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FORECASTING FOREIGN EXCHANGE RATES

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CONTENT

ABSTRACT:

Managing foreign exchange rates is important for reducing firms' vulnerabilities from exchange rate movements which could adversely affect their profit margins and their asset value.

I develop in this thesis the major issues regarding exchange rate management by addressing the problem of currency risk exposure and the strategies and techniques used to counter impact that risk. One of the techniques used to reduce currency risk exposure is the estimation of reliable forecasting exchange rate models.

Indeed such models have been studied extensively by the scientific community since Fisher (1911) in his book entitled "the purchasing power of money" to recent days.

In this regard, I expose a literature review about the efficient market hypothesis and I analyze the main available exchange rate forecasting models. They fall into three categories; the fundamental, the econometric and the chartist models.

Then, I develop an original a one month exchange rate forecasting model for four major European currencies: the Euro (EUR), the Swedish Krona (SEK), the Great British Pound (GBP) and the Swiss Franc (CHF); with the U.S. Dollar (USD) as the benchmark currency. The particularity of the model is to study how these currencies interact with each other. I proceed in three steps:

1- a regression analysis for each currency is conducted by drawing on each of the three fundamental approaches: the interest parity approach, the monetary approach and the Taylor rule approach;

2- due to the interdependence of these particular countries' economies and due to the geopolitical and cultural interdependence between the European countries in general, a principal component analysis (PCA) is performed to validate the existence of common components that suggest interaction among the four above mentioned European currencies;

one PCA is performed for the interest approach; one PCA for the money supply approach; and one PCA for the Taylor rule approach using as variables the residuals obtained from the regression analysis conducted in step 1.

3- a new regression analysis is studied for each currency based on each of the three fundamental approaches, and including as an independent variable, one at a time, the residuals obtained for each of the three other currencies.

Therefore, I analyze how the values of those four European currencies interrelate over a one month period. Models including interactions with other currencies appear to be the most significant and robust forecasting models.

Finally, I conclude by questioning the efficient market hypothesis suggesting a framework that can be used for further development.

KEY WORDS USED:

Efficient market hypothesis, forecasting techniques, economics and fundamentals models, chartists' models, random walk, currency risk exposure.

1- INTRODUCTION

Foreign exchange risk (also known as FX risk, exchange rate risk or currency risk) is a financial risk that exists when a financial transaction is denominated in a currency other than that of the base currency of the company. Foreign exchange risk also exists when the foreign subsidiary of a firm maintains financial statements in a currency other than the reporting currency of the consolidated entity. Bartram, S. and Bodnar, G. (2008) state that the risk lies in the possibility of an adverse movement in the exchange rate of the denomination currency in relation to the base currency before the date when the transaction is completed.

Corporate businesses are becoming more global. However, those global firms with active overseas sales create substantial amounts of foreign currency positions, on-balance sheet and off-balance sheet.

The currency crises of the 1990s and early 2000s, such as the Mexican peso crisis, Asian currency crisis, 1998 Russian financial crisis, and the Argentine peso crisis led to substantial losses from foreign exchange and led firms to pay closer attention to their foreign exchange risk.

Alan Shapiro (1975) mentions that it has been shown that the sector of the economy in which the subsidiary of a multinational corporation operates in has far greater consequences for the impact of inflation or devaluation on the firm's dollar value than the traditional accounting definition of net current assets.

What are the types of currency exposure that companies are facing and how are they currently managed? The answers to these questions are detailed in the following section.

1-1. <u>Currency risk exposure</u>

Currency risk exposure is divided into four main categories, the transaction exposure, the economic exposure, the translation exposure and the contingent exposure.

<u>Transaction exposure</u>:

Transaction exposure occurs whenever a firm has contractual cash flows (receivables and payables) whose values are subject to unanticipated changes in exchange rates due to a contract being denominated in a foreign currency. To realize the domestic value of its foreign-denominated cash flows, the firm must exchange foreign currency for domestic currency. As firms negotiate contracts with set prices and delivery dates in the face of a volatile foreign exchange market with exchange rates constantly fluctuating, the firms face a risk of changes in the exchange rate between the foreign and domestic currency. As such, transaction exposure refers to the risk associated with the change in the exchange rate between the time an enterprise initiates a transaction and settles it.

Applying public accounting rules causes firms with transactional exposures to be impacted by a process known as "re-measurement" or “re-valuation”. The current value of contractual cash flows is re-measured at each balance sheet date. If the value of the currency of payment or receivable changes in relation to the firm's base or reporting currency from one balance sheet date to the next, the expected value of these cash flows will change. According to the IFRS list of standards, “IAS 21: the Effects of Changes in Foreign Exchange Rates” states that changes in the value of these contractual cash flows due to currency valuation changes will impact current income.

Economic exposure:

Economic exposure, also known as forecast risk, occurs when a firm's market value is influenced by unexpected exchange rate fluctuations. Such exchange rate adjustments can severely affect the firm's market share position with regards to its competitors, the firm's future cash flows, and ultimately the firm's value. Economic exposure can affect the present value of future cash flows. Any transaction that exposes the firm to foreign exchange risk also leads to economic exposure. However, economic exposure can be caused by other business activities and investments which may not be mere international transactions, such as future cash flows from fixed assets. A shift in exchange rates that influence the demand for a good in some country would also be an economic exposure for a firm that sells that good.

Translation exposure:

Translation exposure occurs when a firm's financial reporting is affected by exchange rate movements. According to IFRS, firms must prepare consolidated financial statements for reporting purposes. This consolidation process for multinationals entails translating foreign assets and liabilities or the financial statements of foreign subsidiaries from foreign to domestic currency. While translation exposure may not affect a firm's cash flows, it could have a significant impact on a firm's reported earnings and therefore its stock price.

Contingent exposure:

Contingent exposure occurs when a firm bids for foreign projects or negotiating other contracts or foreign direct investments. Such an exposure arises from the potential for a firm to suddenly face a transaction or economic foreign exchange risk, contingent on the outcome of some contract or negotiation. For example, a firm could be waiting for a project bid to be accepted by a foreign business or government that if accepted would result in an immediate receivable. While waiting, the firm faces a contingent exposure from the uncertainty as to whether or not that receivable will exist. If the bid is accepted and a receivable is paid the firm then faces a transaction exposure. As such, a firm may prefer to manage contingent exposures.

Adler and Dumas (1984) show that even firms whose entire operations are domestic may be affected by exchange rates if their input and output prices are influenced by currency movements.

For practical purposes, two questions capture the extent of a company's foreign exchange exposure.

1. How quickly can the firm adjust prices to offset the impact of an unexpected exchange rate change on profit margins?

2. How quickly can the firm change sources for inputs and markets for outputs? Or, alternatively, how diversified are a company's factor and product markets?

The strategies used for exchange risk management are detailed in the following section.

1-2. Exchange rate risk management strategies

Investors and businesses exporting or importing goods and services or making foreign investments have an exchange rate risk which can have severe financial consequences. However, according to Bartram, S. and Bodnar, G. (2008) strategies can be taken to manage this risk. They are divided into three main categories:

- a- operational strategies,
- b- currency risk mitigation strategies,
- c- forecasting exchange rates strategies.

a- Operational strategies

The first category of exchange risk management is the operational strategy that is split into three main sub categories:

- diversifying production,
- sourcing flexibility,
- diversifying financing.

a-1) Diversifying production

The strategy of diversifying production facilities and markets for products would mitigate the risk inherent in having production facilities or sales concentrated in one or two markets. However, the drawback here is that the company may have to forgo economies of scale. One should be aware that going into an unknown market with an unfamiliar product offering means a lack of experience in the new skills and techniques required. Therefore, the company exposes itself to a great amount of uncertainty. Moreover, diversification might require significant expanding of human and financial resources, which may detract focus, commitment, and sustained investments in the core industries. Therefore, a firm should choose this option only when the current product or current market orientation does not offer further opportunities for growth. In order to measure the chances of success, different tests can be conducted: the attractiveness test, the cost-of-entry test, the better-off test.

The attractiveness test consists in choosing an attractive industry by using the five forces Porter (1980)'s model, i.e., by determining the existing competitive rivalry between suppliers, the threat of new market entrants, the bargaining power of buyers, the power of suppliers, and the threat of substitute products (including technology change).

The cost-of-entry test consists in assuring that diversifying into a new business does not eat up the expected returns, otherwise it cannot build shareholder value; the cost of entry must not capitalize all future profits.

The better-off test consists of evaluating the benefit from the acquisition of a new unit, the parent company has no rationale for holding the new unit in its portfolio over the long term if it does not offer potential for significant advantage, sometimes it is better to sell the unit and free up corporate resources; the new unit must gain competitive advantage from its link with the corporation or vice versa.

a-2) Sourcing flexibility

The strategy of having sourcing flexibility and alternative sources for key inputs is appropriate in case exchange rate fluctuations make inputs too expensive from one region. Sourcing flexibility can be defined from two perspectives. The first perspective refers to the capability of the focal firm to change the structure of its upstream supply chain. The second perspective refers to the ability of the company's suppliers to provide it with flexibility in three dimensions of delivery, volume, and product.

The first perspective has a direct relationship to the sourcing strategies that the focal firm may apply for different categories of a procured component. Furthermore, the existence of the second perspective is highly dependent on the relationship between the focal company and its suppliers, where strategic procurement plays an indispensable role.

The required level of sourcing flexibility may depend on the levels of delivery, volume, and product flexibility, It has a close connection to the diverse strategies and it is well dependent on the internal operational capabilities of the suppliers along with the established relationship between buyer and supplier.

a-3) Diversifying financing

The strategy of diversifying financing by having access to capital markets in several major nations gives a company the flexibility to raise capital in the market with the cheapest cost of funds.

Investment diversification means spreading capital across different investments in order to reduce overall investment risk. So, if one investment performs poorly over a certain period, other investments may perform better over that same period, reducing the overall losses of the investment portfolio.

Diversification is a vital strategy for all investors. Generally, particular investments or asset classes will perform better than others over a specific period depending on a range of factors including:

- Current market conditions.
- Interest rates.
- Currency markets.

For example, during periods of increased stock market volatility, your stock portfolio may suffer losses. If you also hold investments in other asset classes such as fixed income assets or real estate property that may perform better over the same period, the returns from these investments will smooth the returns of your overall investment portfolio.

Diversification within an asset class, such as investing across stocks, also reduces your overall losses for a specific period, as one sector may outperform another over the same period.

So, by diversifying investments, a firm can achieve smoother, more consistent investment returns over the medium to longer term.

b- Currency risk mitigation strategies

The second category of exchange risk management is the currency risk mitigation strategy that is divided into five main sub-categories:

- matching currency flows,
- currency risk sharing agreement,
- back to back loans,
- currency swaps,
- cash flow hedge.

Matching currency flows is a simple concept that requires foreign currency inflows and outflows to be matched. For example, if a U.S. company has significant inflows in euros and is looking to raise debt, it should consider borrowing in euros.

Currency risk-sharing agreement is a contractual arrangement in which the two parties involved in a sales or purchase contract agree to share the risk arising from exchange rate fluctuations. It involves a price adjustment clause, such that the base price of the transaction is adjusted if the rate fluctuates beyond a specified neutral band. In such a case, the two parties share the profit or loss. By fostering cooperation between the two parties, currency risk sharing eliminates the zero-sum game nature of currency fluctuations, in which one party benefits at the expense of the other.

Currency risk sharing depends on the relative bargaining position of the two parties to the transaction and their willingness to enter into such a risk-sharing arrangement. If the buyer (or seller) can dictate terms and perceives there is little risk of their profit margin being affected by currency fluctuation, they may be less willing to share the risk.

Back-to-back loans, also known as a credit swap, is an arrangement between two companies located in different countries to borrow each other's currency for a defined period, after which the borrowed amounts are repaid. As each company makes a loan in its home currency and receives equivalent collateral in a foreign currency, a back-to-back loan appears as both an asset and a liability on their balance sheets.

For example, if a U.S. company is engaged in a back-to-back loan arrangement with a Mexican company, the U.S.company borrows pesos from that company, while the same company borrows dollars from the U.S.company.

Usually, if a company needs money in another currency, the company heads to the currency market to trade for it. The issue with trading currency is that a currency with high fluctuations can result in great loss for the company. A back-to-back loan is very convenient for a company that needs money in a currency that is very unstable. When companies engage in back-to-back loans, they usually agree on a fixed spot exchange rate, usually the current one. This eliminates the risk associated with the volatility of exchange rates because the companies are repaying their loans based on the agreed upon fixed rate.

Back-to-back loans are rarely used today but they still remain an option for companies seeking to borrow foreign currency.

Currency swaps is a popular strategy that is similar to a back-to-back loan but does not appear on the balance sheet. In a currency swap, two firms borrow in the markets and currencies where each can get the best rates, and then swap the proceeds.

A cash flow hedge is when a company, for example, expects to purchase a piece of machinery for €10 million in a years' time. In order to offset the risk of increases in the euro rate, the company enters into a forward contract to purchase €10 million in 1 year for a fixed amount (£6,500,000). The forward contract is designated as a cash flow hedge and has an initial fair value of zero.

At the year end, the Euro has appreciated and the value of €10 million is £6,660,000. The machine will still cost €10 million so the company concludes that the hedge is 100% effective. Thus the entire change in the fair value of the hedging instrument is recognized directly in reserves.

The effect of the cash flow hedge is to lock in the price of €10 million for the machine. The gain in equity at the time of the purchase of the machine will either be released from equity as the machine is depreciated or be deducted from the initial carrying amount of the machine.

A hedge of net investment in a foreign operation is accounted similarly to a cash flow hedge and generally, a hedge is viewed as being highly effective if actual results are within a range of 80% and 125%.

c- <u>Forecasting exchange rates strategies</u>

The third strategy of exchange risk management is forecasting exchange rates or the ability to forecast the direction of exchange rates. Having an exchange rate forecast to guide decision making can be very important to minimize risks and maximize returns.

There are numerous methods of forecasting exchange rates. However, none of these methods have been shown to be superior to any other. This illustrates to the difficulty of generating a quality forecast. These techniques, divided into fundamental, econometric and chartist are detailed in the literature review section of this thesis (section 2-2).

1-3. Foreign exchange rates forecast inaccuracies

In addition to currency risk exposure, markets face exchange rate forecast inaccuracy. The need for managing exchange rates as well as the need for reliable exchange rate forecasts has been highlighted by the scientific community. Many studies have been devoted to the estimation of the equilibrium of exchange rates from the 1900s to recent years. Some of these studies are the Purchase Power Parity by Fisher (1911) and Isard (1995), the monetary approach by Frenkel (1976), Mussa (1976), and Bilson (1978), the Interest Rate Parity by Fama (1970), the trade balance model by Mundell (1963) and Fleming (1962), the Taylor rule by Molodtsova and Papell (2009), the political risk premium by Aliber (1973) and Dooley (1974).

In practice, there is still a need for an accurate forecasting model. When looking at the forecasts of of many prestigious financial institutions, we observe that the results of their exchange forecasts are divergent as shown in table 1-1 for the EUR/USD rates and table 1-2 for the GBP/USD rates.

The tables are extracted from Reuters on the 13th April 2016 and show the difference in forecast among several banks.

Table 1-1: Forecast EUR/USD for some financial institutions.

