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Information technology sector and equity markets: an empirical investigation

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The aim of this article is to study linkages between equity and information technology sector prices. We thus investigate the price adjustment dynamics of the Information Technology (IT) sector in response to the 2007–2009 worldwide market shock for two representative developed countries (France and the USA). Using a Vector Autoregression (VAR) methodology and different econometric specifications of a smooth transition Error-Correction Model (ECM), we find significant price reactions from the USA and French IT sectors to changes in the global capital markets over the period between 11 February 2005 and 9 July 2009. The IT price response is however stronger for the USA than for France. The empirical results suggest that the IT price convergence process towards equilibrium is typically asymmetric and nonlinearly mean-reverting for the USA.

Keywords: information technology sectors; stock prices; nonlinearity

JEL Classification: G10; C22

I. Introduction

Financial markets around the world have experienced dramatic transformations in terms of organization, infrastructure and trading processes over the last decade. In addition to market deregulation policies and regulatory changes across almost all countries, massive technological advances, including the widespread use of the Internet, have significantly contributed to these transformations by offering new business opportunities, creating new forms of competition and a new and dynamic economic sector, namely, Information Technology (IT), with several worldwide giants such as Apple, Microsoft and Oracle.[1]

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[1] According to the Information Technology Association of America, IT covers 'the study, design, development, implementation, support or management of computer-based information systems, particularly software applications and computer hardware'. It is part of Information and Communication Technology (ICT), which also regroups sectors such as electronics, telecommunications, hardware, software and related services.

The products and services provided by the latter are now widely employed in more or less all sectors of the modern economy, and the impact of the IT sector has been widely analysed in academic literature at societal, organizational and individual levels (Ang and Pavri, 1994; Mallick and Ho, 2008; Ho and Mallick, 2010).[2]

The importance of the IT sector on financial markets is obviously reflected in the rapidity and instantaneity with which information flows are released to and exchanged between investors for use in their business decision-making process, regardless of their location.[3] Indeed, the order book and security price quotations in organized markets, formerly managed manually, have been progressively replaced by automatic trading systems as IT equipment developed. A large percentage of investors are now able to trade financial assets through electronic networks without having to pass by dealer- or broker-based trading platforms. It is also common for firms to use the Internet to communicate with investors, and to offer and distribute shares. That is to say, several levels of market intermediation are becoming dispensable with the introduction of IT-assisted solutions.

Greater interaction between economic agents resulting from IT use is also an important factor in the increased capacity of financial markets to facilitate the exchange of financial instruments and physical commodities, and multi-party negotiations. Globally, the use of IT has led to an improvement in existing processes and financial market structures, leading to a higher degree of operational, allocational and informational efficiency. Claessens *et al.* (2002), for example, point out that the implementation of new trading systems and electronic communication networks in many industrial and emerging markets has facilitated global securities trading and substantially reduced the cost of bank service delivery. Typically, they show that the cost of online brokerage is just 25% of traditional costs.

Consequently, we may reasonably expect the IT sector and financial markets to have become more interlinked over time. Recent studies by Mallick and Ho (2008) and Ho and Mallick (2010) investigated the impact of IT-related investment shocks on firms' profitability and performance, and consequently on financial returns. The authors indicate that the higher the IT added-value, the stronger the firm's performance and growth. They suggest that such IT investment may stimulate the firm activity, and also impact the demand. Accordingly, IT investment and spending may affect financial returns and also be dependent on such markets, implying thus further significant linkages between the IT sector, real markets and international capital markets (e.g. the dot bubble). A proper understanding of these linkages is interesting, with implications for diversification, and investment and risk management as the IT sector offers a high value-added and valuable asset class. Little is known, however, about this issue since most prior empirical studies in the finance literature have essentially been concerned with the impact of IT on economic growth (e.g. Jorgenson and Stiroh, 1999; Oliner and Sichel, 2001; Ko, 2008) and financial performance (Devaraj and Kohli, 2003; Kamssu *et al.*, 2003; Shin, 2006). For example, focusing on the combined effects of financial integration and Information and Communication Technology (ICT) development on growth volatility, Ko (2008) reports that economies with high ICT development and/or a high degree of financial integration are exposed to greater output fluctuations following monetary policy shocks, but lower output fluctuations in the case of fiscal policy shocks. Based on an intuition that diversification may increase the demand for IT because of the need for coordinated action among multiple market segments, Shin (2006) shows significant impact of IT on the financial performance of diversified firms.

