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DOES GOLD ACT AS INFLATION HEDGE IN THE USA AND JAPAN?

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ABSTRACT. ***This study investigates the rigidity of gold price adjustment and the inflation-hedging ability of gold in U.S. and Japan applying the linear and non-linear cointegration test and the non-linear threshold regression model. Based on thirty-six years of gold price and Consumer Price Index (CPI) data, it is found in the short-run that gold return is unable to hedge against inflation in both countries when gold price adjustment is in the low-momentum regime. During high-momentum regime, the gold return is unable to fully hedge against inflation in Japan because of the rigid adjustment between gold price and CPI; however, the gold return fully hedges against inflation in U.S. where the gold price adjustment is not rigid. These findings also explain why gold in U.S. effectively hedges against inflation and gold in Japan just partially hedges against inflation in the long-run.***

KEYWORDS: gold price, inflation hedge, cointegration test, price rigidity, non-linear model, the USA, Japan.

JEL classification: C32, E31, E44.

Introduction

Gold is the asset that has attracted people for thousands of years and this attraction continues to the present day because, according to Worthington and Pahlavani (2006), unlike most commodities, gold is durable, relatively transportable, universally acceptable and easily authenticated. The demand for gold is ever increasing, not only for jewellery, coins, and bars but also for many industries, such as electronics, space, as well as medical technology. It is gold which still a form of currency in many countries is after the collapse of the Bretton Woods system in 1971.

Many economic analysts suggest that gold prices are determined and influenced by a number of factors, such as mine production, fabrication demand, and the recovery of gold from scrap. Much greater influence is exerted by trends in central bank sales and purchases. Trend in investment demand is the most important of all. Investors buy gold for a number of reasons. They buy gold as a hedge against any economic, political, or currency crises. They also buy gold for diversification and financial arbitrage when investment confidence is increasing because they have the common sense that physical assets, unlike financial assets, are the best way to hedge against recession and inflation. The development of the gold market is followed closely by financial analysts and monetary policy makers and gold price is regarded as a good criterion of the inflationary trend in the future for it moves earlier than official measures of inflation.

Fisher (1930), the economist who first pointed out the relationship between expected inflation and interest rate, provides the theoretical basis for this study. Fisher (1930) concludes that the expected nominal return to an asset comprises expected return and expected inflation rate. In other words, when expected inflation rises, asset return will rise. Later, the primary empirical test on inflation hedge of assets including U.S government bonds and bills, real estate, labour income, and stock returns was carried out by Fama, Schwert (1977). Ghosh *et al*. (2004) point out that people buy gold for two purposes. The first is the "use demand", where gold is used directly in the production of jewellery, medals, coins, electrical components, and so on. The second is the "asset demand" for gold, where it is used by governments, fund managers and individuals as an investment. The asset demand for gold is traditionally associated with the view that gold provides an effective "hedge" against inflation and other uncertainty. However, according to Ghosh *et al*. (2004), gold may be an inflation hedge in the long-run but it is also characterized by significant short-run price volatility.

When it comes to inflation, the value of gold is considered to be preserved, for its price will increase along with the rise in the general level of prices. In other words, it is believed that a higher inflation rate relates to what gold prices said should be happening. However, the question is that how well gold hedge really works. Each country has its own economic conditions or characteristics. This issue is worth examining and verifying under non-linear model which might discover the key reasons that the linear model is unable to do.

This study mainly focuses on the presence of adjustment rigidity between gold price and consumer price index (CPI). Theoretically, the asset price displays the rigidity because the non-complete competitive market generates the price discrimination and the non-complete pass-through of costs to consumers, which causes the asset price to be unable to respond to the changes of CPI and lead to the disequilibrium of the market. Gold price is not an exception. Hence, it is wondered if the long-run equilibrium price of gold does not exist or the inflation hedge of gold is ineffective. Actually, when the short-run market disequilibrium is taken into consideration, it is discovered that the long-run relationship between gold price and CPI is still stable within the framework of a non-linear model. Relative to the research methodology and subject of recent studies, such as that considered by Ghosh *et al*. (2004), Twite (2002), Capie *et al*. (2005), Worthington, Pahlavani (2006), we do not only examine if the inflation hedge of gold is a non-linearity with different momentum regimes, but also create the short-run non-linear model to verify the relationship between gold return and inflation in the short-run.

Two large economies, United States and Japan, are involved in this study for exploring the inflation hedging effectiveness of gold in the long-run as well as in the short-run. The steps and intentions of this empirical research covers: (1) the threshold cointegration is employed to test for the cointegration between gold price and CPI and for the inflation hedging ability of gold in the long-run; (2) the threshold error correction model is created to examine if the disequilibrium adjustment of prices between gold price and CPI is characterized by asymmetry, if yes, the disequilibrium adjustment of prices momentum is then used as a threshold variable to explore the inflation hedging effectiveness of gold investment within high and low regime.

The empirical results after the threshold cointegration test of Enders, Siklos (2001) prove that the relationship between the gold price in Yen and Japanese CPI presents the non-linear (asymmetric) threshold cointegration and the relationship between the gold price in U.S. dollar and U.S. CPI presents the linear (symmetric) cointegration. Therefore, using gold as an inflation hedge is almost absolutely effective in U.S. in the long-run, however, only partly effective in Japan. Additionally, the result of non-linear threshold error correction model reveals that inflation in both countries could indirectly influence the gold return through the short-run disequilibrium adjustment of prices within high-momentum regime and the rise in gold return can stimulate the rise in inflation. However, the inflation hedging ability of gold in the short-run is only evident in U.S. It also displays that the relationship between gold price and CPI in both countries does not exhibit the causality within low-momentum regime. Especially, it is discovered that the adjustment rigidity between gold price and CPI, and the price adjustment in high-momentum regime are the key elements influencing the inflation hedging ability of gold investment.

The remainder of this paper is organized as follows. Section 2 briefly reviews the related literature. In Section 3 the data, empirical approach and main results are presented. Finally, in Section 4 the conclusions are stated.

1. Literature Review

The economic and financial literature has yielded a larger number of in-depth studies relating to the critical functions of gold in economy, which can be roughly classified into four main groups.

1. Focusing on the impacts of macroeconomic news on gold price, Sherman (1982, 1983), Ariovich, (1983), Fortune (1987), Dooley *et al*. (1995), Sjaastad, Scacciallani (1996), and Lucey *et al*. (2004) investigate the relation between economic variables and gold price and find the effects of exchange rates, interest rates, income, etc. releasing on gold prices.
2. Focusing on the prediction of gold price, Koutsoyiannis (1983), Baker, Van (1985), Diba, Grossman (1984), Pindyck (1993) examine the factors that influence the variations of the gold price.
3. Focusing on the benefit of gold in portfolios, Sherman (1986), Jaffe (1989), Chua *et al*. (1990), Ciner (2001), and Michaud *et al*. (2006) study the correlation between Gold and other major assets and find that this correlation is low, or negative, which offers the power of diversification across much of a long-term portfolio.
4. Focusing on the inflation hedge of gold, Chappell, Dowd (1997), Kolluri (1981), Laurent (1994), Mahdavi, Zhou (1997), Moore (1990), Ghosh *et al*. (2004), Capie *et al*. (2005), Levin, Wright (2006), Worthington, Pahlavani (2006), explore the short-run as well as long-run relationships between the gold price and the general price level to investigate the hedge inflation effectiveness of gold.

The idea that gold as an inflation hedge is not new, which is virtually found with related papers like "*gold is an asset of "safe havens" against the debasement of paper money" , "gold is leading indicators of inflation*" *or "gold is an inflation hedge"* and so on. Mahdavi, Zhou (1997) test the performance of gold and commodity prices as leading indicators of inflation with cointegration and vector error-correction model (VECM) over 1958-1994. Their findings show that the stability of the gold price signalling inflation may vary depending on the time span being examined. Ranson, Wainright (2005) conclude that the price of gold is the superior predictor of the next year inflation. Capie *et al*. (2005) apply Exponential generalized autoregressive conditional heteroskedasticity (EGARCH) technique to investigate the exchange rate hedge of gold price by using weekly data over the period 1971- 2004. They find that the gold returns can be a hedge against U.S. dollar depreciation and that there is a negative relationship between gold price and sterling-dollar and yen-dollar exchange rates but the strength of this relationship varies over time.

Laurent (1994), Harmston (1998), Ghosh *et al*. (2004) who study the relationship between the gold price and wholesale price find that gold acts effectively as a long-run inflation hedge in U.S., Britain, France, Germany, and Japan. Using monthly gold price data

(1976–1999), and cointegration regression techniques, Ghosh *et al*. (2004) investigate the contradiction between short-run and long-run movements in the gold price and find that the gold price rises over time at the general rate of inflation and hence is an effective hedge against inflation under a set of conditions. Levin and Wright (2006) examine the factors that contribute to the fluctuation of gold price with cointegration and VECM techniques over 1976- 2005. Their findings are triple. First, there is a long-run relationship between the price of gold and U.S. price level. Second, there is a positive relationship between changes in the gold price and changes in U.S. inflation, U.S. inflation volatility, and credit risk, while there is a negative relationship between gold price movements and changes in the trade weighted U.S. dollar exchange rate and the gold lease rate. Third, in the major gold consuming countries such as Turkey, India, Indonesia, Saudi Arabia, and China gold acts effectively as a long-term hedge against inflation.

