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**Working Paper**

## Estimating heterogeneous agents behavior in a two-market financial system

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# FinMaP-Working Paper No.48



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FINMAP –

**FINANCIAL DISTORTIONS AND MACROECONOMIC  
PERFORMANCE: EXPECTATIONS, CONSTRAINTS AND  
INTERACTION OF AGENTS**

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**TITLE**

Estimating heterogeneous agents behavior in  
a two-market financial system

by: Zhenxi Chen, Weihong Huang and Huanhuan  
Zheng

## ABSTRACT

In this paper, we propose a two-market empirical model with heterogeneous agents based on Chiarella et al. (2012). Using monthly data of French and US stock markets, the regression shows that individual markets have feature of two-regime switching process. By including inter-market traders whose trading decision is based on fundamental value of foreign market, the two-market model has a better capability in explaining both markets with domestic fundamental traders turning to be significant. The existence of inter-market traders implies that the two markets impact each other through their fundamental and hence share some common set of factors, which provides foundation of market interactions, such as market co-movement.

*Keywords: Cross-correlation; co-movement; heterogeneous agents; financial multi-market interactions*

*JEL Classifications: D84, G12, G15*

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# Estimating heterogeneous agents behavior in a two-market financial system<sup>1</sup>

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In this paper, we propose a two-market empirical model with heterogeneous agents based on Chiarella et al. (2012). Using monthly data of French and US stock markets, the regression shows that individual markets have feature of two-regime switching process. By including inter-market traders whose trading decision is based on fundamental value of foreign market, the two-market model has a better capability in explaining both markets with domestic fundamental traders turning to be significant. The existence of inter-market traders implies that the two markets impact each other through their fundamental and hence share some common set of factors, which provides foundation of market interactions, such as market co-movement.

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## 1. INTRODUCTION

Given the background of globalization and financial market integration, market co-movement or cross-correlation has attracted attention of researchers long ago and becomes a more and more obvious phenomenon in recent years. One of the common place to show co-movement is stock markets, either within stock markets such as market component, or between different stock markets. Markets co-movement has been widely reported in empirical literature. Egert and Kocenda (2011) find strong correlation among returns of Germany,

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France and UK even up to 0.9. Kenett et al. (2012) find that developed Western markets are highly correlated. In addition, strong co-movement was observed when financial crisis spread to various markets in the past decades. Preis et al. (2012) show that average correlation among DJIA (Dow Jones Industrial Average) members increases with market stress.

Heterogeneous agents models (HAM) have proven to be successful in explaining financial markets theoretically (e.g. Day and Huang, 1990; Brock and Hommes, 1998; Lux, 1998; Chiarella et al., 2003; Hommes et al., 2005; He and Westerhoff, 2005; Huang et al., 2010). This inspires the empirical investigation using HAM. Westerhoff and Reitz (2005) shows behavioral heterogeneity in US corn market. Frijns et al. (2010) verify that traders with different beliefs about volatility are active in option market. Manzan and Westerhoff (2007) and De Jong et al. (2010) find the existence of heterogeneous traders in foreign exchange markets. Lux (2012) uses agent-based model to estimate the opinion formation of German investors. Boswijk et al. (2007) and Chiarella et al. (2012) estimate behavioral heterogeneity in S&P 500 using techniques of nonlinear least square and Markov regime switching respectively. In the paper of Chiarella et al. (2012), they show the existence of boom and bust two states. The bust state is characterized by depressing price movements and high volatility.

However, all the above mentioned empirical HAM literatures focus on a single market only. Interactions among financial markets, including market co-movement, are not addressed. Indeed, theoretical models have been developed to investigate the interactions among multiple markets. Westerhoff and Dieci (2006) develop a model in which chartists and fundamentalists invest in two speculative markets. They manage to calibrate price dynamics resembling to actual speculative prices. Chiarella et al. (2007) investigate a model where heterogeneous agents invest among multiple assets. Investors anticipate correlations and conduct portfolio diversification to maximize utility. It is shown that this activity might be a source of complexity in the market. Dieci and Westerhoff (2010) build up a three-market model in which two stock markets are linked via foreign exchange market. The foreign exchange market is populated with chartists and fundamentalists while the two

stock markets have only fundamentalists. It is concluded that upon market interactions, stock markets may be destabilized while the stabilizing effect on the foreign exchange market and the whole market system can be observed. Schmitt and Westerhoff (2014) develop a two-market model and calibrate a number of stylized facts of international stock markets. Huang and Chen (2014) also develop a two-market model. They show the existence of a dual effect of stabilizing and destabilizing between the two mutual opening markets. In addition, they also prove theoretically the existence of cross-correlation or market co-movement between the two markets. In terms of empirical application of HAM for multiple markets, De Jong et al. (2009) are among the pioneers. They investigate stock markets of Hong Kong and Thailand during the 1997 Asian crisis. In addition to the typical fundamentalists and chartists, they innovatively introduce into each market a third type of traders, internationalists, whose demand function in the domestic market is based on the chartist analysis in foreign market. These three types of traders play their roles during the crisis. The inclusion of internationalists provides an indication of the cross-correlation between the two markets and captures the contagion effect during the crisis.