Contributor	One Month Forecast	Three Months Forecast	Six Months Forecast	Twelve Months Forecast
4CAST	1.140	1.100	1.060	1.050
ABN AMRO	1.130	1.150	1.150	1.150
ALLIED IRISH	1.110	1.110	1.090	1.070
ALPHA BANK	1.120	1.100	1.070	1.080
ANZ BANK	1.120	1.100	1.070	1.120
AUREL	1.120	1.090	1.100	1.030
BANCO BPI	1.120	1.100	1.080	1.100
BARCLAYS	--	--	--	--
BAYERNLB	--	1.090	1.060	1.020
BBVA	1.100	1.100	1.110	1.120
BMO	1.090	1.090	1.060	1.040
BNP PARIBAS	--	1.160	1.150	1.120
BOFAML	1.120	1.080	1.050	1.000
BTMU	1.130	1.120	1.100	1.080

Note: Table 1-1 is an extraction poll from Reuters on the 13th of April 2016 showing the exchange rates forecast for the EUR/USD of some financial institutions over 1 month, 3 months 6 months and 1 year.

Table 1-1 (continued): Forecast EUR/USD for some financial institutions

Contributor	One Month Forecast	Three Months Forecast	Six Months Forecast	Twelve Months Forecast
CA-CIB	--	1.100	1.090	1.070
CBA	1.130	1.100	1.130	1.190
CIBC	--	1.100	1.120	1.160
CITIGROUP	--	1.130	1.110	1.100
COMMERZBANK	--	1.120	1.110	1.060
CREDIT SUISS	--	1.170	1.130	--
DANSKE BANK	1.120	1.120	1.140	1.180
DBS Bk	--	1.100	1.100	1.100
DEKABANK	--	1.120	1.100	1.050
DESJARDINS G	1.120	1.090	1.070	1.060
DEUTSCHE BAN	1.113	1.060	1.030	--
DNB	1.120	1.100	1.090	1.040
DZ BANK	1.115	1.080	1.080	1.080
Dai-ichiLife	--	--	--	--
EUROBANK	1.150	1.170	1.200	1.220
Erste Bank	--	--	--	--
GOLDMAN	1.130	1.040	1.000	0.950
HANDELSBANK	--	1.100	1.000	0.950
HELABA	1.150	1.150	1.100	1.050
HSBC	1.150	1.160	1.180	1.200
IDEAGLOBAL	--	--	--	--
IFR MARKETS	1.150	1.120	1.085	1.050
IHS GLOBAL	1.120	1.070	1.085	1.130
INFORMA GLOB	1.125	1.100	1.100	1.100
ING FINANCIA	1.100	1.100	1.100	1.150
INTESA SANP	1.100	1.050	1.080	1.130
INVESTEC	1.120	1.090	1.100	1.160
JPMORGAN	1.133	1.120	1.130	--
JULIUS BAER	1.120	1.130	1.130	1.150
KBC Securiti	--	1.080	1.070	1.060

Note: Table 1-1 is an extraction poll from Reuters on the 13th of April 2016 showing the exchange rates forecast for the EUR/USD of some financial institutions over 1 month, 3 months 6 months and 1 year

Table 1-2: Forecast GBP/USD for some financial institutions.

Contributor	One Month Forecast	Three Months Forecast	Six Months Forecast	Twelve Months Forecast
4CAST	1.420	1.400	1.375	1.360
ABN AMRO	--	1.400	1.420	1.500
ALLIED IRISH	1.420	1.480	1.470	1.470
ALPHA BANK	1.405	1.450	1.460	1.480
ANZ BANK	1.410	1.350	1.450	1.550
AUREL	1.410	1.430	1.440	1.450
BANCO BPI	1.430	1.450	1.470	1.450
BAYERNLB	--	1.430	1.410	1.460
BBVA	1.390	1.450	1.580	1.630
BCV GROUP	--	--	--	--
BMO	1.390	1.370	1.390	1.470
BNP PARIBAS	--	1.510	1.550	1.580
BOFAML	1.440	1.460	1.460	1.470
BTMU	1.400	1.418	1.467	1.520
CA-CIB	--	1.430	1.450	1.470
CBA	1.410	1.380	1.440	1.510
CIBC	--	1.410	1.450	1.550
CITIGROUP	--	1.430	1.440	1.430
COMMERZBANK	--	--	--	--
CREDIT SUISS	--	1.430	1.410	--
DANSKE BANK	1.420	1.400	1.540	1.570
DEKABANK	--	1.490	1.510	1.520
DESJARDINS G	1.420	1.420	1.440	1.490
DEUTSCHE BAN	1.417	1.370	1.330	--
DNB	1.400	1.380	1.430	1.410
DZ BANK	1.377	1.350	1.350	1.380
EUROBANK	1.440	1.520	1.560	1.610
GOLDMAN	1.450	1.460	1.430	1.400
HANDELSBANK	--	1.420	1.290	1.230
HELABA	1.460	1.530	1.510	1.500
HSBC	1.430	1.400	1.550	1.600

Note: Table 1-2 is an extraction poll from Reuters on the 13th of April 2016 showing the exchange rates forecast for the GBP/USD of some financial institutions over 1 month, 3 months 6 months and 1 year.

In summary, a better understanding of the firm foreign currency types of exposure and risk management is essential to equity investors and creditors. It is a critical first step towards understanding the firm's foreign currency risk management in order to examine what drives its foreign currency positions.

2- RESEARCH QUESTION AND LITERATURE REVIEW:

As mentioned in the previous section, forecasting exchange rate has long been studied by the scientific community since the the beginning of the 20th century..

I start this section by defining and detailing the efficient market hypothesis. Then, I expose the main available scientific forecasting techniques.

In light of the efficient market hypothesis (EMH) and the available scientific evidence, can firms rely on robust exchange rate forecast models?

2-1. Efficient Market Hypothesis

In 1970, Eugene Fama published his now-famous thesis, "Efficient Capital Markets: A Review of Theory and Empirical Work." Fama synthesized the existing work and contributed to the focus and direction of future research by defining three different forms of market efficiency: the weak form, the semi-strong form, and the strong form.

In a weak-form efficient market, future returns cannot be predicted from past returns or any other market-based indicator, such as trading volume or the ratio of puts (options to sell stocks) to calls (options to buy stocks).

In a semi strong efficient market, prices reflect all publicly available information about economic fundamentals, including the public market data (in weak form), as well as the content of financial reports, economic forecasts, company announcements and so on.

The distinction between the weak and semi-strong forms is that fundamental analysis based on available information such as public accounting data, public information regarding competition and industry-specific knowledge may help predict future exchange rates in the case of the weak form, it is absolutely useless in the case of the semi-strong form, finally, in strong form, the highest level of market efficiency, prices reflect all public and private information.

A simple way to distinguish among the three forms of market efficiency is as follows. The weak form precludes only technical analysis from being profitable, while the semi-strong form precludes the profitability of both technical and fundamental analysis, and the strong form implies that even those with privileged information cannot expect to earn excess returns.

While most of the empirical research of the 1970s supported the semi strong market efficiency hypothesis, a number of apparent inconsistencies arose by the late 1970s and early 1980s. These so-called anomalies include, among others, the “small-firm effect” and the “January effect,” which together document the tendency of stocks to earn excessive returns, especially in January.

Fama (1998) also notes that anomalies sometimes involve under-reaction or overreaction and thus, could be viewed as random occurrences that often go away when different time periods or methodologies are used.

These apparent inefficiencies contributed to the emergence of a new school of thought or a new theory called behavioral finance, which countered the assumption of rational expectations with evidence from the field of psychology. Behavioral finance states that people tend to make systematic cognitive errors when forming expectations. One such error that might explain overreaction in stock prices is the representative heuristic, which holds that individuals attempt to identify trends even where there are none and that this can lead to the mistaken belief that future patterns will resemble those of the recent past.

Following this school of thought, the financial writer Justin Fox published a bestselling book in 2010 entitled The Myth of the Rational Market. The economist Robert Shiller described EMH as "the most remarkable error in the history of economic thought." Jeremy Grantham, a professional investment manager, said that EMH was "more or less directly responsible" for the 2008 financial crisis.

The empirical evidence indicates that the issue of (EMH) is far from settled. Proponents of technical analysis often cite Dooley and Shafer (1983), Sweeney (1986), and Neely (1997) as evidence that trading rules can make systematic profits over and above transactions costs. As such, they claim that the foreign exchange market is far from efficient, and that past prices do provide insight into future prices.

Neely (1997) concludes that the discovery of profitable technical trading rules and other evidence against (EMH) have led to a rethinking about the importance of institutional features that might justify extrapolative technical analysis such as private information, sequential trading, central bank intervention as well as the role of risk. Risk is hard to define and measure, and this difficulty has obscured the degree of inefficiency in the foreign exchange market.

In contrast, recent studies, and in particular Rubio (2004), indicate that the foreign exchange market is efficient. These results provide some comfort for exchange rate theorists.

The aim of Rubio's thesis is to determine the potential profitability of technical analysis applied on the foreign exchange market. He tests some simple technical analysis rules: simple moving averages (SMA), weighted moving averages (WMA), exponential moving averages (EMA), range trades (RT), filters, and relative strength index (RSI) in the five markets of Australia, Japan, Canada, Switzerland, and the UK. He concluded that only long positions are tracked and reported. When commissions are not included in the analysis, some investment strategies outperform the index. But he finds little evidence that these excess returns are compensation for bearing excessive risk.

If the EMH holds, then empirically stock market prices or the exchange rates should evolve according to a random walk and not predicted..

If s_{t+1} is the exchange rate at time t+1 and s_t is the exchange rate at time t, then the random walk hypothesis is represented by regression (1)

$$\Delta s_{t+1} = \propto + \varepsilon_{t+1} \quad (1)$$

where

$$\Delta s_{t+1} = s_{t+1} - s_t \quad (2)$$

The random walk hypothesis was first exposed by French mathematician Louis Bachelier in 1900. According to Louis Bachelier, that stock prices are random, like the steps taken by a drunk, and therefore are unpredictable. It was then proposed by Kendall (1953). The same ideas are later developed by Eugene Fama (1965). The term random walk is made popular by Malkiel (1973), a professor of economics at Princeton University.

Meese and Rogoff (1983 and 1988), noticed that random walk explains or describes exchange rates better than economic models. Furthermore, the conclusion drawn from the literature related to the random walk hypothesis is that economic models are useless for explaining exchange rates dynamics.

However, this might not be the case in reality especially that as mentioned earlier in this section, there is still a controversy about the EMH.

2-2. Forecasting techniques

The major forecasting techniques in practice are detailed in this section. Some companies generate their own forecasts, while others pay specialized firms to do the job. Forecasting techniques can be classified in any of the following approaches:

1- economic or fundamental analysis,

2- ARMA, ARCH, GARCH techniques,

3- technical and chartist models.

2-2.1 Economic or fundamental analysis

Between these different approaches, predictors can be based on economic fundamentals such as inflation, interest rates, money supply, gross domestic products. This is because the relevant information is being gradually introduced to the expectations of investors.

The fundamentalists compare the market exchange rates with the fundamental rate and they forecast the future market rate.

I start by exposing the different approaches used by the fundamentalists.

2-2.1.1 Purchasing power parity approach

The purchasing power parity (PPP) theory is perhaps the most popular due to its indoctrination in most economic textbooks. The PPP forecasting approach is based on the theoretical Law of One Price, which states that identical goods in different countries should have identical prices.

For example, this law argues that a pencil in the Euro zone should have the same price than a pencil in the U.S. after taking into account the exchange rate and excluding transaction and shipping costs. In other words, there should be no arbitrage opportunity for someone to buy pencils cheap in one country and sell them in another with a profit.

Based on this underlying principle, the PPP approach predicts that the exchange rate will change to offset price changes due to inflation. For example, suppose that prices in the U.S. are expected to increase by 4% over the next year while prices in the Euro zone are expected to rise by only 2%. The inflation differential between the two countries is: 4%-2%=2%

This means that prices in the U.S. are expected to rise faster relative to prices in Euro zone. In this situation, the purchasing power parity approach would predict that the U.S. dollar depreciate by approximately 2% to keep prices between both countries relatively equal. So, if the current exchange rate was 1.12 euro for one US dollar, then the PPP would forecast an exchange rate of (1+0.02)*1.12=1.1424 in one year.

The law of one price between two countries can be defined as follows. We take the euro as the domestic currency and the U.S. dollar as the foreign currency. We denote P^i_{EU}, the price of good i when sold in the Euro zone and P^i_{US} the corresponding price in dollars in the U.S. The law of one price implies that the Euro price of the good i is the same wherever it is sold:

$$P^i_{EU} = E€/\$ \times P^i_{US} . \quad (3)$$

Equivalently, the Euro/dollar exchange rate is the ratio of the good ´s European price and US money prices:

$$E€/\$ = P^i_{EU} / P^i_{US} . \quad (4)$$

For the PPP theory, let PEU be the Euro price of a reference commodity basket sold in the Euro zone and PUS the dollar price of the same basket sold in the US. The PPP predicts a Euro Dollar exchange rate of:

$$E€/\$ = P_{EU} \times P_{US}\ . \qquad (5)$$

We can rearrange the regression in order to get an alternative interpretation of PPP:

$$P_{EU} = E€/\$ \times P_{US} \qquad (6)$$

The left side of the regression shows the euro price of the commodity basket in the euro zone, while the right side shows the euro price multiplied by the euro price of a dollar and that is the Euro price of the basket when purchased in the U.S. Equivalently, the right side measures the purchasing power of one euro when exchanged for dollars and spent in the U.S.

In expression (5), the purchasing power parity explains the movements in the exchange rate between two countries' currencies by changes in the countries´ price levels, while the exchange rate between two countries equals the ratio of the countries' price levels. PPP therefore holds when every currency´s domestic purchasing power is always the same as its foreign purchasing power.

The PPP theory has two main variants in which the PPP hypothesis might hold: the absolute and the relative hypothesis.

The absolute PPP hypothesis is summarized in the simple formula of the price ratio being equal to the exchange rate. The absolute PPP holds when the purchasing power of one unit of currency is exactly equal in the domestic economy and in a foreign economy, once it is converted into foreign currency at the market exchange rate. This hypothesis holds when the nominal foreign exchange rate between two currencies is such that the purchasing power of one unit of currency is exactly the same in the foreign economy as in the domestic economy, once it is converted into foreign currency at that rate (Isard,1995).

The absolute PPP hypothesis states that the exchange rate between the currencies of two countries should equal the ratio of the price levels of the two countries, specifically:

$$S = P / P^* \qquad (7)$$

where S is the nominal exchange rate (spot exchange rate) measured in units of foreign currency per unit of domestic currency; P is the domestic price level; and P* is the foreign price level. Equivalently, absolute PPP implies that the nominal exchange rate between two currencies is equal to the ratio of national price levels.

The relative PPP hypothesis holds when the percentage change in the exchange rate over a given period offsets the difference in inflation rates in the countries considered over the same period. In this way the purchasing power of one unit of the domestic currency in the domestic economy relative to its purchasing power in the foreign economy when converted at the prevailing exchange rate is the same at the end of the period as at the beginning of the period. The relative PPP theory states that the change in the exchange rate should equal the difference in inflation rates (change in prices).

The relative PPP hypothesis states that the exchange rate should bear a constant proportionate relation to the ratio of national price levels, in particular:

$$S = kP / P^*, \tag{8}$$

where k is a constant parameter.

Either variant implies a constant real exchange rate (Q):

$$Q = SP^* / P \,. \tag{9}$$

If we take logarithms of both sides of the equations (7) and (8), we obtain:

$$s = c + p^* - p \,, \tag{10}$$

where s, p* s , p are the logarithms of S,P*,P and c = ln(k) = 0 under absolute PPP.

