Global Saving Glut, Monetary Policy, and Housing Bubble: Further Evidence

Qiao Yu*
Hanwen Fan
Xun Wu

Abstract: Recently, a heated debate has emerged in the economic literature, focusing on the major factors driving the global financial crisis. Among the many theories proposed, the global saving glut hypothesis is widely received, yet highly controversial. This paper provides evidence to further assess the validity of the global saving glut assumption. According to the empirical and historical evidence produced in the study, it is difficult to accept the arguments that external factors played a decisive role of causing the financial crisis in the core of the global capitalism.

Key Words: global saving glut, monetary policy, housing bubble, financial crisis

JEL Classification: E50, F30, G01

*The authors are from School of Public Policy & Management, Tsinghua University, Beijing, China. Comments and suggestions are welcomed. Please correspond to Qiao Yu, School of Public Policy & Management, Tsinghua University, Beijing 100084. Email: qiaoyu@tsinghua.edu.cn; Tel: (8610)6278-3475.

It is generally agreed that housing bubble of the United States at the turn of this century led to the unprecedented global financial crisis and subsequent great recession. Among many theories which attempt to explain reasons for the real estate bubble and the following financial crisis, the hypothesis of global saving glut suggested by Ben S. Bernanke (2005, 2007, 2009, 2010, 2011), a Distinguished Fellow at Brookings Institution and former Chairman of the Board of Governors of the Federal Reserve System, is a most influential yet controversial one.

Bernanke (2005) raised a concept of global saving glut and initially used it to account for the U.S. current account deficit. Then he (2007a, 2007b) claimed that the global saving glut "played an important role in the decline in long-term rates".[1] Although Bernanke (2009) did not directly attribute the financial crisis to the global saving glut, he considered that "to achieve more balanced and durable economic growth and to reduce the risks of financial instability, we must avoid ever-increasing and unsustainable imbalances in trade and capital flows".

In January 2010, Bernanke delivered a keynote speech entitled "Monetary Policy and the Housing Bubble," at the annual American Economic Association (AEA) meeting, in which he thoroughly discussed adequacy of the Fed's monetary policy and examined relationship between monetary policy and the rise in housing prices in the first half of the decade. Based on the evidence offered, he (2010a) concluded that the "direct linkages (between monetary policy and housing bubble), at least, are weak." Moreover, he said, "(monetary) policy during that period—though certainly accommodative (to reduce capital flows)—does not appear to have been inappropriate……What does explain the variability in house price appreciation across countries? In my previous remarks, I have pointed out that capital flows from emerging markets to industrial countries can help to explain asset (housing) price appreciation and low long-term real interest rates in the countries receiving the funds—the so-called global saving glut."

Bernanke (2010b) reiterated that "because large flows of capital into the United States drove down the returns available on many traditional long-term investments, such as Treasury bonds, investors' appetite for alternative investments—such as loans to finance corporate mergers or commercial real estate projects—increased greatly in the years leading up to the crisis. These securities too were packaged and sold through the shadow banking system." Bernanke (2010c) further explained that "a key driver of this 'uphill' flow of capital is official reserve accumulation in the emerging market economies that exceeds private capital in-flows to these economies. The total holdings of foreign exchange reserves by selected major emerging market economies… have risen sharply since the crisis and now surpass $5 trillion…China holds

[1] "the emergence of a global saving glut……driven by the transformation of many emerging-market economies—notably, rapidly growing East Asian economies and oil-producing countries--from net borrowers to large net lenders on international capital markets……Changes in the global pattern of saving and investment surely played an important role in the decline in long-term rates," (Bernanke, 2007a); "Changes in the global pattern of saving and investment surely played an important role in the decline in long-term rates." (Bernanke, 2007b).

about half of the total reserves of these selected economies, slightly more than $2.6 trillion."

Moreover, Bernanke (2011) pointed out that "the failures of the U.S. financial system in allocating strong flows of capital, both domestic and foreign, helped precipitate the recent financial crisis and global recession…A significant portion of these capital inflows reflected a broader phenomenon that, in the past, I have dubbed the global saving glut. Over the past 15 years or so, for reasons on which I have elaborated in earlier remarks, many emerging market economies have run large, sustained current account surpluses and thus have become exporters of capital to the advanced economies, especially the United States. These in-flows exacerbated the U.S. current account deficit and were also a factor pushing U.S. and global longer-term interest rates below levels suggested by expected short-term rates and other macroeconomic fundamentals."

In sum, the global saving glut hypothesis contains a cluster of logically articulated arguments: 1) monetary policy of the U.S. Federal Reserve is appropriate prior to the financial crisis during the first decade of this century; 2) the linkage between monetary policy and housing price appreciation across industrial countries including the United States is statistically insignificant and economically weak during this period; 3) the monetary policy is accommodative to cope with capital flows from reserve-rich countries, especially developing and emerging-market nations; and 4) massive accumulation of foreign reserves and consequent capital inflows from these economies to the United States leads to low long-term real rates and housing price bubble, so as to bring about the financial crisis.

However, the literature has far from reached a consensus regarding this important assumption. On the one hand, many authors offered theoretical explanations and presented some empirical evidences in favor of the global saving glut hypothesis from various respects. For example, Caballero, Farhi and Gourinchas (2008) used a formal framework to account for central role of international financial development heterogeneity on the global imbalances and low interest rates. Warnocka and Warnockd (2009) estimated that if there were absent the substantial foreign inflows into U.S. government bonds, the long-term Treasury yield would be 80 basis points higher. Dokko et al. (2009) argued that monetary policy was not a primary factor in the housing bubble and also suspect that tighter monetary policy would not have been the best response to the bubble. Bean et al. (2010) showed that low policy rates only played a modest direct role to the growth in credit and the rise in house prices in the run-up to the crisis. Poole (2010) pointed out that the federal policies were just supporting actors for the financial crisis but the responsibility rests primarily with the private sector. Kuttner (2012) reviewed empirical studies and concluded that impact of interest rates on house prices appears to be quite modest and the estimated effects are too small to explain the housing boom in the United States and elsewhere over the past decade. Hofmann and Bogdanova (2012) suggested that monetary policy has probably been systematically accommodative globally due to "an asymmetric reaction of monetary policy to the different stages of the financial cycle in core advanced

economies, and global behavioral monetary policy spillovers through resistance to undesired capital flows and exchange rate movements in other countries, especially in EMEs."

On the other hand, Taylor (2007, 2009, 2010, 2012) argued that excessively low policy rates led to the housing bubble. Based on the statistical analysis, Taylor (2009) concluded that "government actions and interventions caused, prolonged, and worsened the financial crisis. They caused it by deviating from historical precedents and principles for setting interest rates, which had worked well for 20 years". Seyfried (2010) found that loose monetary policy significantly affected housing price inflation in Ireland, Spain and the United States in the recent years. Rötheli (2010) stated that the easing monetary policy was responsible for the financial crisis and it is necessary to employ monetary policy to restrain financial boom–bust cycles in the future. Mishikin (2011) commended that "although it is far from clear that the Federal Reserve is to blame for the housing bubble, the explosion of microeconomic research, both theoretical and empirical, suggests that there is a case for monetary policy to play a role in creating credit bubbles." Sá, Towbin and Wieladek (2011) used a panel data of the OECD countries to prove that monetary policy and capital inflows shocks had a significant and positive effect on real house prices, real credit to the private sector and real residential investment. Borio and Disyatat (2011) indicated that it was not global excess saving but credit creation, a defining feature of a monetary economy, which played a key role as main contributor to the financial crisis. Sánchez (2011) suggested that expansionary monetary policy beyond optimal rules during a long-lasting period and policies of artificially promoting credit expansion should be avoided, because they produced inadequate incentives for private sectors. McDonald and Stokes (2013) employed three alternative models and monthly data of the period 1987 to 2010 to reveal that the Federal funds rate in the U.S. had negative impacts on changes of housing prices. Based on panel data of 18 OECD countries from 1920 to 2011, Bordo, and Landon-Lane (2013) documented that loose monetary policy (either an interest rate below the target rate or a money growth rate above the target growth rate) positively affected general asset prices. This result was robust across multiple asset prices and different specifications, and it was present with other alternative explanations such as low inflation or "easy" credit controlled.

