will appreciate.

The second regression test performed using this model considers the first period of the sample, consisting of 115 monthly observations. The summary statistics for this regression can be found in Table 5 in the appendix.

For this period of time, copper price remained fairly stable and without great volatility. The P-Value for this variable is 0.330662929; therefore it is not statistically significant at a 5% confidence level. Since this variable does not add evidence of exchange rates determination, the results are very similar to the ones obtained in the second regression performed using the original model.

For the third regression, we utilized the observations for the second period of time. At this point, copper prices suffered a rapid increase due to growing international demand and a drop in inventory levels worldwide. Also our dependant variable Δe_t started appreciating after a prolonged depreciating trend.

The summary statistics for this regression can be found in Table 6 in the appendix.

The coefficients are;

$$\Delta e_t = 0.001251887 - 0.11440637\ (\Delta\%_{CopperPrice})$$

In this case, and for the first time in our study, the differential on inflation levels is not significant at a 5% confidence level, with a P-Value of 0.258064303. On the other hand, the P-Value for the change in copper price is 0.003354111; making it highly significant. Once again, results show us that an increasing copper price would result in an appreciating currency. The adjusted R square coefficient is 10.2890058%, the highest obtained so far, meaning that 10.29% of exchange rates movements are explained by variations in copper price.

A new regression was performed using only the change in copper price variable and excluding all other independent variables from the model. Summary statistics can be found in table 8 for the full sample and table 9 for the second period.

Here we can see that the influence of copper for the second period studied is considerably higher than for the full sample.

The coefficients for the regression using only the second period are shown below.

$$\Delta e_t = 0.001492064 - 0.132153835\ (\Delta\%_{CopperPrice})$$

The adjusted R square value for the analysis using the full sample is 6.54%, and increased to 11.08% when analyzing only the second period. The increased explanatory power of this variable is clear.

Summarizing the results obtained so far, we can conclude that after splitting the data in two periods, we find different exchange rate determinants in each one of them. The break in the data was made in September 1999, where the central bank of Chile decided to modify its foreign exchange rate policy. Before this period, the goal of the CCB was to target and lower inflation, and precisely this is the variable that showed us the greatest role in the exchange rate determination. The results shows us that all other independent variable considered were not statistically significant in any of the regressions performed.

If the differential between the change in the US inflation and the change in the Chilean inflation $(I^{US\$} - I^{CLP})$ is a negative value, then the CLP will depreciate. In other words, if the Chilean inflation is higher than the US inflation in a certain period of time, we can expect the Chilean currency to depreciate. That was the case for almost the complete period from 1990 to 1999.

After adding a fourth variable to the model, the results showed us that the role of copper in the exchange rate determination increased dramatically after year 2003. Before that year, its average price was 94.62 US$/Lb. In the second half of the sample, its average price was 218 US$/Lb, reaching its top price of 393 US$/Lb.

For this period ('99 - '08), regression results showed that all other variables were not statistically significant.

A positive variation in copper price will result in an appreciating currency.

Also the adjusted R square coefficient for this regression is 10.29%, being the highest obtained so far.

The analysis showed us that money supply was never significant in any of the regressions performed. This result was somehow expected because this model was also used in the study by Grauwe and Vansteenkiste (2007) and they could not find significance for this coefficient either.

It is interesting to notice that in one regime the variables in question may have a significant effect on the exchange rate, while in other regime their effect is not significantly different from zero. In this case, for the first period studied the significance of inflation is evident, while for the second period this explanatory power is displaced by the influence of copper prices.

The results are similar to the ones obtained by the earlier mentioned study by Grauwe and Vansteenkiste (2007), where they performed similar tests to high and low inflation countries. Let´s recall that in their study they could not find a relation between the fundamentals and the currencies of low inflation nations, whereas this link was stable and significant for high inflation countries.

