Options On Foreign Exchange

THIRD EDITION

David F. DeRosa

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Contents

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Third Edition

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For Julia DeRosa

Preface

It is well known that foreign exchange is the world's largest financial market. What is less well known is that the market for currency options and other derivatives on foreign exchange is also massively large and still growing. Currency options are less visible than options on other financial instruments because they trade in the main in the private interbank market. Sadly, the field of foreign exchange is not popular with authors of technical business books. The attention that is given to foreign exchange pales in comparison to the vast outpouring of books on the bond and stock markets.

This book has been written for end-users of currency options, newcomers to the field of foreign exchange, and university students. I employ the real-world terminology of the foreign exchange market whenever possible so that readers can make a smooth transition from the text to actual market practice.

I use this book as the textbook for a course entitled "Foreign Exchange and Its Related Derivative Instruments" that I teach in the IEOR department of the Fu Foundation School of Engineering and Applied Science at Columbia University. I taught forerunners of this course (using the previous editions) at the Yale School of Management and University of Chicago's Booth School of Business. Students may be interested in a companion volume to this book that I edited for John Wiley & Sons. That book, *Currency Derivatives,* is a collection of scientific articles that have had an important impact on the development of the market for derivatives on foreign exchange.

This is the third edition of *Options on Foreign Exchange*. The foreign exchange market has undergone major transformations since the first edition came out in 1992 and

this is especially the case since the second appeared in 2000. During the decade of 2000–2010 one could say there has been at least three remarkable developments in the foreign exchange market, each of which is has been incorporated in this new edition. The first is that the size of the foreign exchange market has grown enormously; by one count $4 trillion of foreign exchange changed hands in a day in 2010 (compared to $1.2 trillion in 2001). A substantial portion of this growth has to be ascribed to the success of electronic trading platforms and computerized dealing networks. Second, market stresses during the turmoil of 2007–2008 revealed anomalies in the foreign exchange market, both in the forward market and in the market for options on foreign exchange. Third, these abnormal market conditions have been the impetus for acceleration in the development in new and advanced option models.

WHAT'S NEW TO THIS EDITION

This edition has a substantial amount of new material, mostly included in reaction to market experience and the general development in the theoretical and applied understanding of currency options.

  I have included new discussions of the volatility surface and the Vanna-Volga method. There are also new sections on static replication, numerical methods, and advanced models (stochastic and local volatility varieties). The materials on barrier, binary, and other exotic options are greatly expanded. There are a great number of new numerical examples in this edition.

BEFORE YOU BEGIN

I am fairly certain that nobody can become fully versed in the topics of currency options without becoming involved in

the market. This book offers the next best thing. To that end it is important to start out learning about these products in the context of correct market terminology and protocol. That is why I always attempt to introduce and use trading room vernacular in this book. On the other hand, a certain level of mathematical understanding is also required. Some math is unavoidable, but its level of difficulty is easily overestimated. True enough, there a lot of equations in this book. However most of the important concepts can be grasped with little more than working knowledge of algebra and elementary calculus.

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Acknowledgments

Many people have been of assistance to me in the preparation of this new edition of *Options on Foreign Exchange.*

Chapter 1

Foreign Exchange Basics

I start with some basic knowledge about foreign exchange that the reader will want to have before tackling currency options.

THE FOREIGN EXCHANGE MARKET

An exchange rate is a market price at which one currency can be exchanged for another. Exchange rates are sometimes called pairs because there are always two currencies involved. If the exchange rate for Japanese yen in terms of U.S. dollars is 90.00, it is meant that yen can be traded for dollars—or dollars traded for yen—at the rate of $1 for 90.00 yen.

A spot foreign exchange transaction (or deal)[1] is an agreement to exchange sums of currencies, usually in two bank business days' time. This transaction is the core of the foreign exchange market. A forward transaction is a deal done for settlement, or value, at a time beyond spot value day. There are two kinds of forwards. Forward outrights are similar to spot deals. The exchange rate is agreed when the deal is done on the trade date, but currencies settle at times in the future further out on the settlement calendar, say in a week, or a month, or in many months. A forward swap is the combination of a spot deal and a forward deal done in opposite directions. Forward outrights and forward swaps will be covered in detail later in this chapter.