Although the above-mentioned researchers explored the issue from different perspectives, there were no decisive and convincing evidence regarding it. Therefore, more studies must be pursued to fully assess validity of the global saving glut assumption. This paper aims to provide additional evidence to verify the global saving glut hypothesis. Section I will broadly evaluate appropriation of the Fed's monetary policy in line with the Taylor rule by using wide range of data sets. Section II will further document relationship between monetary policy and housing prices across countries. Section III will discuss linkage between the Fed's monetary policy and foreign reserves of the East Asian export-oriented economies and the Organization of Petroleum Exporting Countries (OPEC) member countries. Section VI will search documentary clues to identify if monetary policy is accommodative to internal or external factors. Finally, Section V will provide concluding remarks.

I. Appropriateness of the Fed's Monetary Policy

A fiery dispute regarding major cause of the U.S. housing bubble is whether the Fed's monetary policy was too easier than it should be. Since no one knows "rightness" of the policy, the federal funds rate estimated by the Taylor rule (Taylor, 1993) was taken as a yardstick to assess this issue. The implicit assumption is if conduct of the monetary policy obeyed the Taylor rule, it would be an appropriate one free from the responsibility for the housing bubble. The Taylor rule is given as follows.

$$i_t = 2 + \pi_t + a\left(\pi_t - \pi_t^*\right) + b\left(y_t - y_t^*\right) \quad (1)$$

Where i_t is the federal funds rate in a given period t, π_t is the actual inflation rate in period t, π_t^* is the target inflation rate in period t, $(\pi_t - \pi_t^*)$ is the difference between actual inflation rate and target inflation rate in period t, y_t is the actual output in period t, y_t^* is the potential output in t period, and $(y_t - y_t^*)$ is the output gap in period t. According to Taylor's suggestion (1993), the parameters a and b are taken the value of 0.5.

Indeed, the implication of the Taylor rule has become a focal issue in meetings of the Federal Open Market Committee (FOMC) starting from the 1990s and onwards due largely to the fact that money aggregate target was abandoned and interest rate target was resumed (Kahn, 2012). Moreover, a very striking part of the U.S. monetary policy is that the projected policy rate by the Taylor rule is very close to the actual federal funds rate by tracing back to the period of 1987 to 2000 (Rotemberg, 2013). This phenomenon further reinforces routine practice in the FOMC's meetings.

While outlining limitations of the Taylor rule method, Bernanke (2010a) took it as a rule of thumb to assess appropriateness of the monetary policy from the first quarter of 2000 to the first quarter of 2009. He presented two estimated lines of the federal funds rate obtained from equation (1) on the slide 4 (Bernanke, 2010a), the first is the federal funds rate path implied by the Taylor rule based on the current Consumer Price Index (CPI), and the alternative is the path prescribed by the Taylor rule with the forecasts of Personal Consumption Expenditures (PCE) price index which consist of the Greenbook forecasts for the period through 2004 and the forecasts by the methods of Orphanides and Wieland from 2005 (GOW forecasts).[2] To compare these two estimated paths, one can observe that the latter is closer to the actual line of the target interest rate than the former. Bernanke concluded that the estimated federal funds rate by the Taylor rule using forecast inflation is a more useful policy benchmark than that using current inflation since monetary policy considers the forecast policy variables rather than the current ones. Against this backdrop, therefore, the Fed's monetary policy from 2002 to 2006 "appears to have been reasonably appropriate".

Due to the fact that the simple comparison between these two federal funds rate

[2] The FOMC makes a variation of the Taylor rule by using its anticipations of future values of inflation rather than the past values. Yet this could be a possible mistake for the Fed to use its projected forward rates to guide its future policy (Rotemberg, 2013).

paths based on two sets of inflation indices is rather intuitive, it is difficult to tell if one estimated federal funds rate is superior to the other as the policy guide. In order to formally examine appropriateness of the monetary policy, we employ a dynamic non-parametric method called as the Wilcoxon Signed-Rank Test (Mendenhall et al, 1986) to verify: 1) whether any federal funds rate path estimated by the Taylor rule with a variety of inflation measures is statistically different from the actual target rate line; and 2) whether any pair of the estimated federal funds rate paths by the Taylor rule with various inflation measures is statistically different (Appendix 1 gives the details of the Wilcoxon Signed-Rank Test). Theoretically, if the estimated federal funds rate path prescribed by the Taylor rule with GOW forecasts of PCE index were more proper for policy guide than alternative estimated paths, it would be statistically no difference from the actual target rate line, but would statistically differ from others.

In addition to the estimated rate path with the GOW forecasts of PCE index shown in Bernanke's speech, we produced six paths of federal funds rate estimations by alternatively using various inflation measures for the purpose of robustness tests. In specific, we used both current and forecast data of the CPI, PCE and core PCE, respectively, to obtain six estimated federal funds rate paths prescribed by the Taylor rule. Figure 1 draws all of these estimated paths with different measurement of inflation, together with the actual target rate line. At a single glance, one can notice that the estimated path with the GOW forecasts of PCE index given by Bernanke (2010a) is not always the closest one to the actual target rate line among all estimated paths, particularly in the period of 2000 to 2003 and the period of 2006 to 2009. Yet, we cannot phase out the assumption that the estimated path with the GOW forecasts of PCE index is the best policy guide without having statistically solid evidence.

Table 1 presents the standardized Wilcoxon statistics testing for the null hypotheses that there are neither differences between any estimated federal funds rate path and the actual target rate line, nor differences among any pair of the estimated paths. According to the statistical results, we have the following conclusions: 1) the null hypothesis of no difference between the estimated rate path with the GOW forecasts of PCE index reported in Bernanke's speech (2010a) and actual target rate line is significantly rejected; 2) the null hypotheses of no differences between other six estimated rate paths and the actual target rate line are significantly rejected; 3) the null hypotheses of no difference between the estimated rate path with the GOW forecasts of PCE index and any of estimated rate path with either current (forecast) CPI or current (forecast) PCE index are also significantly rejected; 4) the null hypotheses of no difference between the estimated rate path with the GOW forecasts of PCE index and the one with the current (forecast) core PCE index cannot be rejected; and 5) the null hypotheses of no difference between the estimated paths with current and forecast CPI indices (current and forecast PCE indices, as well as current and forecast core PCE indices) cannot be rejected.

