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Abstract.

Since there is not a single European stock market, the main objective of this work is to verify whether the euro introduction affects the integration of the European stock markets. To investigate whether the integration of the European stock markets has increased after the introduction of the euro. To do so, the Vector Autoregression (VAR) methodology is applied, more specifically the Impulse Response Function (IRF) is estimated. The conclusions of this study show that the main European stock markets are more and more integrated after euro. Inside the European stock exchanges, the German one has become a leader market after the euro. The stock exchanges of the euro area are acquiring a major importance with respect to the markets of other two main financial areas, the US$ and the ¥, and maintain their influence on the Swiss stock market. Moreover, the national stock markets in Europe have reduced their US stock market's dependence, and increased their influence on the yen stock market.

Key words: Euro – Stock Markets – Financial integration – VAR analysis – Europe.

JEL classification codes: G-15; C-22; F-02.

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I. Introduction.

Despite the successful introduction of the euro onto wholesale financial markets in the EMU area on January 1, 1999, it is still not possible to speak of a single Euro-area stock market. Securities trading traditionally followed national lines. As a result, continued fragmentation reflects a host of national differences in market practices, laws, tax treatment and regulation. So very specific problems arise, such as the cross-border use of collateral, which in fact impede the genuine internationalisation of this activity across the EU. These differences, coupled with the lack of a single infrastructure platform for the market, impose costs and inefficiencies that prevent the full potential benefits of a unified equity market from becoming widely available. In fact, fragmentation creates important practical difficulties in cross-border clearing and settlement (Giovannini Group, 2001), and so costs remain too high in Europe. Lannoo and Levin (2001) show that US and EU costs are comparable, but that cost structures differ insofar as trading costs are relatively low thanks to the efficiency of European markets, whereas cross border clearing and settlement costs are more expensive in Europe.

However, as a consequence of the introduction of the euro that has replaced the European national currencies, the elimination of the exchange rates will probably accelerate the integration. Moreover, recent years have seen positive progress towards financial integration in the EU with the implementation of single market legislation, including the measures of the Financial Services Action Plan (FSAP) (EC, 2002).

Although in many respects the EU's securities markets remain fragmented, there have been several attempts and progress in integration –for example, in the euro-area government bond market, but persistent yield spreads remain between Member States–. In equity markets, there have been high-profile consolidation efforts in Europe. Most notable of these has been the creation of Easdaq, similar to American Nasdaq; the new European market; Euro NM, which joins Nouveau Marché (Paris), NMAX (Amsterdam), EuroNM (Brussels), Never Markt (Frankfurt) and Nuovo Mercato (Milan); the Euronext, which merged the Amsterdam, Brussels and Paris Exchanges in mid-2000, was floated as a public company in mid-2001 and

later, joined Lisbon stock exchange and British futures market (LIFFE); and the Norex, which merged Danish, Swedish and Icelandic stock exchanges. The process of integration also goes beyond traditional exchanges, as illustrated by the Virt-x merger that combined the Swiss exchange and the UK-based electronic exchange Tradepoint[1]. Not all consolidation efforts have been successful, however, with the failed merger of Deutsche Börse and the London stock exchange (iX) a notable example (EC, 2001).

Since there is not a single European stock market yet, the main objective of this work is focused on verifying whether the introduction of the euro affects the integration of the European stock markets. The empirical analysis consists of the Euro-impact on the integration of the European securities markets. Firstly, the differences between the national stock markets in Europe are described by analysing several characteristics that affect the integration of the European stock markets. Secondly, the increase of the integration of European stock markets after the introduction of the euro is analysed. To do so, the Vector Autoregression (VAR) methodology is applied, more specifically the estimation of the Impulse Response Function (IRF). Some previous results are found through a correlation analysis among stock prices and volatilities of major world stock exchanges. The relationship between the stock price indices before and after-Euro is also examined. Finally, the impact of the stock prices' movements in one market on another is investigated.

The remainder of this paper is organised as follows. Section 2 reports the previous studies about linkages and dynamic interactions among international stock markets. Section 3 presents the data and describes the stock markets studied in this work. Section 4 provides the methodology. In section 5 the results are presented and discussed. Section 6 summarises the main concluding remarks.

[1] Maybe there have been more decisive agreements between the European forward markets. In fact, Spanish bond's futures market (MEFF RF) and French futures market (MATIF) settled an alliance to create the Euro GLOBEX in order to allow any access to both markets from both countries.

II. Financial literature on linkages among national stock markets.

From a theoretical or empirical point of view, many studies analyse the linkages among national stock markets indices. The theory of efficient markets suggests that if there are not imperfections, a stock market index reflects all available information, including any other kind of information contained in other stock exchanges indices. If national stock markets were integrated, the lags of the prices' adjustment in these stock markets would be reduced (Koch and Koch, 1991).

The empirical results usually evidence significant correlation between markets located in near geographic areas. This is frequently attributed to a number of different factors such as the relaxation of controls on capital movements and foreign exchange transactions, improvements in computer and communication technology that have lowered the cost of cross-border information flows and financial transactions, and expansion in the multinational operations of major corporations (whose shares are often listed on several stock exchanges), among others. This globalisation of financial transaction has led that stock markets are becoming more synchronised, and the adjustment delays of international prices are increasingly shorter.

Recent research in the literature of financial markets integration has investigated the presence of cointegration relationships between national stock market indices in order to assess long-run comovements in those markets. Rangvid (2001) proposes an increasing number of cointegrating relationships as an indicator of whether European stock markets have become more integrated in the last three decades, i.e., whether the markets have experienced a process of convergence.

However, there have been several studies about linkages and dynamic interactions among international stock markets with conflicting evidence. The results vary, depending on the choice of markets, the sample period, the frequency of observations (daily, weekly or monthly), and the different methodologies employed to investigate the interdependence of stock markets. The lack of interdependence across national stock markets has been presented

as evidence supporting the benefits of international portfolio diversification (Grubel, 1968; Sharpe, 1995; Solnik, 1995).

The synoptic Table 1 presents a survey of the literature grouped by evidence in pro and contra the international stock market linkages, and so on in favour and against the Euro effect on stock markets, summarising the main authors and their results.

Table 1: Survey of the financial literature about international stock market linkages

EVIDENCE ON MARKETS LINKAGES	
Authors	**Methodology and main results**
Grubel (1968), Levy and Sarnat (1970), Aqmon (1972), Ripley (1973), Lessard (1976), Panton *et al.* (1976), Hilliard (1979)	- Methodology: correlation, variance-covariance or spectral analysis. - Results: The changes in the stock price indices in several markets are generally related.
Philippatos *et al.* (1983).	- Intertemporal stability of international stock markets. - National market indices are interrelated over time through a common factor.
Jaffe and Westerfield (1985), Schollhammer and Sand (1985), Arshanapalli and Doukas (1993)	- The degree of international co-movements among stock prices indices has increased substantially. - The US stock market has a considerable impact on the French, German and UK markets. - The Japanese equity market performance has no links with both the US stock market and the stock markets in France, Germany and UK.
Eun and Shim (1989).	- Methodology: VAR. - Results: substantial cross-country interactions and an influential role for the US market.
Meric and Meric (1989), Asan and Naka (1996).	- The longer the time period the greater the degree of stability among international stock market relationships.
Hamao *et al.* (1990), Susmel and Engle (1994), Booth *et al.*, (1997).	- Methodology: ARCH models. - Results: linkages and spillovers in stock markets.
Ayuso and Blanco (2000).	- Methodology: GARCH model for each of the residual series of the VAR model to analyse the sensitivity to cross-border determinants of stock prices. - Results: the linkage of USA, Japan, UK, French, Italian, Spanish and German markets has increased during 1995-99 compared to 1990-94.
Moreno and Olmeda (2002)	- The European markets have been more integrated during 1999-2001. - The German stock market has increased its leadership into the Euro-area, because German predominant role in the European monetary policy.
Rangvid (2001)	The degree of convergence among three major European stock markets is analyzed within the framework of a recursive common stochastic trends analysis. - Methodology: vector-autoregressive model (VAR). - The results point towards a decreasing number of common stochastic trends influencing the stock markets, i.e. the degree of convergence among European stock markets has been increased during the recent two decades.

EVIDENCE AGAINST MARKETS LINKAGES	
Authors	**Methodology and main results**
Roll (1988), Dwyer and Hafer (1988)	-The timing and magnitude of declines differ across markets around the world. - No evidence that the levels of stock price indices for the US, Japan, Germany and the UK are related.
Maldonado and Saunders (1981), Chan *et al.* (1992)	- The intertemporal relationships between correlation coefficients are unstable –stock market indices are not cointegrated–.
De Miguel *et al.* (1998), Moreno and Olmeda (2002)	- Methodology: VAR. - Results: for the 1995-97 period, the stock market indices were hardly correlated. In contrast, they tested autoregressive components for the volatilities. The stock market indices (daily prices) among EU northern and center countries were more correlated than among southern countries and than between northern and southern countries. - The northern and the center stock market indices have long-run link, as well as the Mediterranean stock exchanges.
García Pascual (2003)	This paper examines long-run comovements in the UK, French, and German stock markets using cointegration techniques. After fixing the power of the cointegration test, no evidence is found of an increasing number of cointegrating vectors. An alternative approach to measure increasing integration, based on the speed of adjustment coefficients, is proposed.

There are several reasons why different countries' stock prices may have a significant long-run relationship. Most empirical studies –including those cited in Table 1–, describe the statistical dependencies across stock markets but do not attempt to identify or discuss the economic reasons for such dependencies. The presence of strong economic ties and policy coordination between countries, such as it happens in EU and EMU, can indirectly link their stock prices over time. With technological and financial innovation, the advance of international finance and trade, and deliberate regional and global co-operation, the geographical divide among various national stock markets are less obvious (Gelos and Sahay, 2000). Jeon and Chiang (1991) mention deregulation and market liberalisation measures, rapid developments in communication technology and computerised trading systems, and increasing activities by multinational corporations as factors contributing to such integration. In addition, the EU implies the formation of common trading block and the euro introduction supposes the development of integrated economic system. Because of all these reasons, closer linkages between stock markets within European countries are expected. In fact, in an analysis of the degree of convergence between three European stock markets, Rangvid (2001) argues that if national stock prices are driven by the same relatively few common stochastic

trends, they could be considered as somewhat converged and integrated in the sense that they are driven by the same permanent shocks.

III. Data and descriptive analysis.

The equity markets included in this study are the 16 biggest and longest established ones in Europe, plus the US and the Japanese stock exchanges. The European stock markets include the Swiss equity market and the 15 EU equity markets, which are the 12 Euro-area markets (Austrian, Belgian, Finnish, French, German, Greek –since 2001–, Irish, Italian, Luxembourg, Dutch, Portuguese and Spanish), and the Danish, Swedish and UK stock markets. Therefore, the dependencies among the Euro-area stock exchanges, the EU markets, and other three financial areas equity markets –US dollar (US$), yen (¥), and Swiss franc (SF) – are analysed.