It is well known that the foreign exchange market is a very large market, but exactly how large is hard to say. Our single best source as to the size and structure of the worldwide foreign exchange market is an extensive survey of trading done by the Bank for International Settlements (BIS) in conjunction with the central banks of 50 or so nations.[2] The most recent survey, published in 2010 (BIS 2010), documented the virtual explosion in foreign exchange trading since the previous surveys done in 2007, 2004, and 2001. After adjustments for double counting,[3] $4 trillion of foreign exchange changed hands per day in April 2010 compared to $3.3 trillion, $1.9 trillion, and $1.2 trillion in April of 2007, 2004, and 2001, respectively. These statistics cover transactions in spot, forward outright, forward swaps, currency swaps, and options (Exhibit 1.1).[4] There are at least two other recent central-bank-sponsored surveys covering specific segments of the foreign exchange market, both dating from October 2009. A Bank of England survey[5] of the London market (BOE 2009) estimated $1,430 billion in total daily turnover (including spot, outright forwards, non-deliverable forwards, and foreign exchange swaps). A Federal Reserve Bank of New York (NYFED 2009) survey[6] of the New York market estimated $679 billion of trading the same instruments.

Exhibit 1.1 Global Foreign Exchange Market Turnover (Daily Averages in April, in Billions of U.S. Dollars)

Source: (1) BIS (2010) and (2) Mihaljek and Packer (2010).

Turnover in Emerging Markets (2)

	2004	2007	2010
Spot transactions	119	188	203
Outright forwards	21	47	73
Foreign exchange swaps	125	231	277
Currency swaps	3	4	7
Options and other products	10	18	24
Total	279	489	585

Total Global Turnover (1)

	1998	2001	2004	2007	2010
Spot transactions	568	386	631	1,005	1,490
Outright forwards	128	130	209	362	475
Foreign exchange swaps	734	656	954	1,714	1,765
Currency swaps	10	7	21	31	43
Options and other products	87	60	119	212	207
Total	1,527	1,239	1,934	3,324	3,981
Memo: Turnover at April 2010 Exchange Rates	1,705	1,505	2,040	3,370	3,981
Exchange-traded derivatives	11	12	26	80	168
Global turnover by counterparty					
With reporting dealers	961	719	1,018	1,392	1,548
With other financial institutions	299	346	634	1,339	1,900
With non-financial customers	266	174	276	593	533

Foreign exchange trading is done practically everywhere there is a banking center. According to the BIS 2010 survey, the largest centers by share of total world turnover were the

United Kingdom (37 percent), the United States (18 percent), Japan (6 percent), Singapore (5 percent), Switzerland (5 percent), Hong Kong (5 percent), and Australia (4 percent). Not to be forgotten are the emerging markets nations where recently published data (BIS; Mihaljek and Packer 2010) ([Exhibit 1.1](#)) show to be rapidly expanding centers for foreign exchange trading.

There are well more than 100 currencies. As a general rule practically every country has its own currency[7] (with the European countries in the euro zone being a prominent, but not unique, exception). Yet trading in the foreign exchange market is remarkably concentrated in a handful of exchange rates ([Exhibit 1.2](#)). What is noteworthy is that the sum of trading in the dollar against the euro, yen, and sterling (in order of volume) made up 51 percent of all foreign exchange trading in 2010. In one sense, the foreign exchange market is largely the price of the dollar, inasmuch as in 2010 the dollar was on one side of 84.9 percent of all trades[8,9] (followed by the euro (39.1 percent), the yen (19.0 percent), sterling (12.9 percent), and the Australian dollar (7.6 percent).[10] But even a currency with a small share of total turnover can have a large volume of trading because the overall size of the market is enormous.

Exhibit 1.2 Reported Foreign Exchange Market Turnover by Currency Pair (Daily Averages in April, in Billions of U.S. Dollars and Percent)

	2001		2004		2007		2010	
	Amount	% Share	Amount	% Share	Amount	% Share	Amount	% Share
U.S. dollar/euro	372	30%	541	28%	892	27%	1101	28%
U.S. dollar/yen	250	20%	328	17%	438	13%	568	14%
Sterling/U.S. dollar	129	10%	259	13%	384	12%	360	9%
Australian dollar/U.S. dollar	51	4%	107	6%	185	6%	249	6%
U.S. dollar/Swiss franc	59	5%	83	4%	151	5%	168	4%
U.S. dollar/Canadian dollar	54	4%	77	4%	126	4%	182	5%
U.S. dollar/Swedish krona	6	0%	7	0%	57	2%	45	1%
U.S. dollar/Other	193	16%	300	16%	612	18%	705	18%
Euro/yen	36	3%	61	3%	86	3%	111	3%
Euro/Sterling	27	2%	47	2%	69	2%	109	3%
Euro/Swiss franc	13	1%	30	2%	62	2%	72	2%
Euro/other	22	2%	44	2%	123	4%	162	4%
Other currency pairs	28	2%	50	3%	139	4%	149	4%
All currency pairs	1,239	101%	1,934	100%	3,324	100%	3,981	100%