In sum, the outcomes of the Wilcoxon Signed-Rank test suggest that the federal funds rate path prescribed by the Taylor rule with the GOW forecasts of PCE index does not statistically outperform other estimated paths based on a variety of inflation measures. There may be two possibilities to interpret these findings. First, it is

difficult to tell which estimated federal funds rate prescribed by the Taylor rule is more adequate to guide the monetary policy due largely to incompletion of inflationary indices used for calculation. Second, the Taylor rule itself may be too restrictive to be a general policy guide.[3] Nevertheless, the empirical evidence in this section fails to support the argument that the Fed's monetary policy was appropriate in the first decade of the century in line with the benchmark provided by the Taylor rule claimed by Bernanke (2010a), regardless of which inflation measurement is taken into account and whether current or forecast inflation is used.

Table 1 - Wilcoxon Test results between Estimated Rate Paths and Actual Target Rate Line

	Target	**Path 1**	**Path 2**	**Path 3**	**Path 4**	**Path 5**	**Path 6**	**Path 7**
Target	---	-2.843***	-4.198***	-3.647***	-3.234***	-2.908***	-2.277**	-2.125**
Path 1		---	-3.633***	-3.183***	-2.154**	-2.125**	0.943	0.326
Path 2			---	0.181	4.931***	2.886***	4.111***	4.394***
Path 3				---	3.038***	3.024***	3.343***	3.553***
Path 4					---	-0.993	3.096***	3.024***
Path 5						---	2.632***	3.510***
Path 6							---	-1.552
Path 7								---

Notes: see notes in Figure 1. *** is statistically significant at 1 percent level, ** is statistically significant at 5 percent level.

II. Relationship between Monetary Policy and Housing Prices

To further support the arguments of insignificant monetary factor in housing bubbles, Bernanke (2010a) presented cross-country evidence to document relationship between monetary policy and housing prices in twenty advanced countries, which was produced by Fatas and others (2009). Figure 2 is the original estimate result duplicated from the slide 9 of Bernanke's keynote speech in the AEA annual meeting of 2010. In this figure, the horizontal axis is the average Taylor rule residuals to indicate degree of ease or tight monetary policy; the vertical axis is the change in real house prices. The regressive result shown in this figure is statistically insignificant (R^2=0.05, t=-0.97), implying that the relationship between the monetary policy and appreciation of house prices is quite weak, and easiness of monetary policy explains little growth rate of housing prices.[4]

[3] Taylor (1993) pointed out that under different macroeconomic environments, coefficients of the Taylor formula may be different. Cochrane (2006) argued that a policy target based on pre-determined coefficients of the Taylor formula may lead to serious inflation or deflation in the long term. Cochrane (2007a) showed that coefficients of the Taylor rule are unable to be estimated because they are backward-looking outcomes rather than forward-looking ones. Cochrane (2007b) also demonstrated that the establishment of Taylor rule requires an explosive dynamic process, or else it will lead to severe inflation or deflation. However, in reality, this explosive dynamic process is hard to realize. In other words, an interest rate policy that seems to have a target actually undertakes risk of inflation or deflation in the future. By considering distortion in different markets, Melvin and Taylor (2009) doubted the Taylor rule's availability in the low inflation environment.

[4] According to Fatas and others (2009), the regression shown in the Figure 3.13 suggested that R^2 =0.03, which is

Yet, the original regression shown in Figure 2 is severely flawed because there is a mismatch between dependent variable and explanatory variable over the sample period. On the one hand, the period of the dependent variable is from the fourth quarter of 2001 to the third quarter of 2006 (April 2001 to March 2006), covering 20 quarters. On the other hand, the explanatory variable ranges from the first quarter of 2002 to the third quarter of 2006 (January 2002 to March 2006), just having 19 quarters. In other words, the explanatory variable lags behind the dependent variable by one quarter and the time span of the former is one quarter shorter than that of the latter. Be reminded that in regression the explanatory variable should lead the dependent variable or both variables take the same sample period, but not the other way around.

We correct the problem of data mismatch in Figure 2 and re-estimate the relationship between dependent and explanatory variables. Figure 3 is the modified regression I with the same sample period of January 2002 to March 2006 for both dependent and explanatory variables, covering time span of 19 quarters. Figure 4 is the modified regression II with the period of February 2002to April 2006 for the dependent variable and the period of January 2002 to March 2006 for the explanatory variable, so that the former is one quarter lagged behind the latter, both with time spans of 19 quarters. Compared to Figure 2, Figures 3 and 4 have opposite outcomes, suggesting that the relationship between the monetary policy and appreciation of house prices is by no means weak, and easy monetary policy has certain non-ignorable effect on growth of housing prices.

Table 2 Estimates of Relationship between Monetary Policy and Housing Prices

	Original Regression Bernanke (2010a)	**Modified Regression I**	**Modified Regression II**
Time span of dependent variable	4/2001-3/2006	1/2002-3/2006	2/2002-4/2006
Time span of explanatory variable	1/2002-3/2006	1/2002-3/2006	1/2002-3/2006
Observations of dependent variable	20	19	19
Observations of independent variable	19	19	19
$\boldsymbol{R^2}$	0.046	0.173	0.199
***t*-statistic of null hypothesis that slope of trend line is 0**	-0.97	-1.94*	-2.114**
***p*-statistic of null hypothesis**	0.3442	0.0679	0.0487

even smaller than Bernanke's estimate, so that they claimed that "there is virtually no association between the measures of monetary policy stance and house price increases".

that slope of trend line is 0

Sources: the Greek Housing price is from the Bank of Greece, http://www.bankofg reece.gr/Pages/en/Statistics/realestate/default.aspx; the Austrian housing price is from the Oesterreichische (Austria) National bank, http://www.oenb.at/en/stat_melders/datenangebot/preise/preisen twicklung/sektorale_preisentwicklung.jsp#tcm:16-147793; the housing prices of the oth er countries are from the OECD: http://www.oecd.org/document/0,3746,en_2649_201185_46462759_1_1_1_1,00.html. The average of Taylor rule residuals come from Bernanke (2010a). Note: ** is statistically significant at 5 percent level, * is statistically significant at 10 percent level.

Table 2 summarizes the estimated results of all these three regressions. After correction of the data mismatch problem, the negative relationship between monetary policy and appreciation of housing prices is a statistically significant and economically meaningful, and about 17-20 percent of the variability in housing price rises can be explained by easiness of monetary policy in industrial countries. It is obvious that the null hypothesis of the zero slope of trend line is rejected in the modified regressions, although it cannot be rejected in the original regression.

III Linkage between the U.S. Monetary Policy and Others' Foreign Reserv es

Another key argument of the global saving glut hypothesis is that the Fed's monetary policy is generally accommodative to reduce capital inflows due to massive accumulation of official foreign reserves from emerging economies, resulting in low long-term real rates and subsequent housing bubble in the United States. Be reminded that long term interest rate is average of short term rates plus term premium. If long-term rates of interest are affected by foreign reserves, so do short-term rates of interest. As such, the U.S. monetary policy conducted with the federal funds rate should be bounded by accumulated global savings of reserve-rich countries. In order to verify this assumption, we will conduct significance tests to evaluate whether the monetary policy is subject to external factors or not in this section. In particular, we will test for if there have strong linkages between the federal funds rate or broadly defined money stock (M2) as well as long-term rate in the United States and foreign reserves from the East Asian economies and the OPEC countries, respectively.