The findings of prior studies that prove the effective inflation hedge of gold are almost consistent. However, there is a constraint on research technique employed because they all apply the linear model to explore the relationship between the gold return and inflation. Thus, they ignore the possible non-linear relationship between these two variables. It is known that the gold price and inflation might result in business cycle fluctuations, which cause the non-linearity or asymmetry of the model fitted for their relationship. If asymmetric phenomenon is not taken into account in the model estimation or is not verified before the estimation, the empirical findings might be biased.

Recent studies suggest that the relationship between commodity price fluctuations and inflation should be asymmetric, caused by the business cycle, characteristic of price adjustment, etc. Kyrtsou, Labys (2006) construct a noisy chaotic multivariate model describing the relationship between commodity price and inflation. They strongly confirm their argumentation about the incapability of linear tools to ‘‘understand’’ economic dynamics when a bi-directional non-linear relationship between U.S. inflation and commodity prices has been identified again.

The primary purpose of this study is to present further asymmetric effect on the relation between CPI and gold price in the short-run and long-run which might be caused by the imperfect competition in the market and the existence of the transaction cost. The research technique of this study differs from the ones employed by Ghosh *et al*. (2004), Twite (2002), Capie *et al*. (2005), and Worthington, Pahlavani (2006). We first use the threshold model to examine the threshold effect and the possible non-linear relationship between the gold return and inflation. Our analysis is based on the different speeds and the rigidity of price adjustment.

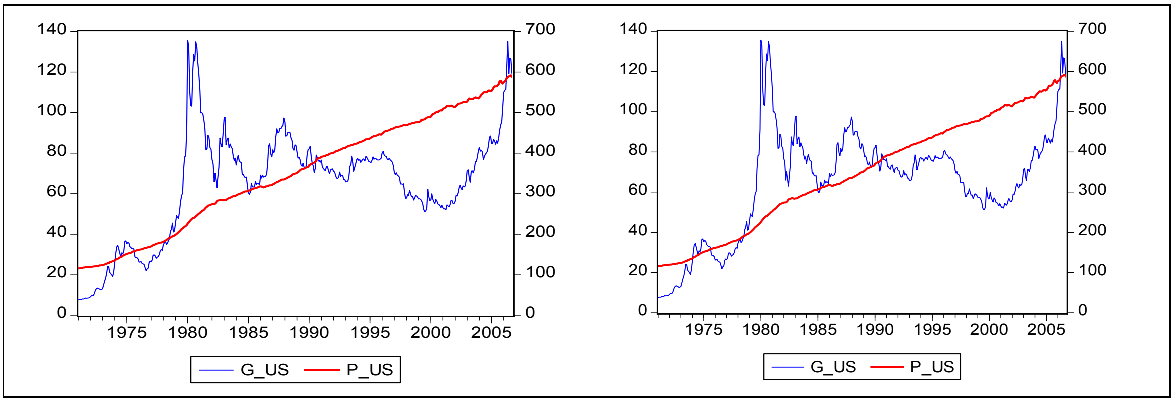
This paper contributes to the literature in several ways, to the best of our knowledge; this is the first paper to apply both, the long-run nonlinear and the short-run threshold model to examine whether gold is an effective inflation hedge. In addition, we study the non-linear short-run adjustment towards long-run equilibrium from the viewpoint of the price adjustment rigidity. Finally, we employ the bivariate nonlinear vector autoregression (VAR) model, not univariate VAR model used by Capie *et al*. (2005). Relative to the univariate VAR model which endogenous variables need support from theoretical models or strong assumptions, the bivariate VAR (or nonlinear VAR) model does not need any extra support and can be used to systematically examine the dynamic relationships among the variables to avoid bias from the assumption of the one-way causality between two variables.

2. Data, Methodology and Empirical Results

2.1 Data Description

This study mainly focuses on the inflation hedge ability of gold in U.S and Japan during January 1971 to October 2006 with the monthly data of CPI and gold prices in the yen and U.S dollar. The data source for CPI is the International Financial Statistics of International Monetary Fund (IMF) and the data source for gold price is the World Gold Council. Gold is priced in both the U.S dollar and Yen per ounce and these prices are based on the London pm fix[1].

In order to preliminarily understand the relationship between CPI and gold price in Japan and U.S., the movement of gold price in these two markets is illustrated in *Figure 1*. It is seen that CPI in both countries is generally on an upward trend. However, the situation is somewhat different, the rising speed of U.S.'s CPI is faster than Japan's and Japan's CPI has shown the falling movement since the financial crisis of 1997. Regarding the movement of gold price, it is observed that the gold price is more volatile during 1974 – 1980; the reason should be the effect of oil crisis. The after-effects of the first oil crisis were noticed in 1973, U.S.'s industrial production value decreased 14% and GDP dropped off 4.7%; Japan's industrial production value diminished more than 20% and GDP fell off 7%. The second oil crisis occurred in 1979 and caused a 3% drop in GDP of U.S.



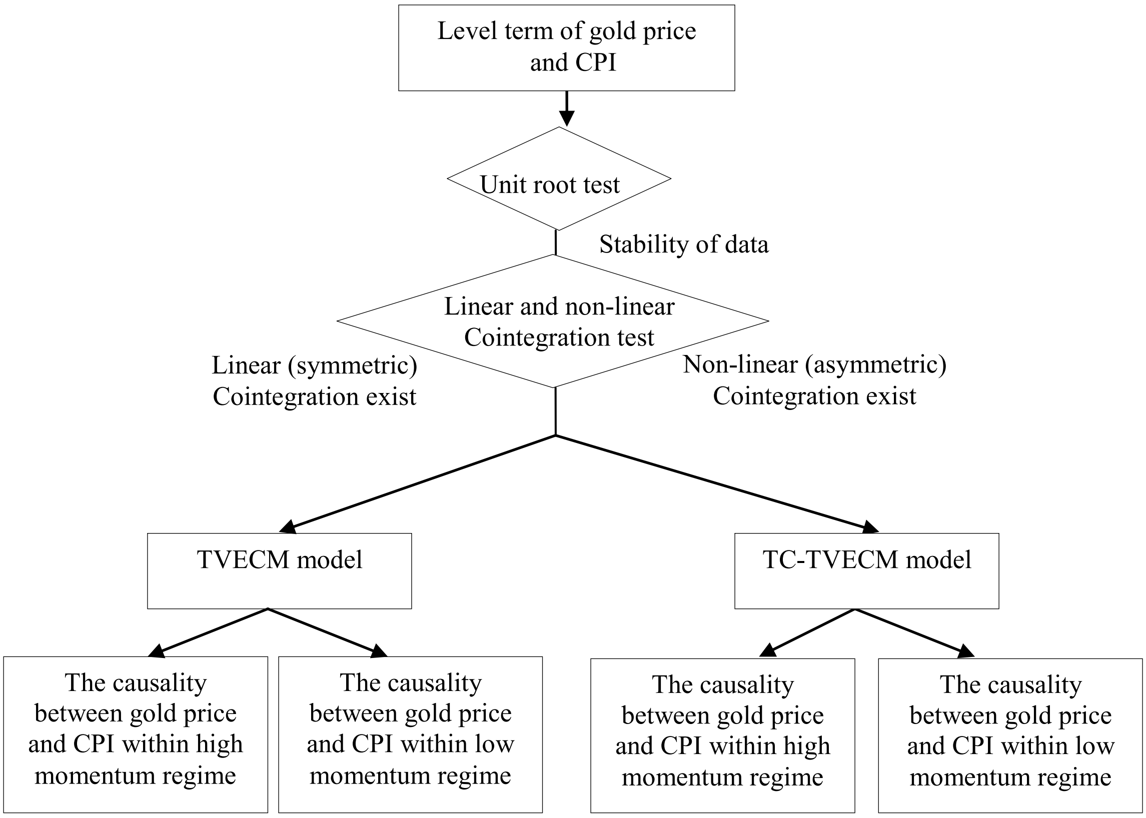
Source: created by the authors.

Figure 1. **The Trend of Gold Price (G) and Consumer Price Index (P) In Japan and U.S**

These two oil crises led to the high ground of gold and the gold price reached its peak in 1980. Worrying about inflation, FED has continuously raised the interest rate of U.S. dollar since September 2005, and gold price goes up in the same time. The price of gold soars to a new peak month by month since then, driven by the weak dollar, strong oil prices, and global inflationary fears. It is clear that the gold price in U.S. dollar is more volatile than in the Yen. The gold price in Yen has been on downward tendency since 1980; however, the gold price in U.S. dollar has been on upward tendency after the continuous decline in 1980. This presents the visual difference between gold price in Yen and in U.S dollar. Meanwhile, it is also

[1] The related Website is: http://www.gold.org/value/stats/statistics/monthlysince1971.html. Additionally, it is undeniable that thirty years of data doesn't result in many data points. This limit comes from data itself. Even though the gold price data is daily, CPI data is monthly. Therefore, only monthly data is applicable for empirical study. The low degrees of freedom may impact the structure and estimation of the model used. However, our fitted models and all diagnose tests conform to requirements of statistics, ensuring the stability of our empirical results.

observed that CPI and gold price move in the same direction in U.S., whereas the gap between CPI and gold price is wider in Japan, implying the presence of rigidity.[2]



Source: created by the authors.

