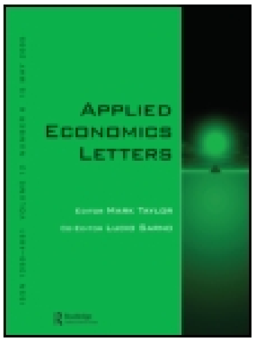

Applied Economics Letters

ISSN: 1350-4851 (Print) 1466-4291 (Online) Journal homepage: https://www.tandfonline.com/loi/rael20

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To cite this article: Wo-Chiang Lee & Hui-Na Lin (2012) Threshold effects in the relationships between USD and gold futures by panel smooth transition approach, Applied Economics Letters, 19:11, 1065-1070, DOI: 10.1080/13504851.2011.613747

To link to this article: https://doi.org/10.1080/13504851.2011.613747

Applied Economics Letters, 2012, **19**, 1065–1070

Threshold effects in the relationships between USD and gold futures by panel smooth transition approach

Wo-Chiang Lee[a,*] and Hui-Na Lin[a,b]

[a] *Department of Banking and Finance, Tamkang University, New Taipei City, Taiwan*
[b] *Department of Banking and Finance, Chihlee Institute of Technology, New Taipei City, Taiwan*

Using a Panel Smooth Transition Regression (PSTR) model, this study sets crude oil as threshold variable, and Volatility Index (VIX) and Morgan Stanley Capital International (MSCI) for Emerging Market Index (MSCI-E) as control variables to investigate the nonlinear dynamic relationship between USD/yen and gold futures in the Commodity Exchange, Inc. (COMEX). Empirical results show that the transition function is a logistic type. In region 1, the price of crude oil is low. The sign of VIX is positive. USD/yen exerts negative impact on gold market due to the way that gold market functions as a factor of hedge against portfolio and geopolitical risk. In region 2, the price of crude oil is higher (the demand for crude oil may be stronger). The economy is prosperous; VIX turns low; USD/yen increases. Investors have more money from other financial markets to buy gold, thus, causing gold futures price to rise. Besides, gold is both a hedge and a safe haven for developing countries but not for emerging countries; therefore, the relationships between gold and MSCI-E are positive in both regions.

Keywords: Panel Smooth Transition Regression model; VIX; transition function; threshold effects

JEL Classification: G10; F31; G13; G15

I. Introduction

Commodity derivatives markets have experienced tremendous growth in the recent years. Since the lowest level of gold futures price of \$262 in 2001, until the recent high of \$1510.60, the price of gold has risen more than five times. In times of economic uncertainty, attention turns to investing in gold as a safe haven (Smith, 2002).

The US dollar is a very important factor concerning the price of gold. Traditionally, a weaker US dollar makes gold look like a safer place for people to put their cash. Capie *et al*. (2005) found gold was a good external hedge against exchange rate fluctuation. Wang and Lee (2010) built a threshold vector autoregressive model to investigate the causality between the gold return and the yen depreciation rate. The results indicate that yen depreciation rate is greater than 2.62%, so investing in gold could avoid the depreciation loss.

It would be interesting and useful to distinguish whether gold and the US dollar move together over time and also to understand the moving forces behind each one of them. Does the gold and US dollar or emerging stocks substitute for the same type of risk or are they different in the sense that they can be used

*Corresponding author. E-mail: wclee@mail.tku.edu.tw

Applied Economics Letters ISSN 1350–4851 print/ISSN 1466–4291 online © 2012 Taylor & Francis
http://www.tandfonline.com
http://dx.doi.org/10.1080/13504851.2011.613747

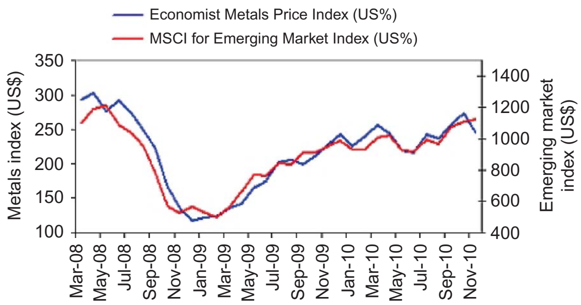

Fig. 1. Comparison of Economist Metals Price Index (US$) and MSCI for Emerging Market Index (MSCI-E) (US$)
Sources: I-Net Bridge; Plexus Asset Management.

in portfolios that diversify away risk? Would the flight to the safety of gold hold when the dollar depreciates and emerging stocks fall?

