A COMPARATIVE STUDY OF BUBBLE COMPONENTS

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A COMPARATIVE STUDY OF BUBBLE COMPONENTS

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DECLARATION OF ORIGINALITY

I, Alp Güven Buğra Akyüz, certify that

- I am the sole author of this thesis and that I have fully acknowledged and documented in my thesis all sources of ideas and words, including digital resources, which have been produced or published by another person or institution;
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ABSTRACT

A Comparative Study of Bubble Components

The co-movement of prices across the world was highlighted during the Credit Crunch of 2008 and the following periods. Since the price drop is attributed to bursting bubbles, it is of interest whether bubbles also follow a diffusion process across countries. This thesis, calculates the bubble percentages using the Kalman Filter approach and runs Granger causality test in order to determine how bubbles spill over across countries. The results suggest that bubbles indeed spill over and the diffusion process is determined by the development level and economic ties of countries rather than geographical proximity. Moreover, bubbles spill over to emerging markets from developed ones and not the other way around. Whereas, the bubbles spill over across developed economies in a bilateral fashion.

ÖZET

Hisse Fiyatlarındaki Balon Kısımların Karşılaştırmalı İncelemesi

2008 Kredi Krizi ve sonrasında dünya çapında hisse fiyatlarının ortak hareketi dikkat çeken seviyelere ulaşmış bulunmaktadır. Fiyatlardaki aşağı yönlü hareketin büyük kısmı balon (köpük) fiyatların patlamasına atfedildiğinden dolayı ülkeler arasında bu fiyat şişmelerinin yayılma şekli merak konusudur. Bu çalışma, Kalman Filtresi yöntemini kullanarak fiyatlardaki balon yüzdesini hesaplamayı ve Granger nedensellik testini kullanarak balon fiyatların ülkeler arasındaki yayılma şeklini araştırmaktadır. Elde edilen sonuçlar balonların ülkeler arasında yayıldığını ve bu sürecin ülkeler arası coğrafi yakınlık ile değil iktisadi faaliyet bağlantıları aracılığıyla belirlendiği yönündedir. Ek olarak, balonlar gelişmiş ülkelerden gelişmekte olan ülkelere doğru tek taraflı taşınmaktadır. Gelişmiş ülkeler arasında bu süreç iki yönlü olarak tespit edilmiştir.

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CHAPTER 1

INTRODUCTION

The credit crunch of 2008 highlighted the interdependencies across global markets, especially the co-movement of asset and commodity prices. Since the global price drops were suggested to at least partially originate from bursting bubbles, the question of whether there are dependencies among bubbles across countries emerges. In particular, it could be investigated if the bubbles in one country lead to bubbles in others, hence suggesting a causality. In other words, if crises are being spread across countries, it can be asked if it is possible for the bubbles preceding them to gradually form with a similar diffusion system.

The anecdotal example of the most recent crisis draws a picture where the burst of the bubble in the U.S. markets was followed by financial turmoil in the developed world, then the rest. This suggests a contagion effect is in place during times of financial crisis. The spectrum of countries involved in chronological order ranges from developed to emerging, giving rise to the question whether the formation of bubbles also followed the same direction in this example. If it did, then the next question would be if there is an identifiable pattern for bubble diffusion in more general terms. Therefore, the first and main hypothesis of this thesis is:

Hypothesis 1: Bubbles diffuse from originating country to others, independent of the level of development.

The contagion effects of financial crises are not sufficient to prove that bubbles are also spread from one country to other. In order to determine if bubbles diffuse, possible hypotheses corresponding to different scenarios must be tested. As a starting point, one can confine the bubbles to financial and finance-related markets and hypothesize mechanisms that would create bubbles and spread them around.

There might be a number of possibilities for bubble formation. Since a large portion of the investment made all over the world comes from the developed countries, it might be possible that a general trend of overinvesting (hence driving the prices up to inflate bubbles) in the developed world also leads to channeling more funds to the emerging countries to inflate bubbles there as well. A similar logic would apply to the case of negative bubbles. A negative bubble[1] is created when the prices are lower than the actual[2] value of the stock. When a bubble bursts, the prices do not settle at the fundamental value but rather continue to fall below their actual level due to the momentum in stock prices, hence a burst positive bubble creates a negative bubble. As a contribution of this thesis, both bubble types are included in the analysis to give a more detailed and complete picture. The chronological order running from developed countries to emerging ones consists the second hypothesis of this study:

Hypothesis 2: Bubbles diffuse from developed countries to emerging ones.

A candidate for a counter-example for this scenario might be given as the dotcom crisis in the early 2000s. It started in the U.S. and affected European countries; however the rest of the world did not experience the substantial price drop at comparable levels (at least not in a way that is traceable to bubbles[3]). This is not to say that there was not a global crisis; but to suggest how its effects were channeled from one country to another.

The 1998 crisis originating from the Russia's moratorium did not immediately affect all economies until it triggered the bankruptcy of the Long Term Capital Management L.P. hedge fund and caused the U.S. and European bubbles to burst and affect the rest of the world. Hence it can be argued that the effects of a bubble are enhanced if it affects a developed country in its diffusion.

Hypothesis 3: Bubble diffusion process is enhanced if it reaches a developed country.

It should be reminded that crises are rare events. Therefore the bubble formation and bursts causing crises are rare and likely unique events. Hence it is not possible to test our hypotheses in a straightforward way by running regressions. Instead, this

[1]Most of the literature is focused on positive bubbles, i.e. an inexplicable increase in prices that is not driven by the changes in fundamentals and their bursts. Negative bubbles, on the contrary, have been mostly neglected since a negative burst means an increase in the price levels.

[2]It is problematic to argue what the actual price of a stock is, if it is not the market price; however one can imagine the fundamental value of the stock as being its actual value and the observed market price as the combination of this price and the bubble component. The later sections of this paper assume that this is the case.

[3]The Turkish and Argentinian experience is mostly attributed to the weak political and legal infrastructure back then and not the bubbles per se.

thesis aims to pave the way and illustrate a methodology to arrive at separated vectors for bubbles and actual prices that can be used in further research.

Hypothesis 4: Bubble percentages are larger for emerging markets than developed ones for the same spillover period.

It can be argued that it is the central position of developing countries in the global market network and not their level of development that determines their effect on bubble diffusion. However, since being more developed is mostly the reason for a country to have a central position, the two can be used interchangeably.

In order to be able to test for direction of bubble diffusion (or causality links), a method should be implemented to separate the bubble component from the observed stock price. One of the recent approaches in calculating the bubble component is to use Kalman filters. Kalman filters are popular tools in signal processing that is developed to separate the error in measurements to arrive at the actual value of a variable. In our case, this corresponds to separating the bubble component from the observed price based on past price and dividend data to arrive at the actual price level. The main advantage of employing this method is in its efficiency and reduced computational complexity. This thesis contributes to the bubble literature by extending the work of Hatipoğlu and Uyar (2012) on the U.S. and Turkish stock exchange to various developed and emerging markets and performing tests of causality.

CHAPTER 2

RELATED LITERATURE

Many studies were conducted on rational bubbles following the work of Shiller (1981) and Leroy and Porter (1981) showing that the price volatility cannot be explained by the new information on future dividends or the present value of future earnings. Many reasons were provided for this volatility including non-constant discount factors, noise traders, fads etc. but they fell short of adequately explaining it. As a result a new wave of studies started approaching this subject with a stock price and dividend nexus. The prominent ones in this strand are Campbell and Shiller (1988), Diba and Grossman (1988), Timmerman (1995), Nasseh and Strauss (2004), Koustas and Serletis (2005). Bubble models are constructed in either exogenous or endogenous form. The former approach treats bubbles as fully independent. The latter approach that started with Froot and Obstfeld (1991) accounts for the changes in asset fundamentals. This approach revolves around the notion of intrinsic bubbles and performs better than the exogenous bubbles approach since it allows for shocks to transfer to pricing decisions through asset fundamentals.

