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Conventions in the Foreign Exchange Market:Do they really explain Exchange Rate Dynamics?

Gabriele Di Filippo[1]

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Do they really explain Exchange Rate Dynamics?

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Abstract

The present paper provides a new explanation for the dynamics of exchange rates based on conventions that prevail among market participants. The model relies on a two states Markov switching framework: a bull state and a bear state. In the bull state, agents are optimistic and put more weight on positive news about the domestic economy inducing an appreciation of the domestic currency. In the bear state, agents are pessimistic and overweight negative news associated to the domestic economy leading to a depreciation of the domestic currency. Results show that market switches between a bull state and a bear state explain the dynamics of the euro/dollar exchange rate between January 1995 and December 2008. Besides, the model highlights the life-cycle of conventions in the foreign exchange market and provides lessons for public authorities to reduce exchange rate volatility. Eventually, the model offers a solution to the exchange rate disconnection puzzle.

Key-Words: Exchange Rate Dynamics, Convention Theory, Imperfect Knowledge Economics, Markov Switching

JEL Codes: G10, G12, F31

Introduction

The present paper provides a new explanation for the dynamics of exchange rates based on conventions that prevail among market participants. The model relies on a two states Markov switching framework: a bull state and a bear state. In the bull state, agents are optimistic and put more weight on positive news about the domestic economy inducing an appreciation of the domestic currency. In the bear state, agents are pessimistic and overweight negative news associated to the domestic economy leading to a depreciation of the domestic currency. Results show that market switches between a bull state and a bear state explain the dynamics of the euro/dollar exchange rate between January 1995 and December 2008. Besides, the model highlights the life-cycle of conventions in the foreign exchange market and provides lessons for public authorities to reduce exchange rate volatility. Eventually, the model offers a solution to the exchange rate disconnection puzzle.

The intuition behind the convention model is based on a stylised fact highlighted by De Grauwe (2000). De Grauwe argues that agents tend to look for fundamentals that confirm the observed movements in the exchange rate. For instance, the large depreciation of the euro relative to the dollar between January 1999 and December 2002 was attributed to the strong growth performance in the United States relative to the euro zone. On the contrary, the appreciation of the euro relative to the dollar between December 2002 and December 2004 was justified by large current account deficits in the United States compared to the euro zone. Bachetta and Van Wincoop (2005) theorised this idea in a scapegoat model. However the model of Bachetta and Van Wincoop does not offer a satisfying reduced form structure from which an empirical exchange rate model can be built. The convention model proposed here borrows more elements from the Imperfect Knowledge Economics (IKE) approach pioneered by Frydman and Goldberg (2007).

Empirical results from the convention model show that when market agents are bull, an increase in the industrial production in Europe and in the United States (US) leads to an appreciation of the dollar. Therefore agents overweight the growth rate of the US economy thereby ignoring the growth rate in the euro zone (the coefficient associated to the growth rate in the euro zone appears not significant). Conversely, when agents are bear, an increase in the external debt in Europe and in the United States leads to a depreciation of the dollar. Bear agents overweight the external debt of the United States and ignore the European debt.

The analysis of filtered probabilities allows identifying three major conventions in the foreign exchange market for the euro/dollar exchange rate. The first convention is the new economy convention that covered the period January 1995 - December 2000. Investors were bull in the US economy and bear in the European economy. Then, between July 2003 and December 2005 two competing conventions prevailed in the market. A bear convention that focuses mainly on large US current deficits; and a bull convention that focuses notably on the spectacular recovery of the US economy from the internet bubble burst. After January 2006, fundamentals worsened in the United States: the bear convention started to dominate the bull one. The spark of the subprime crisis in June 2007 led to the definite domination of a bear sentiment in the market.

The model also suggests that exchange rate volatility increases when there is uncertainty among market participants concerning the prevailing convention. Along with Orléan (2006), I argue that in order to reduce exchange rate volatility, public authorities should intervene in the market to reduce uncertainty by facilitating the emergence of a new convention. This intervention can be direct (through speeches or notes releases) or indirect (through a major media).

Eventually, the convention model resolves the disconnection puzzle since it shows that switches between a bull and a bear sentiment among market participants explain the dynamics of the euro/dollar exchange rate.

Section 1 presents the main pillars of convention theory and a reduced form of the convention model. Section 2 analyses the plausible conventions that prevailed for the euro/dollar among market agents. Section 3 provides estimation results of the convention model. Results interpretations are presented in section 4. Section 5 concludes.

1. Theoretical concepts

1.1 The main principles of the convention theory

Convention theory has been developed by the pioneered work of Lewis (1969), Sugden (1989) and Peyton Young (1996). Convention theory comes as an alternative to the traditional theory of asset pricing. Traditional models of asset pricing are based on the efficient market hypothesis (EMH) and the rational expectation hypothesis (REH). Such models assume objectivity *ex ante* of the future and the existence of a unique intrinsic asset value (the fundamental value). In the tradition of the Arrow-Debreu model, the REH states that a representative agent can predict the future value of an asset by associating *ex ante* predetermined probabilities to exogenous future events. A rational agent can hence assess the fundamental value of an asset by computing the expected returns of the asset in each state of the Nature conditional on the disposable stock of information. According to the EMH, every asset price has one unique fundamental value that includes all the relevant information of the asset.

Models based on the EMH and the REH offer poor empirical performances concerning the explanation and prediction of asset price dynamics, especially exchange rates (Meese and Rogoff (1983), Cheung, Chinn and Garcia Pascual (2005)). Such models led to unresolved asset pricing puzzles. Besides, assuming the existence of a unique fundamental value for an asset appears rather unrealistic. In a previous work, Bouveret and Di Filippo (2009) show that in the case of the euro/dollar exchange rate, the market does not rely on a unique definition of a fundamental value but rather on a large panel of fundamental values. Each fundamental value belongs to a specific model designed by a particular agent. These facts cast doubts on the pertinence of models based on the traditional asset pricing theory.

Convention theory adopts a rather opposite view to the traditional theory. Following Knight (1921) and Keynes (1936), convention theorists claim that the future is totally uncertain. No agent has the ability to know the probability distribution of future outcomes. The future is here shaped by the heterogeneity of opinions that agents frame on the fundamental value of an asset. There are as many fundamentals as there are opinions about the fundamental value of an asset. The future becomes hence subjective: each agent has his/her own opinion of the future. All these opinions lead to the existence of multiple price equilibria in the market. The key question is how do these opinions converge to a particular equilibrium? Individual opinions converge towards a particular equilibrium through a mimetic mechanism. This mechanism was early illustrated by Keynes (1936) in his beauty contest. The primary objective for an agent in the market is to anticipate the reaction of the majority of participants in the market. As a matter of fact, if a market is bull on a given asset, an agent will have to buy this asset even if fundamentals tell him/her to sell this asset. This self-referential behaviour is rational at an individual level although it can lead to unrational phenomena (such as price bubbles) at a collective level.

The self-referential behaviour consists in detecting striking events that could catch the attention of the market. The choice of a striking factor is based on a trial-and-error strategy.

The search for striking factors takes the form of bets on the future and implies an increase in the volatility of asset prices. The market will stabilise itself when all agents through mimetism will focus on a particular striking event.

At this point, agents have found a particular model based on specific fundamentals. All agents in the market legitimate this model. This particular model is called a convention. A convention therefore creates a focal point that helps to resolve the problem of multiple price equilibria in the market. Once a convention is determined in the market, asset price volatility decreases. A convention acts therefore as a guide through the uncertainty of the future. Indeed agents can rely on the convention to form their expectations of the future value of the asset.

A convention can thus be defined as a particular fundamental model adopted by the majority of agents in a market concerning the future economic perspectives (Orléan (2006)). A convention often ignores other fundamentals that go against it. In order to live long enough, lessons drawn from a convention have to match empirical facts. However, the market will not abandon a convention at the first anomalies. The market will do so when there will be a series of events that are in opposition to the current convention. Agents' belief in the convention vanishes and the convention disappears from the market. Market participants will then have to find a new convention.

1.2 Defining a theoretical structure for a convention model of exchange rate

The main idea behind the convention model is based on a stylised fact highlighted by De Grauwe (2000). De Grauwe argues that agents tend to look for fundamentals that confirm the observed movements in the exchange rate. For instance, the large depreciation of the euro relative to the dollar between January 1999 and December 2002 was attributed to the strong growth performance of the US economy relative to the European economy. On the contrary, the appreciation of the euro relative to the dollar between December 2002 and December 2004 was justified by large US current account deficit.

Bachetta and Van Wincoop (2005) theorised this fact in the scapegoat model. The theoretical model rests on a monetary model of exchange rate. Such models appear unfitted to model the empirical dynamics of exchange rates. As a result, the model structure proposed here does not rely on a reduced form of the model of Bachetta and Van Wincoop. The convention model borrows more elements from the Imperfect Knowledge Economics (IKE) approach by Frydman and Goldberg (2007).

Along with Frydman and Goldberg, the model considers two types of representative agents in the market: an optimistic (or bull) agent and a pessimistic (or bear) agent.

Optimistic agents are defined as agents willing to buy assets denominated in the domestic and foreign currencies. In line with the confirmation bias (Kahneman, Slovic and Tversky (1991)), optimistic agents will put more weight on fundamentals that confirm their bull sentiment. Bull agents will therefore overweight good news thereby underweighting (and perhaps ignoring) bad news. Bull agents will select one or several striking domestic and foreign fundamentals (respectively X_i and X_i^*) among a set of fundamentals Ω. According to economic theory, the selected fundamentals will justify an appreciation of the currency in the domestic and in the foreign economies:

$$\frac{dS}{dX_i} > 0 \quad \text{and} \quad \frac{dS}{dX_i^*} < 0 \quad \text{with } X \text{ and } X^* \in \Omega \tag{1}$$

Conversely pessimistic agents will sell assets denominated in the domestic and foreign currencies. Pessimistic agents will put more weight on fundamentals that confirm their bear sentiment by selecting one or several salient fundamentals among a set of fundamentals Ω. In

line with economic theory, the selected fundamentals justify a depreciation of the currency in the domestic and in the foreign economies:

$$\frac{dS}{dX_i} < 0 \quad \text{and} \quad \frac{dS}{dX_i^*} > 0 \quad \text{with } X \text{ and } X^* \in \Omega \tag{2}$$

As the proportion of bull and bear agents varies across time in the market, the market switches between two states: a bull state and a bear state. The structure of the reduced-form model can thus be defined as follows:

$$\Delta s_t = \begin{cases} \alpha_{1,0} + \sum_{i=1}^{N} \alpha_{1,i} X_{1i,t} + \sum_{i=1}^{N} \beta_{1,i} X_{1i,t}^* + \varepsilon_{1,t} & S_t = Bull \\ & \text{if} \\ \alpha_{2,0} + \sum_{i=1}^{N} \alpha_{2,i} X_{2i,t} + \sum_{i=1}^{N} \beta_{2,i} X_{2i,t}^* + \varepsilon_{2,t} & S_t = Bear \end{cases} \tag{3}$$

$$\text{With } \frac{ds}{dX_{1i}} > 0 \ ; \ \frac{ds}{dX_{1i}^*} < 0 \quad \text{and} \quad \frac{ds}{dX_{2i}} < 0 \ ; \ \frac{ds}{dX_{2i}^*} > 0$$

The final variation of the endogenous variable Δs_t works as follows: when the market is in the bull state, if agents are relatively more optimistic in the domestic economy than in the foreign economy then the domestic currency appreciates ($\Delta s_t > 0$). Conversely, when the market is in the bear state, if agents are relatively more pessimistic in the domestic economy than in the foreign economy then the domestic currency depreciates ($\Delta s_t < 0$).