This phenomenon is explained as follows. Transaction costs are present in traded goods and define a band where arbitrage opportunities do not hold. This is the same for both, high and low inflation countries. If exogenous shocks are introduced in the underlying fundamentals for the low inflation countries, these shocks will usually tend to be small relative to the transaction costs band (differential inflation shocks are typically 1% or 2% per year), hence, arbitrage will not be profitable and will not take place. The connection between the news in the fundamentals and the currencies for these countries will not be strong. Moreover, if a shock is larger compared to the transaction cost band, arbitrage will take place, but as a consequence the relationship between the fundamentals and the exchange rate will be unstable.

On the other hand, for high inflation countries, shocks in the fundamental values tend to be large compared to the transaction costs band, allowing for strong arbitrage relations. This implies a stronger and more stable relationship between the fundamental values and the foreign exchange rate.

III. The following analysis will consider daily exchange rates information and daily copper prices starting Jan 1, 1990 to Jul 31, 2008. The objective for this new analysis is to determine the time that it takes to the market to react to new copper prices and to reflect these changes in the currency determination. The model used in this analysis is derived from the Granger Casualty test and is basically a lagged linear regression. The Granger causality is a statistical concept of causality that is based on prediction. According to Granger causality, if a signal *X* "Granger-causes" (or "G-causes") a signal *Y*, then past values of *X* should contain information that helps predict *Y* above and beyond the information contained in past values of *Y* alone. In our study, we are trying to find evidence in past values of copper prices and how long it takes to be reflected in the currencies.

The model can be represented as follows;

$$\Delta e_t = \alpha + \beta_t(\Delta\%_{Copper\ Price}) + \beta_{t-1}(\Delta\%_{Copper\ Price}) + \beta_{t-2}(\Delta\%_{Copper\ Price}) + \beta_{t-3}(\Delta\%_{Copper\ Price})$$

Where $\Delta e_t = \frac{\Delta CLP}{\Delta USD}$, β_t represents the change in copper prices on the same day, β_{t-1} represents changes in copper prices the previous day and β_{t-2} & β_{t-3} represent two and three days lag respectively.

Complete Summary statistics for this test can be found on table 16.

The coefficients are shown below.

Table 2. Lagged Regression Coefficients

	Coefficients	*Standard Error*	*t Stat*	*P-value*
Intercept	6.3873E-05	0.000119192	0.535882148	0.592097026
Delta CP PR	0.008757582	0.007557047	1.158862886	0.246644469
Delta CP PR -1	-0.078383687	0.007570042	-10.35445843	1.54794E-24
Delta CP PR -2	-0.031023761	0.007570987	-4.097717127	4.33174E-05
Delta CP PR -3	0.013199982	0.007558277	1.746427518	0.080883586

- Delta CP PR (change in copper price)

These results show us that our variable β_t is not significant at a 5% confidence level, while β_{t-1} and β_{t-2} are significant. The null hypothesis has to b accepted for β_t.

β_{t-3} is significant at a 10% confidence level.

The signs of β_{t-1} and β_{t-2} are expected, considering the results obtained in previous sets of regressions using monthly data. An increase in copper price will lead to an appreciating currency. The sign of β_{t-3} may correspond to market adjustments after variations in copper price.

The adjusted R square for this model is 5.6%.

The market would respond on average between one and two days after the variation in copper price to reflect the new exchange rate.

CONCLUSION

Our research objective was to analyze the relationship between exchange rate changes and the variations in the underlying fundamentals. We considered the Chilean peso, and compared it to the US dollar. We tested the performance of this currency for the last eighteen years.

The results show that the determinants of the exchange rate may vary over time. The independent variables that have an effect on the exchange rate may lose their explanatory power when economic conditions change or a switch in the foreign exchange rate policy dictated by central banks or, as we proved, when variations on certain markets takes place.

The model that we used includes three dependable variables. Theory supports these variables and incorporates them in their explanation on how exchange rates move over time. These variables are the money supply (M2), changes in domestic price levels and monetary policy interest rate.