Foreign exchange dealing has become steadily more concentrated among a handful of powerful dealing banks. Indeed, according to the BIS, the top five dealers captured more than 55 percent of the market by 2009, up from a little

more than 25 percent in 1999 (see Gallardo and Heath 2009).[11] At the same time that trading in foreign exchange has been growing, the number of banks doing large-scale foreign exchange trading has been shrinking. Roughly speaking, the number of money center banks that account for 75 percent of foreign exchange turnover has roughly dropped by two-thirds in the period between 1998 and 2010 (BIS 2010). On a geographic basis, the number of such banks shrunk from 24 to 9 in the U.K., from 20 to 7 in the United States, from 7 to 2 in Switzerland, from 19 to 8 in Japan, and from 23 to 10 in Singapore during this decade. This is probably best seen as an outcome of the general trend of consolidation in the financial services industry. In the meantime the development of electronic trading has materially altered the nature of the foreign exchange market. The lower section of Exhibit 1.1 shows global foreign exchange turnover by counterparty to the reporting banks. Note that the historical pattern is for dealing banks (i.e., "reporting" in the language of the BIS surveys) to trade primarily with other dealing banks. That pattern began to change as early as 2001. An explanation is that electronic trading has resulted in dealing banks now trading less with other dealing banks and more with other financial institutions that are not themselves dealing banks. The 2010 survey is the first time that the volume of trading between dealers and nondealers was reported to have been greater in volume than trading within the dealer community. The BIS category of nonreporting financial institutions includes smaller banks, mutual funds, money market funds, insurance companies, pension funds, hedge funds, currency funds, and central banks, among others.[12] The magnitude of this shift is remarkable when one considers that 85 percent of the increase in the global turnover in foreign exchange originated from dealers trading with this category of other financial institutions.

THE INTERNATIONAL MONETARY SYSTEM

Bretton Woods and the Smithsonian Period

For the first quarter century after the Second World War, the international monetary system consisted of a program of fixed exchange rates. Fixed exchange rates were established under the Bretton Woods agreement signed by the Allied powers in 1944 in advance of the end of the Second World War. The Bretton Woods agreement required all member central banks to keep their foreign exchange reserves in U.S. dollars, pounds Sterling, or gold. More importantly, member countries agreed to stabilize their currencies within a 1 percent band around a target rate of exchange to the U.S. dollar. The dollar, in turn, was pegged to gold bullion at $35 per ounce. Parts of the system lasted until 1971.

  Periodically, currencies had to be revalued and devalued when market pressures became too great for central banks to oppose. Cynics dubbed the Bretton Woods a "system of creeping pegs." In 1971, after a series of dramatic "dollar crises," the dollar was devalued against gold to $38 an ounce,[13] and a wider bandwidth, equal to 2.25 percent, was established. This modification to the system, called the Smithsonian Agreement, postponed the collapse of the system of fixed exchange rates for two years. In 1973, President Richard Nixon scrapped the entire structure of fixed exchange rates that had begun with Bretton Woods. Since that time, exchange rates for the major currencies against the dollar have been floating.

The Euro

On January 1, 1999, 11 European nation members of the European Monetary Union, Austria, Belgium, Finland, France, Germany, Ireland, Italy, Luxembourg, Netherlands, Portugal, and Spain, adopted a new common currency, called the euro. The legacy currencies of these eleven nations, such as the German mark and French franc, circulated in parallel to the euro for a time but were exchangeable to the euro at fixed exchange rates. Total conversion to the euro happened on January 1, 2002, at which time the European Central Bank issued euro notes and coins. Additional countries have joined the euro since that time: Greece in 2001, Slovenia in 2007, Cyprus and Malta in 2008, Slovakia in 2009, and Estonia in 2011. At the current time 17 countries have adopted the euro. Noteworthy by their absence are the United Kingdom and Denmark. Switzerland is not part of the European Monetary Union.

The road to the creation of the euro was difficult. For nearly two decades, starting with the creation of the European Monetary System in March 1979, parts of Europe experimented with a fixed exchange rate system that was known as the Exchange Rate Mechanism (ERM). Under the ERM, member countries agreed to peg their currencies to a basket currency called the European Currency Unit (ECU). Currencies were allowed to move in relation to the ECU within either the narrow band of plus or minus 2.25 percent or the wide band of plus or minus 6 percent.

