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Increasing correlation in equity markets and consequences on an international portfolio

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SUMMARY

ABSTRACT

This work analyzes an ample range of equity indexes in order to investigate how international financial integration has changed during the last two decades. To obtain a sample that represents a large number of countries are employed, respectively, fifteen and ten stock indexes of developed and emerging markets. The degree of financial integration over the time series is computed with three different measures: *(i)* dynamic standard correlation, *(ii)* standard correlation in different sub-periods and *(iii)* adjusted R squared. Efficient frontiers over different intervals are then employed to assess how movements in the correlation between equity returns has affected the degree of diversification of an international portfolio. In particular, the global minimum variance portfolio and the tangency portfolio are estimated to verify the change in the investment risk over the time series.

INTRODUCTION

Financial markets have undergone a substantial evolution over the last decades. In particular, the equity market, which is probably considered in the financial world the most important and followed on a global scale, attracts the attention of this work.

Technological innovations have given the most significant contribution among the many developments that have affected financial markets. One of the major driver of market changes is the advent of information technology (IT), which has allowed to overcome numerous barriers between various countries in the world. The transformation from a human-based model to an electronic model is considered one of the most important technological advances that has affected the entire investment world.

In equity markets, the movement has been from a single trading room, the New York Stock Exchange (NYSE) where equities exchanges happened through a human-based model, to a network of electronic trades. This fact has enormously contributed to the improvement of information diffusion, to the quality of financial analysis and to the communication speed between the agents in the market.

Another important element of increasing financial integration, delimited to the European countries, has been the creation of European Union. This fact, which has implicated the creation of a single currency, has reduced commercial and financial barriers, giving space to a greater integration between countries with considerable consequences on the financial and stock exchanges.

One of the main implication of integration between financial markets is the increase of correlation coefficients between returns of similar assets. Increasing correlations between financial markets entail lower diversification benefits. If financial markets move in the same direction, the

advantage of moving money into foreign markets is substantially lower than a previous situation characterized by lower correlations.

Only few decades ago has been estimated by numerous literature (see, among the other, (Grubel, 1968) and (Levy and Sarnat, 1970)) that correlations between equity markets were low.

The aim of this work is to analyze the equity market over a long time series to inspect if correlations are increased during time and if this increase is relatively permanent and not only a merely consequence of financial shocks.

The analysis of correlations will be then employed to verify the changes in the degree of diversification of an international portfolio.

In order to inspect a large number of equity markets, this work employ different stock indexes of developed and emerging countries.

The next pages are organized as follow: in the first chapter there is a description of the data employed and then an analysis of time series graphs and of the main statistics.

In the second part is first presented the most influential literature on international financial integration and the measures to estimate it. The work proceeds then on the analysis of financial integration with the computation of: (i) the dynamic standard correlation, (ii) the standard correlation in different sub-periods and (iii) the adjusted R-squared.

The third chapter investigates the effects of financial integration changes on the diversification of an international portfolio. In order to achieve this goal are employed different efficient frontiers that highlight the effect of correlation on diversification portfolio.

The work ends with a general conclusion that explain the effects of all the analysis conducted.

CHAP. 1 DATA

1.1 Time series description

The aim of this work is to analyze the integration between equity markets over the last decades. The data used for this empirical analysis are weekly returns of the main equity indexes of different countries.
The sample is divided in two groups: Developed Markets and Emerging Markets.
The indexes used are respectively from:

- Developed Markets (15 indexes): Australia, Austria, Belgium, Canada, France, Germany, Hong Kong, Japan, Netherlands, Spain, Sweden, Switzerland, United Kingdom and United States (2 indexes);
- Emerging Markets (10 indexes): Argentina, Brazil, India, Indonesia, Korea, Mexico, Philippines, Pakistan, Sri Lanka, Taiwan.

The indexes time series are downloaded from *Yahoo.finance.com*.
The sample period of this analysis starts from 01/01/1994 to 01/01/2017 for Developed Markets (23 years, 1200 observations) and from 01/01/1998 to 01/01/2017 (19 years, 991 observations) for Emerging Markets.
Returns are computed as logarithmic difference between prices at time t and prices at time t-1 of the time series: $r_t = \ln(P_t) - \ln(P_{t-1})$
I use weekly return to prevent some high-frequency data issues that normally happen with daily observations: (i) presence of zero returns; (ii) non-synchronicity and (iii) excess noise (Billio *et al.*, 2016)[1].

[1] In Billio *et al.* (2016) work are used monthly data. About this topic, Pukthuanthong and Roll (2009) write: "*There are reasons (thin trading and other microstructure effects) to think that longer return intervals might be better even though the number of observations would be reduced*".

Monthly data are generally used to prevent these type of issues, anyway weekly returns are a good tradeoff that allow to generate a robust number of observations.

I want to highlight that the sample used is homogeneous, the countries belonging to the Developed Markets group and to the Emerging Markets group remain respectively the same over time.

To capture all possible integration movements between international equity markets, like differences in cross-country currency variations, the sample returns are maintained in local currency (see (Volosovych, 2011).

Moreover, the period analyzed in this work is large enough to take in considerations events that could have had a possible positive impact on the comovement between equity markets returns and to capture their consequences over the time.

Just to mention a few of these events, it is worth quoting the large scale internet diffusion began in the 2000s and, relative to Europe, the introduction of a single currency for the Union, the Euro, in 1999 for financial markets and in 2002 for the countries[2].

Tab. 1 illustrates the indexes used for the two sample groups with the relative code to easily find them on *Yahoo.finance.com*.

[2] In the Developed Markets group there are six countries that belong to the European Union.

Tab. 1 *Name, abbreviation and code of the stock market indexes analyzed in this work.*

	DEVELOPED MARKETS		
Country	Index	Symbol	Code in Yahoo.finance
Australia	S&P/ASX 200	Aust	^AXJO
Austria	ATX	Autr	^ATX
Belgium	BEL 20	Belg	^BFX
Canada	S&P/TSX Composite	Cana	^GSPTSE
France	CAC 40	Fran	^FCHI
Germany	DAX	Germ	^GDAXI
Hong Kong	HANG SENG	HoKo	^HSI
Japan	NIKKEI 225	Japa	^N225
Netherlands	AEX	Neth	^AEX
Spain	IBEX 35	Spai	^IBEX
Sweden	OMX Stockholm 30	Swed	^OMX
Switzerland	SMI PR	Swit	^SSMI
United Kingdom	FTSE 100	UK	^FTSE
United States	S&P 500	S&P	^GSPC
United States	NASDAQ Composite	Nasd	^IXIC

	EMERGING MARKETS		
Country	Index	Symbol	Code in Yahoo.finance
Argentina	MERVAL	Arge	^MERV
Brazil	IBOVESPA	Braz	^BVSP
India	S&P SENSEX	Indi	^BSESN
Indonesia	JAKARTA Composite	Indo	^JKSE
Korea	KOSPI Composite	Ko	^KS11
Mexico	IPC	Mexi	^MXX
Philippines	PSEI	Phil	^PSEI.PS
Pakistan	KARACHI 100	Paki	^KSE
Sri Lanka	COLOMBO All-Share	SrLa	^CSE
Taiwan	TSEC	Taiw	^TWII

1.2 Descriptive analysis

Fig. 1 shows the trend of the 15 Developed Markets equity indexes during the period taken in consideration for this work.

It's possible to notice some common paces in almost all countries. The sample could be divided into three main parts.

A first part starts with the beginning of the time series and ends in year 2000. Although with different intensity, and with the exception of Australia and Austria, this first period is characterized by a common growth that culminates around year 2000. The most significant evidence of this is very clear in the graph of USA (Nasdaq), Sweden and France. This increase was mainly generated by the diffusion of Information Technologies (IT) that gave rise to the so called *Internet Bubble.*

After this period of over-normal growth there is a widespread decrease, consequence of the burst of the bubble.

The second part of the graph starts with the end of the IT crisis in the 2003 and finishes with the financial crisis of 2007-2008.

This is probably the most evident trend and it characterizes all countries analyzed. This period is typified by a common growth that starts at the beginning of 2003. This comovement, with different strength, continues until 2007-2008. A clear image of this powerful growth is evident, in particular, in Austria, Belgium, Hong Kong and Spain graphs. After the mid of 2007 the prices decline is robust and steady for all the sample.

It is undeniable as the strong growth during pre-crisis period is then combined with a likewise, or even more, powerful decrease during the crisis. In particular, Austria, Belgium and Hong Kong provide a clear evidence of the strong decline happened during this period.

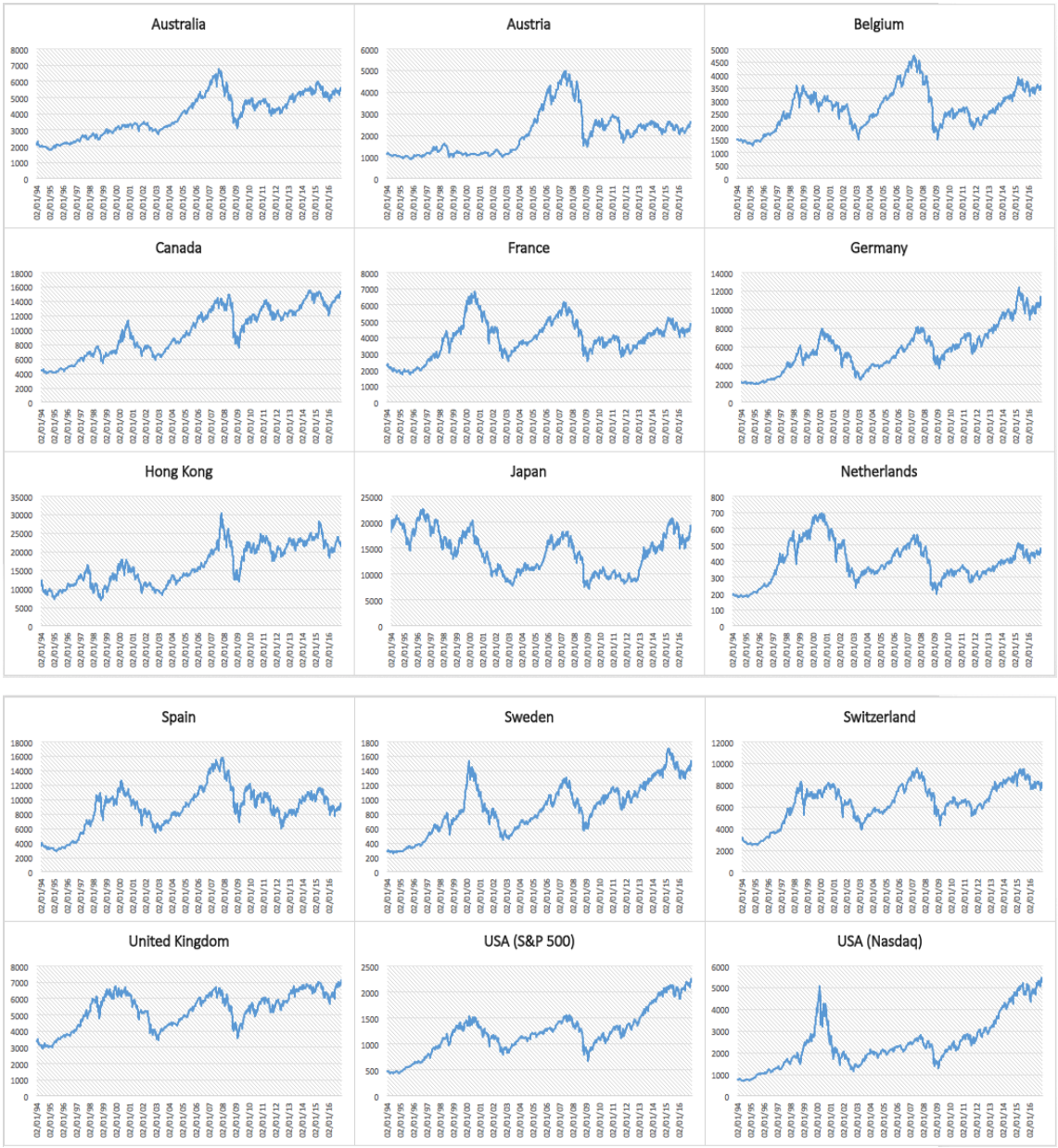

Fig.1 *Developed Markerts, historical time series from 01/1994 to 01/2017.*

The last part of the time series begins with the end of the financial crisis in the mid of 2009 and finishes at the beginning of 2017.

Over this cycle there is a general increase in all indexes, but with very different strengths, with some interruptions in 2011 and 2015 (as it is possible to see for instance in Austria, Belgium, Germany and Switzerland) and with some exceptions like Hong Kong and Spain.

Completely different is the situation for Emerging Markets time series.

In this case observations start in 1994 differently from the previous sample. The trend is extremely different from what it is possible to see in Developed Markets graphs but, also here, there are some interesting comovements between the indexes.

The first part of the time series is characterized by a tranquil period, in particular, the trend of Argentina, India, Indonesia, Mexico, Philippines, Pakistan and Sri Lanka is substantially stationary and it does not point out significant variations.

In these countries there is no evidence of the so called *Internet* Bubble; this is probably the most interesting difference with the trend of the Developed Markets previously analyzed and it represents an important advantage for the diversification of a portfolio on an international level. The only Emerging Markets time series that show a strong sensitivity to the IT diffusion are Korea and Taiwan, while in Brazil graphs the evidence is much lower.

The second part of the time series starts in 2003 and finishes with the beginning of the financial crisis in 2007-2008. This trend is much more similar to the one identified in the same period for the Developed Markets indexes.

For almost all countries it is possible to notice a steady increase that begins around 2003-2004. Also here, the strength of this trend is extremely various between the indexes.

While in Brazil, Korea and also India the power of the growth in very high, the same is not for Pakistan and Sri Lanka where the increase is not very evident. Totally different is the case of Argentina, in this country there is no evidence, or is extremely imperceptible, of the growth happened before the crisis period.

After the financial crisis decrease, that is more or less equal in all countries, there is a third part of the graph that is characterized by a powerful growth.

This trend starts around the beginning of 2009 and, for most of the indexes,

continues until the observations end in 2017.

Probably the clearest representation of that is the Pakistan graph; the increase is very strong and continues steadily without interruptions.

Very similar is the case of India, Indonesia, Mexico and Philippines but with some temporary decreases in the period 2013-2015.

Korea and Taiwan represents two exceptions; in this countries the growth is not emphasized as in the others.

The outlier is, also here, Argentina; the powerful increase starts in 2013-2014 and not in 2009 like the other countries.

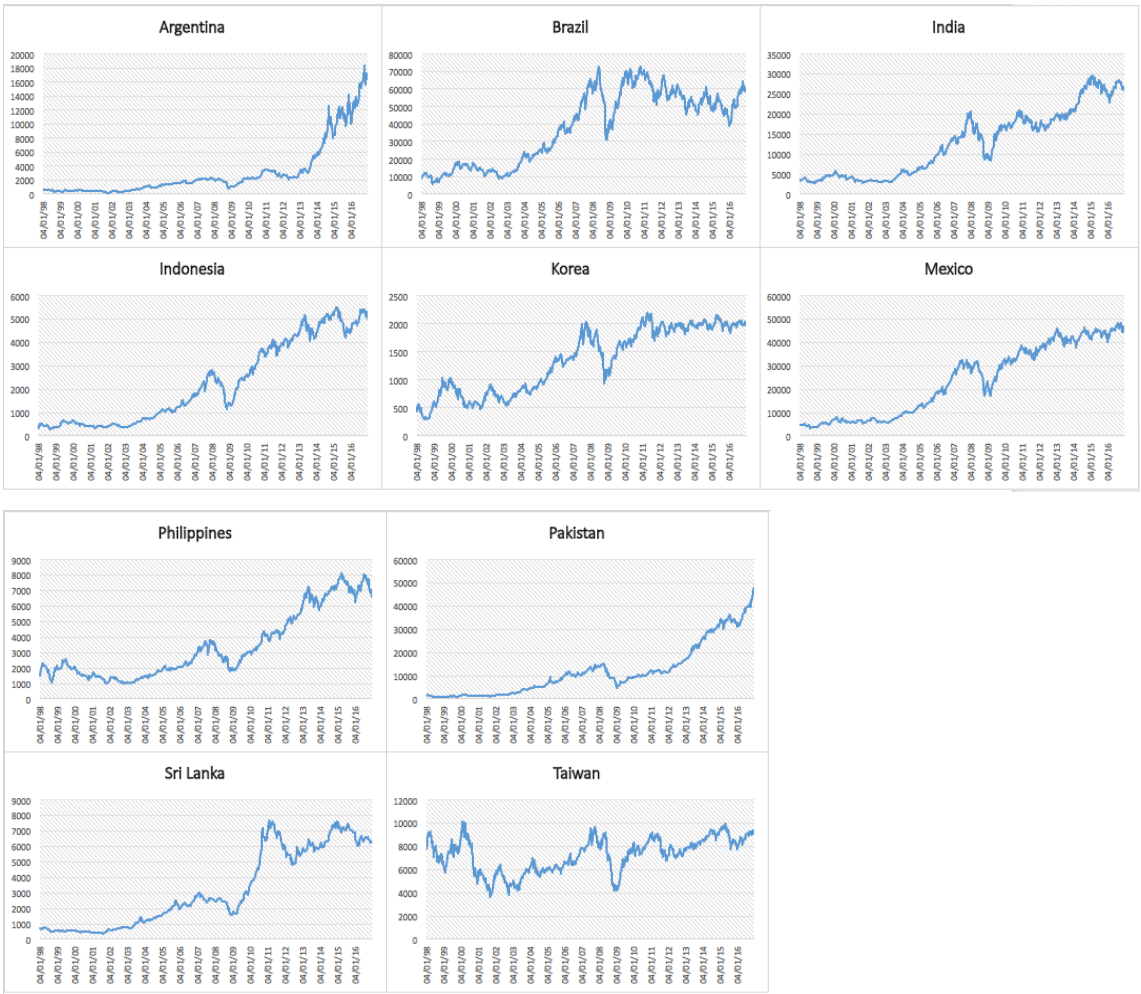

Fig. 2 *Emerging Markerts, historical time series from 01/1998 to 01/2017.*

After this brief analysis of the two countries groups trends is significant to notice, at least at a general level, how intense the comovements between the indexes are.

