Japan and the World Economy 24 (2012) 274–282

Contents lists available at SciVerse ScienceDirect

Japan and the World Economy

journal homepage: www.elsevier.com/locate/jwe

Application of the Tobit model with autoregressive conditional heteroscedasticity for foreign exchange market interventions

Ho-Chyuan Chen [a], Kuang-Liang Chang [b,*], Shih-Ti Yu [c]

[a] Department of Economics, National Chung Cheng University, Chiayi City, Taiwan
[b] Department of Applied Economics, National Chiayi University, Chiayi City, Taiwan
[c] Department of Quantitative Finance, National Tsing Hua University, Taiwan

ARTICLE INFO

Article history:
Received 3 November 2009
Received in revised form 21 April 2012
Accepted 21 June 2012
Available online 13 July 2012

JEL classification:
E31
E58

Keywords:
Tobit GARCH
Central bank intervention
Bank of Japan
Censored data
Probit

ABSTRACT

In this empirical study, we apply the Tobit-GARCH model to investigate the intervention function of the Bank of Japan (BoJ) in the JPY/USD exchange market. The proposed model has the advantage of handling intervention data with both a majority of zero observations and conditional heteroscedasticity. Thus, the model provides better estimates of the intervention function than such conventional models as the standard Tobit, OLS, Probit, and traditional GARCH models. Results show that the intervention behavior of the BoJ is affected more by its half-year long-term target than its previous-day short-term target, and the BoJ generally follows the policy of "leaning against the wind". The US-JP interest rate spread was never a trigger of BoJ's interventions during the sample period. The BoJ did not respond to the domestic stock index by the sales-intervention of the JPY, even when the economy was sluggish during the lost decade (1992–2004). However, its intervention behavior was significantly affected by U.S. interventions and was significantly persistent across some of the periods.

1. Introduction

To identify what triggers interventions of a central bank in the foreign exchange market, many studies have focused on estimating the intervention (or reaction) functions of central banks (see, e.g., Alkeminders and Eijffinger, 1994; Almekinders and Eijffinger, 1996; Baillie and Osterberg, 1997; Kim and Sheen, 2002; Frenkel et al., 2005; Ito and Yabu, 2007; Jun, 2008). In this paper, we propose an alternative method to estimate the reaction function of a central bank: the Tobit regression with GARCH errors (Tobit-GARCH hereafter). The model has not yet been applied in related studies.

One of the main challenges in specifying these central bank reaction functions is that most interventions take a value of zero, which implies that the response of the dependent variable to the explanatory variables is nonlinear in the regression of the intervention function. This clearly implies that OLS estimates of the central bank intervention function (see, e.g., Eijffinger and Gruijters, 1991; Ito, 2003; Rogers and Siklos, 2003) will be inconsistent. By separating the bank's reactions to purchases and sales and by treating them as censored from the bottom, Tobit models overcome the problem that the dependent variable takes a value of zero most of the time (see, e.g., Alkeminders and Eijffinger, 1994; Humpage, 1999; Kim and Sheen, 2002; Rogers and Siklos, 2003; Brandner and Grech, 2005). However, if one ignores the conditional heteroscedasticity in standard Tobit models, the estimates of the coefficients will be inconsistent (see, e.g., Hurd, 1979; Arabmazar and Schmidt, 1981, 1982). This problem motivated us to develop a Tobit model that takes into account conditional heteroscedasticity.

On the other hand, Kim and Sheen (2002) adopt a friction model (as in Almekinders and Eijffinger, 1996) to describe purchase, sale, and no interventions in a unique regression function. They specify three separate distributional assumptions for these three intervention variables.[1] Ozlu and Prokhorov (2008) use a threshold regression, which allows for direct modeling of the relationship between the interventions and their determinants. However, all of these studies overlooked conditional heteroscedasticity.

The problem of a majority of zeros for the dependent variable can also be circumvented by using a quality dummy variable for the intervention. Probit approaches (see, e.g., Baillie and Osterberg,

* Corresponding author at: Department of Applied Economics, National Chiayi University, #580 Sinmin Rd., Chiayi City 60052, Taiwan. Tel.: +886 5 2732855.
E-mail address: klchang@mail.ncyu.edu.tw (K.-L. Chang).