Figure 2. **Flow Chat of Empirical Procedure**

Figure 2 that reports the entire empirical procedure is used to illustrate how to get the empirical results. The unit root test is first applied to the log of gold prices and CPIs. When variable is I (1) series, Engle and Granger (1987) linear cointegration test and Enders, Siklos (2001) nonlinear threshold cointegration test are further applied to check if the long-run relationship between variables is stable. Then, the inflation hedge ability of gold return in the long-run can be verified under this relationship. If the short-run relationship is nonlinear and the long-run relationship is stably linear (symmetric), TVECM (threshold vector error correction model) is used as the framework model to analyze the short-run adjustment process; and if the long-run relationship is stably nonlinear (asymmetric), then TC-TVECM (threshold cointegration-threshold vector error correction model) is used as the framework model to analyze the short-run adjustment process. The causality test is finally employed to examine the inflation hedging ability of gold in the short-run.

2.2 Unit Root Test

Nelson, Plosser (1982) indicate that many macroeconomic variables are characterized by non-stationary factors, which do not satisfy the hypothesis of stationarity or residual

[2] Compared to studies that employ the dummy variables to examine the impact of structural breaks, this paper focuses on the variation of gap between variables and creates structural breaks based on the characteristics of variable. Hence, the threshold regression model is best choice for providing investors the better time where inflation hedge of gold is effective.

stationarity of regression and lead to the spurious regression. Unit root test aims at verifying the integrated order of time series and deciding to utilize the level, or differential variable for empirical process. Four unit root tests, including Augmented Dickey-Fuller (1979, ADF), Phillips, Perron (1988, PP), Elliott *et al*. (1996, DF-GLS), and Ng, Perron (2001, NP-MZ_a), are employed to test the stationarity of variables.

Table 1. Unit root test

	ADF		PP		DF-GLS		NP-MZ_a	
Level	Statistic value	lags	Statistic value	Bandwidth	Statistic value	lags	Statistic value	lags
$\ln g\_jp$	-3.131	[9]	-2.574	[6]	-1.318	[9]	-3.865	[9]
$\ln p\_jp$	-3.119	[8]	-3.267	[10]	-0.482	[7]	-0.071	[5]
$\ln g\_us$	-3.103	[7]	-2.971	[3]	-1.383	[11]	-3.200	[10]
$\ln p\_us$	-1.919	[10]	-0.870	[13]	-0.251	[7]	-0.423	[5]
First difference								
$\Delta\ln g\_jp$	-5.002***	[8]	-15.63 ***	[2]	-4.890***	[8]	-26.88***	[8]
$\Delta\ln p\_jp$	-4.028***	[7]	-17.49***	[10]	-2.994**	[6]	-32.12***	[4]
$\Delta\ln g\_us$	-6.801***	[6]	-15.54***	[1]	-3.831***	[10]	-19.95***	[9]
$\Delta\ln p\_us$	-3.565**	[9]	-15.26***	[11]	-3.813***	[6]	-28.72***	[4]

Note: ADF equation includes constant and time trend. The maximum lag applied is 12 periods. The numbers in parentheses [.] are the lag order in ADF, DF-GLS and NP-MZ_a tests. The optimal lags are selected according to AIC. Bandwidths are for the Newey-West correction of the PP test. *** and ** respectively indicate the 1% and 5% significant level. Critical values of ADF, PP, and DF-GLS are from Mackinnon (1991). Critical values of NP-MZ_a are from Ng-Perron (2001).

Source: own calculations.

The equation of unit root regression contains both, constant and time trend. The results of four unit root tests reported in *Table 1* significantly show the I (1) characteristic of all level variables and the stationarity of differential variables.

2.3 Cointegration Test

Testing for the long-run relationship between gold price and CPI, Engle, Granger (1987)'s linear cointegration test and Enders, Siklos (2001)'s nonlinear threshold cointegration test are separately applied. Testing technique of Enders, Siklos (2001) comprises two tests, TAR (Threshold autoregressive) and MTAR (Momentum threshold autoregressive). This long-run relationship is given by:

$$\ln g_t = \theta_0 + \theta_1 \ln p_t + e_t \qquad (1)$$

$\ln g_t$ is the log of gold price, $\ln p_t$ is the log of CPI. θ_0 is the constant term or the true value of gold price; θ_1 is the hedging coefficient that denotes how well gold investment could hedge against inflation or the cross-price elasticity between gold price and CPI, and *et* is the error term. θ_1=1 means that the percentage change in CPI is equal to the percentage change in gold price, showing the complete inflation hedge of gold price in the long-run. 0< θ_1 <1 presents the partial inflation hedge of gold price.

According to Engle, Granger (1987), the presence of long-run relationship involves stationary *et*. In order to accept the stationarity of *et*, $-2 < \rho < 0$ should be obtained in the second step procedure:

$$\Delta e_t = \rho e_{t-1} + \varepsilon_t \tag{2}$$

where ε_t is the white-noise disturbance. If -2 < ρ < 0, the long-run equilibrium relationship (1) with symmetric adjustment (2) is accepted. However, the standard cointegration framework in (2) is misspecified if the adjustment process is asymmetric. For that reason, Enders, Siklos (2001) proposed the asymmetric adjustment, called the threshold autoregressive (TAR) model:

$$\Delta e_t = I_t \rho_1 e_{t-1} + (1 - I_t)\rho_2 e_{t-1} + \varepsilon_t \tag{3}$$

where *It* is the indicator function such that:

$$I_t = \begin{cases} 1 & if \;\; e_{t-1} > \tau \\ 0 & if \;\; e_{t-1} \le \tau \end{cases} \tag{4}$$

and τ is the threshold value. As an alternative adjustment process, the momentum threshold (MTAR) model is as follows:

$$\Delta e_t = M_t \rho_1 e_{t-1} + (1 - M_t)\rho_2 e_{t-1} + \varepsilon_t \tag{5}$$

$$M_t = \begin{cases} 1 & if \;\; \Delta e_{t-1} > \tau \\ 0 & if \;\; \Delta e_{t-1} \le \tau \end{cases} \tag{6}$$

The MTAR can capture the properties such that the threshold depends on the change of a previous period in *et*. When the adjustment processes (3) and (5) are serially correlated, (3) and (5) are re-written as:

$$\Delta e_t = I_t \rho_1 e_{t-1} + (1 - I_t)\rho_2 e_{t-1} + \sum_{i=1}^{p} \gamma_i \Delta e_{t-i} + \varepsilon_t \tag{7}$$

$$\Delta e_t = M_t \rho_1 e_{t-1} + (1 - M_t)\rho_2 e_{t-1} + \sum_{i=1}^{p} \gamma_i \Delta e_{t-i} + \varepsilon_t \tag{8}$$

Testing for threshold cointegration, Enders, Siklos (2001) propose two types of tests, called the Φ and *t-Max* statistics. The Φ statistic using a *F* statistic involves procedure testing for the null hypothesis $\rho_1 = \rho_2 = 0$, and the *t-Max* statistic employing a *t* statistic requires the test for the null hypothesis with the largest $\rho_i = 0$ between ρ_1 and ρ_2. The threshold parameter τ, which is restricted to the ranges of the remaining 70% of *et* or Δ*et* when the largest and smallest 15% values are discarded, is selected as an unknown value so as to minimize the sum of the squared residuals obtained from (3) and (5). If the null hypothesis of no cointegration is rejected, we can test for the null hypothesis $\rho_1 = \rho_2$ by a standard *F* statistic because the system is stationary.

Table 2. Engle-Granger cointegration test and cointegration parameters

Variables	θ_0	θ_1	ADF Test
Gold price in Yen	8.099 (26.86)***	0.607 (8.84)***	-3.328 [11]
Gold price in U.S. dollar	1.753 (10.63)***	0.940 (23.77)***	-3.918** [13]

Note: ADF equation includes constant and time trend. The maximum lag applied is 18 periods. The numbers in parentheses [.] are the lag order. The optimal lag is selected according to AIC. The values in (.) are t-value；*** and ** indicates the 1% and 5% significant level, respectively. 1% and 5% critical values that obtained through bootstrapping method are -3.92 and -3.34, respectively.

Source: own calculations.

Table 3. TAR and MTAR cointegration test

	Model	N of lags	$H_0 : \rho_i = 0$	$H_0 : \rho_1 = \rho_2 = 0$	τ	$H_0 : \rho_1 = \rho_2$	
			t-Max	Φ		F	p-value
Gold price in Yen	TAR	7	-1.331	2.260	-0.336	0.105	0.745
	MTAR	7	**-3.295*** **	**7.352** **	0.042	**10.18*** **	**0.001**
Gold price in U.S. dollar	TAR	3	-1.775	3.952	-0.101	0.010	0.919
	MTAR	3	-1.038	3.979	-0.028	0.061	0.803

Note: The maximum lag applied is 12 periods; the optimal lag is determined by the minimum value of AIC. *** and ** show the 1% and 5% significant level. Approximate critical values for the *t*-Max and Φ tests are tabulated by Enders and Siklos (2001).

Source: own calculations.