The structure of the convention model is opposed to the one assumed by traditional models of exchange rate. The convention model rests on a non-linear structure and assumes an asymmetric world. Traditional models are built on a linear structure and suppose a symmetric world.

The assumption of an asymmetric world is drawn from lessons exposed by the literature about news on the exchange rate. Prast and De Vor (2000), Galati and Ho (2001) and Andersen *et al.* (2003), show that investors react asymmetrically to news on a given fundamental between two countries. Empirical results suggest that news coming from the United States are overweighted by market agents compared to news coming from the euro area.

The convention model offers several advantages compared to recent models of exchange rate such as the heterogeneous agents models (Vigfusson (1997), Bessec and Robineau (2003), De Grauwe and Grimaldi (2006)). Heterogeneous agent models explain the dynamics of exchange rates based on the behaviour of fundamentalist and chartist agents. Such models fully predetermined the behaviour of economic agents by associating an exogenous rule to each agent. Agents therefore act as robots in these models. On the contrary, the convention model follows the IKE approach by partially predetermining the behaviour of agents. Indeed, agents can use whatever rules or investment strategies. Such rules are allowed to evolve over time. Moreover, the convention model does not rely on the controversial definition of a fundamental exchange rate. On the contrary, heterogeneous agents models have to specify an arbitrarily value for the fundamental exchange rate in the fundamentalist rule.
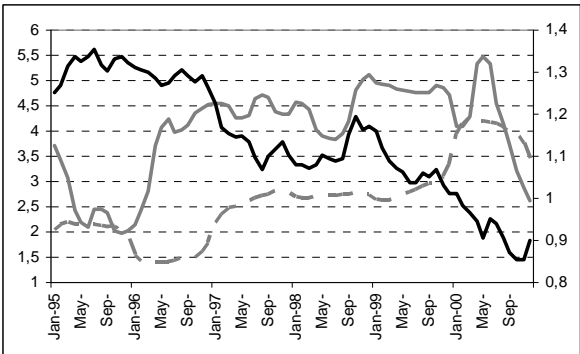
2. Identifying the prevailing conventions on the euro/dollar exchange rate

The strategy to build the convention model is based on two steps. The first step consists in identifying striking macroeconomic variables that are considered in the conventions for the euro/dollar exchange rate. We rely on major articles from financial journals (Wall Street Journal and The Economist) as well as academic ones to assess the mood of the market. The period of analysis spans January 1995 to December 2008.

2.1 January 1995 - December 2000: the internet convention or the superiority of the US economy compared to the euro zone

In the second half of the 1990s, the US economy experienced a stronger growth rate than Europe (an average of 8,3 % for the United States *versus* 5 % for Europe (figure 1)). Stronger growth in the United States was attributed to larger investments in new technologies compared to Europe. Such investments helped increase the productivity differential in favour of the United States (figure 2). In December 2008, the differential in productivity growth rates amounted to 3 %. Numerous economists praised the glorious perspectives offered by the US economy. Some economists such as Jeremy Rifkin even claimed that the US economy had reached a higher structural growth rate. The market was clearly in presence of a convention defining the US economy as more profitable than the European economy.

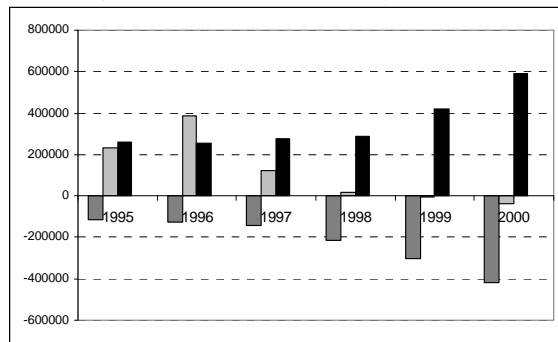| Figure 1: Annual real growth rate of gross domestic product	Figure 2: Annual productivity growth rate
Source: Thomson Datastream	Source: Thomson Datastream
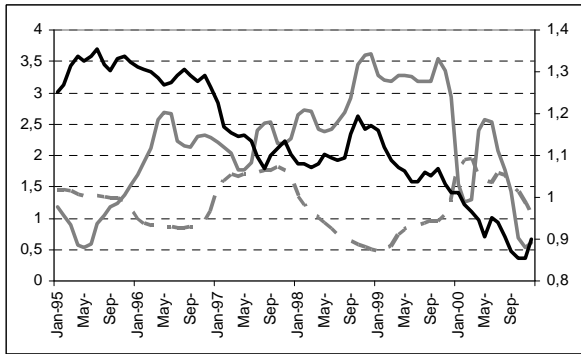
NB: The dashed grey line refers to the euro zone; the solid grey line refers to the United States and the solid black line represents the euro/dollar nominal exchange rate.

Financial investors therefore expected higher returns rate in US stocks than in European stocks. They invested massively in US stocks, especially in companies belonging to the sector of the new economy (the ever-known start-ups). Net equity flows in the United States increased by an average of 24 % a year between 1998 and 2000 (figure 3). The annual average growth rate of the S&P500 between January 1995 and December 2000 amounted to 21 % a year (figure 23).
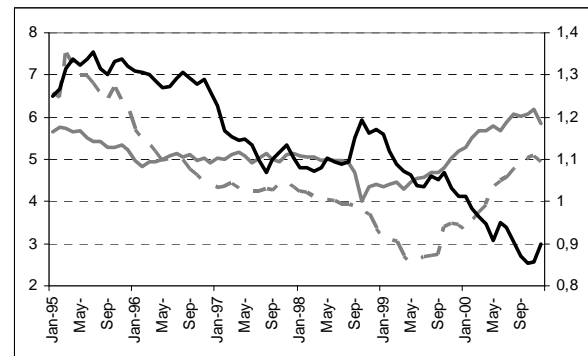
The birth of the euro zone in 1999 and the youth of the European Central Bank (ECB) - which had to set its credibility among market agents - led investors to be more timorous in the European economy than in the US economy.

Figure 3: Net equity flows in the United States (in millions of dollars)	**Figure 4: Short run (3 months) interest rate**
Source : Bureau of Economic Analysis	**Source : Thomson Datastream**

NB: For Figure 3, the dark grey represents the US current balance; the clear grey represents net flows of investment in Treasury bills and government bonds; the black represents net flows of investment in equity and foreign direct investment. For Figure 4, the dashed grey line refers to the euro zone; the solid grey line refers to the United States and the solid black line represents the euro/dollar nominal exchange rate.

The net inflow of capitals in the United States led to an appreciation of the dollar against the euro between January 2001 and December 2000. This appreciation was also induced by an interest rate differential in favour of the United States.

Therefore, between January 1995 and December 2000, markets were relatively more optimistic on the perspectives of the US economy relative to the ones of the European economy. The bull sentiment that prevailed in the market was referred to as the new economy convention or the internet convention.

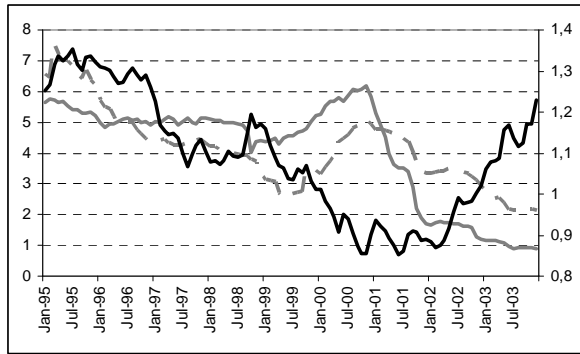**2.2 January 2001-June 2003: The burst of the internet bubble and the end of the new economy convention**

The over-optimistic sentiment in the US economy led to a bubble in stock prices. The bubble burst in January 2001. This exogenous shock put an end to the new economy convention. Investors realised that their expectations on the perspectives of the US economy were too optimistic.

Financial papers began to put the accent on variables hidden by the internet convention. Stronger US growth rate was gauged on a growing debt of the public and the private sectors. US companies over-estimated the future demand and faced higher debt and excess capacities. The high level of US consumption rested on an increasing debt allowed by the positive wealth effect induced by the rise in stock prices.

The increase in public and private debt induced mechanically an increase in the deficit of the current account balance (figure 6) and signed the return of the twin deficits. A lot of economists began to ask about the sustainability of US deficits (Mann (2002)) and a possible fall in the dollar.
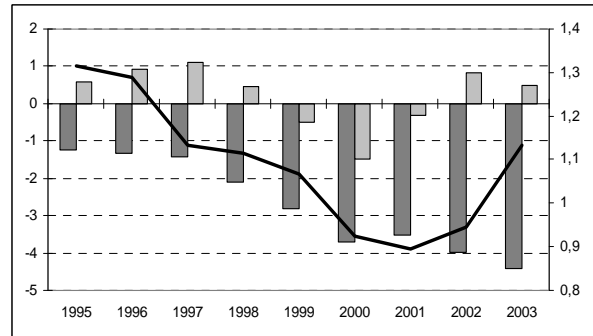
To counter the economic slowdown induced by the internet bubble burst, the Federal Reserve decreased dramatically its rates of interest. The differential of interest became now in favour of the European economy (figure 5).

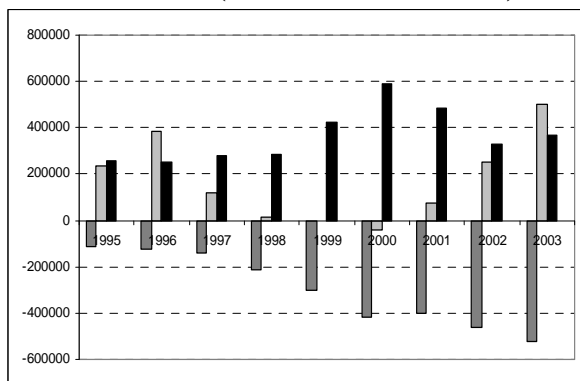| **Figure 5: Short run (3 month) interest rate**	**Figure 6: Current balances over GDP**
Source: Thomson Datastream	**Source: Thomson Datastream**

NB: For Figure 5, the dashed grey line refers to the euro zone; the solid grey line refers to the United States and the solid black line represents the euro/dollar nominal exchange rate. For Figure 6, the dark grey represents the US current balance and the clear grey represents the European current balance.