The modelling of returns results in the loss of important information on possible common trends when prices are cointegrated. To resolve this problem, the dependencies in daily stock prices are studied using cointegration techniques (VAR). The data used in this empirical analysis are the last daily equity indices elaborated by Morgan Stanley Capital International, Inc. (MSCI), which are widely applied in the financial literature[2] (Table 2 presents the stock markets indices employed in this study). To construct an MSCI Country Index, which are representative of the national stock markets, every listed security in the market is identified, and data on its price, outstanding shares, significant owners, free float, and monthly trading volume are collected. The securities are then organised by industry group, and stocks are selected, targeting 60% coverage of market capitalisation. Selection criteria include: size, long- and short-term volume, cross-ownership and float. By targeting 60% of each industry group, the MSCI index captures 60% of the total country market capitalisation while maintaining the overall risk structure of the market –because industry, more than any other single factor, is a key characteristic of a portfolio or a market–.

[2] MSCI indices are the most widely used benchmarks by global portfolio managers. According to a survey conducted by Pensions & Investments, over 90% of international institutional equity assets in the US are benchmarked to MSCI Indices.

Table 2. Stock markets Price Indices

Financial areas	MSCI Equity Indices	Variable
Euro-area or European Monetary Union (EMU)	Austria	AUS
	Belgium	BEL
	Finland	FIN
	France	FRA
	Germany	GER
	Greece	GRE
	Ireland	IRE
	Italy	ITA
	Luxembourg	LUX
	Netherlands	NET
	Portugal	POR
	Spain	SPA
European Union (EU)	Denmark	DEN
	Sweden	SWE
	United Kingdom	UK
Other Financial areas	Japan	JAP
	Switzerland	SWI
	USA	USA

The currency for every series of data is US dollar to avoid the effect of the exchange rate. Roll (1992) suggests that equity index behaviour is affected by two factors: the technical procedure of index construction and composition, and the role of exchange rates. When indices are expressed in a national currency, part of the index volatility is induced by monetary phenomena such as changes in anticipated and actual inflation rates. To avoid interpretation problems the equity indices are denominated in a common currency, US$.

The time period considered in this study is from 30 April 1997 to 23 May 2002 (1,321 observations). As the aim of this work is verifying whether the euro has accelerated the integration between the European equity markets and which are its effects on other stock exchanges, the total sample have been segmented in two sub-periods. The first sub-sample includes the before-Euro period (from 30 April 1997 to 31 December 1998, 436 observations), when stock transactions are in each European national currency. The second sub-sample includes end-of-day stock price indices ranging from 1 January 1999 to 23 May 2002 (885 observations) –for the after-Euro period–.

Table 3 gives some descriptive statistics on the stock markets in the 18 countries. The Swiss Stock Exchange has the largest market value per GDP of all markets analysed. The EU stock markets capitalisation was about 100% of GDP in 1999, but the range went from 16.9% in Austria to 198.3% in UK. The market capitalisation of shares listed on the Euronext stock Exchange (Brussels, Paris and Amsterdam) exceeded $1.8 billion (GB) at the end of 2001 and more than 1,500 companies were quoted. In Germany, the market value of shares quoted on the stock exchange exceeded $1 billion (GB) and almost 1,000 companies were listed. The market capitalisation of shares listed on the London Stock Exchange exceeded $2 billion (GB) and more than 2,000 companies were listed. However, the average 15 EU market capitalisation was still more or less the half of the New York Stock Exchange (NYSE). The average company size also differed among the European countries and between these as a whole (with an average size of $1,003 millions) and the average size of US companies ($5,687 millions). In contrast, the value of share trading was almost similar in the EU stock markets and in the NYSE. In these comparisons, however, several cautions should be considered. For example, the average size of the effective listed companies in Spain is greater that the size showed in Table 3, and it would be more similar to the Italian average size if the great number of Spanish small investment firms (with very little liquidity) were not included. The value of share trading present a positive bias in Germany and Netherlands (euro-zone), Sweden, Denmark and UK (EU-zone) and US Nasdaq, where all transactions among dealers are counted; against the rest of stock exchanges considered, which only compute the changes of property of shares.

Table 3. Background information on equity markets

Panel A 2001	Market value divided by GDP,**1999**	No. of companies with shares listed			Capitalis. of shares of domestic Cies. (Excl.Funds) ($mill)	Average comp. size (US$ mill)	Value of share trading (Total, incl.invest. funds) (US$ mill)			
		Total	Domestic Cies.	Foreign Cies.			Total	Domestic Cies.	Foreign Cies.	Investment Funds
AUSTRIA (Vienna)	16.90	113.0	99.0	14.0	25,204.3	254.6	7,699.6	7,340.0	359.6	0.0
BELGIUM (Euronext Brussels)	78.85	265.0								
FRANCE (Euronext Paris)	111.12	966.0	1,132.0	491.0	1,843,528.6	1,628.6	3,179,788.8	3,150,417.7	19,432.7	9,938.4
NETHERLANDS (Euronext Amsterdam)	187.71	392.0								
FINLAND (Helsinki)	NA	155.0	152.0	3.0	190,455.8	1,253.0	181,568.4	180,051.5	1,516.9	0.0
GERMANY (Deutsche Börse)	72.08	983.0	748.0	235.0	1,071,748.7	1,432.8	1,441,633.0	1,305,670.4	135,962.6	0.0
GREECE (Athens)	157.38	314.0	313.0	1.0	83,481.3	266.7	37,781.4	37,158.4	42.9	580.1
IRELAND (Irish)	58.10	87.0	68.0	19.0	75,297.8	1,107.3	22,735.6	22,539.4	196.2	0.0
ITALY (Italy)	66.11	294.0	288.0	6.0	527,467.3	1,831.5	1,558,881.5	1,501,947.1	56,934.4	0.0
LUXEMBOURG (Luxembourg)	197.68	257.0	48.0	209.0	23,782.8	495.5	700.1	434.0	4.2	261.9
PORTUGAL (Lisbon)	58.49	99.0	97.0	2.0	46,337.6	477.7	27,601.5	27,459.9	50.6	91.0
SPAIN (Madrid)	77.04	1,480.0	1,458.0	22.0	468,203.2	321.1	842,227.1	839,230.0	2,997.1	0.0
12 Euro-area equity markets	**98.31**	**5,405.0**	**4,403.0**	**1,002.0**	**4,355,507.4**	**989.2**	**7,300,617.0**	**7,072,248.4**	**217,497.2**	**10,871.4**
DENMARK (Copenhagen)	60.54	217.0	208.0	9.0	85,145.0	409.4	72,365.4	66,129.5	1,275.6	4,960.3
SWEDEN (Stockholm)	156.39	305.0	285.0	20.0	236,514.4	829.9	386,730.1	304,731.0	81,999.1	0.0
UK (London)	198.29	2,332.0	1,923.0	409.0	2,164,716.2	1,125.7	4,550,503.6	1,877,165.0	2,651,441	21,897.7
15 EU equity markets	**106.91**	**8,259.0**	**6,819.0**	**1,440.0**	**6,841,883.0**	**1,003.4**	**12,310,216.1**	**9,320,273.9**	**2,952,213**	**37,729.4**
SWITZERLAND (Swiss)	267.46	412.0	263.0	149.0	527,374.6	2,005.2	594,935.7	577,369.8	14,727.1	2,838.8
USA (NYSE)	180.78	2,400.0	1,939.0	461.0	11,026,586.5(*)	5,686.7	10,489,322.5	9,601,646.6	787,244.3	100,431.6
JAPAN (Tokyo)	104.74	2,141.0	2,103.0	38.0	2,293,841.5	1,090.7	1,660,525.2	1,656,317.3	400.2	3,807.7

Panel B 2001	Average Amount Traded per day (US$ millions)	Average Value of Transactions (US$ miles)	Number of transactions in equity shares (in miles)	Number of shares traded (millions)	Turnover velocity of domestic shares (calculated with monthly figures)	Concentration of 5% most capitalised domestic companies		**2000**		**2000/90** Stock price index (**) Cumulative change (%)	**2000/99** Stock price index change (%)
						5% mark. Value	N. Cies.	PER (%)	Gross Dividend Yield (%)		
BELGIUM (Euronext Brussels)								14.5%	2.9%	72.60%	-5.02%
FRANCE (Euronext Paris)	12,518.9	58.7	54,136.0	49,555.0	138.4%	76.3%	57	NA	1.6%	73.48%	-1.04%
NETHERLANDS (E.Amsterdam)								21.3%	1.9%	--	-3.87%
FINLAND (Helsinki)	729.2	56.8	3,196.0	11,398.5	99.2%	84.2%	8	NA	2.5%	92.33%	-10.60%
GERMANY (Deutsche Börse)	5,698.2	17.2	84,000.0	32,832.0	118.3%	66.1%	37	NA	NA	78.27%	-7.54%
GREECE (Athens)	150.5	2.5	15,130.0	7,033.7	42.1%	57.1%	16	27.5%	10.3%	72.50%	38.77%
IRELAND (Irish)	89.9	120.3	189.0	4,242.0	23.6%	55.1%	3	17.1%	1.5%	79.00%	12.84%
ITALY (Italy)	2,818.3	16.0	44,265.0	140,247.7	113.4%	62.8%	14	NA	NA	73.02%	5.37%
LUXEMBOURG (Luxembourg)	2.8	27.8	34.8	29.7	1.7%	60.6%	3	NA	2.0%	74.91%	NA
PORTUGAL (Lisbon)	111.7	10.5	2,640.9	7,316.9	53.3%	62.4%	5	NA	1.4%	74.55%	-8.21%
SPAIN (Madrid)	3,368.9	27.2	30,935.5	77,731.0	175.8%	68.7%	73	18.6%	1.7%	74.65%	-12.68%
12 Euro-area equity markets	**2,552.0**	**35.7**	**234,920.8**	**330,756.6**	**79.4%**	**63.1%**	**22.1**	**18.4%**	**2.8%**	**68.67%**	**0.06%**
DENMARK (Copenhagen)	290.6	34.5	2,097.0	2,895.0	66.6%	66.5%	10	NA	NA	65.29%	17.06%
SWEDEN (Stockholm)	1,546.9	36.4	10,628.0	47,044.0	119.4%	67.0%	14	26.0%	1.7%	81.73%	-12.02%
UK (London)	17,986.2	139.3	32,668.0	901,527.4	83.8%	83.6%	96	23.3%	2.2%	65.55%	-10.21%
15 EU equity markets	**3,421.1**	**43.0**	**280,313.8**	**1,282,222.9**	**81.4%**	**66.4%**	**25.9**	**19.8%**	**2.7%**	**69.14%**	**-0.32%**
SWITZERLAND (Swiss)	2,379.7	62.4	9,530.0	1,775.9	93.9%	82.7%	13	17.0%	1.7%	83.84%	11.91%
USA (NYSE)	42,295.7	30.9	339,104.8	307,509.3	86.9%	63.8%	97	25.2%	1.2%	72.52%	1.01%
JAPAN (Tokyo)	6,750.1	NA	NA	204,194.0	60.0%	62.5%	105	85.5%	1.0%	-35.05%	-25.46%

(*) If market capitalisation of shares listed on Nasdaq ($2,739,674.7 millions) is added, total market capitalisation (NYSE and Nasdaq) is 13,766,261,2.