First of all, we conduct *F*-test to serve the end. Without losing generality, both restricted and unrestricted regressive equations are set up as follows. Here we take the regressive model as an example to test for linkage between the U.S. federal funds rate and other economies' foreign reserves. The restricted equation is:

$$T_1 = \beta_0 + \beta_1\left(\pi_t - \pi_t^*\right) + \beta_2\left(y_t - y_t^*\right) + u \qquad (2a)$$

And the unrestricted equation is:

$$T_1 = \beta_0 + \beta_1\left(\pi_t - \pi_t^*\right) + \beta_2\left(y_t - y_t^*\right) + \beta_3 x + u \qquad (2b)$$

Where t is time period, π_t is the inflation rate in the t period, π_t* is the target of inflation rate in the t period, (π_t - π_t*) is the deviation of actual inflation rate to its target; y_t is the actual GDP in the t period, y_t* is the potential GDP in the t period, (y_t -

y^*) is the gap between actual and potential GDP; x is foreign reserves; T_1 refers to federal funds rate. Alternatively, we will use T_2 (broadly defined money stock) and T_3 (interest rate of five-year Treasury bond) to replace T_1 in the equation (2).

Assume that if there is no influence of foreign reserves on the US federal funds rate (T_1) or money stock (T_2) or long-term interest rate (T_3) , β_3=0; otherwise, $\beta_3 \neq 0$. Hence, the null hypothesis and alternative hypothesis of this model are:

$$H_0 : \beta_3 = 0 \ \textit{v.s.}\ H_1 : \beta_3 \neq 0 \tag{3}$$

Define sum of residuals of the restricted equation as SSR_r, and sum of residuals of the unrestricted equation as SSR_{ur}, then the F-statistic is:

$$F = \frac{(SSR_r - SSR_{ur})/q}{SSR_{ur}/(n-k-1)} \sim F(q, n-k-1) \tag{4}$$

Where n is the number of observations, q is the number of restrictions, and k is the number of independent variables in the unrestricted equation.

In addition, we also perform a robust test to further verify for relationship between the U.S. monetary policy and other countries' foreign reserves. For this purpose, we employ a semi-parametric regression model (Yatchew, 1998):

$$\mathrm{y} = \mathrm{z}\beta + f(\mathrm{x}) + \varepsilon \tag{5}$$

Where $\mathrm{E}(\mathrm{y}|\mathrm{z},\mathrm{x}) = \mathrm{z}\beta + f(\mathrm{x})$, $\sigma_\varepsilon^2 = \mathrm{Var}[\mathrm{y}|\mathrm{z},\mathrm{x}]$. (y_1, x_1, z_1),…,(y_T, x_T, z_T) are i.i.d. data sets. The form of function f is unknown, while y is linear in z and β is the corresponding coefficient. The test procedure is as the following: reorder data sets so that $x_1 \leq \cdots \leq x_T$; calculate $s_{diff}^2 = \frac{1}{2T}\sum(y_t - y_{t-1})^2$; perform restricted regression of y on x and x^2 to obtain $\hat{\gamma}_0 + \hat{\gamma}_1 x_t + \hat{\gamma}_2 x_t^2$; compute $s_{res}^2 = \frac{1}{T}\sum(y_t - \hat{\gamma}_0 - \hat{\gamma}_1 x_t - \hat{\gamma}_2 x_t^2)^2$; and calculate statistic V and perform one-sided test comparing to critical value from $N(0,1)$. The testing statistic is expressed as:

$$\mathrm{V} = T^{1/2}\frac{s_{res}^2 - s_{diff}^2}{s_{diff}^2} \sim N(0,1) \tag{6}$$

Table 3 presents computed statistics of significance tests based on both of F-test method and robust semi-parametric test procedure.[5] The outcomes obtained from these tests are quite consistent. According to the results, there was virtually no statistically significant linkage between the monetary policy conducted by the federal funds rate and foreign reserves held by the East Asian economies and OPEC countries, even though it seems that the U.S. money stock measured by M2 and long-term rate

[5] The growth rate of each variables during the period of 2000Q2-2009Q2 is used for the significance tests.

of interest represented by interest rate of five-year Treasury bond might be affected by the East Asian foreign reserves. As a consequence, there has no solid base to accept the assumption that the Fed's monetary policy is accommodative to global savings and subsequent capital inflows.

Table 3 Significance Tests of Relationship between US Monetary Policy and Foreign Reserves

Dependent variables:	**T_1 (federal funds rate)**		**T_2（money supply M_2）**		**T_3（long-term rate）**	
	F-test statistic	Robust-test statistic	*F*-test statistic	Robust-test statistic	*F*-test statistic	Robust-test statistic
Explanatory variables:						
x_1 (East Asia foreign reserves)	0.92	-0.243	3.40*	4.445***	6.69**	0.115
	(0.3442)	(0.596)	(0.0740)s	(0.000)	(0.014)	(0.454)
x_2 (East Asia & OPEC foreign reserves)	0.77	0.500	0.20	0.072	0.19	-0.888
	(0.3856)	(0.309)	(0.6585)	(0.471)	(0.664)	(0.813)

Sources: 1) the federal funds rate and M_2 are from the the Federal Reserve: http://www.ny.frb.org/markets/omo/dmm/fedfundsdata.cfm; http://www.federalreserve.gov/rele ases/h6/hist/h6hist7.txt; and 5-year treasury bonds interest rate is from St.Louis Fed: http://research.stlouisfed.org/fred2/. 2) the foregin reserves of East Asian economies including China, Japan, South Korea, Singapore, Malaysia, Thailand, Indonesia, Hong Kong and Taiwan. The foreirgn reserves of the East Asians and OPEC countries are from from the United Nations: http://data.un.org/Data.aspx?q=Foreign+Exchange+ Reserves&d=IFS&f=SeriesCode%3a.1. 3) the inflation rate, inflation target, GDP, and potential GDP of the United States are from the Federal Reserve: http://research.stlouisfed.org/fred2/.
Notes: figures in parentheses are *p-values.* ***, **, and * are statistically significant at 1 percent, 5 percent and 10 percent levels, respectively.

IV Accommodative Monetary Policy by Internal and External Factors

It is long arguable whether monetary policy is endogenously or exogenously determined. Given the fact that monetary policy is accommodative in most time, it may be subject to either external factor s or internal issues. As for monetary policy of the United States, in particular, it has experienced a few periods emphasizing alternatively on both international and domestic situations under different circumstances over the past hundred years of its history. Generally, the Federal Reserve paid significant attention to international factors in its first two decades, and it had relative inattention to such factors in the following two-plus decades. Even if it renewed attention to international aspects of monetary policy in the 1960s, the Federal Reserve has had "benign neglect of the international dimension" in the most recent decades (Eichengreen, 2013).

Under the gold standard system, major economies were bounded by international flows of the precious metal due largely to balance of payment positions, especially trade imbalances. As a result, considerations of sustaining this system evidently affected monetary policies of central banks in leading countries, including the U.S. Federal Reserve. For example, in 1927 the Federal Reserve pursued expansionary policy by lowering interest rates so as to help England return back to the gold standard, moving astray from its then objective of lending only for the purposes productive credits. Another example occurred in 1931, when the Fed raised discount rates to encourage gold inflows and prevent it out, reflecting that "faithfulness to the ideals of the gold standard must have mattered too" (Rotemberg, 2013).