Froot and Obstfeld (1991) along with Driffill and Sola (1998) generalize this model by calculating bubbles from dividends that are determined by a two-state Markov-switching model. This study follows this strand and assumes bubbles are based on fundamentals as modeled in Froot and Obsfeld (1991), Driffill and Sola (1998) and van Norden and Schaller (2002). Our study, however, allows for *negative* bubbles, or in other words asset underpricings. It is expected to provide better results if both regular (positive) bubbles are modeled with negative ones since stocks can both be underpriced or overpriced for similar reasons. In modeling terms, our bubbles do not have non-negativity constraints. As it will be emphasized in later sections, this approach proves to be appropriate since negative bubbles are calculated to be higher in magnitude. The model employed here approximates the standard linear stock price determination with rational expectations process with log-linearization. The state space defined is similar to the one put forward by Wu (1997); bubbles are defined as unobserved state vectors. The difference is that the dividend process parameters are defined as time series variables and attempt to discover non-linearities in both. In our setup, bubbles are stochastic variables with non-constant growth rates. As argued in Santos and Woodford (1997) and Battalio and Schultz (2006), this approach performs better in representing non-linear and rational bubbles.

Instead of checking first whether bubbles exist, it is simply assumed that they do as in Balke and Wohar (2009) and are aimed to be identified. The approach here deviates from their ex ante regime switching model, however, and instead utilizes estimates of time varying coefficients to identify non-linearities. Following the works of Wu (1997) and Lau, Tan and Rahman (2005) bubbles are estimated with Kalman filters.

CHAPTER 3

DATA

The data come from the Bloomberg database. It contains the closing prices and dividend information for the prominent indices of 7 countries: Argentina, Brazil, France, Germany, Greece, The United Kingdom and The United States. The time interval changes depending on the availability of information. The earliest data included in the analysis here goes back to 1993. All prices and dividends are recorded in their respective local currencies. The dividend information is obtained by summing the dividends distributed in each period across the stocks in each index. List of countries and periods are given below (Table 1).

Table 1: List of countries and periods

Country	Periods Included
Argentina	2002-2015
Brazil	1995-2015
France	1993-2015
Germany	1993-2015
Greece	1995-2015
UK	1993-2015
USA	1993-2015

CHAPTER 4

METHODOLOGY

Consider the following present value model with variable discount rates,

$$e^{-r_t} = \frac{\mathbb{E}_t[P_{t+1} + D_t]}{P_t} \tag{1}$$

where r_t is the discount rate, D_t is the real dividend per share, P_t is the real price of a share at the beginning of period, and $\mathbb{E}_t$ is the expectations operator. The solution of the equation above consists of two terms, the rational bubble component, and the market fundamental component.

$$P_t = \lim_{s\to\infty} \exp\left(-\sum_{j=0}^{s} r_{t+j}\right) \mathbb{E}_t P_s + \mathbb{E}_t \sum_{s=0}^{\infty} \exp\left(-\sum_{j=0}^{s} r_{t+j}\right) D_{t+s} \tag{2}$$

If the transversality condition holds, i.e. $\lim_{s\to\infty} \exp\left(-\sum_{j=0}^{s} r_{t+j}\right) \mathbb{E}_t P_s = 0$, then the price is solely determined by the present value of expected future dividend stream:

$$P_t = \mathbb{E}_t \sum_{s=0}^{\infty} \exp\left(-\sum_{j=0}^{s} r_{t+j}\right) D_{t+s} \tag{3}$$

which is called the market fundamental solution. Then, according to Campbell and Shiller (1988), dividing (1) by D_{t-1} gives

$$\frac{P_t}{D_{t-1}} = \left(\frac{\mathbb{E}_t P_{t+1}}{D_{t-1}} + \frac{\mathbb{E}_t D_t}{D_{t-1}}\right) e^{r_t} \tag{4}$$

By taking natural logs and using lowercase letters to denote natural logs for the corresponding uppercase letters, e.g. $\log P_t = p_t$, one can log-linearize expression (4) around a steady-state constant growth rate for dividends $g = \Delta d_{t+j}$ for $j = 0, 1, 2, \ldots$ and a constant growth rate r to obtain a particular linear solution.

$$p_t^p = d_{t-1} - \mathbb{E}_t \left(\sum_{i=0}^{\infty} e^{-i(r-g)} (r - d_{t+i)}\right) - h \tag{5}$$

where $h = \log(\exp(r-g)-1)-(r-g)/(1-\exp(r-g))$[4]. The general solution includes a bubble term, b_t;

$$p_t^g = d_{t-1} - \mathbb{E}_t\left(\sum_{i=0}^{\infty} e^{-i(r-g)}(r-d_{t+i})\right) - h + b_t \tag{6}$$

where b_t follows

$$\mathbb{E}_t(b_{t+1}) = e^{t(r-g)} b_t \quad \text{for } t = 0, 1, 2, \ldots \tag{7}$$

This explosive process for the bubble component, b_t, drives the market price, p_t, away from the fundamental asset value and causes p_t to also have an explosive behavior.

Based on the data, since both the price and dividend index tend to have unit roots, one can consider using the difference form of (6). Then the general solution can be written in differences as:

$$\Delta p_t^g = \Delta p_t^p + \Delta b_t \tag{8}$$

The variables in the previous equation (8) are differences in logs and should be stationary. Since Δb_t is not observed, it is treated as an unobserved state vector. Since both prices and dividends are observable they are treated as measurement vectors. To estimate bubbles using Sigma-Point Kalman Filter technique (Appendix B), we express the price equation, the parametric bubble process and the dividend process in a state-space form as follows:

$$\Delta p_t = \Delta d_t + F_t \Delta Y_t + \Delta b_t \tag{9}$$

$$\Delta Y_t = A_t + (C_t - I) Y_{t-1} + \upsilon_t \tag{10}$$

$$\Delta b_t = (\rho_t - 1) b_{t-1} + \eta_t \tag{11}$$

F_t, A_t, C_t are time variable coefficients which follow a random walk process. ρ_t represents the growth rate of the bubble as a function of the difference between the discount rate and the growth rate of the dividends. In addition,

[4]For finite price p_t, r must be greater than g and $e^{-(r-g)}$ less than one.

$$Y_t = (d_t, d_{t-1}, d_{t-2}, \ldots, d_{t-h+1})' \tag{12}$$

is a h-vector and

$$C_t = \begin{bmatrix} \phi_t^1 & \phi_t^2 & \phi_t^3 & \ldots & \phi_t^{h-1} & \phi_t^h \\ 1 & 0 & 0 & \ldots & 0 & 0 \\ 0 & 1 & 0 & \ldots & 0 & 0 \\ \ldots & \ldots & \ldots & \ldots & \ldots & \ldots \\ 0 & 0 & 0 & 0 & 1 & 0 \end{bmatrix} \tag{13}$$

is an $h \times h$ matrix, $m = (1, 0, 0, \ldots, 0)$ is a h-row vector, and $F_t = mC_t(I - C_t)^{-1}[I - (1 - \rho_t)(I - \rho_t C_t)^{-1}]$ is also a h-row vector and I is an $h \times h$ identity matrix. η_t and υ_t are assumed to be independent, serially uncorrelated and to have zero mean and finite variance σ_η^2 and σ_υ^2, respectively.