(**) **Name of Indices**: Euro area: Vienna SE Index; Spot Return Index (All Share); SBF 250; CBS All Share; HEX; DAX Return; ASE General price Index; ISEQ Overall; MIB Historical; Shares Price Index; BVL; General Index. Other EU: Total Share Index; SX General, FT SE 100. Extra EU: Swiss Performance Index (SPI); NYSE Composite; TOPIX. NA: Not Available

Sources: IMF International Financial Statistics 2000 and International Federation of Stock Exchange (FIVB).

The Euro-area stock exchanges are relatively closed in terms of the trading value of foreign companies (it represents 3.0% over the total value), and in a lesser extent in terms of their number of foreign companies with share listed. By value of foreign share trading, the most open market is the London stock exchange, where 17.5% of listed companies are foreign, and the value of their share trading exceeds 58.3% over the total value. Then, the Swedish stock market with a value of foreign share trading of 21.2% over the total, and finally, the German market, where the value of foreign share trading reaches 9.4% over the total value. By number of foreign companies with share listed, the most open stock exchange is the Luxembourg one, where the foreign companies quoted on represent the 81.3% over the total[3], but their value represent only 0.6% over the total trading value. On the other hand, the less open stock exchanges, from this point of view, are the Japanese, Greek, Portuguese, Spanish and Finland equity markets.

It is also noticed the differences between the average amount traded per day in each country, which exceeds $42,000 millions in US and is about $2,500 millions in the 12 euro-area equity markets. Between the European stock exchanges these differences are even higher (e.g. $2.8 millions in Luxembourg, and 17,986.2 millions in UK) (see Panel B, Table 3). The major market capitalisation, the large number of companies with shares listed, and the minor concentration of the most capitalised companies could improve the stock market efficiency (e.g. Japan, US and UK). But the concentration of the most capitalised companies is different in each country. Switzerland, Sweden, Luxembourg and Greece have important stock markets, but they are too concentrated in their most capitalised companies.

Moreover, the European equity markets show different performances. It is worth pointing out the relative under-performance of the euro-area markets compared to that of the US. In 2000, most of the European country indices lost ground compared to the US, except the Greek, Irish, Denmark and Italian stock markets (see Panel B, Table 3). A large rise in the Greek market was explained in part by prospects for convergence with the single currency area and by the relative low level of starting point. In the Irish market, the economy growth played an

[3] The EU markets average, the euro-area markets average and the US stock market present almost similar percentages (range 17.4-19.2%). But there are high differences within the EU equity markets (range 0.3 in Greece to 81.3 in Luxembourg).

important role in its high performance. Moreover, the convergence also benefited Ireland and Luxembourg. During the whole 1990-2000 period, both the European and US markets showed important increases, with the only exception of the Austrian market. For this period, the Finland stock market was the best performed, with an index cumulative change of 92.33%, maybe because it was mainly leading by the telecommunication sector.

IV. Methodology.

The methodology used in this study mainly consists of a Vector Autoregression analysis (VAR). Whether the integration of European stock markets has increased after the introduction of the euro is investigated by estimating the Impulse Response Function (IRF) and through the variance decomposition.

The return on a equity market *i*, R_{it}, is measured by,

$$R_{it} = \log(I_{it} / I_{i,t-1}) \qquad [1]$$

where I_{it} is the last daily data of the index of the stock exchange *i* in the day *t*.

The volatilities of stock exchanges are calculated, following Moreno and Olmeda (2002), as

$$V_{it} = R_{it}^2 \qquad [2]$$

where V_{it} is the volatility of the stock exchange *i* in the day *t*.

The vector autorregression (VAR) is commonly used for forecasting systems of interrelated time series and for analysing the dynamic impact of random disturbances on the system of variables. All variables have an identical and symmetrical deal, so the feed-back effect can be analysed (Sims, 1980). Because of that, this methodology is especially useful to study markets series. The VAR approach sidesteps the need for structural modelling by modelling every endogenous variable in the system as a function of the lagged values of all of the endogenous variables in the system. The mathematical form of a VAR is

$$y_t = A_1 y_{t-1} + ... + A_p y_{t-p} + Bx_t + \varepsilon_t \qquad [3]$$

where y_t is a k vector of endogenous variables, x_t is a d vector of exogenous variables, $A_1,...,A_p$ and B are matrices of coefficients to be estimated, and ε_t is a vector of innovations that may be contemporaneously correlated with each other but are uncorrelated with their own lagged values and uncorrelated with all of the right-hand side variables.

Since only lagged values of the endogenous variables appear on the right-hand side of each equation, there is no issue of simultaneity, and OLS is the appropriate estimation technique. Note that the assumption that the disturbances are not serially correlated is not restrictive because any serial correlation could be absorbed by adding more lagged *y*'s.

The stock exchanges are continually influencing between them; there is a permanent informational flow. The earliest stock exchange for trading each day is Tokyo, after the European exchanges (where the trading hours are overlapped between them), and later the US stock exchange. So the earliest stock exchange for trading (Japanese and European) will affect the first prices in the US stock market, and this last in turn will influence on the former ones at the next day, with one period lag. The definition of a VAR with two lagged values of the endogenous variables is,

$$\begin{aligned} Y_t &= a_{11}Y_{t-1} + a_{12}Z_{t-1} + b_{11}Y_{t-2} + b_{12}Z_{t-2} + c_1 + \varepsilon_t^Y \\ Z_t &= a_{21}Y_{t-1} + a_{22}Z_{t-1} + b_{21}Y_{t-2} + b_{22}Z_{t-2} + c_2 + \varepsilon_t^Z \end{aligned} \qquad [4]$$

where the daily returns of whatever national stock markets (Y_t and Z_t) are jointly determined by a two variable VAR; the only exogenous variable is a constant c; ε_t^Y and ε_t^Z are the uncorrelated innovations; and *a, b, c* are the parameters to be estimated.

In this study, the main uses of the VAR in empirical applications are applied, such as the impulse response analysis, variance decompositions, and Granger causality tests. The impulse response function traces the effect of a one standard deviation shock to one of the innovations on current and future values of the endogenous variables. A shock to the *i*-th variable (a country's stock market return) directly affects the *i*-th variable, and is also transmitted to all of the endogenous variables (the rest of national stock markets returns) through the dynamic structure of the VAR.

A change in ε_t^Y will immediately change the value of current Y_t. It will also change all future values of Y_t and Z_t since lagged Y_t appears in both equations. If the innovations, ε_t^Y and ε_t^Z are uncorrelated, interpretation of the impulse response is straightforward. ε_t^Y is the innovation for Y_t and ε_t^Z is the innovation for Z_t. The impulse response functions for ε_t^Z measures the effect of a one standard deviation national stock market shock on current and future European stock markets returns.

The innovations are, however, usually correlated, so that they have a common component, which cannot be associated with a specific variable. A somewhat arbitrary but common method of dealing with this issue is to attribute all of the effect of any common component to the variable that comes first in the VAR system. In our study, the common component of ε_t^Y and ε_t^Z is totally attributed to ε_t^Y, because ε_t^Y precedes ε_t^Z. ε_t^Y is then the Y_t innovation, and ε_t^Z, the Z_t innovation, is transformed to remove the common component.

In contrast, variance decomposition decomposes variation in an endogenous variable into the component shocks to the endogenous variables in the VAR. The variance decomposition gives information about the relative importance of each random innovation to the variables in the VAR. Then it is possible identify the part of the prediction error that is due to innovation in the same stock market or to others stock markets shocks.

On the other hand, as correlation does not necessarily imply causation, the Granger (1969) causality test approaches to the question of whether the variable Y causes Z in a short term. This test consists of seeing how much of the current Z can be explained by past values of Z and then seeing whether adding lagged values of Y can improve the explanation. Z is said to be Granger-caused by Y if Y helps in the prediction of Z, or equivalently if the coefficients on the lagged Y's are statistically significant. Note that two-way causation is frequently the case; Y Granger causes Z and Z Granger causes Y. It is important to note that the statement "Y Granger causes Z" does not imply that Z is the effect or the result of Y. Granger causality measures precedence and information content but does not by itself indicate causality in the

more common use of the term. The null hypothesis in the Granger causality test is therefore that the variable *Y* does not Granger-cause the variable *Z*.

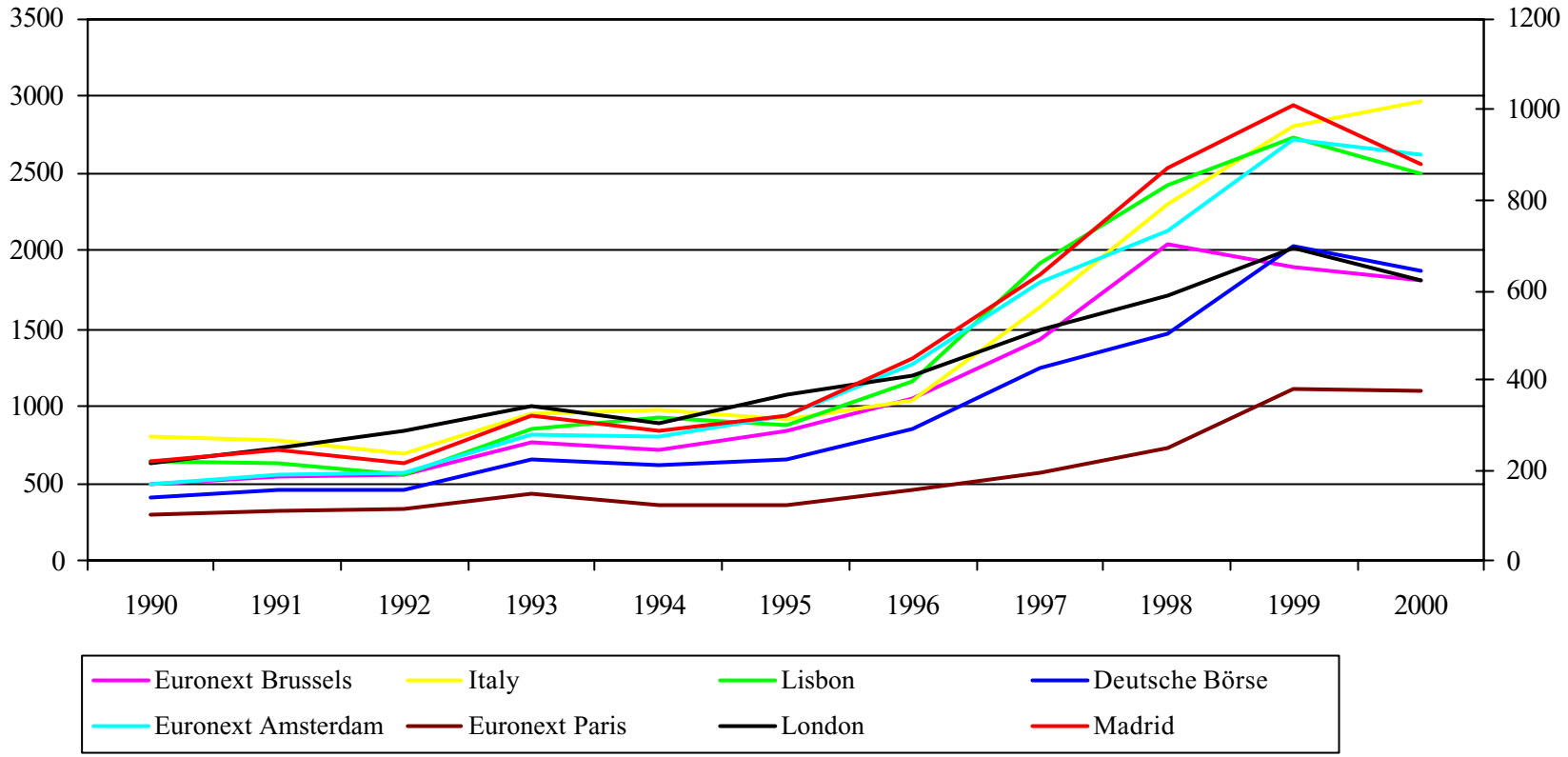
It is important to note that the statement "*Y* Granger causes *Z*" does not imply that *Z* is the effect or the result of *Y*. Granger causality measures precedence and information content but does not by itself indicate causality in the more common use of the term. The null hypothesis in the Granger causality test is therefore that the variable *Y* does not Granger-cause the variable *Z*.

