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CONTENTS

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VOLATILITY INDEX, TIME-VARYING RISK PREMIUMS AND STOCK RETURNS

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ABSTRACT

This paper rewrites the Fama-French three-factor model as a panel smooth transition regression framework to investigate the non-linear dynamics of stock returns and the potential differentiated effects of a representative investor sentiment variable – the VIX – on the nexus of stock return and the three risk factors. The empirical results support that the stock returns display a non-linear path, depending on the change in VIX. The three risk premiums are time-varying, not constant obtained from the traditional FF model. In determining investment targets, there is a trade-off between small stocks and growth stocks. Even though, small/growth stocks still have higher risk premiums than large/value stocks at any level of VIX. In panic periods (high VIX), holding small/growth stocks has more size and negative value premiums.

KEYWORDS

Fama-French model, time-varying risk premium, panel smooth transition regression (PSTR) model, volatility index (VIX), transition variable.

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1. INTRODUCTION

The traditional capital asset pricing model (CAPM), developed by Sharpe (1964) and Lintner (1965), states that the risk premium of a financial asset is positively related to its exposure to market risk. However, the model was found to be insufficient in explaining the expected returns of stocks (e.g., Banza, 1981, Reinganum, 1981, Rosenberg et al., 1985). Fama and French (1993) develop a famous model to evaluate the asset return, named the Fama-French three-factor model (hereafter FF model), by adding the firm size and book-to-market factors into the standard CAPM. They find evidence that small capitalization stocks and high book-to-market stocks tend to have higher returns than those predicted by the CAPM. Since that time on, a substantial body of empirical work has investigated the validity of the FF model (e.g., Fama & French, 2006, Lawrence et al., 2007; Simpson & Ramchander, 2008).

While the FF model made a big improvement over the CAPM, it couldn't explain some major anomalies which lead to a low forecasting performance of asset returns (e.g., Daniel & Titman, 1997,Aleati et al., 2000, Faff, 2004). To resolve this problem, a branch of research adds new factors into the FF model. For example, Carhart (1997) augments the FF model using a fourth factor – momentum. By addressing one of the biggest anomalies, the momentum factor made a large contribution to the explanatory power of the factor model. Based on investment-based asset pricing, Hou et al., (2015) propose a new factor model that consists of the market factor, size factor, investment factor and return-on-equity factor to explain many of the anomalies that neither the FF model nor Carhart four-factor model can explain. Recently, Fama and French (2015) introduce a five-factor asset pricing model (beta, size, value, investment and profitability) to see if these new factors – profitability and investment – add explanatory power.

In addition to introducing new factors, specifying a more proper model is another method to improve the forecasting performance of the FF model (Simpson & Ramchander, 2008). In practice, structural changes in stock returns may occur as stock markets encounter obvious adjustments in the economic environment and public policy (Cifter, 2015, Turtle & Zhang, 2015). Fatal economic and non-economic events, such as the Subprime Mortgage Crisis in 2007 and the European sovereign debt crisis in 2008, have made stock prices display a non-linear dynamic process. However, the FF model is unable to capture this regime-switching process. To describe this characteristic, constructing a non-linear regime-switching model is necessary.

To achieve this objective, this study uses the panel smooth transition regression (PSTR) model, recently developed by Fok et al. (2004) and González et al. (2005). A simple PSTR model consists of two linear parts linked by a non-linear transition function, and it allows the variable under investigation to move within two different regimes with a smooth transition process, depending on the value of a specific transition variable. The PSTR model is particularly useful for situations where the non-linear dynamics are driven by a common regime-switching component, but where the response to this component can be different across variables. For example, the stock returns may be affected by worldwide recessions, but some firms may enter into (or get out of) recessions earlier than others. To arrive at a parsimonious model, we assume a second-level model for the parameters in the regime-switching mechanism of the PSTR model, where these are then related to company-specific characteristics**.**

In a PSTR model, the transition variable plays a crucial role in influencing the marginal effects of regressors on the dependent variable. Thus, the selection of a proper transition variable is important. According to the time-varying risk premium theory, a positive volatility shock generally causes a higher future required rate of return, thus causing current prices to decline. The volatility index (VIX), developed by the Chicago Board Options Exchange in 1993, is a measure of the market expectations of stock return volatility over the next 30 calendar days, and is intended to provide a benchmark of expected short-term market volatility. The VIX index will increase when the stock index option price increases since the options price is positively related to volatility. Padungsaksawasdi and Daigler (2014) indicate that using VIX to examine the return-volatility nexus can eliminate statistical issues, including sampling errors and model specification errors, and can demonstrate the perception of risk by option traders in financial markets. Thus, the VIX is a proper candidate to serve a transition variable in the PSTR model.