Table 2 reports the results of Engle-Granger cointegration test and the estimation of long-run coefficients. Cointegration test results show the existence of long-run relationship between gold price in U.S. dollar and U.S. CPI, and the inexistence between gold price in Yen and Japanese CPI. *Table 3* describes the results of TAR and MTAR test. TAR results show that the long-run relationship between gold price and CPI in both countries is not stable. The results of MTAR cointegration test shows that this relationship in U.S. is not characterized by the non-linearity (asymmetry), however, this relationship in Japan is significantly a non-linear threshold cointegration with not only ρ_i t test (t-Max) test but also with join test (Φ-test). Therefore, to get the appropriate inferences, it is necessary to consider the effect of asymmetry on the long-run relationship between the gold price in Yen and Japanese CPI. Based on the above-mentioned test results, the inflation long-run hedging effectiveness can be determined applying the cointegration parameter. The value of θ_1 in *Table 2* tells us that when Japanese CPI rises 1%, the gold price in Yen rises 0.607%, showing a partial inflation hedge of gold. When U.S. CPI rises 1%, the gold price in U.S. dollar rises 0.94%, approaching a complete inflation hedge of gold. This implies that the rigidity of price adjustment in the short-run might slightly affect the long-run inflation hedging ability of gold in U.S. and heavily affect the long-run inflation hedging ability of gold in Japan. In other words, the price rigidity in the short-run might be the cause of the near full hedge of gold in U.S. and part hedge in Japan. To verify this conclusion, the short-run relationship is analyzed using TC-TVECM for Japan and TVECM for U.S.

2.4 Linearity Test

Before the model creation, it is necessary to check if the relationship between variable is characterized to be non-linear. Tsay (1998) model is employed to test the linearity of time series, and the momentum between prices presented by differential of error correction term of lag-d ΔECT_{t-d} ($ECT_t = \ln g_t - \hat{\theta}_0 - \hat{\theta}_1 \ln p_t$) is applied to be the threshold variable. This threshold variable is used to respond to MTAR test and Ender (2004) which takes momentum to estimate the error correction model. We think that the differential of error correction term or the disequilibrium adjustment of prices is able to present high and low momentum, which might have different effects on inflation hedging ability of gold in the short-run.

Table 4. Testing for VAR model Lag-periods

Lag	LR	FPE	AIC	SC	HQ
Gold price in Yen					
1	60.12	0.00	-10.36	**-10.26****	-10.32
2	10.01	0.00	-10.37	-10.23	-10.31
3	17.05	0.00	-10.39	-10.21	-10.32
4	10.40	0.00	-10.39	-10.18	-10.31
5	32.65	0.00	-10.46	-10.20	-10.36
6	20.15	0.00	-10.49	-10.20	-10.37
7	19.88	0.00	-10.52	-10.19	-10.39
8	11.65	0.00	-10.53	-10.16	-10.38
9	9.54	0.00	-10.53	-10.12	-10.37
10	15.96	0.00	-10.56	-10.11	-10.38
11	10.85	0.00	-10.57	-10.08	-10.37
12	66.76	0.00	-10.72	-10.19	**-10.51****
13	4.74	0.00	-10.71	-10.15	-10.49
14	**10.45****	**7.58e-08****	**-10.72****	-10.11	-10.48
15	0.97	0.00	-10.70	-10.06	-10.45
16	6.37	0.00	-10.70	-10.02	-10.43
17	3.18	0.00	-10.69	-9.97	-10.40
18	6.76	0.00	-10.69	-9.93	-10.39
Gold price in U.S. dollar					
1	128.74	0.00	-11.89	**-11.82****	-11.86
2	17.58	0.00	-11.92	-11.80	-11.87
3	15.92	0.00	-11.94	-11.78	**-11.88****
4	12.88	0.00	-11.95	-11.76	-11.87
5	8.97	0.00	-11.95	-11.72	-11.86
6	6.08	0.00	-11.95	-11.68	-11.84
7	19.75	0.00	-11.98	-11.67	-11.86
8	13.21	0.00	-12.00	-11.64	-11.86
9	3.10	0.00	-11.98	-11.59	-11.83
10	28.72	0.00	-12.04	-11.61	-11.87
11	16.75	0.00	-12.06	-11.59	-11.88
12	12.12	0.00	-12.07	-11.57	-11.87
13	13.42	**1.93e-08****	**-12.09****	-11.54	-11.87
14	5.61	0.00	-12.08	-11.50	-11.85
15	0.88	0.00	-12.07	-11.44	-11.82
16	1.89	0.00	-12.05	-11.39	-11.79
17	7.54	0.00	-12.05	-11.35	-11.78
18	**12.33****	0.00	-12.07	-11.32	-11.77

Note: LR represents the sequential modified LR test statistic, FPE expresses the final prediction error, AIC is the Akaike information criterion, SC denotes the Schwarz information criterion, HQ indicates the Hannan-Quinn information criterion. ** denotes the 5% significant level.

Source: own calculations.

In order to test the linearity of series, the optimal lag of model should be first determined and *Table 4* shows the results of optimal lag selection with five criteria including LR (sequential modified LR test statistic), FPE (Final prediction error), AIC (Akaike information criterion), SC (Schwarz information criterion), and HQ (Hannan-Quinn information criterion). These results reveal that the lag of gold price in Yen p=14; the lag of gold price in U.S. p=13.

Table 5. Testing for linearity

d \ p	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Gold price in Yen														
1	0.10	0.14	0.16	0.25	0.24	0.32	0.35	0.26	0.45	0.44	0.57	0.63	0.76	0.88
2		0.00	0.00	0.01	0.03	0.01	0.01	0.02	0.03	0.02	0.02	0.03	0.03	**0.03**
3			0.00	0.01	0.06	0.08	0.04	0.05	0.03	0.03	0.10	0.07	0.16	0.20
4				0.08	0.35	0.39	0.64	0.73	0.79	0.55	0.44	0.32	0.28	0.36
5					0.59	0.33	0.57	0.30	0.47	0.38	0.37	0.16	0.19	0.22
6						0.40	0.70	0.68	0.69	0.34	0.75	0.90	0.94	0.98
7							0.33	0.34	0.24	0.18	0.29	0.33	0.43	0.42
8								0.40	0.52	0.43	0.33	0.42	0.69	0.83
9									0.25	0.10	0.13	0.39	0.48	0.52
10										0.39	0.50	0.29	0.31	0.41
11											0.19	0.35	0.45	0.48
12												0.07	0.04	0.09
13													0.07	0.12
14														0.70
Gold price in U.S. dollar														
1		0.16	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.03	**0.01**	0.02
2			0.00	0.01	0.02	0.05	0.10	0.03	0.01	0.04	0.19	0.28	0.19	0.36
3				0.00	0.01	0.10	0.04	0.10	0.03	0.05	0.19	0.17	0.10	0.17
4					0.00	0.01	0.01	0.00	0.00	0.00	0.04	0.17	0.10	0.12
5						0.14	0.29	0.18	0.04	0.14	0.41	0.40	0.33	0.48
6							0.44	0.22	0.11	0.11	0.33	0.38	0.45	0.59
7								0.12	0.03	0.02	0.14	0.22	0.28	0.31
8									0.01	0.01	0.08	0.05	0.05	0.11
9										0.02	0.19	0.12	0.16	0.19
10											0.14	0.21	0.22	0.44
11												0.03	0.07	0.14
12													0.39	0.52
13														0.15

Note: The above values are the p-values of Chi square test for linearity.

Source: own calculations.

Table 5 reports the linear test, showing that when *p*=14 and the lag of threshold variable *d*=2 the gold price in Yen rejects the linear hypothesis, and when *p*=13, *d*=1 the gold price in U.S. rejects the linear hypothesis.

2.5 Non-linear Error Correction Model

When the asymmetric threshold cointegration between variables is found, we further apply the asymmetric error correction model to analyze and infer the possible reasons causing this asymmetric relationship. Enders (2004) suggests the use of MTAR form to create the error correction model for the analysis. However, we consider that this error correction model merely examines the long-run asymmetry of deviation adjustment and overlooks the possible existence of short-run non-linear adjustment.

With regard to the short-run analysis, Tong (1978) and Tong and Lim (1980) develop the threshold autoregressive (TAR) model that is based on an optimal threshold value to divide the short-run dynamic status of one variable into two regimes. Within TAR framework and results of cointegration test, it is found that the gold price in Yen is characterized by the non-linear cointegration. Therefore, to take the presence of threshold cointegration between gold return and inflation into consideration, we create the threshold vector error correction model (TVECM) with threshold cointegration (TC) in the long-run to carry out the estimation. This model is named TC-TVECM model and described as follows.

TC-TVECM model :

$$\Delta \ln g_t = \begin{cases} \alpha_{10} + \sum_{i=1}^{p} \alpha_{1,1i} \Delta \ln g_{t-i} + \sum_{i=1}^{p} \alpha_{1,2i} \Delta \ln p_{t-i} + \omega_{11} M_t ECT_{t-1} \\ \qquad + \omega_{12}(1 - M_t) ECT_{t-1} + e_{g1t}, \quad \Delta ECT_{t\text{-}d} > \gamma \\ \alpha_{20} + \sum_{i=1}^{p} \alpha_{2,1i} \Delta \ln g_{t-i} + \sum_{i=1}^{p} \alpha_{2,2i} \Delta \ln p_{t-i} + \omega_{21} M_t ECT_{t-1} \\ \qquad + \omega_{22}(1 - M_t) ECT_{t-1} + e_{g2t}, \quad \Delta ECT_{t\text{-}d} \le \gamma \end{cases} \qquad (9)$$

$$\Delta \ln p_t = \begin{cases} \beta_{10} + \sum_{i=1}^{p} \beta_{1,1i} \Delta \ln g_{t-i} + \sum_{i=1}^{p} \beta_{1,2i} \Delta \ln p_{t-i} + \varpi_{11} M_t ECT_{t-1} \\ \qquad + \varpi_{12}(1 - M_t) ECT_{t-1} + e_{p1t}, \quad \Delta ECT_{t\text{-}d} > \gamma \\ \beta_{20} + \sum_{i=1}^{p} \beta_{2,1i} \Delta \ln g_{t-i} + \sum_{i=1}^{p} \beta_{2,2i} \Delta \ln p_{t-i} + \varpi_{21} M_t ECT_{t-1} \\ \qquad + \varpi_{22}(1 - M_t) ECT_{t-1} + e_{p2t}, \quad \Delta ECT_{t\text{-}d} \le \gamma \end{cases} \qquad (10)$$

Where the gold return $\Delta \ln g_t = \ln(g_t / g_{t-1})$, the inflation $\Delta \ln p_t = \ln(CPI_t / CPI_{t-1})$. α, β are the short-run estimated coefficients. e_{1t}, e_{2t} represent the error terms of two regimes. ECT_{t-1} is the correction term of period *t*-1 in long-run equilibrium: $ECT_{t-1} = \ln g_{t-1} - \theta_0 - \theta_1 \ln p_{t-1}$. The estimation of optimal threshold value γ is referred to method of Weise (1999) which uses the minimum determinant of residual covariance as a basis.