V. Main results.

A. Correlation analyses.

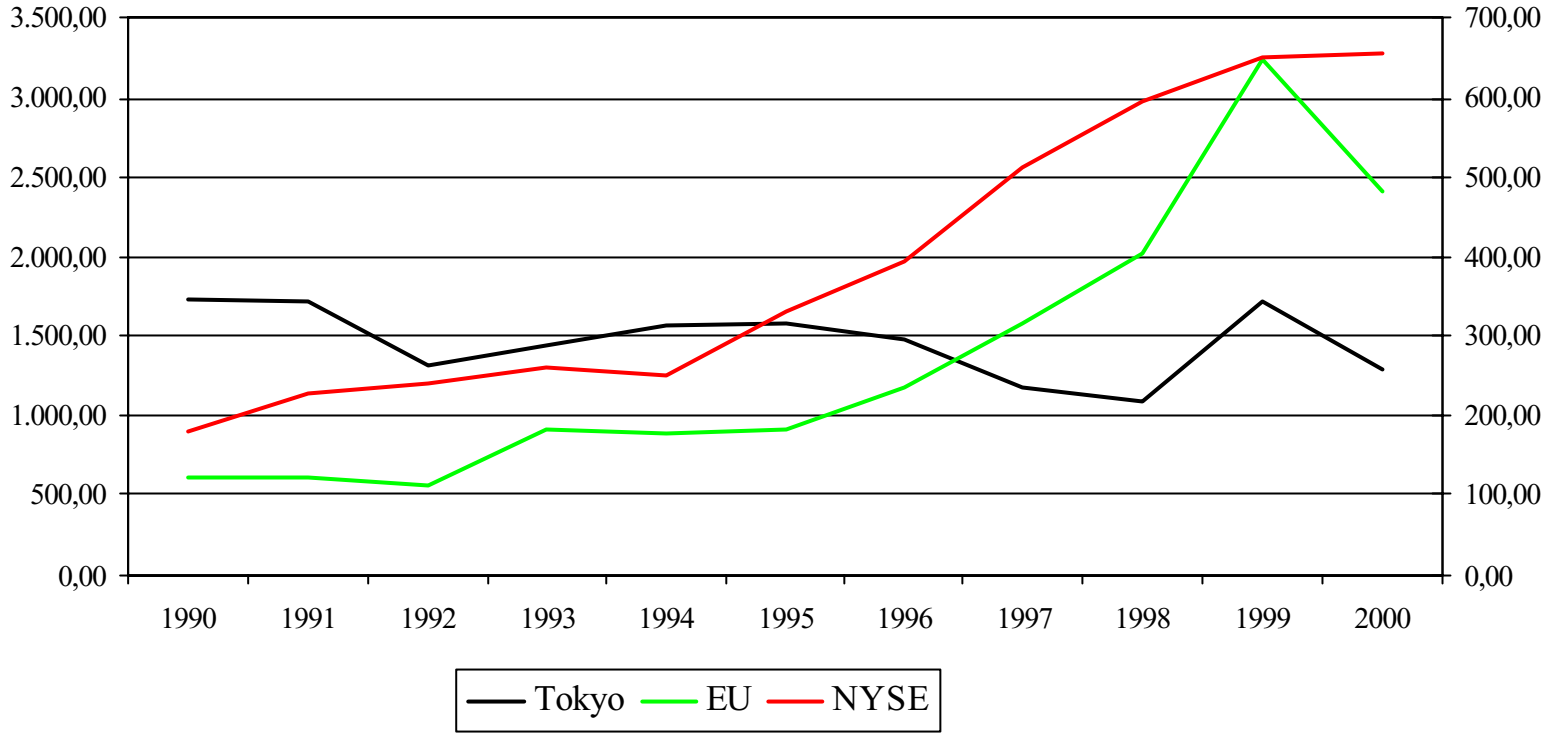
Firstly, the degree of market integration is based on the computation of the correlation between the stock prices indices, the volatilities and the returns on between the 18 stock markets selected (see Table 2). In order to analyse if they will be more integrated after the euro than previously, the total sample is divided in two sub-samples: one sub-sample includes the national stock markets indices for the before-Euro period (from 30 April 1997 to 31 December 1998) and the other includes the same indices for the after-Euro period (from 1 January 1999 to 23 May 2002). This approach is based on rather simple intuition: the more integrated markets are, the higher the comovement between their prices. A simple graph of the evolution of the main stock price indices at year-end during 1990-2000 period evidences the same trend of the European equity indices (except London equity index in some years until the introduction of the euro), and so the possible interdependence among them (see Graph 1). But, as Graph 2 shows, national stock markets in different zones are less related.

Graph 1. Evolution of the main stock price indices at year-end (1990-2000)



Source: International Federation of Stock Exchange (FIVB).

Graph 2. Evolution of the main zone indices at year-end (1990-2000)



Source: International Federation of Stock Exchange (FIVB).

In this connection, the appendix A shows the correlation matrix of daily stock prices of the 18 selected stock exchanges during both periods (before and after euro). As price correlation matrix shows, after the euro the correlation has only increased in 37 outs of the 153 possible combinations, with the Japanese stock exchange accounting for the remaining 17 cases. On average, the correlation between these price indices decreased from 0.70 during the 1997-98 period to 0.66 during 1999-2002 (this average correlation only between EU markets went from 0.68 to 0.65).

The appendix B provides the correlation of daily returns on the 18 selected stock exchanges during both periods. After the euro (January 1999-May 2002), the correlation of the returns on the French and German stock exchanges have increased (more than 21%) respect to the before euro period (April 1997-December 1998), as well as the correlation of the main European stock markets (e.g. the returns on the German and Italian markets are almost 17% more correlated). In addition, after the euro, the Dutch, Spanish, and Italian stock markets are also more related between them and with the rest of markets, according to their returns correlations. On the other hand, the correlation of returns on the German and US stock exchanges has increased more than 30% after the introduction of the euro (in 1999-2002). However, on average, the correlation of returns on all selected stock exchanges maintained more or less the same level (0.47 during 1997-98 and 0.40 during 1999-2002).

Finally, the appendix C presents the correlation matrix of volatilities between the different stock markets. On average, the correlation of volatilities has decreased 0.07 point (from 0.70 in 1997-98 to 0.63 in 1999-2002). On the other hand, the average correlation of volatilities between the euro-area stock markets has only reduced from 0.64 to 0.60 in 1999-2002. Given that it is reasonable to think that, according to this indicator, the degree of market integration is lower in 1999-2002. However, the euro has revived the integration process of the Luxembourg stock exchange with the rest of exchanges, as the high increase of the average correlation of volatilities shows.

The weak results of these correlation analyses could be explained by previous high level of correlation between the European equity indices before 1 January 1999. Indeed, before the

introduction of the common currency there have been in Europe several previous attempts of stock markets integration, as well as a relaxation of controls on capital movements and foreign exchange transactions, improvements in computer and communication technology that have lowered the cost of cross-border information flows and financial transactions, and a expansion in the multinational operations of major corporations. Moreover, this evidence can not be considered as supporting the view of a lower degree of financial market linkages, it is well known that the lower correlation is neither a necessary nor a sufficient condition for smaller market integration (Adler and Dumas, 1983). If markets are completely integrated and, therefore, there are no arbitrage opportunities, returns on different assets can be divided into a common component and an idiosyncratic one. The latter, however, may be sufficiently important as to render ex post correlation rather low.

B. Vector Autoregression analysis (VAR).

This approach is built on the previous one and is aimed at measuring to what extent the price indices of others markets can help to explain the index values of one particular market. Table 4 shows the main results of this approach, which consists of a comparison between the (sum of squared) residuals of a simple univariate autoregressive model for each index and the (sum of squared) residuals of a VAR model for the 18 stock exchange indices considered[4]. First of all, it has be noted that the 18 markets considered do not share common trading hours and consequently implications cannot be drawn from comparisons between countries within the same period[5]. Nevertheless, we are not interested in a comparison between countries within the same period but in a comparison of different periods for the same country. Yet there is no reason to think that the implications of the different trading hours –whatever they might be– have changed after the introduction of the euro.

[4] Using returns on the different stock exchanges in this analysis, the results are less significant, because modelling of returns results in the loss of important information on possible common trends when prices are cointegrated.

[5] For example, the relatively low improvement ratio for the US stock exchange could be due to the fact that this is the stock exchange that closes the latest each day, thus being open to news that arrive when other stock exchanges are closed.