In sum, the aim of this paper is to rewrite the FF model as a PSTR specification for investigating the non-linear dynamics of stock return and the potential differentiated effects of a representative investor sentiment variable – the VIX – on the nexus of stock return and the three determinants. In performing empirical estimation, we uses 60 semiconductor firms listed on the Taiwan Security Exchange Corporation over the period 2005:1Q to 2013:2Q as sample objects.

This paper contributes to the existing literature in three distinct ways. First, we provide an econometric method in a non-linear and panel context for the estimation of stock return, which can simultaneously deal with the non-linearity and heterogeneity problems; we trace the dynamic non-linear relationship between stock return and it determinants (i.e., the three factors in the FF model); and we determine whether stock return demonstrates a smoothly regime-switching process. Second, using the typical proxy variable for investor sentiment – the VIX – as the transition variable (also can be considered as the fourth factor in this study) in PSTR model, one can prove whether the VIX non-linearly causes the change in stock return. Finally, estimating a PSTR model with the VIX as the transition variable, we specifically account for the differentiated marginal effects of the three factors on stock return. These traits are particularly important for allowing the investors to make and modify suitable security investment strategies.

The remainder of this paper is organized as follows. Section 2 briefly outlines the PSTR specification of the FF model, with the aim of accounting for potential differentiated effects of the three factors in the FF model on stock returns when the VIX is assigned as the transition variable and located in different regimes. Section 3 provides the procedures for estimating the PSTR specification of the FF model. Section 4 presents the data and empirical results, and the final section concludes.

2. THE MODEL

The FF model states that the expected return of a broadly diversified stock portfolio in excess of a risk-free rate is a function of that portfolio's exposure to three risk factors – the market (or equity) premium, size premium and value premium. Thus, the FF model can be expressed as follows:

$$R_{it} - R_{ft} = \theta_{0i} + \theta_1 (R_{mt} - R_{ft}) + \theta_2 SMB_t + \theta_3 HML_t + \varepsilon_{it} \quad (1)$$

where *i* = 1,2,...,*N* is the number of stocks and *t* = 1,2,...,*T* is the number of periods. R_{it} is the return on stock *i* at time *t*. R_{mt} is the market return, measured by the Taiwan Stock Exchange Capitalization Weighted Stock Index (TAIEX); R_{ft} is the risk-free rate, measured by the return on 1 month term deposit rate in Taiwan, and $(R_{mt} - R_{ft})$ is the market premium. Log returns are used to measure returns. SMB_t is the size premium, measured by the difference between the returns of a portfolio of small stocks and the returns of a portfolio of large stocks. HML_t is the value premium, measured by the difference between the returns of a portfolio of high book-to-market (value) stocks and the returns of a portfolio of low book-to-market (growth) stocks. ε_{it} is a residual. In addition to the positive market premium stated in the CAPM, the underlying premise of this model is that small stocks and value stocks are riskier than large stocks and growth stocks and thus carry higher expected returns.

A basic PSTR model with two extreme regimes can be expressed as follows:

$$y_{it} = \mu_i + \beta_0' x_{it} + \beta_1' x_{it} W(q_{it}; \gamma, c) + \varepsilon_{it} \quad (2)$$

where *i* = 1,2,...,*N* is the number of cross-section units and *t* = 1,2,...,*T* is the number of periods. y_{it} is a dependent variable and x_{it} is a K-dimension vector regressors. $W(q_{it}; \gamma, c)$ is the transition function with value in the interval [0,1] and is dependent on the transition or threshold variable q_{it}. van Dijk *et al.* (2002) indicate that the transition variable can be an exogenous variable or a combination of the lagged endogenous one. γ is the transition parameter that describes the transition speed between different regimes. c is the threshold value of the transition variable. μ_i is a time-invariant individual effect. Following Fouquau *et al.* (2008), the logistic specification can be used for the transition function:

$$W(q_{it}; \gamma, c) = 1 \Big/ \left[1 + \exp\left(-\gamma \prod_{j=1}^{m} (q_{it} - c_j) \right) \right] \quad (3)$$

where *m* is the number of location parameters and $c_1 \le c_2 \le \cdots \le c_m$. When $m = 1$ and $\gamma \to \infty$, the PSTR model reduces to a panel transition regression (PTR) model. In practice, it is usually sufficient to consider m = 1 or m = 2 to capture the non-linearities due to regime switching (González *et al*., 2005). The case m =1 corresponds to a logistic PSTR model, and *m* =2 refers to a logistic quadratic PSTR specification (Fouquau *et al.*, 2008). In addition, it is easy to extend the PSTR model to more than two regimes:

$$y_{it} = \mu_i + \beta_0' x_{it} + \sum_{j=1}^{r} \beta_j' x_{it} W_j (q_{it}; \gamma_j, c_j) + \varepsilon_{it} \quad (4)$$

where *r* + 1 is the number of regimes and $W_j(q_{it}; \gamma_j, c_j)$, *j* = 1,...,*r*, are the transition functions (see Eq. (3)).