Inspired by De Jong et al. (2009) and Chiarella et al. (2012), this paper proposes a two-market model to study stock markets of France and US represented by CAC 40 and DJIA and estimates the trading behaviors of fundamental group, chartist group and inter-market traders using monthly data from January 2000 to April 2013. After verifying that individual markets have the feature of two-state regime switching, we include inter-market traders to form a two-market model. Excess demand of inter-market traders in one market is based on fundamental value of foreign market, instead of the foreign price changes in De Jong et al. (2009). The inclusion of inter-market traders remedies the omitted variable of the single market model and therefore the domestic fundamental traders become significant. The estimation result suggests the existence of inter-market traders in both markets, implying that price adjustments in both markets have a common set of factors in terms of fundamental values of the two markets. Therefore, evidence is found for a foundation of markets co-movement or cross-correlation.

The rest of the paper is organized as follows. In Section 2, we develop the methodology

of two-state regime switching empirical models for the single market and two-market frameworks and discuss the data used in this paper. Section 3 presents the regression results for the two frameworks and shows that the two-market framework with inter-market traders has a better capability in explaining the two markets. Lastly, Section 4 concludes the paper.

## 2. METHODOLOGY AND DATA

### 2.1. Methodology

We develop a two-market asset pricing model with stock markets of France and US in this section. In each market, two groups of traders, fundamental and chartist groups are active. They trade based on market fundamental value and chartist reference values respectively. Inspired by Brock and Hommes (1998), we assume there are trend chasers and contrarians in each group. A trend chaser believes that the trend of price deviation from the reference value will continue while a contrarian holds an opposite one. That is, a contrarian believes that the price deviation will be reversed. A third group of investors is noise traders. Fundamental value of the market can be derived from real economic conditions. Fundamental group is assumed to have access to this fundamental value and treats it as trading reference while chartist group and noise traders do not have the information due to their trading nature or information cost. Chartists and noise traders trade based on market conditions and historical prices. They believe that the market has high and low two market states and follows a two-state Markov regime switching process. Depending on the Markov state  $n$  ( $n = 1$  or  $2$ ), chartists postulate reference price  $v_t$  in each state and trade based on the price deviation from that reference price. Meanwhile noise traders just decide their order  $e_t$  following a normal distribution  $N(0, \sigma_{n,t}^2)$ . Conditional volatility  $\sigma_{n,t}^2$  is regime-dependent. Details of this regime-dependent properties will be discussed later. The last group of traders in this paper is inter-market traders, whose trading in the domestic market is based on the fundamental value of the foreign market. We first describe the trading strategies of the all types of traders and their excess demand as well as the price adjustment functions that relate price to excess demands.

### 2.1.1. Fundamental group

In market  $j$  ( $j = \text{Fr}$  denoting France or US for United States), fundamental group ( $f$ ) is assumed to know the information of fundamental value,  $u_t^j$ . Based on the price deviation from the fundamental value  $p_{t-1}^j - u_t^j$ , excess demand function of investors follows a rule as:

$$D_{f,t}^j = b_f^j \left( p_{t-1}^j - u_t^j \right), \quad (1)$$

where  $b_f^j$  is the demand coefficient of fundamental group. There are trend chasers and contrarians in this group. A trader is called fundamental trend chaser if  $b_f^j = b_{ft}^j > 0$  or fundamental contrarian if  $b_f^j = -b_{fc}^j < 0$ . A fundamental trend chaser buys (sells) by assuming that the trend of positive (negative) price deviation will continue from the previous period. In contrast, a fundamental contrarian invests in an opposite way with a belief that price will return back to fundamental value. Hence, a fundamental contrarian sells (buys) given positive (negative) price deviation from fundamental value.

Following Chiarella et al. (2012), fundamental value  $u_t^j$  is derived based on static Gordon growth model of Gordon and Shapiro (1956) as well as Fama and French (2002),

$$u_t^j = d_t^j \frac{1 + g^j}{y^j}, \quad (2)$$

where  $d_t^j$  is dividend flow,  $g^j$  is the average growth rate of dividend, and  $y^j$  is the average dividend yield.

### 2.1.2. Chartist group

Instead of using the fundamental value, chartists rely on reference prices (or benchmark prices)  $v_t^j$  for their trading decision.  $v_t^j$  is related to historical price and market beliefs.

Given current price  $p_{t-1}^j$  and reference price  $v_{t-1}^j$ , chartist price deviation is denoted as  $p_{t-1}^j - v_{t-1}^j$ . Based on the chartist deviation price, demand of chartists is expressed as

$$D_{c,t}^j = b_c^j \left( p_{t-1}^j - v_{t-1}^j \right), \quad (3)$$

where  $b_c^j$  is the demand coefficient of chartists.



All chartists share the same belief of reference price  $v_t^j$ . The difference among them is captured by the sign of  $b_c^j$ . A trader is named chartist trend chaser if  $b_c^j = b_{ct}^j > 0$  and a chartist contrarian if  $b_c^j = -b_{cc}^j < 0$ . A chartist trend chaser believes that price will deviate further away from the current reference price. In contrast, a chartist contrarian believes that price deviation from current reference price will be reduced or even reversed.