This fact is valid in particular within the same group of countries, but it is also evident between the two groups.

Some graphs are at least extremely similar on a first view; an emblematic example of this is represented by France and Sweden prices fluctuations. In these countries, variations occur almost in the same time and in the same direction.

For what concern the Emerging Markets sample, another visible example of the integration between the indexes is notable in the price variations respectively of Indonesia and Philippines, India and Mexico and Brazil and Korea.

Finally, looking at the integration between the two sample groups, the time series taken in considerations start in two different moments; anyway in the period 1998-2017 is possible to notice a clear example of comevement, especially during the crisis period, but also after this event, between equity movements of Korea (Emerging Markets group) and Australia, Canada and Hong Kong (Developed Markets group) indexes.

This common trend between the countries analyzed may suggest a strong correlation between price variations.

The aim of this work is to analyze the development of the correlation between the indexes and to identify if this measure of integration is increased during the time.

The aim of this work is to identify how this correlation is changed during the sample series and if this comovement is increased during the time.

1.3 Statistical properties

Tab. 2 reports the analysis of the main descriptive statistics relative to the Developed Markets group.

The first measure reported is the mean. This value is not very different between almost all the 15 indexes analyzed in these group and it is positive for all the sample. The average value is 0.09%. The exception is Japan index with a mean that is slightly over 0. At the opposite there is the value of Nasdaq index (USA 2) with a weekly mean of 0.16%.

Standard deviation highlights how indexes prices variation is very similar in all the countries involved. All the sample reports a value that is approximately between 2% and 3%. The average is 2.80%. The index with the lowest standard deviation is FTSE 100 (UK) with 1.89% and the one with the highest value is HANG SENG (Hong Kong) with 3.33%. This two values confirm that the variance is substantially uniform in all the indexes.

The minimum and maximum value are slightly different between the countries. The highest negative value is the one of Austria, -34%, while United Kingdom has the lowest one, -11%. Different is the situation for the maximum observation, here the values present not significant discrepancies with an average value of +13.50%.

Anyway the difference between minimum and maximum is negative in all cases. This means that the negative values are higher than the positive ones.

This fact is also confirmed by the skewness that is negative in all the sample.

The distributions have a negative asymmetry and this is quite normal and very frequent in equities returns.

Also kurtosis presents values that suggest how the time series do not follow a normal distribution. In this case the average value for kurtosis is 6.88[3]. In this countries group two indexes are largely over the average kurtosis value;

[3] In a normal distribution, kurtosis and skewness have respectively a value of 3 and 0.

Austria with 15 and Switzerland with 11. The positive exceptions are Hong Kong that, with a value of 3.11, is very close to normality and United Kingdom that with a value of 2.96 can be considered essentially normal.
Therefore, also for this measure there are values far from normality but this is something frequent and normal for equities distributions (Ruppert, 2010), especially in a sample period like this that consider the *Internet Bubble* and the severe financial recession of 2007-2008.

Tab. 2 *Analysis of the main descriptive statistics of Developed Markets indexes.*

	AUSTRALIA	*AUSTRIA*	*BELGIO*	*CANADA*	*FRANCE*	*GERMANY*	*HONG KONG*	*JAPAN*
Mean	0.0008	0.0007	0.0007	0.0010	0.0006	0.0014	0.0006	0.0000
Standard Error	0.0006	0.0009	0.0008	0.0007	0.0009	0.0009	0.0010	0.0009
Median	0.0023	0.0025	0.0036	0.0029	0.0023	0.0045	0.0023	0.0019
Standard Deviation	0.0203	0.0309	0.0270	0.0233	0.0299	0.0319	0.0337	0.0305
Sample Variance	0.0004	0.0010	0.0007	0.0005	0.0009	0.0010	0.0011	0.0009
Kurtosis	5.4688	15.4797	9.3838	6.8600	5.1241	4.6731	3.1178	6.5053
Skewness	-0.8195	-1.6057	-1.1809	-0.9001	-0.7031	-0.6191	-0.3693	-0.8166
Range	0.2613	0.5136	0.3902	0.3036	0.3748	0.3929	0.3384	0.3933
Minimum	-0.1702	-0.3413	-0.2611	-0.1754	-0.2505	-0.2435	-0.1992	-0.2788
Maximum	0.0911	0.1723	0.1291	0.1282	0.1243	0.1494	0.1392	0.1145
Sum	0.9811	0.8125	0.8784	1.2407	0.7453	1.6470	0.6930	0.0532
Observations	1199	1199	1199	1199	1199	1199	1199	1199

	NETHERLANDS	*SPAIN*	*SWEDEN*	*SWITZERLAND*	*UK*	*USA 1*	*USA 2*
Mean	0.0008	0.0008	0.0014	0.0008	0.0006	0.0013	0.0016
Standard Error	0.0009	0.0009	0.0009	0.0008	0.0005	0.0007	0.0009
Median	0.0031	0.0034	0.0034	0.0031	0.0019	0.0024	0.0033
Standard Deviation	0.0301	0.0312	0.0303	0.0263	0.0189	0.0238	0.0323
Sample Variance	0.0009	0.0010	0.0009	0.0007	0.0004	0.0006	0.0010
Kurtosis	8.7304	4.1778	4.3900	11.6179	2.9601	6.6617	8.1363
Skewness	-1.0853	-0.6599	-0.4572	-1.0027	-0.4986	-0.7717	-0.9671
Range	0.4234	0.3741	0.4045	0.4149	0.2062	0.3144	0.4655
Minimum	-0.2875	-0.2383	-0.2253	-0.2520	-0.1177	-0.2008	-0.2918
Maximum	0.1358	0.1359	0.1792	0.1629	0.0885	0.1136	0.1738
Sum	0.9207	0.9446	1.6713	0.9937	0.7369	1.5612	1.9280
Observations	1199	1199	1199	1199	1199	1199	1199

In Tab. 3, the same descriptive statistics previously used describe the main characteristics of Emerging Markets indexes.

The most interesting aspect is to compare the statistics of the two groups[4].

In Emerging Markets sample, the mean value is not uniform between the indexes but is considerably higher than the one registered for the Developed Markets group. In this case the average mean value is 0.21% against the 0.09% already mentioned.

In absolute terms Argentina and Pakistan have the highest value with a percentage of 0.34. At the opposite, the lowest value of the Emerging Markets sample is 0.02% of Taiwan.

As expected as consequence of a higher mean, also the standard deviation is higher respect to the previous countries group. Here the average value is 3.60% and is not very different between the indexes. The exception is Sri Lanka index with a returns standard deviation of 2.64%. The highest value is the one of MERVAL index (Argentina) with a statistic of 4.94% also confirmed by the previous analysis that highlights how this country shares with Pakistan the highest absolute mean.

Also for Emerging Markets group, the minimum and maximum value are slightly different between the indexes, and are quite similar to the values registered in Developed Markets sample. In this case the highest negative value is the one of Argentina, -31%, while Sri Lanka has the lowest one, -11%. It is very interesting to notice how these two values are registered in the same countries that have respectively the highest and lowest standard deviation. It is also notable how the range between the minimum values (-31% and -11%) is almost the same appeared in the Developed Markets group.

For what concern the maximum weekly observation, the highest value is again the one of MERVAL (23%), while the average of 17.88% is substantially higher than the one computed in the fifteen countries.

The difference between Emerging Markets minimum and maximum values is not negative in all cases. This fact happens for COLOMBO All-Share (Sri Lanka)

[4] Anyway, must always be considered that the sample period is different for the two groups.

and TSEC (Taiwan) indexes. It is significant to see that the skewness of these two countries is respectively positive (0.60) and only slightly negative (-0.29). Probably the most interesting values of this statistical analysis are kurtosis and skewness.

In this ten countries group kurtosis is much lower than in the Developed Markets group, with an average of 3.98 against a previous value of 6.88.

Taiwan index has a kurtosis of 2.96, very close to normality and extremely sporadic in equity returns.

Skewness is negative in 9 countries out of 10, but it is significantly lower compared to the previous sample. In these indexes the values are not so far from 0, with a mean of -0.26.

Tab. 3 *Analysis of the main descriptive statistics of Emerging Markets indexes.*

	ARGENTINA	***BRAZIL***	***INDIA***	***INDONESIA***	***KOREA***
Mean	0.0034	0.0019	0.0020	0.0028	0.0015
Standard Error	0.0016	0.0013	0.0011	0.0012	0.0012
Median	0.0060	0.0042	0.0039	0.0040	0.0036
Standard Deviation	0.0494	0.0418	0.0334	0.0363	0.0381
Sample Variance	0.0024	0.0017	0.0011	0.0013	0.0015
Kurtosis	3.50	3.38	2.55	5.23	3.66
Skewness	-0.38	-0.29	-0.36	-0.36	-0.30
Range	0.5495	0.4408	0.3055	0.4210	0.4036
Minimum	-0.3118	-0.2232	-0.1738	-0.2330	-0.2293
Maximum	0.2377	0.2176	0.1317	0.1880	0.1744
Sum	3.3557	1.8879	2.0206	2.7372	1.5255
Count	990	990	990	990	990

	MEXICO	***PHILIPPINES***	***PAKISTAN***	***SRI LANKA***	***TAIWAN***
Mean	0.0023	0.0015	0.0034	0.0022	0.0002
Standard Error	0.0010	0.0010	0.0011	0.0008	0.0010
Median	0.0036	0.0024	0.0067	0.0005	0.0028
Standard Deviation	0.0328	0.0317	0.0354	0.0264	0.0318
Sample Variance	0.0011	0.0010	0.0013	0.0007	0.0010
Kurtosis	4.68	4.14	4.54	5.12	2.96
Skewness	-0.07	-0.09	-1.06	0.60	-0.29
Range	0.3651	0.3634	0.3289	0.2928	0.3322
Minimum	-0.1793	-0.2015	-0.2010	-0.1133	-0.1491
Maximum	0.1858	0.1618	0.1280	0.1795	0.1832
Sum	2.3062	1.5055	3.3922	2.1892	0.1790
Count	990	990	990	990	990

CHAP. 2 LITERATURE

2.1 Defining financial integration

The studies about integration in international financial markets are widely diffused in financial literature. The papers on this topic are sufficiently vast (see, among many others, Panton, Lessig and Joy, 1976; Kearney and Lucey, 2004; (Morana and Beltratti, 2008); (Bekaert, Hodrick and Zhang, 2009)) that is not possible to be fully inclusive of all the aspects debated.

The focus of this work is on equity market integration, that is itself a subset of economic integration. This literature review inspects the most influential and seminal papers that have been written on the topic of equity market integration among the world's developed and emerging markets.

First of all, the most important and influential studies on defining, measuring and drawing the involvements of equity market integration among the developed markets have often served as the starting point for numerous articles on integration among the emerging equity markets, and between these and the developed markets. Second, the studies cited in this work cover many of the important emerging markets regions including Asia, Oceania and Latin America that are inspected in the Emerging Markets sample previously analyzed.

Defining international financial integration is notable the contribution of Watson et al. (1988) that describes the development in financial integration happened in the last four decades in terms of internationalization, securitization and liberalization. He notices how, for what concern internationalization, the activities in financial exchange markets has developed faster than real output in the major industrial realities. In addition, this has been associated with even faster growth in offshore financial market activity.

In terms of securitization, there has been a shifting from indirect finance to direct finance through international bond markets. Liberalization has produced the suppression of domestic quantity and price restrictions, larger international participation in domestic financial markets, more cross-border capital flows, and new financial instruments (Kearney and Lucey, 2004).

To define the integration extent between international financial markets, three basic approaches are involved. These can be gather into two vast categories; direct and indirect measures.

The first approach involves the fact that rates of return on financial assets with similar risk features and maturity are equalized across political jurisdictions. This approach, explained by (Kearney and Lucey, 2004), "is based on the logic that unrestricted international capital flows would, through seeking the best available return, lead to an equalization of the rates of return across countries".

This approach, called the equalization of rates of return, is considered a direct measure because it invokes the law of one price; in this case assets with equal cash flows should have the same return. The drawback of this method is the difficulty to find financial assets that are sufficiently similar in terms of theirs risk characteristics to allow significant comparisons to take place.

The second approach introduces the aspect of international capital market completeness.

Stockman (1988) "asserts that financial integration is perfect when there exists a complete set of international financial markets that allows economic and financial market participants to insure against the full set of anticipated states of nature". This involves the presence of a more complete set of markets characterized by efficient operations. This procedure is an indirect measure and can be used as a valid benchmark to evaluate the merit of deregulatory policy proposals.

The last approach lies on the principle to which domestic investment is

financed from world savings rather than from domestic savings.
In defining this approach (Feldstein and Horioka, 1980) say that: "perfect capital mobility requires that for a country that is small in world financial markets, exogenous changes in national savings can be financed from abroad with no change in real interest rates". Anyway, this definition employs the conditions of real interest parity and that all determinant of domestic investment have no correlation with national savings.
For these reasons the equalization of rates of return and the international capital market completeness are seen as the two most significant definitions of financial integration.

2.2 Measuring financial integration

Three main categories can be identified to gather the existing financial integration indicators: price-based indicators, quantity-based indicators and regulatory (or institutional) measures (Billio *et al.*, 2016).
Data availability, reliability of the data on which the indicators are based, economic relevance of the indicators and the ease of bulding and updating the indicators are usually the criteria employed to judge the usefulness of the previously cited indicators (Adam *et al.*, 2002).
Much of the articles on measuring international equity market integration, even though the shortage of robust justification, has focused on the quantity-based indicators of integration, as opposed to returns (Kearney and Lucey, 2004). These articles use as assumption the existence of a degree of international integration and that the test of issues like the amount of domestic stocks in a well-diversified portfolio can highlight deviations from a perfect integration. Examples of these studies are (Tesar and Werner, 1995), (Lewis, 1999) and (Ayuso and Blanco, 1999). Although this literature has

highlighted the presence of home bias in the asset allocation decisions of investors, there is not examination of the characteristics of international integration in asset markets which can produce this bias.

(Bekaert, Harvey and Lumsdaine, 2003) produce indirect studies of quantity-based indicators giving evidence on the significant development in world equity market integration by highlighting structural breaks in the amount of international capital flows.

(Portes and Rey, 2000) contribute with an analysis on the timing and complexity sequences of cross-border equity flows.

More interesting and more focalized on the evaluation of returns and prices as opposed to quantities, an important numbers of researchers make use of price-based indicators. These indicators are considered direct measures of integration and catalyze more interest than quantity-based indicators because they satisfy the previously four criteria described to judge these same indicators.

Moreover, differently from quantity indicators based on cash flow data, price-based indicators have a clearer interpretation due to their satisfaction of the law of one price.

For these reasons, a significant number of articles evaluate the increase of equity market correlations, the extent of common stochastic trends and the specification of dynamic patterns towards larger integration between equity returns.

Some different measurement frameworks are evident in the literature on price-based indicators: Vector Auto Regression (VAR) models, testing the evolution in the standard correlation or cointegration structure of markets models, error-correction models, GARCH models, asset pricing models and common component approach.