This article aims to fill this gap by empirically investigating the extent of the price and return relationship between the IT sector and the world stock market during the recent 2007–2009 global financial crisis. Our main focus is on the following questions: 'how should the IT sector respond to a shock from the world stock market given its degree of integration with the latter?' and 'how strong are their

[2] Ang and Pavri (1994) discuss previous studies on the impact of IT sectors and come to the following conclusions: (i) the impact of the IT sector at societal level is directly linked to the transformation of industrial economies into information economies, as well as to the issue of employment and job creation; (ii) at organizational level, most of the related studies investigate the impact of IT adoption on organizational change and point to the importance of IT as part of the corporate strategy for a number of firms; (iii) at individual level, ongoing research has focused principally on the relationship between, on the one hand, the use of IT products and, on the other hand, user satisfaction, job satisfaction, productivity, organizational climate, work attitudes and user expectations for new developments. Overall, these authors conclude that previous findings are not always consistent because it is often complex to analyse and interpret the impact of IT due to the large number of explanatory factors that need to be taken into consideration.

[3] One should note that IT facilitates information flows through software and interfaces that ease information exchange, dissemination and evaluation.

interdependences in terms of price and return spillover effects?'

By applying both linear and nonlinear models to daily data on the world market index and IT sector indices from the USA and France, where the IT sector is undergoing rapid growth and development, we show that IT stock prices adjust to the equilibrium established with the global stock market in a nonlinear manner. The introduction of nonlinearity is justified by the expected asymmetrical feedback between the IT sector and the stock markets. To illustrate such asymmetry, we cite the Internet bubble in 2000, which shows that even if the financial market benefitted from new information technology before 2000, losses and the market downturn were considerable after 2000.

In other words, when we put the questions under study in perspective with the recent global financial crisis, our results indicate that this dynamic adjustment process is *also* typically asymmetric and nonlinearly mean-reverting for the USA, where financial markets were particularly anxious during the financial crisis episodes. Further, the return spillover analysis sheds light on the significant transmission of financial shocks from the world stock market index to IT indices. The evidence obtained suggests that sectorial diversification into IT stocks might not be profitable in times of crisis as this sector tends to comove significantly with the world stock market.

The remainder of this article is organized as follows. Section II describes the data and methodology used to explore the price adjustment dynamics and return dependences between the IT sectors and world stock markets. Section III reports and discusses the empirical findings. The concluding remarks are provided in Section IV.

II. Data and Methodology

Data

Our dataset consists of USA and French IT stock market indices (IT CAC40 and NYSE ARCA Tech 100) as well as the World stock market index. They are respectively obtained from Datastream International (Thomson Reuters) and the Morgan Stanley Capital International database. The data are at daily frequency and cover the period from 11 February 2005 to 9 July 2009. The choice of this study period enabled us to test the impact of the recent global financial crisis on the price dynamics of the technology sector in two industrialized countries.

The use of these IT indices is justified by the fact that they are commonly referred to as benchmarks for measuring the market performance of companies using technological innovations in the USA and French technology sectors. Indeed, major technology-related companies from different industries such as computer hardware, software, telecommunications and electronics are included in these IT indices for the respective countries.

Methodology

Both linear and nonlinear modelling techniques are employed to investigate the relationship between the financial markets and the technology sector in the short and long term. First, a Vector Autoregressive (VAR) model is estimated in order to assess the return spillovers between the studied indices after checking for the stationary condition of return series. Next, an appropriate Exponential Smooth Transition Error-Correction Model (ESTECM) is introduced to explore the IT price adjustment dynamics and to test for a nonlinear mean-reverting process in IT index prices.