According to Eq. (4), we can rewrite the FF model (Eq. (1)) as a PSTR framework:

$$\begin{aligned} R_{it} - R_{ft} &= \theta_{0i} + \theta_{10}(R_{mt} - R_{ft}) + \theta_{20} SMB_t + \theta_{30} HML_t + \\ &\sum_{j=1}^{r} \left(\theta_{1j}(R_{mt} - R_{ft}) + \theta_{2j} SMB_t + \theta_{3j} HML_t \right) \times W_j (VIX_t; \gamma_j, c_j) + \varepsilon_{it} \end{aligned} \quad (5)$$

where VIX_t is the VIX at time *t*. For the quarterly data used in this study, VIX is measured by the value of the end of a specific quarter *t*. We will explain it in more detail later on. For r=1, the marginal effect of $(R_{it} - R_{ft})$ with respect to the *k*-th regressor is equal to $\theta_{k0} + \theta_{k1} W_1(VIX_t; \gamma_1, c_1),\ k = 1,2,3$. A positive (negative) value of θ_{k1} simply indicates an increase (decrease) in the effect with the value of the transition variable.

3. ESTIMATION AND SPECIFICATION TESTS

To estimate the PSTR model, two main problems of specification need to be resolved, namely the choice of transition variable and the determinant of the number of transition functions. Following Wu et al. (2013), we adopt a three-step procedure for estimating our constructed stock return model. First, we perform the linearity test to investigate whether stock return satisfies the linearity condition. Then, if linearity is rejected, we determine the number of transition functions. Finally, we remove individual-specific means and apply non-linear least squares to estimate the parameters of Eq. (5).

3.1 SELECTION OF TRANSITION VARIABLE

Whaley (2000) indicates that VIX is referred to as the investor fear gauge because high levels of VIX have coincided with high degrees of market turmoil in the US. Other studies document the ability of implied volatility to predict future excess market returns (Dennis et al., 2006; Giot & Laurent, 2007, Diavatopoulos et al., 2008, Durand et al., 2011). For example, Fleming et al. (1995) find evidence that VIX index and stock index return has negative contemporaneous relationship. Giot (2005) finds that extremely high levels of VIX may signal attractive buying opportunities. Thus, there is a positive relationship between volatility changes and future stock market returns. In addition, Ghosh (2009) finds that a VIX above 30 is considered to be high and outside the normal range and that a VIX below 30 reveals that the stock market is relatively stable. Thus, this study selects the VIX as the transition variable in Eq. (5).

In fact, VIX developed by the CBOE (CBOE volatility index) has the most complete data among all VIX's. While other countries also construct various kinds of volatility indices, these indices cover inadequate lengths of time. To perform the estimation of the PSTR model and get the threshold value of transition variable (i.e., the VIX in this paper), we need to have a sufficient length of time. Thus, CBOE volatility index is a good candidate. In addition, the US is the biggest financial center in the world; therefore, the changes in CBOE volatility index may influence financial markets all over the world. That is, the CBOE volatility index has spillover effects on financial markets of other countries. Wu et al. (2015) have empirically supported this postulation. Finally, our empirical result in Table 5 has verified the spillover effects through transition function and three risk factors.