Table 4. The explanatory power of the other market indices on the own market index (daily data)

Before-Euro period: 97/4/30 - 98/12/31 No. Observ.: 436 q: 17	AUS	BEL	FIN	FRAN	GER	GRE	IRE	ITA	LUX
SRR univ (1)	74377.44	101885.9	16026.47	83287.74	170855.3	37179.31	9.519	17541.26	3.586
SRR VAR (2)	67465.47	90577.43	14066.23	75440.47	139896.2	33083.25	8.262	15374	3.236
((1)-(2))/(1)	9.29%	11.10%	12.23%	9.42%	18.12%	11.02%	13.21%	12.36%	9.77%
	NET	POR	SPA	UK	DEN	SWE	SWI	USA	JAP
SRR univ (1)	366963.2	2.286	12927.45	62647.55	266143.4	1116295	457872.2	59669.56	760798.8
SRR VAR (2)	322933.3	2.005	11545.8	54349.47	236178.4	970543.7	390468.9	54246.54	711118.6
((1)-(2))/(1)	12.00%	12.32%	10.69%	13.25%	11.26%	13.06%	14.72%	9.09%	6.53%

After-Euro period: 99/1/1 - 02/5/23 N. observ.: 845 q: 34	AUS	BEL	FIN	FRAN	GER	GRE	IRE	ITA	LUX
SRR univ (1)	60160.41	221862.8	581418.3	304341.5	386813.3	132934.3	14653.95	25913.9	148622.7
SRR VAR (2)	54905.55	196152.9	455045.1	248967.9	333001.9	118374.2	12208.25	22888.45	128572.6
((1)-(2))/(1)	8.73%	11.59%	21.74%	18.19%	13.91%	10.95%	16.69%	11.68%	13.49%
	NET	POR	SPA	UK	DEN	SWE	SWI	USA	JAP
SRR univ (1)	532415	1.983	22844.31	138628.8	598401.2	6897006	563747.4	215130.2	1336809
SRR VAR (2)	443111.9	1.732	20191.22	114237.3	516748.3	5540466	494046.9	193854.2	1069897
((1)-(2))/(1)	16.77%	12.67%	11.61%	17.59%	13.65%	19.67%	12.36%	9.89%	19.97%

Notes: q is the number of new regressors in the VAR when compared with the univariate model.
SRR: Sum of squared residuals.

Source: Own elaboration based on MSCI (Morgan Stanley Capital International) Equity Indices.

According to Table 4, during the before-euro period, in 1997-98, the sum of the squared residuals was reduced, on average, by 11.63% when other market indices are taken into account to explain the behaviour of the equity index values. After the introduction of the euro, in 1999-2002, the reduction amounts to 14.51%, thus revealing a higher average degree of linkage between the markets considered. This major linkage, however, could be overestimated in Table 4, given that the VAR approach adds only 17 parameters to each univariate model during 1997-98 whereas 34 parameters are added during 1999-2002. So for this after-euro period (1999-2002), the VAR model includes two lags, whereas for the before-euro period (1997-98) a single lag is sufficient to eliminate any residual autocorrelation. Accordingly, respect to the univariate model, the VAR adds 34 more parameters (2 lags x 17 countries) during 1999-2002 and only 17 (1 lag x 17 countries) during 1997-98.

Furthermore, the improvement of the explanatory power of other indices on the own equity index due to the introduction of the euro is not uniform across the 18 countries, even 5 outs of 18 show a decrease (Austria, Germany, Greece, Italy and Switzerland). In 1999-2002, the degree of linkage between these markets is lower than in 1997-98. It could be explain, in part, because the German, Austrian and Swiss markets had already started an integration process through the DM; and the Italian market, with great weight of listed foreign companies, is internationalised.

Only on the euro-area exchange indices average, excluding the Greek market because Greece joined to Euro in 1 January 2001, before the euro the sum of the squared residuals is reduced by 11.86% when other market indices are taken into account and after the euro, this reduction rises to 14.28%. So the euro affects the integration of these 18 national stock markets even more than it does these 11 euro-area stock markets (the increase of the explanatory power of the other market index values is, on average, 2.87 points when all stock markets are considered, and 2.42 points when only these 11 euro-area markets are included).

B.1. Testing for Granger causality.

Granger (1969) causality tests let to identify the existence of short-run causation relationships between the stock markets indices. The explanatory power in a regression of one stock market index y_t on lagged values of y_t and x_t (another stock market index) is tested. Table 5 shows the results of this causality test (with two lags) in both periods considered. The test of the null hypothesis, H_0, that one stock market does not Granger cause another stock market can be based on simple F tests in the single equation of the VAR model. In both periods, as F-statistic values shown in Table 5, we reject the hypothesis that US stock exchange does not Granger cause the rest of stock exchanges considered at 5% significance level. So lagged values of US equity index have explanatory for all of the equity indices in the system; the US stock exchange is the most exogenous to the system.

Table 5. Short-run causality relationships: Granger causality

Before Euro	AUS	BEL	DEN	FIN	FRA	GER	GRE	IRE	ITA	JAP	LUX	NET	POR	SPA	SWE	SWI	UK	USA
AUSTRIA		0,86	0,63	2,97	2,41	0,75	1,53	**4,52**	0,78	0,24	1,46	1,36	0,16	2,61	2,11	0,61	2,03	**26,79**
BELGIUM	0,81		0,11	0,45	**5,13**	1,30	1,32	**4,50**	1,19	1,12	1,05	2,03	0,11	**7,83**	0,56	1,01	1,62	**13,81**
DENMARK	2,35	1,09		0,08	1,98	0,09	0,45	**4,78**	1,55	**6,74**	1,20	1,13	1,11	2,29	0,44	0,99	**7,27**	**11,76**
FINLAND	0,76	2,96	0,22		1,51	0,94	0,70	**5,78**	0,67	**3,43**	2,09	0,14	2,36	2,02	1,44	1,89	2,43	**41,31**
FRANCE	1,84	0,52	0,96	1,05		2,96	2,25	**10,79**	1,38	2,13	1,69	0,84	**4,55**	**3,16**	0,90	0,51	1,17	**16,32**
GERMANY	1,36	1,80	1,24	0,89	**20,26**		0,46	**10,76**	**8,81**	1,45	1,41	**8,40**	**4,52**	**17,75**	**8,39**	**5,84**	**8,88**	**37,51**
GREECE	1,50	**7,58**	2,37	**12,58**	**17,74**	**13,89**		**4,80**	**10,77**	0,32	**3,77**	**8,43**	**7,38**	**13,41**	**10,96**	**11,07**	**9,96**	**20,33**
IRELAND	2,36	**4,31**	3,07	**12,76**	**12,26**	**13,35**	**5,14**		**5,73**	0,51	0,31	**8,28**	**5,22**	**20,29**	**12,42**	**11,35**	**18,47**	**68,42**
ITALY	0,39	0,22	0,33	0,09	2,59	2,46	1,75	**5,97**		2,82	0,36	1,21	1,27	**5,87**	2,60	1,59	3,09	**21,98**
JAPAN	**5,75**	**4,68**	**6,79**	**4,63**	**10,59**	**6,14**	**5,76**	2,32	**4,74**		1,62	**12,57**	**4,81**	**8,42**	**11,62**	**13,83**	**15,60**	**10,98**
LUXEMBOURG	**3,63**	**16,45**	**3,58**	**11,13**	**23,95**	**14,39**	1,84	2,60	**10,91**	1,82		**13,30**	**12,13**	**17,08**	**11,67**	**17,32**	**15,95**	**22,25**
NETHERLANDS	0,83	0,94	1,79	0,27	**5,72**	0,04	0,24	**14,64**	1,57	2,71	1,92		2,95	**6,59**	1,03	1,70	**6,54**	**22,49**
PORTUGAL	0,06	0,79	0,93	0,54	2,70	2,13	**4,25**	2,56	0,36	2,08	1,30	2,30		**5,23**	0,83	0,88	2,28	**12,42**
SPAIN	0,81	0,00	0,20	0,41	0,79	**4,48**	**4,10**	**5,24**	0,36	1,75	0,44	2,37	1,08		**3,50**	0,01	0,49	**10,53**
SWEDEN	2,50	0,27	0,85	0,34	1,33	0,86	0,68	**8,70**	0,21	**3,59**	0,32	3,05	2,66	1,67		0,85	2,89	**16,76**
SWITZERLAND	0,22	0,21	0,97	0,58	2,26	1,27	0,86	**7,71**	0,71	1,61	0,02	**3,44**	1,75	**4,67**	1,26		1,39	**8,86**
UK	2,62	0,06	0,27	0,24	0,62	1,10	1,49	**5,91**	0,14	2,12	0,67	2,32	1,75	1,38	2,43	0,17		
USA	0,91	1,96	0,15	0,16	2,15	0,59	1,78	0,32	1,71	0,11	0,60	2,27	0,90	3,04	1,58	1,64	**4,18**	**19,17**
After Euro	AUS	BEL	DEN	FIN	FRA	GER	GRE	IRE	ITA	JAP	LUX	NET	POR	SPA	SWE	SWI	UK	USA
AUSTRIA		1,19	1,27	1,54	0,48	0,23	0,05	1,12	0,14	1,03	0,43	0,35	0,34	0,92	0,36	2,74	1,58	**7,93**
BELGIUM	1,41		**3,55**	**4,39**	1,40	1,06	2,56	**3,89**	0,72	2,72	0,56	0,20	0,94	0,37	1,61	2,21	0,70	**11,61**
DENMARK	3,06	0,57		**5,22**	**4,72**	1,43	0,59	0,60	0,94	**4,32**	**4,13**	1,35	0,53	0,55	**4,11**	0,87	0,43	**24,55**
FINLAND	1,64	1,30	2,04		2,88	**8,07**	2,37	0,98	**3,34**	**8,39**	2,46	0,38	**4,50**	2,32	2,31	1,12	**4,41**	**59,78**
FRANCE	2,24	1,98	1,41	**3,89**		**6,46**	1,96	3,08	1,49	**8,38**	0,25	0,09	0,51	0,62	**5,37**	2,33	1,12	**36,16**
GERMANY	0,49	**3,62**	1,54	0,62	0,28		3,06	0,46	1,25	**5,85**	0,91	0,00	0,56	1,44	0,60	2,59	1,23	**21,54**
GREECE	2,86	**5,76**	2,19	**3,45**	**8,80**	**10,59**		2,20	**3,33**	0,18	1,32	**4,58**	2,76	**3,50**	2,80	**6,74**	**10,63**	**29,41**
IRELAND	1,04	**7,31**	0,31	0,08	**4,03**	**7,76**	0,40		**3,35**	0,18	0,19	**4,42**	0,66	**5,60**	1,43	**12,06**	**11,22**	**35,83**
ITALY	0,50	2,41	0,83	1,67	0,16	1,10	1,52	0,40		**3,33**	0,45	0,27	0,61	0,55	1,15	**3,31**	0,74	**12,88**
JAPAN	**3,18**	**12,94**	**4,42**	**17,37**	**37,09**	**37,90**	**5,19**	**2,59**	**22,89**		**4,52**	**26,05**	**6,70**	**17,67**	**16,39**	**13,51**	**31,69**	**46,05**
LUXEMBOURG	**5,03**	1,11	0,21	**16,71**	**12,92**	**10,96**	2,50	**5,29**	**4,91**	**7,75**		2,89	2,82	**3,23**	**18,37**	1,35	2,68	**16,40**
NETHERLANDS	0,38	**3,45**	0,42	1,65	0,90	2,75	1,94	0,77	2,95	**7,07**	0,15		1,01	1,71	1,44	2,73	2,31	**38,29**
PORTUGAL	**7,78**	1,32	0,28	0,47	0,05	1,60	1,83	1,04	1,30	**3,75**	0,49	0,61		0,29	0,38	1,00	0,56	**8,53**
SPAIN	2,83	0,91	0,16	1,44	1,85	1,29	**3,75**	0,57	1,21	**4,23**	0,09	1,13	**4,86**		0,69	1,29	2,12	**14,72**
SWEDEN	2,23	2,09	**3,59**	0,37	**5,56**	**10,70**	**3,52**	0,68	**5,03**	**5,15**	**3,98**	1,15	**4,75**	**4,87**		0,91	**8,63**	**61,27**
SWITZERLAND	1,35	1,81	0,41	**3,21**	1,60	0,52	0,66	0,60	2,80	**3,10**	0,13	1,45	2,21	0,07	2,16		0,82	**10,11**
UK	0,96	**3,90**	0,96	0,23	0,38	0,13	2,65	0,92	0,25	**3,31**	1,41	0,30	2,32	0,82	0,92	2,21		**40,73**
USA	0,50	**3,78**	0,27	0,71	1,10	2,34	3,09	1,67	**3,13**	**4,56**	0,13	2,15	**3,42**	**3,86**	1,75	1,89	**3,36**	

Each cell, C_{ij}, presents F-statistic value that tests the null hypothesis, H_0, that the stock market in column *j* does not Granger cause the stock market in row *i*. F values in blod denote rejection of H_0 at 5% significance level.