The data corresponded to monthly observations for the independent variables for both countries, The United States of America and Chile. This data set was analyzed as a whole in a first stage and separated into two groups for a more detailed study. By taking a preliminary look at the data, two natural break points appear. The first one takes place when the central bank of Chile decided to change the foreign monetary policy regime. Before September 1999 the objective of the CCB was to target inflation. After that, they adopted a freely floating exchange rate regime. The second breaking point takes place in March 2003, where the Chilean peso reached his historical lowest level of 745.21 pesos per US Dollar. After running simple linear regression analysis and comparing the results on both sample groups, we find that the first data division explained in a better way the determinants of the Chilean peso movements. The break in the long depreciating trend of the Chilean peso compared to the US Dollar has different explanations that are not covered in this study, for example, the euro community started utilizing € as their currency. That period (2003) was the initiation of a process where the US Dollar lost value against many currencies, principally the €, £ and Chinese ¥.

Once we defined our data split, we performed simple linear regressions utilizing the model derived from the Markov-switching autoregressive (MS-AR).

We find that for the first period (1990 - 1999) changes in price levels played a significant role in the exchange rate determination. Both money supply and monetary policy interest rate were found to be not significant in the analysis. For the second period (after the switch in the exchange rate policy) we found that Inflation does not have the same explanatory power as in the first period.

Our analysis continued including a fourth variable into our model. Copper plays a great role in the Chilean Economy, as this country is the biggest producer and exporter of copper worldwide. Exchange rate movements seem to move in concordance with variations in international copper prices. The results of our regression analysis showed us that for the first period, inflation continues to be the strongest variable in the determination of the exchange rate. However, the strong augment in price that copper experienced starting in year 2000 shows us an increasing explanatory power of this variable. As copper prices boosted, the influence of copper becomes more and more important in determining the value of the Chilean peso. Our study showed us that for the second period, inflation is not significant anymore and variations in international copper prices become our main dependable variable.

Our concluding analysis consisted in measuring the time that the market reacts to variations in copper prices. For this, we performed a simple lagged regression derived from the Granger-causes concept. On average, the market reflects the currency adjustments one and two days after the price variations.

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APPENDIX

Fundamental Model - Change in Money Stock, Fed Interest Rate and Inflation. - Complete Sample

Regression Statistics	
Multiple R	0.219547637
R Square	0.048201165
Adjusted R Square	0.034981737
Standard Error	0.019878344
Observations	220

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*
Intercept	0.000252117	0.001487929	0.169441595	0.865607888	-0.002680602	0.003184836
(I US - I Ch)	-0.604220554	0.183076367	-3.300374396	0.001129498	-0.965065433	-0.24337568
(MS US - MS Ch)	0.001837492	0.018325092	0.100271904	0.920221469	-0.0342814	0.037956384
(r US - r Ch)	0.006746988	0.01430251	0.47173456	0.637592431	-0.021443365	0.034937342

Fundamental Model - Change in Money Stock, Fed Interest Rate and Inflation - First Period 1990 - 1999

Regression Statistics	
Multiple R	0.272874936
R Square	0.074460731
Adjusted R Square	0.049446156
Standard Error	0.015059647
Observations	115

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*
Intercept	0.001994857	0.001731549	1.15206536	0.251769465	-0.001436322	0.005426037
(I US - I Ch)	-0.442222329	0.162206046	-2.726299918	0.007445252	-0.763644428	-0.12080023
(MS US - MS Ch)	0.01716942	0.015319625	1.120746763	0.264814603	-0.013187439	0.047526279
(r US - r Ch)	0.01860858	0.02079971	0.894655699	0.372907026	-0.022607434	0.059824593

Fundamental Model - Change in Money Stock, Fed Interest Rate and Inflation - Second Period 1999 - 2008

Regression Statistics	
Multiple R	0.229935429
R Square	0.052870302
Adjusted R Square	0.024737736
Standard Error	0.023888785
Observations	105

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*
Intercept	-0.000539375	0.00238137	-0.226497956	0.821271917	-0.005263372	0.004184622
(I US - I Ch)	-1.289662897	0.655645047	-1.967013863	0.051925028	-2.59028627	0.010960475
(MS US - MS Ch)	-0.074231854	0.052527454	-1.413201048	0.160671117	-0.178432191	0.029968483
(r US - r Ch)	0.007306387	0.020752335	0.352075398	0.725515264	-0.033860663	0.048473436

