How Does Systematic Risk Impact Stocks ? A Study On the French Financial Market

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Abstract: From CAC40 French stock index, we induce the implied market factor's level through the inversion of a closed form pricing formula for European calls on the CAC40. For this purpose, we assume that the CAC40 index is a disturbed observation of the actual market factor, the market factor's diffusion following a geometric Brownian motion. All the assumptions prevailing in a Black & Scholes world are assumed to hold. Based on daily data, the results show that the level of the implied market factor and its instantaneous return's volatility are leptokurtic distributed. Having a proxy for the systematic risk, we also study the impact of the implied market factor on a basket of French assets. First, we compute correlations of assets' returns with the return of the implied market factor, and realize as well a VAR study and a Granger causality test. Second, we estimate regressions of French assets' returns on the return of the implied market factor. Then, we characterize the prevailing relationship between the weekly rolling volatility of the return of the implied market factor and weekly rolling volatilities of the French asset returns. These two studies lead to mitigated results.

Keywords: *Call pricing; Granger causality; implied volatility; option pricing; systematic risk.*

1. INTRODUCTION

It is well known that systematic risk affects the prices of financial asset traded in the market. Indeed, the Capital Asset Pricing Model (CAPM) theory argues that each financial asset is exposed to an undiversifiable risk, named systematic or market risk as introduced by Sharpe (1963, 1970) and Treynor (1961), among others. Such a risk could be proxied through a well diversified portfolio so far as such a portfolio presents an idiosynratic risk as low as possible. Common practice tells to use the available stock indices as proxies for such a well diversified portfolio. However, a recent study of Campbell et al. (2001) shows that the number of stocks in such an index has to be high enough to offset the idiosyncratic risk. They underline the fact that the number of assets required to create a well diversified portfolio has grown through time. Therefore, using market indices with an insufficient number of stocks may be inaccurate and even wrong as a benchmark for systematic risk. However, Campbell et al. (2001) show that market volatility (i.e., that part of the global volatility due to the market factor) tends to drive global volatility. Therefore, in this paper we address the question of how to find a proxy for the market factor in markets where only small stock indices are available and where options on such indices are traded. This task is hard given that the undiversifiable risk is not directly observable and can only be proxied.

Our paper is organized as follows. In section 2, we introduce the assumptions and theoretical framework proposed to find a proxy for the systematic risk factor. In section 3, we employ an empirical application of such a framework. We focus on the French financial market and on its CAC40 stock index. In section 4, we study the impact of the implied market factor on a pool of French stocks. The impact of the systematic risk is analyzed through a two steps methodology, namely a correlation study and a Granger causality test. Section 5 attempts to test for a non linear relationship between the implied market factor and French financial assets. This study is realized in two stages: a linear regression analysis and a volatility analysis. Finally, we end our study with concluding remarks and suggestions for future research.

2. THEORETICAL FRAMEWORK

In this section, we introduce our assumptions and theoretical framework allowing the induction of the market factor.

2.1. Valuation setting

Our study assumes that each small stock index is a non perfect proxy of the systematic risk factor. Specifically, we suppose that any small stock index represents a disturbed observation of the market factor. Each small stock index, at current time t, I_t depends on the market factor X_t in the following way :

$$I_t = \Lambda_t X_t \quad (1)$$

where Λ_t represents a (strictly) positive determinist scale factor whose value is time varying and bounded on $\Re_+^*$. Moreover, Λ_t is supposed to be a continuous and derivable function of time. This parameter could encompass many effects or factors such as short term shocks due to announcements effects or due to some specific events occurring in the financial market. We further suppose that most of the assumptions related to the option valuation framework of Black & Scholes (1973) hold. To sum up, tradings are continuous, there are no transaction costs and no taxes. Moreover, there is no arbitrage opportunity and a constant spot risk free interest rate r prevails in the market which is complete[1]. Since most of the stocks that constitute the financial indices pay dividends, we assume that the index I pays a dividend at a continuous (annualized) rate q (see Merton [1973], Black [1975]). We also assume that the market factor follows a geometric Brownian motion, that is, its instantaneous rate of return[2] has a constant drift (μ) and volatility (σ).