Source: Own elaboration based on MSCI (Morgan Stanley Capital International) Equity Indices.

The results indicate that in 1999-2002, inside of the euro-area stock markets, the German, Belgium, Italian, Luxembourg and Finland equity indices Granger cause more stock markets than they did in 1997-98. However, the Spanish, Irish and Dutch stock exchanges have lost explanatory power on some of the stock exchanges analysed during 1999-2002. While the euro has hardly affected the explanatory power of the Austrian, French, Greek and Portugal stock markets on the rest of markets.

In addition to this, during the second period, lagged values of the Swedish, Swiss and UK stock market indices Granger cause a minor number of stock markets. So, according to this causality test, the euro do not increase the integration of these extra euro-area markets.

It is noticed the increase of the explanatory power of the Japanese market, which Granger cause 13 stock exchanges of the 17 markets in 1999-2002. Therefore, in this period, it appears that Granger causality runs also the other way: from all stock exchanges to the Japanese one.

B.2. Cointegration and long-run equilibrium relationships.

Given a group of non-stationary series, we may be interested in determining whether the series are cointegrated, and if they are, in identifying the cointegrating (long-run equilibrium) relationships. We implement VAR-based cointegration tests using the methodology developed by Johansen (1991, 1995). Johansen's method is to test the restrictions imposed by cointegration on the unrestricted VAR involving the series.

An unrestricted VAR does not assume the presence of cointegration. Because of that, we should run the Johansen cointegration test to confirm that the variables are not cointegrated, and so there is not any vector error correction model (VEC). We adopt the bivariate perspective to analyse the long-run relationships among the indices, which consists of testing the cointegration between each equity index and each one of the other indices, because if we include all indices analysed, the multivariate VEC would be over-parametric. For reasons of

brevity, the results are not shown, but for neither of these two sub-samples (1997-98 and 1999-2002), there are any cointegrating equations at 5% significance level[6].

B.3. Effect of stock exchange shock on other stock exchanges. Impulse response function.

The impulse response function identifies the effect of a one standard deviation shock in one stock exchange to one of the innovations on current and future values of other stock exchange. We estimate the impulse response functions of the different stock market considered to innovations in each one of the other markets. Figure 3 shows the graphs that represent the impulse response of each country to a one shock in each one of the rest of markets during the before-euro period (1997-98). Figure 4 presents the same IRF for the second sub-sample (1999-2002). In both Figures, we only show the graphs of the impulse response functions of the main stock exchanges analysed, and the ordering to introduce them in the VAR model consists of incorporating the stock markets ordering by trading hours, according to the previous financial literature (Moreno and Olmeda, 2002). So firstly German stock market; then, by this order, French, Italian, Spanish and UK stock exchanges (although all European markets open at the same time), and lastly the US stock exchange.

As general conclusion of these results, after the introduction of the euro, in 1999-2002, German stock market has increased its influence on the rest of markets, European and non-European. But the effect of one German market's innovation on the euro-area stock markets during 1999-2002 is even higher than the effects of own time innovations in these European markets on themselves.

Moreover, the impulse response of the different stock exchanges to one US exchange shock hardly has reduced in 1999-2002 (after the introduction of the common currency). In contrast, the effect of one French exchange shock on the different markets analysed has reduced in 1999-2002.

[6] It is usual that the not cointegration's hypothesis could not be rejected using data from five years.

B.4. Variance decompositions

Variance decomposition decomposes variation in one stock market (endogenous variable) into the component shocks to the stock markets considered (endogenous variables in the VAR). The variance decomposition gives information about the relative importance of each random innovation in a stock market to the rest of stock markets (variables in the VAR).

Table 6 presents the results of the variance decomposition for each stock market (for the lag 3) before and after the introduction of the euro. The results show the relative importance of each market innovation to each market individually, during both periods. The remaining columns give the percentage of the variance due to each innovation; each row adds up to 100. The last column of Table 6 shows the total of the prediction error variance due to the euro-area stock markets. After the euro, the variance of each euro-area stock market, except the French one, is more explained by the sum of these euro-area markets. This increment is not due to the French and Spanish stock exchanges have increased their relative importance (percentage) in the variance of the euro-area markets. Basically, it is due to a higher dependence of these stock markets to the German market during the after-euro period. So the relative importance of the German stock exchange has increased as a consequence of the euro introduction, while that of the rest of European national exchanges has decreased.

Table 6. Variance decomposition

Before-euro period	To one innovation in							
Explained markets. Variance Decomposition of:	S.E.	GERMANY	FRANCE	ITALY	SPAIN	UK	USA	Sum of Euro-area markets
GERMANY	32.309	89.237	4.832	0.107	0.971	0.538	4.315	95.147
FRANCE	24.185	43.142	53.093	0.107	0.510	0.299	2.849	96.852
ITALY	10.573	42.025	19.875	33.908	0.562	0.091	3.539	96.370
SPAIN	9.684	42.265	17.844	2.743	35.193	0.025	1.930	98.045
UK	20.610	32.244	13.282	0.686	1.548	48.801	3.438	
USA	18.991	11.378	11.039	0.300	1.689	4.534	71.061	

After-euro period	To one innovation in							
Explained markets. Variance Decomposition of:	S.E.	GERMANY	FRANCE	ITALY	SPAIN	UK	USA	Sum of Euro-area markets
GERMANY	36.987	**97.076**	**0.014**	0.182	**0.069**	**0.050**	**2.610**	97.340
FRANCE	32.096	**69.491**	**26.382**	0.047	**0.015**	**0.045**	**4.021**	95.935
ITALY	9.278	**55.511**	**8.896**	33.825	**0.025**	0.066	**1.677**	98.257
SPAIN	8.857	**49.832**	**7.651**	**6.331**	34.531	0.087	**1.568**	98.345
UK	21.610	**36.032**	**4.644**	**1.231**	0.951	**51.571**	**5.571**	
USA	26.164	**19.448**	**1.086**	**0.118**	**0.027**	**2.797**	76.524	

Ordering: Germany, France, Italy, Spain, UK, USA.
S.E. is the forecast error of the variable.

- Each row represents the total variance of prediction error of each stock exchange, and each column indicates the percentage of the variance due to each innovation. So each column shows the explanatory power of each national market to explain each one market (in each row).
- The cases that suppose significant increases of explanatory power from the first period to the second are in bold, and the cases that represent significant reductions in red.

Source: Own elaboration based on MSCI (Morgan Stanley Capital International) Equity Indices.

The process of European market integration could have affected the increasingly weight of German market. For instance, the German stock exchange explained 43% of the variance of French one before the euro, and after-euro it explains almost 70% of French market's variance. In Italian exchange, this percentage goes from 42% before-euro to 55.5% after-euro. And in Spanish exchange, this relative importance of the German exchange rises from 42% before-euro to 50% after-euro. Therefore, the German stock market has become a leader stock exchange inside the euro zone. Moreover, this higher importance of the German exchange after the introduction of the euro is not only in that euro area, but also in other European exchanges and extra-European markets. In fact, the percentages of the German exchange that explain the UK and US stock exchanges have also increased (from 32 to 36% for UK market,

and from 11 to 19% for US market). However, the rest of European stock exchanges have lost power to explain the US stock exchange during the second period.

Respect the UK stock exchange, where euro does not been introduced as currency, we can verify that it has reduced its relative importance to explain the German, French and US stock markets during 1999-2002.

Finally, analysing more deeply the US stock exchange, the percentages of this US market that explain the euro-area stock markets have been reduced, except in the French case. It could be due to an achievement of independence of these euro-area markets to the US one. However, after the euro, the US stock market has increased its relative importance to explain the UK market (an extra-euro market).

VI. Main conclusions.

Despite progress, the transformation of 15 national stock markets to single European stock market is not yet complete. The EU's stock market is still governed by 15 different legal systems, and major other obstacles –legal, regulatory, tax or technical– to cross-border activity within the EU result in some degree of segmentation. Moreover, protectionist pressures are still at work and evidence shows that investors in the EU equity markets still have a strong 'home bias' (EC, 2002). There are also important degree of dispersion in the performance of national stock market indices, and since the beginning of 1999 there has also been a significant degree of dispersion in sectoral performances (EC, 2002).

To achieve a major European integration of stock markets it will be necessary to ensure equal access to market infrastructure, such as trading platforms, clearing and settlement systems. Removal of unfair tax measures (as well as non-tax administrative measures) which represent discrimination against cross-border suppliers. Harmonisation of rules essential for investor protection is also important for both supply- and demand-side reasons.

Relate to infrastructure, the euro has clearly added to the pressures from technological change and globalisation for the creation of new alliances among Europe's exchanges. This empirical

study confirms several relevant issues on the euro effect as integrated element of the European stock exchanges.

To sum up, the main findings of this empirical analysis can summarise as follows:

1) The stock markets considered presented a high degree of integration in 1997-98. The degree of correlation between both stocks prices and volatilities did not increase in 1999-2002 (after-euro period). On returns, however, it is noticed the increase of the correlation between the main stock exchanges: German, French, Italian, Dutch and Spanish ones, in 1999-2002. It could be explained due to the euro has increased the possibilities of international diversification of portfolios and the adjustment of each exchange to the benchmark of the more efficient markets.

2) In 1999-2002 (after-euro) the explanatory power of the equity indices considered on each equity index: (i) reduced in Germany, Austria and Switzerland; (ii) increased in France, Netherlands, Luxembourg, UK, Ireland, Sweden, Denmark and Finland; and (iii) maintained in Italy and Greece (with slight reductions) and Portugal and Spain (with slight increases). Both Germany and Switzerland markets were really integrated in 1997-98. In 1999-2002 (after-euro), the German stock exchange became the reference of the rest of European stock exchanges. As a consequence, Switzerland stock market lost international weight in 1999-2002. On the other hand, the European northern and center stock markets, which were already really integrated in 1997-98 (before-euro), were more affected by the rest markets in 1999-2002 (after-euro) due to the higher integration between the French and Dutch stock exchanges, the minor weight of the UK stock market, the peripheral (and non-euro) character of the Swedish and Danish stock exchanges, and, in general, the major influence of the German stock exchange on all of them. The Southern stock exchanges were less influenced by the rest euro-area exchanges due to their minor degree of previous integration with the northern and center markets. But, in 1999-2002 the influence of the rest stock markets on Spanish one (where few foreign companies were quoted) increased slightly.