In line with (Billio *et al.*, 2016) "VAR-based studies make use of impulse response analysis to investigate the effects of contagion and the degree of

interdependence, whereas cointegration-based studies aim to assess the presence of a long-run equilibrium among cross-country financial variables, such as stock or bond prices".

Asset pricing models generally involve standard CAPM framework; the difficulty with this measure and its derivatives is how to state what is expected from the model. Some models assume a perfect integration between all world's capital markets and so the source of securities risk can be associated merely with the covariance of the local returns with the world market portfolio (Kearney and Lucey, 2004).

In other models the standard CAPM is associated to the returns of a single region. Here, the implicit assumption is that the market considered is perfectly segmented from all the other markets or that it could be considered an appropriate approximation of the world market. Neither of these approaches use adequate and plausible assumptions and for these they have not satisfied empirical tests.

(Errunza and Losq, 1985) and (Errunza, Losq and Padmanabhan, 1992) develop a better and more appropriate approach where is employed an international CAPM in which "segmentation can be other than either of the extreme cases". The main problems of this models is the assumption that the size of segmentation remain fixed over time. An improvement to this approach is done by (Bekaert and Harvey, 1995) and (De Santis and Imrohoroglu, 1997) that employ a variation in the degree of segmentation over time.

As in the words of (Kearney and Lucey, 2004) "These papers show that the degree of integration generally rises over time but that the degree of integration is closely related to the degree of currency risk and currency instability".

Also VAR and cointegration methods present some important problems. First of all, these two models are unable to return a numerical measure of financial

integration. In addition, cointegration models are static approaches and so incapable to underline the dynamic evolution of a process.

A great number of studies analyze the international integration of equity markets from the perspective of an increase in returns correlations over the observed time series.

The standard correlation (SC) is a widely used measure of comovement that can be easily employed and is subject to a clear interpretation. To highlight the integration in a group of securities returns from different markets, the most implemented methods is to consider the average of the correlation coefficients computed for each country pair (Mauro, Sussman and Yafeh, 2002; (Quinn and Voth, 2008). Other papers analyze standard correlation over different sub-periods (Goetzmann *et al.*, 2005)(Quinn and Voth, 2008).

Anyway standard correlation does not take in consideration the dynamics of the relationship between standard deviations, because it assumes that these comovement does not vary over time (Billio *et al.*, 2016).

To take account of these volatility movements between stock markets, dynamic conditional correlation models are normally employed.

However, also for these models there are some issues. (Longin and Solnik, 1995) highlight how correlation seems to increase only when equity returns are negative (bear markets) and not when they increase (bull markets). (Forbes and Rigobon, 2002) estimate how conditional correlation is exposed to volatility bias. Consequence of this is the increase of conditional correlation during periods of high volatility with the possibility of reaching a wrong conviction that there is a contagion effect during a shock or crisis. For these reasons there is not a widespread consensus on the use of conditional heteroscedasticity models (Volosovych, 2013) and so these indicators will not be taken in consideration in this work.

Standard correlation and other correlation-based metrics are largely employed in financial literature as integration measure, anyway also these

approaches have received some critiques. One of these is presented by (Bekaert, Hodrick and Zhang, 2009): "Correlations are an important ingredient in the analysis of international diversification benefits and international financial market integration. Of course, correlations are not a perfect measure of either concept".

In the spirit of developing a more robust indicator than the standard correlation, (Pukthuanthong and Roll, 2009) and (Volosovych, 2011) introduce two PCA-based integration measures.

(Pukthuanthong and Roll, 2009) conduct their analysis introducing a new approach sustained by the explanatory power of a multi-factor model. In their work they use as global factor the first ten principal components, which express around the 90% of the cross-sectional variation in market returns. Then, for each market is obtained the $\bar{R}^2$ in each calendar year. The cross-market average $\bar{R}^2$ is then employed as an alternative financial integration measure (Billio *et al.*, 2016).

In line with the studies of (Nellis 1982) and (Mauro, Sussman and Yafeh, 2002), (Volosovych, 2011) computes the degree of financial integration with the employment of the proportion of total variation in singular returns showed by the first principal component[5].

Also PCA-based measures present some issues. For instance, to infer the elements of the PCA there is generally a trade-off between the covariance and the correlation matrix. The standardization of the variables of the correlation matrix is computed. The aim of this easy modification is to employ all variables with a same weight, even if they present differences in their variance. Anyway, this transformation is usually not required when variables

[5] In the paper of (Mauro, Sussman and Yafeh, 2002), after an analysis on sovereign bond spreads for a sample of emerging markets, is highlighted how the first principal component elucidates a large part of spreads variation in the period 1877-1913 and an even larger part in 1992-2000.
In the previous studies of (Nellis 1982) the extent of interest rate variation is expressed by the first principal component to compute the extent of international financial integration.

present the same unit. In line with the work of (Billio *et al.*, 2016) about this topic: "To be sure that high changes in the variance will not dominate the principal components, this transformation is often accounted for. Of course, this may represent a non-negligible drawback. Therefore, by using the covariance matrix there can be the risk that variables with high variance will influence the overall analysis".

After this brief review of the main financial integrator indicators propose by financial literature is undeniable as each measure has its positive implications and also his drawbacks. This work will proceed in the analysis of international financial integration with a focus on the standard correlation and R squared.

CHAP. 3 FINANCIAL INTEGRATION ANALYSIS

The aim of this chapter is to analyze the correlation between the equity market indexes cited in the first chapter.

The purpose of this comparative analysis is to identify if correlation between equity indexes returns is increased over the time series period. These correlation data will be then employed to verify the consequences on the diversification of an international portfolio.

In order to capture the evolution of international financial integration, this work bases its analysis following the conclusions present in the papers of (Billio *et al.*, 2016). In this article the authors conclude their analysis on different types of financial integration measures tested on a large sample of equity markets with this result: "Standard Correlation, on average, explains movements in international diversification benefits as well as, if not better than, more sophisticated measures (i.e., PCA-based and heteroscedasticity-adjusted measures).

In this empirical analysis will be employed three different methods to estimate financial integration.

The first one consists in a computation of bilateral correlations between all the indexes of the same group. It will be used a rolling window to estimate the correlations between each countries equity returns.

The second method is an analysis of correlation matrix in, respectively, two and three different sub-periods.

The last method employs a PCA to estimate the principal component factors that will be use to run a regression in order to compute the adjusted R squared.

This analysis will be conduct first on the Developed Markets countries and then will be repeated on the Emerging Markets and Developed and Emerging together countries.

Computations are made with the use of the statistical software R and with Excel.

3.1 Dynamic standard correlation

Developed Markets

The first methodology employed in this work is the computation of the standard correlation between the returns of the 15 Developed Markets equity indexes. This measure is considered one of the most used proxies for capturing international markets comovement and therefore financial integration (Kearney and Lucey, 2004). The analysis is conducted with the employment of bilateral correlations computed with the use of a rolling window of 60 weeks. Broadly speaking, the standard correlation is estimated for each country pairs with the use of a rolling window. The Developed Markets sample has fifteen different indexes that represent a country, the results are 225 (15 X 15) rolling windows that estimate a dynamic standard correlation. To obtain a single dynamic standard correlation is then estimated the cross-country average correlation between each of the 225 rolling windows.

The size of the rolling window over which correlation is estimated is considerably influential for the output result. If the window length is too short, there are insufficient observations to estimate accurate correlation coefficients. Otherwise, if the window length is too large, the correlation trend is smoothed and is not possible to capture significant medium-term changes in integration. This work is in line with the main financial literature articles that normally use a rolling window of 60 observations. Anyway, the results have been tested with the employ of different window sizes and they show robustness.

In Fig. 3 is shown the dynamic standard correlation obtained as cross-country average of the 225 bilateral correlations.

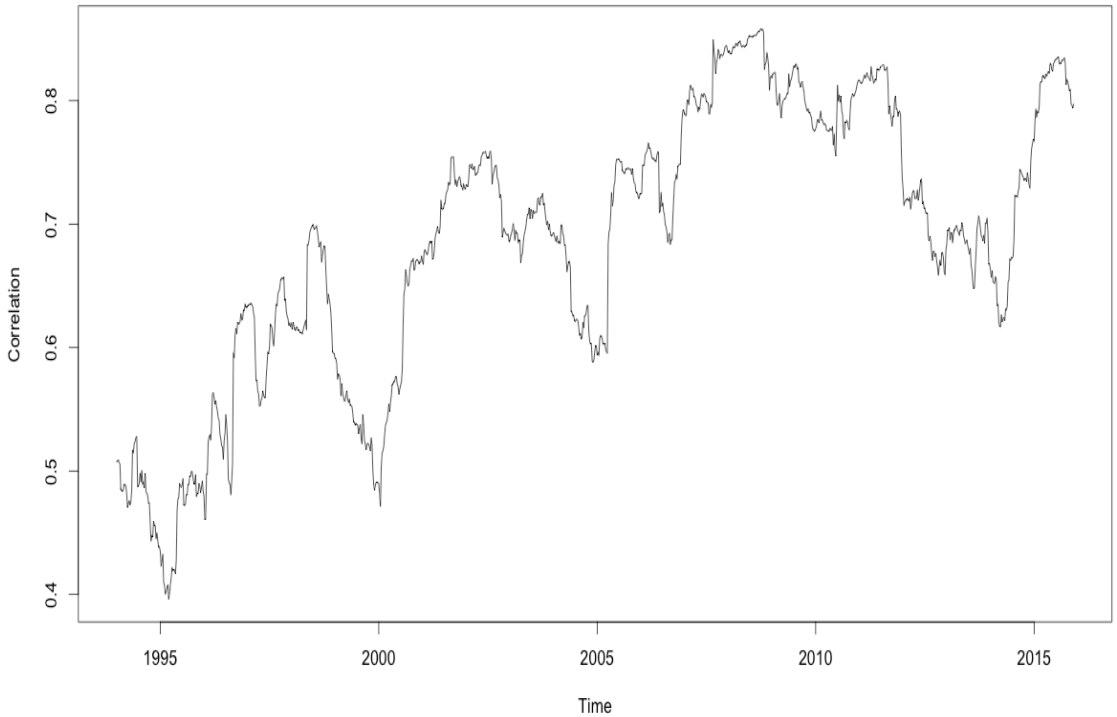

Fig. 3 *Dynamic standard correlation from 1994 to 2017 for the Developed Markets sample.*

It is clear from the graph how the standard correlation is increased during time. Even though there are some evident breaks in the path, the general trend shows a constant increase during the sample period.

Moreover, what it is interesting to notice is that the correlation is positive in every period and, with the light exception of 1995, it never goes down 0.4.

A second very significant aspect is that the relative minimum bounds are every time higher than the previous one. For instance, in 1995 there is the first minimum; it coincides with the absolute minimum, and it is lower than 0.4. The second relative minimum point is at the beginning of 2000 and its

value is light below 0.5, the following relative low bound is at the beginning of 2005 and has a standard correlation of 0.6. The last relative minimum, before 2015, coincides with the absolute high minimum and has a value lower than 0.7.

Also extremely significant in the evaluation of this trend is the position of relative maximum bounds over the sample period. As for the relative minimum points, also in this case each relative maximum is higher than the previous one. The only exception is the last relative maximum point, after 2015, that is slightly lower than the previous in 2008.

The first relative maximum is at the beginning of the sample period and has a value slightly higher than 0.5. The second relative maximum point is in 2008 and has a standard correlation of 0.7. The following relative maximum is in the period 2002-2003 and has a value of 0.75. After this relative maximum there is the absolute maximum, with a value around 0.9 in the crisis period of 2008-2009.

This analysis of the lower and upper bounds highlights an increasing trend during the sample period; probably the most substantial and significant increase happens in the period 2000-2009.

To better inspect this trend has been computed a decomposition of the time series.

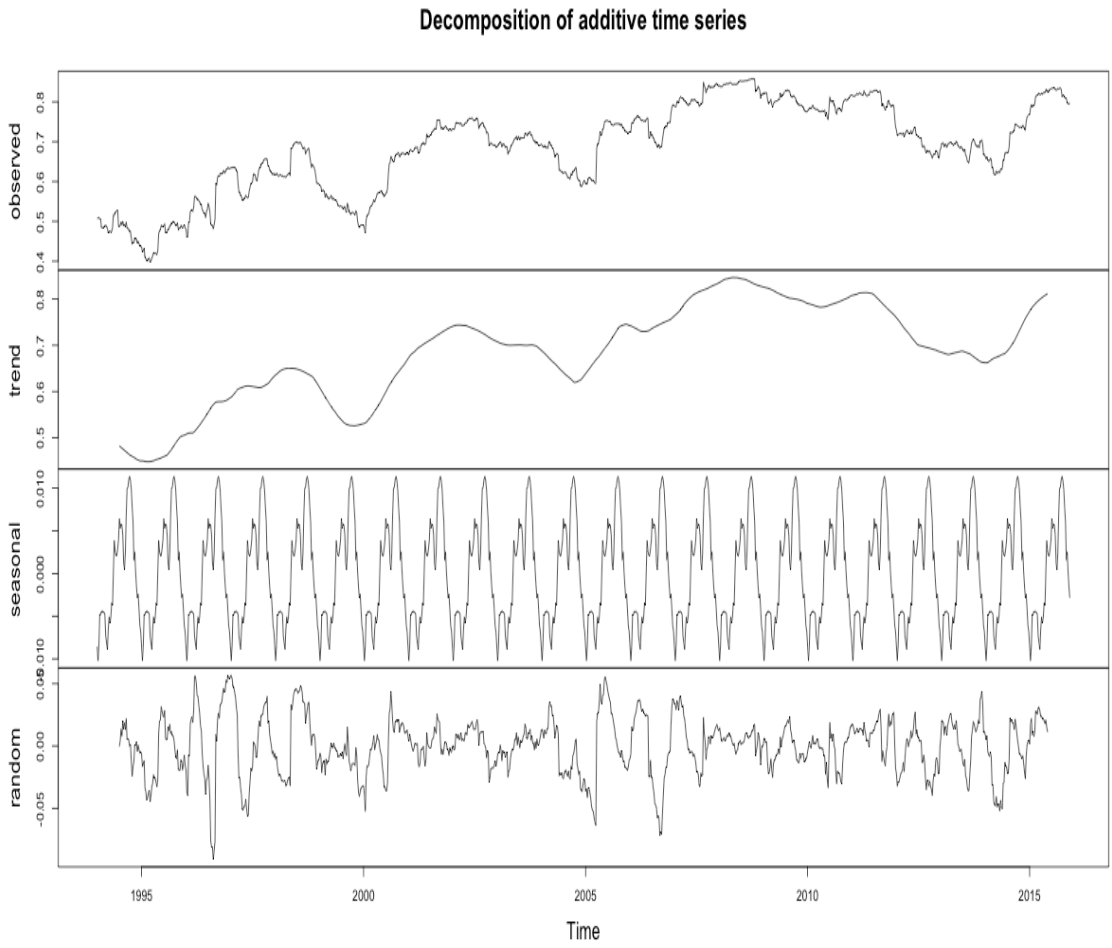

Fig. 4 *Decomposition of the time series (dynamic standard correlation computed in the sample period 1994-2017 for the Developed Markets).*

In Fig. 4 is possible to see in the first row the same trend of the standard correlation above estimated. The most interesting part of this decomposition is in the second row, where the decomposition returns the general trend of the time series. This general trend is very meaningful; it highlights the increase of the standard correlation from the starting point value below 0.5 to a value below 0.9 in the last part of the time series.

A liner combination of the standard correlation trend is highlighted in Fig. 5; it is clear how the standard correlation coefficient (p in the figure) is increased during the sample period.