There has been much less work on gold demand in emerging market countries. Baur *et al.* (2010) mentioned in literature, gold is both a hedge and a safe haven for major European stock markets and the United States but not for Australia, Canada, Japan and large emerging markets such as the BRIC[1] countries. Do *et al.* (2009) proved that gold could be a substitute commodity for stocks in some emerging countries but could be a complement for stocks in the other emerging countries.

Gold future in the Commodity Exchange, Inc. (COMEX)[2] is the most traded on the world markets, thus study gold future in COMEX representatives the gold future in the world. There are some studies regarding the impact of foreign exchange rates on gold in the literature. However, the impact of factors such as the Volatility Index (VIX)[3] and Morgan Stanley Capital International (MSCI) for Emerging Market Index (MSCI-E) on the gold in COMEX is still rare.

Meanwhile, the MSCI-E has also recently become an important factor on gold and silver. MSCI-E is primarily driven by commodity prices and in particular by metal prices, as seen from the comparison of the MSCI-E and Economist Metals Price Index (Fig. 1). Accordingly, gold price had risen because the dollar plummeted, and the MSCI-E climbed.

Also noteworthy is that Chicago Board Options Exchange (CBOE) implied volatility as measured by the VIX. Known to the investing community, they acted to build up investors' collective defence against market downturns. The VIX has moved steadily lower even when bad news was released. When the VIX jumped above a bearish descending trend line our initial reaction was that naturally news of a country going insolvent and needing a post security would cause a bit of a panic – which would explain the fund fighting into gold and US dollar.

It is not until recently that Bhar and Hamori (2004) studied the information flow between the price change and the trading volume in COMEX gold futures contracts. The other studies that document gold futures in COMEX are few (Lin *et al.*, 2007; Lee and Lin, 2011).

It is thus interesting to evaluate the influence and nonlinear dynamic relationship that US dollar (hence USD/yen) has on gold according to crude oil price. This study applies Panel Smooth Transition Regression (PSTR) model, which was recently developed by Gonzàlez *et al.* (2005) to set crude oil as threshold variable, and determine the relative influence of variables on the linkage of gold (silver) futures in COMEX. The objectives of this study are threefold: (1) use PSTR to prove nonlinear relationship between USD/yen and gold futures; (2) set control variables of VIX and MSCI-E to explore the relationship between USD/yen and gold futures according to different ranges of crude oil price; and (3) exhibit the relationship between VIX (MSCI-E) and gold in COMEX market.

The remainder of this article is organized as follows: Section II introduces the PSTR model. Section III provides our empirical results. Section IV provides conclusion and remarks.

II. PSTR Model

We will first briefly review the PSTR model.[4] The basic PSTR model with two extreme regimes is defined as follows:

$$y_{it} = \mu_i + \beta_0' x_{it} + \beta_1' x_{it} g(q_{it}; \gamma, c) + u_{it} \quad (1)$$

for $i = 1, \ldots, N$ and $t = 1, \ldots, T$, where N and T denote the cross section and time dimensions of the panel, respectively. The dependent variable y_{it} is a scalar, x_{it} is a k-dimensional vector of time-varying exogenous variables, μ_i represents the fixed individual effect and u_{it} are the errors. Transition function $g(q_{it}; \gamma, c)$ is a continuous function of the observable variable q_{it} and is normalized to be bounded between 0