The ERM was a costly experiment in fixed exchange rate policy. In its 20 years of operation, from 1979 to 1999, ERM central rates had to be adjusted over 50 times. More spectacular yet were the two major ERM currency crises, one in September 1992 and the other in August 1993, each of which involved massive central bank losses in the defense of the fixed exchange rate grid. Finally after the second crisis, fluctuation bands were widened to plus or

minus 15 percent, a move that effectively neutered the ERM.[14]

Fixed Exchange Rate Regimes

A great variety of fixed exchange rate regimes have come and gone in the twentieth century, especially with respect to the minor currencies and emerging market currencies. Only a handful of fixed exchange rate systems have been worth the trouble. One success story was the Austrian shilling, which remained faithfully pegged to the German mark for nearly 20 years before joining the ERM in January 1995.

But there were a great many other cases of fixed exchange rate regimes that ended badly.[15] History shows that pegged exchange rates are astonishingly explosive and damaging when they fail. The examples of the Mexican peso in 1994, Thai baht, Czech koruna, Indonesian rupiah in 1997, and the Russian ruble in 1998 are cases in point.

Fixed exchange rate regimes in their most simple form consist of a currency being pegged outright to the value of another currency.[16] A few fixed exchange rate regimes are operated under the framework of a currency board, such as the one that is in place for the Hong Kong dollar. Under the workings of a currency board, the government commits to maintaining a reserve of foreign exchange equal to the outstanding domestic base money supply and to exchange domestic and foreign reserve currency at the pegged exchange rate upon demand.

Basket peg systems are another fixed exchange rate regime. The Thai baht was operated as a basket peg currency prior to its spectacular collapse in July 1997. Under the basket regime, the Bank of Thailand pegged the baht to a basket of currencies made up of U.S. dollars, German marks, and Japanese yen, though the exact makeup of the basket was never revealed.

Another species of a fixed exchange rate regime pegs the currency, but permits gradual depreciation over time. Examples are the Mexican peso prior to the December 1994 crisis and the Indonesian rupiah before it collapsed in July 1997.

Still other currencies fit somewhere between floating and pegged exchange rate regimes. Singapore, for example, operates what at times has been described as a managed floating regime.

Exchange Rate Intervention

Since the end of the Bretton Woods–Smithsonian regimes, the value of the U.S. dollar against the currencies of America's major trading partners has been determined by the forces of free-market supply and demand. This is a bit of an exaggeration because all exchange rates have at times been subject to manipulation through intervention by governmental bodies.

Intervention had a large presence in the foreign exchange market for a time in the 1980s. A predecessor of the current G-7 council,[17] called the G-5 council, initiated the Plaza intervention[18] in September 1985 (see Funabashi 1989). At that time, the council decided that a lower value for the dollar was warranted. Accordingly, its member nations' central banks launched a massive program to sell the dollar. The Plaza maneuver is remembered in foreign exchange history as the most successful coordinated intervention; the dollar fell by more than 4 percent in the first 24 hours. Two years later the council refocused its attention at the variability of exchange rates at another historic meeting, this time at the Louvre in February 1987.

But the appetite for intervention on the part of governments and their central banks ebbs and flows with economic circumstances and political leanings. For example, the administration of President George W. Bush seemed to

have had no interest in foreign exchange intervention, whereas that of his predecessor, President Clinton, aggressively used intervention in an attempt to maintain what it called a strong dollar.

While most major central banks have given up on intervention, at least in current times, Japan remains convinced of the need to use intervention to manage the value and the volatility of the yen. Central banks of emerging markets nations regard foreign exchange intervention as an important tool to be used in parallel with monetary policy.

Exchange Rate Crises

Exchange rate crises are primarily manifestations of fixed exchange rate arrangements coming to their end. These are brief periods of spectacular volatility, not only of exchange rates but also of associated interest rates, bond prices, and stock prices. Their history is important to traders and risk managers, not to mention economists.

The granddaddy of all foreign exchange crises was the aforementioned collapse of the Bretton Woods system of fixed exchange rates in August 1971.[19] The next-most-memorable crisis was in September 1992 during the ERM period before the launch of the euro. This was the episode that ended Great Britain's participation in the ERM and earned famed speculator George Soros the reputation for having "broke the Bank of England." August of 1993 is when the second ERM crisis occurred, principally involving the French franc's role in the ERM; 1994 saw the Mexican peso blow out of its crawling peg arrangement.

The Southeast Asian currencies experienced tremendous volatility in the summer of 1997. Two currencies, the Thai baht and the Indonesian rupiah, abandoned long-held fixed exchange rate regimes. The Malaysian ringgit and Philippine peso suffered steep losses in value against the U.S. dollar.