As mentioned earlier,  $v_{t-1}^j$  is state dependent, switching stochastically between two states  $s_t^j \in S = \{1, 2\}$ . The dynamics behind the switching process can be captured by transition probabilities

$$P(s_t = l | s_{t-1} = k) = P_{l,k} \quad (4)$$

for  $k, l \in S$ .  $P_{l,k}$  indicates the probability of a switch from state (regime)  $k$  to state (regime)  $l$ . The switching probabilities are assumed as constants and should satisfy constraints of  $0 \leq P_{l,k} \leq 1$  and  $\sum_{l=1}^2 P_{l,k} = 1$  for  $k = 1, 2$ . The state  $s_t^j$  can be estimated by a filter estimation/Markov regime switching model through the market prices. Technical details regarding Markov regime switching can be found in Hamilton (1994). As the reference prices are state contingent on the states, the regime dependent  $v_t^j$  is given by

$$v_t^j = \begin{cases} v_{1,t}^j, & s_t^j = 1, \\ v_{2,t}^j, & s_t^j = 2. \end{cases} \quad (5)$$

### 2.1.3. Noise traders

Noise traders do not rely on a fundamental value or price pattern to trade. However, their trading behavior is affected by the state of regime switching process. Information of the market state can be revealed by various news media. Demand of noise traders is expressed as

$$D_{n,t}^j = e_t^j = \begin{cases} N\left(0, \left(\sigma_{1,t}^j\right)^2\right), & s_t^j = 1, \\ N\left(0, \left(\sigma_{2,t}^j\right)^2\right), & s_t^j = 2. \end{cases} \quad (6)$$

that is, the mean of demand of noise trader is zero; but variance is state dependent.

#### 2.1.4. Market maker

We denote the composition of fundamental trend chasers, fundamental contrarians, chartist trend chasers, chartist contrarians, and noise traders in market  $j$  ( $j = \text{Fr or US}$ ) by  $\omega_{ft}^j$ ,  $\omega_{fc}^j$ ,  $\omega_{ct}^j$ ,  $\omega_{cc}^j$  and  $\omega_n^j$ . For simplicity, the compositions of traders are fixed in this paper. Market maker of market  $j$  collects excess demand of all types of traders to update price of market  $j$ . Price impact function in a single market model can be expressed as

$$\begin{aligned}\Delta p_t^j &= p_t^j - p_{t-1}^j \\ &= \delta^j \left[ \begin{aligned} &\omega_{ft}^j b_{ft}^j (p_{t-1}^j - u_t^j) - \omega_{fc}^j b_{fc}^j (p_{t-1}^j - u_t^j) + \omega_{ct}^j b_{ct}^j (p_{t-1}^j - v_{t-1}^j) \\ &\quad - \omega_{cc}^j b_{cc}^j (p_{t-1}^j - v_{t-1}^j) + \omega_n^j e_t^j \end{aligned} \right] \\ &= \alpha^j (p_{t-1}^j - u_t^j) + \beta^j (p_{t-1}^j - v_{t-1}^j) + \varepsilon_t^j\end{aligned}\tag{7}$$

where  $\alpha^j = \delta^j (\omega_{ft}^j b_{ft}^j - \omega_{fc}^j b_{fc}^j)$ ,  $\beta^j = \delta^j (\omega_{ct}^j b_{ct}^j - \omega_{cc}^j b_{cc}^j)$ , and  $\varepsilon_t^j = \delta^j \omega_n^j e_t^j$ . Noise term  $\varepsilon_t^j$  still has state-dependent distribution

$$\varepsilon_t^j = \begin{cases} N\left(0, (\sigma_1^j)^2\right), & s_t^j = 1, \\ N\left(0, (\sigma_2^j)^2\right), & s_t^j = 2. \end{cases}\tag{8}$$

where  $\sigma_1^j = \delta^j \omega_n^j \sigma_{1,t}^j$ , and  $\sigma_2^j = \delta^j \omega_n^j \sigma_{2,t}^j$ . Therefore, each market undergoes a price updating process with regime-dependent mean and variance. Specifically,

$$\begin{cases} \Delta p_t^{Fr} = \alpha^{Fr} (p_{t-1}^{Fr} - u_t^{Fr}) + \beta^{Fr} (p_{t-1}^{Fr} - v_{t-1}^{Fr}) + \varepsilon_t^{Fr}, \\ \Delta p_t^{US} = \alpha^{US} (p_{t-1}^{US} - u_t^{US}) + \beta^{US} (p_{t-1}^{US} - v_{t-1}^{US}) + \varepsilon_t^{US}. \end{cases}\tag{9}$$

#### 2.1.5. Inter-market traders

We also introduce to each market a new group of traders, inter-market traders, whose trading decision is based on information of fundamental value of the other market. Demand of inter-market traders in market  $j$  is assumed to be

$$D_{i,t}^j = b_i^j (p_{t-1}^k - u_t^k) + b_s^j \Delta S_t,$$

where  $b_i^j$  is demand coefficient of inter-market traders;  $k$  is the market other than  $j$ ; and  $b_s^j$  is demand coefficient for the change of exchange rate that is denoted by  $\Delta S_t = S_t - S_{t-1}$ . Adding the demand of inter-market traders into the single market model to form the two-market model, we get

$$\begin{aligned}\Delta p_t^j &= p_t^j - p_{t-1}^j \\ &= \alpha^j (p_{t-1}^j - u_t^j) + \beta^j (p_{t-1}^j - v_{t-1}^j) + \delta^j b_i^j (p_{t-1}^k - u_t^k) + \delta^j b_s^j \Delta S_t + \varepsilon_t^j \\ &= \alpha^j (p_{t-1}^j - u_t^j) + \beta^j (p_{t-1}^j - v_{t-1}^j) + \gamma^j (p_{t-1}^k - u_t^k) + \lambda^j \Delta S_t + \varepsilon_t^j,\end{aligned}$$