Investors became hence relatively less confident in the US economy than in the European economy. They deserted investments in stocks and foreign direct investment (FDI) in the United States. Between January 2001 and June 2003, the S&P500 lost 44 % and the Eurostoxx 60 %. The financial scandals of Enron and Worldcom and then the attacks of the 11th September 2001 kept increasing the bear sentiment on the US economy. Equity flows in the United States decreased (figure 7) and the dollar stopped its appreciating trend begun earlier in January 1995 (figure 8). The dollar started to depreciate in June 2002. This depreciation was however contained by interventions of East-Asian central banks. Such agents bought US bonds to prevent a severe appreciation of their currency against the dollar.
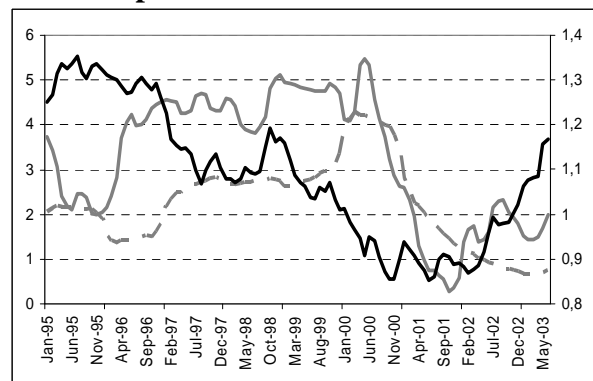
The bear sentiment of investors on the US economy does not mean that investors became bull in the European economy. Indeed, the excess in the current balance experienced by the euro zone at that period (figure 6) suggests that the rate of growth has been very low and is still very low in the Euro zone during this period.

Figure 7: Net equity flows and net bond flows in the US (in millions of dollars)	**Figure 8 : Annual real growth rate of gross domestic product**
Source: Bureau of Economic Analysis	**Source: Thomson Datastream**

NB: For Figure 7, the dark grey represents the US current balance; the clear grey represents net flows of investment in Treasury bills and government bonds; the black represents net flows of investment in equity and foreign direct investment. For Figure 8, the dashed grey line refers to the euro zone; the solid grey line refers to the United States and the solid black line represents the euro/dollar nominal exchange rate.

As a result, between January 2001 and June 2003, financial markets faced an increase in uncertainty either in the Euro zone or in the United States. Fears of deflation induced by lower growth rates prevailed among economists and central bankers. The market definitely
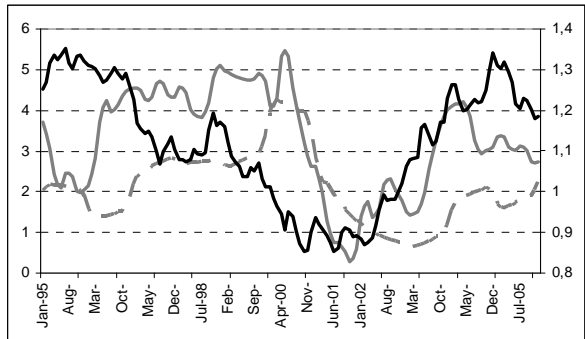
abandoned the internet convention. Agents became bear either in the United States and or in the euro zone. The bear sentiment was relatively stronger in the United States than in the euro zone.

2.3 July 2003-December 2005: The birth of two competing conventions: the US consumption as the engine of the world economy *versus* the US as a net debtor

From July 2003, fears of deflation induced by the bubble burst vanished. The US economy was recovering surprisingly fast from the burst of the internet bubble (figure 9). Factors behind the US recovery are the large decrease of interest rates by the Federal Reserve (figure 10) coupled with an increase in public spending (through the decrease in taxes under the Bush government and the increase in military spending (related to wars in Iraq and in Afghanistan)).

Conversely, the Euro area was dealing with a weaker growth rate. Economists started to ask about the pertinence of the institutional structure of the euro zone. They began to blame the Growth and Stability Pact because it could prevent the euro area from higher growth rates. The Euro area seemed unable to lead a pertinent policy to counter its economic slowdown. Between July 2003 and December 2005 the annual growth rate reached 1,7 % in the Euro Area compared to 4,8 % in the United States (figure 9). Lower interest rates associated to surging house prices (figure 13) allowed US households to ease their access on credit and to increase their consumption. At that time, financial papers argued that the US consumption was the engine of the world economy.

| **Figure 9: Annual real growth rate of gross domestic product**	**Figure 10: Short run (3 months) interest rate**
Source: Thomson Datastream	**Source: Thomson Datastream**
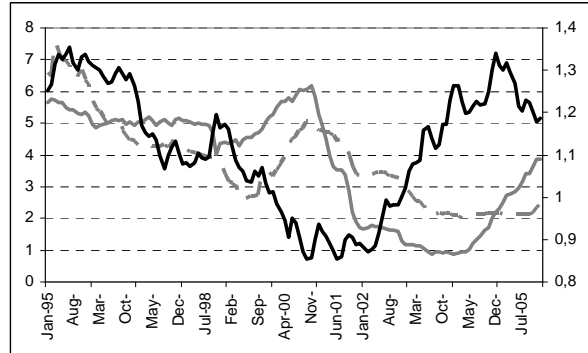
NB: The dashed grey line refers to the euro zone; the solid grey line refers to the United States and the solid black line represents the euro/dollar nominal exchange rate.

However, several factors seemed to limit the confidence of investors in the US economy. Indeed, the US consumption was gauged on a higher level of debt for households. Besides, the return of growth in the United States generated no increase in employment. As shown in figure 11, the growth rate of employment was close to the one in the Euro zone although the growth differential was strongly in favour of the United States (figure 9). This fact was partly explained by relocations of US firms to China. Such relocations led the US economy to increase imports of Chinese goods which contributed to increase the US deficit (figure 12). In 2005, the US current deficit reached 6 % of GDP.
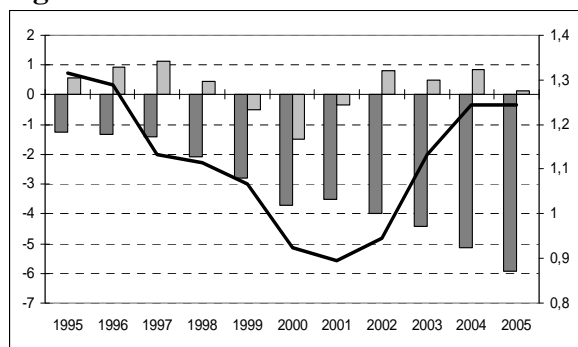
All these factors explain why the dollar still depreciates even after the recovery of the US economy between July 2003 and December 2004.

Figure 11: Employment growth rate
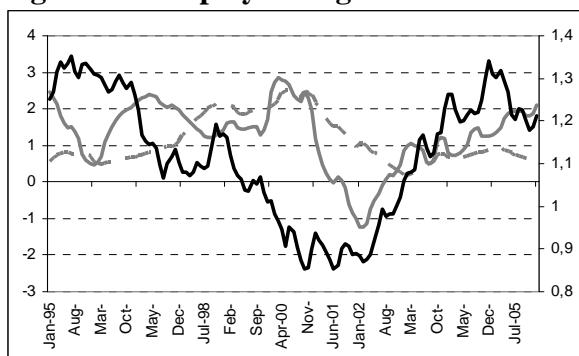
Source: Thomson Datastream

Figure 12: Current balance over GDP

Source: Thomson Datastream

NB: For Figure 11, the dashed grey line refers to the euro zone; the solid grey line refers to the United States and the solid black line represents the euro/dollar nominal exchange rate. For Figure 12, the dark grey represents the US current balance and the clear grey represents the European current balance.

At the beginning of 2004, higher growth in the US and increasing oil prices pushed the Federal Reserve to increase its rates of interest (figure 10). The interest rate differential became in favour of the US economy in December 2004.

Finally, between July 2003 and December 2005, two competing conventions appeared in the market. A first convention (bear convention) focused mainly on large US current deficits and expected a fall in the dollar. A second convention (bull convention) pointed to the fast recovery of the US economy after the bubble burst and its good resistance relative to the increase in oil prices (figure 14). The bull sentiment was also attributed to the success of the fine monetary policy of Alan Greenspan, chairman of the Federal Reserve at that time. The domination of the bear convention may explain the depreciation of the dollar between July 2003 and December 2004. Conversely, the domination of the bull convention may explain the appreciation of the dollar between January 2005 and December 2005.
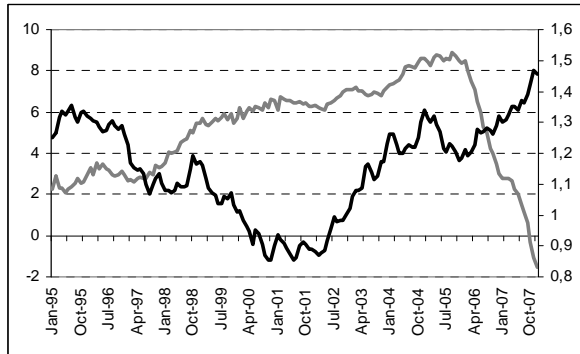
2.4 January 2006 – June 2007: the weakening of the bull convention

Between January 2006 and June 2007, the bull sentiment associated to the resistance and the high potential of the US economy became more and more threatened by several negative factors.

Indeed, the sustained growth in the United States between July 2003 and December 2005 was gauged on a positive growth rate of house prices. Between January 2006 and September 2007, the growth rate of US house prices decreased (figure 13). Economists began to warn about a possible burst of a bubble in US house prices.

On the other hand, oil prices were surging and acted as a burden on the budget of US households. The barrel of Brent reached 96,05 $ in November 2007 (figure 14). Investors feared a decrease in US households' consumption either by the decrease in house prices that could close access to credit for households or by the increase in oil prices that reduce the disposable income of households. Fears were also accentuated by the increase in interest rates by the Federal Reserve (figure 18) which raised the burden of debt for US households.

Figure 13: House prices annual growth rate	**Figure 14: Oil price dynamics (Brent)**
Source: Thomson Datastream	Source: Thomson Datastream
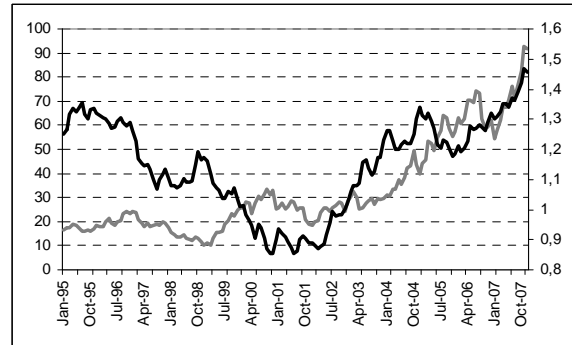
NB: For Figure 13 and 14, the solid black line represents the euro/dollar nominal exchange rate.

The second category of negative factors is related to worrying concerns about the sustainability of the US current balance. US current deficits approached more than 6 % of GDP in 2006 and about 5,5 % of GDP in 2007 (figure 15). Fears i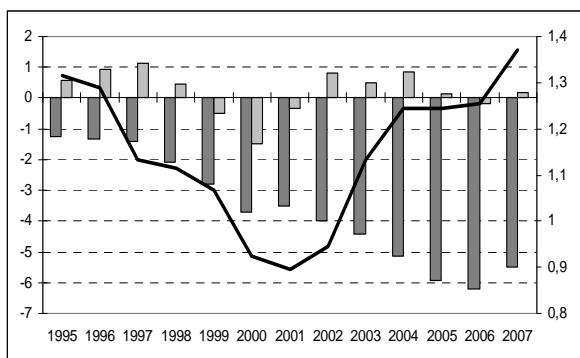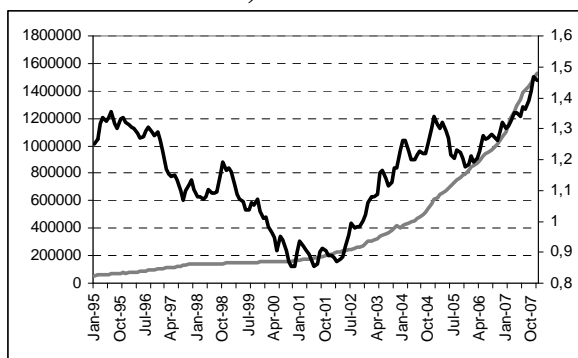ncreased among investors about a possible fall in the dollar and hence in the value of assets denominated in dollars. Threats by Chinese authorities to convert part of their huge stock of accumulated dollars (figure 16) in another currency accentuated fears in a dollar fall.