Afterwards, the Federal Reserve is basically free from external constraints and able to focus on domestic objectives. Once regaining its policy autonomy, the Federal

Reserve centered on the dual mandate goals—price stability and maximum employment—which were laid out in 1946 by the Employment Act. Later on, policymakers of the Federal Reserve modified their review to regard achievement of price stability as the necessary conditions for employment objective due to the inflationary shocks and the way of combating it over the 1970s (Bernanke, 2013). Against the background of the recent financial crisis and the Great Recession, the Fed has already aligned the order of its dual mandate goals in 2012, which is expressed as "fulfilling its statutory mandate from the Congress of promoting maximum employment, stable prices, and moderate long-term interest rates".[6] In addition, the Federal Reserve has also paid a greater attention on financial stability, which "is probably the largest shift in central bank objectives wrought by the crisis" (Yellen, 2013).

Changes of the monetary policy depend on opinions and judgments of members in the Federal Open Market Committee (FOMC), which are formed by perception, comprehension and prioritization of these policymakers on various domestic and foreign factors. To some extent, key words mentioned in minutes of the FOMC may intuitively reveal major concerns of the policymakers and also provide *ex post* clues of the U.S. monetary policy focus. Hence, we reviewed summary of the FOMC minutes from January 1996 to December 2014 and accounted numbers of key words of both domestic and foreign matters repeated in the documents so as to picture if the accommodative monetary policy in recent years is mainly governed by internal factors or otherwise.

Table 4 lists all domestic and foreign factors mentioned in the summary of the FOMC minutes. In specific, the domestic group includes both nominal terms and real terms, while the foreign group has nominal terms, real terms, regional concerns and global issues. There are 7,275 observations in the domestic group and 712 observations in the foreign group found in the summary of the FOMC minutes from 1996 to 2014. As for nominal terms in the domestic group, prices category is the highest used in the documents, consisting of 44 percent of the total observations. Within this category, prices, energy prices and consumer prices are highly watched. Interest rates are also emphasized, around 10 percent of the total. In real terms, investment, unemployment and GDP are three frequently repeated variables, accounting for 16.4 percent, 9.5 percent and 6.8 percent, respectively. Meanwhile, government spending and budget deficit are also emphasized. On the other hand, balance sheet, East Asia and trade deficit are three frequently mentioned words in the foreign group, explaining 41 percent, 30 percent and 21 percent of the total observations, respectively. But exchange rates only account for 4.2 percent and capital flows merely over 1 percent in the foreign group.

[6] http://www.federalreserve.gov/monetarypolicy/files/FOMC_LongerRunGoals.pdf

Table 4 Analytic Statistics of Key Words in the Fed Minutes Summary 1996-2014

Variable	Total Observations	Mean of Observations	Maximum of Observations	Minimum of Observations	Variable in its Group(%)	Variable in 10,000 Words(%)
DOMESTIC GROUP						
I. Nominal Terms						
1) Price Category	3230	170.00	270	68	44.40%	41.05
prices	1962	103.26	197	25	26.97%	24.93
retail prices	6	0.32	1	0	0.08%	0.08
producer price (index)	90	4.74	10	0	1.24%	1.14
consumer price（index）	508	26.74	41	16	6.98%	6.46
GDP deflator	0	0.00	0	0	0.00%	0.00
housing/property prices	14	0.74	4	0	0.19%	0.18
energy prices	624	32.84	86	12	8.58%	7.93
asset prices	26	1.37	5	0	0.36%	0.33
2) Interest Rate Category	743	39.11	81	16	10.21%	9.44
interest rate	608	32.00	75	15	8.36%	7.73
long-term interest rate	56	2.95	8	0	0.77%	0.71
short-term interest rate	79	4.16	10	0	1.09%	1.00
II.Real Terms		0.00				
3) GDP	495	26.05	88	5	6.80%	6.29
4) (GDP) growth rate	51	2.68	9	0	0.70%	0.65
5) national income	23	1.21	6	0	0.32%	0.29
6) investment	1191	62.68	83	30	16.37%	15.14
7) government spending	547	28.79	52	15	7.52%	6.95
8) household expenditures	17	0.89	5	0	0.23%	0.22
9) unemployment rate	688	36.21	130	9	9.46%	8.74
10) budget deficit	290	15.26	27	8	3.99%	3.69
Domestic Total	7275	382.89	545	257	100.00%	92.46
FOREIGN GROUP						
I.Nominal Terms						
1) exchange rate category	30	1.58	5	0	4.21%	0.00
exchange rate	27	1.42	4	0	3.79%	0.34
exchange rate volatility	0	0.00	0	0	0.00%	0.00
nominal exchange rate	1	0.05	1	0	0.14%	0.01
real exchange rate	0	0.00	0	0	0.00%	0.00
fix exchange rate	0	0.00	0	0	0.00%	0.00
flexible exchange rate	0	0.00	0	0	0.00%	0.00
currency appreciation	0	0.00	0	0	0.00%	0.00
currency depreciation	3	0.16	2	0	0.42%	0.04
currency manipulation	0	0.00	0	0	0.00%	0.00
II.Real Terms						
2) balance sheet	293	15.42	71	0	41.15%	3.72
3) trade balance	10	0.53	4	0	1.40%	0.13
4) trade deficit	149	7.84	11	1	20.93%	1.89
5) capital flow/account	4	0.21	2	0	0.56%	0.05
6) capital inflow	3	0.16	2	0	0.42%	0.04
7) capital outflow	3	0.16	3	0	0.42%	0.04
III.Regional Concerns						
8) East Asia/Asia	213	11.21	86	0	29.92%	2.71
9) OPEC	0	0.00	0	0	0.00%	0.00
10) EU(european union)	6	0.32	4	0	0.84%	0.08
IV.Global Factors						
11) global inbalance	0	0.00	0	0	0.00%	0.00
12) global saving	0	0.00	0	0	0.00%	0.00
13) foreign reserves	1	0.05	1	0	0.14%	0.01
Foreign Total	712	37.47	98	4	100.00%	9.05

Sources: the FOMC minutes, 1996-2014, http://www.federalreserv e.gov/boarddocs/

Figure 5 shows loci of total numbers for both domestic and foreign factors. While number of domestic factors declined from its peak around 400 to bottom of 257 in 2002, it rebounded to 355 in 2007 and then continued increasing in the financial crisis and subsequent great depression. On the other hand, since annual observations of foreign variables cited in the minutes were just 18.38 during 1999-2006, it is quite apparent that policymakers of the Federal Reserve paid very limited attention to foreign factors in this period, during which the property bubble was nurtured and developed. Yet, the Fed had relatively higher concern on international factors in the midst of crises—number of foreign variables appeared in the minutes recorded 97 in 1998 when the East Asian financial crisis went worse and it reached 98 in 2009 when the global financial crisis climaxed.

In addition, Figure 6 gives percentage of foreign variables with respect to domestic ones so as to document priority in the FOMC meetings. Even though foreign factors relative to domestic ones recorded 24 percent in 1998 and 2009 in which both the East Asian financial crisis and the global financial crisis peaked, the annual average of foreign variables to domestic ones was 5.87 percent (with maximum of 8.95 percent and minimum of 4.23 percent) in the period of 1999-2006, during which housing bubble loomed large. In general, historical evidence based on the key words of the FOMC minutes reveals that home issues dominated the FOMC decision-making process in the first half of this century, and monetary policy was accommodative much more on domestic than foreign factors.[7]

V. Concluding Remarks

Recently there has been heated debate on causes the global financial crisis among policymakers, academia and market-participants all over the world. This issue is very important because it will not only comprehend reasons of why the financial crisis took place in the central area of the world market, but also consist of measures of how to prevent reoccurrence of full-fledged financial collapse in the future. Among many theories offered, the global saving glut hypothesis is widely received yet highly controversial. Therefore, it is quite necessary to have more solid empirical studies to assess validity of this assumption. This paper provides further evidence to verify truthfulness of the global saving glut theory. The novelty of our analysis is to use various approaches to assess a cluster of the focal arguments consisting of the global saving glut hypothesis.