We address the question of how to proxy the market factor when starting from a small stock index which is a non perfect proxy of the market factor. To achieve this goal, we consider the pricing of options on such an index. Indeed, observations of index prices and call market prices will give information about both the scale factor and the implied market factor.

2.2. Option pricing

In this part, we introduce a call pricing formula to evaluate European calls written on the dividend paying stock index previously introduced.

We consider a European call on the stock index I whose strike price and expiring date are respectively K and T. At maturity, the value of such a call is $C(T,I_T)=max(0,I_T-K)=(I_T-K)^+$. The no opportunity arbitrage valuation principle states that the current value of any contingent claim is equal to the discount expected value of its future cash flows under the risk neutral probability. Therefore, given dynamic (1) of the stock index, the formula for a European call on the dividend paying stock index I at current date t reads:

$$C(T-t,K,I_t,r,\Lambda_t,\Lambda_T,\sigma)=\frac{\Lambda_T}{\Lambda_t} I_t e^{-q(T-t)} N(d_1) - Ke^{-r(T-t)} N(d_2) \quad (2)$$

where $N(.)$ represents the standard normal law's cumulative distribution function ; $d_1 = \frac{\ln\left(\frac{\Lambda_T}{\Lambda_t}\right) + \ln\left(\frac{I_t e^{-q(T-t)}}{K}\right) + \left(r + \frac{\sigma^2}{2}\right)(T-t)}{\sigma\sqrt{T-t}}$ and $d_2 = d_1 - \sigma\sqrt{T-t}$.

In our European call formula (2), all parameters are known except the scale parameter at instants t and T (Λ_t and Λ_T), and the volatility (σ). If we assume that the small stock index is a perfect proxy of the market factor, we get the classical Black & Scholes option pricing formula since we have $\Lambda_t = \Lambda_T = 1$ for each date $t < T$. Therefore, the introduction of a disturbance in our setting modifies the classical Black & Scholes formula through the ratio (Λ_T/Λ_t) in our call formula.

In what follows, we will use our knowledge about index prices and about market prices for European index calls to extract some information about the scale parameter Λ and the volatility parameter (σ). Such a process will help us to obtain information about the market factor itself.

3. EMPIRICAL STUDY

In this section, we apply our European call pricing formula to the French stock market and its CAC40 stock index.

3.1. Data

In this subsection, we describe our data and the computation of the risk free rate. We use daily data going from 2 January 2002 to 19 March 2002, namely 55 observations. The data are obtained from Bloomberg. We observe one month r_{1M}, three months r_{3M} and six months r_{6M} risk free interest rates. We consider the market prices of the CAC40 French stock index. This index[3] is composed of the forty most liquid stocks listed on the French market and pays a continuous annualized dividend rate q equal to 2.265%. We also obtain closing prices of three European calls[4] on the CAC40. These calls are traded on the French options market called MONEP (Marché des Options Négociables de Paris). European calls on CAC40 Index, whose maturity is 28 March 2002, are called CAC 3/02 C4000, CAC 3/02

[1] This is equivalent to assume that each variable is observable in the market or could be proxied.

[2] This setting implies that the drift and volatility parameters satisfy the Lipschitz conditions. Such conditions warranty the existence and the unicity of the solution to the stochastic differential equation satisfied by the market factor's dynamic (given a starting value).

[3] The CAC40 Index is a weighted stock index whose weights are proportional to each of its 40 stocks' capitalization. The 40 selected stocks are supposed to be the most important and representative of the French financial market.

[4] We consider option contracts of the continuous listing class.

C4500 and CAC 3/02 C5000. These calls have the following strike prices, respectively, 4000, 4500 and 5000 euros.

Given our European call pricing formula, we compute the risk free rate as a function of time to maturity. We choose a quadratic interpolation method to get our short term risk free rate from the one, two and three months term risk free rates. Let *r(t,T)* be the risk free rate at current time *t* for time horizon *T*. This rate is then represented by the following relation:

$$r(t,T) = a\,(T-t)^2 + b\,(T-t) + c \qquad (3)$$

with

$$\begin{cases} a = 72\left[r_{3M}(t) - 2r_{2M}(t) + r_{1M}(t)\right]. \\ b = 12\left[r_{2M}(t) - r_{1M}(t) - \dfrac{a}{48}\right] \\ c = r_{1M}(t) - \dfrac{a}{144} - \dfrac{b}{12} \end{cases}$$

This method leads to a good proxy for the risk free rate given that our European calls' time to maturity *(T-t)* is at most three calendar months.