Under either variant of PPP, a change in the ratio of price levels implies a proportionate change in the nominal exchange rate, such that:

$$\Delta s = \Delta p^* - \Delta p \,. \tag{11}$$

Expression (11) says that the percentage change in the nominal exchange rate is equal to the difference between the inflation rates in the domestic and the foreign country. The PPP implies that the difference in the rate of change in prices at home and abroad, seen as the difference in the inflation rates, should be equal to the percentage depreciation or appreciation of the exchange rate. The PPP exchange-rate calculation is controversial because of the difficulties of finding comparable baskets of goods to compare purchasing power across countries. Deviations from parity imply differences in purchasing power of a "basket of goods" across countries, which means that for the purposes of many international comparisons, countries' GDPs or other national income statistics need to be "PPP-adjusted" and converted into common units.

However, it is often difficult to determine whether literally the same basket of goods is available in two different countries. Thus, it is common to test the relative PPP, which holds that the percentage change in the exchange rate over a given period just offsets the difference in inflation rates in the countries concerned over the same period. If the absolute PPP holds, then the relative PPP also holds. However, if the relative PPP holds, then the absolute PPP does not necessarily hold, since it is possible that common changes in nominal exchange rates are happening at different levels of purchasing power for the two currencies (perhaps because of transactions costs, for example).

In theory, any deviation from PPP should result in an immediate change in prices and/or the exchange rate in such a way that the parity still holds. However, due to barriers like transaction costs and non-tradability, PPP does not hold perfectly in practice. The theoretical consensus is that these deviations are supposed to be temporary so that prices should converge to each other.

2-2-1.2. Relative economic strength

As the name may suggest, the relative economic strength approach looks at the strength of economic growth in different countries in order to forecast the direction of exchange rates. The rationale behind this approach is based on the idea that a strong economic environment and potentially high growth is more likely to attract investments from foreign investors. The investor, in order to purchase investments in the desired country, would have to purchase the country's currency - creating increased demand that should cause the currency to appreciate.

In addition to observing the relative economic strength between countries, this approach takes a more general view and looks at all investment flows. For instance, another factor that can draw investors to a certain country is interest rates. High interest rates will attract investors looking for the highest yield on their investments. This will increase the demand for the currency, and will in turn result in an appreciation of the currency.

Conversely, low interest rates can also sometimes induce investors to avoid investing in a particular country or even borrow that country's currency at low interest rates to fund other investments. Many investors did this with the Japanese yen when the interest rates in Japan were at extreme lows. This strategy is commonly known as the carry-trade.

Unlike the PPP approach, the relative economic strength approach does not forecast what the exchange rate should be, but it gives the investor a general sense of whether a currency is going to appreciate or depreciate, and an overall feel for the strength of the movement. This approach is typically used in combination with other forecasting methods to develop a more complete forecast.

2-2-1.3. Trade balance

This trade balance approach was developed in the early 1960s by Canadian economist Robert Mundell (winner of the 1999 Nobel Prize in economics) and the British economist J. Marcus Fleming (1911–1976). In this period, both authors were members of the International Monetary Fund's Research Department, where they independently extended the traditional Keynesian model to an open economy setup in which the capital and goods markets are internationally integrated. The resulting research constitutes the original version of the Mundell-Fleming model (Mundell 1963, Fleming 1962).

The Mundell-Fleming model integrates international trade and finance into macroeconomic theory. It shows that, under a flexible exchange rate regime, fiscal policy does not have any power to affect output, while monetary policy is very effective. The opposite is true if the exchange rate is fixed. The assumption that international capital markets are completely integrated plays a crucial role in determining these results.

In a flexible exchange rate system, since a monetary expansion tends to decrease the interest rate, this policy also encourages an outflow of financial capital as domestic investors seek higher returns by purchasing foreign bonds. Investors need to buy foreign currency, and thus sell the domestic currency, to acquire those foreign bonds. Consequently, the supply of domestic currency increases. The domestic exchange rate depreciates; that is, more units of domestic currency must be exchanged for each unit of foreign currency. This makes domestic goods cheaper compared to foreign goods, which improves the trade balance (purchases of imports decline and sales of exports increase) and stimulates domestic output and employment. The domestic money demand therefore increases, equilibrium that emerges after the monetary expansion, the interest rate is unaltered, while output is increased proportionally to the increase in the money supply.

In the case of a fiscal expansion, the initial increase in domestic government spending creates an excess demand for goods and tends to raise output, employment, and income. This, in turn, raises the demand for money and the level of the interest rate. The fact that the domestic interest rate is now higher causes an inflow of capital, which causes an appreciation of the domestic exchange rate (fewer units of domestic currency must be provided for each unit of foreign currency). In this case, therefore, domestic goods become more expensive compared to foreign goods, and the trade balance deteriorates (more imports are purchased and fewer exports are sold), which depresses domestic output, employment, and income. A new equilibrium is reached, in which the trade balance is worsened while output and the interest rate are restored to their original levels.

Free capital mobility and trade integration therefore determine the ability of monetary policy to stimulate the domestic economy but frustrate the effects of fiscal policy when the exchange rate is flexible.

In a fixed exchange rate system, the results illustrated above are reversed in a pegged exchange rate regime. With pegged interest rates, the central bank increases or decreases the money supply as necessary so as to maintain a fixed exchange rate. In this case, the pressure for exchange rate depreciation that follows a monetary expansion is neutralized by central bank interventions in the foreign exchange market, with no final effect on domestic output. Similarly, the central bank intervenes to neutralize the domestic exchange rate appreciation that follows a fiscal expansion. This allows the fiscal policy shock to raise the level of domestic output. The central bank commitment to a given exchange-rate level therefore makes the fiscal policy highly efficient.

What is an 'expansionary policy?

An expansionary policy is a macroeconomic policy that seeks to expand the money supply to encourage economic growth. One form of expansionary policy is fiscal policy, which comes in the form of tax cuts, transfer payments, rebates and increased government spending. Another form is monetary policy, which is enacted by central banks through open market operations, reserve requirements and interest rates.

2-2-1.4. Interest rate parity

As per Engel C. (2016) and Fama E. (1984); if the conditions for risk-free arbitrage exist, the ratio of the forward to the spot exchange rate will equal the interest differential between assets with otherwise similar characteristics measured in local currencies,

$$f_{t,\,t+k} - s_t = (i_{t,\,k} - i^*_{t,k}) \qquad (12)$$

where s_t is the price of foreign currency in units of domestic currency at time t, $f_{t,t+k}$ is the forward value of s for a contract expiring in k periods in the future (both in logs), $i_{t,k}$ is the k-period yield on the domestic instrument, and $i^*_{t,k}$ is the corresponding yield on the foreign instrument.

Regression (12) is a risk-free arbitrage condition that holds regardless of investor preferences. To the extent that investors are risk averse, however, the forward rate can differ from the expected future spot rate by a premium that compensates for the perceived riskiness of holding domestic versus foreign assets. We define the risk premium, $\eta_{t,\,t+k}$, accordingly:

$$f_{t,\,t+k} = s^e_{t,\,t+k} + \eta_{t,\,t+k} \qquad (13)$$

Substituting regression (13) into (12) then allows the expected change in the exchange rate from date t to date t+k to be expressed as a function of the interest differential and the risk premium:

$$\Delta s^e_{t,\,t+k} = (i_{t,\,k} - i^*_{t,k}) - \eta_{t,\,t+k} \qquad (14)$$

The Uncovered Interest Parity (UIP) refers to the relation expressed in regression (14) when the risk premium is zero and investors are risk-neutral. In this case, the expected exchange rate depreciation equals the current interest differential. Regression (14) is not directly testable since market expectations of future exchange rate movements are never observable.

Typically, the UIP hypothesis is tested jointly with the assumption of rational expectations in exchange markets. In this case, future realizations of s_{t+k} will equal the value expected at time t plus a white-noise error term $\xi_{t,t+k}$ that is uncorrelated with all information known at t, including the interest differential and the spot exchange rate:

$$s_{t+k} = s^{re}_{t,\,t+k} + \xi_{t,t+k} \qquad (15)$$

where $s^{re}_{t,\,t+k}$ is the rational expectation of the exchange rate at time t+k formed in time t.

Substituting regression (15) into (14) yields the following relationship:

$$\Delta s_{t,\,t+k} = (i_{t,\,k} - i^{*}_{t,k}) - \eta_{t,\,t+k} + + \xi_{t,t+k} \qquad (16)$$

where the left-hand side of regression (15) is the realized change in the exchange rate from t to t+k.

Under the unbiasedness UIP hypothesis, the last two terms in regression (15) are assumed to be orthogonal to the interest differential. Thus, in a regression context, the estimated parameter on the interest differential will have a probability limit of unity in the following regression:

$$\Delta s_{t,\,t+k} = \beta\,(i_{t,\,k} - i^{*}_{t,k}) + \epsilon_{t,\,t+k} \qquad (17)$$

By defining

$$LIB = (i_{t,\,k} - i^{*}_{t,k}) \qquad (18)$$

and plugging it into regression (17) we get the following regression

$$\Delta s_{t,\,t+k} = \propto + \beta\, LIB + \epsilon_{t,\,t+k} \qquad (19)$$

Take this simple example. Suppose that the same security trades in two different places, London and Tokyo. For simplicity, we shall assume that it is a stock.

The table below shows a snapshot of the prices quotes at both locations every second

Table 2-1: Arbitrage example for an identical security trade in London and Tokyo

Time	London Price	Tokyo Price	Difference	London Desk	Tokyo Desk
8:05:00	54.32	54.32	0		
8:05:01	54.31	54.31	0		
8:05:02	55.20	55.10	0.1	Sell 10 @ 55.20	Buy 10 @ 55.10
8:05:03	55.80	55.70	0.1	-	-
8:05:04	55.85	55.75	0.1	-	-
8:05:05	54.32	54.32	0	Buy 10 @ 54.32	Sell 10 @ 54.32
8:05:06	54.33	54.33	0		
8:05:07	53.76	53.76	0		
8:05:08	53.89	53.89	0		
8:05:09	53.56	53.56	0		
8:05:10	53.00	53.00	0		
Lock in	8.80	(7.80)			
Net risk free profit	1.00				

Note: Table 2-1 is a simple example of an arbitrage for an identical security trades in two different places, London and Tokyo. For simplicity, let's say it's a stock, but it doesn't really matter.

Table 2-1 is a simple example of an arbitrage for an identical security trades in two different places, London and Tokyo. For simplicity, let's say it's a stock, but it doesn't really matter.

At 8:05:02, an arbitrageur sees that there is a divergence between the two quotes. London is quoting a higher price than Tokyo. The difference is 10 cents. At that time, the trader enters two orders, a buy order in Tokyo, where the stock is cheap and a sell order in London, where the stock is expensive.

Because the arbitrageur has bought and sold the same amount of the same security, theoretically he does not have any market risk. He has locked-in a price discrepancy, which he hopes to unwind to realize a riskless profit.

Now the profit is $1 as soon as the orders are executed. He does not need to unwind, He could decide to deliver in London the share bought in Tokyo. However it is worth mentioning that the profit opportunity vanishes three seconds later, probably under the pressure of arbitrages.

This is not a huge profit. However, it took merely three seconds and did not involve any price risk.

Arbitrage is similar to “picking pennies”. The opportunities are very small. This is why you have either to do it big or do it often.

Before the days of computerized trading, such opportunities were more frequent and tested longer. Most banks employ some arbitrageurs whose job is to implement arbitrage strategies whenever opportunities arise.

2-2-1.5. Monetary approach

The monetary approach can be attributed to Frenkel (1976), Mussa (1976), and Bilson (1978). This version assumes that goods' prices are perfectly flexible and thus that PPP holds instantaneously:

$$s = p - p^*, \tag{20}$$

where s is the logarithm of the spot exchange rate, defined as the price of the foreign currency in terms of the domestic currency and p and p* are the respective logarithm of the domestic and foreign price levels. Assuming conventional money demand functions at home and abroad,

$$m = p + \varphi y - \lambda i, \tag{21}$$

$$m^* = p^* + \varphi y^* - \lambda i^*, \tag{22}$$

where m and m* are the respective logarithms of the domestic and the foreign money supplies, y and y* are the respective logs of domestic and the foreign real income; and i and i* are the domestic and the foreign interest rates respectively. φ is the coefficient or the elasticity with respect to income and λ is the coefficient or the elasticity with respect to interest rate.

For simplicity, the elasticity with respect to income, φ, and the elasticity with respect to the interest rate, λ, are considered equal across countries. Combining regressions (20) and (21) and (22), we obtain one representation of the flexible price monetary regression:

$$s = (m - m^*) - \varphi (y - y^*) + \lambda (i - i^*) \tag{23}$$

If uncovered interest parity holds, then,

$$i - i^* = \Delta se, \tag{24}$$

where Δse is the expected depreciation of domestic currency. The PPP is assumed to hold so that:

$$\Delta se = \pi - \pi^*, \tag{25}$$

where π and π* are the expected inflation rates, at home and abroad, respectively.

Substituting (25) into (23), we get an alternative representation of the flexible price monetary regression:

$$s = (m - m^*) - \varphi (y - y^*) + \lambda (\pi - \pi^*). \tag{26}$$

Regression (26) says that the exchange rate, as the relative price of money, is determined by the supply and demand for money. An increase in the supply of the domestic money causes a proportionate depreciation of the exchange rate. An increase in the demand for the domestic money which may result from an increase in the domestic income or a decrease in the expected inflation, causes an appreciation of the exchange rate. The regression has been widely estimated econometrically.

One can then assume that the change in exchange rate at date t+k is a function of the money supply difference and the inflation difference plus an error term.

$$\Delta s_{t, t+k} = \propto + \beta (m_{t, k} - m_{t, k}{}^*) + \lambda (\pi_{t, k} - \pi_{t, k}{}^*) + \epsilon_{t, t+k} \tag{27}$$

let us define

$$MS = (m_{t, k} - m_{t, k}{}^*) \tag{28}$$

and

$$INF = (\pi_{t, k} - \pi_{t, k}{}^*) \tag{29}$$

Plugging regressions (28) and (29) into regression (27) yields the following regression:

$$\Delta s_{t, t+k} = \propto + \beta\, MS + \lambda\, INF + \epsilon_{t, t+k}. \tag{30}$$

2-2-1.6. Taylor rule fundamental approach

Evaluating exchange rate models out of sample is initiated by Meese and Rogoff (1983), who could not reject the naïve no-change random walk model in favor of the existing empirical exchange rate models of the 1970s. Starting with Mark (1995), the focus of the literature shifts towards deriving a set of long-run fundamentals from different models, and then evaluating out-of-sample forecasts based on the difference between the current exchange rate and its long-run value. Engel, Mark, and West (2008) use the interest rate implied by a Taylor rule, and Molodtsova and Papell (2009) use the variables that enter Taylor rules to evaluate exchange rate forecasts.

Taylor rule fundamental model examines the relationship between the exchange rate and a set of variables that arise when central banks set the interest rate according to the Taylor rule. Following Taylor (1993), the monetary policy rule postulated to be followed by central banks can be specified as:

$$i_t = \pi_t + \phi(\pi_t - \overline{\pi}) + \gamma y_t + R \qquad (31)$$

where i_t is the target for the short-term nominal interest rate, π_t is the inflation rate, $\overline{\pi}$ is the target level of inflation; y_t is the output gap i.e., the percent deviation of actual real GDP from an estimate of its potential level, and R is the equilibrium level of the real interest rate.