Fundamental Model + Copper Price Variations - Full Sample

Regression Statistics	
Multiple R	0.318937299
R Square	0.101721001
Adjusted R Square	0.085008833
Standard Error	0.019356235
Observations	220

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*
Intercept	0.001263161	0.00147613	0.855724552	0.393102801	-0.001646379	0.0041727
(I US - I Ch)	-0.486028054	0.181300713	-2.680784013	0.00791446	-0.84338247	-0.12867364
(MS US - MS Ch)	0.004456595	0.017858778	0.249546453	0.803176367	-0.030744112	0.039657302
(r US - r Ch)	0.011432884	0.013988257	0.817320122	0.41465029	-0.016138797	0.039004564
% Change COPPER	-0.080420134	0.02246952	-3.579076586	0.000426143	-0.124708885	-0.03613138

Fundamental Model + Copper Price Variations - First Period 1990 - 1999

Regression Statistics	
Multiple R	0.279334794
R Square	0.078027927
Adjusted R Square	0.044803708
Standard Error	0.015114873
Observations	116

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*
Intercept	0.002331346	0.001725694	1.350961786	0.179455078	-0.001088231	0.005750923
(I US - I Ch)	-0.409838736	0.162746808	-2.518259755	0.01321942	-0.73233239	-0.08734508
(MS US - MS Ch)	0.017789744	0.015367875	1.157592953	0.249515036	-0.012662725	0.048242213
(r US - r Ch)	0.023025809	0.021163861	1.087977733	0.278961637	-0.018911792	0.06496341
% Change COPPER	-0.025548833	0.026148621	-0.977062324	0.330662929	-0.077364069	0.026266404

Fundamental Model + Copper Price Variations - Second Period 1999 - 2008

Regression Statistics	
Multiple R	0.371118956
R Square	0.137729279
Adjusted R Square	0.102890058
Standard Error	0.02292137
Observations	104

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*
Intercept	0.001251887	0.0023965	0.522381164	0.602571956	-0.00350329	0.006007063
(I US - I Ch)	-0.752811767	0.661797739	-1.137525444	0.258064303	-2.065962025	0.560338491
(MS US - MS Ch)	-0.051734457	0.051432206	-1.00587669	0.316927118	-0.153787109	0.050318195
(r US - r Ch)	0.007737537	0.019915125	0.38852564	0.698461373	-0.031778391	0.047253464
% Change COPPER	-0.114406366	0.038058948	-3.006030668	0.003354111	-0.189923574	-0.03888916

Fundamental Model + Copper + Dummy Variable for regime change - Full Sample

Regression Statistics	
Multiple R	0.32004048
R Square	0.102425909
Adjusted R Square	0.081454551
Standard Error	0.019393794
Observations	220

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*
Intercept	0.001919104	0.002178882	0.880774833	0.3794278	-0.002375714	0.006213923
(I US - I Ch)	-0.455930382	0.195927656	-2.327034329	0.020898258	-0.842125581	-0.06973518
(MS US - MS Ch)	0.004188149	0.017905409	0.233904104	0.815283038	-0.031105403	0.0394817
(r US - r Ch)	0.010779153	0.014105824	0.764163276	0.445611688	-0.017024995	0.0385833
% Change COPPER	-0.079409514	0.022647686	-3.506297012	0.000553507	-0.124050622	-0.03476841
RegDum	-0.001177357	0.002871907	-0.409956654	0.682247839	-0.006838206	0.004483491

Copper Model - Full Sample

Regression Statistics	
Multiple R	0.263983363
R Square	0.069687216
Adjusted R Square	0.065419726
Standard Error	0.019562338
Observations	220

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*
Intercept	0.002968622	0.001329311	2.233203532	0.026551637	0.000348676	0.005588567
% Change COPPER	-0.08963467	0.022181234	-4.041013575	7.37842E-05	-0.133351788	-0.04591755

Copper Model - Second Period 1999 - 2008

Regression Statistics	
Multiple R	0.345601829
R Square	0.119440625
Adjusted R Square	0.110807689
Standard Error	0.022819997
Observations	104

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*
Intercept	0.001492064	0.002318382	0.643579668	0.52129243	-0.003106436	0.006090563
% Change COPPER	-0.132153835	0.035528999	-3.719604769	0.000326584	-0.202625435	-0.06168224

The Following four tables show the results obtained when splitting the data in the observation number 158 (February 2003) in the inflexion point of the currencies.