The equation (9) and (10) are known as the TC-TVECM model. $\Delta ECT_{t\text{-}d} > \gamma$ shows that the adjustment momentum between gold price and consumer price is faster, which is called high-momentum period or regime 1. And $\Delta ECT_{t\text{-}d} \le \gamma$ shows that the adjustment momentum between gold price and consumer price is slower, which is called low-momentum period or regime 2. The short-run error correction model of gold return is represented by equation (9), in which ω_{11}, ω_{12} (ω_{21}, ω_{22}) respectively stand for the adjustment speed of error correction term in regime 1 (regime 2) with indicator M_t and $(1-M_t)$. Both, the long-run equilibrium error and gold return present the positive adjustment if the coefficient of adjustment speed is positive, and the opposite adjustment if the coefficient of adjustment speed is negative. Similarly, the short-run error correction model of inflation is represented by equation (10), in which ω_{11}, ω_{12} (ω_{21}, ω_{22}) respectively stand for the adjustment speed of error correction term in regime 1 (regime 2) with indicator M_t and $(1-M_t)$. The long-run equilibrium error and inflation rate present the positive adjustment if the coefficient of adjustment speed is positive, and the opposite adjustment if the coefficient of adjustment speed is negative.

The TC-TVECM model represented by equation (9) might be used to examine the existence of rigidity adjustment of gold price in the short-run. $\Delta ECT_{t\text{-}d} > \gamma$ means that the variation margin of gold price is larger than the variation rate of long-run CPI after a change in CPI, the variation margin of gold price must adjust downward. $\Delta ECT_{t\text{-}d} \leq \gamma$ indicates that the variation margin of gold price is narrower than the variation rate of long-run CPI, the variation margin of gold price must adjust upward. The variation speed of gold price is adjusted upward or downward through the asymmetric error correction term $M_t ECT_{t-1}$ and $(1-M_t)ECT_{t-1}$. ω_{11} is not equal ω_{12}, signifying the high momentum period or regime 1 where the rigidity adjustment in gold price exists. $|\omega_{11}|>|\omega_{12}|$ infers the upward rigidity adjustment of gold price, and $|\omega_{11}|<|\omega_{12}|$ suggests the downward rigidity adjustment of gold price. Within regime 2 or low-momentum period, $|\omega_{21}|>|\omega_{22}|$ implies the upward rigidity adjustment of gold price, and $|\omega_{21}|<|\omega_{22}|$ intends the downward rigidity adjustment of gold price.

As the gold price in U.S. dollar is simply characterized by the linear cointegration, the equation (9) and (10) should be back to the framework of TVECM model as follows:

TVECM model:

$$\Delta lng_t = \begin{cases} \alpha_{10} + \sum_{i=1}^{p} \alpha_{1,1i} \Delta \ln g_{t-i} + \sum_{i=1}^{p} \alpha_{1,2i} \Delta \ln p_{t-i} + \omega_1 ECT_{t-1} + e_{g1t}, \ \Delta ECT_{t\text{-}d} > \gamma \\ \alpha_{20} + \sum_{i=1}^{p} \alpha_{2,1i} \Delta \ln g_{t-i} + \sum_{i=1}^{p} \alpha_{2,2i} \Delta \ln p_{t-i} + \omega_2 ECT_{t-1} + e_{g2t}, \ \Delta ECT_{t\text{-}d} \leq \gamma \end{cases} \tag{11}$$

$$\Delta \ln p_t = \begin{cases} \beta_{10} + \sum_{i=1}^{p} \beta_{1,1i} \Delta \ln g_{t-i} + \sum_{i=1}^{p} \beta_{1,2i} \Delta \ln p_{t-i} + \varpi_1 ECT_{t-1} + e_{p1t}, \ \Delta ECT_{t\text{-}d} > \gamma \\ \beta_{20} + \sum_{i=1}^{p} \beta_{2,1i} \Delta \ln g_{t-i} + \sum_{i=1}^{p} \beta_{2,2i} \Delta \ln p_{t-i} + \varpi_2 ECT_{t-1} + e_{p2t}, \Delta ECT_{t\text{-}d} \leq \gamma \end{cases} \tag{12}$$

The equation (11) and (12) still maintain the high and low-momentum period of the short-run adjustment.

According to *Table 5*, we select $\Delta ECT_{t\text{-}2}$ as the threshold variable to create the TC-TVECM model for the gold price in Yen and $\Delta ECT_{t\text{-}1}$ as the threshold variable to create the TVECM model for the gold price in U.S. dollar. Then, the estimation of TC-TVECM model is:

$$\Delta \ln g_t = \begin{cases} \alpha_{10} + \sum_{i=1}^{14} \alpha_{1,1i} \Delta \ln g_{t-i} + \sum_{i=1}^{14} \alpha_{1,2i} \Delta \ln p_{t-i} + \omega_{11} M_t ECT_{t-1} + \omega_{12}(1-M_t) ECT_{t-1}, \ \Delta ECT_{t\text{-}2} > -0.04 \\ [0.00] \quad [0.40]^{***} \qquad [0.24] \qquad [0.02] \qquad [-0.02]^{***} \\ \alpha_{20} + \sum_{i=1}^{14} \alpha_{2,1i} \Delta \ln g_{t-i} + \sum_{i=1}^{14} \alpha_{2,2i} \Delta \ln p_{t-i} + \omega_{21} M_t ECT_{t-1} + \omega_{22}(1-M_t) ECT_{t-1}, \ \Delta ECT_{t\text{-}2} \le -0.04 \\ [0.02] \quad [-0.69] \qquad [0.05] \qquad [0.13] \qquad [0.00] \end{cases} \tag{13}$$

$$\Delta \ln p_t = \begin{cases} \beta_{10} + \sum_{i=1}^{14} \beta_{1,1i} \Delta \ln g_{t-i} + \sum_{i=1}^{14} \beta_{1,2i} \Delta \ln p_{t-i} + \varpi_{11} M_t ECT_{t-1} + \varpi_{12}(1-M_t) ECT_{t-1}, \ \Delta ECT_{t\text{-}2} > -0.04 \\ [0.00] \quad [0.02]^{**} \qquad [0.90]^{***} \qquad [-0.00] \qquad [0.00] \\ \beta_{20} + \sum_{i=1}^{14} \beta_{2,1i} \Delta \ln g_{t-i} + \sum_{i=1}^{14} \beta_{2,2i} \Delta \ln p_{t-i} + \varpi_{21} M_t ECT_{t-1} + \varpi_{22}(1-M_t) ECT_{t-1}, \Delta ECT_{t\text{-}2} \le \text{-}0.04 \\ [-0.00] \quad [-0.06] \qquad [0.25]^{***} \qquad [0.01] \qquad [-0.00] \end{cases} \tag{14}$$

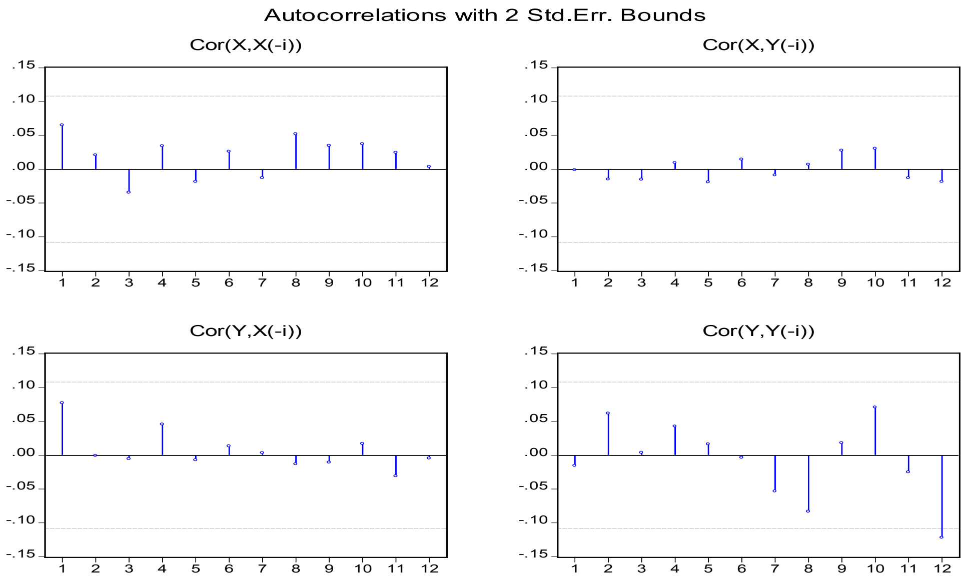
In equation (13) and (14), the value in [.] denotes the estimated coefficient or coefficient sum. "**" and "***" denote the 5% and 1% significant level respectively. The estimated threshold value is -0.04, showing that when $\Delta ECT_{t\text{-}2} > -0.04$ the adjustment momentum between prices is faster and belongs to the high momentum period, and when $\Delta ECT_{t\text{-}2} \le -0.04$ the adjustment momentum between prices is slower and belongs to the low momentum period.