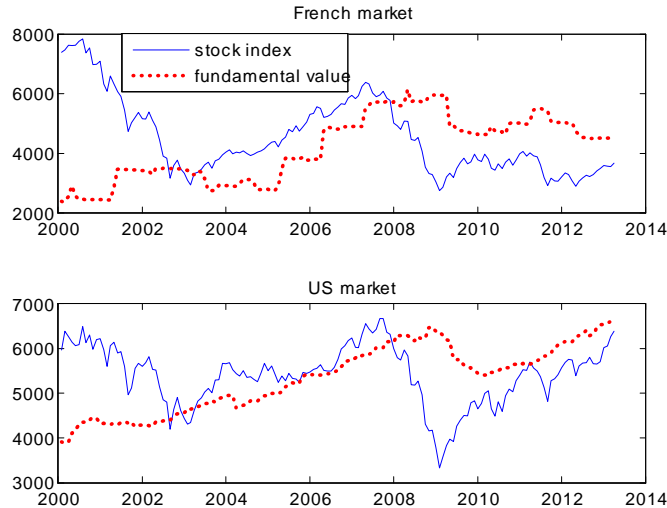
where  $\gamma^j = \delta^j b_i^j$  and  $\lambda^j = \delta^j b_s^j$ . Specifically, for two markets France and US, we have the two-market price updating model as

$$\begin{cases} \Delta p_t^{Fr} = \alpha^{Fr} (p_{t-1}^{Fr} - u_t^{Fr}) + \beta^{Fr} (p_{t-1}^{Fr} - v_{t-1}^{Fr}) + \gamma^{Fr} (p_{t-1}^{US} - u_t^{US}) + \lambda^{Fr} \Delta S_t + \varepsilon_t^{Fr}, \\ \Delta p_t^{US} = \alpha^{US} (p_{t-1}^{US} - u_t^{US}) + \beta^{US} (p_{t-1}^{US} - v_{t-1}^{US}) + \gamma^{US} (p_{t-1}^{Fr} - u_t^{Fr}) + \lambda^{US} \Delta S_t + \varepsilon_t^{US}. \end{cases} \quad (10)$$

## 2.2. Data

We use data from Bloomberg including indexes and dividend of both CAC 40 (France) and DJIA (US), Consumer Price Index (CPI) and exchange rate denoted by Euro/US dollar from January 2000 to April 2013. All the indexes and dividend are discounted by CPI to get the real values for evaluation in this paper.

Real stock price and calculated real fundamental value are compared in Fig. 1 for both France and US. In most of the time, stock price does not equal to fundamental value in each market. In addition, the two markets have similar co-movement between stock price and fundamental value. For both markets, prices are much above fundamental values before 2003, mainly during the "dot com" bubble period. After that, prices and fundamental values rise together till 2007, when subprime crisis occurs. The effect of the crisis is to push prices below fundamental values. The difference between the two markets is reflected in the period after the crisis. Price of France remains stagnant and below the fundamental value while price and fundamental value of US recover almost to the pre-crisis level. Table 1 summarizes



**FIG. 1** Real stock price and fundamental value of French and US stock markets.

TABLE 1  
Statistics summary, sample period from January 2000 to April 2013.

variable	$p_t^{Fr}$	$d_t^{Fr}$	$g_t^{Fr}$	$u_t^{Fr}$	$p_t^{US}$	$d_t^{US}$	$g_t^{US}$	$u_t^{US}$	$S_t$
Mean	4551.30	124.33	0.005	4175.52	5412.66	123.43	0.003	5327.21	1.22
Std. dev.	1277.50	32.86	0.048	1103.43	659.99	17.42	0.012	752.22	0.19
Min	2754.65	70.84	-0.174	2379.17	3328.54	90.30	-0.064	3897.40	0.85
Max	7845.21	183.08	0.255	6148.50	6667.11	153.76	0.053	6636.19	1.58

the statistics of the time series data. It is shown that France has larger standard errors with its variables and tends to have larger monthly fluctuation.

### 3. ESTIMATION RESULTS

#### 3.1. Model estimation with single market framework

We estimate the single market framework defined in eq. (9) based on maximum likelihood method coded by Perlin (2012). As a beginning, separate regressions are run to check the existence of fundamental and chartist groups of traders. Detailed estimation results are presented in Table 2. For both markets, the two switching regions for noise traders are statistically significant, implying that both markets have regime-switching behaviors. For

France, coefficient of fundamental group,  $\alpha$ , is statistically insignificant while it is significant for chartist group with negative  $\beta$ , indicating that contrarians dominate the chartist groups. Chartist group is only active at regime 1 as  $v_2$  is insignificant. For US, the separate regressions show the existence of fundamental and chartist groups with significant coefficients. Chartist group has two switching regimes with reference values  $v_1$  and  $v_2$ . Both coefficients for fundamental group ( $\alpha$ ) and chartist group ( $\beta$ ) are negative, suggesting contrarians dominating both groups. Traders of the two groups believe that price will move towards their trading reference values. To make it fly in the ointment, the coefficients of fundamental group and the second reference value of chartists become insignificant when regression for US is run on both fundamental and chartist groups. In studying S&P 500, Chiarella et al. (2012) also encounter similar insignificant coefficients. They found it due to the multicollinearity between the fundamental and chartist groups as their trading have the same direction most of the time.

The sequel regressions with the inclusion of inter-market traders provide another explanation for the insignificance of fundamental group in both market: omitted variables, i.e., fundamental value of the foreign market and the exchange rate.