We first investigated dynamics for appropriateness of the U.S. monetary policy at the turn of the century. To serve the end, a series of the federal rate paths are estimated by the Taylor rule with a spectrum of data sets, and they are used to compare to the actual policy locus and contrast with each other. According to the testing results, the argument that the Fed's monetary policy was appropriate in the first decade of the

[7] In his 137 speeches over the period of 2005-2011, Bernanke mentioned "global saving glut" 62 times, "global imbalances" 53 times, "Asia" 131 times, "current account deficit" 305 times, and "budget deficit" only 45 times. This indicates that Bernanke focused more on foreign factors than domestic issues, which is different from the FOMC's concerns.

century in line with the benchmark gauged by the Taylor rule cannot be accepted, regardless of which inflation measure is taken into account and whether current or forecast inflation is employed. We also reexamined general nexus between monetary policy and housing prices across advanced economies by applying the same data set used in Bernanke's speech (2010a). By correcting mismatch of time span for the dependent and explanatory variables, we re-estimated the regression equations to obtain results which are quite different from the one quoted by Bernanke. That is, the negative relationship between monetary policy and appreciation of housing prices in the advanced countries is statistically significant and the impact of monetary policy on housing prices cannot be neglected. Then we study the linkage between monetary policy of the U.S. Federal Reserve and global savings by testing for whether the federal funds rate, broadly defined money stock (M2) and long-term rate of the United States are strongly affected by foreign reserves from the East Asian economies and the OPEC countries. The results of *F*-test and robust semi-parametric test are consistent, indicating that there was no statistically significant linkage between the U.S. monetary policy conducted by the federal funds rate and foreign reserves held by the East Asian and OPEC economies. Finally, we trace out the key words of internal and external factors in the FOMC minutes to find *ex post* evidence regarding prioritized matters in the Fed decision making process. According to the evidence, the FOMC policymakers focused basically on domestic issues for considering adjustment of monetary policy in the period of 1999-2006, during which property bubble emerged.

At the least, the empirical and historical evidence produced in this study fails to support the global saving glut hypothesis. That is, it is difficult to accept the arguments that external factors played a major role in the financial crisis occurred in core area of the global capitalism. On the other hand, the empirical outcomes presented here also do not rule out existence of certain complex mechanisms connecting capital flows to the U.S. monetary policy. A possibility is that there lacks adequate framework to analyze monetary policy in the context of rapidly integrated world economy so that linkage between global saving and the U.S. monetary policy is not yet fully understood by conventional wisdom.

References

[1] Bean, Charles, Matthias Paustian, Adrian Penalver and Tim Taylor, 2010, "Monetary Policy after the Fall", Federal Reserve Bank of Kansas City, Jackson Hole Symposium.

[2] Bernanke, Ben S., 2005, "The Global savings glut and the U.S. Current Account Deficit", speech delivered at the Sandridge Lecture, Virginia Association of Economics, Richmond, Virginia.

[3] Bernanke, Ben S., 2007a, "Global Imbalances: Recent Developments and Prospects", at the Bundesbank Lecture, Berlin, Germany.

[4] Bernanke, Ben S., 2007b, "Globalization and Monetary Policy", at the Fourth Economic Summit, Stanford Institute for Economic Policy Research, Stanford, California.

[5] Bernanke, Ben S., 2009, "Asia and the Global Financial Crisis", at the Federal Reserve Bank of San Francisco's Conference on Asia and the Global Financial Crisis, Santa Barbara, California.

[6] Bernanke, Ben S., 2010a. "Monetary Policy and the Housing Bubble", at the Annual Meeting of the American Economic Association, Atlanta, Georgia.

[7] Bernanke, Ben S., 2010b, "Economic Challenges: Past, Present, and Future", at the Dallas Regional Chamber, Dallas, Texas.

[8] Bernanke, Ben S., 2010c, "Rebalancing the Global Recovery", at the sixth European Central Bank Central Banking Conference, Frankfurt, Germany.

[9] Bernanke, Ben S., 2011, "Global imbalances-Links to Economic and Financial Stability", at the Banque de France Financial Stability Review Launch Event, Paris, France.

[10] Bernanke, Ben S., 2013, "A Century of US Central Banking: Goals, Frameworks, Accountability", *Journal of Economic Perspectives*, Vol. 27, Nov. 4, 3-16.

[11] Bordo, Michael D. and John Landon-Lane, "Does Expansionary Monetary Policy Cause Asset Price Booms; Some Historical and Empirical Evidence", *NBER Working Paper*, No.19585, October 2013.

[12] Borio, Claudio and Piti Disyatat, 2011, "Global imbalances and the financial crisis: Link or no link?", *BIS Working Paper, No 346*, May 2011.

[13] Caballero, Ricardo J., Farhi, Emmanuel, and Gourinchas, Pierre-Olivier, "An Equilibrium Model of 'Global Imbalances' and Low Interest Rates", *The American Economic Review*, Vol. 98, Issue 1, 358-393.

[14] Cochrane, John H., 2006, "Identification and Price Determination with Taylor Rules: A Critical Review", talk given at NBER EFG Meeting, Federal Reserve Bank of New York, Sep. 29, 2006.

[15] Cochrane, John H., 2007a, "Identification with Taylor Rules: A Critical Review", Manuscript, University of Chicago.

[16] Cochrane, John H., 2007b, "Inflation Determination with Taylor Rules: A Critical Review", Manuscript, University of Chicago.

[17] Dokko, Jane, Doyle, Brian, Kiley, Michael, Kim, Jinill, Sherlund, Shane, Sim, Jae, & Van den Heuvel, Skander, 2009, "Monetary Policy and the Housing Bubble", *FEDS Working Paper*, 2009-49, Board of Governors of the Federal Reserve System, *www.federalreserve.gov/pubs/.../2009/200949/200949pap.pdf*

[18] Eichengreen, Barry, 2013, "Does the Federal Reserve Care about the Rest of the World?", *Journal of Economic Perspectives,* Vol. 27, No. 4, Fall, 87-104.

[19] Fatás, Antonio, Prakash Kannan, Pau Rabanal, and Alasdair Scott, 2009, "Lessons for Monetary Policy from Asset Price Fluctuations", in *World Economic Outlook* (Fall), chapter 3, IMF, Washington, www.imf.org/external/pubs/ft/weo/2009/02/pdf/c3.pdf.

[20] Federal Reserve, 2015, "Statement on Longer-Run Goals and Monetary Policy Strategy", http://www.federalreserve.gov/monetarypolicy/files/FOMC_LongerRunGoals.pdf

[21] Hofmann, Boris and Bilyana Bogdanova, 2012, "Taylor Rules and Monetary Policy: a Global 'Great Deviation'?", *BIS Quarterly Review*, September, 37-49, *www.bis.org/publ/qtrpdf/r_qt1209f.pdf*.