The TVECM model of gold price in U.S. dollar is estimated as follows:

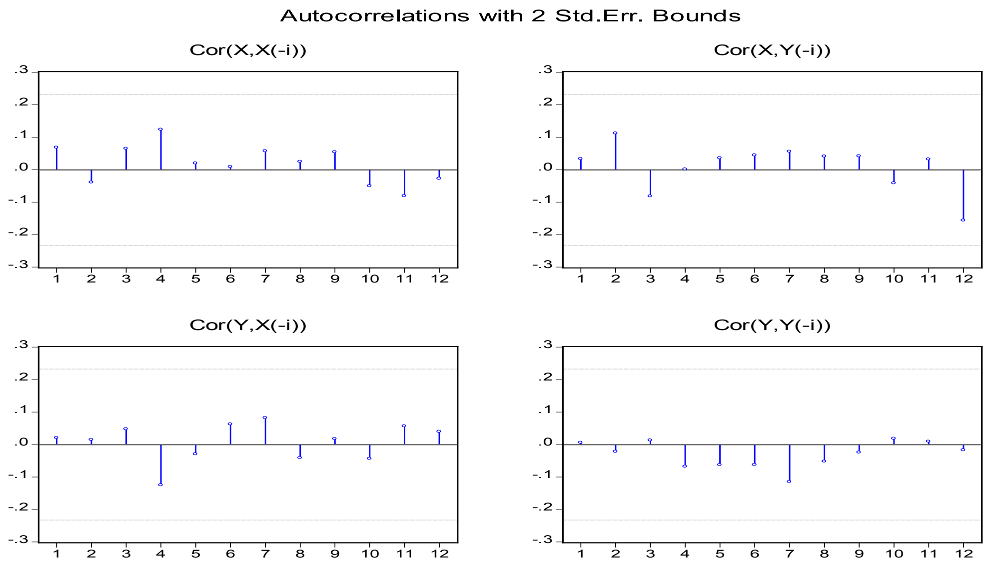
$$\Delta \ln g_t = \begin{cases} \alpha_{10} + \sum_{i=1}^{13} \alpha_{1,1i} \Delta \ln g_{t-i} + \sum_{i=1}^{13} \alpha_{1,2i} \Delta \ln p_{t-i} + \omega_1 ECT_{t-1}, \ \Delta ECT_{t\text{-}1} > -0.03 \\ [-0.00] \ [0.61]^{***} \qquad [0.73]^{***} \qquad [-0.03]^{***} \\ \alpha_{20} + \sum_{i=1}^{13} \alpha_{2,1i} \Delta \ln g_{t-i} + \sum_{i=1}^{13} \alpha_{2,2i} \Delta \ln p_{t-i} + \omega_2 ECT_{t-1}, \ \Delta ECT_{t\text{-}1} \le -0.03 \\ [-0.03] \ [-0.34] \qquad [1.55] \qquad [-0.03] \end{cases} \tag{15}$$

$$\Delta \ln p_t = \begin{cases} \beta_{10} + \sum_{i=1}^{13} \beta_{1,1i} \Delta \ln g_{t-i} + \sum_{i=1}^{13} \beta_{1,2i} \Delta \ln p_{t-i} + \varpi_1 ECT_{t-1}, \ \Delta ECT_{t\text{-}1} > \text{-}0.03 \\ [0.00] \quad [0.03]^{**} \qquad [0.85]^{***} \qquad [-0.00] \\ \beta_{20} + \sum_{i=1}^{13} \beta_{2,1i} \Delta \ln g_{t-i} + \sum_{i=1}^{13} \beta_{2,2i} \Delta \ln p_{t-i} + \varpi_2 ECT_{t-1}, \Delta ECT_{t\text{-}1} \le -0.03 \\ [0.00] \quad [0.02] \qquad [0.59]^{***} \qquad [0.00] \end{cases} \tag{16}$$

where, the estimated threshold value is -0.03, indicating that when $\Delta ECT_{t\text{-}2} > -0.03$ the adjustment between prices belongs to the high momentum, and that when $\Delta ECT_{t\text{-}2} \le -0.03$ the adjustment between prices belongs to the low momentum. The comparison between the gold price in Yen and in U.S dollar shows that the cross-section price elasticity between the gold price in Yen and Japanese CPI is lower than one between the gold price in U.S. dollar and U.S. CPI in the long-run. Therefore, the threshold value of adjustment momentum is -0.03, higher than -0.04 of U.S.



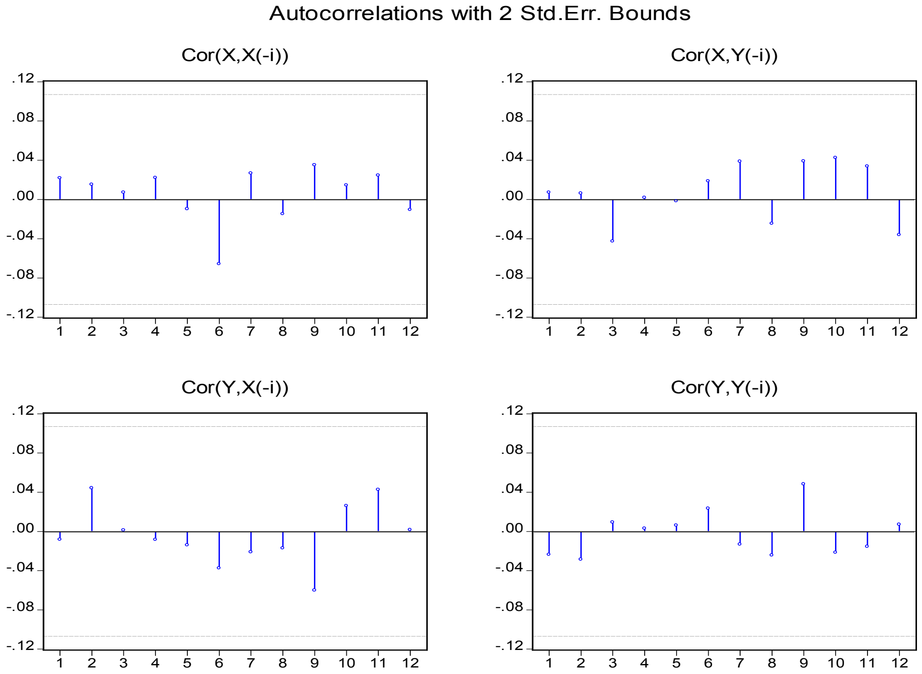
$$\text{X}=e_{g1t}\text{, Y}=e_{p1t}\text{,}\quad \Delta ECT_{t\text{-}2} > -0.04$$



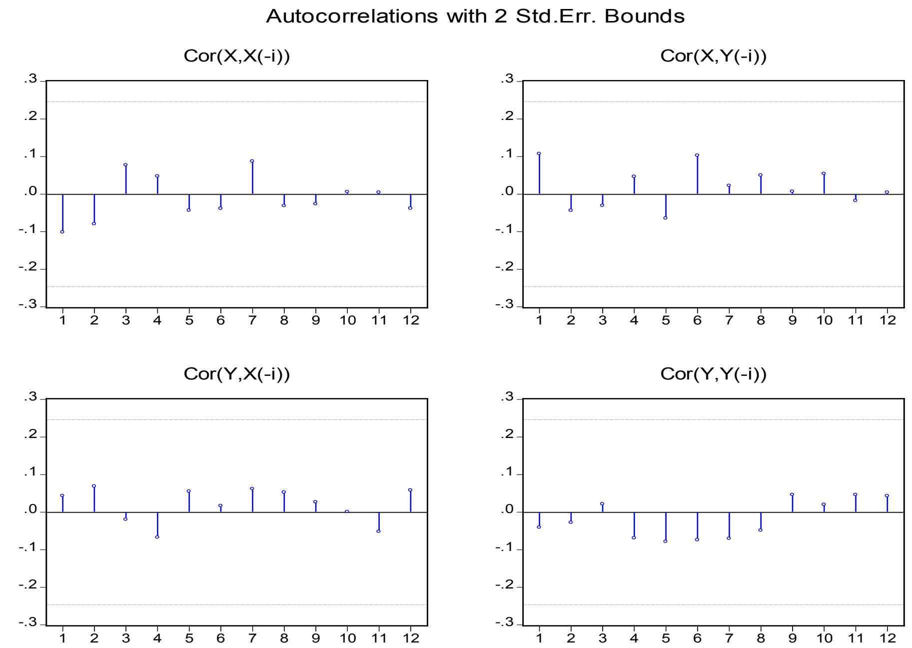
$$\text{X}=e_{g2t}\text{, Y}=e_{p2t}\text{,}\quad \Delta ECT_{t\text{-}2} \leq -0.04$$

Source: own calculations.