In the state space setup (Appendix A) log values of the dividends assumed to follow an ARIMA(n,1,0) process. To determine the optimal autoregressive order, n, the log dividend process is estimated by the maximum likelihood method for different selections of n. As the cap of n, 2 is selected. Then for each selection of n, the Akaike information criterion is calculated to determine the best n. The model with the smallest Akaike information criterion, which indicates better fitness on the data, is selected to estimate the dividend process.

CHAPTER 5

RESULTS

The results are categorized into two: bubble behavior at the individual country level and direction of causality among countries.

The main result at the individual country level is that the market overreacts to irregular movements contrary to the most recent trend in the market. In other words, sudden price movements breaking the market momentum result in greater bubbles in the same direction. For example, one can observe the negative bubble corresponding to the price drop in the year 1998 for the U.S. case (Figure 1). The second result is that the negative bubble percentages are greater in size than positive ones[5]. This provides further evidence regarding the necessity of allowing for negative bubbles in the underlying model. The variation in the bubble percentages seem to drop as a steady price increase pattern is achieved as observed in the U.S. data.

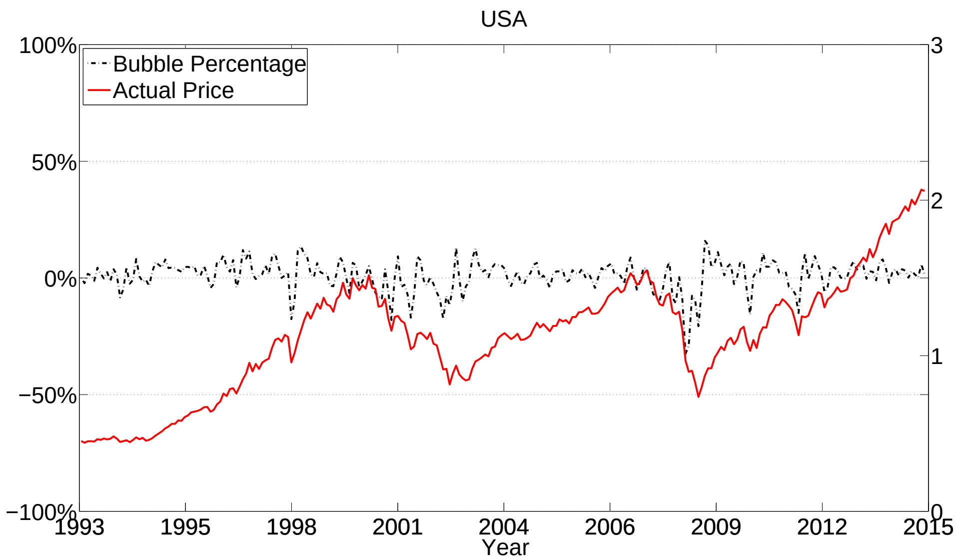

Figure 1: USA bubble percentages

Similar results are obtained for the U.K. prices (Figure 2). Steady increases correspond to smaller bubble percentages. The small but momentum-breaking price decrease in 1998 causes a negative bubble equivalent in size to the ones created by

[5]A portion of this difference can be attributed to the nature of percentages, e.g. a 20 unit increase in a 100 unit price level would consist a 20% increase whereas a 20 unit decrease would show as a 25% decrease. With that being said, the drops in bubble percentages are still large enough for the argument to be valid.

the large steady price decreases in the early 2000s. This may suggest that the mispricing in the market is driven by a defensive strategy that assumes the worst, i.e. the prices will continue to drop substantially. Another interesting find is that the U.K. experience following the Credit Crunch of 2008 draws a picture of slow bubble recovery. The negative and positive bubbles gradually diminish as the prices increase. The length of this recovery period is noteworthy: it takes the market about six years to reduce the bubble percentage. If we interpret the bubble percentage as over or underreacting to the price movements, it can be said that it takes time for investors to learn about the crisis situation they are in and start pricing assets more accurately in the new environment.

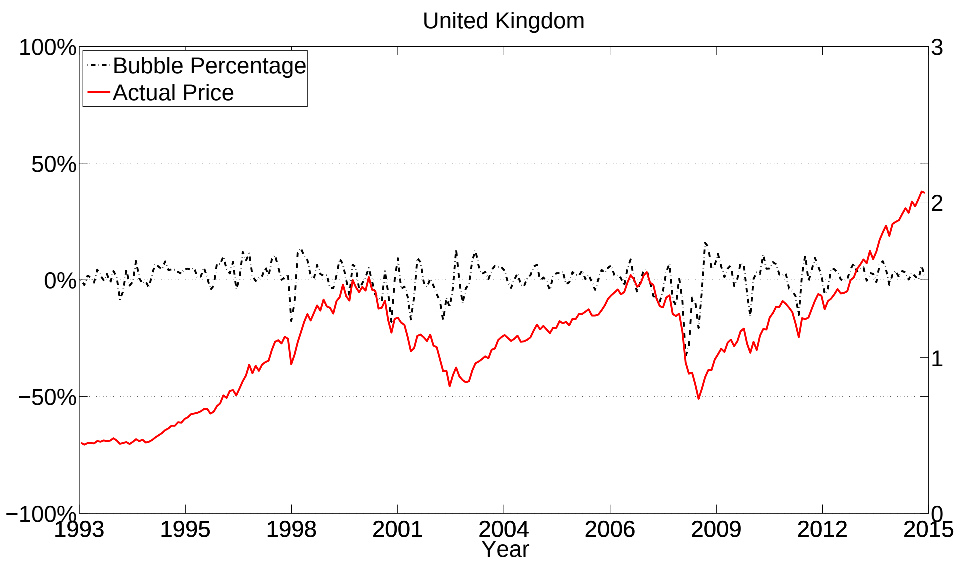

Figure 2: UK bubble percentages

For the most part, the French experience (Figure 3) tells a similar tale to those of the U.S. and the U.K. with the exception of having wider dispersion in bubble percentages; the spread is about twice in size. The reasons for this spread differential are not clear in our setting; however, it might constitute a possible research path for further studies.

The behavior of bubbles in the German index (Figure 4) is very similar to that of France, both in direction and size. In general, the patterns observed suggest that there are similarities in the movements of stock indices as well as bubble percentages

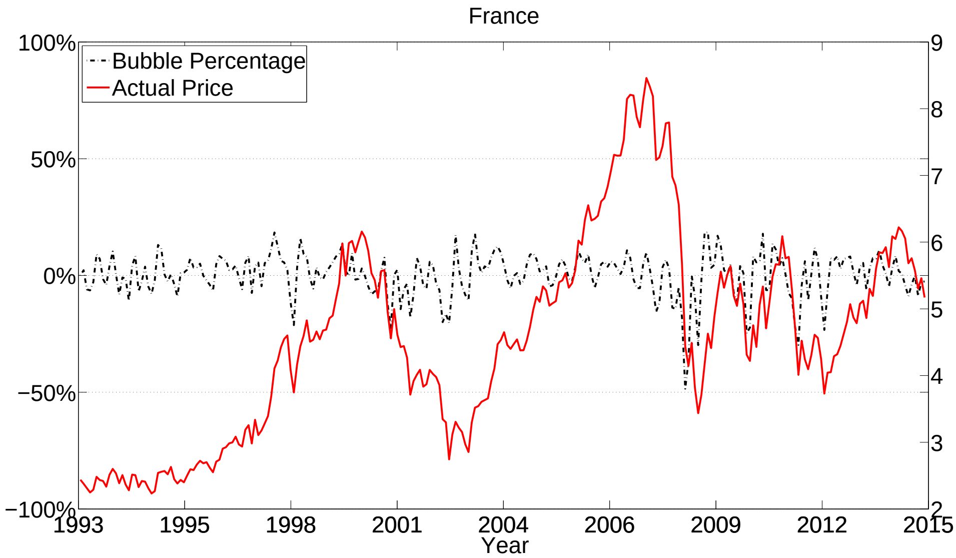

Figure 3: France bubble percentages

across these developed countries, strongly suggesting that there are ties that connect them to drive and unify their behavior. As a result, bubbles would spill over from one country to another. The direction and magnitude of such spillovers then become important in identifying where the financial markets are headed.