[1] See also Jun (2008).

0922-1425/$ – see front matter
http://dx.doi.org/10.1016/j.japwor.2012.06.002

1997; Dominguez, 1998) and ordered Probit approaches (see, e.g., Frenkel et al., 2003; Ito and Yabu, 2007) identify determinants that affect the probability of a central bank intervention.[2] The ordered Probit model described by Ito and Yabu (2007) assumes that the intervention dummy takes values of 1, −1, and 0 for purchases, sales, and no intervention respectively.[3]

The infrequency of central bank interventions in foreign exchange markets explains the conditional heteroscedasticity in the intervention data.[4] We confirm this heteroscedasticity in the present study by performing a Lagrange multiplier test of the statistical significance of the ARCH errors.[5] Recognizing the prevalence of zero values for the dependent variable and the importance of conditional heteroscedasticity, we empirically apply Calzolari and Fiorentini's (1998) theoretical extension of the standard Tobit model to estimate the central bank intervention function in a way that allows for the possibility of conditional heteroscedastic error processes of the GARCH type. Because the exact likelihood function is not feasible with such a specification, Calzolari and Fiorentini (1998) propose an approximation of the likelihood function by treating the model as conditionally Gaussian. They then use Monte Carlo simulations to prove that the Tobit-GARCH model outperforms the standard Tobit model when the error terms follow a GARCH process.

In the present study, we apply the Tobit-GARCH model to test six primary determinants of the Bank of Japan's (hereafter BoJ) intervention in the Japanese Yen/U.S. Dollar (JPY/USD) foreign exchange market:[6] (a) daily deviations from a representative trend of the exchange rate, (b) the Fed's intervention in the New York JPY/USD exchange market, (c) the interest rate differentials between Japan and the U.S., (d) the first-business-day effect, (e) the Nikkei 500 stock index, and (f) lagged interventions. Due to the different philosophies underlying BoJ interventions, structural breaks (which really exist) are taken into account in the model.[7]

Central banks generally consider the trend of the exchange rate to be a potential target rate. In this paper, we find that the BoJ has significantly applied a "leaning against the wind" policy to bring the exchange rate closer (a) to its half-year long-term target from April 1, 1991 to July 2, 2004, (b) to its previous-day short-term target from June 21, 1995 to July 2, 2004, and (c) to its previous-month medium-term target from April 1, 1991 to June 20, 1995. The significance of the half-year long-term potential target for the entire sample period (April 1, 1991 to July 2, 2004) confirms the claim of LeBaron (1999) that 150-day terms are commonly used by market traders. The policy of "leaning with the wind" insignificantly occurred in some periods based on the BoJ's previous-day (short-term) potential target and its previous-month (medium-term) potential target. In other words, the leaning-with-the-wind policy was not significantly adopted by the BoJ, even when Japan suffered economic contraction during the lost decade (1992–2004) after the bubble burst.

In contrast to the findings of Baillie and Osterberg (2000) and Kim and Sheen (2002), our results show that the JP-U.S. interest rate spread was never a triggering factor for BoJ intervention. The BoJ sales intervention of the JPY did not respond to changes in the domestic stock index, even when the economy was sluggish during the lost decade. Besides, the first-business-day effect never affected BoJ interventions. However, in contrast to the conclusion of Frenkel et al. (2005), the BoJ interventions were significantly affected by U.S. interventions. In addition, interventions by the BoJ were significantly persistent from April 1, 1991 to June 20, 1995 and from January 14, 2003 to July 2, 2004, but not in the period from June 21, 1995 to January 13, 2003. This result is inconsistent with that of Ito and Yabu (2007), who find persistence in the period from June 21, 1995 to January 13, 2003.

This paper is organized as follows: Section 2 describes the data source, explanatory variables, and some of the basic statistics. Section 3 specifies the model both theoretically and empirically. Section 4 reports the estimates derived from the Tobit-GARCH model and compares them to estimates from the standard Tobit, OLS, traditional GARCH, and Probit models. Finally, Section 5 presents a discussion of the findings.