[1] A grouping acronym that refers to the countries of Brazil, Russia, India and China, which are all deemed to be at a similar stage of newly advanced economic development.
[2] COMEX is also a division of the New York Mercantile Exchange (NYMEX).
[3] VIX is the ticker symbol for the Chicago Board Options Exchange VIX, a popular measure of the implied volatility of Standard & Poor (S&P) 500 index options.
[4] For more details, see Gonzàlez *et al.* (2005) and Colletaz and Hurlin (2006).

and 1, and these extreme values are associated with regression coefficients β_0 and $\beta_0 + \beta_1$. More generally, the value of q_{it} determines the value of $g(q_{it}; \gamma, c)$ and thus the effective regression coefficients $\beta_0 + \beta_1 g(q_{it}; \gamma, c)$ for individual i at time t. The widely used transition function is a logistic specification as in Equation 2

$$g(q_{it}; \gamma, c) = \left(1 + \exp\left(-\gamma \prod_{j=1}^{m} (q_{it} - c_j)\right)\right)^{-1}$$
$$\text{with } \gamma > 0 \text{ and } c_1 \leq c_2 \leq \ldots \leq c_m \quad (2)$$

where $c = (c_1, \ldots, c_m)$ is a m-dimensional vector of location parameters and the slope parameter γ determines the smoothness of the transitions. The restrictions $\gamma > 0$ and $c_1 \leq \ldots \leq c_m$ are imposed for identification purposes. In practice it is usually sufficient to consider $m = 1$ or $m = 2$, as these values allow for commonly encountered types of variation in the parameters. For $m = 1$, the model implies that the two extreme regimes are associated with low and high values of q_{it} with a single monotonic transition of the coefficients from β_0 to $\beta_0 + \beta_1$ as q_{it} increases, where the change is centred around c_1. When $\gamma \to \infty$, $g(q_{it}; \gamma, c)$ becomes an indicator function $I[q_{it} > c_1]$, defined as $I[A] = 1$ when the event A occurs and 0 otherwise. In that case the PSTR model in Equation 1 reduces to the two-regime panel threshold model of Hansen (1999). For $m = 2$, the transition function has its minimum at $(c_1 + c_2)/2$ and attains the value 1 both at low and high values of q_{it}. When $\gamma \to \infty$, the model becomes a three-regime threshold model whose outer regimes are identical and different from the middle regime. In general, when $m > 1$ and $\gamma \to \infty$, the number of distinct regimes remains 2, with the transition function switching back and forth between 0 and 1 at $c_1, \ldots, c_m$. Finally, for any value of m the transition function becomes constant when $\gamma \to 0$, in which case the model collapses into a homogenous or linear panel regression model with fixed effects.

A generalization of the PSTR model to allow for more than two different regimes is the additive model:

$$y_{it} = \mu_i + \beta_0' x_{it} + \sum_{j=1}^{r} \beta_j' x_{it} g_j(q_{it}^{(j)}; \gamma_j, c_j) + u_{it} \quad (3)$$

where the transition functions $g_j(q_{it}^{(j)}; \gamma_j, c_j), j = 1, \ldots, r$ are of the logistic type. If $m = 1, q_{it}^{(j)} = q_{it}$ and $\gamma_j \to \infty$, for all $j = 1, \ldots, r$, the model in Equation 3 becomes a PSTR model with $r + 1$ regimes. Consequently, the additive PSTR model can be viewed as a generalization of the multiple regime panel threshold model in Hansen (1999). Additionally, when the largest model that one is willing to consider is a two-regime PSTR model with $r = 1$ and $m = 1$ or $m = 2$, Equation 3 plays an important role in the evaluation of the estimated model. In particular, the multiple regime Equation 3 is an obvious alternative in diagnostic tests of no remaining heterogeneity.

The building procedure of PSTR model consists of specification, estimation and evaluation stages. Specification includes testing homogeneity, selecting the transition variable y_{it} and, if homogeneity is rejected, determining the appropriate form of the transition function, that is, choosing the proper value of m in Equation 2. Statistically, the PSTR model is not identified if the data-generating process is homogenous, and a homogeneity test is necessary to avoid the estimation of unidentified models. As to the estimation of parameters $\theta = (\beta_0', \beta_1', \gamma, c')'$ in the PSTR model is a relatively straightforward application of the fixed effects estimator and nonlinear least squares. Evaluation of an estimated PSTR model is an essential part of the model building procedure, which includes the tests of parameter constancy over time and of no remaining nonlinearity.