3.2 LINEARITY AND NO REMAINING NON-LINEARITY TESTS

Following Fouquau et al. (2008), to test the linearity of Eq. (5), we replace the transition function $W_j(q_t;\gamma,c)$ with its first-order Taylor expansion around $\gamma = 0$. Then, we obtain the following auxiliary equation:

$$\begin{aligned} R_{it}-R_{ft} &= \pi_i+\pi_{10}(R_{mt}-R_{ft})+\pi_{20}SMB_t+\pi_{30}HML_t+ \\ &\quad \left(\pi_{11}(R_{mt}-R_{ft})VIX_t+\pi_{21}SMB_tVIX_t+\pi_{31}HML_tVIX_t\right)+\eta_{it} \end{aligned} \tag{6}$$

The linearity test is performed on $H_0:\pi_{11}=\pi_{21}=\pi_{31}=0$. Previous studies provided three test methods – the Fisher, Wald and likelihood ratio tests – to execute the linearity and no remaining non-linearity test (see, for example, Fouquau *et al*., 2008). However, van Dijk et al. (2002) suggest that the Fisher test statistics have better size properties in small samples than the other two tests. Thus, we use LM_F as the selection criterion for the number of transition functions. If we denote SSR_0 to be the panel sum of squared residuals under H_0 (i.e., the linear panel model with individual effects, r=0) and SSR_1 to be the panel sum of squared residuals under H_1 (i.e., the PSTR model with two regimes, r=1), the Fisher (LM_F) test can be written as:

$$LM_F=\left[\left(SSR_0-SSR_1\right)/mK\right]/\left[SSR_0/\left(TN-N-mK\right)\right] \tag{7}$$

where K and m are the number of explanatory variables and the number of location parameters, respectively, and the LM_F statistic has an approximate $F\left[mK, TN-N-mK\right]$ distribution.

As linearity is rejected, a sequential approach is used to test the null hypothesis of no remaining non-linearity in the transition function. For instance, suppose that we want to test whether there is one transition function (H_0: r = 1) against there are at least two transition functions (H_1: r = 2). Thus, consider the model

$$\begin{aligned} R_{it}-R_{ft} &= \theta_{0i}+\theta_{10}(R_{mt}-R_{ft})+\theta_{20}SMB_t+\theta_{30}HML_t+ \\ &\quad \left(\theta_{11}(R_{mt}-R_{ft})+\theta_{21}SMB_t+\theta_{31}HML_t\right)\times W_1\left(VIX_t;\gamma_1,c_1\right)+ \\ &\quad \left(\theta_{12}(R_{mt}-R_{ft})+\theta_{22}SMB_t+\theta_{32}HML_t\right)\times W_2\left(VIX_t;\gamma_2,c_2\right)+\varepsilon_{it} \end{aligned} \tag{8}$$

The null hypothesis of no remaining heterogeneity can be formulated as γ_2 = 0. As before, the test problem is solved by using a first-order Taylor approximation of $W_2\left(VIX_t;\gamma_2,c_2\right)$, which leads to the following auxiliary regression:

$$\begin{aligned} R_{it}-R_{ft} &= \pi_i+\pi_{10}(R_{mt}-R_{ft})+\pi_{20}SMB_t+\pi_{30}HML_t+ \\ &\quad \left(\pi_{11}(R_{mt}-R_{ft})+\pi_{21}SMB_t+\pi_{31}HML_t\right)\times W_1\left(VIX_t;\gamma_1,c_1\right)+ \\ &\quad \left(\pi_{12}(R_{mt}-R_{ft})VIX_t+\pi_{22}SMB_tVIX_t+\pi_{32}HML_tVIX_t\right)+\eta_{it} \end{aligned} \tag{9}$$

The null hypothesis of no remaining non-linearity can thus be defined as H_0: $\pi_{12}=\pi_{22}=\pi_{32}=0$. The Fisher test can be computed as before. Then, we test the null hypothesis of no remaining non-linearity in this model. If it is rejected, estimate a three-regime model. The testing procedure continues until the first acceptance of the null hypothesis of no remaining heterogeneity. At each step of the sequential procedure, the significance level must be reduced by a factor 0 < τ < 1 to avoid excessively large models.

4. EMPIRICAL RESULTS

4.1 ESTIMATION RESULTS

In conducting the empirical estimation, this paper uses a panel data set of 60 semiconductor firms listed on TAIEX from 2005:1Q to 2013:2Q. Thus, there are 2040 (=60*34) observations. The VIX data is provided by the CBOE (http://www.cboe.com/micro/vix/historical.aspx), and the remaining data come from the *Taiwan Economic Journal databank* (http://www.tej.com.tw/twsite/). It is worth mentioning that the panel data approach—PSTR model—has several advantages. Hsiao (2003) indicates that in a panel data context, empirical estimations can resolve the problems of heterogeneity and endogeneity and improves the estimation efficiency. Thus, the estimation results are robust. However, using a panel data set to conduct empirical estimations will face a trade-off between the number of cross-sectional units (semiconductor stocks in this paper) and the length of time period due to the availability of data. The longer the length of time period is, the fewer the selected cross-sectional units would be.