According to the Taylor rule, the central bank raises the target for the short-term nominal interest rate if inflation rises above its desired level and/or the output is above the potential output. The target level of the output deviation from its natural rate y_t is 0 because, according to the natural rate hypothesis[1], output cannot permanently exceed potential output.

Note1: An economy’s natural level of output or potential output occurs when all available resources are used efficiently. It equals the highest level of production an economy can sustain. It is "natural" because an economy returns to its natural level of output following a recession or overheated period.

The target level of inflation is positive because it is generally believed that deflation is much worse for an economy than low inflation. The unemployment gap, which is the difference between the unemployment rate and the natural rate of unemployment, can replace the output gap in regression (31) as in Blinder and Reis (2005) and Rudebusch (2010). In that case, the coefficient γ would be negative so that the Fed raises the interest rate when the unemployment rate is below the natural rate of unemployment. Taylor assumes that the output and inflation gaps enter the central bank's reaction function with equal weights of 0.5 and that the equilibrium level of the real interest rate and the inflation target are both equal to 2 percent. The parameters $\overline{\pi}$ and R in regression (31) can be combined into one constant term, $\mu = R - \phi\,\overline{\pi}$, which leads to the following regression:

$$i_t = \mu + \lambda \pi_t + \gamma y_t \qquad (32)$$

where $\lambda = 1+\phi$. Because $\lambda > 1$, the real interest rate is increased when inflation rises, and so the Taylor principle is satisfied. Following Taylor (2008) and Curdia and Woodford (2010), the original Taylor rule can be modified by subtracting a multiple of the spread between the dollar Libor rate and the overnight indexed swap (OIS) rate (Ref: Appendix),

$$i_t = \mu + \lambda \pi_t + \gamma y_t - \delta s_t \qquad (33)$$

where s_t is the spread. Molodtsova and Papell (2009) do not incorporate several modifications of the Taylor rule that are typically used for estimation.

To derive the Taylor-rule-based forecasting regression, they construct the implied interest rate differential by subtracting the interest rate reaction function for other countries from that for the U.S.:

$$i_t - i^*_t = \alpha + \lambda (\pi_t - \pi^*_t) + \gamma (y_t - y^*_t) - \delta (s_t - s^*_t). \qquad (34)$$

Using uncovered interest rate parity $\Delta e_{t+1} = i_t - i^*_t$ leads to :

$$\Delta e_{t+k} = \omega + \omega_\pi (\pi_t - \pi^*_t) + \omega_y (y_t - y^*_t) - \omega_s (s_t - s^*_t) \qquad (35)$$

where asterisks denote other countries' variables, ω is a constant, and ω_{π} , ω_{y} and ω_{s} are positive coefficients. Alternatively, the unemployment gap differential (with an opposite sign) can substitute for the output gap differential in Regression (35). The variable e_{t} is the log of the U.S. dollar nominal exchange rate determined as the domestic price of foreign currency. As such, an increase in e_{t} is a depreciation of the dollar.

The spread mentioned earlier can be considered with the residual of regression (33-5) leading to

$$\Delta e_{t, t+k} = \omega + \omega_{\pi} (\pi_{t} - \pi^{*}_{t}) + \omega_{y} (y_{t} - y^{*}_{t}) + \epsilon_{t, t+k} \qquad (36)$$

by defining

$$GDP = (y_{t} - y^{*}_{t}) \qquad (37)$$

and

$$INF = (\pi_{t, k} - \pi_{t, k}{}^{*}) \qquad (38)$$

by plugging regressions (37) and (38) into regression (36) we obtain:

$$\Delta e_{t, t+k} = \omega + \omega_{\pi} INF + \omega_{y} GDP + \epsilon_{t, t+k.} \qquad (39)$$

2-2-1.7. Political risk premium

In his reinterpretation of the interest-rate parity theorem, Aliber R, (1973) distinguishes between exchange risk and political risk as determinants of deviations from interest rate parity. Deviations from interest rate parity reflect exchange risk when assets are denominated in different currencies and /or political risk when assets are issued in different countries (under different jurisdictions).

It is now established by Aliber R, (1973), Dooley M, Isard P (1980), that assets differing essentially in only their currencies of denomination, such as Euro currency deposits issued by the same bank, exhibit interest rate differentials equal to the forward exchange rate premiums that must be paid to cover against exchange risk after adjusting for transaction costs. In contrast, it is not well understood to what extent political risk has contributed to disparities between interest rates on assets denominated in the same currency but issued in different political jurisdictions.

2-2-2. Econometric models, ARMA, ARCH, GARCH techniques

This approach analyzes mathematical models to anticipate the movement of the currency and to highlight non-random predictable behavior in a highly liquid market suck as exchange rates. (Pacelli. V, 2012). Following this line of research, several indicators have been designed (such as ARMA, ARCH, GARCH etc.,) to predict, with acceptable accuracy, the trend and strength of the currency.

Autoregressive moving average ARMA process

One of the more popular time series approaches is called the autoregressive moving average (ARMA) process. The rationale for using this method is based on the idea that past behavior and price patterns can be used to predict future price behavior and patterns.

Given a time series of data X_t, the ARMA model is a tool for understanding and, perhaps, predicting future values in this series. The model consists of two parts: an autoregressive (AR) part and a moving average (MA) part. The model is usually referred to as the ARMA (p,q) model, where p is the order of the autoregressive part and q is the order of the moving average part, as defined below.

Notation AR (p) refers to the autoregressive model of order p. The AR (p) model is written:

$$X_t = c + \sum_{i=1}^{p} \varphi_i X_{t-1} + \varepsilon_t, \qquad (40)$$

where c is a constant, φ_i, …, φ_p are parameters and the random variable ε_t is a white noise

Moving average model

Notation MA (q) refers to the moving average model of order q:

$$X_t = \mu + \varepsilon_t + \sum_{i=1}^{q} \theta_i X \epsilon_{t-1} \tag{41}$$

where theθ_i, …, θ_p are the parameters of the model, μ is the expectation of X_t (often assumed to equal 0), and the $\varepsilon_t, \dots, \varepsilon_{t-1}$ are again, white noise error terms.

ARMA model

The general ARMA model is described in the 1951 thesis of Peter Whittle, who used mathematical analysis (Laurent series and Fourier analysis) and statistical inference. ARMA models are made popular by a 1971 book by George E. P. Box and Jenkins, who expounded an iterative (Box–Jenkins) method for choosing and estimating such models.

Notation ARMA (p, q) refers to the model with p autoregressive terms and q moving-average terms. This model contains the AR (p) and MA (q) models,

$$X_t = c + \epsilon_t + \sum_{i=1}^{p} \varphi_i X_{t-i} + \sum_{i=1}^{q} \theta_i \epsilon_{t-i}. \tag{42}$$

Note about the error terms:

Error terms ϵ_t are generally assumed to be independent identically distributed random variables (i.i.d.) sampled from a normal distribution with zero mean: ϵ_t~ N(0,σ2) where σ2 is the variance. These assumptions may be weakened but doing so will change the properties of the model. In particular, a change to the (i.i.d.) assumption would make a rather fundamental difference.

Specification in terms of lag operator:

In some texts the models will be specified in terms of the lag operator L. In these terms then the AR(p) model is given by

$$\varepsilon_t = (1 - \sum_{i=1}^{p} \varphi_i L^i) X_t = \varphi (L) X_t , \quad (43)$$

where φ represents the polynomial

$$\varphi(L) = 1 - \sum_{i=1}^{p} \varphi_i L^i . \quad (44)$$

The MA (q) model is given by:

$$X_t = (1 - \sum_{i=1}^{q} \theta_i L^i) \varepsilon_t = \theta(L) \varepsilon_t \quad (45)$$

where θ represents the following polynomial:

$$\theta(L) = 1 - \sum_{i=1}^{q} \theta_i L^i . \quad (46)$$

A combined ARMA (p,q) model is given by

$$\left(1 - \sum_{i=1}^{p} \varphi_i L^i\right) X^t = \left(1 - \sum_{i=1}^{q} \theta_i L^i\right) \varepsilon_t , \quad (47)$$

Or

$$\varphi(L) X_t = \theta(L) \varepsilon_t . \quad (48)$$

<u>Review of the ARMA with ARCH errors models</u>:

In Weiss (1984) ARMA models with ARCH errors are found to be successful in modelling thirteen different U.S. macroeconomic time series.

Autoregressive conditional heteroscedasticity (ARCH) models are used to characterize and model observed time series. They are used whenever there is a reason to believe that, at any point in a series, the error terms will have a characteristic size or variance. In particular, ARCH models assume the variance of the current error term or innovation to be a function of the actual sizes of the previous time periods' error terms. Often, the variance is related to the squares of the previous innovations[2].

2-The innovation is the difference between the observed value of a variable at time t and the optimal forecast of that value based on information available prior to time t. If the forecasting method is working correctly, successive innovations are uncorrelated with each other, i.e., constitute a white noise time series.

Such models are often called ARCH models (Engle, 1982), although a variety of other acronyms are applied to particular structures of the model which have a similar basis. ARCH models are employed commonly in modeling financial time series that exhibit time-varying volatility clustering, i.e., periods of swings followed by periods of relative calm. ARCH-type models are sometimes considered to be part of the family of stochastic volatility models but strictly this is incorrect since at time t the volatility is completely pre-determined (deterministic) given previous values.

In statistics and econometrics one often assumes that an observed series of data values is the sum of a series of values generated by a deterministic linear process, depending on certain independent (explanatory) variables, and on a series of random noise values. Then regression analysis is used to infer the parameters of the model process from the observed data, e.g., by ordinary least squares, and to test the null hypothesis that each of the parameters is zero against the alternative hypothesis that it is non-zero. Hypothesis testing typically assumes that the noise values are mutually uncorrelated with zero mean and the same Gaussian probability distribution. In other words, the noise is white. If there is non-zero correlation between the noise values underlying different observations then the estimated model parameters are still unbiased, but estimates of their uncertainties (such as confidence intervals) will be biased (not accurate on average). This is also true if the noise is heteroskedastic, that is, if it has different variances for different data points.

2-2-3. Technical and Chartist models

Technical or chartist analysis of financial markets involves providing forecasts or trading advice on the basis of largely visual inspection of past prices, without regard to any underlying economic or 'fundamental' analysis. There is also a skew towards reliance on technical, as opposed to fundamentalist, analysis at shorter horizons, which becomes steadily reversed as the length of horizon considered is increased. A very high proportion of chief dealers view technical and fundamental analysis as complementary forms of analysis and a substantial proportion suggest that technical advice may be self-fulfilling. Taylor and Allen (1992).

I develop in this section two main technical analysis techniques.

2-2-3.2. Relative Strength Index (RSI)

The relative strength index (RSI) is a technical momentum indicator that compares the magnitude of recent gains to recent losses in an attempt to determine overbought and oversold conditions of an asset. It is calculated using the following formula:

$$RSI = 100 - 100/(1 + RS^*) \qquad (49)$$

where RS^* = average of x days' up closes / average of x days' down closes.

The RSI ranges from 0 to 100. An asset is deemed to be overbought once the RSI approaches a value of 70, it means that the asset may be getting overvalued and that it is a good candidate for a pullback. Conversely, if the RSI approaches 30, it is an indication that the asset may be getting oversold and, therefore, likely to become undervalued.

Large surges and drops in the price of a currency will affect the RSI by creating false buy or sell signals. The RSI is best used as a valuable complement to other tools.

2-2-3.3. Fibonacci Sequence

Fibonacci retracement is a method of technical analysis for determining support and resistance levels. It is named after its use of the Fibonacci sequence. Fibonacci retracement is based on the idea that markets will retrace a predictable portion of a move, after which they will continue to move in the original direction.

The appearance of retracement can be ascribed to ordinary price volatility as described by Burton Malkiel, a Princeton economist, in his book A Random Walk Down Wall Street. Malkiel (1973) found no reliable predictions in technical analysis methods taken as a whole. Malkiel argues that asset prices typically exhibit signs of random walk and that one cannot consistently outperform market averages.

Fibonacci retracement is created by taking two extreme points on a chart and dividing the vertical distance by the key Fibonacci ratios. 0.0% is considered to be the start of the retracement, while 100.0% is a complete reversal to the original part of the move. Once these levels are identified, horizontal lines are drawn and used to identify possible support and resistance levels. The significance of such levels, however, cannot be statistically assessed.

Fibonacci ratios are mathematical relationships, expressed as ratios, derived from the Fibonacci sequence. The key Fibonacci ratios are 0%, 23.6%, 38.2%, 61.8% and 100%.

$$F(100) = ((1+\sqrt{5})/2)^\wedge 0 \quad . \qquad (50)$$

The key Fibonacci ratio of 0.618 is derived by dividing any number in the sequence by the number that immediately follows it. For example, 8/13 is approximately 0.6154, and 55/89 is approximately 0.6180.

$$F(61.8) = ((1+\sqrt{5})/2)^\wedge - 1 \quad . \tag{51}$$

The 0.382 ratio is derived by dividing any number in the sequence by the number that is found two places to the right. For example, 34/89 is approximately 0.3820.

$$F(38.2) = ((1+\sqrt{5})/2)^\wedge - 2 \quad . \tag{52}$$

The 0.236 ratio is derived by dividing any number in the sequence by the number that is three places to the right. For example, 55/233 is approximately 0.2361.

$$F(23.6) = ((1+\sqrt{5})/2)^\wedge - 3 \quad . \tag{53}$$

The 0 ratio is:

$$F(0) = ((1+\sqrt{5})/2)^\wedge - \infty \quad . \tag{54}$$

- A support level is a level where the rate tends to find support as it falls. This means the rate is more likely to "bounce" off this level rather than break through it. However, once the rate has breached this level, by an amount exceeding some noise, it is likely to continue falling until meeting another support level.
- A resistance level is the opposite of a support level. It is where the rate tends to find resistance as it rises. This means the rate is more likely to "bounce" off this level rather than break through it. However, once the rate has breached this level, by an amount exceeding some noise, it is likely to continue rising until meeting another resistance level.

Graph 2-1 shows Fibonacci retracement levels shown on the USD/CAD currency pair. In this case, price retraced approximately 38.2% of a move down before continuing.