Before moving on to our empirical investigation, it is necessary to briefly discuss the econometric methodology associated with ESTECMs. Specifically, let X_t and Y_t be two variables that are not stationary in levels, but stationary when they are differentiated d times. In the long term, if it is possible to find a linear combination z_t between these two variables which is stationary, then X_t and Y_t are linearly cointegrated.

$$z_t = X_t - a_0 - a_1 Y_t \quad (1)$$

In Equation 1, X_t and Y_t denote the Morgan Stanley Capital International (MSCI) stock market index and the IT price index, respectively. z_t designates the error term or the residual of the cointegration relationship. Thus, the stationarity of z_t implies the existence of a stable economic relationship between these two variables and indicates that it is possible to forecast the evolution of X_t when that of Y_t is known.

If the mean reversion towards the equilibrium defined by the cointegration relationship as in Equation 1 is linear, the error-correction mechanism is then achieved through a usual ECM. However, as several studies have suggested (e.g. Michael *et al.*, 1997; Peel and Taylor, 2000), the asset price adjustment process may be subjected to persistence, discontinuity, asymmetry and nonlinearity in the presence of market friction, which ultimately prevent the adjustment from being linear. As a result, they propose a new class of nonlinear ECMs to gauge the said characteristics, and find that the ESTECMs appear to be the most powerful for modelling nonlinear patterns in asset price dynamics.

Formally, an ESTECM-type specification can be described as

$$\Delta Y_t = \alpha_0 + \rho_1 z_{t-1} + \sum_{i=1}^{p} \alpha_i Y_{t-i} + \sum_{j=0}^{p} \beta_j X_{t-j} + \left[\alpha'_0 + \rho_1 z_{t-1} + \sum_{i=1}^{p} \alpha'_i Y_{t-i} + \sum_{j=0}^{p} \beta'_j X_{t-j} + \rho_2 z_{t-1} \right] \times \Omega(\gamma, c, z_{t-d}) + \varepsilon_t \quad (2)$$

where $\Omega(\gamma, c, z_{t-d})$ represents the transition function which governs the shift from one regime to another. The latter can be defined by either

$$\Omega(\gamma, c, z_{t-d}) = 1 - \exp\left[-\gamma(z_{t-d} - c)^2\right] \text{ or}$$
$$\Omega(\gamma, c, z_{t-d}) = \left[1 + \exp\{-\gamma(z_{t-d} - c)\}\right]^{-1}$$

In these formulations, $\gamma > 0$ and c refer to the transition speed and the threshold parameter, respectively. The error term ε_t is assumed to follow a normal distribution with zero mean and variance σ^2. ρ_1 and ρ_2 are the nonlinear adjustment parameters in the first and the second regime inherent to the specification of the Smooth Transition Error Correction Model (STECM).

According to the value of the transition function $\Omega(\gamma, c, z_{t-d})$, the model described in Equation 2 is able to capture the dynamics of two regimes corresponding to the extreme values of Ω as well as an intermediate continuum state. The first regime, called the central regime, appears to arise when the IT price adjustment dynamic is close to the equilibrium state established between the IT price and the world market index. It corresponds to the following equation:

$$\Delta Y_t = \alpha_0 + \rho_1 z_{t-1} + \sum_{i=1}^{p} \alpha_i Y_{t-i} + \sum_{j=0}^{p} \beta_j X_{t-j} + \varepsilon_t \quad (3)$$

The second, called the upper regime, whose dynamic is defined by Equation 4, corresponds to the situation in which IT price movements depart from their long-run equilibrium tied to the world stock market

$$\Delta Y_t = \left(\alpha_0 + \alpha'_0\right) + (\rho_1 + \rho_2) z_{t-1} + \sum_{i=1}^{p} \left(\alpha_i + \alpha'_i\right) Y_{t-i} + \sum_{j=0}^{p} \left(\beta_j + \beta'_j\right) X_{t-j} + \varepsilon_t \quad (4)$$

Table 1. Correlation matrix

	RF	RW	RU
RF	1.00	0.08	0.04
RW		1.00	−0.07
RU			1.00

Notes: This table presents the correlations between IT and stock returns. RF, RU and RW denote the stock return of the IT CAC40, NASDAQ and the world index, respectively.