3.2. Systematic risk's induction

In this part, we explain how to estimate the level of the market factor when starting from market prices of a small stock index and closing prices of European calls on such an index.

According to formula (2), estimation of the level of the market factor requires estimation of the scale parameter at instants *t* and *T*, and the volatility (σ). Since we can observe the CAC40 index prices (i.e., small stock index) and the closing prices of related European calls, one solution consists of inverting our formula (2) relatively to the scale parameter at times *t* and *T*, and volatility parameter. We estimate these implied parameters while minimizing the sum of squared valuation errors at each date *t* as follows[5]:

$$\underset{\Lambda_t,\Lambda_T,\sigma}{Min}\left\{\sum_j\left[C^{Obs}(T-t,K_j,I_t)-C(T-t,K_j,I_t,r,\Lambda_t,\Lambda_T,\sigma)\right]^2\right\} \qquad (4)$$

where $K_j \in \{4000, 4500, 5000\}$ and $C^{Obs}(T-t, K_j, I_t)$ corresponds to European call's observed market price. This non linear minimization problem is solved numerically while applying a quasi-Newton method with a Davidon-Fletcher-Powell type algorithm. We obtain[6] $\Lambda_T = 2.3050$ and therefore $X_T = 2033.8482$ euros.

Contrary to our assumption, we notice a time varying implied volatility parameter σ with a quadratic trend (i.e., a 'smirk' type trend). Moreover, the two implied time series of Λ_t and σ exhibit the following statistical profiles respectively :

- mean equal to 2.2881 and 0.2069 ;
- skewness equal to 0.2144 and 1.1208 ;
- excess of kurtosis : -1.0723 and 2.9231.

We then observe a non normal behavior for Λ_t and σ, that is leptokurtic distributions. Specifically, the volatility of the systematic risk factor should be modeled by a non-normal or time-varying stochastic process. This stylized fact is commonly known as the Black & Schole's volatility bias characterizing non-normal observed market returns for assets.

Knowing the market trend, we can now characterize the impacts of systematic risk on the French financial market.

4. IMPACT OF SYSTEMATIC RISK

Given our estimation of the market factor, we try to quantify its impacts on the prices of the French stocks. Our primary econometric study is composed of a correlation study and a Granger causality test.

4.1. Correlation

We study correlations between the implied market factor and, on one hand, French stock indices (i.e.: CAC40, SBF120[7] and SBF250), and on the other hand, 10 stocks of the French market, namely Air liquide (Ai), Danone (Bn), L'Oréal (Or), Renault (Rno), Schneider (Su), Société générale (Gle), Thomson (Tmm), Totalfina Elf (Fp), Valéo (Fr) and Vivendi (Ex). We consider daily closing prices going from January, 2nd 2002 to march, 19th 2002.

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[5] Of course, we could have used other French stock index such as the SBF250 to proxy Λ_t. Recall that this index is a weighted index composed of the 40 stocks of the CAC40, 80 other most liquid stocks and 130 stocks selected for their importance and their sector representativity. There is no traded options on such an index in the MONEP. We tried to do so and then to realize our minimization program relatively to Λ_T and σ.The results we obtained led us to European call pricing errors more than ten times higher than the pricing errors we get in our current study. We could then deduce that the market factor should be proxied by a French stock index composed of more than 250 stocks. Moreover, valuation errors are increasing functions of time to maturity.

[6] In fact, we get different values going from 2.295 to 2.315 for Λ_T. We notice that the related estimations are stable over time (since they slightly vary around a mean level). Since this value parameter should be a constant over time, we use the estimated values' arithmetic mean of Λ_T over the studied time horizon. Such a time variation may be explained by the fact that, at each time *t*, expectations about the index final value and therefore the final value of both the scale parameter and the implied market factor, change from day to day.