### 3.2. Model estimation with two-market framework

In the two-market framework eq. (10), each market includes the foreign price deviation from fundamental value as well as the exchange rate for regression. We first evaluate the case that the trading of inter-market trader is not regime-dependent. The estimation results are reported in columns 2 and 3 of Table 3. Coefficients of fundamental group ( $\alpha$ ) become significant for both markets, implying that missing variable is one of the causes of the insignificance of fundamental group in both markets under the single market framework. The value of  $\alpha$  is positive for France while it is negative for US. This means trend chasers dominate the fundamental group in France while it is contrarians who dominate the group in US. On average, domestic traders in France relying on fundamental value believe the trend of price deviation from the fundamental value will continue while those in US believe price will reverse back to the fundamental value.

TABLE 2

Estimation result of individual group of traders under single market framework, sample period from January 2000 to April 2013. \*, \*\*, and \*\*\* represent significance at 10%, 5% and 1% level. P-value is in parenthesis.

$$\begin{cases} \Delta p_t^{Fr} = \alpha^{Fr} (p_{t-1}^{Fr} - u_t^{Fr}) + \beta^{Fr} (p_{t-1}^{Fr} - v_{t-1}^{Fr}) + \varepsilon_t^{Fr}, \\ \Delta p_t^{US} = \alpha^{US} (p_{t-1}^{US} - u_t^{US}) + \beta^{US} (p_{t-1}^{US} - v_{t-1}^{US}) + \varepsilon_t^{US}. \end{cases}$$

variables	Fundamental group only		Chartist group only		Fundamental and chartist groups	
	France	US	France	US	France	US
$\alpha$	-0.0008 (0.923)	-0.0422** (0.038)			0.0209 (0.169)	-0.0117 (0.64)
$\beta$			-0.0098** (0.013)	-0.0666*** (0.008)	-0.0332* (0.058)	-0.0569 (0.104)
$v_1$			9468.81 (0.127)	6199.37** (0.002)	5630.32** (0.014)	6315.99** (0.059)
$v_2$			-10320.91 (0.248)	4313.53** (0.037)	-253.46 (0.913)	4251.04 (0.190)
$\sigma_1$	161.66*** (0.000)	161.48*** (0.000)	145.05*** (0.000)	142.94*** (0.000)	148.56*** (0.000)	140.16*** (0.000)
$\sigma_2$	328.06*** (0.000)	296.47*** (0.000)	295.59*** (0.000)	282.81*** (0.000)	300.04*** (0.000)	284.31*** (0.000)
$P_{1,1}$	0.9853** (0.017)	0.9813** (0.039)	0.9503*** (0.007)	0.9523*** (0.009)	0.9580*** (0.009)	0.9495*** (0.008)
$P_{1,2}$	0.0417 (0.905)	0.0461 (0.902)	0.0971 (0.798)	0.0834 (0.82)	0.0940 (0.812)	0.0843 (0.818)
LL	-1075.13	-1070.02	-1067.23	-1064.41	-1066.44	-1064.28
AIC	16.10	15.95	16.09	15.95	16.09	15.96

The more interesting part is the result for the coefficients of inter-market traders,  $\gamma$  and  $\lambda$ . Coefficients of inter-market traders with respect to fundamental value of foreign market,  $\gamma$ , are significant for both markets. The difference is that  $\gamma$  is negative in France while it is positive in US. According to this result, the trading of inter-market traders in France is negatively correlated with the price deviation of US from its fundamental value while in US, it is positively correlated with the French price deviation from the fundamental value. One of the possible explanations for this phenomenon is that inter-market traders investing in France use the price signal of US to gauge France and trade with negative feedback while inter-market traders investing in US react to the price movement of France in a manner of positive feedback. In this sense, given unchanged in fundamental values of the two markets, if price of US increases such that price deviation is positive, inter-market traders investing in France treat it as an alert and will sell to push price of France down. In contrast, for a negative price deviation in France, inter-market traders in US are discouraged and will sell to push price of US down. If we go one more step, we can find that the contrary behaviors of inter-market traders in the two markets form a stabilizing mechanism for prices in both markets. An increase of US price leads to a price decreasing in France, which will in turn push down the price of US. The similar stabilizing mechanism can be deduced for France vice versa.

Another explanation for the behavior of  $\gamma$  is the spill-over effect of domestic fundamental investors. Both France and US are well developed markets with very close economic connections, sharing similar underlying fundamental factors and positive cross-correlation. Investors of the fundamental group in one market just carry over their purchasing decision into the other market. That is, trading of inter-market traders in one market is the extension of the domestic fundamental trader in the other market. Hence, if fundamental group purchases in France, inter-market trader investing in US will purchases too and vice versa.

The other coefficient of inter-market traders is respect to exchange rate,  $\lambda$ . As exchange rate is expressed as Euro/US dollar, a positive change in the exchange rate indicates that US dollar appreciates or Euro depreciates.  $\lambda$  for France is marginally significant with p-value 0.112. The positive value suggests that inter-market traders will purchase French asset upon

the depreciation of Euro. The effect of exchange rate in US is different.  $\lambda$  for US is significant with a positive value, implying that appreciation of US dollar attracts inter-market traders into the US stock market.

Coefficients for the two-regime noise traders are statistically significant, indicating the existence of regime switching even under the two-market model. Notice that, noise traders always have larger standard errors in regime 2 for both markets. Coefficient for chartist traders ( $\beta$ ) is only significant at regime 1 in France while it is insignificant in US.