The dominance of disaggregated data over aggregated data in performing empirical estimations is the main reason that we choose Taiwan's semiconductor industry as the sample object. Hsiao et al. (2005) indicate that there are at least four advantages of using the disaggregated data to perform relevant empirical estimations. First, there are more degrees of freedom, more sample variability, and less multicollinearity. Second, it allows more accurate estimate of dynamic adjustment behavior even with a short time series. Third, it provides the possibility to control the impact of omitted variables. Fourth, it provides means to get around structural break tests which are based on large sample theory with dubious finite sample property.

Two extra reasons are used to strengthen the use of Taiwan's semiconductor industry. The first one is the role of Taiwan's semiconductor industry in the global semiconductor market. In 2014, Taiwan was the fourth largest country in the world by the output value of semiconductor industry. Taiwan Semiconductor Association represented approximately 73.4% of worldwide IC foundry revenue, around 62.5% of worldwide packaging and testing revenue, around 18.9% of worldwide design revenue. The second is the importance of the semiconductor industry of Taiwan in her capital markets. In 2015, Taiwan's semiconductor industry accounted for 26.74% of the total market values of overall 31 industries. Evidently, Taiwan's semiconductor industry plays a key role in the domestic economic growth and global semiconductor market.

As mentioned above, at a particular point in time, there is a trade-off between the choices of cross-sectional units and the length of time. To cover an adequate length of time for evaluating the probable regime-switching of stock returns, we choose 2005:Q1 as the start date and 2013:2Q as the end date. The 34 quarterly data represent a period of near nine years and have covered at least two complete business cycles in Taiwan to impact the changes and volatilities of stock returns and other financial variables. [1] Thus, the disturbance of financial crises has been embodied in the changes of VIX, which further disturb the three risk premiums.

In March 2005, 84 semiconductor firms were listed in the Taiwan Security Exchange Corporation (TWSE). Excluding the firms with incomplete data, 60 companies are chosen. The total market values of these chosen companies account for over 88.5% of total market values in the overall semiconductor industry, which can mostly exclude the disturbance of inter-industry effect. Thus, the industry and the chosen companies are representative.

Descriptive statistics and panel unit root test results for the variables used in this paper are displayed in Tables 1 and 2. To avoid the problem of spurious regression, this paper executes three standard panel unit root tests—the ADF-Fisher Chi-square test, the Levin *et al.* (2002) (LLC) test and the IPS test. The results of the tests show that all five variables satisfy the condition of stationarity.

TABLE 1: DESCRIPTIVE STATISTICS

Variable	Mean	Max.	Min.	Std. Dev.	Skewness	Kurtosis	J-B	P-value
R_i-R_f	-0.319	133.2	-65.75	16.30	1.150	8.603	9356	0.000
R_m-R_f	-1.207	14.16	-21.57	6.348	-0.286	3.773	236.0	0.000
SMB	-0.724	5.992	-12.97	3.330	-0.463	4.071	511.3	0.000
HML	-1.567	12.09	-18.21	4.042	-1.183	7.944	7660	0.000
VIX	21.12	59.89	10.42	9.615	1.699	6.211	5575	0.000

Note: R_i-R_f, R_m-R_f, *SMB*, *HML* and *VIX* are the excess return of equity *i*, market premium, size premium, value premium and volatility index, respectively.

TABLE 2: PANEL UNIT ROOT TEST

Variable	ADF-Fisher	P-value	LLC	P-value	IPS	P-value
R_i-R_f	-17.08	0.000	-30.46	0.000	-17.79	0.000
R_m-R_f	-17.10	0.000	-7.781	0.000	-17.68	0.000
SMB	-22.59	0.000	-31.65	0.000	-24.10	0.000
HML	-19.43	0.000	-21.23	0.000	-20.35	0.000
VIX	-8.961	0.000	-2.184	0.000	-2.595	0.000

Note: R_i-R_f, R_m-R_f, *SMB*, *HML* and *VIX* are the excess return of equity *i*, market premium, size premium, value premium and volatility index, respectively.

The test and estimation results for stock return using the FF model and PSTR models are reported in Tables 3 through 5. In Table 3, the linearity tests lead to a rejection of the null hypothesis of linearity for all PSTR specifications with different numbers of location parameters (m=1,2). Evidently, the stock returns of the 60 semiconductor firms display non-linear dynamic paths, and the relationships between stock return and individual determinants are non-linear. Thus, adopting a non-linear PSTR approach to model stock return is relevant, and a linear approach may hide information about the structural changes in financial policies and economic conditions.