This nonlinear specification is particularly interesting because it enables us to reproduce the asymmetric and nonlinear relationship between financial markets and the technology sector. Indeed, depending on the values and the signs of ρ_1 and ρ_2, the nature and strength of mean-reversion in IT prices can be determined, and any presence of nonlinearity is apprehended. In particular, even though ρ_1 can take positive values, ρ_2 and $(\rho_1 + \rho_2)$ have to be negative and statistically significant in order to validate a nonlinear mean-reverting process of IT prices towards the equilibrium. This implies that for small deviations, IT price changes would diverge from the equilibrium and be characterized by a unit root or by explosive behaviour, while for important deviations, the observed adjustment process would be mean-reverting.

According to Van Dijk *et al.* (2002), the ESTECM methodology is similar to that of Granger and Teräsvirta's (1993) Smooth Transition Autoregressive (STAR) models. To empirically implement the ESTECM, we first test the presence of linear cointegration. Second, we apply specification and linearity tests in order to check whether price adjustment is linear or nonlinear. Finally, the estimation of the ESTECM can be carried out using the Nonlinear Least Squares (NLS) method.

III. Empirical Results

We begin with the test of the unit root for all the price series and find that they are integrated of order one, $I(1)$.[4] We then focus on the log-return series that are computed by taking the difference between the natural logarithms of price at time t and time $(t-1)$. We also compute the correlation matrix and report the results in Table 1. We noted insignificant bilateral correlations between the MSCI world market and IT returns. The IT sector in the USA is

[4] The results are not reported here, but are available upon request.

Table 2. Descriptive statistics

	RW	RU	RF
Mean	−0.0002	−0.0002	−0.0003
Median	0.0006	0.0003	0.0004
Maximum	0.0909	0.1285	0.1168
Minimum	−0.0732	−0.1050	−0.0940
SD	0.011	0.0167	0.0147
Skewness	−0.5640	−0.0228	−0.0046
Kurtosis	16.47	10.98	12.28
Jarque–Bera	7627.40	2657.80	3599.50
Probability	0.00	0.00	0.00

Notes: This table presents descriptive statistics for equity and IT returns. The Jarque–Bera denotes the empirical statistic of normality test.

Table 3. Granger causality test

Return series	Test parameters
USA	
F-statistic	2.07
p-value	0.12
Lag number	2
France	
F-statistic	5.29
p-value	0.00
Lag number	2

Note: This table reports the results of the Granger causality test.

negatively and weakly linked to the world stock market. In contrast, the French IT sector is also weakly linked, but positively so, with the MSCI index.

Table 2 reports the descriptive statistics of the IT sector and world market returns. The daily return average for both indices is negative, reflecting the global financial crisis effect. The skewness test, normality test and excess kurtosis suggest evidence of asymmetry in the data.

Next, we analyse the short- and long-term relationships between IT and the world market indices based on the VAR modelling and cointegration framework, respectively.

VAR modelling

To this end, we first applied the Granger causality test. Second, we investigated the short-term dynamic responses of IT indices in France and the USA after a shock affecting the world market index through a three-variable VAR system.

The Granger causality test examines the null hypothesis of noncausality against its causality alternative. This enables us to test whether the world market index has a causal effect on the dynamics of the French and the USA IT indices. From Table 3, we reject the null hypothesis for both IT indices. The VAR model allows us to double check for spillover effects between the IT and equity sectors.

We will now consider the VAR model. The optimal lag number is determined by the information criteria and a likelihood ratio test which tests a VAR($p+1$) against VAR(p). Accordingly, a VAR(2) model is estimated and reported in Table 4.

We noted a significant relationship between the IT sectors and the world stock market in the sense that the world market index significantly affects the

Table 4. VAR estimation

	RW	RU	RF
RW(−1)	0.130	−0.097	0.097
	[4.17]	[−2.18]	[2.40]
RW(−2)	−0.174	0.001	0.074
	[−5.56]	[0.039]	[1.88]
RU(−1)	0.082	−0.132	−0.007
	[3.72]	[−4.19]	[−0.25]
RU(−2)	−0.019	−0.090	−0.04
	[−0.87]	[−2.84]	[−1.61]
RF(−1)	0.033	0.035	−0.058
	[1.32]	[0.99]	[−1.84]
RF(−2)	0.067	0.106	−0.114
	[2.68]	[2.97]	[−3.6]
C	−0.0001	−0.0003	−0.0003
	[−0.51]	[−0.58]	[−0.78]
R-squared	0.063	0.035	0.026
Adj. *R*-squared	0.058	0.0291	0.020
F-statistic	11.27	6.053	4.511
Log-likelihood	3032.1	2680.2	2802.6
Akaike AIC	−6.068	−5.362	−5.608
Schwarz SIC	−6.034	−5.328	−5.573

Note: AIC denotes the Akaike Information Criterion, while SIC refers to the Schwarz Information Criterion.