The Korean won, a currency that was not fully convertible, also was devalued. One of the only convertible currencies in Asia not to be devalued was the Hong Kong dollar.

After the fact, basic macroeconomic analysis can explain this remarkable series of currency crises with a simple set of causal factors that relate to the fundamental domestic conditions in each of these countries. Many of the affected countries had banking systems that were on the verge of total breakdown before the exchange rate problems became manifest. Moreover, several countries were running enormous and unsustainable current account imbalances, and every one of the afflicted countries had managed to run up staggering foreign currency–denominated debts. Speaking of excessive debt, there are Russia (1998) and Argentina (2002) to consider. These were compound crises, in the sense that their fixed exchange rate regimes exploded at the same time their governments announced defaults on maturing sovereign debt.

Nonetheless, in some quarters, the blame for these episodes has been put on hedge funds and currency speculators. It is widely held that capital mobility invites disaster, mistaken though that belief is. No matter what ultimately one chooses to believe was the cause of the crisis or where one enjoys placing the blame, the history of fixed exchange rate regimes clearly demonstrates that exchange rates are capable of making violent and substantial—if not outright discontinuous—movements over short periods of time.

SPOT FOREIGN EXCHANGE AND MARKET CONVENTIONS

Spot Foreign Exchange

The spot exchange rate is a quotation for the exchange of currencies in two bank business days' time (except in the case of the Canadian dollar versus the U.S. dollar, where delivery is in one bank business day).

Foreign exchange settlement days are called value dates. To qualify as a value date, a day must not be a bank holiday in either currency's country and in almost all circumstances must not be a bank holiday in the United States as well.[20] Many traders rely on a specialized calendar called the Euromarket Day Finder published by Copp Clark Professional. A sample page of this calendar for trade date December 21, 2010, is displayed in Exhibit 1.3. Note that the value date for spot transactions on December 21, 2010, is December 23, 2010. An exception is Japan. Because December 23rd is an official holiday (the emperor's birthday), the value date for trades done on December 21, 2010, involving the yen is December 24, 2010.

Exhibit 1.3 Euromarket Day Finder

Tuesday

21

355
Day Number
10
Days Remaining

▼ AUD (Sydney)
▲ CAD (Toronto)
✚ CHF (Zurich)
€ EUR (TARGET)
■ GBP (London)
Ⅰ HKD (Hong Kong)
Ⅰ JPY (Tokyo)
◆ NZD (Wellington/Auck.)
◆ SGD (Singapore)
★ USD (New York)

December 2010

SUN	MON	TUE	WED	THU	FRI	SAT
			1	2	3	4
5	6	7 ᴷ	8 ᴹ	9	10	11
12	13	14	15	16	17	18
19	20	21	22 1	23 ●	24 ᶠ 3	
27 ᴰ	28 ᴰ	29 ᴰ 8	30 9	31 ᶠ ●		

November 2010

S	M	T	W	T	F	S
	1	2	3	4	5	6
7	8	9	10	11	12	13
14	15	16	17	18	19	20
21	22	23	24	25	26	27
28	29	30				

B Brussels
D Dublin
F Frankfurt
K Kuala Lumpur
L Luxembourg
M Milan
P Paris
S Seoul

① Jan 2011

S	M	T	W	T	F	S
		4	5	6	7	8
9	10	11	12	13	14	15
16	17	18	19	20	21	22
23	24	25	26	27	28	29
30	31					

② Feb 2011

S	M	T	W	T	F	S
		1	2	3	4	5
6	7	8	9	10	11	12
13	14	15	16	17	18	19
20	21	22	23	24	25	26
27	28					

③ Mar 2011

S	M	T	W	T	F	S
		1	2	3	4	5
6	7	8	9	10	11	12
13	14	15	16	17	18	19
20	21	22	23	24	25	26
27	28	29	30	31		

④ Apr 2011

S	M	T	W	T	F	S
					1	2
3	4	5	6	7	8	9
10	11	12	13	14	15	16
17	18	19	20	21	22	23
24	25	26	27	28	29	30

⑤ May 2011

S	M	T	W	T	F	S
1	2	3	4	5	6	7
8	9	10	11	12	13	14
15	16	17	18	19	20	21
22	23	24	25	26	27	28
29	30	31				

⑥ Jun 2011

S	M	T	W	T	F	S
			1	2	3	4
5	6	7	8	9	10	11
12	13	14	15	16	17	18
19	20	21	22	23	24	25
26	27	28	29	30		

Tuesday DECEMBER 21