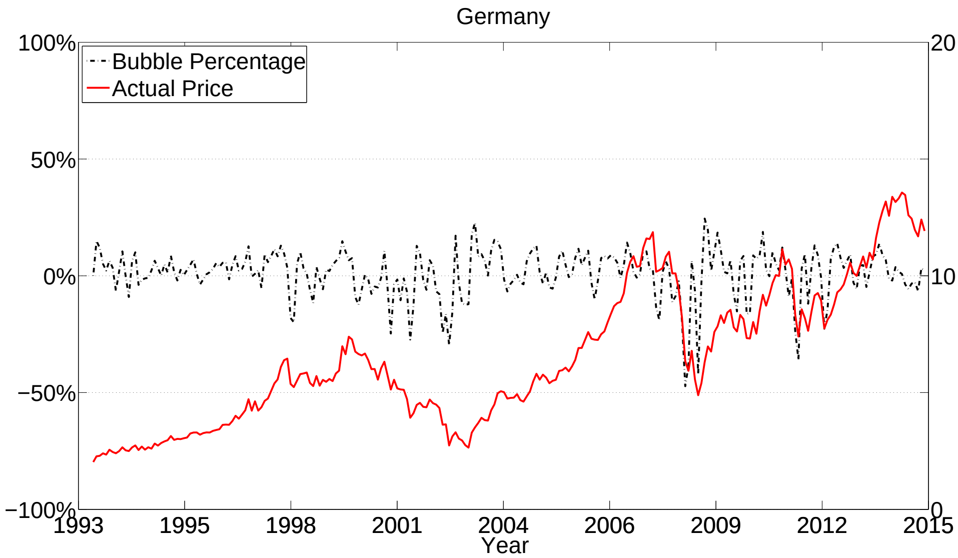

Figure 4: Germany bubble percentages

The markets of developed countries display similarities across themselves in terms of price movements and bubble percentages. In order to investigate whether this is the case for the emerging ones three countries are analyzed: Argentina, Brazil and

Greece. Argentina and Brazil are chosen due to their geographical proximity to each other as well as the U.S. Greece is chosen because it is a European country using Euro as its currency in order to determine whether the similarities between France, Germany and the U.K. are a result of them being part of the same union. Although the U.K. maintains a separate currency and central bank, investigating the case of Greece would help distinguish whether bubbles spill over these countries as a simple result of their economic union or development level.

Argentinian and Brazilian indices (Figures 5 and 6) exhibit the same similarities with the exception of having a much larger spread for bubble percentages. Most notably, the price drop in mid-2008 shows a negative spike in bubble percentages. It signals that negative bubbles are more severe for emerging markets than it is for developed ones. The same cannot be said for positive bubbles which are despite being large rarely surpass 40%. This means that the investors are more cautious regarding emerging markets. They are more willing to underprice the assets traded in emerging countries than those in developed ones and less likely to overprice them even when a substantial price increase is observed over the medium term.

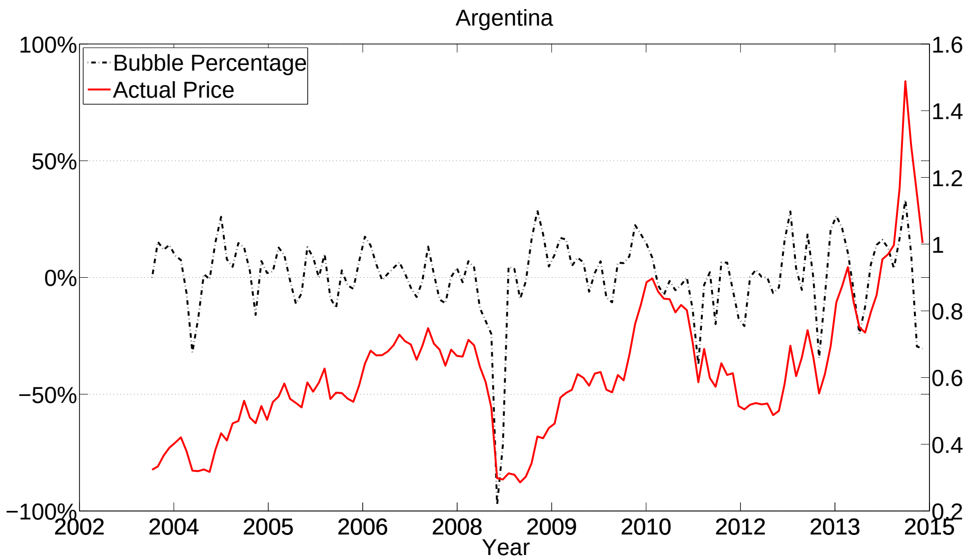

Figure 5: Argentina bubble percentages

Greece (Figure 7) shows a similar pattern until the Credit Crunch however it changes after that. A closer look at the bubble percentages reveals that the switch between

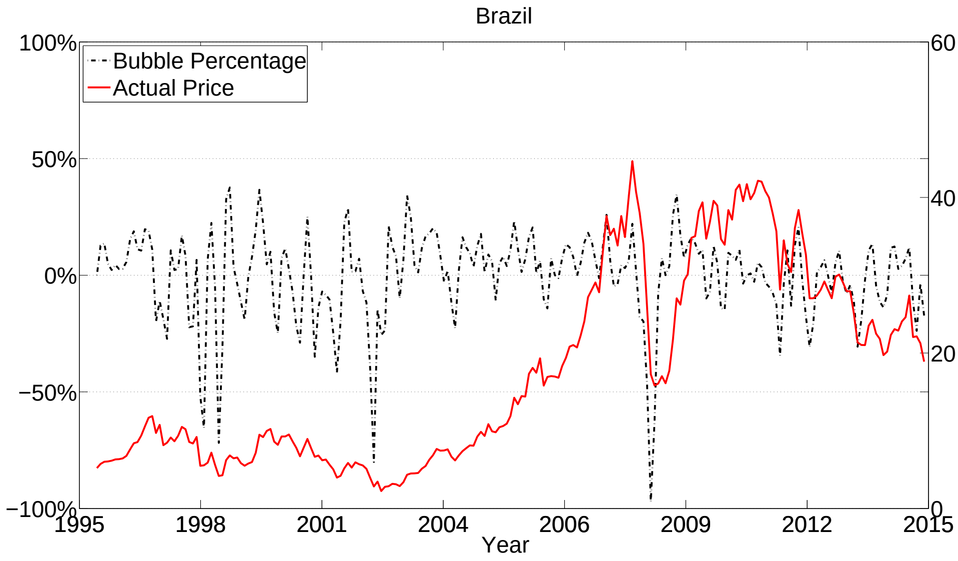

Figure 6: Brazil bubble percentages

negative and positive bubbles had been more frequent. This possibly reflects the frequent negotiations regarding bailouts and debt repayments. Unlike the Argentinian and Brazilian experience, Greece displays a lower spread of bubble percentages despite still being larger than France, Germany and the United Kingdom. The Greek pattern might suggest that a combination of development level and economic ties determines the spread of spillovers.