TABLE 3: LINEARITY TEST

Null hypothesis	r=0	
Alternative hypothesis	r=1	
No. of location parameters (m)	m=1	m=2
Testing statistic		
LM	24.81	27.71
	[0.000]	[0.000]
LMF	8.219	4.589
	[0.000]	[0.000]
LRT	24.86	27.77
	[0.000]	[0.000]

Notes: *LM*, *LMF* and *LRT* denote the statistics of the Wald test, Fisher test and likelihood ratio test, respectively. The digits in brackets are the p-values. The significance level is specified at 5%. r denotes the number of transition functions.

Table 4 displays the results of the no remaining non-linearity tests and provides information about the optimal number of transition functions and location parameters. At 5% significance level, the PSTR model with r=m=1 and the PSTR model with r=3 and m=2 satisfy to be used as candidate models for estimating Eq. (4).

TABLE 4: TEST OF NO REMAINING NON-LINEARITY

Null hypothesis	r=1		r=2		r=3	
Alternative hypothesis	r=2		r=3		r=4	
No. of location parameters (m)	m=1	m=2	m=1	m=2	m=1	m=2
Testing statistic						
LM	6.876	51.05	—	32.47	—	5.204
	[0.076]	[0.000]	—	[0.000]	—	[0.132]
LMF	2.269	8.478	—	5.374	—	1.735
	[0.078]	[0.000]	—	[0.000]	—	[0.136]
LRT	6.879	51.26	—	32.56	—	5.205
	[0.076]	[0.000]	—	[0.000]	—	[0.131]

Notes: *LM*, *LMF* and *LRT* denote the statistics of the Wald test, Fisher test and likelihood ratio test, respectively. The digits in brackets are the p-values. The significance level is specified at 5%. r denotes the number of transition functions.

Table 5 reports the parameter estimates of the FF and PSTR models. In the FF model, the impacts of market risk, size and book-to-market on stock returns are all significant, i.e., 1.451, 0.242 and -0.452, respectively, and the market risk factor has the biggest effect on stock returns among the three factors. The market risk and size factors have positive effects on stock return, consistent with the results in most previous studies (e.g., Perez-Quiros & Timmermann, 2000). However, the value premium does not occur in our panel data set. That is, the growth semiconductor stocks catch more premium than the value semiconductor ones. This result is different from that obtained in Fama and French (2006) by using the US stock market. Blazenko and Fu (2010) give a probable explanation that high profitability dividend paying stocks have low returns whereas high profitability non-dividend paying stocks have high returns. Since profitability and market values relate positively, dividend paying stocks have a value premium whereas non-dividend paying stocks have a negative value premium. In addition, the market risk factor has the biggest effect on stock returns among the three factors.

According to the test results in Table 4, both the PSTR model with r=m=1 and the PSTR model with r=3 and m=2 can pass the non-linear tests, and have at least one transition functions. To decide which one is the optimal model for evaluating the non-linear dynamics of stock return, we use the minimum AIC and BIC. In this situation, the PSTR model with one transition function (r=1) and one location parameter (m=1) is the optimal one for estimating Eq. (4). The estimation results are shown in Table 5.

For the PSTR model, the estimated threshold value c and transition parameter γ are 13.76 and 183.7, respectively. The market (or equity) premium on stock return is significantly positive ($2.287-0.891*W(VIX_t;183.7,13.76)>0$), depending on the value of VIX_t. The value of VIX_t varies in each period; therefore, the effect changes with time. In two extreme cases, i.e., $W(VIX_t;183.7,13.76)=0$ and $W(VIX_t;183.7,13.76)=1$, the effects are 2.287 and 1.396, respectively. Evidently, the larger the VIX is, the smaller the market premium would be. The reason may be that as the VIX is greater than the threshold, investors expect the market will reverse, which leads to the decrease in the market premium. This result is quite different from the constant market premium obtained from the FF model in this paper and previous studies. In most cases, the linear FF model underestimates the market premium (see Table 5, 1.451 vs. 1.396~2.287).

The change in size premium (SMB_t) exerts an insignificantly positive effect on stock return, i.e., $0.077+0.247*W(VIX_t;183.7,13.76)>0$. The insignificant effect is similar to the finding of Brown and Cliff (2004) that investor sentiment has little predictive power for small stocks. In two extreme cases (i.e., $W(\cdot)=0$ and $W(\cdot)=1$), the effects are 0.077 and 0.324, respectively. Clearly, small semiconductor firms get more size premium as the degree of investor panic deepens. The probable reason is that in face of a more panic market sentiment, small semiconductor firms can adjust their operating strategies more motorized than large firms. Again, the effects vary with time, depending on the VIX under different regimes, and the non-linear impact of size premium on stock return is less investigated in previous studies.