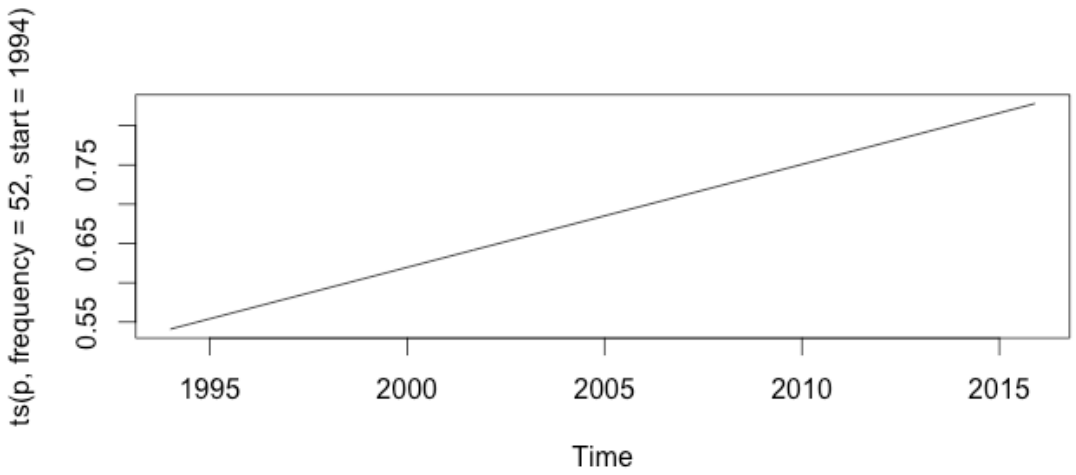

Fig. 5 *Linear combination of the standard correlation coefficient (sample period 1994-2017 for the Developed Markets).*

Emerging Markets

The same analysis is now repeated for the Emerging Markets sample. In this case, it is appropriate to remember that the time series begins in 1998. As in the previous example rolling windows of 60 weeks are employed. The single dynamic standard correlation is estimated as the cross-country average correlation between each of the 100 (10 X 10) rolling windows.

In Fig. 6 is shown the graph of the dynamic standard correlation obtained.

Also here the standard correlation increment is significant, especially in the second part of the graph. The correlation coefficient never goes down 0.4. In this case, as in the previous example, all the relative minimum bounds are every time higher than the previous one. The same characteristic is verified with the relative maximum points.

Analyzing the path of the graph, it is interesting to notice a first important increasing movement that begins in 1999 and ends in in 2002. This movement is followed by a likewise important decrease that ends in 2004.

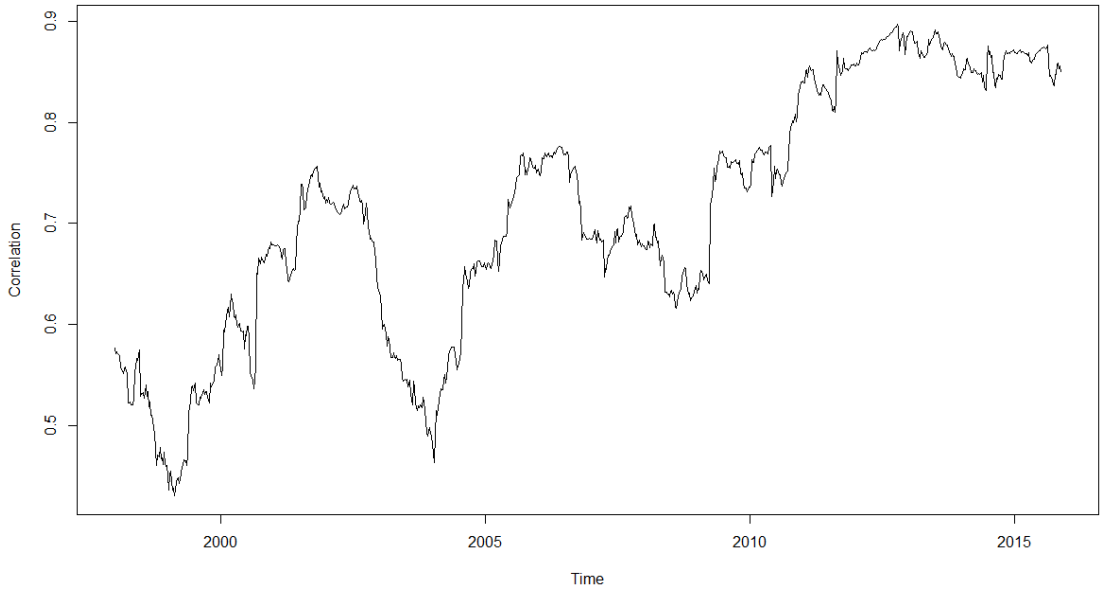

Fig. 6 *Dynamic standard correlation from 1998 to 2017 for the Emerging Markets sample.*

After this part, there is, except for the interruption in 2008 and 2009, a constant increase until the maximum levels of 2013-2014 where the correlation coefficient has a value of about 0.9.

It is very significant to notice how the Emerging Markets indexes here analyzed are not influenced by the effect of increasing correlation that influences the Developed Markets sample during the financial crisis of 2007-2009. As highlighted in Fig. 3, the levels of maximum correlation coincide with the financial crisis, while in the Emerging Markets sample, this period is affected by a relative low correlation.

As before, the decomposition of the time series is computed to better inspect the general trend (Fig. 7).

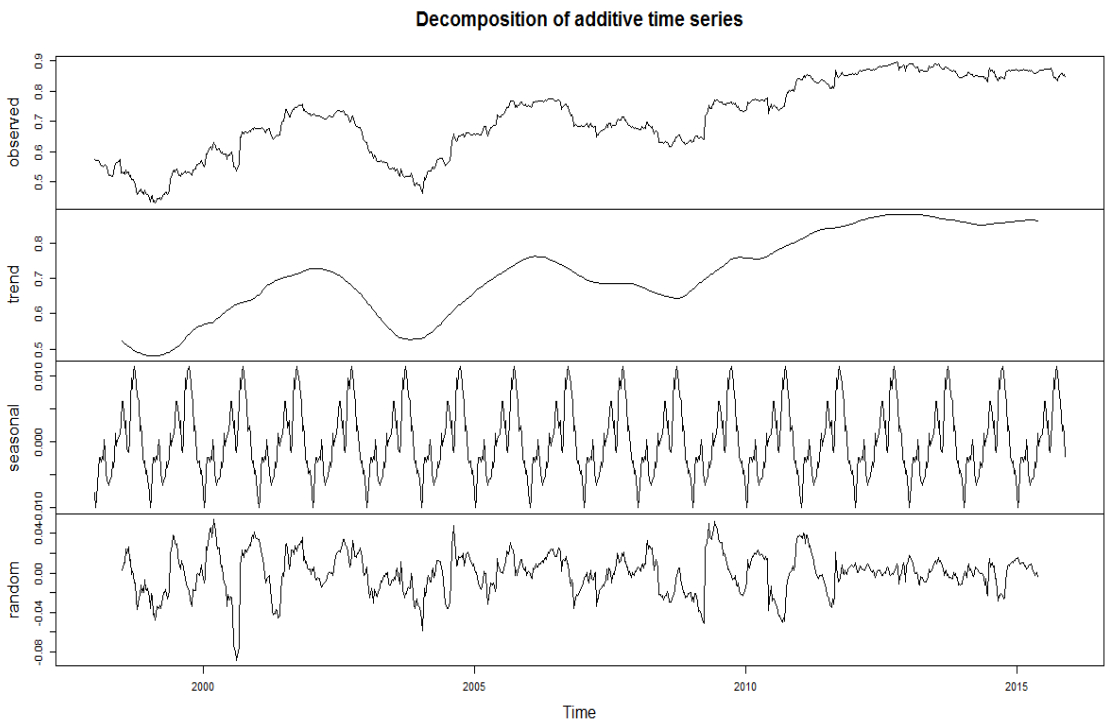

Fig. 7 *Decomposition of the time series (dynamic standard correlation computed in the sample period 1998-2017 for the Emerging Markets).*

In the second row of Fig. 7 the general trend of our dynamic standard correlation confirms the increase happened during the time series. It is significant to notice how the standard correlation coefficient value is below 0.5 at the beginning of the sample period and reaches a value of about 0.9 in the last part of the time series.

Developed and Emerging Markets

In Fig. 8 is possible to see the result of the same analysis, in this case computed on the Developed and Emerging Markets together sample.

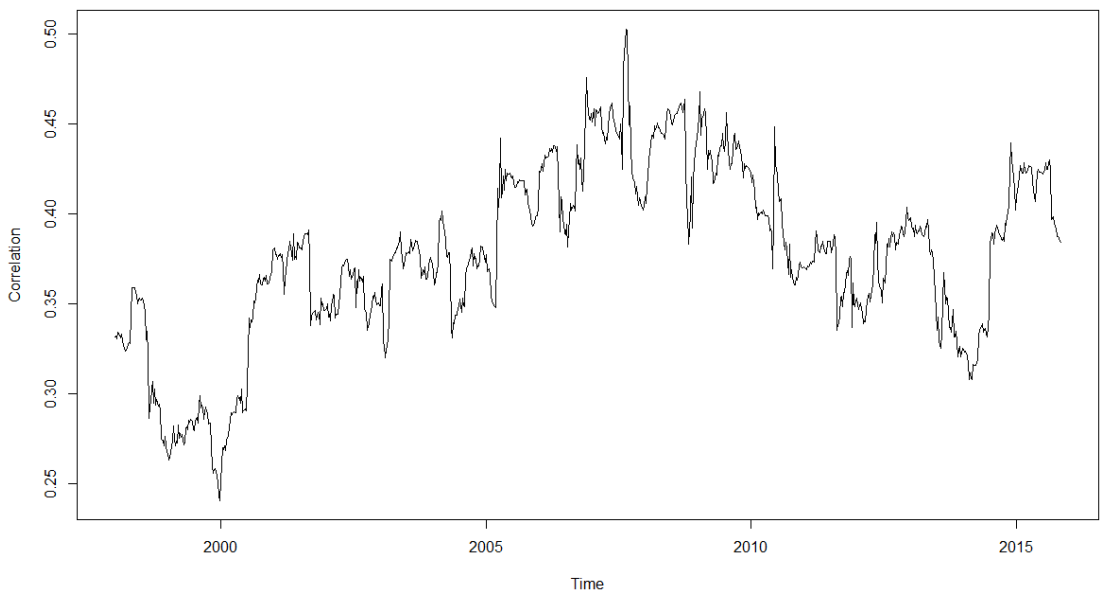

Fig. 8 *Dynamic standard correlation from 1998 to 2017 for the Developed and Emerging Markets together sample.*

In this case, it is appropriate to remember that the time series begins in 1998 in line with the first observation of the Emerging Markets sample. The single dynamic standard correlation is estimated as the cross-country average correlation between each of the 625 (25 X 25) rolling windows.

The standard correlation coefficient in this case is significantly lower than the one observed in the previous two samples. In the Developed and then Emerging Markets preceding analysis the coefficient never goes down 0.5/0.4. Now it has a minimum value of about 0.25 and a maximum of 0.5 against the 0.9 previously registered. The most evident increase starts exactly in 2000 and ends in 2008. After this period there is a decrease until a standard correlation value of 0.30 in 2014 and then again an increase movement that reaches a value of about 0.45 in the last part of the time series.

The decomposition estimated in Fig. 9 highlights accurately these movements as is clear from the general trend shown in the second row.

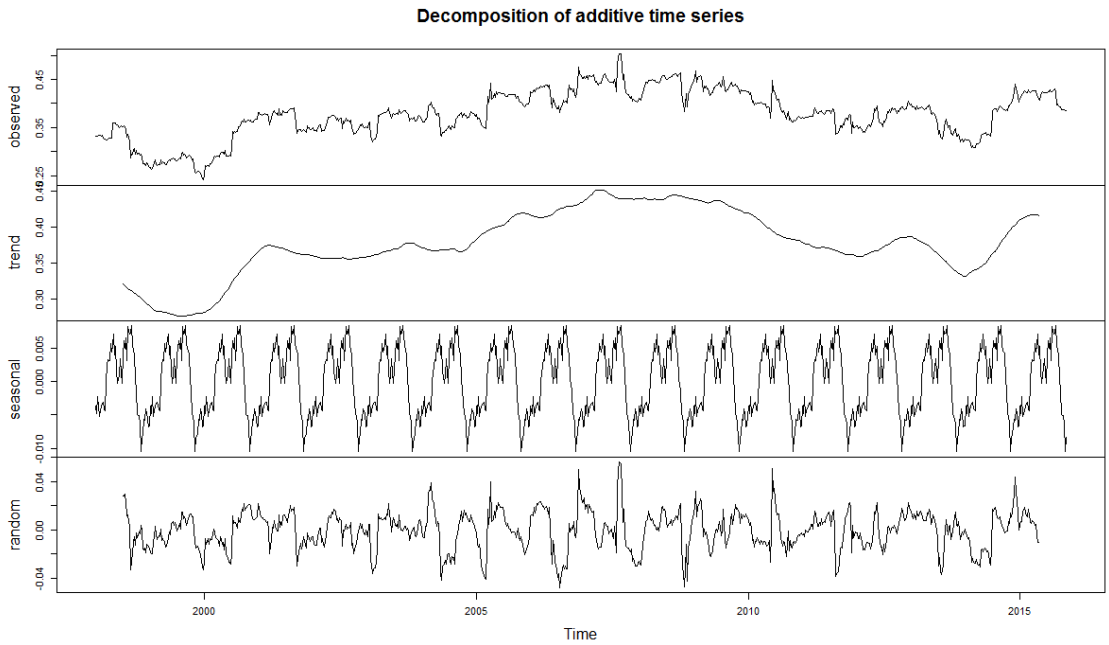

Fig. 9 *Decomposition of the time series (dynamic standard correlation computed in the sample period 1998-2017 for the Developed and Emerging Markets together).*

3.2 Standard correlation in different sub-periods

Developed Markets

The second methodology used to inspect the degree of international financial integration involves the estimation of standard correlation in different sub-periods (see, among the other contributions (Goetzmann *et al.*, 2005) (Quinn and Voth, 2008).

In the specific, this method divides the times series analyzed in equal parts (two or more) and computes the correlation matrix for each sub-period. Then the average of the correlations of each matrix are employed as a measure of evaluation of the level of financial integration between the sample that

compose the matrix.

In this work, the first estimation is on the Developed Markets sample. First of all the time series is divided in two equal parts. The first part goes from 09/01/1994 to 26/06/2005 (599 observations). The second part begins in 03/07/2005 and ends in 18/12/2016 (599 observations). The results are shown in Fig. 10.

1994 - 2005

	AUSTRALIA	AUSTRIA	BELGIO	CANADA	FRANCE	GERMANY	HONG KONG	JAPAN	NETHERL.	SPAIN	SWEDEN	SWITZ.	UK	USA 1	USA 2
AUSTRALIA	1														
AUSTRIA	0.3552	1													
BELGIO	0.4431	0.4334	1												
CANADA	0.4970	0.3454	0.4056	1											
FRANCE	0.4699	0.3960	0.6915	0.5927	1									**AVERAGE**	
GERMANY	0.4846	0.4530	0.6848	0.5800	0.8290	1								0.54	
HONG KONG	0.4913	0.3341	0.3480	0.4027	0.4437	0.4775	1								
JAPAN	0.3859	0.2423	0.2484	0.3413	0.3600	0.3476	0.36264	1							
NETHERLANDS	0.4945	0.4501	0.7697	0.5597	0.8369	0.8442	0.45120	0.3533	1						
SPAIN	0.5239	0.4471	0.6282	0.5465	0.7671	0.7582	0.44384	0.3269	0.7611	1					
SWEDEN	0.2927	0.1766	0.2607	0.2987	0.3250	0.3713	0.24043	0.2069	0.3240	0.3171	1				
SWITZERLAND	0.4332	0.4575	0.7024	0.4854	0.7351	0.7536	0.40085	0.3043	0.7806	0.6978	0.2622	1			
UK	0.4918	0.3717	0.4381	0.4239	0.5059	0.5644	0.43668	0.3218	0.5549	0.4923	0.2829	0.5123	1		
USA 1	0.4937	0.3214	0.5169	0.7318	0.6729	0.6784	0.41605	0.3237	0.6598	0.6035	0.2976	0.6063	0.4569	1	
USA 2	0.4326	0.2055	0.3035	0.7211	0.5595	0.5873	0.38531	0.3234	0.5275	0.5110	0.3117	0.4020	0.3783	0.8165	1

2005 - 2016

	AUSTRALIA	AUSTRIA	BELGIO	CANADA	FRANCE	GERMANY	HONG KONG	JAPAN	NETHERL.	SPAIN	SWEDEN	SWITZ.	UK	USA 1	USA 2
AUSTRALIA	1														
AUSTRIA	0.7298	1													
BELGIO	0.6893	0.8194	1												
CANADA	0.7238	0.7644	0.7248	1											
FRANCE	0.7157	0.8444	0.9047	0.7740	1									**AVERAGE**	
GERMANY	0.6686	0.8044	0.8615	0.7294	0.9357	1								0.75	
HONG KONG	0.7020	0.6517	0.6238	0.6285	0.6372	0.6209	1								
JAPAN	0.6813	0.6530	0.6374	0.6002	0.6833	0.6712	0.6631	1							
NETHERLANDS	0.7264	0.8382	0.9021	0.7793	0.9373	0.8982	0.6364	0.6792	1						
SPAIN	0.6104	0.7756	0.8045	0.6557	0.8705	0.8175	0.5600	0.5950	0.8000	1					
SWEDEN	0.6835	0.8028	0.8408	0.7340	0.8723	0.8577	0.6157	0.6340	0.8564	0.7646	1				
SWITZERLAND	0.6973	0.7283	0.7825	0.6819	0.8154	0.7888	0.5613	0.6549	0.8011	0.7181	0.7788	1			
UK	0.6586	0.6306	0.6145	0.5640	0.6438	0.6178	0.6197	0.5841	0.6862	0.5329	0.6190	0.5697	1		
USA 1	0.6916	0.7629	0.7959	0.8048	0.8388	0.8348	0.6180	0.6444	0.8274	0.7385	0.7898	0.7704	0.5576	1	
USA 2	0.6719	0.7170	0.7539	0.7658	0.7980	0.8070	0.6130	0.6328	0.7843	0.6967	0.7725	0.7276	0.5408	0.9493	1

Fig. 10 *Standard correlation matrices in the period 1994 – 2005 and in the period 2005 – 2016 (Developed Markets sample).*

Both matrices present no negative value. The most interesting evaluation on this data consist in the observation of the change in the average value. In the first period (1994 – 2005) the standard correlations average is 0.54, in the second period (2005 – 2016) is 0.75. This highlights a strong increase in the correlation between these equity markets in a period of about ten years.