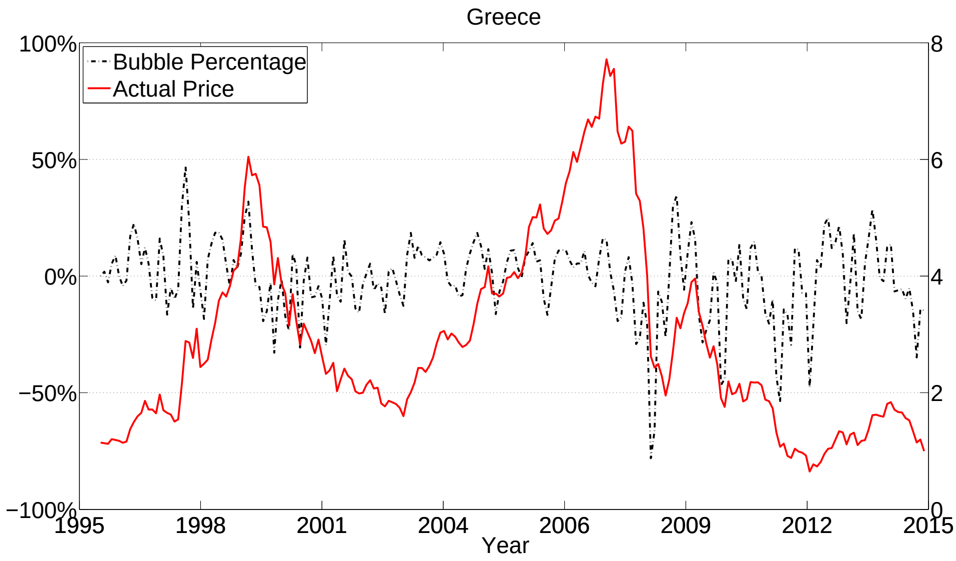

Figure 7: Greece bubble percentages

Assuming the patterns identified consist sufficient proof that bubbles and their spillovers exist, the next question would be whether there is a certain diffusion pattern. A simple test of Granger causality can be employed to determine the direction of causalities, i.e. spillovers. In order to check for the duration it takes spillovers to reach from one country to the other, three lag levels corresponding to 1, 6 and 12 months are used (Tables 2 and 3).

Table 2: Granger Causality Tests for Developed Countries: p-values

Null Hypothesis	*Lags:*	12	6	1
Germany Does Not Granger Cause France		0.0653	0.0000	0.0000
France Does Not Granger Cause Germany		0.0000	0.0000	0.9567
UK Does Not Granger Cause France		0.0489	0.0000	0.0000
France Does Not Granger Cause UK		0.0037	0.0000	0.0000
USA Does Not Granger Cause France		0.6490	0.0050	0.4988
France Does Not Granger Cause USA		0.1105	0.0225	0.3279
UK Does Not Granger Cause Germany		0.0017	0.0000	0.0000
Germany Does Not Granger Cause UK		0.0000	0.0000	0.0063
USA Does Not Granger Cause Germany		0.0384	0.0000	0.0002
Germany Does Not Granger Cause USA		0.1097	0.1063	0.2534
USA Does Not Granger Cause UK		0.0000	0.0000	0.0002
UK Does Not Granger Cause USA		0.0021	0.0209	0.0760

Table 3: Granger Causality Tests for Emerging Countries: p-values

Null Hypothesis	*Lags:*	12	6	1
USA Does Not Granger Cause Argentina		0.1188	0.2296	0.0848
Argentina Does Not Granger Cause USA		0.1136	0.0552	0.5503
USA Does Not Granger Cause Brazil		0.0217	0.0253	0.2223
Brazil Does Not Granger Cause USA		0.5694	0.4306	0.6937
USA Does Not Granger Cause Greece		0.0479	0.0000	0.1719
Greece Does Not Granger Cause USA		0.4858	0.3137	0.4114

The U.S. and U.K. affect each other for nearly all three lag values, with the weakest effect being observed with a .076 p-value for the one-month lag. This result suggests that the bubbles in these two countries spillover to each other yet the direction of causality is hard to determine. The lower p-values suggest that the U.S. is more likely to be the source of the spillovers, especially in the short run.

The results for the U.K. and France suggest an even stronger spillover effect with both countries affecting each other. The p-value regarding the effect of U.K. on France increases with the spillover duration; but remains below the .05 significance mark.

The case of Germany and France consists an interesting example. German bubbles seem to spillover to France in the short term with near-zero p-values; but then it goes above .05 level with a value of .0653. The French bubbles on the other hand do not even remotely spill over to Germany in a single month but definitely show their effect in six months and later on in a year. This result verifies that including three separate lags helps revealing information that would remain hidden otherwise.

The Granger causality results between the U.S. and France are very mixed. France bubbles do not seem to spill over to the U.S. The U.S. bubbles seems to spill over for a rather short period and only in the medium run.

The U.S. bubbles spill over to Germany at all three lag levels. The reverse is also true for the bubbles in Germany despite being with higher p-values. The p-values for the Germany to the U.S. spillovers decrease over time, suggesting that German bubble spillovers affect the U.S. market over the long term with a gradually increasing strength.

The results obtained for the emerging markets are as expected: the U.S. bubbles spill over to Argentina, Brazil and Greece and not the other way around. A significant p-value is obtained for Argentinian bubbles for the 6-month lag level, but it is likely to be a spurious result rather than an anomaly. The U.S. bubbles spill over to Argentina in the short term but lose their effect in the 6-month and 12-month periods. The inverse applies to spillovers to Brazil; they do not arrive in the short-run, however are observed over the medium term. The same goes for Greece. The best p-value for spillovers to Greece is observed at the 6-month lag level, suggesting the effect of the U.S. bubbles is best observed in a short interval. These results all together suggest that economic and financial ties diffuse bubbles faster than geographical proximity.

Three maps are provided for the three lag levels in order to give a visual presentation of the spillover directions (Figures 8, 9 and 10).

The graphs contain increases as well as decreases since the version of the Kalman filter used here allows for negative bubbles which correspond to excessive price decreases following the bursts of bubbles. Bubbles by their nature are not sustainable hence burst at a certain point. This results in an overreaction in the form of excessive sales akin to a firesale that drives prices down. These falls in prices are usually considered parts of crises which are events considered to be abnormal and out of the ordinary. It is probable that negative bubbles are not included in many models for this reason. The extremity of crisis and the prevalence of unprecedented market conditions and regime changes can easily overshadow the effects of negative bubbles. Still, it would not necessarily mean that negative bubbles are not contributing toward the price fall. The oscillations in the graphs are mostly attributable to these factors. In other words, the graphs reflect the ability of the model to capture all kinds of mispricings not just positive ones. It allows the highly abstract present value model to approximate to the real world by presuming that investors cannot always correctly determine or predict the price. Moreover, it calculates how far off investors are in either direction from the fundamental value (present value of the dividends) of the price.