Figure 3. **The Autocorrelation and Cross-Correlation of TC-TVECM for Japan**



$$X = e_{g1t},\ Y = e_{p1t},\quad \Delta ECT_{t-1} > -0.03$$



$$X = e_{g2t},\ Y = e_{p2t},\quad \Delta ECT_{t-1} \leq -0.03$$

Source: own calculations.

Figure 4. **The Autocorrelation and Cross-Correlation of TVECM for U.S.**

In addition, to ensure the inexistence of residual correlation of asymmetric error correction models, *Figure 3* and *Figure 4* display the correlation test. It is found that the models fitted for gold prices are optimal and residuals do not present the autocorrelation or cross-correlation.

2.6 Asymmetric Causality Test

To confirm the causality of short-run dynamic effect and the inflation hedging ability of gold in the short-run, the *Wald* coefficient test is employed to check the causality between variables (strong exogeneity). As the TC-TVECM in equation (9) and TVECM in equation (11) show, the null hypothesis of causality test is $H_0 : \alpha_{1,2i} = 0$, $i = 1,...,p$ ($H_0 : \alpha_{2,2i} = 0$) along with the high- (low-) momentum regime, which shows that $\Delta \ln p$ does not Granger-cause $\Delta \ln g$. The rejection of this null hypothesis means that inflation Granger causes gold return. Observing coefficient and $\sum_{i=1}^{p} \alpha_{1,2i}$ ($\sum_{i=1}^{p} \alpha_{2,2i}$), it is able to determine the interaction between variables within the high- (low-) momentum regime to be positive or negative. The null hypothesis is rejected and the coefficient sum is positive, indicating the inflation hedging effectiveness of gold return in the short-run. Besides, considering the TC-TVECM in equation (10) or TVECM in equation (12) it is seen that the test of null hypothesis, $H_0 : \beta_{1,1i} = 0$, $i = 1,...,p$ ($H_0 : \beta_{2,1i} = 0$), shows that $\Delta \ln g$ does not Granger-cause $\Delta \ln p$. The rejection of this null hypothesis means that gold return Granger-cause inflation. As coefficient and $\sum_{i=1}^{p} \beta_{1,1i}$ ($\sum_{i=1}^{p} \beta_{2,1i}$) demonstrate, we can ascertain that the effect of gold return on inflation within the high- (low-) momentum regime is negative or positive in the short-run.

Moreover, we could verify if the consumer price has the weak exogeneity on gold return through the significance of adjusting coefficients ω_{11}, ω_{12}, ω_{21}, and ω_{22} of error correction term under different regimes, and if the gold price has the weak exogeneity on inflation through the significance of adjusting coefficients ϖ_{11}, ϖ_{12}, ϖ_{21}, and ϖ_{22} of error correction term under different regimes. On the basis of the causality test and the lag parameter, we examine if investing in gold might help to avoid inflation.

Table 6 reports the causality test between the gold return in Yen and Japanese inflation within high and low-regime of TC-TVECM framework. $\hat{\alpha}_{1,2i}$ and $\hat{\alpha}_{2,2i}$ of strong exogeneity test show that inflation does not influence gold return not only in high-momentum regime but also in low-momentum regime. This result proves the inflation hedging ineffectiveness of short-run gold investment in Japan**.** As $\hat{\beta}_{1,1i}$ of Join test and coefficient sum $\sum \hat{\beta}_{1,1i}$ =0.02 show, it is evident that a raise in gold return leads a raise in inflation. To analyze the result of weak exogeneity test, it is discovered that the adjustment coefficient $\hat{\omega}_{12}$ of the error correction term (1-*M*)*ECT is* negative (-0.02) with 5% significant level only within high-momentum regime. $\hat{\omega}_{11}$=0.01 is not significant, representing its value equal 0. $|\omega_{12}|$=0.02 and higher than 0, indicating that the gold price needs to adjust upward for getting back to the long-run equilibrium and that the gold price in Yen presents the rigidity of downward adjustment.

Table 6. Causality Test for the relationship between gold return and inflation in Japan

Dependent Variable	Null Hypothesis H_0:	High Momentum Regime		Low Momentum Regime	
		Sum of coefficients	Chi-square test	Sum of coefficients	Chi-square test
$\Delta \ln g\_jp$	$\Delta \ln p\_jp \times\!\!\rightarrow \Delta \ln g\_jp$	$\sum_{i=1}^{14} \hat{\alpha}_{1,2i}$ =0.24	20.79 (0.11)	$\sum_{i=1}^{14} \hat{\alpha}_{2,2i}$ =-0.90	19.31 (0.15)
	$METC\_jp \times\!\!\rightarrow \Delta \ln g\_jp$	ω_{11}=0.01	0.89 (0.34)	ω_{21}=0.13	3.46 (0.06)
	$(1\text{-}M)ECT\_jp \times\!\!\rightarrow \Delta \ln g\_jp$	ω_{12}=-0.02	6.33*** (0.01)	ω_{22}=0.00	0.00 (0.95)
$\Delta \ln p\_jp$	$\Delta \ln g\_jp \times\!\!\rightarrow \Delta \ln p\_jp$	$\sum_{i=1}^{14} \hat{\beta}_{1,1i}$ = 0.02	25.24** (0.03)	$\sum_{i=1}^{14} \hat{\beta}_{2,1i}$ =-0.06	15.29 (0.36)
	$MECT\_jp \times\!\!\rightarrow \Delta \ln p\_jp$	ϖ_{11}=-0.00	2.63 (0.10)	ϖ_{21}= 0.01	2.81 (0.09)
	$(1\text{-}M)ECT\_jp \times\!\!\rightarrow \Delta \ln p\_jp$	ϖ_{12}=0.00	0.46 (0.50)	ϖ_{22}=-0.00	1.84 (0.17)
	Direction	$\Delta \ln g\_jp$	$\Delta \ln p\_jp$	*M ETC jp*	*(1-M) ECT_jp*
$\Delta \ln g\_jp$	**High Momentum**		×	×	$\overset{+}{\longleftarrow}$
	Low Momentum		×	×	×
$\Delta \ln p\_jp$	**High Momentum**	$\overset{+}{\longleftarrow}$		×	×
	Low Momentum	×		×	×

Note: The optimal threshold value γ =-0.04, the lag of TVECM p=14, and the optimal lag of threshold variable d=2. The notation $\Delta \ln p\_jp \times\!\!\rightarrow \Delta \ln g\_jp$ presents the null hypothesis that the CPI change (inflation) cannot explain the change in gold price; $\Delta \ln g\_jp \times\!\!\rightarrow \Delta \ln p\_jp$ indicates the null hypothesis that the change in gold price cannot explain the CPI change (inflation). The values in "(.)" are the p-values of Chi-square statistic of Joint test, *** and ** denotes the 1% and 5% significant level, respectively.

Source: own calculations.

Table 7 reports the causality test of U.S. case with high and low-momentum regime of TVECM. The result of strong exogeneity test proves the positive bilateral causality between gold return and inflation. In other words, the gold return could hedge against inflation in the short-run and a raise in gold return is followed by a raise in inflation. The result of weak exogeneity test displays that the negative adjustment coefficient (ω_1 =-0.03) of the error correction term (ECT_us) is only detected within high-momentum regime. The adjustment of CPI does not present the rigidity. Most short-run disequilibrium could adjust and back to the long-run equilibrium through the deviation adjustment of error correction.

Table 7. Causality test for the relationship between gold return and inflation in U.S.

Dependent Variable	Null Hypothesis H_0:	High Momentum Regime		Low Momentum Regime	
		Sum of coefficients	Chi-square test	Sum of coefficients	Chi-square test
$\Delta \ln g\_us$	$\Delta \ln p\_us \times\!\!\rightarrow \Delta \ln g\_us$	$\sum_{i=1}^{13} \hat{\alpha}_{1,2i}$ =0.73	30.88*** (0.00)	$\sum_{i=1}^{13} \hat{\alpha}_{2,2i}$ =1.55	17.48 (0.18)
	$ETC\_us \times\!\!\rightarrow \Delta \ln g\_us$	ω_1 = -0.03	11.03*** (0.00)	ω_2 = -0.03	1.70 (0.19)
$\Delta \ln p\_us$	$\Delta \ln g\_us \times\!\!\rightarrow \Delta \ln p\_us$	$\sum_{i=1}^{13} \hat{\beta}_{1,1i}$ = 0.03	23.30** (0.04)	$\sum_{i=1}^{13} \hat{\beta}_{2,1i}$ =0.02	18.73 (0.13)
	$ECT\_us \times\!\!\rightarrow \Delta \ln p\_us$	ϖ_1 =-0.00	0.17 (0.68)	ϖ_2 =0.00	0.57 (0.44)

	Direction	$\Delta \ln g\_us$	$\Delta \ln p\_us$	ECT_us
$\Delta \ln g\_us$	**High Momentum**		$\overset{+}{\longleftarrow}$	$\overset{-}{\longleftarrow}$
	Low Momentum		×	×
$\Delta \ln p\_us$	**High Momentum**	$\overset{+}{\longleftarrow}$		×
	Low Momentum	×		×

Note: The optimal threshold value γ =-0.03, the lag of TVECM *p*=13, and the optimal lag of threshold variable *d*=1. The notation $\Delta \ln p\_us \times\!\!\rightarrow \Delta \ln g\_us$ presents the null hypothesis that the CPI change (inflation) cannot explain the change in gold price; $\Delta \ln g\_us \times\!\!\rightarrow \Delta \ln p\_us$ indicates the null hypothesis that the change in gold price cannot explain the CPI change (inflation). The values in "(.)" are the p-values of Chi-square statistic of Joint test, *** and ** denotes the 1% and 5% significant level, respectively.