However, this effect of all stock markets on Italian exchange (with a major weight of foreign companies) reduced slightly.

3) The short-run causality relationships between the different stock markets evidence the leadership of the German exchange in 1999-2002 (after-euro). In 1997-98 (before-euro), the main European stock exchanges (UK, French, Italian, Swiss and Spanish) affected the German market, as well as US market affected all of them. In 1999-2002 (after-euro), most of theses causations disappeared and the US stock market reduced its influence on the European markets. The non-euro stock exchanges (Swedish, Swiss and UK) reduced their effects on the rest exchanges. And the Japanese stock exchange became to be affected by all other exchanges.

Definitely the results confirm the basic hypothesis of this work, which is the increasingly relationships between the European stock exchanges in 1999-2002 (after the introduction of the euro). The integration in EU equity markets has been mainly evident during the 1990s, but the euro introduction could have accelerated the process's intensity. Moreover, the results are accorded with those of previous studies, which show that the integration of European stock markets has increased after the introduction of the euro, and that the German stock exchange has become the leader market for the rest of European markets.

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Figure 1. Impulse Response Function (IRF) during the before-Euro period

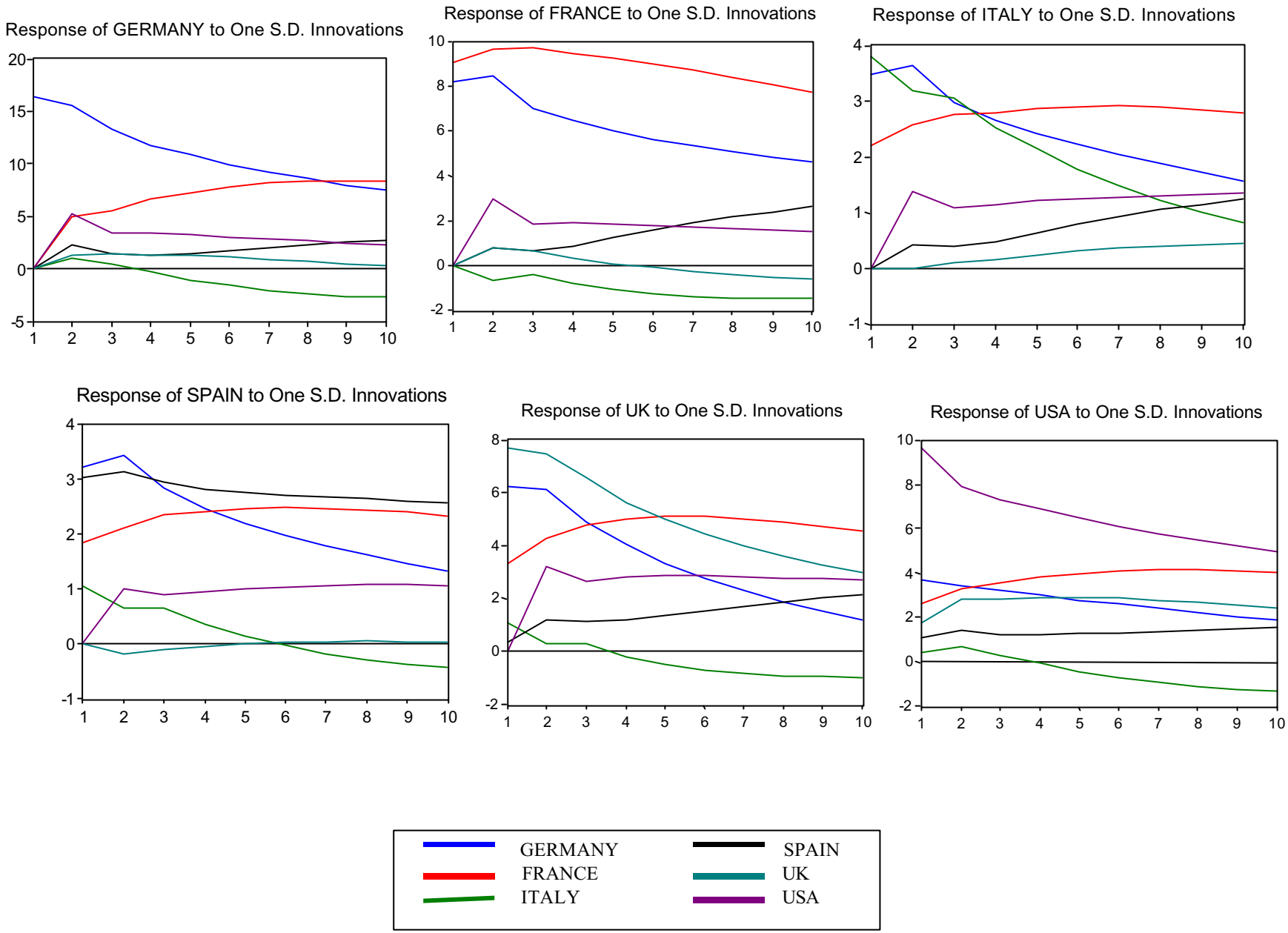
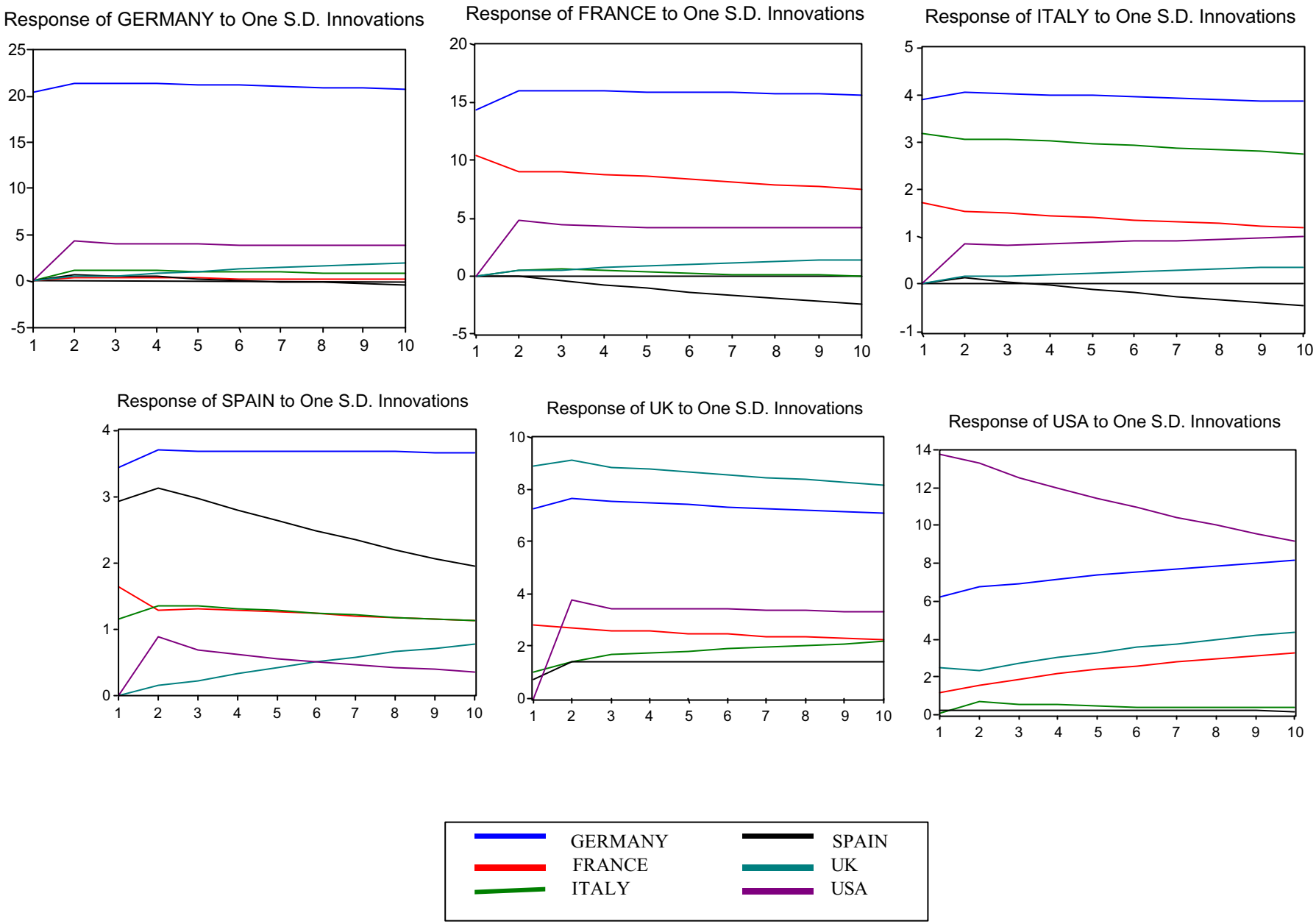


Figure 2. Impulse Response Function (IRF) during the after-Euro period



Appendix: Results of the correlation analysis.

Appendix A. Correlation Matrix of daily equity market indices.