2. Description of variables and data

Most authors typically assume, rather than derive, the reaction functions of central banks. Economists often rely on econometric methods to test whether certain market variables are significant factors in central bank interventions. Following Almekinders and Eijffinger (1996) and Ito and Yabu (2007), we start by briefly deriving a reaction function (as a central bank would conceive it) from a loss function.

From the central bank's viewpoint, a loss occurs and convexly increases when the actual exchange rate deviates from the target rate. The expected loss, which should be minimized, can be expressed as $E_{t-1}Loss_t = E_{t-1}(s_t - \bar{s}_t)^2$, where s_t is the exchange rage at time t; $\bar{s}_t$ is the central bank's target exchange rate, and E_{t-1} is an expectation operator based on a past information set. Because the exchange rate is generally influenced by interventions and because central banks generally assume it to be a random walk, the exchange rate series can be expressed as $s_t = s_{t-1} + \gamma INT_t + c'Z_t + u_t$, where u_t is a white-noise process, INT_t is the central bank's intervention at time t, Z_t is the past information set, and c' is a row vector of coefficients. Accordingly, $E_{t-1}Loss_t = E_{t-1}(s_{t-1} + \gamma INT_t + c'Z_t + u_t - \bar{s}_t)^2$, which is minimized by the central bank with respect to INT_t. The optimal intervention, $INT_t^* = [-(s_{t-1} - \bar{s}_t) - c'Z_t]/\gamma$, is then obtained.

The target rate, $\bar{s}_t$, can be a linear combination of the central bank's various potential targets, as noted by Ito and Yabu (2007). For example, we have $\bar{s}_t = a_1\bar{s}_t^1 + a_2\bar{s}_t^2 + a_3\bar{s}_t^3$, where $a_1 + a_2 + a_3 = 1$ and $\bar{s}_t^j$ is the jth potential target. We then derive $INT_t^* = [-(s_{t-1} - \bar{s}_t) - c'Z_t]/\gamma = \beta_1(s_t - \bar{s}_t^1) + \beta_2(s_t - \bar{s}_t^2) + \beta_3(s_t - \bar{s}_t^3) + \beta_4 Z_t$, where $\beta_i = -a_i/\gamma$ for $i = 1$ to 3, and $\beta_4 = -c'/\gamma$. The optimal intervention is a function of the deviation of the actual exchange rate from each potential target rate. The INT_t^* equation is the basis of our empirical regression model for the central bank's reaction function. In the following, we define various potential target rates that the bank might consider.[8]

Several target exchange rates are considered in the literature. LeBaron (1999) justifies a term of 150 days as a very common choice among market traders; Kim and Sheen (2002) suggest the same thing. Ito and Yabu (2007) find that the past five-year moving average, rather than the one- or three-year moving average, is the relevant long-run target in the minds of policy makers. In addition, we find in our data sample that the short-term deviation is highly correlated to the three-year-term and five-year-term deviations. Thus, to circumvent the collinearity problem, we decide to define only three potential target types for the JPY/USD exchange rate.[9]

[2] See also the logit model in Frenkel et al. (2005).

[3] Other estimation methods include, for instance, the count data model in Frenkel et al. (2004).

[4] See Fig. 2.

[5] See Table 3.

[6] Intervention decisions in Japan are made by the Ministry of Finance and implemented by the Bank of Japan (BoJ), which is the central bank of Japan.

[7] In Section 2, we describe the reason for separating our data into three periods: period 1 extends from April 1, 1991 to June 20, 1995; period 2 from June 21, 1995 to January 13, 2003; and period 3 from January 14, 2003 to July 2, 2004.

[8] Researchers generally find that central bank interventions are caused by a discrepancy between the actual exchange rate and the bank's target rate. See, e.g., Alkeminders and Eijffinger (1994), Almekinders and Eijffinger (1996), Baillie and Osterberg (1997), Kim and Sheen (2002), and Ito and Yabu (2007).

[9] In addition, the correlation between the (half-year) long-term deviation and the one-year-term deviation is about 0.92; the three-year-term deviation is also highly correlated with the five-year-term deviation.