Source: own calculations.

2.7 Empirical Results and Economic Implications

The basic idea of short-run and long-run models is that when there is a long-run equilibrium (stable relationship) between gold price and CPI, these two variables tend to a particular ratio, and hedge is often the source of stable equilibrium price ratios. Shocks might lead to short-run deviation from this equilibrium relationship but adjustments would tend to re-establish the relationship in the long-run. Therefore, VECM model is applied to this relation. However, Enders, Siklos (2001) conclude that a long-run equilibrium stable functional relationship might be non-linear. If there is a non-linear cointegration, linear cointegration that fails to account for non-linearity in the long-run relationship can lead to the misleading estimation and adjustment processes. On the basis of the empirical results presented in *Table 2* and *Table 3*, the relationship between gold price and CPI in U.S shows a linear and not non-linear cointegration. This relation is opposite to the one in Japan in which the non-linear cointegration is evident.

Furthermore, the short-run adjustment of deviation from equilibrium might be non-linear. There are many studies applying the TVECM to analyze price transmission. They assume that prices are linked by a constant long-run equilibrium relationship, while allowing for threshold (or switching) effects in the short-run adjustment process towards this equilibrium. The TVECM (e.g. Goodwin, Piggott, 2001; Meyer, 2004; Serra *et al.*, 2006; Balcombe *et al.*, 2007) distinguishes between regimes depending on whether the deviation of prices from their long-run equilibrium, in other words, the error correction term, is above or below a threshold value. However, we discover the momentum (ΔECT) that is the major factor affecting the process of adjustment. This is also the main innovation of this study. For example, if the ΔECT exceeds a specific threshold determined by the changes of the hedge ratios, more rapid adjustment to the constant long-run equilibrium is expected than if the ΔECT is smaller than the threshold value, in which the adjustment might even cease altogether. Therefore, based on the viewpoint of Tong (1978), Tong, Lim (1980), Tsay (1998) and Ender (2004), we take the threshold cointegration between gold return and inflation into consideration, and we create the TVECM with threshold cointegration (TC) in the long-run to carry out the estimation for the case of Japan. This model is named TC-TVECM. Because the gold price in U.S. dollar is simply characterized by the linear cointegration, we create the framework of TVECM model. These results are presented in *Table 5*, *Table 6*, and *Table 7*.

On the grounds of the above given empirical results, we suggest two major factors influencing the inflation hedging ability of gold investor; (1) the rigidity adjustment between gold price and CPI; (2) the price adjustment within high momentum regime. Figure 5 illustrates these results. It is seen from Japan and U.S. that the gold return is unable to hedge against inflation when price adjustment is in the low- momentum regime. During the high-momentum regime, the gold return in Yen cannot fully hedge against inflation because of the presence of adjustment rigidity between gold price and CPI, whereas, the gold return in U.S. dollar fully hedge against inflation because of the non-rigidity of price adjustment. The reasons for these results should be that the cross-elasticity between the gold price in Yen and CPI is rather low, the adjustment process is not complete, and that the short-run adjustment of price presents the rigidity, revealing an ambiguous cost or the non-complete competition market. In other words, there exists the asymmetry in relation between gold price and CPI in Japanese market, accordingly causing the unfamiliarity with inflation hedging ability of gold. In contrast, U.S. market is characterized by the complete competition, the cross-elasticity of the gold price and CPI is high, the gold price and CPI almost adjust synchronously, the rigidity does not appear in the short-run adjustment. All of these properties help the gold investment to hedge against inflation.

Considering the long-run cointegration and the short-run error correction, Ghosh *et al*. (2004) conclude that the gold investment in U.S. dollar is able to hedge against inflation in the short-run as well as in the long-run. Whereas, Worthington, Pahlavani (2006) just discover the inflation hedge ability of gold in U.S dollar in the long-run. However, their results merely ponder over the symmetry of the model. Different from them, this study specially applies the framework of asymmetric model to examine the inflation hedge effectiveness of gold. It is found that only if the speed of deviation adjustment of gold price and CPI is faster, gold returns have ability to hedge against inflation in the short-run. This finding, relative to the discovery of Ghosh *et al*. (2004) as well as Worthington, Pahlavani (2006), provides more information and accurate results.

The findings of this study show that the inflation hedge of gold is not absolute. The essential keys of inflation hedge are time and market selection. Investors should choose the time of high-momentum period or the time where gold price responds to inflation faster for dodging inflation. On the contrary, investing in gold during low-momentum period does not allow hedging against inflation. Besides, market selection also plays an important role in hedging inflation. Investors should understand if the market is characterized by the rigidity of price adjustment. Especially, it is suggested that it should be better not to invest high rate of gold in one's portfolio just because of gold's inflation hedging ability.

History tells us that only gold maintains its value during wars, upheavals, crisis periods, and changes of empires and governments. Monetary market shows us that gold is an ideal portfolio holding and an inflation hedge in view of uncertainty of world economy. Many central banks incorporate gold into both, a currency basket used for the purposes of exchange rate management and a reserve asset portfolio for reducing the volatility and enhancing the risk/return balance. Gold has long been regarded as a good means of protection against inflation. Although this has been widely believed, it is supported by few formal statistical researches. It is not denied that gold is a good hedge against fluctuations in consumer price, however, it is not absolute in anywhere and anytime. The findings of this study suggest financial analysts and monetary policy makers who are using the price of gold as an indicator of inflation pressures in the economy that gold in many timeframes is not much of an inflation hedge. It is also expected this study to be of interest to both, financial academics and investors. From an academic perspective, the paper contributes to a better understanding of when and where gold can act as an inflation hedge and a new application of threshold model. From the perspective of investors, this article provides a decision aid for making better asset allocation of one's portfolio.

Conclusions

The amount of empirical research, relative to other real assets, on the inflation hedging ability of gold is relatively sparse. Almost all previous works on this issue just paid attention to linear relation and overlooked the existence of non-linear relation, which might limit the segmental analysis of the relationship between gold return and inflation. The discussion on whether a raise in CPI is followed by a raise in gold price or whether gold price is a respond of inflation and acts as an inflation hedge is the initial focus of this study with an emphasis on the adjustment rigidity of gold price and inflation. Analyzing the relationship between variables in the long-run, it is found that the different momentum regimes of disequilibrium adjustment may make the inflation hedge of gold in the long-run linear and stable. Then, a short-run non-linear model for the relationship between gold return and inflation is created to verify their causality.

Two large economies of the world, United States and Japan, are involved in this study to explore the inflation hedging effectiveness of gold in the short-run as well as in the long-run. It is found that the inflation hedging ability of gold in the short-run is only evident in U.S. It is determined that two major factors influencing the inflation hedging ability of gold investment in the short-run are; (1) the adjustment rigidity between gold price and CPI; (2) the price adjustment within high momentum regime. It is seen from the case of Japan and U.S. that the gold return is unable to hedge against inflation when price adjustment is in the low-momentum regime. During the high-momentum regime, the gold return in Yen cannot fully hedge against inflation because of the presence of adjustment rigidity between gold price and CPI, whereas, the gold return in U.S. dollar fully hedge against inflation because of the non-rigidity of price adjustment. These findings also explain why gold in U.S. effectively hedges against inflation and gold in Japan just partially hedges against inflation in the long-run.

The study makes several contributions. First, this is the first paper that employs the non-linear model to investigate the inflation hedge of gold in the short-run. Second, the short-run and long-run threshold effect is synchronal taken into account to test for causality between variables, which is the first use to exploit the inflation hedge of real assets. Third, we find that the rigidity of price momentum adjustment between gold price and CPI within the high or low regime might influence the inflation effectiveness of gold. Future research in this area may help us further examine our results taking evidences of more countries.

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AR AUKSAS YRA INFLIACIJOS VALDYMO PRIEMONĖ JAV IR JAPONIJOJE?

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SANTRAUKA

Straipsnyje tiriamas JAV ir Japonijos aukso kainų reguliavimo nelankstumas ir auksas kaip priemonė suvaldyti infliacija. Taikomi tiesinis ir netiesinis kointegravimo testas ir netiesinio ryšio ribinės regresijos modelis. Remiantis tridešimt šešerių metų duomenimis apie aukso kainą ir vartotojų kainų indeksą (VKI), trumpojo laiko tarpo analizė rodo, kad aukso apyvarta negali būti laikoma priemone suvaldyti infliaciją abiejose šalyse, kai aukso kainos silpnai reguliuojamos. Kai pastarasis procesas vyksta intensyviai, aukso apyvarta neleidžia visiškai suvaldyti infliacijos Japonijoje dėl griežtos reguliacijos tarp aukso kainos ir VKI. Vis dėlto auksas tampa priemone infliacijai valdyti JAV, kai aukso kaina nėra griežtai reguliuojama. Šie tyrimo rezultatai taip pat paaiškina, kodėl auksas JAV yra veiksminga kovos su infliacija priemone, o Japonijoje auksas infliacijos valdymo priemone tampa tik žvelgiant iš ilgalaikės perspektyvos.

REIKŠMINIAI ŽODŽIAI: aukso kaina, infliacijos valdymo priemonė, kointegravimo testas, kainų nelankstumas, netiesinis modelis, JAV, Japonija.