Most of the peaks and pits in the graphs can be traced to real world events, i.e. timing of bubble percentages in the graphs are in line with anecdotal events in financial markets. The fall in the year 1998 is in synchronization with Russia's default and the subsequent failure of global financial institutions especially those focusing on financial derivatives with the fund Long Term Capital Management being the main example. This once more confirms the necessity of allowing the effect of negative bubbles in measurements. The negative percentage observed in our graphs would be clamped to zero otherwise. The results signal financial troubles in the early 2000s, which indeed were observed especially in the United States following the Enron scandal and the burst of the Dot-Com Bubble. These events were followed by rather calm financial markets between the years 2004 and 2008 until the Credit Crunch hit

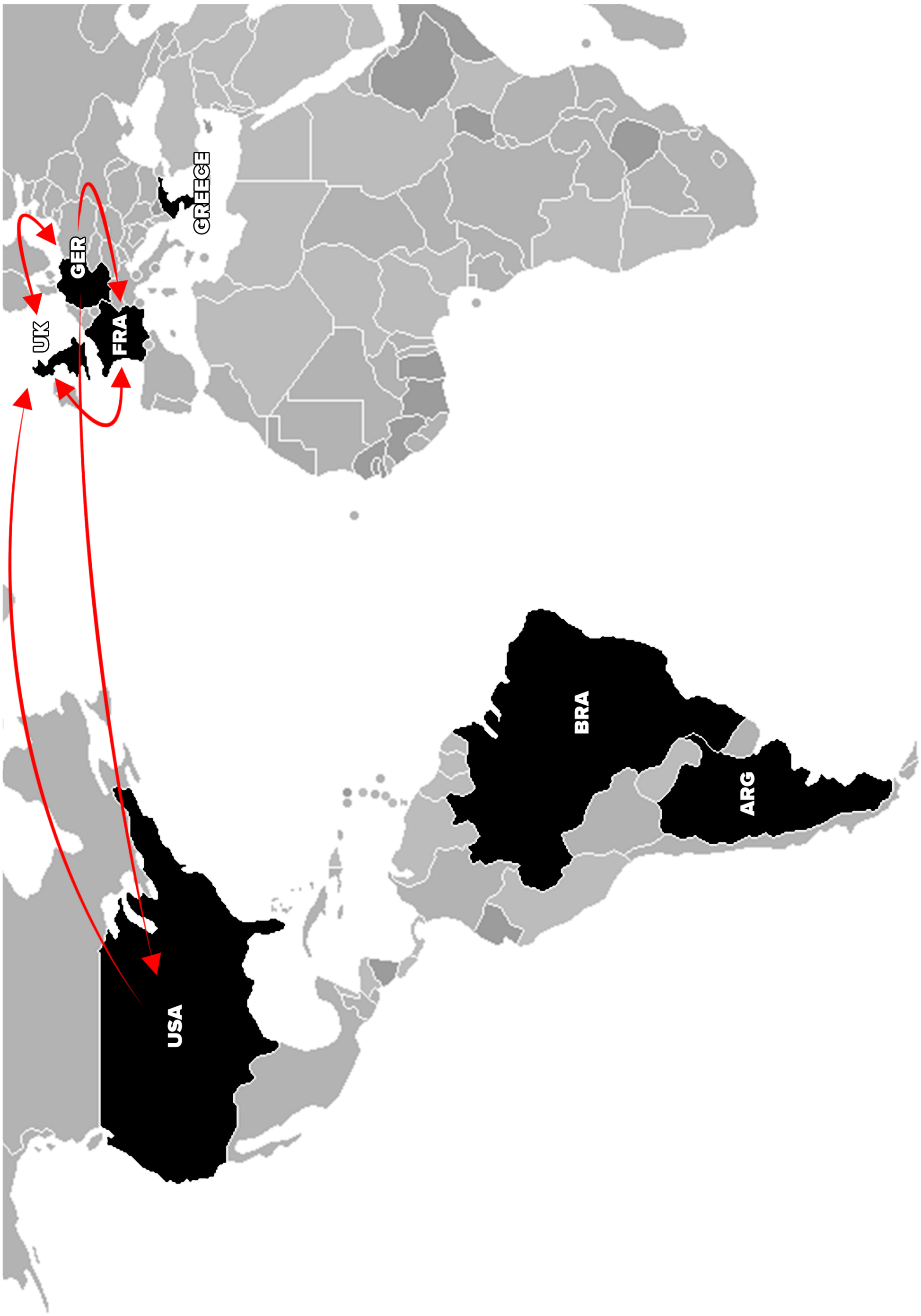

Figure 8: Causality directions (Lag 1)

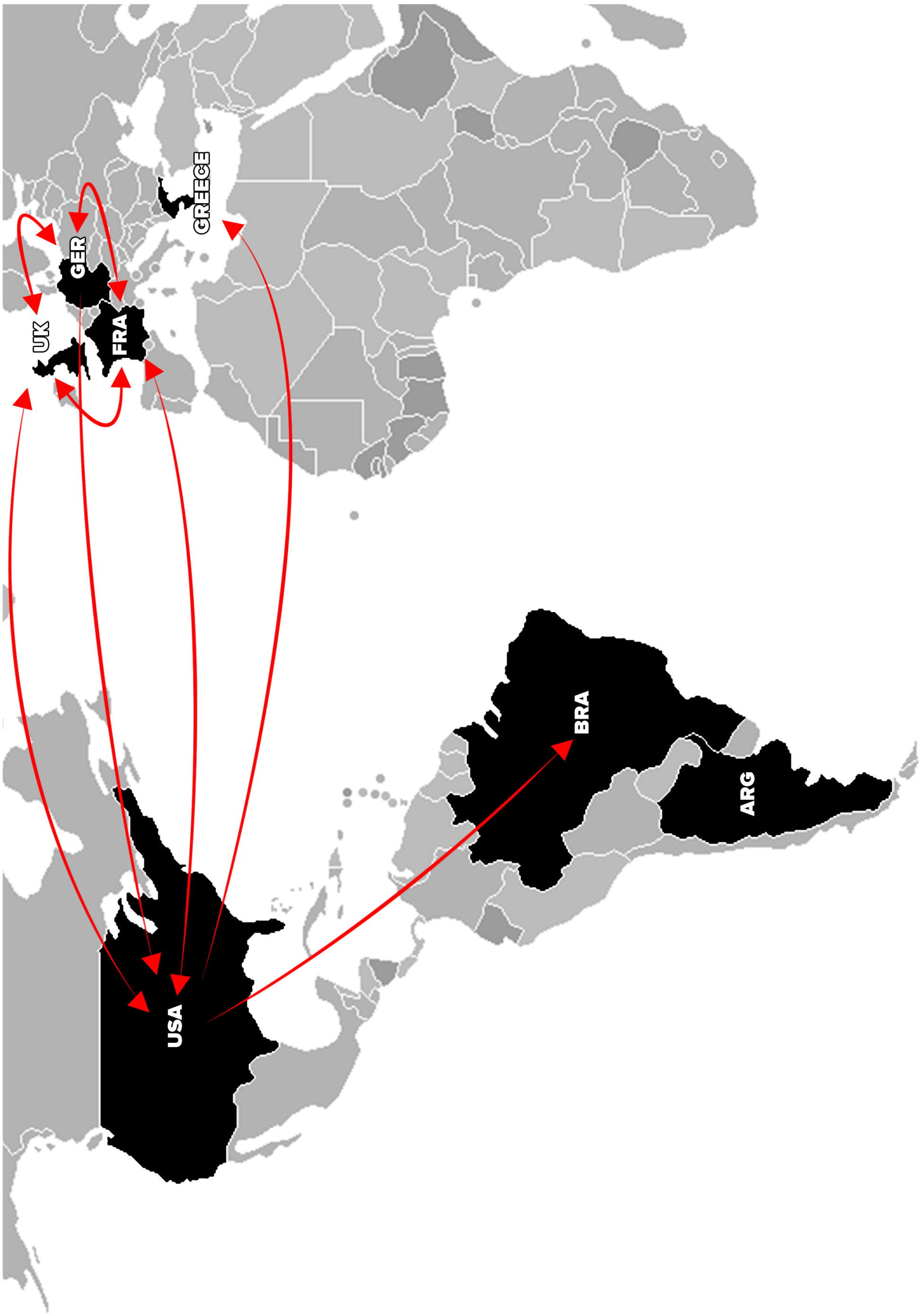

Figure 9: Causality directions (Lag 6)