To further inspect the time series, the sample is now divided in three equal

parts of 399 observations each. The first part goes from 09/01/1994 to 26/08/2001, the second from 02/09/2001 to 19/04/2009 and the third from 26/04/2009 to 11/12/2016. In each period, the average of the standard correlations matrix is computed. Results are reported in Tab. 4 for space reasons.

Tab. 4 *Average of the standard correlations matrices in three sub-periods (Developed Markets sample).*

	SC AVERAGE	
1994 - 2001	0.50	
2001 - 2009	0.75	
2009 - 2016	0.72	

These results confirm the increasing correlation during the time series. In particular, the evident increase is from the first period (1994 – 2001) to the second one (2001 – 2009). In the third periods (2009 – 2016) there is a slight decrease; anyway it confirms that standard correlation between the Developed Markets sample remains at a high level.

Emerging Markets

The computation of standard correlation matrices is now repeated for the Emerging Markets sample.

As before, the time series is divided in two equal parts and then in three equal parts. For what concern the two equal sub-periods the first starts in 11/01/1998 and ends in 01/07/2007 (495 observations), while the second starts in 08/07/2007 and ends in 25/12/2016. Results are shown in Fig. 11.

1998 - 2007

	ARGENTINA	BRAZIL	INDIA	INDONESIA	KOREA	MEXICO	PHILIPPINES	PAKISTAN	PAKISTAN	TAIWAN
ARGENTINA	1									
BRAZIL	0.4347	1								
INDIA	0.1875	0.2399	1						AVERAGE	
INDONESIA	0.1640	0.2351	0.2150	1					0.35	
KOREA	0.1882	0.3032	0.3186	0.3559	1					
MEXICO	0.4826	0.5851	0.2914	0.1935	0.3601	1				
PHILIPPINES	0.2732	0.3392	0.1878	0.3641	0.3063	0.3533	1			
PAKISTAN	0.1008	0.1277	0.1276	-0.0130	0.0250	0.0821	0.0319	1		
PAKISTAN	0.1303	0.1075	0.0758	0.0114	0.0174	0.1129	0.0970	0.1281	1	
TAIWAN	0.2132	0.3076	0.2420	0.2091	0.4330	0.2712	0.2571	0.1062	0.0653	1

2007 - 2016

	ARGENTINA	BRAZIL	INDIA	INDONESIA	KOREA	MEXICO	PHILIPPINES	PAKISTAN	PAKISTAN	TAIWAN
ARGENTINA	1									
BRAZIL	0.6590	1								
INDIA	0.4667	0.5661	1						AVERAGE	
INDONESIA	0.4818	0.5117	0.5685	1					0.52	
KOREA	0.5626	0.6365	0.6318	0.5750	1					
MEXICO	0.6100	0.7207	0.5489	0.4929	0.6327	1				
PHILIPPINES	0.4289	0.5033	0.4842	0.6299	0.5493	0.4863	1			
PAKISTAN	0.1094	0.1187	0.1342	0.1066	0.1654	0.0937	0.1379	1		
PAKISTAN	0.2321	0.2294	0.2906	0.2501	0.2097	0.2329	0.1955	0.0356	1	
TAIWAN	0.4753	0.5625	0.5772	0.5471	0.7356	0.5182	0.5537	0.2173	0.1962	1

Fig. 11 *Standard correlation matrices in the period 1998 – 2007 and in the period 2007 – 2016 (Emerging Markets sample).*

Also here there are no negative value and it is clear to see the growth in the two different sub-periods of the average standard correlation coefficient that increases from 0.35 to 0.52. Differently from the Developed Markets sample, the correlation coefficients here have values that are substantially lower than the values of the previous analysis[6].

As before, to further inspect the time series, the sample is now divided in three equal parts of 330 observations each. The first part goes from 11/01/1998 to 02/05/2004, the second from 09/05/2004 to 29/08/2010 and the third from 05/09/2010 to 25/12/2016. In each period, the average of the standard correlations matrix is computed. Results are reported in Tab. 5 for space reasons.

[6] This fact indicates a general lower standard correlation between the Emerging Markets indexes in respect to the Developed Markets ones.

Tab. 5 *Average of the standard correlations matrices in three sub-periods (Emerging Markets sample).*

	SC AVERAGE	
1998 - 2004	0.34	
2004 - 2010	0.52	
2010 - 2016	0.46	

Also in this case the averages of standard correlations behave in the same way registered for the Developed Markets sample. Results confirm the increasing correlation trend. The evident increase is from the first period (1998 – 2004) to the second one (2004 – 2010). In the third periods (2010 – 2016), as verified for the Developed Markets indexes), there is a slight decrease; anyway the standard coefficient remains at a relatively high value, not very different from the one registered in the second sub-sample.

Developed and Emerging Markets

In this part, where Developed and Emerging Markets indexes are analyzed together, are employed the same sub-periods used for the Emerging Markets. For evident space reasons, results are summarized in Tab. 6 where are highlighted the averages of standard correlation matrices for respectively the two and three sub-samples.

Tab. 6 *Average of the standard correlations matrices respectively in the two and three sub-periods (Developed and Emerging Markets sample).*

	SC AVERAGE	
1998 - 2007	0.39	
2007 - 2016	0.60	
1998 - 2004	0.38	
2004 - 2010	0.61	
2010 - 2016	0.53	

Results are in line with the previous analysis; standard correlation between the equity indexes is increased during the sample period as is possible to see from the values of the two sub-periods (first part of Tab. 6).
A further decomposition in three sub-samples confirms how the comovement between the equity markets slightly decrease in the last part of the sample. Anyway the standard correlation value decrease in the third period is not significant as the increase happened in the first one; it is possible to conclude that the level of financial integration remains at a relatively high value.

3.3 The $\overline{R}^2$

In order to test an alternative measure to the standard correlation, the analysis of the evolution of international financial integration proceeds with the computation of a PCA applied to the equity returns of Developed, Emerging and Developed and Emerging Markets together samples.
The Principal Component Analysis is one good way to assess the change in index correlation during different periods.

The measure employed in this analysis has been proposed by (Pukthuanthong and Roll, 2009) and is developed through the explanatory power of a multi-factor linear model.

The principle behind the PCA is the following: if some quantitative variables are correlated, most of their variability can be explained by a linear combination of them, called common factors. The first factor will explain most of the common variance, the second most of the residual, the third the most of the residual after the first and second, and so on. The factors are orthogonal between them. The formula for calculating the factors is:

$$f_{i,t} = v_{i,1}r_{1,t} + v_{i,2}r_{2,t} + \dots v_{i,C}r_{C,t}$$

where $r_{c,t}$ is the country c's market return at time t and v_{ij} is the jth element of ith PC, also named scoring coefficient or loading. The first $K < C$ global factors are then employed as explanatory variables in a multi-factor regression for all C country index returns (Billio *et al.*, 2016). We use the first 3 factors, and run the following regression:

$$r_{c,t} = \beta_{c,0} + \beta_{c,1}f_{1,t} + .. + \beta_{c,K}f_{K,t} + \epsilon_{n,t}, \qquad c \in \{1, \dots, C\}$$

Where $\beta_{c,K}$ measures country c's exposure to kth global factor.

In order to obtain a robust measure of financial integration, the cross-country average of the adjusted R squared obtained from the previous regressions is computed. In our case, we expect the fifteen (ten and twenty five) indexes to be explained mostly by one factor, which represents global economy. We also expect this factor to be more important over time.

To prove this, first of all we run a PCA on the indexes, to see how important they are.

Developed Markets

Tab. 7 *Summary of the results of the PCA computed on Developed Markets indexes.*

	IMPORTANCE OF COMPONENTS				
	PC1	PC2	PC3	PC4	PC5
Standard Deviation	3.2075	0.88478	0.82112	0.77161	0.70126
Proportion of Variance	0.6859	0.05219	0.04495	0.03969	0.03278
Comulative Proportion	0.6859	0.73805	0.78300	0.82269	0.85548

Tab. 7 means that the first component explains 68% of the variability. This means that global economy is responsible for most of the variance. The second and third factor account for only 5 and 4% respectively. The first three principal components summarize around 80% of total returns variation.

After calculating the factors, we run the regressions to calculate the R squared, dividing the sample in the same three equal periods previously used to computed the standard correlations in different sub-periods: 1994-2001, 2001-2009 and 2009-2016. This is the table showing the values of adjusted R squared for each index-period.

Tab. 8 *$\bar{R}^2$ for each index-period (Developed Markets sample).*

Adj-R sqrd			
	1994 - 2001	**2001 - 2009**	**2009 - 2016**
1	0.75	0.89	0.90
2	0.70	0.90	0.89
3	0.56	0.80	0.75
4	0.51	0.80	0.85
5	0.69	0.90	0.91
6	0.72	0.89	0.87
7	0.72	0.81	0.76
8	0.76	0.96	0.95
9	0.81	0.91	0.89
10	0.60	0.71	0.72
11	0.89	0.88	0.90
12	0.45	0.73	0.64
13	0.83	0.93	0.93
14	0.67	0.81	0.79
15	0.74	0.88	0.74
AVERAGE	0.69	0.85	0.83

Now we can proceed with the computation of the means for each of the three periods, as it is possible to see in the last row of Tab. 8. They indicate that the correlation was much less before 2000, and increased a lot after. This results are in line with the previous analysis computed on three standard correlation matrices. It is confirmed how the financial integration is increased for the Developed Markets equity indexes. As highlighted before, in the third period there is a slight reduction in the integration measure; anyway it confirms how the integration remains at a high level.

Emerging Markets

We run the same PCA analysis on the Emerging Markets indexes, to find out

how they are related each other. This is the table of the importance of components:

Tab. 9 *Summary of the results of the PCA computed on Emerging Markets indexes.*

	IMPORTANCE OF COMPONENTS				
	PC1	PC2	PC3	PC4	PC5
Standard Deviation	1.8086	1.0284	0.9556	0.8681	0.8270
Proportion of Variance	0.4089	0.1322	0.1142	0.0942	0.0855
Comulative Proportion	0.4089	0.5411	0.65520	0.7494	0.8349

In this case (Tab. 9), the first component only takes 40% of the variance. This means the markets have less correlation: on Developed Markets sample, this value was 68%. The second and third factor account for 11% and 9% of the total variance: this means they also give a good contribution.

After calculating the factors, we run the regressions to calculate the adjusted R squared, dividing the sample in three equal periods (the same employed for the computation of the standard correlation in three sub-periods): 1998-2004, 2005-2010 and 2011-2016. Tab. 10 shows the values of adjusted R squared for each index-period. As before, each lines represents an index, each column a period.

Tab. 10 *$\bar{R}^2$ for each index-period (Emerging Markets sample).*

Adj-R sqrd			
	1998 - 2004	**2004 - 2010**	**2010 - 2016**
1	0.47	0.73	0.57
2	0.58	0.79	0.64
3	0.39	0.66	0.58
4	0.47	0.69	0.61
5	0.66	0.77	0.60
6	0.39	0.52	0.42
7	0.92	0.94	0.91
8	0.96	0.99	0.97
9	0.52	0.70	0.54
10	0.68	0.82	0.78
AVERAGE	0.60	0.76	0.66

The average adjusted R squared in the last row highlights how the financial integration grows in the central period and then decreases in the third one; anyway the value of the third period remains higher than the one registered in the first sub-sample[7].

Developed and Emerging Markets

The same PCA analysis is now employed on the Developed and Emerging Markets together sample. Results are summarized in Tab. 11 and Tab. 12.

[7] These results are in line with the movement of the standard correlation coefficient computed in the previous analysis on the correlation matrices in three different sub-periods.

Tab. 11 *Summary of the results of the PCA computed on Developed and Emerging Markets together indexes.*

	IMPORTANCE OF COMPONENTS				
	PC1	PC2	PC3	PC4	PC5
Standard Deviation	3.2634	1.8124	1.0285	0.9676	0.8784
Proportion of Variance	0.4632	0.1428	0.0460	0.0407	0.0335
Comulative Proportion	0.4632	0.6058	0.6518	0.6925	0.7261

The first component explains 46% of the variability. The second and third factor account for 14% and 4% of the total variance. The first three principal components summarize the 65% of total returns variation.

These results are close to the ones registered on the Emerging Markets sample; the first three principal components explain only the 65% of total variance and not the 80% as in the Developed Markets sample.

We divide the sample in three equal periods, the same of the Emerging Markets sample and we run the regressions to calculate the adjusted R squared. The average values are reported in Tab. 12 for evident space reasons. Also here results confirm the increasing financial integration happened in the central sample period and the fact that integration remains at a relative high value in the third part.

Tab. 12 *Averages of* $\bar{R}^2$ *for each index-period (Developed and Emerging Markets together sample).*

Adj-R sqrd			
	1998 - 2004	**2004 - 2010**	**2010 - 2016**
AVERAGE	0.59	0.75	0.69

CHAP. 4 PORTFOLIO DIVERSIFICATION

The aim of this chapter is to inspect the effects of the changes in financial integration and, more specific, correlation between the equity indexes inspected in this work.

The previous analysis that has the purpose of assessing the development of correlation between equity returns is now the basis to verify how portfolio diversification is changed during the sample period.

In order to highlight the diversification changes, efficient frontiers are constructed as combination of our equity indexes.

We compute the efficient frontier in different periods (the same employed for the estimation of standard correlation in different sub-periods) and then we assess the changes focalizing the attention on tangency portfolio and minimum variance portfolio.

4.1 Efficient Frontier

In order to capture the effects of movements in correlation coefficient during time we build different efficient frontiers in two sub-samples and we inspect how these frontiers change between them.

The analysis is conducted respectively on the: Developed Markets, Emerging Markets and Developed plus Emerging Markets sample.

To construct the efficient frontier, we employ the classic method of mean-variance originally proposed by Harry Markowitz in 1952.

The portfolio frontier is the space enclosing all the assets (portfolios) that satisfy the mean-variance principle: for a given expected return is chosen the asset (portfolio) that presents the minimum variance. Broadly speaking, for every returns is select the portfolio with the lowest variance (efficient portfolio) and the set of any portfolio selected shapes the so called portfolio

frontier. In the portfolio frontier, that normally has a blend shape, there is a portfolio that presents the lowest variance. This portfolio is the minimum variance portfolio and constitutes the starting point of the efficient frontier. This minimum variance portfolio is not inevitably the portfolio that presents also the lowest return; it is possible to find other portfolios with a lower return and a higher variance. These portfolios are called inefficient because they restitute a lower return with an higher risk (variance)[8].

The efficient frontier starts in the point where is collocated the so called minimum variance portfolio and continues with other efficient portfolios that show higher returns. Then, it depends on the investor preferences where positioning on the frontier.

Generally, the efficient frontier is associated with a risk-free asset that is represented by treasury bond rates of a developed country[9]. The interception between the point on the *y* axis where is collocated the risk-free rates and the efficient frontier is called the tangency portfolio.

In our analysis we employ the LIBOR Euro – 1 week rates as risk-free rates of return[10]. As of 28th September 2017 this rates is -0.41%, therefore, in our analysis, we assume the risk-free rates equal to zero. In our sample the returns are computed on a weekly basis; it is for this reason that we adopt the 1 week LIBOR.

Correlation coefficient influences the variance between the portfolios in which we want to invest and so consequently impact on the positioning of the efficient frontier. Higher correlation coefficients entail higher variance between financial assets than lower correlation between these assets. This principle is recognized as diversification benefit; higher the number of assets

[8] In financial literature the investment risk is normally associated with the variance.