IT indices. This effect is positive in the French case, while it is cyclical for the USA, i.e. IT index returns are inversely associated with the first lag of world market returns, but they tend to commove with the second lag of world market returns. There is also evidence that the French IT sector leads the price movements in the USA IT sector, but the opposite is not verified.

We also estimate the impulse response functions to gauge the reaction of IT markets after a shock affecting stock markets. From Fig. 1, the response of the French IT index to a shock affecting the world stock market is immediately positive, but it appears

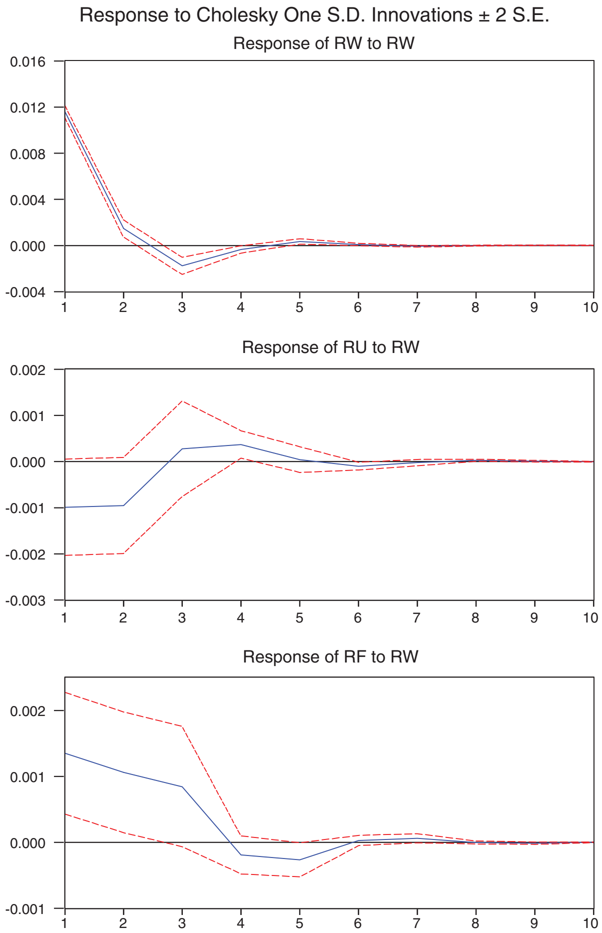

Fig. 1. Impulse response functions

to be smooth, persistent and sometimes negative, i.e. between day 4 and day 6. This reaction disappears after 8–9 days. For the USA, the IT sector also alternates negative and positive responses to stock innovations. The impact of the system shock approaches zero after 9 days. Note, however, that the behaviour of the USA IT sector is more or less the opposite of what we found for the French IT sector, i.e. negative reaction during the first 3 days, then positive, and finally negative again. Overall, such cyclical and asymmetric movements in the response of the IT indices can lead to complex forms of relationships between IT sectors and financial markets that may escape linear modelling, as suggested by the contradiction between the Granger test and VAR model.

To further capture the asymmetry and nonlinearity that potentially characterize the relationship between IT sectors and the stock market, we propose extending this investigation to a nonlinear context.

[5] See Van Dijk *et al.* (2002) for more details about these tests.

Table 5. Linear cointegration tests

	France	The USA
a_0	2.9 (19.5)	0.59 (4.8)
a_1	0.75 (35.4)	0.87 (51.5)
R^2	0.55	0.72
ADF (*p*, model)	−3.88 (10.10*)	−3.93 (3.30**)

Notes: The values between parentheses denote the *t*-ratio. *p* denotes the order for ADF test.
* and ** denote a model with trend and constant, and a model with neither trend nor constant, respectively.