[7] The SBF120 is a weighted stock index composed of the 40 values of the CAC40 and other 80 most liquid stocks of the French financial market. There is no traded options on this index in the MONEP.

Such a setting requires paying attention to the following concern. Most of commonly used descriptive statistics are valid only under the strong assumption of elliptical distribution such as the normal law, which is a spherical distribution. When this is not the case, obtained results are false. Indeed, this feature fits some of the current questions considered by the Basel Committee. Szego (2001) and Artzner et al. (1999, 2000), among others, highlight the coherency problem of risk measures such as linear correlation or covariance. Such risk measures are valid only for, at least, stationary distributions when not elliptical[8]. Following this concern, we compute the correlations between the returns of the implied market factor and the returns of the French stocks. The returns of both series are stationary[9] over the time period studied. We then study the link between the variation of the returns of the systematic risk and the evolution of the returns of the French stocks[10]. The average correlation for our three stock indices is 0.9959. Roughly speaking, the implied market factor seems to be highly correlated with stocks whose correlation coefficients range from 0.2002 for *Bn* to 0.7982 for *Ex*. In the rest of the paper, we are going to study the dependency between systematic risk and French stocks.

4.2. Causality

Any causality study needs a VAR (i.e.: Vector Auto Regressive) specification before.

VAR specification

Our goal is to observe the link between the implied market risk's return R_{X_t} and some French stocks or index returns R_{S_t}. Therefore, we will consider bivariate VAR representations linking R_{X_t} and R_{S_t} with $S_t \in$ {SBF120, SBF250, CAC40, ai, bn, or, rno, su, gle, tmm, fp, fr, ex}. Moreover, the parameters of the VAR process have to be estimated through stationary time series like our assets' returns. The related bidimensional VAR with p lags, called VAR(p), has the following representation:

$$Y_t = A_0 + A_1 Y_{t-1} + A_2 Y_{t-2} + \ldots + A_p Y_{t-p} + \varepsilon_t \quad (5)$$

where $Y_t = (R_{X_t}, R_{S_t})'$ is the vector of variables; $A_0 = (a_1^0, a_2^0)'$ is a vector of constant parameters; $A_p = \begin{bmatrix} a_{1p}^1 & a_{1p}^2 \\ a_{2p}^1 & a_{2p}^2 \end{bmatrix}$ is the coefficients matrix for lag p, and $\varepsilon_t = (\varepsilon_{1t}, \varepsilon_{2t})'$ is the vector of innovations[11] assumed to follow a normal law.

The maximum likelihood method leads to an optimal lag p equal to one[12]. At a five percent level for Student statistics, Air liquide (ai), Société générale (gle) and Renault (rno) stocks have some influence on the implied systematic risk factor[13]. We will now further investigate the results through a causality test.

Granger Causality test

Granger (1969) defines the causality notion as follows: R_{X_t} is said to be the cause of R_{S_t} when taking into account the information set associated to R_{X_t} helps to improve predictions of R_{S_t}.

Analyzing causality of R_{X_t} towards R_{S_t} is equivalent to realize a test encompassing constraints on coefficients of R_{X_t} in its VAR representation (5) (that is, to consider a restricted VAR specification for R_{X_t}, also called RVAR). Specifically, consider the assumption $H_0 : a_{21}^1 = a_{21}^2 = 0$. If we accept H_0, then R_{X_t} does not cause R_{S_t}. To test assumption H_0, we compare the unrestricted VAR (UVAR, which is relation [5]) with the VAR specification restricted to H_0 (RVAR). The related test statistic is the following likelihood ratio:

$$L = (n-c)\ln\left\{\frac{|\Sigma_{RVAR}|}{|\Sigma_{UVAR}|}\right\} \quad (6)$$

where n is the observations' number; c is the coefficients' number estimated in each univariate relation of the unrestricted VAR model; Σ_{RVAR}, Σ_{UVAR} are covariance matrices of restricted and unrestricted VAR models respectively; and $|A|$ represents the determinant of matrix A (refer to Hamilton [1994] for details).