Figure 15: Current balance over GDP	**Figure 16: Chinese dollar reserves (in millions of dollars)**
Source: Thomson Datastream	Source: Thomson Datastream

NB: For Figure 15, the dark grey represents the US current balance and the clear grey represents the European current balance. For Figure 16, the solid grey line refers to Chinese reserves and the solid black line represents the euro/dollar nominal exchange rate.

The rising bear sentiment in the US economy led investors to be relatively more optimistic on the perspectives of the euro zone. Investors became aware that the US economy had not significantly outperformed the European economy in the recent years. Growth in the Euro area was at its fastest pace since January 2002 and the growth differential between the United States and the euro zone became very thin from January 2007 to December 2007 (figure 17). In 2007, inflation fears related to the increase in oil prices led the ECB to increase its interest rates. At the end of 2007 the interest rate differential became in favour of the euro zone (figure 18).

Figure 17: Annual real growth rate of gross domestic product
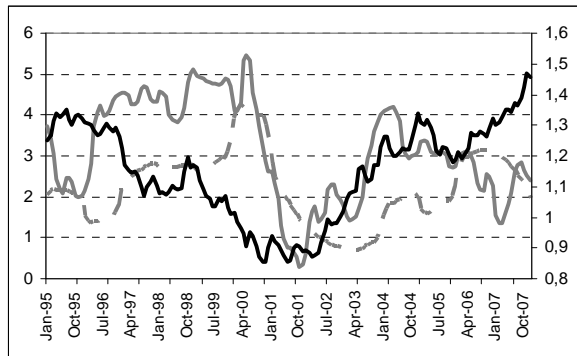
Source: Thomson Datastream

Figure 18: Short run (3 month) interest rates
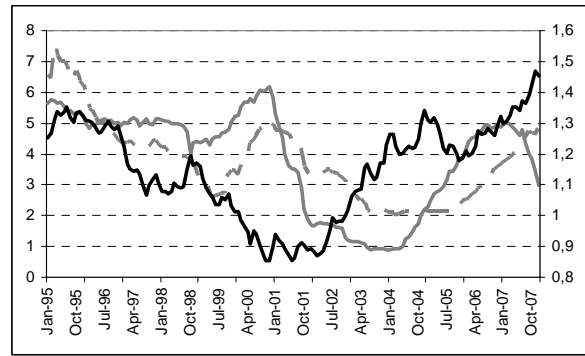
Source: Thomson Datastream

NB: The dashed grey line refers to the euro zone; the solid grey line refers to the United States and the solid black line represents the euro/dollar nominal exchange rate.

In December 2007, investors became uncertain about the perspectives offered by the US economy. Economists and central bankers began questioning whether the US economy would experience a soft-landing or a hard-landing. The bull convention that appeared between July 2003 and December 2005 in the United States was fading out at an increasing pace. The increasing domination of the bear convention may explain why the dollar depreciates between January 2006 and December 2007.

2.5 June 2007 -December 2008: The subprime crisis and the end of the bull convention in the US economy
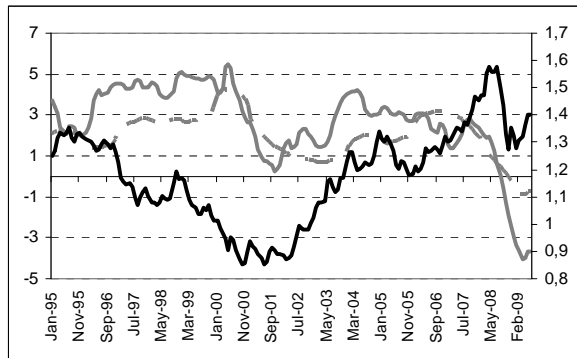
The bankruptcy of two investment funds of Bear Stearns in June 2007 sparked a major financial crisis in the United States. In spring 2007, the Federal Reserve along with the ECB intervened massively in the interbank market to prevent a liquidity crisis.

The Federal Reserve began to decrease its rates in June 2007 (figure 20) while the ECB kept its rates unchanged because of inflation fears caused by increasing oil prices and also because growth forecasts were still more optimistic in the euro zone than in the United States (figure 19).

In October 2007, the bubble on house prices burst (figure 13). Investors faced a great uncertainty about the perspectives of the US economy. Nobody really knew how bad the subprime crisis would have hurt the US economy. Support brought by the Federal Reserve and the ECB to needy banks in the second half of 2007 prevented both economies from a large financial crisis. However, concerns were now surging about a possible contamination of the financial turmoil to the real economy. Economists feared especially a credit crunch triggered by unhealthy banks that invested in subprime assets. A credit crunch would indeed end access of US households to credit, hence stopping US consumption; one of the main components that sustained US growth until then.

In April 2008 growing evidence raised that the US economy was in recession. Conversely, the European economy seemed on a first time less affected by the financial crisis. Figure 22 shows that European employment still rose when unemployment in the US increased. Newspapers pointed to the relative resistance of European economies although the growth rate in the euro zone lowered. With oil prices still surging and preventing the ECB to decrease its rates, economists feared the return of stagflation in the Euro area as well as in the United States.

Figure 19: Annual real growth rate of gross domestic product	Figure 20: Short run (3 months) interest rates
Source: Thomson Datastream	Source: Thomson Datastream
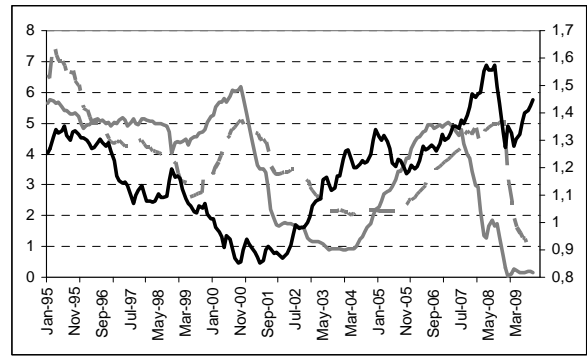
NB: The dashed grey line refers to the euro zone; the solid grey line refers to the United States and the solid black line represents the euro/dollar nominal exchange rate.

The growth rate in the United States became negative and US unemployment surged in August 2008 (figures 19 and 22). Later, in November 2008, the Euro zone experienced a negative growth rate (figure 19). The ECB started to decrease its interest rates in December 2008 (figure 20).

A bear sentiment prevailed among financial markets concerning the economic perspectives either in the euro zone or in the United States. Stock indices started to fall in October 2008. Investors became more averse to risky assets. Net flows of equities in the United States became negative in 2008 (figure 21) and US investors retrieved their capitals from the euro area. This retrieval of capitals partly explains the appreciation of the dollar between July 2008 and November 2008 (figure 19).

Figure 21: Net capitals flows in the United States (in millions of dollars)
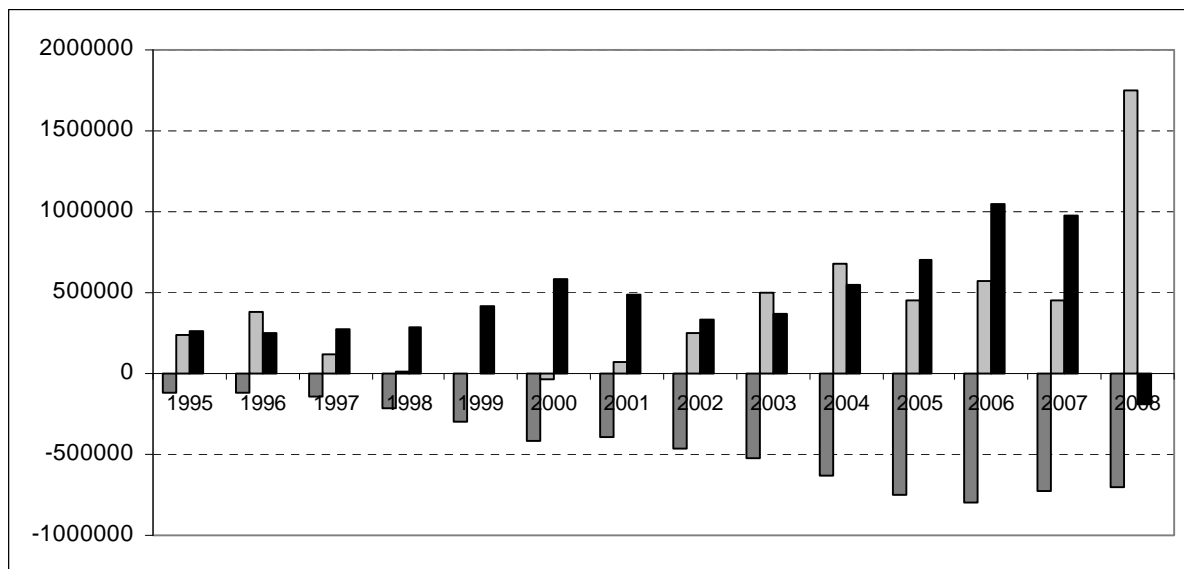
Source: Bureau of Economic Analysis; the dark grey represents the US current balance; the clear grey represents net flows of investment in Treasury bills and government bonds; the black represents net flows of investment in equity and foreign direct investment.

From September 2008 until June 2009 the US and European governments were beginning to set plans to put an end to the financial crisis and to counter the economic recession. However, economists cast doubts on the pertinence of successive plans proposed

by both governments (especially the US government). In May 2009, some economists feared the spectre of a W shaped recession such as in the 1939 crisis. From the peak of June 2007 to the trough of March 2009, the S&P500 fell by 50 % (figure 23). Over the same period, the Eurostoxx has fallen by 57 %.

Figure 22: Employment growth rate
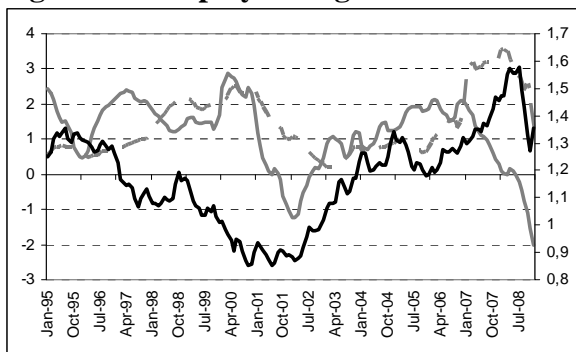
Source: Thomson Datastream

Figure 23: S&P500 dynamics
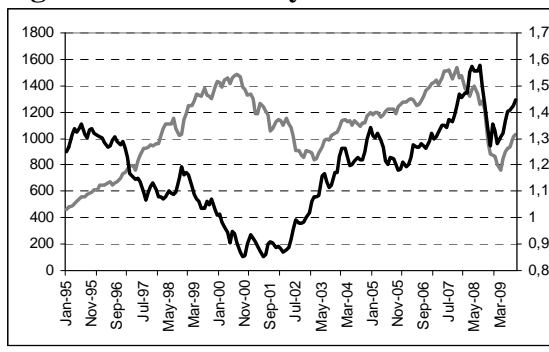
Source: Thomson Datastream

NB: The dashed grey line refers to the euro zone; the solid grey line refers to the United States and the solid black line represents the euro/dollar nominal exchange rate.