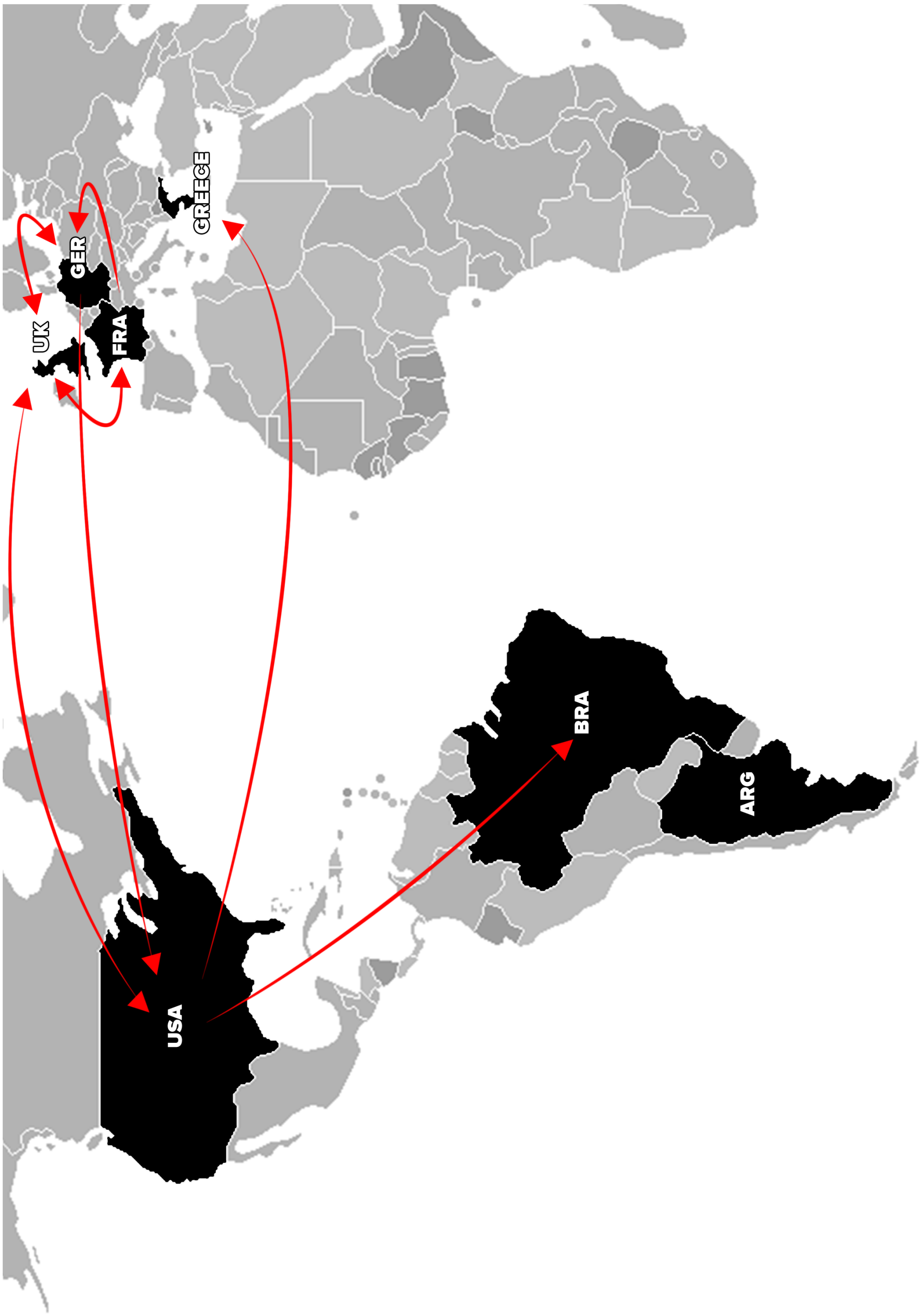

Figure 10: Causality directions (Lag 12)

the markets. It is also possible to observe the effects of the 700 billion dollars stimulus package the U.S. Congress and the U.K. Parliament passed to stimulate the economy in the form of positive bubbles, suggesting that investors were relieved for a few months enough to pay more for the stocks than their worth. It is early to comment on the results near the end of the time period because it is better to practice caution when commenting on results obtained near the end of data points available when using filters.

It should be kept in mind that the model used in here is still in its experimental development phase. It has not been used enough times and by enough researchers to identify all of the pitfalls and possible ways to improve it. The results are likely to be sensitive to the underlying model used or the method chosen for the computation of the variance covariance matrices. Since the method used is essentially a filter operating on empirical observations, the usual disadvantages of working with real world data applies. The weaknesses and strengths of the model would become clearer when more studies are conducted employing it. This process would require a process of trial and error to develop seasoned thinking which would require more than the timespan allowed for this study.

CHAPTER 6

CONCLUSION

This study used a Kalman filter approach to determine the bubble percentages and whether bubbles in one country spill over to others. The results suggest that investors respond with greater magnitude to momentum-breaking price drops than they do to similar price increases in the form of negative bubbles. The size of these negative bubbles are similar to those observed during long periods of price decreases. This result also emphasizes that mispricings of all kinds, whether they are inflated bubbles or cautious underpricings, should be allowed in underlying theoretical models when computing bubbles.

Bubble percentages observed in emerging markets are larger than those in developed ones. This suggests that investors punish emerging markets more severely for deviating from an upward trend. Moreover the positive bubbles associated with upward trends are not observed at the same magnitudes as in developed markets. It is likely to be a result of investors perceiving emerging markets as risky markets and acting more cautiously.

The comparative results suggest that the bubbles in developed countries spill over to each other and they do so bilaterally. The same bilateral spills are not observed for emerging markets; the bubbles spill over from developed markets to emerging ones in a unilateral fashion. Economic and financial ties matter more in determining spillovers across countries.

It would be of interest to consider how bubbles might spill over from one country to the other since the underlying model used here is a simple present value model that considers each economy as closed, i.e. it does not model the spill overs per se, but attempts to measure the bubbles so that they can be compared in magnitude and timing to determine if bubbles in one country precede and cause bubbles in others. Since incorporating the international flows of money in the model would introduce certain costs in terms of computations and finding linearized equations based on analytical solutions that can be calculated with paper and pen, it would not be an economical decision to increase the scope of the paper to account for more realistic settings. Anecdotal examples can be given instead to provide certain ideas on how bubbles might spill over. The first example is the price surge across the world prior to the Russian default that was mainly due to the rise of the derivative products. Financial derivatives allowed for obtaining leveraged positions for a lower cost than it would be with stocks or bonds hence left more money in the investors hands which was mostly invested abroad to diversify their portfolios. Therefore the bubble in the U.S. was followed by bubbles in other countries. It would be helpful to remind the reader that the hypotheses stated here regarding the spillovers do not require bubbles to cause other bubbles, the underlying mechanism might change; however, the hypotheses would hold as long as bubbles appear in different countries following a diffusion pattern. As such the second example involving the U.S. and Turkey can be given: the burst of the bubble in the U.S. resulted in Federal Reserve lowering the interest rate which combined with the general caution toward U.S. stocks and caused investors to channel their funds to emerging markets. In the case of Turkey this resulted in banks having excess funds since they constitute the majority off Borsa Istanbul in terms of value. The credit became more available for the Turkish customers and combined with the relatively favourable terms of the newly introduced mortgage policies, this process resulted in a large demand for housing that caused a bubble in real estate prices while they were dropping across the developed world. This second example suggests firstly that the bubble diffusion process need not be confined to financial markets alone and secondly it is not always in the form of positive bubbles causing positive bubbles. In this anecdote the negative bubble (price drop) in the U.S. mortgage-backed securities caused a positive bubble in the Turkish real estate market.