Above diagonal: Before-Euro (1997/4/30 to 1998/12/31); below diagonal: After-Euro (1999/1/1 to 2002/5/23)

	AUS	BEL	DEN	FIN	FRA	GER	GRE	IRE	ITA	JAP	LUX	NET	POR	SPA	SWE	SWI	UK	USA
AUS[(1)]		0.42	0.81	0.45	0.68	0.76	0.58	0.79	0.68	-0.40	0.67	0.86	0.78	0.72	0.92	0.71	0.75	0.56
BEL[(1)]	**0.89**		0.65	0.95	0.93	0.89	0.88	0.74	0.89	-0.70	0.81	0.69	0.80	0.88	0.49	0.85	0.68	0.87
DEN[(1)]	-0.32	-0.19		0.66	0.82	0.86	0.60	0.91	0.90	-0.71	0.70	0.89	0.93	0.88	0.81	0.90	0.94	0.82
FIN[(1)]	-0.23	-0.05	**0.72**		0.92	0.87	0.90	0.80	0.89	-0.63	0.80	0.76	0.79	0.88	0.58	0.86	0.74	0.92
FRA[(1)]	-0.04	0.14	**0.82**	**0.93**		0.98	0.89	0.89	0.96	-0.70	0.90	0.88	0.93	0.97	0.74	0.94	0.85	0.92
GER[(1)]	0.27	0.43	0.59	0.82	0.90		0.87	0.90	0.95	-0.68	0.87	0.92	0.93	0.95	0.81	0.94	0.85	0.89
GRE[(1)]	**0.63**	0.75	0.10	0.40	0.49	0.73		0.74	0.81	-0.51	0.85	0.75	0.74	0.84	0.65	0.76	0.63	0.78
IRE[(1)]	**0.87**	**0.90**	-0.28	-0.09	0.05	0.41	0.69		0.94	-0.63	0.78	0.92	0.94	0.95	0.83	0.93	0.96	0.92
ITA[(1)]	0.42	0.56	0.53	0.67	0.82	0.90	0.64	0.51		-0.77	0.82	0.88	0.96	0.98	0.74	0.97	0.92	0.95
JAP[(3)]	**0.20**	**0.34**	**0.59**	**0.79**	**0.86**	**0.87**	**0.77**	**0.29**	**0.75**		-0.57	-0.51	-0.73	-0.68	-0.35	-0.71	-0.64	-0.68
LUX[(1)]	-0.17	-0.03	**0.79**	**0.87**	**0.92**	0.78	0.31	-0.10	0.70	**0.73**		0.76	0.81	0.86	0.69	0.80	0.73	0.75
NET[(1)]	0.44	0.58	0.57	0.68	0.84	0.90	0.75	0.49	**0.93**	**0.86**	0.70		0.90	0.90	0.94	0.90	0.91	0.85
POR[(1)]	0.62	0.78	0.23	0.46	0.60	0.82	**0.76**	0.73	0.89	**0.62**	0.46	0.81		0.96	0.79	0.95	0.93	0.88
SPA[(1)]	0.53	0.66	0.41	0.62	0.75	0.92	0.80	0.63	0.91	**0.78**	0.60	0.90	0.93		0.77	0.97	0.91	0.94
SWE[(2)]	-0.09	0.10	0.72	**0.96**	**0.96**	**0.90**	0.52	0.04	0.75	**0.86**	**0.92**	0.77	0.58	0.73		0.76	0.82	0.69
SWI[(3)]	0.68	0.83	0.24	0.31	0.52	0.65	0.68	0.70	0.82	**0.54**	0.34	0.84	0.84	0.79	0.40		0.93	0.94
UK[(2)]	0.72	**0.83**	0.15	0.40	0.54	0.76	0.89	0.78	0.80	**0.73**	0.36	0.86	0.86	0.88	0.53	0.86		0.90
USA[(3)]	0.31	0.46	0.56	0.76	0.86	0.89	0.72	0.40	0.84	**0.91**	**0.76**	**0.93**	0.72	0.85	**0.85**	0.70	0.82	

[(1)] Euro-area countries (12). [(2)] Other EU countries (15). [(3)] Other financial areas (US$, ¥ and SF)

Source: Own elaboration based on MSCI (Morgan Stanley Capital International) Equity Indices.

Appendix B. Correlation Matrix of daily returns on different stock markets.

Above diagonal: Before-Euro (1997/4/30 to 1998/12/31); below diagonal: After-Euro (1999/1/1 to 2002/5/23)

	AUS	BEL	DEN	FIN	FRA	GER	GRE	IRE	ITA	JAP	LUX	NET	POR	SPA	SWE	SWI	UK	USA
AUS[(1)]		0.53	0.53	0.59	0.53	0.65	0.33	0.53	0.50	0.26	0.36	0.54	0.56	0.55	0.51	0.57	0.47	0.15
BEL[(1)]	0.44		0.53	0.57	0.64	0.65	0.38	0.49	0.60	0.35	0.40	0.65	0.58	0.59	0.56	0.68	0.57	0.27
DEN[(1)]	0.40	0.46		0.58	0.54	0.63	0.32	0.47	0.57	0.24	0.29	0.57	0.52	0.55	0.52	0.56	0.51	0.23
FIN[(1)]	0.13	0.23	0.30		0.66	0.70	0.36	0.57	0.64	0.31	0.32	0.68	0.52	0.58	0.74	0.63	0.61	0.35
FRA[(1)]	0.39	0.55	0.52	0.60		0.68	0.32	0.46	0.73	0.31	0.31	0.71	0.61	0.73	0.72	0.71	0.66	0.38
GER[(1)]	0.35	0.53	0.49	0.51	**0.82**		0.33	0.53	0.65	0.31	0.40	0.72	0.59	0.65	0.67	0.73	0.63	0.31
GRE[(1)]	0.21	0.28	0.27	0.19	0.27	0.26		0.36	0.33	0.25	0.27	0.30	0.35	0.36	0.34	0.29	0.26	0.15
IRE[(1)]	0.38	0.44	0.42	0.28	0.45	0.43	0.29		0.46	0.25	0.38	0.48	0.47	0.43	0.48	0.47	0.54	0.16
ITA[(1)]	0.36	0.53	0.46	0.46	**0.80**	**0.75**	0.28	0.42		0.25	0.26	0.66	0.61	0.72	0.65	0.69	0.61	0.29
JAP[(3)]	0.07	0.09	0.15	0.20	0.15	0.12	0.21	0.18	0.11		0.32	0.29	0.34	0.25	0.33	0.29	0.31	0.08
LUX[(1)]	0.17	0.24	0.22	0.20	**0.33**	0.28	0.18	0.23	**0.29**	0.12		0.25	0.39	0.29	0.27	0.30	0.27	-0.08
NET[(1)]	0.38	0.60	0.50	0.51	**0.79**	**0.76**	0.29	**0.49**	**0.75**	0.15	**0.31**		0.56	0.67	0.68	0.74	0.71	0.36
POR[(1)]	0.36	0.43	0.44	0.40	0.60	0.56	0.28	0.38	0.54	0.11	0.21	0.52		0.65	0.55	0.60	0.50	0.22
SPA[(1)]	0.40	0.52	0.47	0.51	**0.79**	**0.72**	0.29	0.41	**0.76**	0.10	0.26	**0.72**	0.60		0.63	0.67	0.59	0.36
SWE[(2)]	0.26	0.34	0.43	0.70	0.68	0.62	0.21	0.35	0.57	0.22	**0.28**	0.59	0.46	0.58		0.68	0.65	0.37
SWI[(3)]	0.35	0.61	0.47	0.38	0.64	0.66	0.26	0.46	0.65	0.12	0.23	0.69	0.48	0.63	0.48		0.66	0.34
UK[(2)]	0.28	0.43	0.40	0.50	**0.69**	**0.67**	0.21	0.43	0.62	0.13	0.21	0.69	0.43	**0.60**	0.56	0.62		0.37
USA[(3)]	0.03	0.20	0.14	0.26	0.35	**0.41**	0.06	0.13	**0.32**	**0.09**	**0.07**	0.32	0.18	0.32	0.29	0.28	0.37	

[(1)] Euro-area countries (12). [(2)] Other EU countries (15). [(3)] Other financial areas (US$, ¥ and SF)

Source: Own elaboration based on MSCI (Morgan Stanley Capital International) Equity Indices.

Appendix C. Correlation Matrix of volatilities between the different stock markets.

Above diagonal: Before-Euro (1997/4/30 to 1998/12/31); below diagonal: After-Euro (1999/1/1 to 2002/5/23)

	AUS	**BEL**	**DEN**	**FIN**	**FRA**	**GER**	**GRE**	**IRE**	**ITA**	**JAP**	**LUX**	**NET**	**POR**	**SPA**	**SWE**	**SWI**	**UK**	**USA**
AUS[(1)]		0,39	0,82	0,41	0,77	0,69	0,59	0,79	0,69	-0,40	0,68	0,87	0,80	0,73	0,92	0,71	0,74	0,55
BEL[(1)]	**0,88**		0,62	0,95	0,86	0,92	0,88	0,72	0,88	-0,67	0,80	0,67	0,76	0,86	0,47	0,84	0,65	0,87
DEN[(1)]	-0,34	-0,23		0,61	0,85	0,81	0,62	0,91	0,89	-0,70	0,71	0,89	0,93	0,87	0,83	0,89	0,94	0,80
FIN[(1)]	-0,25	-0,10	**0,68**		0,83	0,90	0,90	0,77	0,87	-0,59	0,77	0,72	0,73	0,86	0,54	0,84	0,70	0,91
FRA[(1)]	0,20	0,34	0,59	**0,84**		0,97	0,88	0,88	0,95	-0,66	0,88	0,92	0,92	0,95	0,82	0,94	0,84	0,88
GER[(1)]	-0,09	0,06	**0,82**	**0,92**	0,89		0,90	0,89	0,97	-0,68	0,90	0,88	0,91	0,97	0,75	0,94	0,84	0,92
GRE[(1)]	0,58	0,67	0,04	0,33	0,64	0,40		0,76	0,85	-0,51	0,85	0,77	0,75	0,86	0,66	0,79	0,64	0,81
IRE[(1)]	**0,89**	**0,91**	-0,32	-0,11	0,33	-0,02	0,62		0,93	-0,63	0,78	0,93	0,93	0,94	0,84	0,93	0,96	0,91
ITA[(1)]	0,38	0,51	0,54	0,67	0,88	0,81	0,53	0,47		-0,75	0,84	0,89	0,95	0,98	0,75	0,97	0,91	0,94
JAP[(3)]	**0,14**	**0,26**	**0,57**	**0,79**	**0,86**	**0,85**	**0,73**	**0,21**	**0,71**		-0,56	-0,51	-0,70	-0,66	-0,37	-0,70	-0,64	-0,67
LUX[(1)]	-0,23	-0,11	**0,74**	**0,84**	0,74	0,89	0,19	-0,17	0,65	**0,69**		0,77	0,82	0,86	0,70	0,82	0,73	0,76
NET[(1)]	0,40	0,52	0,58	0,67	0,87	0,84	0,67	0,43	**0,92**	**0,84**	0,64		0,90	0,91	0,94	0,90	0,90	0,84
POR[(1)]	0,61	**0,77**	0,21	0,44	0,78	0,55	0,65	0,73	0,86	**0,56**	0,40	0,77		0,95	0,81	0,94	0,92	0,86
SPA[(1)]	0,50	0,62	0,41	0,62	0,90	0,74	0,72	0,59	0,90	**0,76**	0,55	0,88	0,91		0,79	0,97	0,91	0,94
SWE[(2)]	-0,15	0,01	0,70	**0,96**	**0,90**	**0,95**	0,43	-0,02	0,73	**0,85**	**0,90**	0,73	0,53	0,71		0,77	0,82	0,68
SWI[(3)]	0,68	0,81	0,24	0,25	0,57	0,46	0,59	0,70	0,79	**0,48**	0,26	0,82	0,81	0,76	0,31		0,92	0,93
UK[(2)]	0,72	**0,80**	0,13	0,37	0,70	0,50	**0,84**	0,77	0,76	**0,70**	0,28	0,84	0,82	0,86	0,45	0,84		0,89
USA[(3)]	0,27	0,39	0,57	0,75	0,86	0,85	0,64	0,34	0,82	**0,90**	0,72	**0,92**	0,66	0,83	**0,81**	0,66	0,80	

[(1)] Euro-area countries (12). [(2)] Other EU countries (15). [(3)] Other financial areas (US$, ¥ and SF)

Source: Own elaboration based on MSCI (Morgan Stanley Capital International) Equity Indices.

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