The above analysis allows distinguishing 5 phases and three main conventions on the euro/dollar exchange rate between January 1995 and December 2008.

The new economy convention prevailed from January 1995 to December 2000. Investors were relatively more optimistic on the perspectives of the US economy than on the ones of the European economy. Investors were fascinated by stronger US growth rates and expected profits offered by the US economy. The dollar appreciates in this period. The burst of the internet bubble put an end to the new economy convention. Between January 2001 and June 2003, investors were bear either in the United States or in the euro zone. The market was looking for a new convention. The exchange rate between the two economic zones fluctuates around a constant. From July 2003 to December 2005 two competing conventions prevailed among market participants. A bear convention focused mainly on large US current deficits and a bull convention focused notably on the spectacular recovery of the US economy from the internet bubble burst. During this period the dollar fluctuates between appreciating and depreciating trends according to whether the bull convention dominates the bear convention. Between January 2006 and June 2007, the bear convention started to dominate the bull one. Indeed, several factors acted against the bull convention notably the possible burst of the bubble on house prices that could trigger an economic downturn and the surge in oil prices that acts as a burden on US households' disposable income. In June 2007, the subprime crisis put an end to the bull convention. Investors became bear in the United States as well as in the Euro zone. The bear sentiment appeared however weaker in the euro zone.

The next step of the analysis is to build a model of exchange rate based on conventions in order to test whether market sentiment significantly explains the dynamics of exchange rates.

3. Estimation output of the convention model

The empirical model relies on a two-state Markov switching framework. In the bull state, we consider four fundamentals that constituted the basis of the bull conventions identified in section 2. These fundamentals are the growth rate of the industrial production ($\Delta indprod$) and the variation in expected profits ($\Delta profit^a$) in the United States and in the euro

zone. In the bear state, we consider four fundamentals that had a major place in the bear conventions. These fundamentals are the external debt of the United States and the euro zone ($\Delta netiipgdp$)[2], oil prices (Δop) and the US growth rate in house prices (ΔHPI). A description of the data is available in appendix A. The structure of the convention model is defined below:

$$\Delta s_t = \begin{cases} \alpha_{10} + \alpha_{11}\Delta indprod_t^{EU} + \alpha_{12}\Delta indprod_t^{US} + \alpha_{13}\Delta profits_t^{a,EU} + \alpha_{14}\Delta profits_t^{a,US} + \varepsilon_{1,t} & S_t = Bull \\ \alpha_{20} + \alpha_{21}\Delta niipgdp_t^{EU} + \alpha_{22}\Delta niipgdp_t^{US} + \alpha_{23}\Delta op_t + \alpha_{24}\Delta HPI_t^{US} + \varepsilon_{2,t} & S_t = Bear \end{cases}$$

$$(4)$$

The estimation period spans January 1995 to December 2008. A daily frequency data appeared as the best frequency to estimate this model (unsatisfying results were obtained on a monthly and weekly frequency data).

The estimation of the convention model is based on the Expectation Maximization (*EM*) algorithm (Dempster, Laird and Rubin (1977))[3]. The *EM* algorithm is considered as the best algorithm to estimate such model (see Dempster *et al.* (1977), Hamilton (1990), Vigfusson (1996), Bessec and Robineau (2003)). A description of this algorithm is available in appendix C. Table 1 presents the results related to the estimation of the convention model.

Table 1: Results from the estimation of the convention model

States	Coefficients				
	α_{10}	α_{11}	α_{12}	α_{13}	α_{14}
Bull	-0, 22x10^{-2}** [-55,30]	4,55x10^{-2} [1,08]	-5,32x10^{-2}** [-4,89]	0,18** [17,42]	-0,18x10^{-2} [-0,74]
	α_{20}	α_{21}	α_{22}	α_{23}	α_{24}
Bear	0,10x10^{-2}** [26,54]	-0,13x10^{-2} [-0,13]	-1,07x10^{-2}** [-4,23]	0,55x10^{-2}** [2,50]	0,92** [4,01]

NB: Student statistics are mentioned in square brackets; critical values for the test of Student amounts to 1,96 at a 5 % confidence level (**) and at 1,64 at a 10 % confidence level (*).

Estimated coefficients have the expected sign both in the bull state and in the bear state. In the bull state, the coefficient α_{12} associated to the US industrial production is significant and higher than the coefficient α_{11} associated to the European industrial production. Therefore, when markets are bull an increase in the industrial production in Europe and in the US will lead to an appreciation of the dollar. Because investors believe the US economy offers more profitable perspectives than the European economy, agents overweight the growth rate of the US economy thereby ignoring the growth rate in the euro zone (the coefficient α_{11} is not significant).

The coefficient α_{14} associated to expected profits on the S&P500 is not significant contrary to the coefficient α_{13} relative to expected profits on the Eurostoxx. This result is rather surprising. Indeed, with the financial globalisation and its induced market integration, the evolution of stock prices is barely different between the United States and the Eurozone with a causality usually running from the US stock market to European stock markets (see Granger causality tests in appendix D). We attribute the unsignificancy of expected profits on the S&P500 to the presence of multicollinearity between the series representing the expected

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[2] US and European current deficits were first considered in the model but results were not as satisfying as with the net international investment positions.

[3] The model is estimated with GAUSS. Codes are based on the work of Bessec and Robineau (2003).

profits on the S&P500 and on the Eurostoxx. Indeed, the correlation between both series is positive and higher than 70 %[4].

In the bear state, the coefficient in front of the external debt is significant for the United States (α_{22}) contrary to the euro zone (α_{21}). The larger US external debt compared to the weaker amount of the European external debt explains why α_{21} is not significant. Therefore, when markets are bear, an increase in the external debt in Europe and in the United States leads to a depreciation of the dollar since bear agents overweight the external debt of the United States and ignore the European debt.

Coefficients relative to oil prices (α_{23}) and the growth rate of house prices (α_{24}) are also significant and correct signed. Because US agents are greedier consumers of oil relative to European agents, an increase in oil prices acts as a burden on the profits of US companies and on the consumption of US households. Besides, when agents are bear an increase in the growth rate of US house prices leads investors to be more timorous about a possible burst of the house price bubble. As a result, higher oil prices and higher house prices lead investors to reduce their investment in the US economy, inducing a depreciation of the dollar.

The interpretation of estimated coefficients clearly shows that US fundamentals are more important than European fundamentals concerning the determination of the euro/dollar exchange rate. Market agents thus give more weight to news coming from the US economy than to the ones coming from the European economy. As a result, when the market is bull, agents will be relatively more optimistic in the United States than in the Euro zone leading to an appreciation of the dollar against the euro. Conversely, when the market is bear, agents will be relatively more pessimistic in the United States than in the Euro zone inducing a depreciation of the dollar. We carry on the analysis by taking in mind this result especially for section 4.

Table 2 shows the conditional and unconditional probabilities of being in a given state as well as the expected duration of the states.

Table 2: Conditional probabilities, unconditional (or ergodic) probabilities and expected regime duration

States	Conditional Probabilities	Unconditional Probabilities	Regime Expected Duration	State Variances
Bull	$p = 0,93$	$\pi_{Bull} = 0,68$	$d_{Bull} = 14$ days	$\sigma_{Bull} = 4,00 \times 10^{-6}$ [93,45]
Bear	$q = 0,85$	$\pi_{Bear} = 0,32$	$d_{Bear} = 7$ days	$\sigma_{Bear} = 7,00 \times 10^{-6}$ [56,07]

NB: $p = P(S_t=Bull/S_{t-1}=Bear)$; $q = P(S_t=Bear/S_{t-1}=Bull)$; $\pi_{Bull} = (1-q)/(2-p-q)$; $\pi_{Bear} = (1-p)/(2-p-q)$; $d_{Bull} = 1/(1-p)$; $d_{Bear} = 1/(1-q)$; Student statistics are mentioned in squared brackets.

Conditional Probabilities shows that when agents have a bear sentiment on the US economy in the past, there is a higher probability that they will be bull in the United States in the future ($p>q$). Over the period, the probability to be in the bull state amounts to 0,68 while the probability to be in a bear state amounts to 0,32 ($\pi_{Bull} > \pi_{Bear}$). Besides, the duration of being bull in the US economy is twice as much as the duration of being bear in the US economy ($d_{Bull} > d_{Bear}$). These results confirm the common belief among financial investors that the structure of the US economy offers better perspectives than the structure of the European economy. Such a belief finds its justifications through a more active and more

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[4] Another reason for the unsignificancy of α_{14} might be that the series $profit^{a,US}$ is not good enough to fit the profits expected by financial investors in the EUS economy (see appendix A).

flexible US economy compared to the euro zone which is more passive and more rigid. The US economy has indeed a deeper financial system, a higher investment in R&D and a more flexible labour market, *etc.*

The volatility of both regimes is very low. The variance of the bull regime is only slightly lower than the volatility of the bull regime ($\sigma_{Bull} < \sigma_{Bear}$). This rigidity in the variation of the states means that when agents are in a given state, they are reluctant to change to the other state. This fact is in line with the definition of a convention. Indeed, once agents have determined a convention, they disregard fundamentals in opposition to their convention. Agents thus neglect the fundamentals that could lead to reconsider the current convention and hence to a possible change in their current sentiment.

Table 3: Diagnostic Tests related to the convention model

Diagnostic Tests		Statistics
Maximum Likelihood *lnL*		19371,78
Autocorrelation Tests (H_0: No Autocorrelation)	*Regime 1*	8,44 (0,00)
	Regime 2	1,54 (0,28)
	Both Regimes	0,14 (0,79)
Heteroscedasticity Tests (H_0: Homoscedasticity)	*Regime 1*	4,97 (0,04)
	Regime 2	549,80 (0,00)
	Both Regimes	1041,37 (0,00)
Linearity Test (H_0: Linear Model)		30,21 (0,99)

NB: Autocorrelation tests and heteroscedasticity tests follow a $\chi(1)$; Linearity test follows a $\chi(4)$. The critical values for a $\chi(1)$ amounts to 2,70 and 3,84 respectively at a 10 % and 5 % confidence level. The critical values for a $\chi(8)$ amounts to 13,36 and 15,50 respectively at a 10 % and 5 % confidence level; *p-values* are mentioned in parenthesis.