Value factor (HML_t) has a significantly negative effect on stock return, i.e., $-0.778+0.326*W(VIX_t;183.7,13.76)<0$, depending on the value of time-varying VIX. In two extreme cases (i.e., $W(\cdot)=0$ and $W(\cdot)=1$), the effects are -0.778 and -0.452, respectively. While the negative effect is the same as those reported by previous studies (e.g., Krishnaswami et al., 1999, Blazenko & Fu, 2010) and the FF model in this paper, the effect here varies with time and is not permanently constant. In addition, the larger the VIX is, the smaller the negative effect would be. According to the result in Blazenko and Fu (2010), growth stocks with high profitability, high market/bookand non-dividend paying have high returns. However, as investor sentiment (VIX) becomes more panic, the growth stocks gradually lose their value premium advantage.

TABLE 5: ESTIMATION RESULTS OF STOCK RETURNS

Model	Linear	PSTR-VIX
Parameter		r=m=1
θ_{0i}	0.900***	
R_m-R_f		
θ_1	1.451***	2.287***
θ_1'		-0.891***
SMB		
θ_2	0.243***	0.077
θ_2'		0.247
HML		
θ_3	-0.452***	-0.778***
θ_3'		0.326
c		13.76
γ		183.7
R^2	0.342	
AIC		5.153
BIC		5.126

Note: The PSTR-VIX model with r=m=1 is the optimal estimation due to its minimum AIC and BIC.

With the rise in VIX, the overall excess returns fall. For example, as $W(\cdot)=$ 0 and 1, the overall excess returns are 1.586 and 1.268, respectively. This result supports the finding of Glosten et al. (1993) that there exists a negative relationship between conditional expected return and conditional variance of return. The evidence that VIX has asymmetric impacts on excess returns is also found in Campbell and Hentchel (1992). In addition, Theodossiou and Savva (2015) find evidence that the skewness and kurtosis in the distribution of portfolio excess return plays a crucial role in the risk-return relationship. The results in Tables 1 and 5 also support this outcome. In Table 1, the skewness of excess return (R_i-R_f) is positive (1.150), and the excess returns range from 1.268 to 1.586. Thus, we have positive skewness and positive excess return. In spite of this, in the present paper, the impacts of idiosyncratic risks on excess returns are nonlinearly disturbed through the aggregate volatility—VIX, which is ignored by the previous studies. While Ang et al. (2006) document that stocks with high sensitivities to innovations in aggregate volatility (proxied by VIX) have low average returns, and Ang et al. (2009) find evidence that stocks with high idiosyncratic volatility have low future returns in 23 developed markets, these results are based on sorting stocks into five quintiles and is linear. Thus, there is a lack of threshold for the returns to have the process of a smooth regime switching, and cannot integrate these two kinds of risks into an empirical model.

In the work of Jacobs (2015), the variation of investor sentiment has a powerful role in long-short anomalies. However, the predictive power of investor sentiment is mostly restricted to the short leg of strategy returns. In line with this result, the credibility of the estimated risk premiums in Table 5 is higher in the situation of high VIX's than low VIX's. Zaremba (2016) finds similar results that variation in market sentiment plays an important role in the returns on the cross-country value strategies. That is, the change in market sentiment causes a spillover effect on cross-country stock returns. However, the influence in Zaremba is not time-varying and nonlinear.