Table 6. Nonlinear adjustment tests

	France	The USA
$d=1$	0.23	0.01*
$d=2$	0.32	0.12
$d=3$	0.08	0.06
$d=4$	0.76	0.32
$d=5$	0.02*	0.54

Notes: This table reports the results of the LM linearity tests.
* denotes the optimal delay parameter.

STECM modelling

We first test the cointegration hypothesis between the global and IT indices. The results reported in Table 5 indicate that we cannot reject the hypothesis of linear cointegration, suggesting a linear mean-reversion between these indices.

Second, we examine whether the adjustment of IT indices towards the equilibrium with the world stock market is linear or nonlinear using the Lagrange Multiplier (LM) tests introduced by Luukkonen *et al.* (1988) that we apply for several values of the delay parameter *d*. From Table 6, we can note the optimal value of *d*, which defines the transition variable.[5] Accordingly, linearity is rejected for both IT indices for $d=1$ for the USA and for $d=5$ for France.

Regarding the transition function, we tested two specifications: i.e. the logistic and exponential functions. Our findings reveal that the Logistic STECM (LSTECM) offers a better fit for the USA IT sector, whereas the ESTECM is more appropriate for France.

Finally, we estimate STECMs, report their results in Table 7 and note several interesting findings. First, the IT indices seem to be nonlinearly cointegrated with the world market index. Indeed, the significance

Table 7. Estimated results of STECMs

Model parameters	USA LSTECM (2,1)	France ESTECM (2,5)
α_0	0.00005	−0.00003
	(0.06)	(−0.03)
ρ_1	0.0077	0.002
	(0.82)	(0.21)
α_1	−0.16	0.123
	(−4.70)	(1.78)
α_2	−0.11	0.10
	(−3.50)	(1.62)
β_0	–	0.52
		(4.80)
β_1	−0.15	−0.07
	(−3.20)	(−1.81)
α_0'	−0.00003	−0.0007
	(−0.04)	(−0.56)
α_1'	0.10	−0.26
	(1.96)	(−3.15)
α_2'	0.09	−0.28
	(2.12)	(−3.40)
β_0'	–	−0.54
		(−4.70)
β_1'	0.22	0.20
	(2.70)	(1.96)
ρ_2	−0.01	−0.003
	(−5.70)	(−2.8)
γ	96.95	6.94
	(79.40)	(2.30)
c	0.004	−0.003
	(18.60)	(−3.80)
σ_{NL}/σ_L	0.83	0.78
ADF statistics	−23.40	−20.40
ARCH (*p*-value)	0.02	0.01

Notes: This table reports the estimation results of STECMs. σ_{NL} and σ_{L} refer to residual SD of nonlinear and linear models, respectively. Values in $(\cdot)$ denote the *t*-ratios.

and negativity of the second adjustment term ρ_2 and the negativity of the sum $(\rho_1 + \rho_2)$ suggest an asymmetric mean-reversion process in the IT sector indices for both countries. Second, we identify different regimes characterizing IT indices adjustment dynamics. The significance of transition function estimators confirm the slowness associated with regime switching although it is somewhat more abrupt in the USA case. This result may be due to the fact that the financial crisis started in the USA market and perhaps the shock transmission was more rapid than for the French market. Finally, we can note the negative sign for Autoregressive (AR) coefficients that may indicate the IT sector is still under correction and that the crisis is not yet over.

To explicitly illustrate the IT sector adjustment price regimes, we plot the estimated transition functions in Figs 2 and 3. In the French case, persistence is more marked and the transition function does not exceed 22%. This suggests less reaction to the equity market in the French IT sector. In the USA case, the transition function follows an on/off process and reaches a high level with an abrupt switching, suggesting high sensitivity of the IT sector to the capital market. In particular, the IT sector seems to resist small equity shocks, but a hard and unexpected shock can seriously affect IT firm performance and productivity. The difference in terms of results between France and the USA can possibly be explained by the importance of the IT sector in the USA compared to France, as IT-related investment and spending in the USA significantly exceeds that of France. For example, the National Association of Securities Dealers Automated Quotations (NASDAQ) accounts for more IT firms than the IT CAC40. Otherwise, these results have important