Diagnostic tests on the convention model show the absence of autocorrelation in both regimes. ARCH tests however reveal heteroskedasticity in the variance of error terms. Heteroskedasticity is a common observation when modelling financial series at daily frequencies. Heteroskedasticity can be countered by introducing a ARCH/GARCH component in the variance of errors. MacDonald and Marsh (1999) show however that the introduction of such a component does not significantly improve the likelihood of the model and makes the structure of the model more complicated. Besides, we reject the hypothesis of the use of a non-linear Markov structure of order one. This result is often observed in studies using a Markov switching structure of order one (Vigfusson (1997), Bessec and Robineau (2003)). Those studies suggest considering more than two states. In the case of the convention model, we could consider a bear state, a bull state and an intermediate speculative (or random walk) state representing the transition state between the bull and the bear states.

4. Lessons drawn from the convention model

4.1 Filtered probabilities and conventions prevailing among market agents

This section highlights the prevailing conventions among market agents through the analysis of filtered probabilities related to the Markov switching framework. Figure 24 represents the dynamics of the euro/dollar exchange rate (right scale) as well as the probabilities of being relatively more bull in the United States than in the euro zone (left scale). To ease the analysis, filtered probabilities are smoothed with a Hodrick-Prescott filter (with $\lambda = 1500$). The blue margins ($P(S_t=Bull/I_t)>0,5$) indicate that the market is relatively more bull in the US economy than in the European economy. The white margins ($P(S_t=Bull/I_t)<0,5$) indicates that the market is relatively more bear in the US economy than in the European economy.

Figure 27: Euro/dollar dynamics and filtered probabilities $P(S_t=Bull/I_t)$ of being relatively more bull in the United States than in the European economy
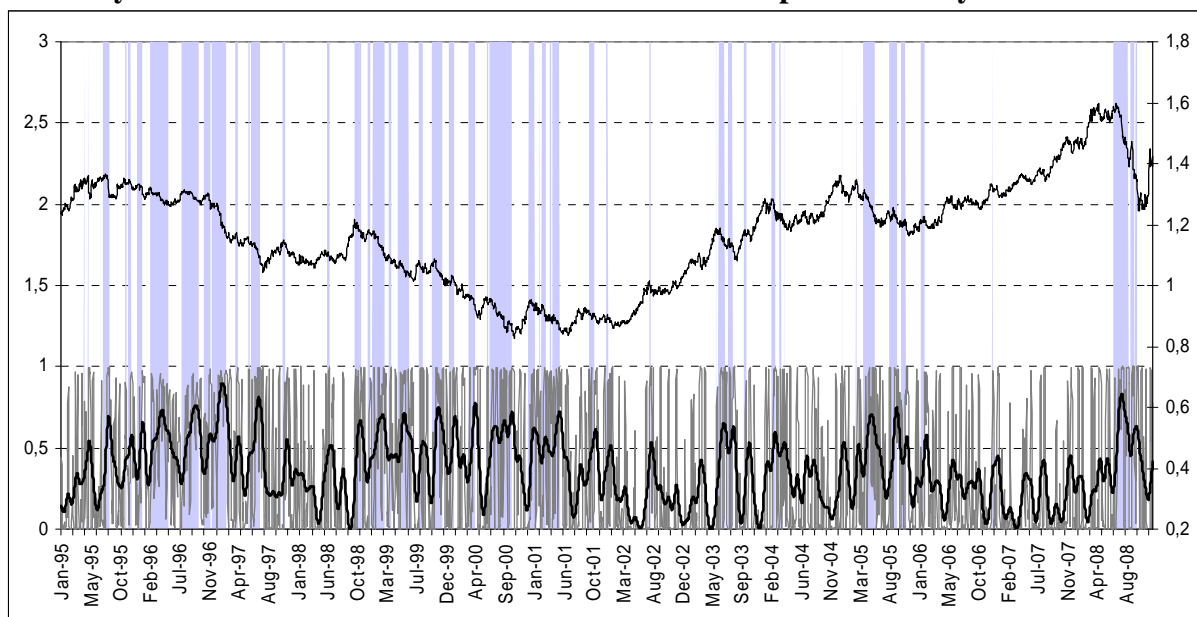
Source: Thomson Datastream for the exchange rate; author computations for the filtered probabilities.

From January 1995 to December 2000, the model gives more weight to the bull state. The model thus represents the higher optimistic sentiment that prevailed in the US economy relative to the European economy. It thus highlights the new economy convention. During this period the dollar appreciated. We note however a strong tendency towards the bear state between September 1997 and September 1998. This observation is related to the financial turmoil induced by the Asian crisis of 1997 and then the Russian crisis of 1998 which causes the quasi-bankruptcy of the Long Term Capital Management fund (LTCM) in the United States.

The burst of the internet bubble in January 2001 led to the collapse of the new economy convention. This convention suddenly disappeared from the market. As shown in figure 24, the market became more pessimistic about the perspectives of the US economy relative to the European economy until June 2003. The dollar depreciated between January 2001 and June 2003.

From July 2003 to December 2005, the market alternates between two conventions: a bull convention based on the resistance of the US economy and its profitable perspectives;

and a bear convention related to concerns about the sustainability of large US current deficits. Between July 2003 and December 2004, the bear sentiment dominates in the market (figure 24). The market is relatively more pessimistic about the US economy than the European economy: the dollar depreciates. Conversely, between January 2005 and December 2005, the bull sentiment dominates the bear one. The market becomes more optimistic about the US economy than the European economy: the dollar appreciates.

The accumulation of negative factors concerning the US economy after January 2006 (larger US current deficits, house price bubble, surge in oil prices) puts an end to the bull sentiment prevailing on the US economy. The bear sentiment invaded the market and definitely dominated the bull sentiment at the start of the subprime crisis in June 2007. The market become at that time more pessimistic in the US economy than in the European economy: the dollar depreciates during this period (figure 24).

As the financial crisis began in the United States, its negative effects were primarily experienced by the US economy. Hence between July 2007 and September 2007, investors became more confident on the European economy relative to the US economy. However, when investors (notably US investors) realised that even the European economy would be affected by the financial turmoil, they started to withdraw their capitals from European markets. This outflow of capitals from the Euro area towards the United States explains the appreciation of the dollar between July 2008 and November 2008. In this period, figure 24 shows an increase in the weight of being relatively more optimistic in the US economy than in the European economy. Indeed, investors are relatively more confident in the US economy compared to the European economy since they preferred keeping their liquidities in the United States although both the euro zone and the United States were in recession at that time. This observation can be related to the home bias: when the aversion of risk increases, US agents prefer keeping their liquidities home rather than abroad.

Finally, the convention model shows that switches between a bull and a bear sentiment among market participants match the dynamics of the euro/dollar exchange rate. Filtered probabilities are able to define when the market experiences a bear sentiment or a bull sentiment. The model thus validates the results from the analysis of the conventions that prevail among market participants for the euro/dollar exchange rate (section 2).

4.2 Lessons for public authorities concerning exchange rate excess volatility

This section shows that the convention model allows decomposing a convention in various phases. Figure 25 represents the filtered probabilities (left scale), the volatility of the euro/dollar exchange rate (right scale) and the dynamics of the euro/dollar exchange rate (no scale).

Figure 25: Convention reversals and euro/dollar exchange rate volatility
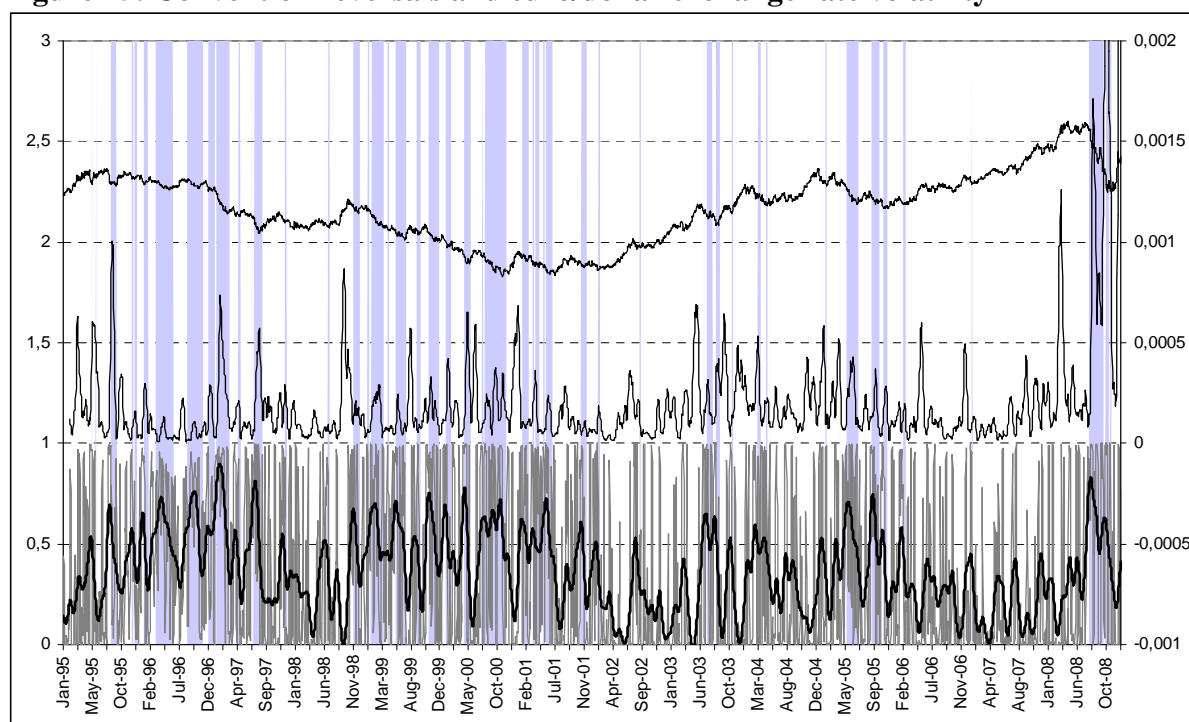
Source: Thomson Datastream for the exchange rate; Authors computations for the filtered probabilities; The volatility of the euro/dollar exchange rate is defined by the monthly smoothed variance of the exchange rate.

From figure 25 and by ignoring punctual peaks of volatility, we notice that before any strong variation in the market sentiment a bunch of high volatility appears in the dynamics of the euro/dollar exchange rate. Between January 1995 and December 2008, we observe four main bunches of high volatility clustering (see figure 26).

The first bunch appears between January 2000 and December 2001 (figure 26). This bunch defines the end of the internet convention and the beginning of the search for a new convention. This new convention was notably based on negative factors such as the large US current account deficits. Filtered probabilities clearly show the switch between the bull state and the bear state. Once, the bear convention has been adopted by the market, the volatility of the exchange rate decreases (January 2002 - March 2003).