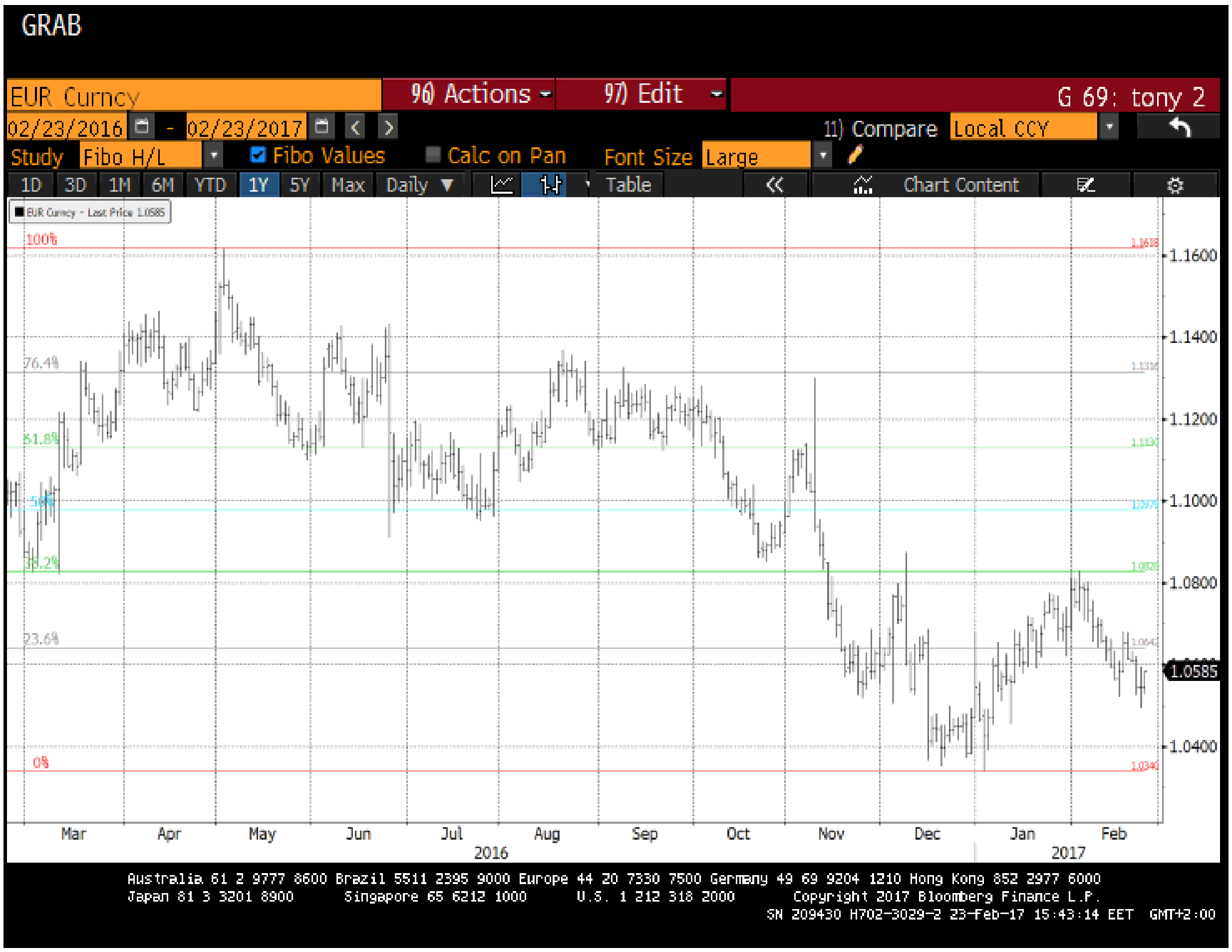
Graph 2-1 USD/CAD currency pair (Metatrader 2010)

Note: Graph 2-1 shows Fibonacci retracement levels shown on the USD/CAD currency pair, in this case, price retraced approximately 38.2% of a move down before continuing.

Graph 2-2: GBP/USD currency pair (Bloomberg screen shot 23-02-2017)

Note: Graph 2-2 shows Fibonacci retracement levels shown on the GBP/USD currency pair. In this case, in November 2016, price retraced approximately 23.6% of an October move down before continuing.

Graph 2-3: EUR/USD currency pair (Bloomberg screen shot 23-02-2017)



Note: Graph 2-3 shows Fibonacci retracement levels shown on the EUR/USD currency pair. In this case, in February 2017, price retraced approximately 38.2% of a move down in January before continuing.

Vincenzo Pacelli (2012) traces the history of exchange rate forecasting by mentioning the below: The economic theory has not yet provided econometric models to produce efficient forecasts of exchange rates, although many studies have been devoted to the estimation of the equilibrium of exchange rates from the 1920s to recent years. In particular, Meese and Rogoff (1983) found that none of the forecasting models of the exchange rate established by economic theory has a better ability to forecast, over a period lower than 12 months, than the forward rate models or random walk, emphasizing the paradox that the variations of exchange rates are completely random.

In the wake of the study of Meese and Rogoff, some authors, including Hsieh (1989), have studied the predictive power of non-linear models such as artificial neural networks, genetic algorithms, expert systems or fuzzy models, leading to conflicting results.

Many econometric models are carried out, such as on ARCH and GARCH models, which are able to analyze and perceive the time variability of the phenomenon of volatility, and are, therefore, useful tools to capture the non-linearity of the changes in exchange rates (Krager and Kugler, (1993) and Brooks, (1996)). The pioneers of the ARCH (Autoregressive Conditional Heteroscedasticity) models are Engle (1982) and Bollerslev (1986), who generalized the model of Engle opening the way for a new generation of models able to capture the dynamics of time series, the GARCH (Generalized Autoregressive Conditional Heteroscedasticity) models and its derivatives.

The purpose of determining the most likely exchange rate is quite different from attempting to beat the market in order to derive speculative profits. Therefore, the purpose is not for speculation, but rather, facilitating decision-making in order to lower the risk of exposure.

Based on the above, I consider that there is still a need for a simple model that provides adequate insight and improves the quality of exchange rate forecast.

3- RESEARCH METHOD AND EMPIRICAL RESULTS

The Efficient Market Hypothesis (EMH) related to exchange rates remains controversial and the strategies to mitigate currency risk exposure suggest that there is a need for the development of reliable exchange rate models.

After detailing the existing forecasting techniques (the fundamental models, the econometric models, and the chartist models), I develop a one month exchange rate forecasting model for four major European currencies (the Euro (EUR), the Swedish Krona (SEK), the Great British Pound (GBP) and the Swiss Franc (CHF) in which the benchmark currency is the U.S. Dollar (USD). The particularity of the model is to study how these currencies interact with each other. For this purpose, I go through three steps:

1- I study a regression analysis for each currency based on each of three fundamental approaches: the interest parity approach, the monetary approach and the Taylor rule approach.

2- Then, because of the interdependence of their economies and due to the geopolitical and cultural inter dependence between the European countries, I perform a principal component analysis (PCA) to validate the existence of common components that suggest interaction among the four above mentioned European currencies.

I perform one PCA based on the interest approach, one PCA based on the money supply approach and one PCA based on the Taylor rule approach. Those PCAs are run on the residuals estimated from those models in step 1.

3- I study a new regression analysis for each currency based on each of the three fundamental approaches by adding as an independent variable, the unexpected component of the exchange rates of the three other currencies.

Hereafter, I analyze how the rates of these four European currencies interact with each other over a one month period and then determine the most significant and robust forecasting model.

Many reasons motivate the choice of a one month horizon is due to many reasons. Firms that do not speculate on financial markets would be more interested in a one month horizon, to get the currency direction for adequate budgeting. On the other hand, unknown variables are likely to appear in a period longer than one month and distort the findings. Hutcheson (2000), while studying the Australian foreign exchange market finds that: “Fundamental analysis is regarded to be better at explaining long term exchange rates movements while technical analysis is better at explaining short term movements”. On the other hand, technical analysis is widely used in the financial community. Taylor and Allen (1992) report that more than 90% of surveyed foreign exchange dealers in London say that they use some form of technical analysis to make their trading decisions. In addition, at the shortest time horizon, 60% of the respondents judged technical analysis to be at least as important as fundamentals when generating exchange rate predictions.

In this thesis, I chose to analyze the links between the rates of four European currencies and their predictive power for future rates. The rationale behind this choice is the economic as well as geopolitical relationship between the four countries issuing those currencies.

The geopolitical approach is based on the presumption that economic interdependence may exist because states trade with each other to obtain strategic goods that are needed for national industry and defense. The geopolitical approach is based on both vertical and horizontal interdependence.

Vertical interdependence measures how a change in the price of a good in Country X will affect Country Y (or how changes in price in State A will affect State B), whilst horizontal interdependence calculates the degree of bilateral trade, transactions and investment involved between both countries. Both vertical and horizontal interdependence data must be used to measure economic interdependence.

Table 3-1 and graph 3-1 show the degree of interdependence of trade and transactions between the 28 countries of the European Union.

Table 3-2 shows the degree of interdependence of trade and transactions between the 28 countries and Switzerland.

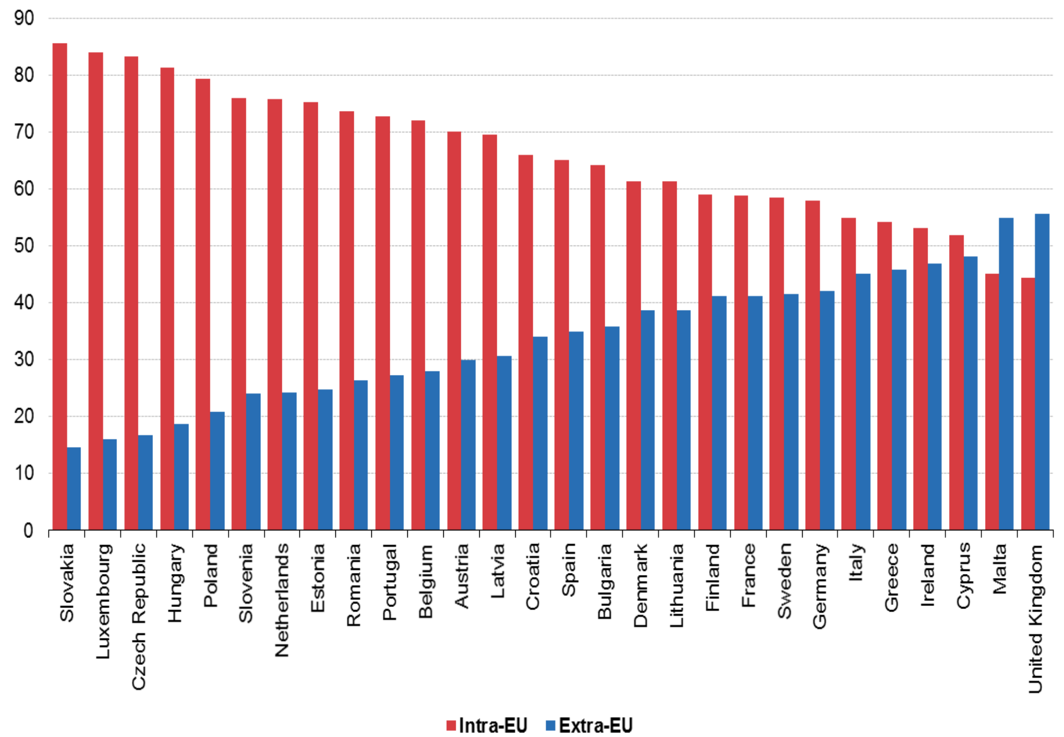
Table 3-1: Intra European export of goods to other member state.

Country	Exports	Share
Germany	694	22.6
Netherlands	389	12.7
France	268	8.7
Belgium	260	8.5
Italy	227	7.4
United Kingdom	184	6.0
Spain	165	5.4
Poland	142	4.6
Czech Republic	119	3.9
Austria	97	3.1
Sweden	74	2.4
Hungary	72	2.4
Ireland	59	1.9
Slovakia	58	1.9
Denmark	53	1.7
Romania	40	1.3
Portugal	36	1.2
Finland	32	1.0
Slovenia	22	0.7
Bulgaria	15	0.5
Lithuania	14	0.5
Greece	14	0.5
Luxembourg	13	0.4
Estonia	9	0.3
Croatia	8	0.3
Latvia	8	0.2
Malta	1	0.03
Cyprus	1	0.03
EU28	1791	100.0

Note: Table 3-1 shows the exports of goods from each European member state to the other 28 European member states for year 2015, in billions of Euros and the respective percentage share.

Source : Eurostat table DS-057009

Graph 3-1: Intra EU exports of goods compared with Extra EU exports of goods by Member State, 2015



Note: Graph 3-2 shows, in percentage of exports, the level of intra-European exports versus the level of level of exports outside Europe for the 28 EU member states in 2015.

Source: Eurostat table DS-018995

Table 3-2: EU-Switzerland trade in goods for years 2014-2015-2016 in billions of Euros

Year	EU imports	EU exports	Balance
2014	96.6	140.3	43.7
2015	102.4	150.5	48.1
2016	121.6	142.4	20.8

Note: Table 3-2 shows the trade in goods between the European member states and Switzerland from years 2014 to 2016 in billions of

3-1. <u>The first step of the research (simple comparative regression analysis)</u>

As mentioned earlier, I conduct a regression analysis for four currencies: the Euro (EUR), the Swedish Krona (SEK), the Great British Pound (GBP), and the Swiss Franc (CHF). In this analysis, I test fundamental models; the interest parity approach, the monetary approach, and the Taylor rule approach.

In the remainder, I define the interest rate approach as model 1, the monetary approach as model 2 and the Taylor rule approach as model 3.

Regression (19) based on the interest rate parity approach, i.e. Model 1, shows that the percentage change in the nominal exchange rate is equal to the difference between the interest rates in the domestic and the foreign country plus a noise error.

$$\Delta s_{t,t+1} = \propto + \beta \, LIB_t + \epsilon_{t,.} \qquad (19)$$

Regression (30) based on the monetary approach, i.e. Model 2, shows that the exchange rate is determined by the supply and demand for money. It also shows that the percentage change in the nominal exchange rate is equal to the difference between the money supply and the difference in the inflation rates between the domestic and the foreign country.

$$\Delta s_{t,t+1} = \propto + \beta \, MS_t + \lambda \, INF_t + \epsilon_{t,} \qquad (30)$$

Regression (39) based on the Taylor rule approach, i.e. Model 3, shows that the percentage change in the nominal exchange rate is equal to the difference between the inflation rates in the domestic and the foreign country and between the difference in output in the domestic and the foreign country.

$$\Delta e_{t,t+1} = \omega + \omega_{\pi} \, INF_t + \omega_{y} \, GDP_t + \epsilon_{t.} \qquad (39)$$

Data collection

- The exchange rates of the EUR, the GBP, the SEK, and the CHF are collected from the Federal Reserve Bank website on a daily basis and the monthly averages are computed to get the monthly rates.
- The interest rates used are the LIBOR rates for the EUR, the GBP and, the CHF. They are collected from the website of Federal Bank of Saint Louis on a daily basis, and the monthly averages are computed to get the monthly rates. For the SEK, The STIBOR is collected from the Sveriges Riksbank website on a monthly basis.
- The value of money supply (M2) in the US are collected from the Federal Reserve website. In Europe the values are collected for the ECB website, in Switzerland, in Sweden and in the U.K. they are taken from the Swiss National Bank, from Sveriges Riksbankandrom the Bank of England websites respectively, all on a monthly basis.
- Inflation rates for the U.S., the Euro Zone, Switzerland, Sweden, and U.K. are collected from website inflation.eu (Triami Media BV Netherlands), where the inflation rates of all countries can be shown on a monthly basis.
- The GDP data are extracted from Reuters on a quarterly basis. Then they are interpolated monthly according to the Cubic Spline method to estimate the monthly values.
- All data is collected and analyzed from 01-01-2000 until 30-06-2016

Analysis

The percentage changes for each currency at time t are calculated based on the following formulas:

Exchange Rates: $\Delta_{s,t} = ((S_t - S)/S)/n \times 100$ (55)

Inflation: $\Delta_{\pi,t} = ((\pi_t - \pi)/\pi)/n \times 100$ (56)

Money Supply: $\Delta_{m,t} = ((m_t - m)/m)/n \times 100$ (57)

Interest rates: $\Delta_{i,t} = ((i_t - i)/i)/n \times 100$ (58)

GDP: $\Delta_{y,t} = ((y_t - y)/y)/n \times 100$ (59)

Let us denote INF_t the difference between the foreign and the domestic inflation rates:

$$INF_t = \pi_t - \pi^*_t, \qquad (60)$$

where π_t is the foreign inflation rate and π^*_t is the domestic inflation rate

The difference between the foreign and the domestic money supply i.e. m_t-m^*_t is denoted MS_t.

$$MS_t = m_t - m^*_t \qquad (61)$$

where m_t is the foreign money supply and m^*_t is the domestic money supply

The difference between the foreign and the domestic interest rates i.e. i_t-i^*_t is denoted LIB_t.

$$LIB_t = i_t - i^*_t \qquad (62)$$

where i_t is the foreign money supply and i^*_t is the domestic interest rates

The difference between the foreign and the domestic GDP is denoted GDP_t and equals to y_t-y^*_t.

$$GDP_{t} = y_t - y^*_t \qquad (63)$$

where y_t is the foreign money supply and y^*_t is the domestic interest rates

The USD is considered as the domestic currency and the U.S. is considered as the domestic country.