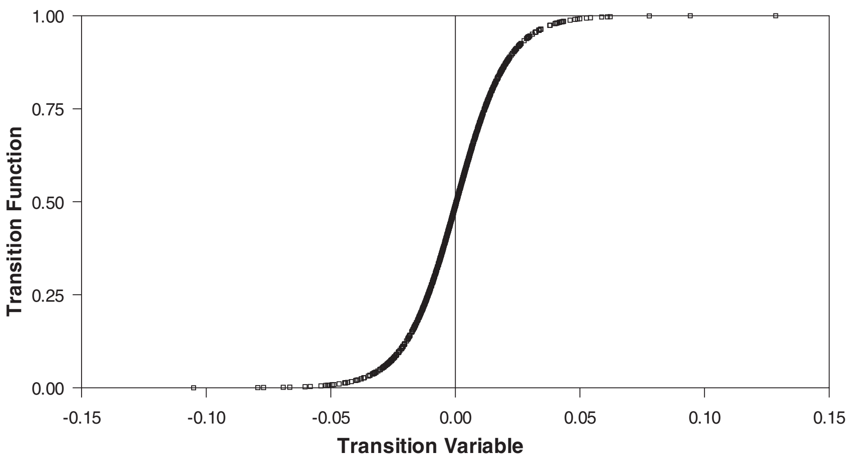

Fig. 2. Transition function for the USA

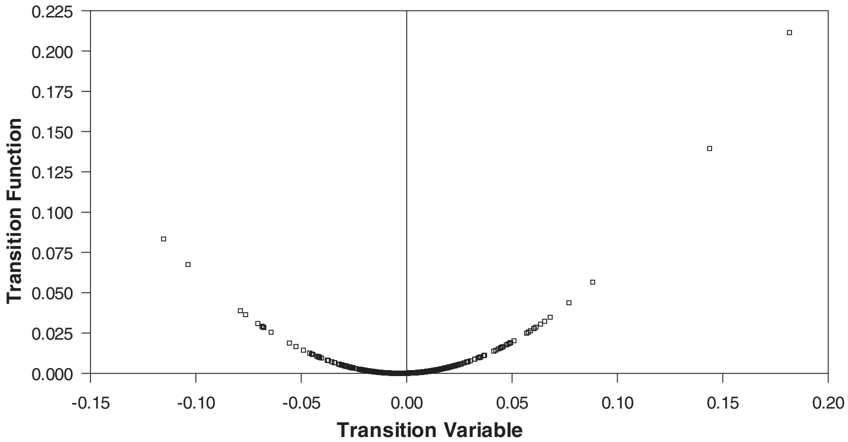

Fig. 3. Transition function for France

implications for investors, enabling them to revise their investment strategies and portfolio choice when investing in IT and/or equity sectors. Indeed, the specification of IT sector price regimes enables them to determine the optimal portfolio investment proportions.

It is finally important to note that a battery of specification tests was performed (e.g. Augmented Dickey–Fuller (ADF) test for stationarity, Autoregressive Conditional Heteroscedasticity (ARCH) test, Teräsvirta's (1994) misspecification tests). All in all, these tests check the robustness of our estimated results and show that STECMs supplant linear models.

IV. Conclusion

This article examines the price adjustment dynamics of IT sectors in response to news and innovations in the world stock market during the financial crisis. The short-term price dynamics were studied via a bivariate VAR model, while the application of nonlinear cointegration tests checked for nonlinear mean reversion for two developed countries (France and the USA). Our findings point to evidence of significant spillover effects between the equity and IT sectors. Interestingly, these effects are asymmetrical and the IT-equity relationship exhibits nonlinearity. These findings are consistent with the assessment that IT sectors are now strongly dependent on price innovations in world stock markets, and that the IT sector was considerably affected by the global financial crisis. Furthermore, the identification of different regimes for IT prices is interesting as it helps investors to identify different investment strategies and portfolio compositions that vary according to the sign and the size of the relationship between equity and IT returns. Finally, the difference in terms of IT-equity linkages between the USA and France should provide information about IT sector innovations and development in both countries.

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