The second bunch of volatility appears in April 2003 (figure 26), when fundamentals show that the US and European economies are recovering from the bubble burst. Hence such fundamentals act as anomalies towards the current bear convention. This leads market agents to bet against the current bear convention. However, market agents do not totally abandon their bear sentiment since US deficits are still increasing at that time. We hence have two competing conventions in the market: a bull convention mainly based on the resistance of the US economy and a bear convention mainly based on the large US deficits[5]. This competition between bull agents and bear agents occurs from April 2003 until September 2006. This competition is clearly represented in figure 26. Based on filtered probabilities, one can observe that every time the market goes bull, exchange rate volatility increases. The volatility increases because agents that believe more in the bear convention try to bet against the bull convention when the bull convention starts to dominate the market. As a matter of facts, from

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[5] To understand why such bull and bear conventions are mainly based on US fundamentals, the reader should remind the result concerning the estimated coefficients of the convention model (section 3). The interpretation of estimated coefficients clearly shows that US fundamentals are more important than European fundamentals concerning the determination of the euro/dollar exchange rate (section 3, page 16).

figure 26, the market is bull and exchange rate volatility increases in the periods June 2003-July 2004 and January 2005-February 2006. Conversely, the market is bear and the volatility decreases between May 2004 and December 2004. This competition between bull and bear agents is related to the existence of striking positive and negative factors at that time in the US economy: respectively, a strong recovery sustained by a high level of consumption while on the other hand larger US deficits. Because of these positive and negative factors, the market struggles to find which convention is more pertinent.

The competition between bull and bear agents ends after September 2006 when negative factors (larger US external debt, surge in oil prices, fears in a burst of the US house price bubble) come as anomalies towards the bull convention that is mainly based on a sound and resistant US economy. From September 2006 until September 2008, the bear convention definitely dominates the bull one. Market agents therefore agreed on the choice of a bear convention. The volatility of the euro/dollar exchange rate decreases significantly during this period. The market becomes here more bull in the European economy than in the US economy until the subprime crisis contaminates the European economy in September 2008.

Between September 2008 until December 2008, investors (and especially US investors) withdraw their capitals from the European economy to keep them safe in the US economy although both the US and the European economies are in recession. Investors become hence relatively more confident in the US economy than in the European economy. This reversal of sentiment is associated with an increase in the volatility of the euro/dollar exchange rate (figure 26).

Figure 26: Convention reversals and euro/dollar exchange rate volatility
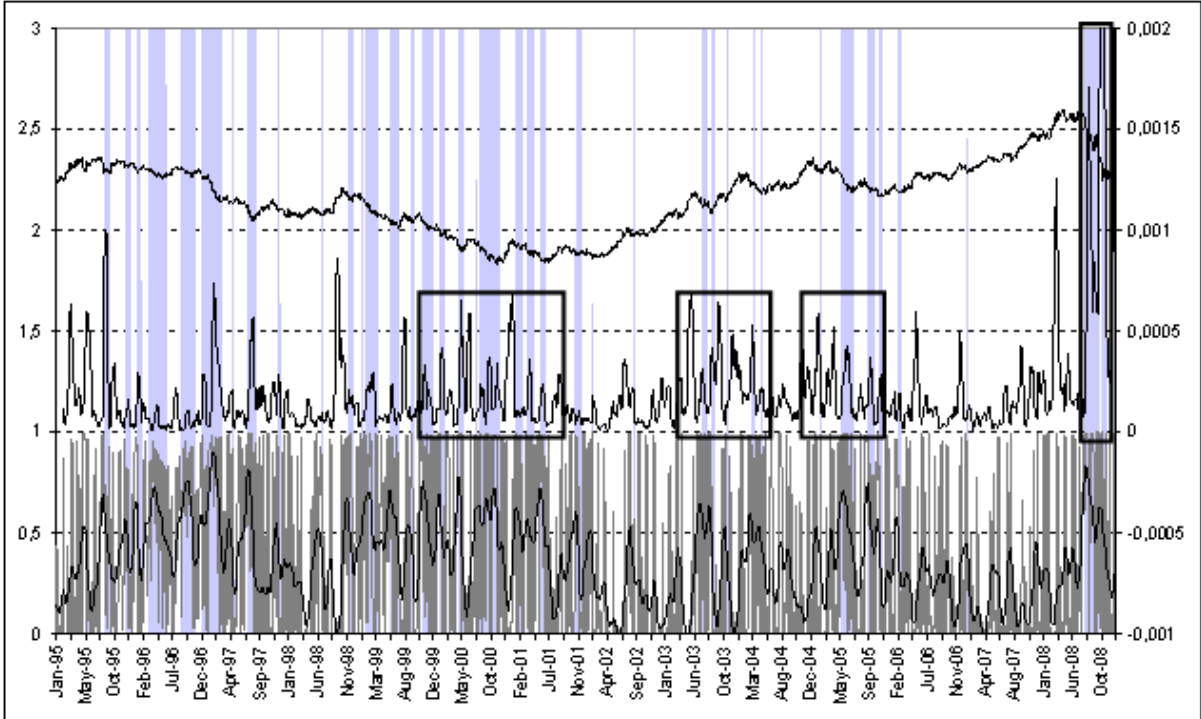
Source: Thomson Datastream for the exchange rate; Authors computations for the filtered probabilities; The volatility of the euro/dollar exchange rate is defined by the monthly smoothed variance of the exchange rate.

A major lesson drawn from the above analysis is that changes in conventions (or in market sentiment) are associated to an increase in the volatility of exchange rates.

Particularly, along with Orléan (2006), one can distinguish three phases in the formation of a convention.

The first phase is represented by the search for striking factors that could constitute a convention. The bet on multiple equilibria for the next convention leads to an increase in exchange rate volatility. Empirical examples are found at the beginning of the second bull convention (April 2003) and, at a more global level, over the period characterised by the competition between the bull and bear conventions from April 2003 until September 2006 (such a competition confronts two possible equilibria in the market).

The second phase represents the finding of a particular convention. Agents stabilise on a unique model and exchange rate volatility decreases dramatically. Empirical justifications are found in the new economy convention (January 1995-September 2000) and in the definite domination of the bear convention (September 2006-August 2008).

Finally a third phase represents the weakening of the current convention through the accumulation of anomalies with the current convention. Agents lose confidence in the current conventions. During this phase, exchange rate volatility increases. The weakening of the internet convention (September 2000 - June 2001) as well as the weakening of the bull sentiment in the European economy before the subprime crisis (August 2008 - December 2008) constitute empirical examples.

Therefore the increase in exchange rate volatility appears when there is uncertainty concerning the prevailing convention in the market. In other words, volatility increases when agents are uncertain about the model to adopt to form their expectations of asset price dynamics in the future. Along with Orléan (2006), we consider that public authorities can play a major role during these phases of uncertainty (first and third phases). Public authorities can reduce uncertainty by facilitating the emergence of a new convention. The confidence of agents will be restored and exchange rate volatility lowered. This intervention can proceed directly by speeches or notes releases. The former method holds especially today since financial markets attribute a large importance to words in speeches given by public authorities (especially central bankers). Another way can be found indirectly through the manipulation of a major media company by public authorities since conventions builds and weakens through the intermediary of financial media as shown in section 2. Eventually, as financial markets must have a high level of confidence in the public authorities that provide such interventions, possible institutions qualified for such interventions are financial market supervisory authorities or central banks.

4.3 Do conventions provide an answer to the exchange rate disconnection puzzle?

The exchange rate disconnection puzzle states that the dynamics of currency prices are disconnected from their fundamentals. The disconnection puzzle was highlighted by Meese and Rogoff (1983). They found that traditional exchange rate models based on a linear symmetric structure offer little explanatory and predictive powers to macroeconomic fundamentals. As argued later by Cheung, Chinn and Garcia Pascual (2005), the relationship between exchange rates and macroeconomic variables appears rather unstable across time. Cheung *et al.* showed that some linear models with particular macroeconomic variables perform well in some periods but not in others.

Compared to traditional exchange rate models, the convention model provides two advantages. First it considers the fact that investors do not react the same way to a shock on a given fundamental (asymmetric structure). Secondly, it takes into account the fact that some variables may be more important in some periods of time while others are not (non-linear structure). Since switches between fundamentals considered in the bull and the bear states explain the dynamics of the euro/dollar exchange rate, the convention model simply resolves the disconnection puzzle.

The failure of traditional models to explain exchange rate dynamics based on macroeconomic fundamentals can thus be related to the fact that their structure do not take into account the varying weight that agents give to different macroeconomic fundamentals. As a consequence, following Frydman and Goldberg (2007) I argue that the exchange rate disconnection puzzle is a pure artefact of the misspecification of traditional exchange rate models. The structure of such models is simply unfitted to explain the dynamics of exchange rates.

5. Conclusion

The present paper provides a new explanation for the dynamics of the euro/dollar exchange rate based on conventions that prevails among market participants. The convention model shows that switches between a bull and a bear sentiment among market participants explain the dynamics of the euro/dollar exchange rate. This model therefore resolves the disconnection puzzle. The paper hence offers a new way to model the behaviour of exchange rates. As results appear rather satisfying, it could be interesting to apply the convention model to other asset prices in order to assess the robustness of the convention theory.

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Appendix

A. Variables considered in the convention model

The period of analysis spans January 1995 to December 2008 on a daily data frequency. Data come from the following sources: *Thomson Datastream*, *Federal Reserve* and *US Federal Housing Finance Agency*.

A.1 Endogenous variable

The endogenous variable is the variation in the (log of) the nominal exchange rate s_t:

$$\Delta s_t = log(S_t/S_{t-1})$$

With *S*, the euro/dollar nominal exchange rate (listed as 1 euro per *S* dollars). To reduce noise, we smooth this series with a Hodrick-Prescott filter (we considered $\lambda=1$).

A.2 Exogenous variables

Exogenous variables are parted between two states (bull or bear) according to the analysis of market sentiment.

- The Bull State

We assume that when the market is bull in the United States, it will overweight US industrial production and US expected profits because the structure of the US economy offers better perspectives than the structure of the European economy. Indeed, a common belief among investors is that the US economy is more active and flexible than the European economy. Factors justifying this belief can be found in a deeper US financial system, higher US investment in R&D, *etc*. As a result, we consider in the bull state two fundamental variables that affect more positively the United States than the Euro zone. We consider the industrial production (*INDPROD*) which plays the role of a proxy for GDP; and expected profits (*PROFIT^a*).

$$\Delta indprod_t = log(INDPROD_t/INDPROD_{t-1})$$

With *INDPROD*, the monthly index of industrial production. This series being available only in monthly frequency, the series was transformed in a daily frequency through a Quadratic Match Average filter.

$$\Delta profit_t^a = log(PROFIT_t^a / PROFIT_{t-1}^a) \qquad \text{With } PROFIT_t^a = \frac{SPI_t}{PER_t}$$

With *SPI*, the stock price index (we consider respectively, the Eurostoxx for the euro zone and the S&P500 for the United States); and *PER*, defines the price earning ratio related to the respective stock indices.