To study the relationships between the implied systematic risk and the returns of the French stocks, we tested two assumptions, namely: 'H_0 : R_{X_t} does not Granger cause R_{S_t}' and 'H_0^*: R_{S_t} does not Granger cause R_{X_t}'. At a fifteen percent level,

[8] Specifically, leptokurtic distributions do not satisfy one of the main properties accounting for risk measures coherency, namely the sub-additivity principle.

[9] Statistics are available upon request. The results show that indices (implied market factor included) and stocks are stationary when considering their first differences only. However, their returns from one day to another are stationary.

[10] The results are extremely close to the correlation coefficients computed for the first differences of indices and stocks' prices.

[11] In practice, the disturbances may be contemporaneously correlated with each other, without being correlated with, on one hand, their own lagged values, and on the other hand, all the lagged values of the variables.

[12] We investigated optimal lags from one to five, looking for a weekly influence at most.

[13] We get the same kind of results when applying a VAR specification to first differences of indices and stocks' closing prices. In this case, we also find an optimal lag equal to one.

both Air liquide's return (ai) and Renault's return[14] (rno) cause the returns of the implied market factor (R_{X_t}). If we enlarge our test level to fourteen percent, we get that Société générale's return (gle) also causes the returns of the implied market factor[15] (R_{X_t}). Our causality study leads therefore to a smaller impact of the implied market factor on French assets than what is expected. The weakness of the results is probably due to the small sample size used. For further investigation, we attempt to find contemporaneous links between our variables (without lag consideration). Specifically, we would like to test for a non linear influence of the price of the implied market factor on the prices of the French stocks and indices.

5. FURTHER INVESTIGATION

In this section, we try to exhibit non linear relations between the implied market factor and French stocks. The non linearity is captured through a study of returns. We proceed in two steps: a regression analysis of assets' returns and a volatility analysis of these daily returns.

5.1. Simple regression

Focusing on a non linear link between the price of the implied market factor and the price of an asset is equivalent to regressing this asset's return on the returns of the implied market factor. Specifically, we look for the following kind of relationship: $S_t = \beta X_t^{\alpha}$ with α and β constant terms, and $S_t \in$ {SBF120, SBF250, CAC40, ai, bn, or, rno, su, gle, tmm, fp, fr, ex}. Moreover, we assume that $R_{S_t} = \frac{S_t - S_{t-1}}{S_{t-1}} \approx \ln\left(\frac{S_t}{S_{t-1}}\right)$ for each time t ranging from 2 to 54. Therefore, $R_{S_t} = \alpha\, R_{X_t}$ for each $t \in \{2,...,54\}$. The non linear link between X_t and S_t is equivalent to a linear regression of S_t return (R_{S_t}) on X_t return (R_{X_t}).

All regressions of French financial assets' returns on the returns of the implied market factor are significant at the 1% level, except for Danone (bn) stock's regression. Among available French stock indices, the highest explanatory power is achieved for CAC40 (i.e.: $R^2(CAC40)$ = 99.29%), whereas the highest explanatory power among French stocks is achieved for Vivendi stock (i.e.: $R^2(ex)$ = 58.88%). Therefore, the implied market factor has an important influence[16], in terms of explaining the daily returns, on all financial assets except for Danone stock (bn).

5.2. Volatility impact

In this section we study the influence of the implied market factor on the volatility of the French financial assets. We consider weekly rolling volatilities of all assets. Since one financial week represents five working days, the weekly rolling volatility of return R_{S_t} at date t writes $\sigma(R_{S_t}) = \sqrt{\frac{1}{5}\sum_{i=t-4}^{t}\left(R_{S_i} - \overline{R}_{S_t}\right)^2}$ with $\overline{R}_{S_t} = \frac{1}{5}\sum_{i=t-4}^{t} R_{S_i}$ for each $t \in \{5,...,54\}$. We therefore have 50 observations for each return series. We analyze the impact of the volatility of the implied market factor, while considering the following first differences regressions:[17]

$$\Delta\sigma(R_{S_t}) = a\, \Delta\sigma(R_{X_t}) + \eta_t \qquad (7)$$

where $\forall t \in \{6,...,54\}$, $\forall X_t$, $\Delta\sigma(R_{X_t}) = \sigma(R_{X_t}) - \sigma(R_{X_{t-1}})$; a is a constant coefficient; η_t is a disturbance following a normal law; $S_t \in$ {SBF120, SBF250, CAC40, ai, bn, or , rno, su, gle, tmm, fp, fr, ex}.