Model 1 (IRP) first estimates the following for each currency

$$\Delta s_{\ t,\,t+1} = \propto + \beta\ LIB_t + \epsilon_{\ t+k} \qquad (19)$$

Results are presented in In Table 4-1 for the EUR, Table 4-2 for the SEK, Table 4-3 for the GBP, and Table 4-4 for the CHF.

Table 4-1: Estimates of Model 1 for the EUR

Currency		EUR
Constant		
	coeff	-0.3010
	P-Value	0.0001
LIB		
	Coeff	-0.3100
	P-Value	0.0001
	VIF	1.0000
R2		0.70

Dependent Variable	Δs	Δ EUR @ t+1
Independent variable	LIB	Δ LIBOR EUR @ t

The results show an R2 of 0.701, with significant results and no multicollinearity suggesting that the variation of the EUR at t+1 is well explained by the interest variable LIB.

Table 4-2: Estimates of Model 1 for the SEK

Currency		SEK
Constant		
	coeff	-0.0840
	P-Value	0.0001
LIB		
	Coeff	-0.2020
	P-Value	0.0001
	VIF	1.0000
R2		0.25

Dependent Variable	Δs	Δ SEK @ t+1
Independent variable	LIB	Δ LIBOR SEK @ t

The results show an R2 of 0.204, with significant results and no multicollinearity suggesting that the variation of the SEK at t+1 is poorly explained by the interest variable LIB and that some important variables are missing,

Table 4-3: Estimates of Model 1 for the GBP

Currency		GBP
Constant		
	coeff	0.148
	P-Value	0.000
LIB		
	Coeff	0.097
	P-Value	0.000
	VIF	1.000
R2		0.021

Dependent Variable	Δs	Δ GBP @ t+1
Independent variable	LIB	Δ LIBOR GBP @ t

The results show an R2 of 0.021, with significant results and no multicollinearity, suggesting that the variation of the GBP at t+1 is very poorly explained by the interest variable LIB and some important factors are missing in the regression.

Table 4-4: Estimates of Model 1 for the CHF

Currency		CHF
Constant		
	coeff	-0.2840
	P-Value	0.0001
LIB		
	Coeff	-0.0860
	P-Value	0.0001
	VIF	1.0000
R2		0.89

Dependent Variable	Δs	Δ CHF @ t+1
Independent variable	LIB	Δ LIBOR CHF @ t

The results show an R2 of 0.892, with significant results and no multicollinearity, suggesting that the variation of the CHF at t+1 is highly explained by the interest variable LIB.

After testing model 1, I conduct a regression analysis by currency for Model 2:

$$\Delta s_{t,t+1} = \propto + \beta MS_t + \lambda INF_t + \epsilon_{t+k.} \quad (30)$$

Results are displayed in Table 4-5 for the EUR, Table 4-6 for the SEK, Table 4-7 for the GBP, and Table 4-8 for CHF.

Table 4-5: Estimates of Model 2 for the EUR

Currency		EUR
Constant		
	coeff	0.1090
	P-Value	0.0001
MS		
	Coeff	0.6200
	P-Value	0.0001
	VIF	1.7140
INF		
	Coeff	0.0001
	P-Value	0.6750
	VIF	1.7140
R2		0.86

Dependent Variable	Δs	Δ EUR @ t+1
Independent variable	MS	Δ Money Supply EUR @ t
Independent variable	INF	Δ Inflation EUR @ t

The results show an R2 of 0.864, with significant results and no multicollinearity, suggesting that the variation of the EUR at t+1 is highly explained by the money supply and inflation variables. The R2 of Model 2 (the monetary approach) is higher than the R2 of Model 1 (the interest parity approach).

Table 4-6: Estimates of Model 2 for the SEK

Currency		SEK
Constant		
	coeff	0.0620
	P-Value	0.0001
MS		
	Coeff	0.6780
	P-Value	0.0001
	VIF	1.3510
INF		
	Coeff	-0.0040
	P-Value	0.0001
	VIF	1.3510
R2		0.80

Dependent Variable	Δs	Δ SEK @ t+1
Independent variable	MS	Δ Money Supply SEK @ t
Independent variable	INF	Δ Inflation SEK @ t

The results show an R2 of 0.794, with significant results and no multicollinearity, suggesting that the variation of the SEK at t+1 is highly explained by the money supply and inflation variables. The R2 of Model 2 (the monetary approach) is much higher than the R2 of Model 1 (the interest parity approach).

Table 4-7: Estimates of Model 2 for the GBP

Currency		GBP
Constant		
	coeff	0.1390
	P-Value	0.0001
MS		
	Coeff	0.6290
	P-Value	0.0001
	VIF	1.4580
INF		
	Coeff	0.0001
	P-Value	0.8490
	VIF	1.4580
R2		0.72

Dependent Variable	Δs	Δ GBP @ t+1
Independent variable	MS	Δ Money Supply GBP @ t
Independent variable	INF	Δ Inflation GBP @ t

The results show an R2 of 0.720, with significant results and no multicollinearity, suggesting that the variation of the GBP at t+1 is highly explained by the money supply and inflation variables. The R2 of Model 2 (the monetary approach) is much higher than the R2 of Model 1 (the interest parity approach).

Table 4-8: Estimates of Model 2 for the CHF

Currency		CHF
Constant		
	coeff	-0.1240
	P-Value	0.0001
MS		
	Coeff	0.3670
	P-Value	0.0001
	VIF	1.3820
INF		
	Coeff	-0.0025
	P-Value	0.0150
	VIF	1.3640
R2		0.79

Dependent Variable	Δs	Δ CHF @ t+1
Independent variable	MS	Δ Money Supply CHF @ t
Independent variable	INF	Δ Inflation CHF @ t

The results show an R2 of 0.794, with significant results and no multicollinearity, suggesting that the variation of the CHF at t+1 is well explained by the money supply and inflation variables. However, the R2 of Model 2 (the monetary approach) is lower than the R2 of Model 1 (the interest parity approach), which suggests that the interest parity approach suits better the CHF.

After testing Model 1 and Model 2, I now test Model 3 for each currency:

$$\Delta e_{t, t+1} = \omega + \omega_{\pi} INF_t + \omega_{y} GDP_t + \epsilon_{t+k} . \quad (39)$$

Results are presented in Table 4-9 for the EUR, Table 4-10 for the SEK, Tables 4-11 for the GBP and Table 4-12 for the CHF.

Table 4-9: Estimates of Model 3 for the EUR

Currency		EUR
Constant		
	coeff	-0.0430
	P-Value	0.0090
INF		
	Coeff	-0.0030
	P-Value	0.0001
	VIF	1.1970
GDP		
	Coeff	0.9370
	P-Value	0.0001
	VIF	1.1970
R2		0.84

Dependent Variable	Δs	Δ EUR @ t+1
Independent variable	INF	Δ Inflation EUR @ t
Independent variable	GDP	Δ GDP EUR @ t

The results show an R2 of 0.839, with significant results and no multicollinearity, suggesting that the variation of the EUR at t+1 is highly explained by the GDP and inflation variables. The R2 of Model 3 (Taylor rule approach) is higher than the R2 of Model 1 (the interest parity approach) but a bit lower than the R2 of Model 2 (monetary approach).

Table 4-10: Estimates of Model 3 for the SEK

Currency		SEK
Constant		
	coeff	0.0940
	P-Value	0.0001
INF		
	Coeff	0.0020
	P-Value	0.0260
	VIF	1.0770
GDP		
	Coeff	1.1120
	P-Value	0.0001
	VIF	1.0770
R2		0.77

Dependent Variable	Δs	Δ SEK @ t+1
Independent variable	INF	Δ Inflation SEK @ t
Independent variable	GDP	Δ GDP SEK @ t

The results show an R2 of 0.774, with significant results and no multicollinearity, suggesting that the variation of the EUR at t+1 is well explained by the GDP and inflation variables. The R2 of Model 3 (Taylor rule approach) is higher than the R2 of Model 1 (the interest parity approach), but a bit lower than the R2 of Model 2 (monetary approach).

Table 4-11: Estimates of Model 3 for the GBP

Currency		GBP
Constant		
	coeff	0.0940
	P-Value	0.0001
INF		
	Coeff	0.0080
	P-Value	0.0001
	VIF	1.0110
GDP		
	Coeff	1.1960
	P-Value	0.0001
	VIF	1.0110
R2		0.72

Dependent Variable	Δs	Δ GBP @ t+1
Independent variable	INF	Δ Inflation GBP @ t
Independent variable	GDP	Δ GDP GBP @ t

The results show an R2 of 0.72, with significant results and no multicollinearity, suggesting that the variation of the GBP at t+1 is well explained by the GDP and inflation variables. The R2 of Model 3 (Taylor rule approach) is higher than the R2 of Model 1 (the interest parity approach) and equal to the R2 of Model 2 (monetary approach).

Table 4-12: Estimates of Model 3 for the CHF

Currency		CHF
Constant		
	coeff	-0.0750
	P-Value	0.0001
INF		
	Coeff	-0.0020
	P-Value	0.0600
	VIF	1.0000
GDP		
	Coeff	0.7450
	P-Value	0.0001
	VIF	1.0000
R2		0.63

Dependent Variable	Δs	Δ CHF @ t+1
Independent variable	INF	Δ Inflation CHF @ t
Independent variable	GDP	Δ GDP CHF @ t

The results show an R2 of 0.633, with significant results and no multicollinearity, suggesting that the variation of the CHF at t+1 is well explained by the GDP and inflation variables. The R2 of Model 3 (Taylor rule approach) is lower than both the R2 of Model 1 (the interest parity approach) and that of Model 2 (the monetary approach).

In summary, over a one month period, Model 1 well explains the variation of the CHF, Model 2 well explains the variation of the EUR and the SEK, while Models 2 and 3 equally explain the variation of the GBP.

The main goal of my research is to investigate whether the predictive power of these models could be improved by taking into account the impact of one currency on each other.

3.2. Second step: A principal component analysis (PCA)

Before testing whether foreign exchange rate forecast can be improved by including the variation in the rates of other currencies, I check whether there exists common components to the rates of the four currencies considered in the study.

I do so by conducting three principal component analyses (PCA). For the first one (PCA1), I use as variables the currency residuals obtained from the regression analysis of Model 1 (regression 19). For the second one (PCA2), I use as variables the currency residuals obtained from the regression analysis of Model 2 (regression 30). For the third one (PCA3), I use as variables the currency residuals obtained from the regression analysis of Model 3 (regression 39).

For the three models I define the currency residuals ϵ as "ϵ-Chf "for the CHF currency, "ϵ-Eur" for the EUR currency, "ϵ-SEK" for the SEK currency and "ϵ-GBP" for the GBP currency.

I start by analyzing the results of PCA1.

Table 4-13: Correlation matrix between PCA1 variables

Variables *	ϵ-Chf	ϵ-Gbp	ϵ-Sek	ϵ-Eur
ϵ-Chf	1.000	.256	.583	.526
ϵ-Gbp	.256	1.000	.750	.384
ϵ-Sek	.583	.750	1.000	.446
ϵ-Eur	.526	.384	.446	1.000

Variables*	Residual of model 1 currency CHF	Residual of model 1 currency GBP	Residual of model 1 currency SEK	Residual of model 1 currency SEK

Note: Table 4-13 shows the correlation matrix between the currency residuals of Model 1.

Table 4-13 shows the correlations between the currency residuals of Model 1 defined as variables in PCA1. The correlation matrix between the variables shows moderate correlations.

Table 4-14: Communalities in PCA1

Variables	Initial	Extraction
ϵ-Chf	1.000	.553
ϵ-Gbp	1.000	.593
ϵ-Sek	1.000	.808
ϵ-Eur	1.000	.535

Note: Table 4-14 shows the communalities, i.e. the proportion of each variable's variance that can be explained by the principal components (PCA1).

Table 4-14 shows the communalities that are the proportion of each variable's variance that can be explained by the components.

Variables with high values are well represented in the common factor space, while variables with low values are not well represented. In our case, we do not have any particularly low values which means that all variables are well represented.

Table 4-15: Total variance in PCA1

Component	Initial Eigenvalues			Extraction Sums of Squared		
	Total	Variance	Cumulative %	Total	Variance	Cumulative %
1	2.488	62.197	62.197	2.488	62.197	62.197
2	.835	20.872	83.070			
3	.523	13.083	96.153			
4	.154	3.847	100.000			

Note: Table 4-15 reports the eigenvalues and the percentage of variance explained by each common factor in PCA1

Table 4-15 reports the eigenvalues and the percentage of variance explained by each common factor in PCA1.

The initial Eigenvalues are the variances of the principal components. Column "Total" in Table 4-15 reports the eigenvalues. Table 4-15 shows that there one major component that explains 62% of the total variance of the variables.

Table 4-16: Component matrix in PCA1

	Component
	1
ϵ-Sek	.899
ϵ-Gbp	.770
ϵ-Chf	.743
ϵ-Eur	.731

Note: Table 4-16 contains PCA1 correlations between the variable and the component.

Table 4-16 contains component loadings, which are the correlations between the variable and the first common component. In PCA1. It shows a high correlation between the variables and the first component.

The existence of such a common component highly correlated with the variables suggests that the variables tend to vary with each other.

After conducting a PCA on the currency residuals obtained from the regression analysis of Model 1 (PCA1), I know conduct a PCA on the currency residuals obtained from the regression analysis of Model 2, (PCA2) I start analyzing the results of PCA2.

Table 4-17: Correlation matrix between PCA2 variables

Variables *	ϵ-Chf	ϵ-Gbp	ϵ-Sek	ϵ-Eur
ϵ-Chf	1.000	.297	.652	.454
ϵ-Gbp	.297	1.000	.680	.841
ϵ-Sek	.652	.680	1.000	.839
ϵ-Eur	.454	.841	.839	1.000

Variables*	Residual of model 2 currency CHF	Residual of model 2 currency GBP	Residual of model 2 currency SEK	Residual of model 2 currency EUR

Note: Table 4-17 shows the correlation matrix between the currency residuals of Model 2

Table 4-17 shows the correlations between the currency residuals of Model 2 defined as variables in PCA2. The correlation matrix of Table 4-17 shows a moderate correlation between the variables.

Table 4-18: Communalities in PCA2

	Initial	Extraction
ϵ-Chf	1.000	.449
ϵ-Gbp	1.000	.715
ϵ-Sek	1.000	.877
ϵ-Eur	1.000	.879

Note: Table 4-18 shows the communalities, i.e. the proportion of each variable’s variance that can be explained by the principal components (PCA2).

Table 4-18 shows the communalities that are the proportion of each variable’s variance that can be explained by the components.

In our case, we do not have any particularly low values, which means that all variables are well represented. However, the CHF residual has a value lower than 0.5, which means that it is not represented as well as the other variables.