[22] Kahn, George A., 2012, "The Taylor rule and the Practice of Central Banking", In *The Taylor Rule of Transformation of Monetary Policy*, Eds., George A. Kahn, Evan F. Koenig, and Robert Lesson, 63-101, Stanford: Hoover Institution Press.

[23] Kuttner, Kenneth N., 2012, "Low Interest Rates and Housing Bubbles: Still No Smoking Gun", *Working paper, core.kmi.open.ac.uk/download/pdf/6277957.pdf*

[24] Mendenhall, William, Richard L. Scheaffer, and Dennis D. Wackerly, 1986, *Mathematical Statistics with Applications*, Boston: Duxbury Press.

[25] Melvin, Michael and Taylor, Mark P., 2009, "The Global Financial Crisis: Causes, Threats and Opportunities. Introduction and Overview", *Journal of International Money and Finance*, Vol. 28, Issue 8, 1243-1245.

[26] McDonald, John F. and Houston H. Stokes, 2013, "Monetary Policy and the Housing Bubble", *Journal of Real Estate Finance and Economics*, 46:437–451.

[27] McDonald, John F. and Houston H. Stokes, 2013, "Monetary policy, mortgage rates and the housing bubble", *Economics & Finance Research*, Vol. 1, 82–91.

[28] Mishkin, Frederic S., 2011, "Monetary Policy Strategy: Lessons from the Crisis", *NBER Working Paper*, No.16755, http://www.nber.org/papers/w16755

[29] Poole, William, 2010, "Causes and Consequences of the Financial Crisis of 2007-2009", *Harvard Journal of Law & Public Policy*, Vol. 33, Issue 2, 421-441.

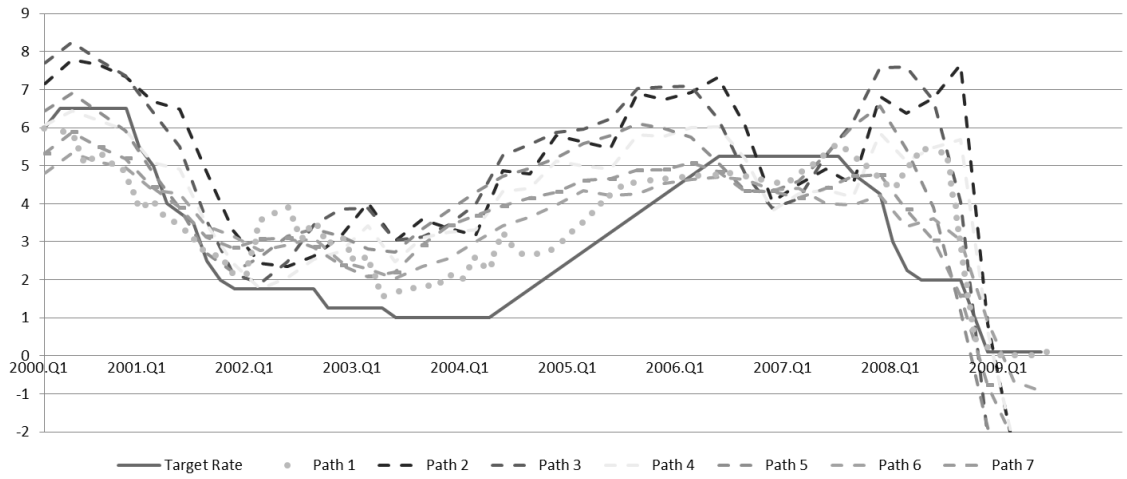
[30] Rötheli, Tobias F., 2010, "Causes of the Financial Crisis: Risk Misperception, Policy Mistakes, and Banks' Bounded Rationality", *Journal of Socio-Economics*, Vol. 39, Issue 2, 119-126.

[31] Rotemberg, Julio J., 2013, "Shifts in US Federal Reserve Goals and Tactics for Monetary Policy: A Role for Penitence?", *Journal of Economic Perspectives,* Vol. 27, No. 4, Fall, 65-86.

[32] Sá, Filipa, Pascal Towbin and Tomasz Wieladek, 2011, "Low interest rates and housing booms: the role of capital inflows, monetary policy and financial innovation",

Working Paper, No. 411, Bank of England, February.
[33] Sánchez, Manuel, 2011, "Financial Crises: Prevention, Correction, and Monetary Policy," *Cato Journal*, Vol. 31, No. 3, http://object.cato.org/sites/cato.org/files/serials/files/cato-journal/2011/9/cj31n3-7.pdf
[34] Seyfried, William, 2010, "Monetary policy and housing bubbles: a multinational perspective", *www.aabri.com/manuscripts/09351.pdf*
[35] Taylor, John B., 1993, "Discretion versus Policy Rules in Practice", C*arnegie-Rochester Conference Series on Public Policy*, Vol. 39, Dec., 195-214.
[36] Taylor, John B., 2007, "Housing and Monetary Policy", in Federal Reserve Bank of Kansas City, *Housing, Housing Finance and Monetary Policy* ,Kansas City: Federal Reserve Bank of Kansas City, 463-476.
[37] Taylor, John B., 2009, "The Financial Crises and the Policy Responses: An Empirical Analysis of What Went Wrong", *Working Paper*, No.14631, National Bureau of Economic Research, Cambridge.
[38] Taylor, John B., 2010, "The Fed and the Crisis: A Reply to Ben Bernanke", *Wall Street Journal*, Jan. 11st, 2010.
[39] Taylor, John B., 2010, "Macroeconomic lessons from the Great Deviation", in D Acemoğlu and M Woodford (eds), *NBER Macroeconomics Annual*, vol 25, 387–95.
[40] Taylor, John B., 2012, "Monetary policy rules work and discretion doesn't: a tale of two eras", *The Journal of Money, Credit and Banking Lecture*, March.
[41] Yatchew, Adonis, "Nonparametric Regression Techniques in Economics", *Journal of Economic Literature*, Vol. XXXVI, June 1998, 669-721.
[42] Yellen Janet L., "Monetary Policy: Many Targets, Many Instruments. Where Do We Stand?", At the "Rethinking Macro Policy II", a conference sponsored by the International Monetary Fund, Washington, D.C., April 16, 2013.