III. Empirical Results and Analysis

The data are retrieved from the Bloomberg database. This article sets VIX and MSCI-E as control variables, investigating the nonlinear relationship between USD/yen and gold futures according to threshold variable of crude oil in COMEX. So, the data set consists of price of gold futures, and spot rate of West Texas Intermediate (WTI) crude oil, USD/yen, VIX[5] and MSCI-E. The sample period for this study covers 20 years, from January 1990 to December 2009. The entire analysis is conducted on return data.

Table 1 reports the descriptive statistics. It shows the high kurtosis and negative skewness pattern. We observe that the characteristics of positive skewness (skewed right) or fat tail are also showed in these series. In addition, all the variables reject the hypothesis of normal distribution, although the Ljung–Box statistics (Q) for up to 10, 15 and 20 lags calculated for each piece of raw data shows the absence of linear autocorrelation.

Table 2 presents the linearity test results between crude oil and gold futures price. The Lagrange Multiplier (LM), Fisher and Likelihood Ratio (LR) linearity tests clearly lead to the rejection of the null

[5] The VIX is known as the fear index.

Table 1. Summary statistics of variables

	COMEX gold	Crude oil	Japan yen	VIX	MSCI-E
Mean	429.7242	34.5962	115.5511	20.0986	480.1994
SD	184.6207	23.4816	13.6488	7.9864	229.5361
Minimum	253.9000	10.7200	80.6300	80.0600	175.3400
Maximum	1 218.3000	145.2900	159.9000	80.0600	1 338.4900
Skewness	1.8418	1.8724	0.4381	1.8697	1.5556
Kurtosis	5.5888	6.6457	3.4376	9.3589	5.1958
J–B statistics	3 581.9054*	4 826.5949*	169.4846*	9 616.4202*	2 562.5717*
$Q(10)$	41 440.1962*	41 772.0202*	41 071.9555*	36 966.9113*	41 827.7396*
$Q(15)$	61 443.4375*	62 162.0366*	60 640.0764*	52 665.2938*	62 291.6974*
$Q(20)$	80 990.3827*	82 114.2031*	79 590.5697*	66 693.8849*	82 436.6161*

Notes: J–B statistics, Jarque–Berra (J–B stat.) normality test; Q, Ljung–Box statistic; VIX, Volatility Index; MSCI-E, MSCI for Emerging Market Index; COMEX, Commodity Exchange, Inc.
*Significant at 5% level.

Table 2. Test of linearity

H_0: linear model against H_1: PSTR model with at least one threshold variable ($r \geq 1$)

	Statistics	p-Value
Wald tests (LM)	1480.6810	0.000
Fisher tests (LM_F)	597.5890	0.000
LR Tests (LRT)	1627.2530	0.000

Notes: The LM and pseudo-LRT statistics have a χ^2 distribution with mk degrees of freedom, whereas the F-statistics has a $F(mk; TN - N - K(m + r + 1))$ distribution. LM_F is its F version. Pseudo-LRT can be computed according to the same definitions by adjusting the number of degrees of freedom. PSTR, Panel Smooth Transition Regression; LM, Lagrange Multiplier; LR, Likelihood Ratio.

hypothesis of linearity for the model. This result implies that there is strong evidence that the relationship between crude oil and gold is nonlinear in COMEX.

This study applies the sequence of tests to determine the order m of the logistic function. In practice, it is usually sufficient to consider $m = 1$ (monotonically increasing with two regimes) or $m = 2$ (symmetric or exponential with three regimes) transition function, as these values allow for commonly encountered types of variation in the parameters. The results are in the specification test sequence in Table 3; this study will select $m = 1$ if the rejection of H_2 is the strongest one. This study finds that the results are monotonically increasing in Fig. 2.