[9] Normally the most representative treasury rates are the one of USA and Germany for European Union.

[10] LIBOR Euro – 1 week rate as of 28/09/2017. Value = -0.41714%. Source: European Central Bank, www.ecb.europa.eu.

and lower the correlation coefficients between them and lower will be the variance of the overall portfolio. A lower variance means a lower investment risk and this is normally the main interest of financial investors. The goal of this analysis is exactly to verify the movements in efficient frontiers to highlight if the variance of the overall portfolio is increased or decreased.
Our analysis starts with the Developed Markets sample and continues with the Emerging Markets and Developed plus Emerging Markets sample.
All computations are made with the use of R software.

4.1.1 Developed Markets

We can calculate the efficient frontiers for developed countries by dividing the sample in two sub-samples, one from January 1994 to June 2005, and one from July 2006 to January 2017. The objective of this calculation is to find out whether the efficient frontier has moved from the first period to the second due to rising correlation. Long only constraint[11] are used in this analysis.
The following chart in Fig. 12 shows the portfolio and the efficient frontier in the period 1994-2005 for the Developed Markets sample. The point in grey represent the lower part of the portfolio frontier, which of course is never used. The red point is the global minimum variance, in this case set at mean 0.11% and variance 1.33%. These values mean that the minimum weekly risk is 1.3%, and delivers a return of 0.11%, also weekly.
The black points are the actual efficient frontier, which will be used as allocation according to each investor's preference. Depicted in blue, the capital market line, represents allocations using also the risk-free asset. This line touches the efficient frontier in the tangency portfolio, which has mean value 0.14% and variance 1.42% for a Sharpe ratio of 0.099.

[11] Long only constraint are used also in the computation of Emerging Markets and Developed plus Emerging Markets efficient frontiers.

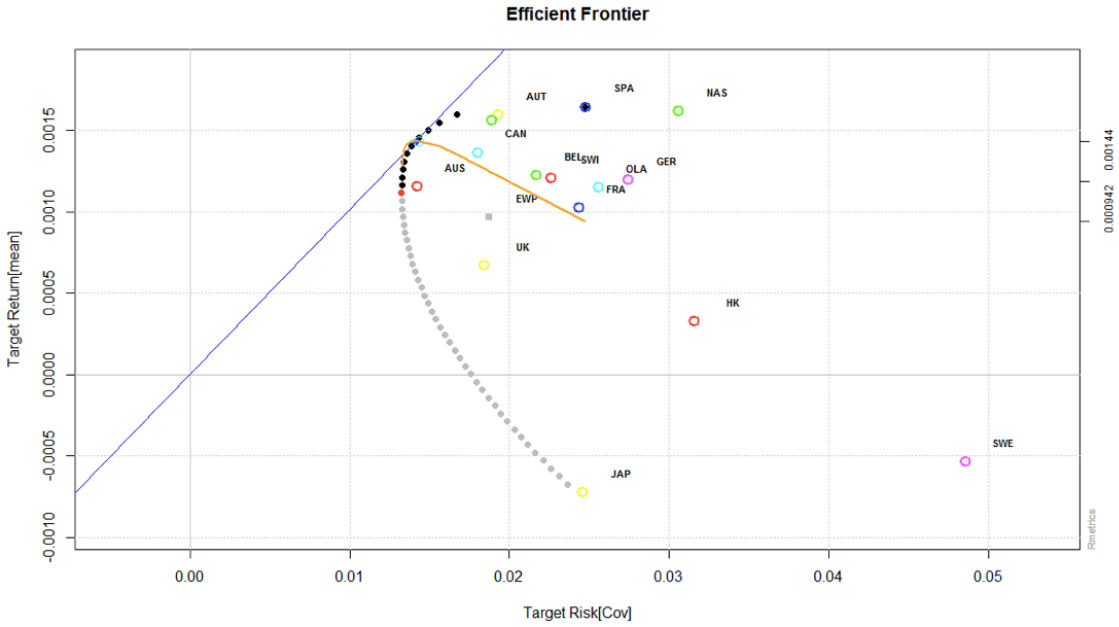

Fig. 12 *Efficient frontier for the Developed Markets sample from January 1994 to June 2005.*

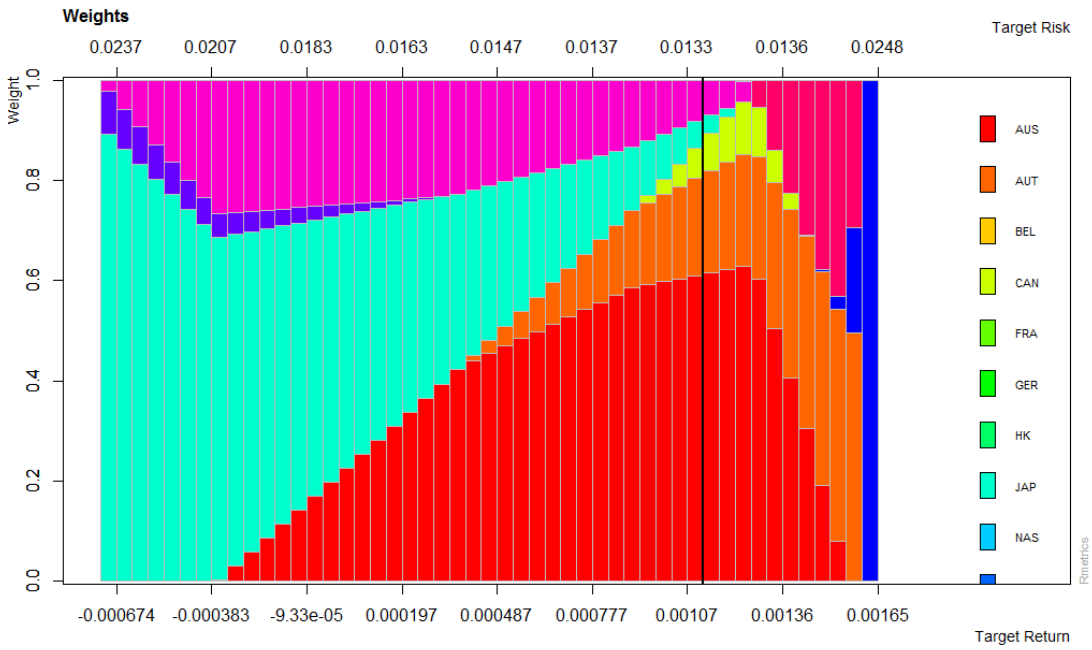

Fig. 13 *Weights of the portfolio for different level of Target Return and Target Risk (Developed Markets sample from January 1994 to June 2005).*

Each country index is shown by combination of risk and return, and of course a single index is less efficient than the frontier. It is also interesting to notice the composition of the portfolio in this period as it is possible to see in Fig. 13. On the *x* axis is reported the target return and above the target risk, on the *y* one is pointed out the weight of the different country indexes.

The tangency portfolio (collocated in the right part of the graph) is mostly composed of Australian, Austrian and USA (S&P 500) indexes.

The black line highlights the composition of the minimum variance portfolio; also here the predominant asset is Australian index followed by Austrian, Belgium, Japan and UK indexes.

We want now compare the movement of the portfolio frontier in the second sub-sample. The same chart can be created for data from July 2006 to January 2017 as is shown in Fig. 14.

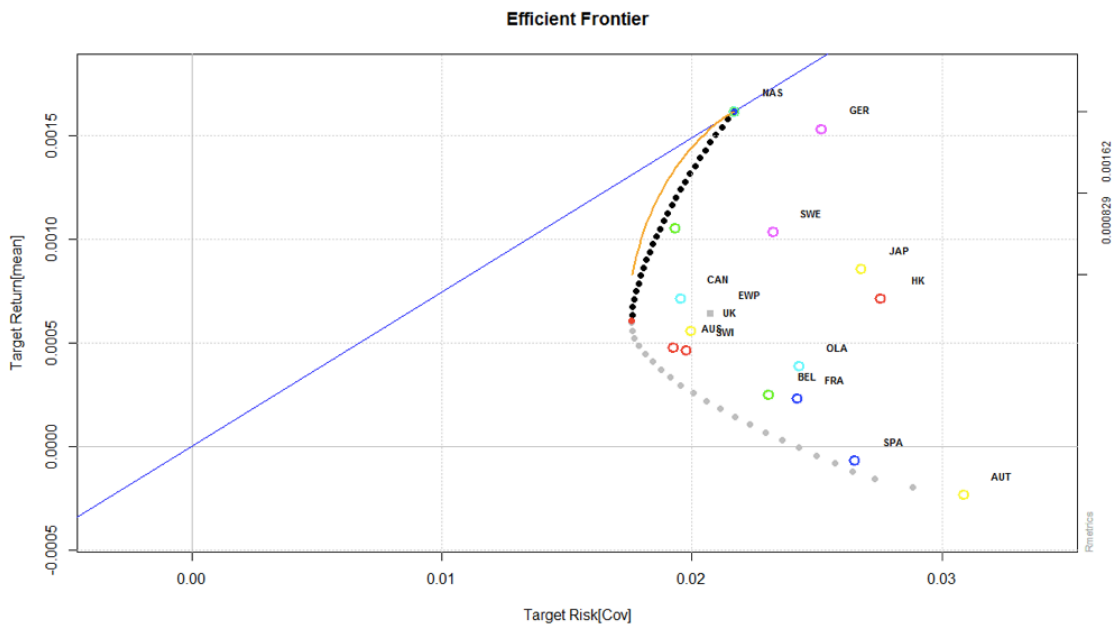

Fig. 14 *Efficient frontier for the Developed Markets sample from July 2006 to January 2017.*

It is now possible to notice how the portfolio frontier has moved on the right. There is a remarkable difference between the two charts. The global minimum portfolio has moved towards the left and downward in respect to the previous sub-sample. It is now positioned in the point with mean value of 0.06% and variance 1.76%. This means that the minimum risk for an investment is much higher than before.

We must consider that this values are on a weekly basis, so at first view it can seem that there is not a significant difference, but in reality is a considerable one on a weekly horizon.

The tangency portfolio is now set at the point with mean of 0.16% and variance of 2.17% for a Sharpe ratio of 0.073[12].

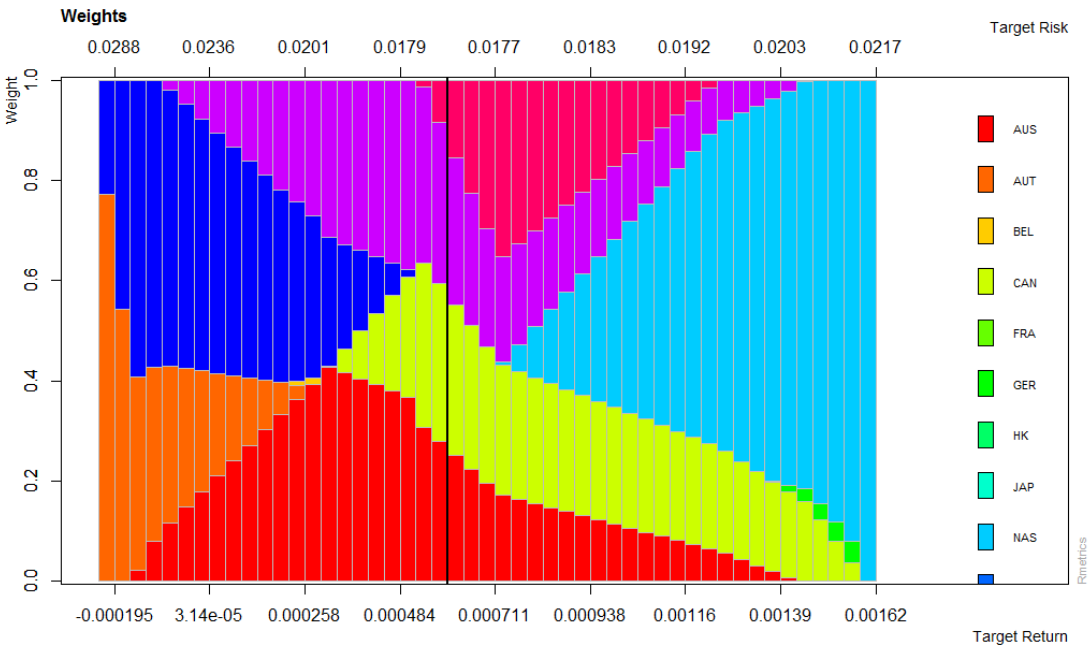

Fig. 15 *Weights of the portfolio for different level of Target Return and Target Risk (Developed Markets sample from July 2006 to January 2017).*

[12] Sharpe ratio is a measure to assess the overall risk-return featurs of a portfolio. Assuming the same level of returns, when the Sharpe coefficient decreases as in this case it means that the overall risk and so variance of the portfolio is increased. www.investopedia.com

This means that to achieve the same output in terms of yield we need to risk a bigger amount of money.

This is a clear effect of the increasing standard correlation between the Developed Markets indexes; the increase in the comovements between returns has decreased the positive effect of diversification and so the overall portfolio variance (risk) is increased.

Also the composition has changed, now the tangency portfolio contains indexes of Nasdaq only as is shown in Fig. 15. The minimum variance portfolio (black line) is now composed by Australian, Belgium, UK and USA (S&P 500) indexes.

Tab. 13 summarizes the results of these analysis on Developed Markets sample.

Tab. 13 *Main features of the Developed Markets efficient frontiers in the two sub-samples (January 1994 – June 2005, July 2005 – January 2017).*

	MV PORTFOLIO		TANGENCY PORTFOLIO		SHARPE RATIO
	mean	variance	mean	variance	value
1994 - 2005	0.11%	1.33%	0.14%	1.42%	0.099
2005 - 2017	0.06%	1.76%	0.16%	2.17%	0.073

4.1.2 Emerging Markets

The same analysis is repeated on Emerging Markets sample. Now, observations start from January 1998. We divide the sample in two sub-periods, January 1998 to June 2007, and July 2007 to January 2017.

The portfolio frontier for the first period is highlighted in Fig. 16.

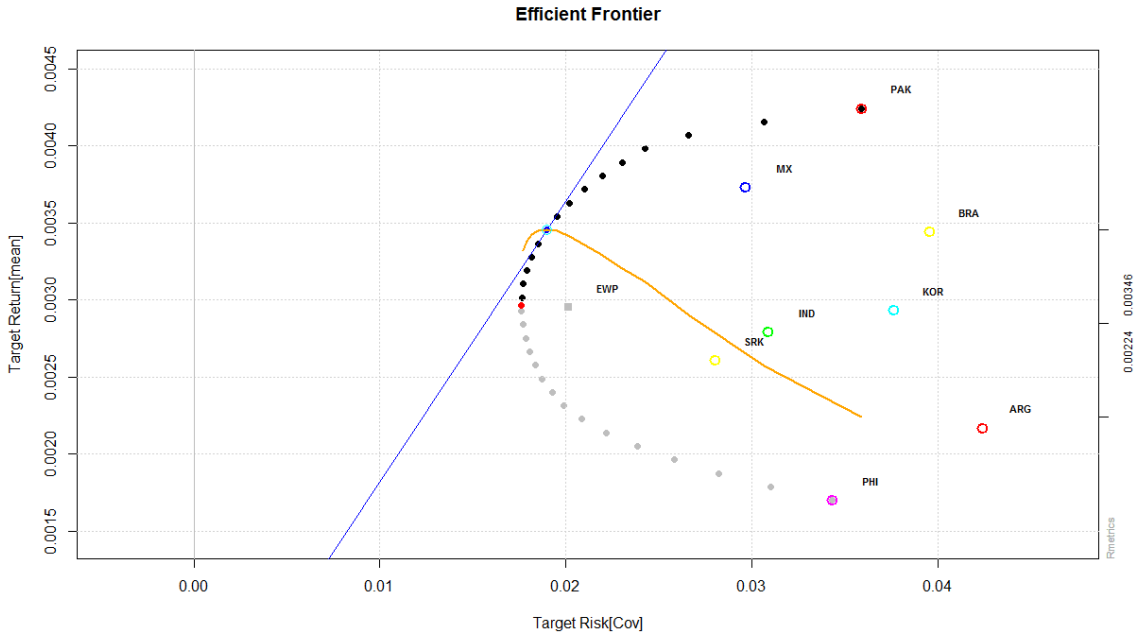

Fig. 16 *Efficient frontier for the Emerging Markets sample from January 1998 to June 2007.*

Also here the efficient frontier is shown with the black points on the graph and starts from the minimum variance portfolio situated in the red point.