Table 4-19: Total variance in PCA2

Component	Initial Eigenvalues			Extraction Sums of Squared		
	Total	% of	Cumulative	Total	% of	Cumulative
1	2.921	73.017	73.017	2.921	73.017	73.017
2	.777	19.413	92.430			
3	.203	5.076	97.507			
4	.100	2.493	100.000			

Note: Table 4-19 reports the eigenvalues and the percentage of variance explained by each common factor in PCA2

Table 4-19 reports the eigenvalues and the percentage of variance explained by each common factor in PCA2.

Column "Total" in Table 4-19 contains the eigenvalues, the estimates show that one major component explains 73% of the variance of all variables with an eigenvalue greater than one.

Table 4-20: Component matrix in PCA2

	Component
	1
ϵ-Eur	.938
ϵ-Sek	.936
ϵ-Gbp	.846
ϵ-Chf	.670

Note: Table 4-20 contains PCA2 correlations between the variable and the component.

Table 4-20 contains component loadings, which are the correlations between the variable and the first common component. In PCA2.

We have a high correlation between the variables and the component, especially when it comes to the EURO and the SEK residual variables, which suggests that a common factor not included in Model 2 impacts the rates of these currencies.

I now conduct a PCA on the residuals of Model 3 (PCA3)

Table 4-21: Correlation matrix between PCA3 variables

Variables *	ϵ-Chf	ϵ-Gbp	ϵ-Sek	ϵ-Eur
ϵ-Chf	1.000	.318	.659	.707
ϵ-Gbp	.318	1.000	.661	.694
ϵ-Sek	.659	.661	1.000	.780
ϵ-Eur	.707	.694	.780	1.000

Variables*	Residual of model 3 currency CHF	Residual of model 3 currency GBP	Residual of model 3 currency SEK	Residual of model 3 currency EUR

Note: Table 4-21 shows the correlations matrix between the currency residuals of Model 3

Table 4-21 shows the correlations between the currency residuals of Model 2 defined as variables in PCA3. The correlation matrix of Table 4-21 shows a moderate correlations between variables.

Table 4-22: Communalities in PCA3

	Initial	Extraction
ϵ-Chf	1.000	.613
ϵ-Gbp	1.000	.607
ϵ-Sek	1.000	.833
ϵ-Eur	1.000	.876

Note: Table 4-22 shows the communalities, i.e. the proportion of each variable's variance that can be explained by the principal components (PCA3).

Table 4-22 shows the communalities that are the proportion of each variable's variance that can be explained by the components.

In our case, we do not have any particularly low values, which means that all variables are well represented.

Table 4-23: Total variance in PCA3

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings		
	Total	Variance	Cumulative %	Total	Variance	Cumulative %
1	2.929	73.228	73.228	2.929	73.228	73.228
2	.682	17.054	90.281			
3	.234	5.860	96.142			
4	.154	3.858	100.000			

Note: Table 4-23 reports the eigenvalues and the percentage of variance explained by each common factor in PCA3

Table 4-23 reports the eigenvalues and the percentage of variance explained by each common factor in PCA3.

Column "Total" in Table 4-23 contains the eigenvalues. The first common component explains 73% of the total variance of all variables with an eigenvalue greater than one.

Table 4-24: Component matrix in PCA3

	Component
	1
ϵ-Eur	.936
ϵ-Sek	.913
ϵ-Chf	.783
ϵ-Gbp	.779

Note: Table 4-24 contains PCA3 correlations between the variable and the component.

Table 4-24 contains component loadings, which are the correlations between the variable and the component. In PCA3.

We have a high correlation between the variables and the component, especially when it comes to the EURO and the SEK residual variables.

In the three PCAs, I find a major common factor which is highly correlated with the EUR and the SEK residuals.

This suggest that introducing those residuals in exchange rates forecasting models may improve their predictive power.

I test this hypothesis in the third step of my research.

3.3. Third step: Regression analysis with interactions between currencies

I continue the analysis by studying how the PCA variables tend to impact Model 1, Model 2 and Model 3.

In Model 1, for each currency, I add as an independent variable, one at a time, the residual of the other currencies used in PCA1, which leads to three regression analyses. For instance, if the considered currency is the EUR, I add as an independent variable ϵ-Chf, ϵ-SEK, and ϵ-GBP, alternatively, leading to three different regression analyses.

The same procedure is applied to the other currencies. If the considered currency is the SEK, I add as an independent variable ϵ-Chf, ϵ-Eur, and ϵ-GBP, alternatively, leading to three different regression analyses. I then do the same for the CHF and the GBP.

Therefore, regression (39) Model 1 becomes therefore

$$\Delta s_{t,t+1} = \propto + \beta\, LIB_t + \gamma\, RCUR_t + \epsilon_{t+k}, \qquad (64)$$

where we add RCUR the residual term of another currency.

I define regression (64) as Model 4 and its empirical results are displayed in Table 4-25 to 4-28:

Table 4-25: Estimates of model 4 for the EUR

Currency		EUR		
Constant				
	Coeff	-0.206	0.041	-0.292
	P-Value			
LIB				
	Coeff	-0.203	0.055	-0.300
	P-Value	0.000	0.001	0.000
	VIF	1.717	5.220	1.008
RCUR				
	Coeff	0.537	1.412	1.211
	P-Value	0.000	0.000	0.000
	VIF	1.727	5.220	1.008
R2		0.80	0.93	0.79
Dependent Variable	Δs	Δ EUR @ t+1	Δ EUR @ t+1	Δ EUR @ t+1
Independent variable	LIB	Δ LIB EUR @ t	Δ LIB EUR @ t	Δ LIB EUR @ t
Independent variable	RCUR	ϵ-Sek @ t	ϵ-Gbp @ t	ϵ-Chf @ t

Note: Table 4-25 shows the stimates of regression (64) Model 4 for the Eur

Table 4-25 shows that when we add the GBP, SEK and CHF residual terms of Model 1 (IRP), the results show that R2 improves; However, when we add the GBP residual, the VIF is high, which indicates the existence of some multicollinearity between the variables.

Table 4-26: Estimates of model 4 for the SEK

Currency		SEK		
Constant				
	Coeff	0.069	-0.105	-0.111
	P-Value	0.000	0.001	0.000
LIB				
	Coeff	0.015	-0.232	-0.240
	P-Value	0.250	0.000	0.000
	VIF	1.462	1.035	1.033
RCUR				
	Coeff	1.108	0.662	1.974
	P-Value	0.000	0.000	0.000
	VIF	1.462	1.035	1.033
R2		0.87	0.40	0.51

Dependent Variable	Δs	Δ SEK @ t+1	Δ SEK @ t+1	Δ SEK @ t+1
Independent variable	LIB	Δ LIB SEK @ t	Δ LIB SEK @ t	Δ LIB SEK @ t
Independent variable	RCUR	ϵ-Gbp @ t	ϵ-Eur @ t	ϵ-Chf @ t

Note: Table 4-26 shows the stimates of regression (64) Model 4 for the Sek

Table 4-26 shows that when we add the EUR and CHF residual terms of Model 1 (IRP), the results are significant with acceptable VIF, but the R2 is still low; Further, when we add the GBP residual variable, the variable LIB is not significant anymore.

Table 4-27: Estimates of model 4 for the GBP

Currency		GBP		
Constant				
	coeff	0.074	0.102	0.133
	P-Value	0.000	0.001	0.000
LIB				
	Coeff	-0.160	-0.063	0.045
	P-Value	0.000	0.200	0.354
	VIF	1.217	1.301	1.087
RCUR				
	Coeff	0.904	0.710	0.903
	P-Value	0.000	0.000	0.000
	VIF	1.217	1.301	1.087
R2		0.69	0.21	0.09

Dependent Variable	Δs	Δ GBP @ t+1	Δ GBP @ t+1	Δ GBP @ t+1
Independent variable	LIB	Δ LIB GBP @ t	Δ LIB GBP @ t	Δ LIB GBP @ t
Independent variable	RCUR	ϵ-Sek @ t	ϵ-Eur @ t	ϵ-Chf @ t

Note: Table 4-27 shows the stimates of regression (64) Model 4 for the Gbp

Table 4-27 shows that when we add the SEK residual terms of Model 1 (IRP), the results are significant with acceptable VIF, but the R2 is still low. Here again when we add the EUR and the CHF residual terms, the results are not significant anymore for the independent variable LIB.

Table 4-28: Estimates of model 4 for the CHF

Currency		CHF		
Constant				
	coeff	-0.262	-0.229	-0.272
	P-Value	0.000	0.000	0.000
LIB				
	Coeff	-0.071	-0.049	-0.078
	P-Value	0.000	0.000	0.000
	VIF	1.517	5.409	1.236
RCUR				
	Coeff	0.270	0.427	0.285
	P-Value	0.000	0.000	0.000
	VIF	1.517	5.409	1.236
R2		0.95	0.93	0.93

Dependent Variable	Δs	Δ CHF @ t+1	Δ CHF @ t+1	Δ CHF @ t+1
Independent variable	LIB	Δ LIB CHF @ t	Δ LIB CHF @ t	Δ LIB CHF @ t
Independent variable	RCUR	ϵ-Sek @ t	ϵ-Gbp @ t	ϵ-Eur @ t

Note: Table 4-28 shows the stimates of regression (64) Model 4 for the Chf

Table 4-28 shows that when we add the SEK, GBP and EUR residual terms of Model 1 (IRP), their coefficients are significant and R2 becomes very high, but when we add the GBP residual, the VIF is high, which indicates the existence of some multicollinearity.

I conclude from the results that model 4, represented by regression (64), best fits the CHF where for which the R2 is very high, especially with the SEK is introduced in the model.

I then conduct the same analysis by taking the residuals of Model 2. For each currency, I add as independent variable, one at a time, the residual of the other currencies used in PCA2, leading to three regression analyses.

If the considered currency is the EUR, I add as an independent variable ϵ-Chf, ϵ-SEK, and, ϵ-GBP, alternatively, leading to three different regression analyses.

The same procedure is applied to the other currencies. If the considered currency is the SEK, I add as an independent variable ϵ-Chf, ϵ-Eur, and, ϵ-GBP, alternatively, leading to three different regression analyses. I then do the same for the CHF and the GBP.

Regression (30) of Model 2 becomes therefore

$$\Delta s_{t,\,t+1} = \propto + \beta\, MS_t + \lambda\, INF_t + \gamma\, RCUR_t + \epsilon_{t+k}\,, \qquad (65)$$

where we add RCUR the residual term of another currency.

I define regression (65) as Model 5. Its empirical results are displayed in Table 4-29 to 4-32.

Table 4-29: Estimates of Model 5 for the EUR

Currency		EUR		
Constant				
	coeff	0.0930	0.0960	0.0990
	P-Value	0.0001	0.0001	0.0001
MS				
	Coeff	0.5650	0.5710	0.5780
	P-Value	0.0001	0.0001	0.0001
	VIF	1.7820	1.7670	1.8380
INF				
	Coeff	-0.0010	0.0001	0.0001
	P-Value	0.0040	0.0370	0.3870
	VIF	1.7290	1.7190	1.7180
RCUR				
	Coeff	0.7880	0.7750	0.5560
	P-Value	0.0001	0.0001	0.0001
	VIF	1.0420	1.0370	1.0980
R2		0.96	0.96	0.90

Dependent Variable	Δs	Δ EUR @ t+1	Δ EUR @ t+1	Δ EUR @ t+1
Independent variable	MS	Δ MS EUR @ t	Δ MS EUR @ t	Δ MS EUR @ t
Independent variable	INF	Δ INF EUR @ t	Δ INF EUR @ t	Δ INF EUR @ t
Independent variable	RCUR	ϵ-Sek @ t	ϵ-Gbp @ t	ϵ-Chf @ t

Note: Table 4-29 shows the stimates of regression (65) Model 5 for the Eur

Table 4-29 shows that when we add the SEK, the GBP and, the CHF residual terms of Model 2, the coefficients of the residuals are significant and R2 are very high. R2 reaches an exceptional level of 0.96 when the SEK and the GBP residual variables are introduced.

<u>Table 4-30: Estimates of Model 5 for the SEK</u>

Currency		SEK		
Constant				
	coeff	0.0600	0.0610	0.0670
	P-Value	0.0001	0.0001	0.0001
MS				
	Coeff	0.6400	0.6960	0.6950
	P-Value	0.0001	0.0001	0.0001
	VIF	1.3820	1.3550	1.3570
INF				
	Coeff	-0.0030	-0.0040	-0.0050
	P-Value	0.0001	0.0001	0.0001
	VIF	1.3640	1.3510	1.3870
RCUR				
	Coeff	0.6860	0.9370	0.8280
	P-Value	0.0001	0.0001	0.0001
	VIF	1.0240	1.0070	1.0270
R2		0.89	0.94	0.89

Dependent Variable	Δs	Δ SEK @ t+1	Δ SEK @ t+1	Δ SEK @ t+1
Independent variable	MS	Δ MS SEK @ t	Δ MS SEK @ t	Δ MS SEK @ t
Independent variable	INF	Δ INF SEK @ t	Δ INF SEK @ t	Δ INF SEK @ t
Independent variable	RCUR	ϵ-Gbp @ t	ϵ-Eur @ t	ϵ-Chf @ t

Note: Table 4-30 shows the stimates of regression (65) Model 5 for the Sek

Table 4-30 shows that when we add the GBP, the EUR and the CHF residuals terms of Model 2, coefficients are significantly positive and R2 becomes very high. R2 reaches an exceptional level of 0.94 when the EUR residual variable is introduced.

Table 4-31: Estimates of Model 5 for the GBP

Currency		GBP		
Constant				
	coeff	0.2320	0.2510	0.2330
	P-Value	0.0001	0.0001	0.0001
MS				
	Coeff	0.5930	0.6760	0.5900
	P-Value	0.0001	0.0001	0.0001
	VIF	1.4710	1.4830	1.5390
INF				
	Coeff	0.0001	-0.0010	0.0001
	P-Value	0.8640	0.1540	0.7960
	VIF	1.4590	1.4610	1.4580
RCUR				
	Coeff	0.6960	0.9630	0.4050
	P-Value	0.0001	0.0001	0.0001
	VIF	1.0100	1.0800	1.0870
R2		0.85	0.92	0.75

Dependent Variable	Δs	Δ GBP @ t+1	Δ GBP @ t+1	Δ GBP @ t+1
Independent variable	MS	Δ MS GBP @ t	Δ MS GBP @ t	Δ MS GBP @ t
Independent variable	INF	Δ INF GBP @ t	Δ INF GBP @ t	Δ INF GBP @ t
Independent variable	RCUR	ϵ-Sek @ t	ϵ-Eur @ t	ϵ-Chf @ t

Note: Table 4-31 shows the stimates of regression (65) Model 5 for the Gbp

Table 4-31 shows that when we add the SEK, the EUR and the CHF residual terms of Model 2, coefficients are significantly positive and R2 becomes very high while VIF remains low. R2 reaches an exceptional level of 0.92 when the EUR residual variable is introduced. However, but the P-Value related to the inflation variable INF is greater than 0.05, which means that it is not significant. Therefore, when studying the GBP, we can remove the inflation variable from the model.