### 3.3. Regime dependent of inter-market traders

The existence of inter-market traders suggests that individual markets are subject to influence of the other markets. When the influence of foreign market becomes stronger, markets contagion can be observed, especially during depressed periods. Question arising in this paper will be whether the influence of foreign markets is constant or not. We evaluate different combinations of coefficients with regime switching feature to get the final version of specification, whose results are reported in columns 4 and 5 of Table 3. For both markets, coefficients of inter-market traders,  $\gamma$  and  $\lambda$ , have regime switching behavior. The main finding is that coefficients of fundamental value of foreign markets,  $\gamma$ , are significant except for regime 1 in US market.  $\gamma$  in regime 2 has larger values than those in regime 1. In other words, when domestic stock markets become more volatile in price movements, they become more vulnerable to the influence from foreign markets. The coefficient of foreign exchange rate,  $\lambda$ , is only significant at regime 1 with positive value for both markets. The chartist group is significant in France without regime switching behavior. While for US, it is insignificant. The weak influence of the chartist group in the two markets can be evidenced in the sequel analysis of excess demand.

We discuss the inference based on the final version of specification. The switching of the two regimes is captured by transition probabilities. In France,  $P_{1,1}^{Fr} = 0.9754$ , implying that once in regime 1, France will remain in regime 1 in the next period with probability 0.9754 and the expected duration of regime 1 will be  $1/(1 - 0.9754) = 41$  months.  $P_{1,2}^{Fr} = 0.0744$  means  $P_{2,2}^{Fr} = 0.9256$ , suggesting the expected duration of regime 2 to be  $1/(1 - 0.9256) = 13$



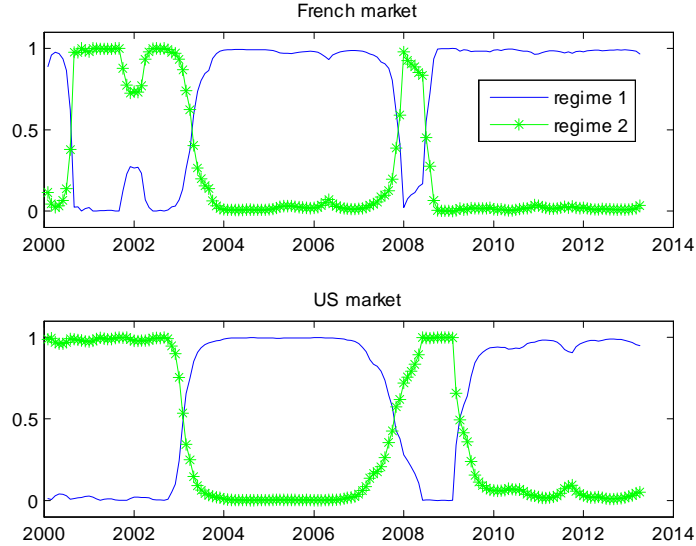
TABLE 3

Estimation result under two-market framework, sample period from January 2000 to April 2013. Subscript 0 indicates no regime switching. \*, \*\*, and \*\*\* represent significance at 10%, 5% and 1% level. P-value is in parenthesis.

$$\begin{cases} \Delta p_t^{Fr} = \alpha^{Fr} (p_{t-1}^{Fr} - u_t^{Fr}) + \beta^{Fr} (p_{t-1}^{Fr} - v_{t-1}^{Fr}) + \gamma^{Fr} (p_{t-1}^{US} - u_t^{US}) + \lambda^{Fr} \Delta S_t + \varepsilon_t^{Fr}, \\ \Delta p_t^{US} = \alpha^{US} (p_{t-1}^{US} - u_t^{US}) + \beta^{US} (p_{t-1}^{US} - v_{t-1}^{US}) + \gamma^{US} (p_{t-1}^{Fr} - u_t^{Fr}) + \lambda^{US} \Delta S_t + \varepsilon_t^{US}. \end{cases}$$

variables	Inter-market traders without regime switching		Inter-market traders with regime switching	
	France	US	France	US
$\alpha$	0.0911*** (0.000)	-0.131*** (0.006)	0.0838*** (0.000)	-0.1065** (0.029)
$\beta$	-0.036** (0.044)	-0.0231 (0.512)	-0.0551** (0.013)	-0.0160 (0.643)
$\gamma_0$	-0.1405*** (0.003)	0.0517** (0.020)		
$\gamma_1$			-0.0655* (0.064)	0.0348 (0.125)
$\gamma_2$			-0.2590*** (0.000)	0.0534** (0.036)
$\lambda_0$	759.69 (0.112)	1427.76*** (0.003)		
$\lambda_1$			1329.81*** (0.006)	1473.94*** (0.008)
$\lambda_2$			-1514.59 (0.427)	1446.74 (0.217)
$v_0$			4477.63** (0.011)	6130.98 (0.603)
$v_1$	4850.34** (0.025)	4132.94 (0.620)		
$v_2$	310.02 (0.897)	8426.74 (0.314)		
$\sigma_1$	144.61*** (0.000)	145.78*** (0.000)	163.46*** (0.000)	149.23*** (0.000)
$\sigma_2$	294.31*** (0.000)	279.93*** (0.000)	295.20*** (0.000)	295.10*** (0.000)
$P_{1,1}$	0.9843** (0.019)	0.9751** (0.016)	0.9754*** (0.004)	0.9854** (0.018)
$P_{1,2}$	0.0429 (0.906)	0.0631 (0.849)	0.0744 (0.854)	0.0416 (0.903)
LL	-1059.92	-1059.30	-1064.54	-1060.97
AIC	16.05	15.92	16.11	15.95