Fundamental Model - Change in Money Stock, Fed Interest Rate and Inflation - First Period 1990 - 2003

Regression Statistics	
Multiple R	0.188739591
R Square	0.035622633
Adjusted R Square	0.016713273
Standard Error	0.017752725
Observations	157

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*
Intercept	0.004165401	0.001648171	2.527287265	0.012510028	0.000909291	0.007421511
(I US - I Ch)	-0.40019354	0.177860292	-2.25004431	0.025872265	-0.7515726	-0.04881447
(MS US - MS Ch)	0.009127144	0.017618362	0.518047267	0.605173597	-0.02567952	0.043933809
(r US - r Ch)	0.010593976	0.014103314	0.751169214	0.453704644	-0.0172684	0.038456346

Fundamental Model - Change in Money Stock, Fed Interest Rate and Inflation - Second Period 2003 - 2008

Regression Statistics	
Multiple R	0.15245748
R Square	0.023243283
Adjusted R Square	-0.02642231
Standard Error	0.023013459
Observations	63

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*
Intercept	-0.00690401	0.002963606	-2.32959753	0.023269662	-0.01283417	-0.00097385
(I US - I Ch)	-0.63486799	0.733919522	-0.86503761	0.390521842	-2.10343755	0.833701571
(MS US - MS Ch)	-0.04117006	0.057515706	-0.71580547	0.476934981	-0.15625872	0.073918604
(r US - r Ch)	-0.01232468	0.039370278	-0.3130452	0.755350259	-0.09110442	0.066455067

Fundamental Model + Copper Price Variations - First Period 1990 - 2003

Regression Statistics	
Multiple R	0.22732449
R Square	0.051676424
Adjusted R Square	0.02672054
Standard Error	0.017662156
Observations	157

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*
Intercept	0.004263683	0.001640906	2.598370651	0.010288394	0.001021754	0.007505612
(I US - I Ch)	-0.37283555	0.177772897	-2.09725753	0.037626114	-0.72406037	-0.02161072
(MS US - MS Ch)	0.009800577	0.017533505	0.558962805	0.577009695	-0.02484026	0.044441416
(r US - r Ch)	0.013333015	0.014134879	0.943270577	0.347039391	-0.01459318	0.041259208
% Change COPPER	-0.04557351	0.028410583	-1.60410324	0.110767126	-0.10170412	0.010557107

Fundamental Model + Copper Price Variations - Second Period 2003 - 2008

Regression Statistics	
Multiple R	0.326640577
R Square	0.106694066
Adjusted R Square	0.045086761
Standard Error	0.022197334
Observations	63