Table 4-32: Estimates of Model 5 for the CHF

Currency		CHF		
Constant				
	coeff	-0.1270	-0.1270	-0.1260
	P-Value	0.0001	0.0001	0.0001
MS				
	Coeff	0.3400	0.3400	0.3470
	P-Value	0.0001	0.0001	0.0001
	VIF	1.0480	1.2010	1.0550
INF				
	Coeff	-0.0030	-0.0010	-0.0020
	P-Value	0.0001	0.0720	0.0070
	VIF	1.0040	1.0250	1.0000
RCUR				
	Coeff	0.5540	0.2900	0.4300
	P-Value	0.0001	0.0001	0.0001
	VIF	1.0520	1.2240	1.0550
R2		0.89	0.82	0.84

Dependent Variable	Δs	Δ CHF @ t+1	Δ CHF @ t+1	Δ CHF @ t+1
Independent variable	MS	Δ MS CHF @ t	Δ MS CHF @ t	Δ MS CHF @ t
Independent variable	INF	Δ INF CHF @ t	Δ INF CHF @ t	Δ INF CHF @ t
Independent variable	RCUR	ϵ-Sek @ t	ϵ-Gbp @ t	ϵ-Eur @ t

Note: Table 4-32 shows the stimates of regression (65) Model 5 for the Chf

Table 4-32 shows that when we add the SEK and the EUR residuals of Model 2, the coefficients are significantly positive and R2 are high. When the GBP residual variable is introduced, the inflation variable loses statistical significance.

For the CHF, Model 4 remains very successful and appropriate, whereas for the EUR and the SEK, Model 5 fits much better.

I replicate the analysis on Model 3. For each studied currency, I add as an independent variable, one at a time, the residuals of other currencies used in PCA3. This leads to three regression analyses.

For instance, if the considered currency is the EUR, I add as an independent variable ϵ-Chf, ϵ-SEK, and, ϵ-GBP, alternatively, in three distinct regressions. I follow the same procedure for the SEK, the GBP and, the CHF.

Consequently, regression (39) of Model 3 becomes

$$\Delta e_{t,\, t+1} = \omega + \omega_{\pi}\, INFt + \omega_{y}\, GDP_{t} + \omega_{r}\, RCUR_{t} + \epsilon_{t,\, t+k}, \qquad (66)$$

where I add RCUR the currency residual independent variable.

I define regression (66) as Model 6. Its empirical results are displayed from Tables 4-33 to 4-36:

Table 4-33: Estimates of Model 6 for the EUR

Currency		EUR		
Constant				
	coeff	-0.0450	-0.0450	-0.0180
	P-Value	0.0001	0.0001	0.0650
INF				
	Coeff	-0.0030	-0.0030	-0.0010
	P-Value	0.0001	0.0001	0.0001
	VIF	1.1970	1.1980	1.5350
GDP				
	Coeff	0.8500	0.8330	0.9660
	P-Value	0.0001	0.0001	0.0001
	VIF	1.2440	1.2780	1.2020
RCUR				
	Coeff	0.7600	0.7230	0.8410
	P-Value	0.0001	0.0001	0.0001
	VIF	1.0440	1.0750	1.3100
R2		0.94	0.92	0.94

Dependent Variable	Δs	Δ EUR @ t+1	Δ EUR @ t+1	Δ EUR @ t+1
Independent variable	INF	Δ INF EUR @ t	Δ INF EUR @ t	Δ INF EUR @ t
Independent variable	GDP	Δ GDP EUR @ t	Δ GDP EUR @ t	Δ GDP EUR @ t
Independent variable	RCUR	ϵ-Sek @ t	ϵ-Gbp @ t	ϵ-Chf @ t

Note: Table 4-33 shows the stimates of regression (66) Model 6 for the Eur

Table 4-33 shows that when we add the SEK, the GBP, or the EUR residual terms of Model 3, their coefficients are significantly positive, and R2 becomes high with VIF remaining low. The highest R2 is obtained when the CHF residual variable is introduced.

Table 4-34: Estimates of Model 6 for the SEK

Currency		SEK		
Constant				
	coeff	0.0900	0.0990	0.1210
	P-Value	0.0001	0.0001	0.0001
INF				
	Coeff	0.0020	0.0010	-0.0040
	P-Value	0.0001	0.0170	0.0001
	VIF	1.0810	1.0820	1.5350
GDP				
	Coeff	1.0600	1.1910	1.2390
	P-Value	0.0001	0.0001	0.0001
	VIF	1.0930	1.1040	1.1450
RCUR				
	Coeff	0.6960	0.8560	0.9170
	P-Value	0.0001	0.0001	0.0001
	VIF	1.0150	1.0250	1.4300
R2		0.87	0.92	0.91

Dependent Variable	Δs	Δ SEK @ t+1	Δ SEK @ t+1	Δ SEK @ t+1
Independent variable	INF	Δ INF SEK @ t	Δ INF SEK @ t	Δ INF SEK @ t
Independent variable	GDP	Δ GDP SEK @ t	Δ GDP SEK @ t	Δ GDP SEK @ t
Independent variable	RCUR	ϵ-Gbp @ t	ϵ-Eur @ t	ϵ-Chf @ t
Note:	Table 4-34 shows the stimates of regression (66) Model 6 for the Sek			

Table 4-34 shows that when we add the GBP, the EUR, or the CHF residual terms of Model 3, their coefficients are significantly positive and R2 are high (with VIF remaining low). The highest R2 is obtained when the EUR residual variable is added.

Table 4-35: Estimates of Model 6 for the GBP

Currency		GBP		
Constant				
	coeff	0.0930	0.0960	0.1030
	P-Value	0.0001	0.0001	0.0001
INF				
	Coeff	0.0090	0.0080	0.0060
	P-Value	0.0001	0.0001	0.0001
	VIF	1.0110	1.0150	1.3780
GDP				
	Coeff	1.0950	1.2360	1.1680
	P-Value	0.0001	0.0001	0.0001
	VIF	1.0400	1.0150	1.0190
RCUR				
	Coeff	0.6560	0.7220	0.4130
	P-Value	0.0001	0.0001	0.0001
	VIF	1.0290	1.0070	1.3850
R2		0.85	0.86	0.76

Dependent Variable	Δs	Δ GBP @ t+1	Δ GBP @ t+1	Δ GBP @ t+1
Independent variable	INF	Δ INF GBP @ t	Δ INF GBP @ t	Δ INF GBP @ t
Independent variable	GDP	Δ GDP GBP @ t	Δ GDP GBP @ t	Δ GDP GBP @ t
Independent variable	RCUR	ϵ-Sek @ t	ϵ-Eur @ t	ϵ-Chf @ t

Note: Table 4-35 shows the stimates of regression (66) Model 6 for the Gbp

Table 4-35 shows that when we add the SEK, the EUR, or the CHF residual terms, the coefficients of those variables are significantly positive and R2 are high. The highest R2 is obtained when the EUR residual variable is added.

Table 4-36: Estimates of Model 6 for the CHF

Currency		CHF		
Constant				
	coeff	-0.0810	-0.0850	-0.0760
	P-Value	0.0001	0.0001	0.0001
INF				
	Coeff	-0.0020	-0.0020	-0.0040
	P-Value	0.0390	0.0950	0.0001
	VIF	1.0020	1.0040	1.0240
GDP				
	Coeff	0.6930	0.6950	0.7350
	P-Value	0.0001	0.0001	0.0001
	VIF	1.0190	1.2000	1.0010
RCUR				
	Coeff	0.6910	0.4080	0.7970
	P-Value	0.0001	0.0001	0.0001
	VIF	1.0200	1.2030	1.0240
R2		0.79	0.68	0.82

Dependent Variable	Δs	Δ CHF @ t+1	Δ CHF @ t+1	Δ CHF @ t+1
Independent variable	INF	Δ INF CHF @ t	Δ INF CHF @ t	Δ INF CHF @ t
Independent variable	GDP	Δ GDP CHF @ t	Δ GDP CHF @ t	Δ GDP CHF @ t
Independent variable	RCUR	ϵ-Sek @ t	ϵ-Gbp @ t	ϵ-Eur @ t

Note: Table 4-36 shows the stimates of regression (66) Model 6 for the Chf

Table 4-36 shows that when we add the SEK, the EUR, or the GBP residuals, their coefficients are significantly positive and R2 values remain moderate. The highest R2 is obtained when the EUR residual variable is added.

As a summary, Model 4 based on the interest parity approach, i.e. regression (64) seems to be very robust. It outperforms the predictive power of all other models for the CHF. The best results are obtained when the SEK residual variable is added.

Model 5 based on the monetary approach, i.e. regression (65) seems very robust as well. It outperforms the predictive power of the other models for two currencies (SEK and EUR). Indeed, the best results for the SEK are obtained in Model 5 with the EUR residual as an additional variable. In addition, the best results for the EUR are obtained in Model 5 with the GBP residual as an additional variable.

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Model 5 based on the monetary approach could be modified when it comes to the GBP. The inflation variable could be removed as it fails to be significant. The best results for the GBP are obtained in Model 5 with the EUR residual as an additional variable. However, the regression on the GBP could be performed as well with other currencies. Indeed if we look back at Graph 3-1, we can clearly see that for the United Kingdom, the export of goods outside the 28 European member states is greater than the export of goods with the 28 European member states. Furthermore this comes in line with the results of Table 4-20 in PCA2 and Table 4-24 in PCA3 which show that the correlation of the PCA component with the GBP residual variable is lower than its correlation with the EUR and the SEK residual variables.

Table 4-37 compares the performances of all the models including the residual currency term.

Table 4-37: R2 comparison

	Model 1	Model 4 with residual term		Model 2	Model 5 with residual term		Model 3	Model 6 with residual term	
EUR	0.70	0.93	ϵ-Gbp	0.86	0.96	ϵ-Gbp	0.84	0.94	ϵ-Chf
SEK	0.25	0.87	ϵ-Gbp	0.80	0.94	ϵ-Eur	0.77	0.92	ϵ-Eur
GBP	0.02	0.69	ϵ-Sek	0.72	0.92	ϵ-Eur	0.72	0.86	ϵ-Eur
CHF	0.89	0.95	ϵ-Sek	0.79	0.89	ϵ-Sek	0.63	0.82	ϵ-Sek

Note: Table 4-37 compares the R2 of all models highlighting the best estimates

4- **LIMITATIONS**

Nearly all described models have their limitations. For instance, in this thesis, the political risk premium described in section (2-2.1.7) is not taken into consideration. It could be included in the final model and made part of a further study that takes into consideration the sudden impact of political changes.

The models are performed only for a one month period. But, it could be interesting to look over longer periods as well. Indeed, some studies proved the importance of fundamentals in predicting long term exchange rates.

The empirical findings of Frenkel (1976) imply that further research into shifts in money demand and in the long-run real exchange rate, within the framework of the monetary model, appear justified.

Nelson C. Mark, Doo-Yull Cho (1997) found that monetary variables seem to explain variation in the long-run equilibrium real exchange rate.

A unified source of information should be used in comparing models. Molodtsova and Papell (2009) found that the first limitation is that the use of a Taylor rule requires that a single measure of inflation be used to obtain the rule prescriptions. The price index used in the Carnegie Rochester thesis is the GDP price deflator. Other researchers have used the inflation measure based on the consumer price index (CPI).

The limitation of using simple rules for monetary policy making stems from the fact that, by their nature, simple rules involve only a small number of variables. However, the state of a complex economy like that of the United States and Europe may not be fully captured by any small set of summary statistics. Taking an exchange rate variable implies the existence of other hidden fundamentals.

Another limitation I want to highlight is that simple policy rules may not capture risk-management considerations. In some circumstances, the risks to the outlook or the perceived costs of missing an objective on a particular side may be sufficiently skewed that policymakers will choose to respond by adjusting policy in a way that would not be justified solely by the current state of the economy or the modal outlook for output and inflation gaps.

Many forecasting techniques are available. All of them are not treated in detail in this thesis, especially those related to technical analysis and to econometric models, such as ANN Active neural network, ARCH, and GARCH techniques, where controversial forecasting improvement has been made.

Finally, behavioral finance may be developed further in a future study.

5- CONCLUSION

Exchange rate management is treated in detail in this thesis by showing the exchange rate risk and the strategies used to hedge against that risk, whether operational or financial. This thesis shows the need for robust forecasting models, even if this issue has long been addressed by the scientific community.

In addition, the thesis reviews the major available forecasting methods: the fundamental analysis, the econometric approach, and the technical analysis.

Then, I develop the main issue of the thesis which is a one month exchange rate forecasting model for four major European currencies: the Euro (EUR), the Swedish Krona (SEK), the Great British Pound (GBP), and the Swiss Franc (CHF); against the U.S. Dollar. The particularity of the model is to study how those currencies interact among each other.

This thesis concludes that including third currency terms in forecasting models based on fundamentals drastically increases their predictive power over a one month horizon. The Swiss Franc interacts with the Swedish Krona in the interest parity approach, and the Euro interacts with the Great British Pound in the monetary approach. The Swedish Krona interacts with the Euro to improve the monetary approach. The results of the developed models question the Efficient Market Hypothesis (EMH).

As mentioned is this paper, other studies based on fundamental analysis such as Molodtsova and Papell (2009) concludes the evidence predictability over a three month period. Frenkel (1976) finds that monetary variables seem to explain variation in the long-run equilibrium real exchange rate.

Others like Dornbusch (1976) examine the profitability of chartists' techniques, suggesting the existence of significant profits in foreign exchange rates. The study shows that exchange rates are excessively volatile, i.e., movements in nominal exchange rates are larger than movements in macroeconomic fundamentals.

At longer time horizons, however, Taylor and Allen (1992) find that the importance of Chartism becomes less pronounced.

The thesis is aimed first to target corporations and companies dealing with international trade, but its findings may help investors and institutions dealing with foreign exchange.

Finally, this study could be easily extended to all European currencies outside the Eurozone and further studies could be conducted to extend those findings to other countries and investigate the impact of other currencies outside the Eurozone, especially in regions that have a high level of international trade such as South East Asia and Latin America.

6- Appendix:

Definition of LIBOR and IOS spread

The LIBOR–OIS spread is the difference between LIBOR and the (OIS) rates. Three-month LIBOR is generally a floating rate of financing, which fluctuates depending on how risky a lending bank feels about a borrowing bank. The OIS is a swap derived from the overnight rate, which is generally fixed by the local central bank. The OIS allows LIBOR-based banks to borrow at a fixed rate of interest over the same period. In the United States, the spread is based on the LIBOR Eurodollar rate and the Federal Reserve's Fed Funds rate.

LIBOR is risky in the sense that the lending bank loans cash to the borrowing bank, and the OIS is stable in the sense that both counterparties only swap the floating rate of interest for the fixed rate of interest. The spread between the two is, therefore, a measure of how likely borrowing banks will default. This reflects counterparty credit risk premiums in contrast to liquidity risk premiums. However, given the mismatch in the tenor of the funding, it also reflects worries about liquidity risk as well. The spread between the two rates is considered to be a measure of health of the banking system. It is an important measure of risk and liquidity in the money market, considered by many, including former US Federal Reserve chairman Alan Greenspan, to be a strong indicator for the relative stress in the money markets. A higher spread (high Libor) is typically interpreted as indication of a decreased willingness to lend by major banks, while a lower spread indicates higher liquidity in the market. As such, the spread can be viewed as indication of banks' perception of the creditworthiness of other financial institutions and the general availability of funds for lending purposes

The LIBOR–OIS spread has historically hovered around 10 basis points (bps). However, in the midst of the financial crisis of 2007–2010, the spread spiked to an all-time high of 364 basis points in October 2008, indicating a severe credit crunch. Since that time the spread has declined erratically but substantially, dropping below 100 basis points in mid-January 2009 and returning to 10–15 basis points by September 2009.

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