The global minimum has mean equal to 0.30% (much better than Developed Markets sample) and variance equal to 1.76%, slightly worse than the Developed Markets in the first period.

The tangency portfolio has a Sharpe ratio of 0.26, significantly higher than the value of 0.09 registered in the previous analysis. This portfolio has mean equal to 0.35% and variance equal to 1.90%.

As reported in Fig. 17, the less risky portfolio is, in large part, composed by Sri Lanka index, and then by Pakistan, Philippines, Mexico, India and Korea indexes. The tangency portfolio is mainly composed by Sri Lanka, Pakistan and Mexico indexes and with a small weight by India and Korea indexes.

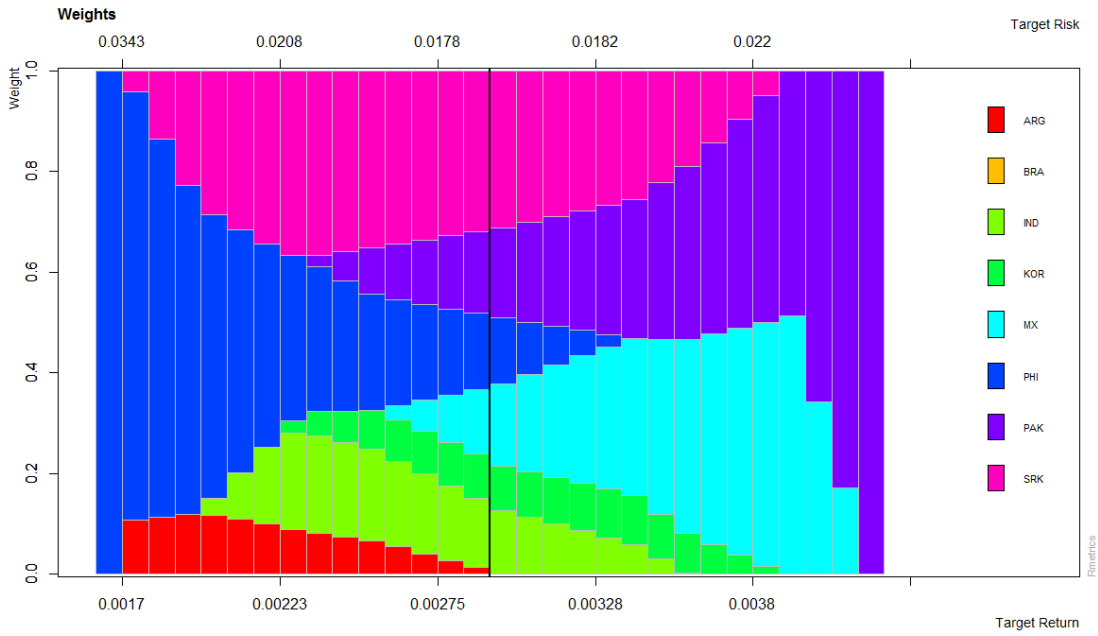

Fig. 17 *Weights of the portfolio for different level of Target Return and Target Risk (Emerging Markets sample from January 1998 to June 2007).*

We can now investigate what happens in the second period: the point of global minimum variance has moved to the left and downwards. It now stands at mean value of 0.16% and variance of 1.45%. This means that investing in this period has become less risky but also less profitable than before, given the fact that the expected value is decreased from 0.30% to 0.16%. Moreover, the tangency portfolio has worsened (meaning that the Sharpe ratio has fallen), and now stands at a mean value of 0.25% and variance of 1.75%, for a Sharpe ratio of 0.14. This means that in this period the investments where less profitable. The portfolio frontier and the composition of portfolios are reported, respectively, in Fig. 18 and Fig. 19.

Now, the minimum variance portfolio is mainly represented by Sri Lanka, as in the previous sub-period, and then by Pakistan, Philippines, Mexico and Korea indexes. The tangency portfolio is composed in equal parts by Argentina, Pakistan and Sri Lanka indexes.

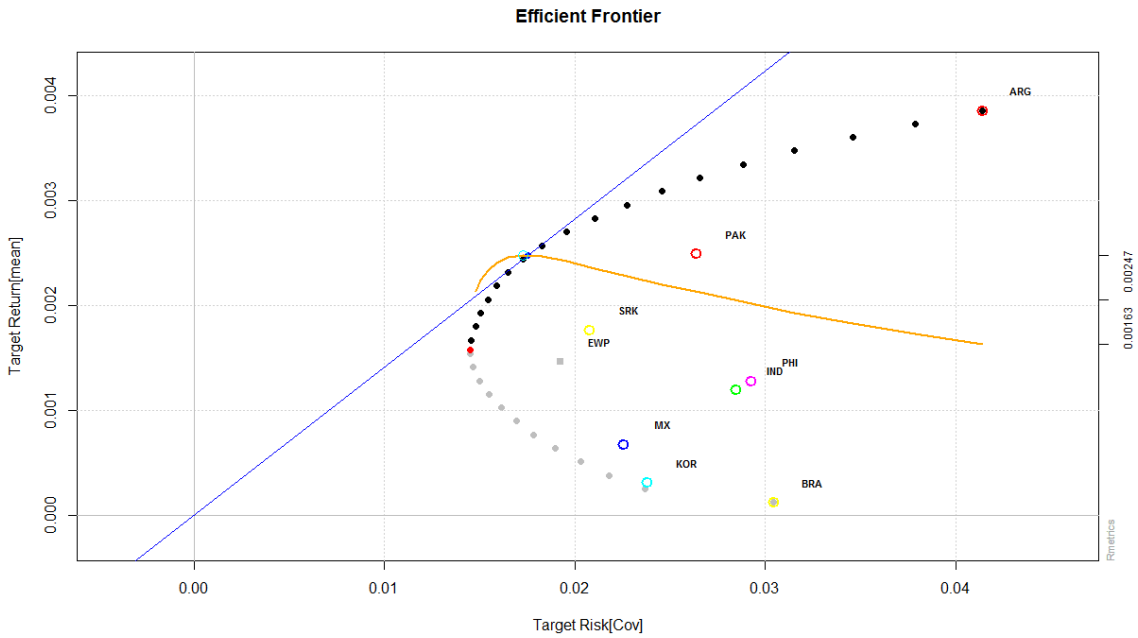

Fig. 18 *Efficient frontier for the Emerging Markets sample from July 2007 to January 2017.*

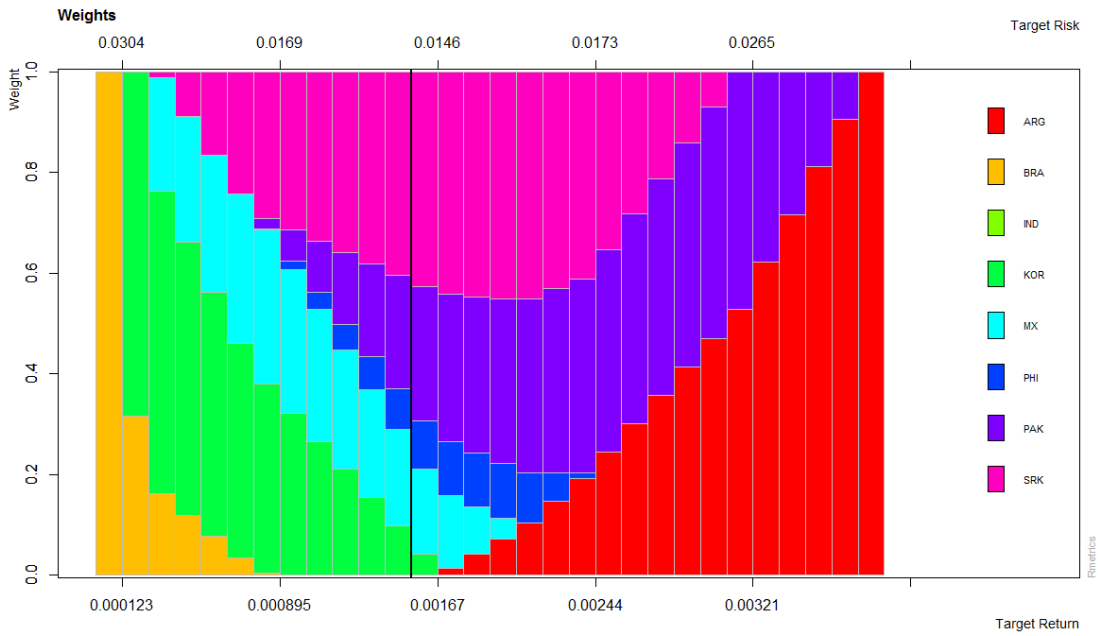

Fig. 19 *Weights of the portfolio for different level of Target Return and Target Risk (Emerging Markets sample from July 2007 to January 2017).*

As before, Tab. 14 summarizes the main portfolio characteristics.

Tab. 14 *Main features of the Emerging Markets efficient frontiers in the two sub-samples (January 1998 – June 2007, July 2007 – January 2017).*

	MV PORTFOLIO		TANGENCY PORTFOLIO		SHARPE RATIO
	mean	variance	mean	variance	value
1998 - 2007	0.30%	1.76%	0.35%	1.90%	0.26
2007 - 2017	0.16%	1.45%	0.25%	1.75%	0.14

4.1.3 Developed and Emerging Markets

It is also very interesting to see what happens when we combine both Developed and Emerging Markets together, using the stability of developed countries and the projected growth of the emerging ones.

Considering that the Emerging Markets sample has less observation than the Developed Markets one, we must adapt the time series than now begins in January 1998[13].

Fig. 20 highlights the analysis results. In the first period, January 1998 to June 2007, the global minimum variance has moved to the left, thanks to the presence of many assets. Its variance is only 1.10%, with a mean of 0.22%. This represents the less risky portfolio until now.

The tangency portfolio also shows good results, with Sharpe ratio of 0.23 at a mean level of 0.28% and variance of 1.21%.

[13] It coincides with the first observation available for Emerging Markets sample.

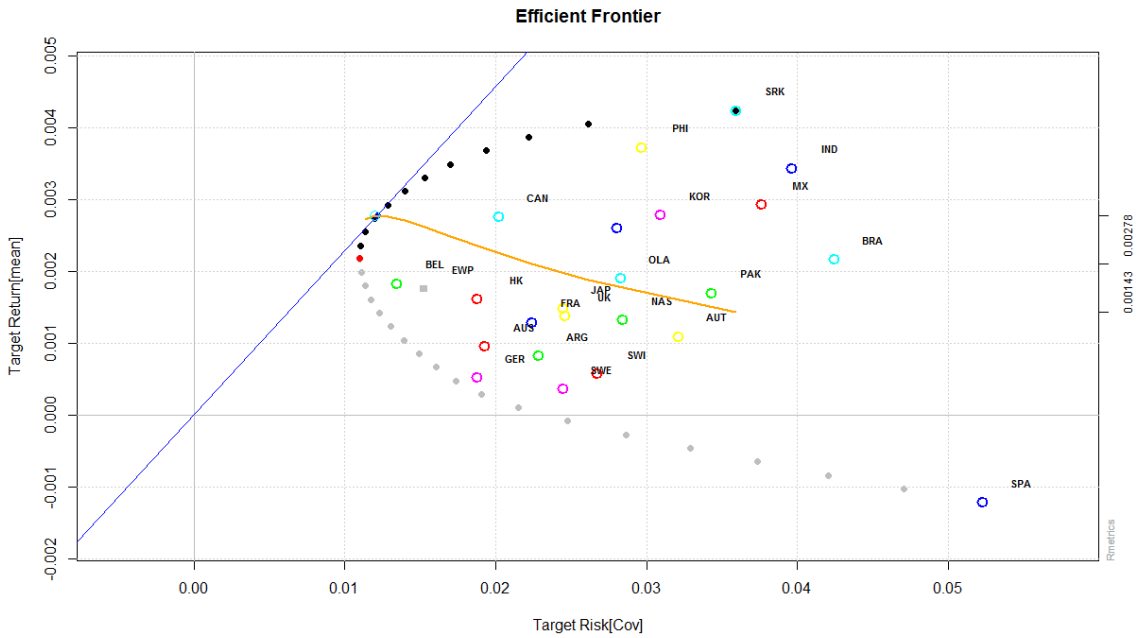

Fig. 20 *Efficient frontier for the Developed and Emerging Markets sample from January 1998 to June 2007.*

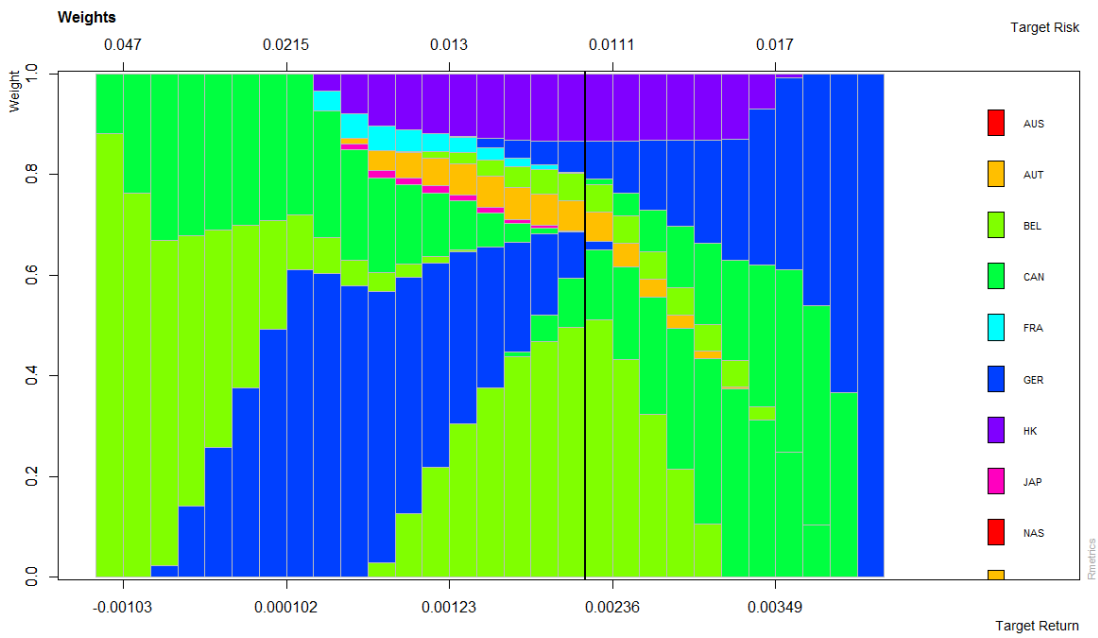

Fig. 21 *Weights of the portfolio for different level of Target Return and Target Risk (Developed and Emerging Markets sample from January 1998 to June 2007).*

As it is possible to notice from the graph, the contribution given by the large number of assets is significant on the level of diversification; the minimum variance and tangency portfolio present an important low variance in respect to the sample with only Developed or Emerging indexes.

Allocation favors Belgium, Canada, Austria, Germany and Hong Kong for both the minimum variance and the tangency portfolio as it is shown in Fig. 21.

In the second period, the one which includes the financial crisis, the frontier has moved downward. For almost the same level of risk (1.10%), now the expected value for the minimum variance portfolio is 0.09% on a weekly basis. In the tangency portfolio happens what we foresee as consequence of increasing correlation: the portfolio has moved on the right and downward.

This means that the variance is increased, and so the diversification benefit is reduced from the first period, returning a riskier portfolio. The results can be easily compared in Tab. 15 and are shown in Fig. 22. Now the variance has value of 1.49% and also the expected value has reduced with a value of 0.22%. The negative position of the portfolio, in respect to the first sub-period, is also confirmed by the Sharpe ratio value of 0.14, decreased from the previous one.

Allocation is in this case is very similar to the first sub-sample portfolios (Fig. 23); the tangency portfolio is composed by Austrian, German, Hong Kong and Japanese indexes, while the minimum variance portfolio maintains the indexes of Belgium, Canada, Hong Kong and Germany and the addiction of France.