Table 3. Sequence of homogeneity tests for selecting *m*

Select $m = 2$ if the rejection of H_2 is the strongest one, otherwise select $m = 1$

	Statistics	p-Value
H_3: B3 = 0	$F3 = 43.1050$	0.0000
H_2: B2 = 0|B3 = 0	$F2 = 124.8240$	0.0000
H_1: B1 = 0|B2 = B3 = 0	$F1 = 199.1960$	0.0000

The next step is to determine the number of transitions in the model. Table 4 testing for nonremaining nonlinearity consists of checking whether there is one transition function (H_0: $r = 1$) or whether there are at least two transition functions (H_1: $r = 2$); in addition, this study also tests two transition functions (H_0: $r = 2$) or whether there are at least two transition functions (H_1: $r = 3$). The testing results show that the reasonable numbers of threshold $r = 2$, which means that there are two regions. Each region has two regimes.

Table 5 shows the PSTR models' parameters estimation results. The transition function is logistic specification ($m = 1$ with two regimes) and there are two regions ($r = 2$), C are location parameters in regions 1 and 2, and the values are 34.7834 and 52.6408, respectively. The above result shows that there are structural changes at these two points (see also Fig. 2). The transition function is a logistic specification.

One can observe that the USD/yen is positive (2.9849), the value of VIX is negative (–10.2323) and MSCI-E is negative (–0.4075) if no any structure change for crude oil. When the crude oil is below 34.7894, the economy is sluggish. MSCI-E is declining. Money flights to gold and US dollar from other financial assets to avoid risk.

In region 1, when the crude oil is between 34.7834 and 52.6408, the parameter of USD/yen is negative, while VIX and MSCI-E are positive. The signs match the desired results. Gold climbs because of the dollar depreciation, fear index climbing and MSCI-E increase. When the time is poorer and the crude oil demand is weak, USD/yen exerts negative impact on the gold market due to the way that gold market functions as a factor of hedge against portfolio and geopolitical risk. In addition, when the VIX increases (fear index is higher) investors will invest in safe products such as gold.

Table 4. Testing the number of regions: tests of no remaining nonlinearity

H_0: PSTR with $r = 1$ against H_1: PSTR with at least $r = 2$		
	Statistics	p-Value
Wald tests (LM)	154.0300	0.0000
Fisher tests (LM_F)	52.2250	0.0000
LR Tests (LRT)	155.4450	0.0000
H_0: PSTR with $r = 2$ against H_1: PSTR with at least $r = 3$		
Wald tests (LM)	1.1700	0.7600
Fisher tests (LM_F)	0.3890	0.7610
LR Tests (LRT)	1.1700	0.7600

Notes: Maximum $r = 3$, $m = 1$, the reasonable numbers of threshold $r = 2$. PSTR, Panel Smooth Transition Regression; LM, Lagrange Multiplier; LR, Likelihood Ratio.

Table 5. Parameter estimation results for PSTR model

	β_0	$\beta_0 + \beta_1$	$\beta_0 + \beta_2$
USD/yen	2.9849* (9.5652)	−8.0845* (−17.9667)	3.9166* (6.7402)
VIX	−10.2323* (−24.7317)	34.7057* (25.6234)	−16.8157* (−6.7669)
MSCI-E	−0.4075* (−10.6224)	0.9270* (9.7588)	0.4361* (3.6866)
(C_1,C_2)		(34.7834), (52.6408)	
(γ_1,γ_2)		(0.7768), (0.2522)	
SSE		535 121 334.2980	

Notes: Threshold variable: crude oil; control variables: USD/yen, VIX, MSCI-E. C are location parameters; γ is the slope parameter (smooth parameter or transition speed); PSTR, Panel Smooth Transition Regression; VIX, Volatility Index; MSCI-E, MSCI for Emerging Market Index.
*Significant at 5% level.