This study is among the first attempts to measure bubble components using the Sigma Point Kalman Filter approach. It is likely to have rooms for improvement that are yet to be identified. As described in previous sections the model utilizes a very simple present value model, therefore it constitutes a simple benchmark against which other models can be tested. The performance of the model for longer investment horizons might be obtained by restricting the sample to developed countries only and extending the time period covered.

Another possible route to explore for improvements is to consider other financial (or otherwise) markets and their interactions to check the performance of the filter in detecting bubbles under different scenarios. In theory, there is nothing that restricts the use of Kalman filter to stock prices. The same principle can be used by altering the underlying pricing model. In certain cases (such as with the real estate prices), the underlying model can be maintained and the dividends can be replaced with the rent data. This offers the possibility to apply the filter to many emerging markets that were excluded from the sample here due to their lack of regular dividend payments or policies. Although this would not contribute to the financial bubbles literature directly, it would be of interest to observe the performance of the Kalman filters in general.

APPENDIX A

STATE SPACE MODEL

The state-space model proposed in this paper is as follows:

$$
\begin{aligned}
\Delta p_t &= \Delta d_t + F_t \Delta Y_t + \Delta b_t && (1)\\
\Delta Y_t &= A_t + (C_t - I)Y_{t-1} + \upsilon_t && (2)\\
\Delta b_t &= (\rho_t - 1)b_{t-1} + \eta_t && (3)
\end{aligned}
$$

Transforming the above model one can get

$$
\begin{aligned}
x_{k+1} &= f(x_k, u_k, t_k) + \omega_k && (4)\\
z_k &= h(x_k, t_k) + \upsilon_k && (5)
\end{aligned}
$$

where $f(.)$ is non-linear function of the state variables, x_k, control or signal variables, u_k and exogenous variables t_k. ω_k and υ_k are i.i.d. shocks with zero mean and covariance matrices Q_k and R_k, respectively.

$$p_t = F_t A_t + p_{t-1} + (\rho_t + 1)b_t + [F_t(C_t - I)]Y_{t-1} + \Delta d_{t-1} \quad (6)$$

$$Y_t = A_t + C_t Y_{t-1} + \upsilon_t = \begin{bmatrix} u \\ 0 \end{bmatrix} + \begin{bmatrix} h_{1,t} & h_{2,t} \\ 1 & 0 \end{bmatrix} \begin{bmatrix} \Delta d_{t-1} \\ \Delta d_{t-2} \end{bmatrix} + \begin{bmatrix} \delta_t \\ 0 \end{bmatrix} \quad (7)$$

$$\Delta b_t = (\rho_t - 1)b_{t-1} + \eta_t \quad (8)$$

$$C_t = C_{t-1} + \kappa_{1,t} \quad (9)$$

The state vector is defined as follows:

$$x_k = \begin{bmatrix} b_k \\ p_k \\ Y_k \end{bmatrix} \quad (10)$$

Previous definition can be summarized in the following non-linear function

$$f(x_k, u_k, t_k) = \alpha x_{k-1} + \beta u_k + \varepsilon$$

where

$$\alpha = \begin{bmatrix} \rho_t & 0 & 0 \\ \rho_t + 1 & 0 & F_t(C_t - I) \\ 0 & 0 & C \end{bmatrix}$$

$$\beta = \begin{bmatrix} 0 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix}$$

$$\varepsilon = \begin{bmatrix} \eta_k \\ F_t \upsilon_k \\ \upsilon_k \end{bmatrix}$$

$$h(x_k, t_k) = Hx_k$$

$$H = I$$

APPENDIX B

SIGMA-POINT KALMAN FILTER ALGORITHM

The filter is implemented via the following algorithm where plus $(+)$ sign denotes the posterior and minus $(-)$ sign denotes the prior estimate and the approximate sign $(\approx)$ denotes the current estimate.

$$\begin{aligned} x_{k+1} &= f(x_k, u_k, t_k) + \omega_k \\ y_k &= h(x_k, t_k) + \upsilon_k \\ \omega_k &\sim (0, Q_k) \\ \upsilon &\sim (0, R_k) \end{aligned}$$

- Initialization

$$\hat{x}_0^+ = \mathbb{E}[x_0] \quad , \quad P_{x_0}^+ = \mathbb{E}[(x_0 - \hat{x}_0^+)(x_0 - \hat{x}_0^+)^T]$$

- For $k = 1, \ldots, \infty$:

  1. Calculate sigma-points:

$$\begin{aligned} \hat{x}_{i,k-1} &= \hat{x}_{i,k-1} + \approx\!\!{x}_i \quad , \quad i = 1, \ldots, 2n \\ \approx\!\!{x}_i &= \left(\sqrt{nP_{x_{k-1}}^+}\right)_i^T \quad , \quad i = 1, \ldots, n \\ \approx\!\!{x}_{n+i} &= \left(\sqrt{nP_{x_{k-1}}^+}\right)_i^T \quad , \quad i = 1, \ldots, n \end{aligned}$$

2. Time-update equations:

$$\begin{aligned}
\hat{x}_i &= f(\hat{x}_{i,k-1}, u_k, t_k) \\
\hat{x}_k^- &= \frac{1}{2n}\sum_{i=1}^{2n} \hat{x}_{i,k} \\
P_{x_k}^- &= \frac{1}{2n}\sum_{i=1}^{2n} (\hat{x}_{i,k} - \hat{x}_k^-)(\hat{x}_{i,k} - \hat{x}_k^-)^T + Q_{k-1} \\
\hat{x}_{i,k} &= \hat{x}_k^- + \approx{x}_i \quad , \quad i = 1, \ldots, 2n \\
\approx{x}_i &= \left(\sqrt{nP_{x_k}^-}\right)_i^T \quad , \quad i = 1, \ldots, n \\
\approx{x}_{n+i} &= \left(\sqrt{nP_{x_k}^-}\right)_i^T \quad , \quad i = 1, \ldots, n \\
\hat{y}_{i,k} &= h(\hat{x}_{i,k}, t_k) \\
\hat{y}_k &= \frac{1}{2n}\sum_{i=1}^{2n} \hat{y}_{i,k}
\end{aligned}$$

3. Measurement-update equations:

$$\begin{aligned}
P_{y_k} &= \frac{1}{2}\sum_{i=1}^{2n} (\hat{y}_{i,k} - \hat{y}_k)(\hat{y}_{i,k} - \hat{y}_k)^T + R_k \\
P_{x_k y_k} &= \frac{1}{2}\sum_{i=1}^{2n} (\hat{x}_{i,k} - \hat{x}_k)(\hat{y}_{i,k} - \hat{y}_k)^T \\
K_k &= P_{x_k y_k} P_{y_k}^{-1} \\
\hat{x}_k^+ &= \hat{x}_k^- + K_k(y_k - \hat{y}_k) \\
P_{x_k}^+ &= P_{x_k}^- - K_k P_{y_k} K_k^T
\end{aligned}$$

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