- The Bear State

Concerning the bear state, we consider variables that affect more negatively the United States than the euro zone. Four variables are considered: the external debt (*NIIPGDP*), oil prices (*OP*) and a price index of house prices in the United States (*HPI*). Those variables are defined below:

$$\Delta niipgdp_t = NIIPGDP_t - NIIPGDP_{t-1}$$

With *NIIPGDP*, the net international position over the GDP of the respective economic zone. This variable represents the burden of debt in the United States and the depreciation risks induced on the dollar. We include this variable for the euro zone even if the external debt of the euro zone is very small compared to the US external debt. This series being available only in an annual frequency, the series was transformed in a daily frequency through a Quadratic Match Average filter. We then smoothed it with a Hodrick-Prescott filter (we considered $\lambda = 6812100$).

$$\Delta op_t = log(OP_t/OP_{t-1})$$

With *OP*, the oil price as listed for the barrel of brent of the North Sea. This variable is seen as an expected indicator of growth in the United States. US households being a large consumer of oil, an increase in oil prices will trigger fears in investors' sentiment that the US consumption will decrease and therefore that growth in the United States will slowdown.

$$\Delta HPI_t = log(HPI_t/HPI_{t-1})$$

With *HPI*, the house price index IAS360 delivered by the US Federal Housing Finance Agency (formerly OFHEO). The US price index is seen here as a proxy of fears associated to the increase in the real estate bubble between July 2003 and June 2007: the higher the positive growth rate in the US house price index, the higher the probability of a burst in the house bubble. We do not consider this variable for the euro zone since house prices did not experience a bubble (only perhaps in the Spanish economy negligible at a European level). This series being available only in monthly frequency, the series was transformed in a daily frequency through a Quadratic Match Average filter.

Some readers may cast doubts on the method chosen to filter annually and monthly macroeconomic series in a daily frequency. However the filtering of macroeconomic series is not quite problematic here since such series follow high trends and have low volatility. This argument goes particularly for the variable *NIIPGDP*. It would have been more problematic if we would have filtered annually or monthly financial series to daily frequencies since such series are much more volatile than macroeconomic series.

Besides, the interest rate differential is not included in the convention model for two reasons. First, it is difficult to attribute any optimistic or pessimistic market sentiment to this variable. Secondly, the interest rate differential between the United States and the euro zone is too low over the estimation period to explain the dynamics of the euro/dollar exchange rate.

B. Stationnarity Tests

Stationnarity tests are based on three tests: the Augmented Dickey-Fuller (ADF) test, the Phillips-Perron (PP) test and the Kwiatkowski-Phillips-Schmidt-Shin (KPSS) test. Results are presented in tables B.1 and B.2.

Table B.1: Stationnarity tests on the endogenous variable

Variables	ADF	PP	KPSS
Δs	-24,50*** (0,00)	-14,30*** (0,00)	0,07*

NB: For the ADF test the Akaike criteria with 2 lags is considered; *p-values* are mentioned in parenthesis; stars denote a stationary series at a 1 % (***), 5 % (**), 10 %(*) confidence level.

Table B.2: Stationnarity tests on the exogenous variables

Bull State				Bear State			
Variables	ADF	PP	KPSS	Variables	ADF	PP	KPSS
$\Delta indprod^{EU}$	-24,19*** (0,00)	-59,06*** (0,00)	0,17***	$\Delta niipgdp^{EU}$	-77,75*** (0,00)	-88,13*** (0,00)	0,13**
$\Delta indprod^{US}$	-23,61*** (0,00)	-60,46*** (0,00)	0,25***	$\Delta niipgdp^{US}$	-18,05*** (0,00)	-65,04*** (0,00)	0,62
$\Delta profit^{a,EU}$	-63,84*** (0,00)	-63,79*** (0,00)	0,23***	Δop	-62,09*** (0,00)	-62,09*** (0,00)	0,04**
$\Delta profit^{a,US}$	-38,50*** (0,00)	-64,48*** (0,00)	0,27***	ΔHPI	-16,41*** (0,00)	-66,41*** (0,00)	-1,20

NB: For the ADF test the Akaike criteria with 2 lags is considered; *p-values* are mentioned in parenthesis; stars denote a stationary series at a 1 % (***), 5 % (**), 10 %(*) confidence level.

Stationnarity tests validate the stationnarity of the series considered on the convention model.

C. Description of the *EM* algorithm

The estimation of the convention model is based on the Expectation Maximization (*EM*) algorithm (Dempster, Laird and Rubin (1977)). The *EM* algorithm is an iterative optimization method that allows finding the maximum likelihood of parameters in probabilistic models where the model depends on unobserved latent variables. The *EM* algorithm alternates between performing an expectation step (*E*) and a maximization step (*M*).

In the *E* step, the missing parameters are estimated given the observed data and current estimates of the model parameters. The *E* step introduces a hidden variable *Z* that makes the estimation of the likelihood function easier.

Let *X*, be a vector of random variables and θ be a vector of parameters. The objective is to find the maximum likelihood estimate of θ. In other words, we wish to find θ in a set Ω such that $F(X, \theta)$ is a maximum. The likelihood function is described as a function of the parameter θ given the data *X*:

$$L(\mathrm{X},\theta) = \ln F(X, \theta) = \sum_{i=1}^{N} \ln f(x_i, \theta)$$

Since ln(x) is a strictly increasing function, the value of θ that maximises $F(X, \theta)$ also maximises $\ln F(X, \theta)$. We define $L(\mathrm{X}, Z, \theta)$ such that:

$$L(\mathrm{X, Z, }\theta) = \ln F(X,Z,\theta) = \sum_{i=1}^{N} \ln f(z_i / x_i, \theta) + \sum_{i=1}^{N} f(x_i, \theta)$$

Hence: $$L(\mathrm{X,}\theta) = \mathrm{L(X, Z, }\theta) - \sum_{i=1}^{N} \ln f(z_i / x_i, \theta)$$

The *E* step computes an expectation of the log likelihood function with respect to the current estimate of the distribution for the latent variables. The *E* step can be interpreted as building a local lower-bound to the posterior distribution. This is achieved by using the conditional expectation conditional on the present value of θ (θ_k):

$$E[L(X,\theta/ \theta_k)] = E[L(X, Z, \theta/ \theta_k)] - E[\sum_{i=1}^{N} \ln f(z_i / x_i, \theta) /\theta_k]$$

<=> $$L(X, \theta, \theta_k) = \mathrm{Q}(\theta, \theta_k) - \mathrm{H}(\theta, \theta_k)$$

In the *M* step, the bound is optimised thus improving the estimate for the unknown parameters. The likelihood function is maximised under the assumption that the missing data are known. The *M* step computes the parameters which maximizes the expected log likelihood found in the *E* step. The next value of the parameter θ, θ_{k+1} is chosen such that:

$$L(\mathrm{X,}\theta_{k+1}/\theta_k) \geq L(\mathrm{X,}\theta_k/\theta_k) \qquad\qquad \forall \theta \in \Omega$$

In other words, the *M* step chooses the parameters values θ_{k+1} that maximises the quantity $L(\mathrm{X}, \theta_{k+1} /\theta_k)$ computed in the *E* step:

$$M(\theta_{k+1}) = \arg \max_{\theta \in \Omega} \left\{ L(X,\theta_{k+1} / \theta_k) \right\}$$

The parameter θ are then used to determine the distribution of the latent variables in the next *E* step. The *E* and *M* steps are reiterated until the convergence of the algorithm. The convergence is achieved for the vector parameter θ that provides the maximum value of the likelihood function. Convergence is assured since the algorithm is guaranteed to increase the likelihood for each iteration.

The procedure of the *EM* algorithm can thus be summarised as follows. The vector of parameters θ is initialised: coefficients values based on the estimation of the bull/bear equation considered linearly allow defining the vector θ_0. The two steps of the algorithm are then computed. Whenever the algorithm has not converged we reiterate the procedure. The *EM* algorithm has the advantage to converge faster towards the optimal values of the log-likelihood function. However, the major drawback associated to the *EM* algorithm is that it can provide only local maximum likelihood. To counter this drawback we compute the *EM* algorithm based on different initial parameter values in order to increase the probability to reach the global maximum likelihood.

E. Granger causality tests between US stocks and European stocks

Results concerning Granger causality tests on stock indices and on expected profits on stocks in the United States and in the euro zone are presented in table D.

Table D: Granger Causality tests between US stocks and European stocks

| Null Hypothesis	Statistics
S&P500 does not Granger cause *Eurostoxx*	285,95 $(2\text{x}10^{-116})$
Eurostoxx does not Granger cause *S&P500*	0,01 (0,98)
profit^{a,US} does not Granger cause *profit^{a,EU}*	7,29 (0,00)
profit^{a,EU} does not Granger cause *profit^{a,US}*	1,91 (0,14)

NB: Two lags are considered in the Granger causality tests; *p-values* are mentioned in parenthesis

Table D shows that we reject the hypothesis that "*S&P500 stocks* does not Granger cause *Eurostoxx*" and that "*profit^{a,US}* does not Granger cause *profit^{a,EU}*" at a 5 % confidence level. Conversely, the hypotheses assuming that "*Eurostoxx* does not Granger cause *S&P500*" and that "*profit^{a,EU}* does not Granger cause *profit^{a,US}*" are rejected at a 5 % confidence level. This test confirms that the causality in stock prices runs from the Unites States to the euro zone.

F. Smoothed Probabilities

Figure 27 represents the smoothed probabilities estimated from the convention model.

Figure 27: Euro/dollar dynamics and smoothed probabilities $P(S_t=Bull/I_T)$ of being relatively more bull in the United States than in the European economy
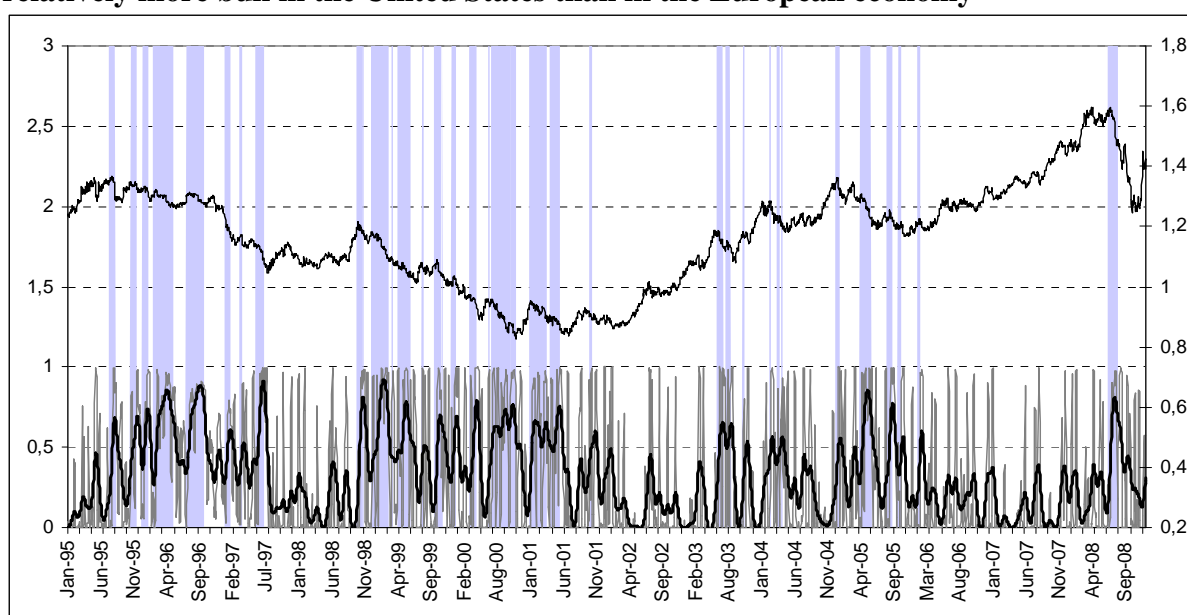
Source: Thomson Datastream for the exchange rate; author computations for the smoothed probabilities.