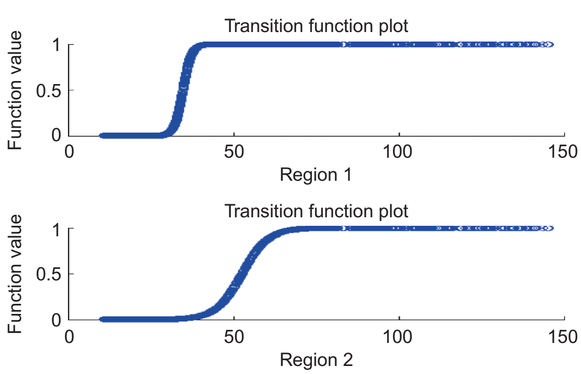

Fig. 2. Transition function with $m = 1$

In region 2, crude oil has a structure change at 52.6408. The slope parameter indicates how rapidly the transition of g from 0 to 1 takes place. While the slope parameter is 0.2522, it shows a slow transition. While crude oil is larger than 52.6408, the parameters of USD/yen and MSCI-E are positive, and VIX is negative. When time is prosperous (crude oil price is higher due to stronger demand), the VIX is low, US dollar is up and MSCI-E is rising. Investors have more money from other financial markets to buy gold.

Investors in emerging countries (such as India and China), who favour gold, will have more money from stock markets to buy gold, thus causing the price of gold futures to increase. Besides, gold is both a hedge and a safe haven for developing countries but not for emerging countries (Baur *et al.*, 2010); therefore, the relationship between gold and MSCI-E is positive in both regions.

The sign is negative for MSCI-E in the range without structure break and positives in both regions. The possible explanation is that gold could be a substitute commodity for stocks in some emerging countries but could be a complement for stocks in the other emerging countries (Do *et al.*, 2009).

Equation 4 shows the full PSTR model for region 1:

$$\begin{aligned}\text{Gold}_{it} = {} & \mu_i + 2.9849\text{USD/yen}_{it} - 10.2323\text{VIX} \\ & - 0.4075\text{MSCI-E} \\ & + \beta_1' g(\text{Crudeoil}_{it}, 0.77675, 34.7834) \\ & (-11.0694\text{USD/yen}_{it} + 44.93801\text{VIX} \\ & + 1.3345\text{MSCI-E}) \\ & + \beta_2' g(\text{Crudeoil}_{it}, 0.252168, 52.6408) \\ & (0.9317\text{USD/yen}_{it} - 6.5834\text{VIX} \\ & + 0.8436\text{MSCI-E})\end{aligned} \tag{4}$$

IV. Conclusion and Remarks

Empirically, this study constructed a model to discuss the nonlinear dynamic relationship between USD/yen and gold according to crude oil prices. We find that the transition function is a logistic type. Transition speed will affect the shape of the transition function. The lesser (greater) the transitional speed is, the smoother (steeper) the transition function. Meanwhile, the model has two regions. Each region has two regimes. A nonlinear dynamic relationship exists between USD/yen and gold. If no any structure changes for crude oil, the economy turns sluggish and MSCI-E is declining. Money flights to gold and US dollar from other financial assets to avoid risk. In region 1 (2) the sign of USD/yen is negative (positive). In region 1, when the time is poor (the price of crude oil is low because of the weak demand), VIX is high and USD/yen exerts negative impact on gold market due to the way that gold market functions as a factor of hedge against portfolio and geopolitical risk. The gold is response to negative shock of exchange rate market when market experiences stress, the increased volatility from other markets is transmitted to the gold market which acts as safe haven. In region 2, when the time is prosperous (the price of crude oil is higher because the demand for crude oil is stronger), VIX turns low, and both the exchange market and emerging markets are up. Besides, gold is both a hedge and a safe haven for developing countries but not for emerging countries (Baur *et al.*, 2010); therefore, the relationship between gold and MSCI-E is positive in both regions. The signs are opposing. Negative for MSCI-E in the range without structure break and positive in both regions. The possible explanation is that gold could be a substitute commodity for stocks in some emerging countries but could be a complement for stocks in the other emerging countries (Do *et al.*, 2009). The implications suggest that investors should take crude oil as a crucial indicator for buying gold futures.

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