When considering first differences regressions of weekly rolling volatilities (7), only those concerning assets CAC40, Vivendi (ex), Totalfina Elf (fp), Valéo (fr), Société générale (gle), l'Oréal (Or), Renault (or), SBF120 and SBF250 are significant at a 1% level. Among the indices, SBF250 presents the highest explanatory power (i.e.: $R^2(SBF250)$=97.16%) whereas, among stocks, Vivendi presents the highest explanatory power (i.e.: $R^2(ex)$=52.16%). The results[18] suggest that implied market factor has a strong influence on the volatilities of the CAC40, l'Oréal, Renault, SBF120, SBF250, Société générale, Totalfina Elf, Valéo, and Vivendi assets. However, the implied market factor does not succeed in explaining the whole evolution of financial assets.

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[14] In fact, a ten percent level is sufficient for rno's return.

[15] We get the same results for the *CAC40* index but with larger test levels since we find that *rno* causes *CAC40* at a 15% level, ai causes *CAC40* at a 30% level and *gle* causes *CAC40* at a 50% level. Such results are therefore less evident than for the implied market factor return's case. We would like to further underline that the same results are obtained for the *SBF120* and *SBF250* indices' returns for test levels larger than those of the implied market factor's return and smaller than those of the *CAC40*. Moreover, we also get the same kind of results when considering the first differences of daily stocks and indices closing prices.

[16] Our results here are more significant and conclusive (when considering the number of influenced assets and the importance of this influence) than those obtained for the CAC40 index, and those obtained for the study of regressions of financial assets prices' first differences on the first differences of the implied market factor's price.

[17] Notice that the weekly rolling volatilities we compute are not stationary in level but they become stationary variables when considering their differences of first order. Statistical results remain available upon request.

[18] These results are more significant than those we get when estimating regressions of weekly rolling volatilities of assets on those of the CAC40 index (always for first differences).

6. CONCLUSION

Following the wide literature about systematic risk initiated by Sharpe (1963), we address the problem of finding a good proxy for market risk when considering a small stock index with traded options. We proceed in four steps: a theoretical framework, an empirical application of this setting and two empirical studies attempting to assess the implied systematic risk's impact on French financial assets.

First, the small stock index is assumed to be a disturbed observation of the actual market factor. This stock index depends on the market factor through a scale factor. We induce an analytical formula pricing European calls on the stock index. In our closed form formula, all parameters are known except the scale parameter and the volatility of the market factor.

Second, inverting our European call pricing formula given observed market prices of European calls on the index, we get scale parameter's values at dates t and T, and the volatility parameter. These estimations allow us to compute the level of the implied market factor when considering stock index prices. We realize this empirical study on the French financial market while considering its CAC40 stock index. The implied volatility parameter is time varying, and distributions of both the volatility parameter and market factor are leptokurtic.

Third, we study correlations between implied returns of the market factor and the returns of the French assets. Our results are poor in so far as our VAR study as well as Granger causality test only shows the strong influence of daily returns of stocks Air liquide and Renault on the returns of the implied market factor.

Finally, we investigate a non linear relationship between French assets' prices and the level of the implied market factor. This leads to a study of linear regressions of the returns of the French assets on the returns of the implied market factor. The results obtained are fruitful in that the returns of the implied market factor appear to have a strong influence on the returns of the French assets, except for Danone. We also estimate first differences regressions of French assets weekly rolling volatilities on the weekly rolling volatility of the implied market factor. The implied market factor exhibits a strong link with assets CAC40, L'Oréal, Renault, SBF120, SBF250, Société générale, Totalfina Elf, Valéo and Vivendi. However, it fails in explaining the whole evolution of these assets. Maybe that idiosyncratic risk plays an important role in our case.

Suggested improvements for the study are the lengthening of the time period. A larger sample could give stronger and more significant results. Second, building a diversified portfolio could give a benchmark for systematic risk, which could be compared with our implied market factor. Prior to this, we should address what the optimal number of stocks and the composition of a well diversified portfolio should be.

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