Tab.15 *Main features of the Developed and Emerging Markets efficient frontiers in the two sub-samples (January 1998 – June 2007, July 2007 – January 2017).*

	MV PORTFOLIO		TANGENCY PORTFOLIO		SHARPE RATIO
	mean	variance	mean	variance	value
1998 - 2007	0.22%	1.10%	0.28%	1.21%	0.23
2007 - 2017	0.09%	1.10%	0.22%	1.49%	0.14

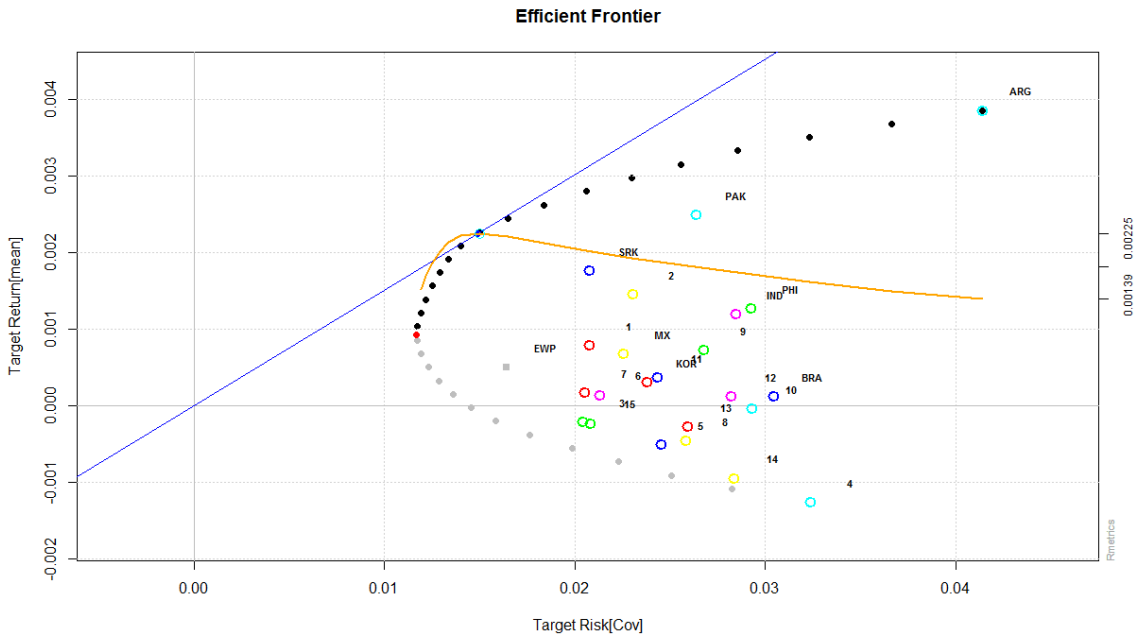

Fig. 22 *Efficient frontier for the Developed and Emerging Markets sample from July 2007 to January 2017.*

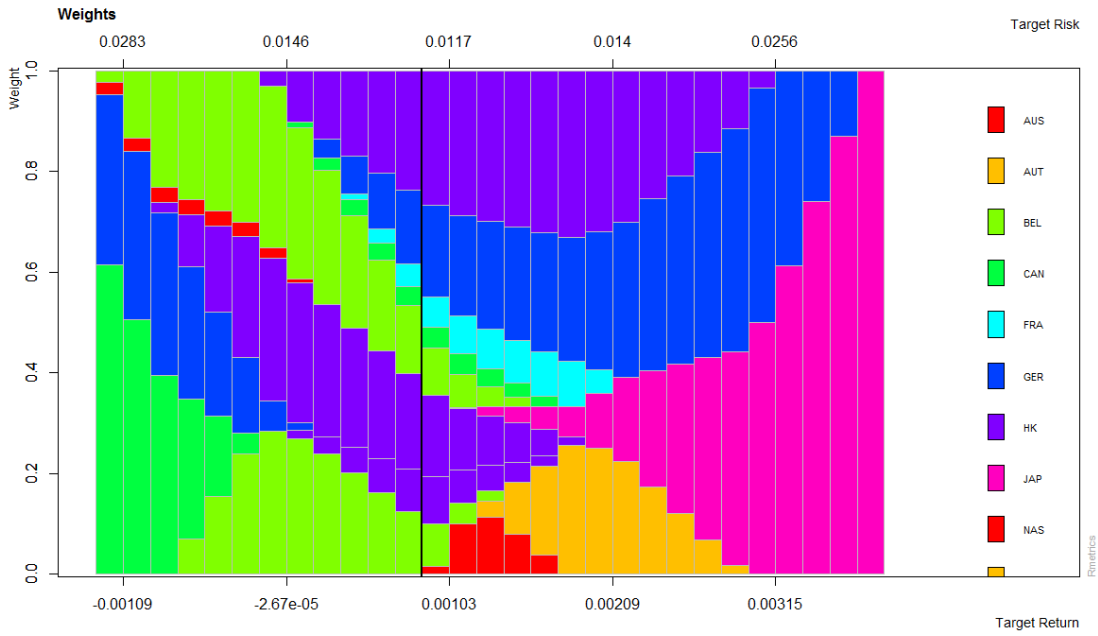

Fig. 23 *Weights of the portfolio for different level of Target Return and Target Risk (Developed and Emerging Markets sample from July 2007 to January 2017).*

CONCLUSIONS

The aim of this thesis work has been to analyze the financial integration between equity markets of developed and emerging countries in order to obtain an international scenario and then to verify the consequences of these financial comovements on the diversification of an international portfolio.

After a brief introduction, the data employed for the empirical analysis have been presented; 15 equity indexes for developed countries, 10 equity indexes for emerging countries for a total of 25 stock indexes analyzed.

In order to capture a significant number of observations, the time series utilized start, respectively, in 1994 for developed countries and 1998 for emerging countries and end at the beginning of 2017.

A meticulous review of the most influential financial literature on this topic has been conducted in Chap. 2. Among the others, the attention has been focalized in particular on the contribution of Mauro et al. (2002), Kearney and Lucey (2004), Goetzmann et al. (2005), Quinn and Voth (2008), Pukthuanthong and Roll (2009), Volosovych (2011) and Billio et al. (2016).

Above all, the contribution of Billio et al. (2016) in which observes how the standard correlation, on average, explains better variations in financial integration phenomena than more sophisticated measures as heteroscedasticity-adjusted ones, has been the starting point for our empirical analysis.

The computational work to capture international financial integration has been conducted in Chap. 3; dynamic standard correlation, standard correlation in different sub-periods and adjusted R squared are the three measures employed to assess financial comovements in equity returns.

In particular, in all the samples analyzed is evident the increasing correlation over the time series and, especially, after the year 2000 and in the central part of our sample periods.

Also adjusted R squared confirms these results; the highest values observed are in the central part of our time series for all the three samples inspected.

To verify the consequences of movements in financial integration on the diversification of an international portfolio, different efficient frontiers are estimated in Chap. 4. To assess the effects of increasing correlation in equity returns, the portfolio frontiers has been employed in two different sub-periods for all the three samples (Developed, Emerging and Developed and Emerging together countries). The frontier movement has been analyzed to capture the level of diversification.

In particular, the repositioning of global minimum variance portfolio and tangency portfolio has been estimated. The evidence is that the frontiers and the relative portfolios have moved on the right; the level of variance is increased and therefore the diversification benefit is reduced.

All this analysis reflects how financial integration and, more specifically, the correlation between equity indexes of all world is increased over the last two decades. The consequences of this increasing comovement between equity returns have a negative impact on the risk of international equity investments, in particular in the periods of high correlation, with the result of a general reduction in the diversification benefit.

R CODE

DYNAMIC STANDARD CORRELATION

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rm(list=ls())

#1. IMPORT

library(quantmod)
getSymbols("^AXJO", from=as.Date("1994-01-04"), to=as.Date("2017-01-01"))
getSymbols("^GSPC", from=as.Date("1994-01-04"), to=as.Date("2017-01-01"))
getSymbols("^IXIC", from=as.Date("1994-01-04"), to=as.Date("2017-01-01"))
getSymbols("^FTSE", from=as.Date("1994-01-04"), to=as.Date("2017-01-01"))
getSymbols("^ATX", from=as.Date("1994-01-04"), to=as.Date("2016-12-28"))
getSymbols("^BFX", from=as.Date("1994-01-04"), to=as.Date("2017-01-01"))
getSymbols("^GSPTSE", from=as.Date("1994-01-04"), to=as.Date("2017-01-01"))
getSymbols("^FCHI", from=as.Date("1994-01-04"), to=as.Date("2017-01-01"))
getSymbols("^GDAXI", from=as.Date("1994-01-04"), to=as.Date("2017-01-01"))
getSymbols("^HSI", from=as.Date("1994-01-04"), to=as.Date("2017-01-01"))
getSymbols("^OMX", from=as.Date("1994-01-04"), to=as.Date("2017-01-01"))
getSymbols("^N225", from=as.Date("1994-01-04"), to=as.Date("2017-01-01"))
getSymbols("^AEX", from=as.Date("1994-01-04"), to=as.Date("2017-01-01"))
getSymbols("^IBEX", from=as.Date("1994-01-04"), to=as.Date("2017-01-01"))
getSymbols("^SSMI", from=as.Date("1994-01-04"), to=as.Date("2017-01-01"))

#2. AVERAGE

ts.weekUSA<-apply.weekly(GSPC,FUN=mean,na.rm=TRUE)
ts.weekNAS<-apply.weekly(IXIC,FUN=mean,na.rm=TRUE)
ts.weekAUS<-apply.weekly(AXJO,FUN=mean,na.rm=TRUE)
ts.weekAUT<-apply.weekly(ATX,FUN=mean,na.rm=TRUE)
ts.weekBEL<-apply.weekly(BFX,FUN=mean,na.rm=TRUE)
ts.weekUK<-apply.weekly(FTSE,FUN=mean,na.rm=TRUE)
ts.weekCAN<-apply.weekly(GSPTSE,FUN=mean,na.rm=TRUE)
ts.weekFRA<-apply.weekly(FCHI,FUN=mean,na.rm=TRUE)
ts.weekGER<-apply.weekly(GDAXI,FUN=mean,na.rm=TRUE)
ts.weekHK<-apply.weekly(HSI,FUN=mean,na.rm=TRUE)
ts.weekSWE<-apply.weekly(OMX,FUN=mean,na.rm=TRUE)
ts.weekJAP<-apply.weekly(N225,FUN=mean,na.rm=TRUE)
ts.weekOLA<-apply.weekly(AEX,FUN=mean,na.rm=TRUE)
ts.weekSPA<-apply.weekly(IBEX,FUN=mean,na.rm=TRUE)
ts.weekSWI<-apply.weekly(SSMI,FUN=mean,na.rm=TRUE)

#3. RETURNS

log_rUSA=diff(log(ts.weekUSA$GSPC.Adjusted))
```

```
log_rNAS=diff(log(ts.weekNAS$IXIC.Adjusted))
log_rAUS=diff(log(ts.weekAUS$AXJO.Adjusted))
log_rAUT=diff(log(ts.weekAUT$ATX.Adjusted))
log_rBEL=diff(log(ts.weekBEL$BFX.Adjusted))
log_rUK=diff(log(ts.weekUK$FTSE.Adjusted))
log_rCAN=diff(log(ts.weekCAN$GSPTSE.Adjusted))
log_rFRA=diff(log(ts.weekFRA$FCHI.Adjusted))
log_rGER=diff(log(ts.weekGER$GDAXI.Adjusted))
log_rHK=diff(log(ts.weekHK$HSI.Adjusted))
log_rSWE=diff(log(ts.weekSWE$OMX.Adjusted))
log_rJAP=diff(log(ts.weekJAP$N225.Adjusted))
log_rOLA=diff(log(ts.weekOLA$AEX.Adjusted))
log_rSPA=diff(log(ts.weekSPA$IBEX.Adjusted))
log_rSWI=diff(log(ts.weekSWI$SSMI.Adjusted))

assieme=cbind(as.numeric(log_rUSA),as.numeric(log_rNAS),as.numeric(log_rAUS),
as.numeric(log_rAUT), as.numeric(log_rBEL), as.numeric(log_rUK),
as.numeric(log_rCAN), as.numeric(log_rFRA), as.numeric(log_rGER),
as.numeric(log_rHK), as.numeric(log_rSWE), as.numeric(log_rJAP),
as.numeric(log_rOLA),  as.numeric(log_rSPA), as.numeric(log_rSWI))

#4. TRIDIMENSIONAL ARRAY
n=dim(assieme)[1]
k=dim(assieme)[2]
wind=60

my.array<-array(0,dim=c((n-wind),k,k))

tolti=ceiling(wind/2)

for ( j in 1:k){
  for ( l in 1:k){
    for (i in 1:(n-wind))
    {

my.array[i,j,l]=cor(assieme[i:(i+wind),j],assieme[i:(i+wind),l],use="pairwise.compl
ete.obs")

    }
  }}
ts.plot(my.array[,2,3])  #rolling correlation between country 2 and country 3
medie225=numeric((n-wind))

for (i in 1:(n-wind))
{
  medie225[i]=mean(my.array[i,1:15,1:15])
}
```

```
ts.plot(medie225)
medie225ts=ts(medie225,frequency=52,start=1994)
plot(medie225ts)

Correlation=ts(medie225,frequency=52,start=1994)
plot(Correlation)


#5. TREND
dec=decompose(medie225ts)
plot(dec)

t=1:(n-wind)
fit=lm(medie225ts~t)
summary(fit)
p=predict(fit)
plot.ts(ts(p,frequency=52,start=1994))
```

PCA - $\overline{R}^2$

```
pca <- prcomp(assieme[2:1200,1:15], retx=TRUE, center=TRUE, scale=TRUE)

x1=pca$x[,1]
x2=pca$x[,2]
x3=pca$x[,3]

rq=matrix(0,3,k)
for (j in 1:(k)){
  fit=lm(assieme[2:400,j]~x1[1:399]+x2[1:399]+x3[1:399])
  rq[1,j]=summary(fit)$r.squared
  fit=lm(assieme[401:800,j]~x1[400:799]+x2[400:799]+x3[400:799])
  rq[2,j]=summary(fit)$r.squared
  fit=lm(assieme[801:1200,j]~x1[800:1199]+x2[800:1199]+x3[800:1199])
  rq[3,j]=summary(fit)$r.squared
}

rqr=t(round(rq,2))
colMeans(rqr,2)
summary(pca)
```

EFFICIENT FRONTIER

```
#  http://www.finance-r.com/s/efficient_frontier_fPortfolio/complete/
require("financeR")
require("xts")
require("fPortfolio")
library("timeSeries")
data1=cbind(as.numeric(log_rAUS),as.numeric(log_rAUT),as.numeric(log_rBEL),as
.numeric(log_rCAN),as.numeric(log_rFRA),as.numeric(log_rGER),as.numeric(log_r
HK),as.numeric(log_rJAP),as.numeric(log_rNAS),as.numeric(log_rOLA),as.numeric(
log_rSPA),as.numeric(log_rSWE),as.numeric(log_rSWI),as.numeric(log_rUK),as.nu
meric(log_rUSA))[2:600,]
data2=cbind(as.numeric(log_rAUS),as.numeric(log_rAUT),as.numeric(log_rBEL),as
 .numeric(log_rCAN),as.numeric(log_rFRA),as.numeric(log_rGER),as.numeric(log_r
 HK),as.numeric(log_rJAP),as.numeric(log_rNAS),as.numeric(log_rOLA),as.numeric
 (log_rSPA),as.numeric(log_rSWE),as.numeric(log_rSWI),as.numeric(log_rUK),as.n
 umeric(log_rUSA))[601:1200,]

scenarios <- dim(assiemeEm)[1]
assets <- dim(assiemeEm)[2]
data_ts1 <- as.timeSeries(cbind(assieme[212:705,],assiemeEm[2:495,]))
data_ts2 <- as.timeSeries(cbind(assieme[706:1200,],assiemeEm[496:990,]))
names(data_ts)=c("ARG","BRA","IND","KOR","MX","PHI","PAK","SRK")
names(data_ts1)=c("AUS","AUT","BEL","CAN","FRA","GER","HK","JAP","NAS","OLA
 ","SPA","SWE","SWI","UK","ARG","BRA","IND","KOR","MX","PHI","PAK","SRK")
names(data_ts2)=c("AUS","AUT","BEL","CAN","FRA","GER","HK","JAP","NAS","OLA
 ","SPA","SWE","SWI","UK","ARG","BRA","IND","KOR","MX","PHI","PAK","SRK")

spec <- portfolioSpec()
setSolver(spec) <- "solveRquadprog"
setNFrontierPoints(spec) <- 30
constraints <- c('LongOnly')
portfolioConstraints(data_ts1, spec, constraints)

frontier <- portfolioFrontier(data_ts2, spec, constraints)
print(frontier)
tailoredFrontierPlot(object=frontier)  #graph of the efficient frontier
weightsPlot(frontier, col=rainbow(assets))

#global minimum
globminSpec <- portfolioSpec()
 minvariancePortfolio(data =data_ts2,spec = globminSpec,constraints =
 "LongOnly")

# tangent
defaultSpec <- portfolioSpec()
tangencyPortfolio(data_ts2, spec = defaultSpec, constraints = "LongOnly")
```

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