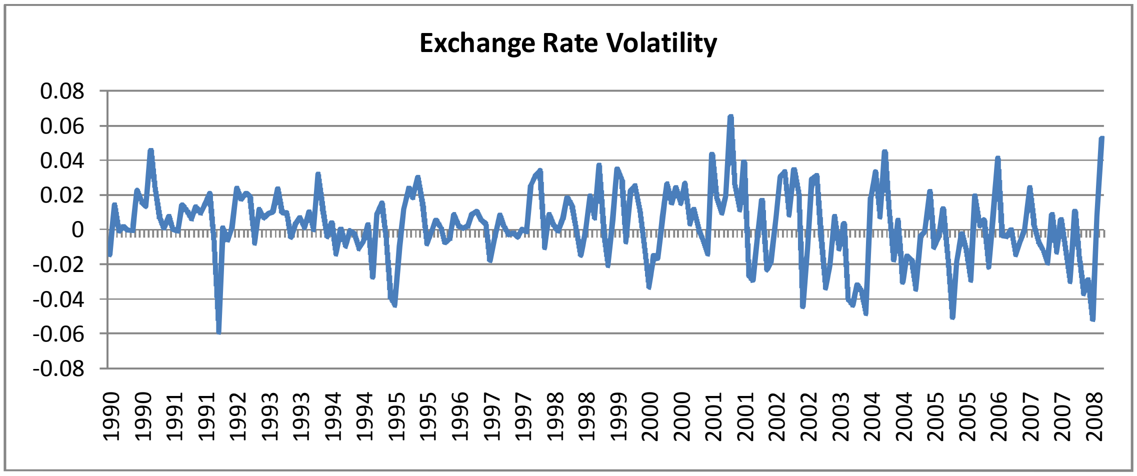
	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*
Intercept	-0.0041939	0.003086521	-1.35877872	0.179477674	-0.01037224	0.001984444
(I US - I Ch)	-0.08051803	0.746879139	-0.10780597	0.914521681	-1.57555905	1.414522993
(MS US - MS Ch)	-0.02524864	0.055896106	-0.45170656	0.65316506	-0.13713685	0.086639575
(r US - r Ch)	-0.01005051	0.037986658	-0.26458	0.792270997	-0.08608907	0.065988047
% Change COPPER	-0.09385988	0.040322822	-2.3277112	0.023437755	-0.17457478	-0.01314499

Lagged Regression derived from the Granger Casualty test - Daily data Jan 2000 - Jul 2008

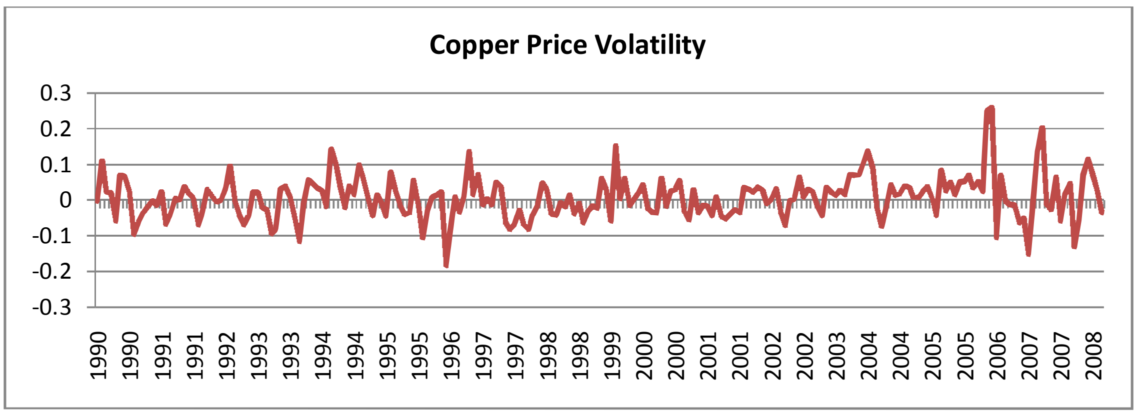
Regression Statistics	
Multiple R	0.240508217
R Square	0.057844202
Adjusted R Square	0.056041033
Standard Error	0.005422683
Observations	2095

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*
Intercept	6.3873E-05	0.000119192	0.535882148	0.592097026	-0.00016987	0.000297621
Delta CP PR	0.008757582	0.007557047	1.158862886	0.246644469	-0.00606254	0.023577705
Delta CP PR -1	-0.07838369	0.007570042	-10.3544584	1.54794E-24	-0.09322929	-0.06353808
Delta CP PR -2	-0.03102376	0.007570987	-4.09771713	4.33174E-05	-0.04587122	-0.0161763
Delta CP PR -3	0.013199982	0.007558277	1.746427518	0.080883586	-0.00162255	0.028022516

Exchange Rate Volatility



Copper Price Volatility



Inflation Volatility