months. Similarly, in US,  $P_{1,1}^{US} = 0.9854$ , the market will remain in regime 1 with the expected duration of  $1/(1 - 0.9854) = 69$  months. Probability to remain in state 2  $P_{2,2}^{US} = 1 - P_{1,2}^{US} = 0.9584$ , with an expected duration of 24 months. In both markets, regime 2 has a shorter duration and investors face relatively shorter depressed periods. Based on the entire sample prices, we can calculate the smoothed probabilities at each period (algorithm details can be found from Kim and Nelson, 1999). Probabilities for regimes 1 and 2 are plotted in Fig. 2. In the timeframe when "dot com" bubble bursts before 2003, both markets are in the bust regime 2 state. From then on, both markets are in regime 1 state and enjoy the booming period till the occurrence of subprime crisis, in which both markets fall in regime 2 state again. After the subprime crisis, regime 1 starts to gain control and dominates. The switching regimes match the market episodes well. In addition, the state evolvments are similar for both markets, suggesting some commonality underlying the two markets. Notice that influence from foreign markets becomes stronger in regime 2 while both markets fall in regime 2 in the similar timeframe, contagion may occur between the two markets in regime 2.



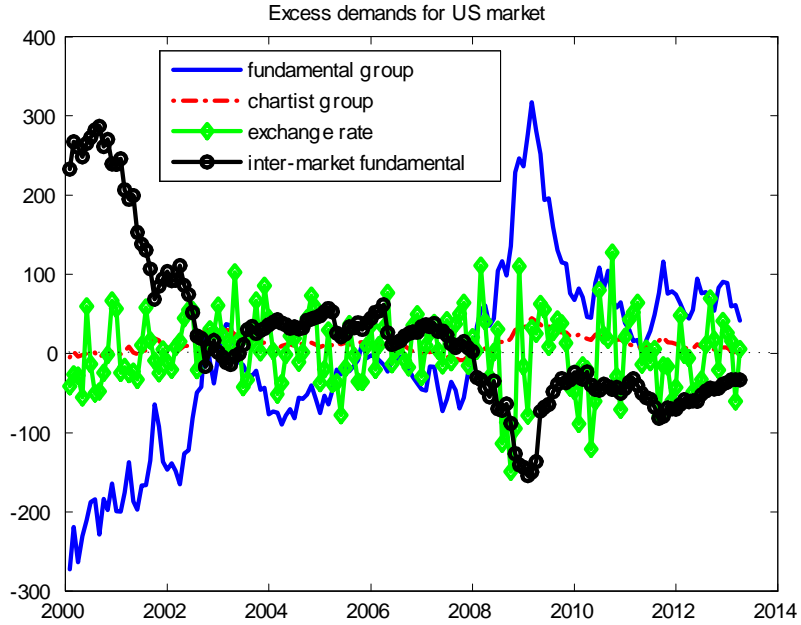
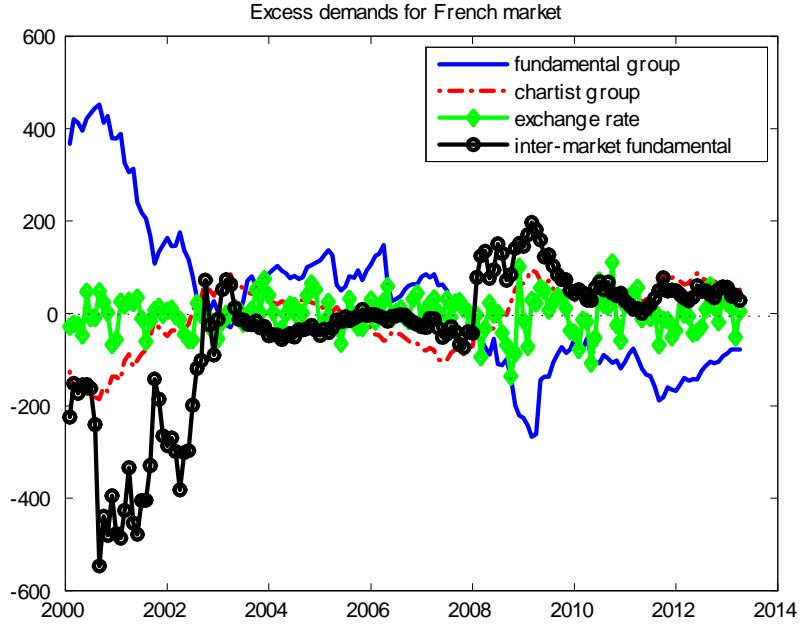
**FIG. 2** Smoothed probability of switching regimes for French and US stock markets, Green color with markers is for state 2.

To investigate the roles of different groups of traders, we plot their excess demands in Fig. 3. For the whole sample period, influence of chartist group in US is very weak. Another observation is that there is no systematic influence from the movement of exchange rate. The main players in the two markets are fundamental group and inter-market traders. During the burst of "dot com" bubble before 2003, inter-market traders and chartist group are main sellers to push price of France down while fundamental group is net buyer to push price up. In the early 2000, excess demands of the fundamental group overwhelm the sales of other traders and push the price of France to the peak. After that, demand of fundamental group decreases rapidly and we see the fast declining of the French market. In the origin of "dot com" bubble, US, it is fundamental group who are the main sellers to push price down while inter-market traders based on French fundamental are net buyers. This period corresponds to the regime 2 in both markets and inter-market traders have more influence than the normal periods. Traders relying on fundamental value of US sell in both US and France while those utilizing French fundamental value try to disk access but fail after a while.