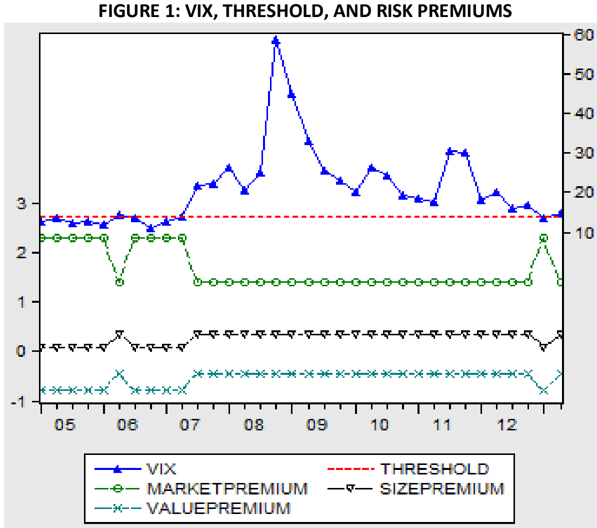
4.2 TIME-VARYING RISK PREMIUMS AND INVESTMENT STRATEGIES

Using the estimation results in Table 5, we can further analyze the dynamic paths of the three risk premiums. Fig. 1 illustrates the dynamic paths of risk premiums in terms of the three factors in the Eq. (5). According to the threshold value of VIX (13.76), we can divide the sample period into two sub-sample periods – 2005:1Q-2007:2Q and 2007:3Q-2013:2Q. In the former period, VIX is below its threshold, and in the latter period, VIX is above its threshold. In fact, the European sovereign debt crisis occurred in the latter period. That is, VIX rises very quickly to a high level as economy faces serious economic/financial crisis. In the latter period, the market premium and negative value premium decrease, and size premium increases. Clearly, in the panic periods, an increasing VIX strengthens the attraction of small stocks and weakens the value premium of growth stocks. In addition, all the three risk premiums have faced at least three switching points in their dynamic paths. Again, these results support the argument mentioned above that the risk premiums are non-linear and vary with time.

From the empirical results, we suggest the following investment strategies. First, in determining investment targets, there is a trade-off between small stocks and growth stocks, because low VIX causes size premium to decrease and negative value premium to enlarge, and high VIX causes size premium to increase and negative value premium to reduce. For example, at extremely low levels of VIX's, W(.)=0, the size premium is 0.077, and value premium is -0.778, which means that growth stocks have excess returns than value stocks and small stocks have excess returns than large stocks. Contrarily, at extremely high levels of VIX's, W(.)=1, the size premium is 0.324 (=0.077+0.247), and value premium is 0.452 (=-0.778+0.326), which means that value stocks have excess returns than growth stocks. Thus, with the rise in VIX, small stocks have more premiums; however, growth stocks have fewer premiums. Even though, small/growth stocks still have higher risk premiums than large/value stocks at any level of VIX. That is, holding small/growth stocks is relatively favorable. Second, in panic periods (high VIX), holding small/growth stocks has more size and negative value premiums. For example, the size and negative value premiums are 0.855 in low VIX regime (0<VIX<13.76) and are 0.776 in high VIX regime (13.76<VIX). Third, market premium in high VIX regime is lower than low VIX regime.

Moskowitz and Grinblatt (1999) find evidence that industry momentum investment strategies get more profit than momentum investment strategies, even after controlling for size, book-to-market equity, and individual stock momentum. Thus, investors can use industry momentum investment strategies to choose specific industries as investment targets, and then employ the constructed model in this paper to evaluate three nonlinear and time-varying risk premiums.

FIGURE 1: VIX, THRESHOLD, AND RISK PREMIUMS



Note: VIX, THRESHOLD, MARKETPREMIUM, SIZEPREMIUM, and VALUEPREMIUM denote the volatility index, the threshold value of VIX, market premium, size premium, and value premium.

5. CONCLUSION

This paper re-estimates the three premiums in Fama-French (1993) model by reconstructing the model as a panel smooth transition regression (PSTR) framework. In estimating the PSTR model, we consider the representative investor sentiment variable – the VIX – as the transition variable, which can be considered as the fourth factor, can control for other factors associated with stock returns and can potentially explain the heterogeneity in time between stock returns and the three factors.

Our main results can be summed up as follows. First, the relationships between stock returns and its determinants, including the market (beta) factor, size factor and, value factor, are non-linear and change over time when VIX is introduced as a transition variable. Second, the market premium decreases with the rise of VIX, and the size and value premiums increases with the increase of VIX. Third, the size premium is statistically insignificant, and the value premium is negative. Fourth, the VIX non-linearly causes changes in stock returns.

Our results have the following implications of investment strategy. First, in determining investment targets, there is a trade-off between small stocks and growth stocks; however, small/growth stocks have higher risk premiums than large/value stocks at any level of VIX. Second, in panic periods (high VIX), holding small/growth stocks has more size and negative value premiums. Third, in measuring the premiums, it is crucial for investors to consider the VIX variable – the proxy for investor sentiment, otherwise they will misjudge the impacts of individual factors on stock returns.

NOTES

1. The periods of the twelfth, thirteenth, and fourteenth business cycle range from 2005:2M to 2009:2M, 2009:3M to 2012:1M, and 2012:2M to now, respectively.
2. Following the proposition of González et al. (2005) and the followers, this paper allows the number of location parameters (m) to be either one or two.
3. We only display the results from the optimal estimation model; however, the remaining estimation results are available upon request.

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