During the booming period before the subprime crisis in 2008, price of France is mainly driven up by fundamental group while it is inter-market traders who are main drivers for price increment in US. During the subprime crisis till 2010, traders utilizing US fundamental value are the main force to support the prices of the two markets to rebound by 2010, especially in US market. In contrast, traders relying on French fundamental value are main sellers to push down the prices of the two markets during the crisis, especially in France. The excess demands of inter-market traders might imply that capital flows out from US and flows into Europe during subprime crisis.

Beginning in 2010 when Euro Debt crisis emerges, traders relying on French fundamental continue to sell in both markets with milder magnitudes. Again, traders utilizing US fundamental continue to purchase assets of both markets. The purchasing quantities are not as large as the ones during the subprime crisis. Based on analysis of the excess demands during the Euro Debt crisis in the two markets, we can infer that if there is no negative external impact from the European area, the price of US stock market could have even reached a

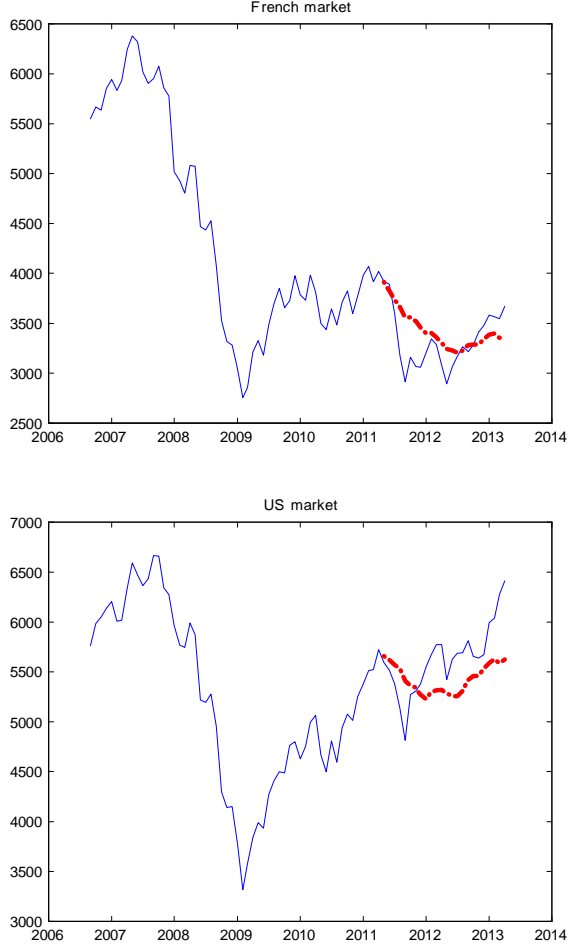
higher level. Although the market performance of France is depressed, inter-market capitals continue to flow into Europe in view of booming US stock market and investment opportunity in Europe.



**FIG. 3** Excess demands of traders for French and US stock markets.

### **3.4. Out-of-sample forecast**

To verify the forecasting capability of the model, we conduct an out-of-sample dynamic forecast. We first use the two-market model with regime switching inter-market traders to estimate the parameters based on sample periods from January 2000 to March 2011. The estimated parameters are used to forecast the prices in the rest of the periods. That is, we use 135 data points to forecast 24 periods or the remaining two years. As shown in Fig. 4, the predicted prices manage to capture the recover of the price from the Euro Debt crisis and match the actual prices quite well. This indicates the capability of the model to explain the two stock markets.



**FIG. 4** Out-of-sample forecast for French and US stock markets. The bold dash-lines are the forecasted prices.

#### 4. CONCLUSION

Given the context of globalization and financial integration, interactions among different markets, such as cross-correlation, surface out and become an important phenomenon. Nevertheless, most of the existing empirical heterogeneous agents literature focus on a single market model only while a single market model might not capture these kinds of market interactions.

Following the methodology of Chiarella et al. (2012), this paper first demonstrates the

regime switching features for the monthly price changes of stock markets of France and US under a single market framework even though the fundamental groups are seemingly statistically insignificant. By including inter-market traders whose trading decision is based on the fundamental value of the foreign market and foreign exchange rate, the fundamental groups in both markets become statistically significant, suggesting that omitted variables render the insignificance of regression under the single market framework. Further investigations show that inter-market traders are regime dependent with respect to the foreign fundamental and foreign exchange rate. The regime switching behavior of inter-market traders suggests that both markets are more sensitive to foreign fundamental during volatile periods.

The existence of inter-market traders implies that condition in one market can affect other markets. It also reveals a channel of market interactions. Fundamental values of both markets are common factors of price changes in individual markets. This provides a behavioral explanation for inter-market phenomena such as markets co-movement or cross-correlation. In the context of financial integration, individual market cannot isolate itself from the market system or just focuses solely on innovations and market state in its own market. Market players need to look at a bigger picture including other markets. This is because innovations/shocks in other markets might eventually affect its market even though there might not be direct impact from those innovation/shocks.

Compositions or weights of different agents in this paper are assumed to be constant for simplicity, to have a better understanding of market activities, it is desired to have the feature of varying agent compositions. This should be pursued in future research.

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