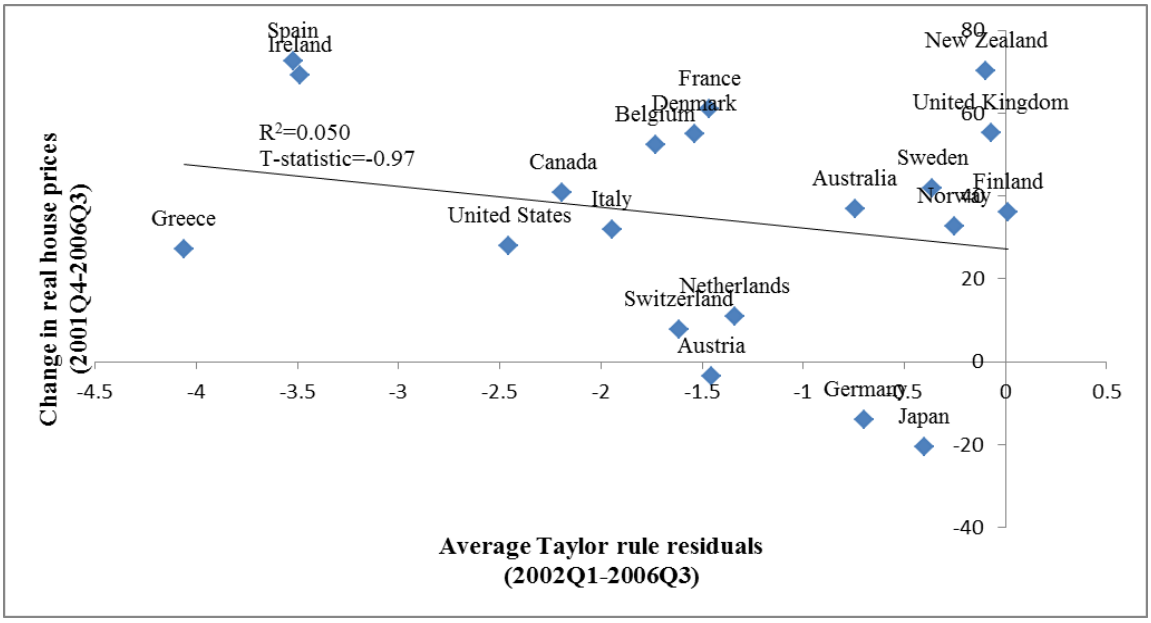
Figure 1 - Estimated federal funds rate paths against the actual target rate line



Sources: Target rate is from the Federal Reserve, http://www.federalreserve.gov/monetarypolicy/openmarket.htm, http://www.federalreserve.gov/newsevents/speech/bernanke20100103b.htm; PCE, core PCE and GDP is from the Bureau of Economic Analysis, http://www.bea.gov/; CPI is from the Bureau of Labor Statistics, http://www.bls.gov/; real potential output（potential GDP）is from the Federal Reserve Bank of St. Louis, http://research.stlouisfed.org/fred2/series/GDPPOT/.

Notes: Path 1 is the estimated line with GOW Forecasts of PCE index obtained from Bernanke (2010a), Path 2 is the estimated line with current CPI index; Path 3 is the estimated line with forecast of CPI Index; Path 4 is the estimated line with current PCE index; Path 5 is the estimated line with forecast of PCE index; Path 6 is the estimated line with current core PCE index; and Path 7 is the estimated line with forecast of core PCE index. The forecasts of inflation indices in Path 3, 5, and 7 are respectively obtained by using linear regression with their own previous four-quarter observations.

Figure 2 Original regression: monetary policy and house prices across countries



Source: Bernanke (2010a).

Figure 3 Modified regression I: monetary policy and house prices across countries

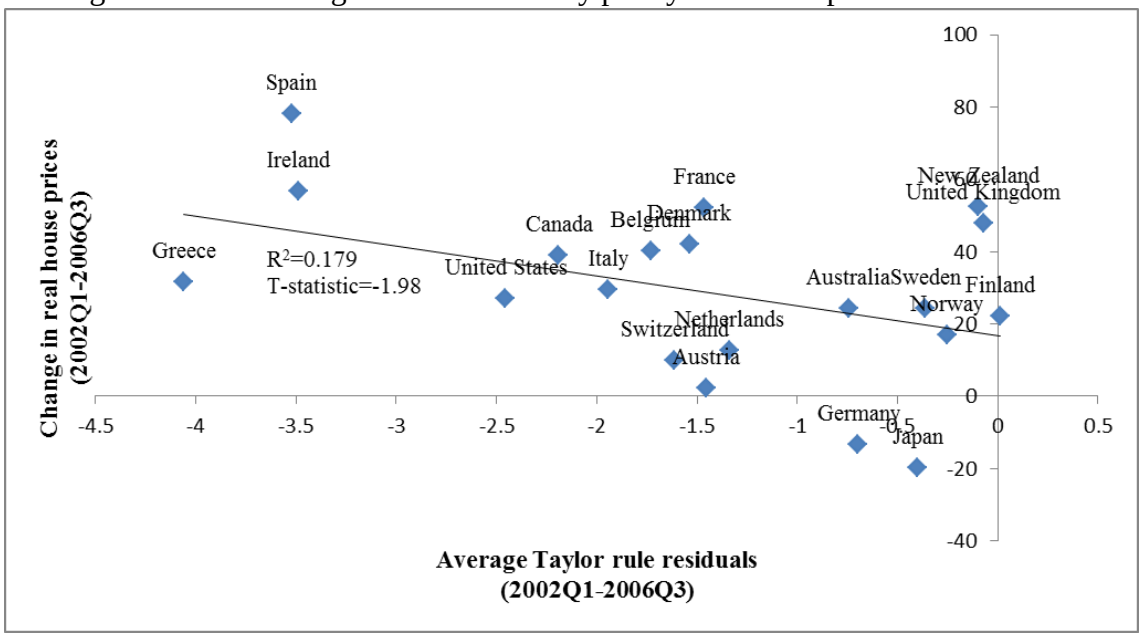


Figure 4 Modified regression II: monetary policy and house prices across countries

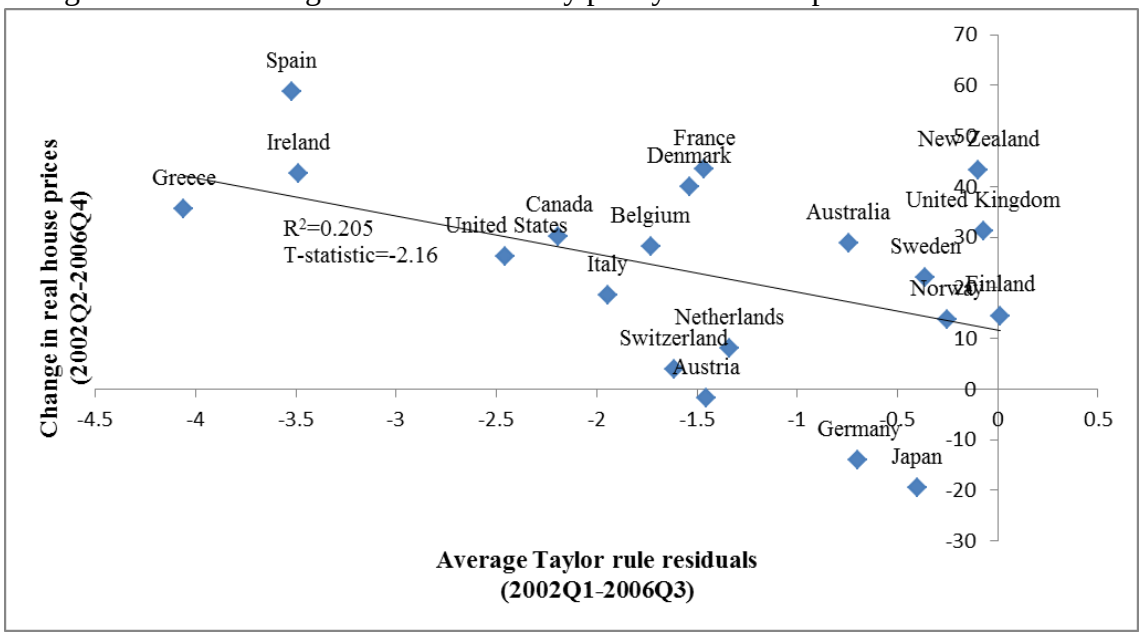


Figure 5 Numbers of domestic and foreign key-words in Fed minutes 1996-2014

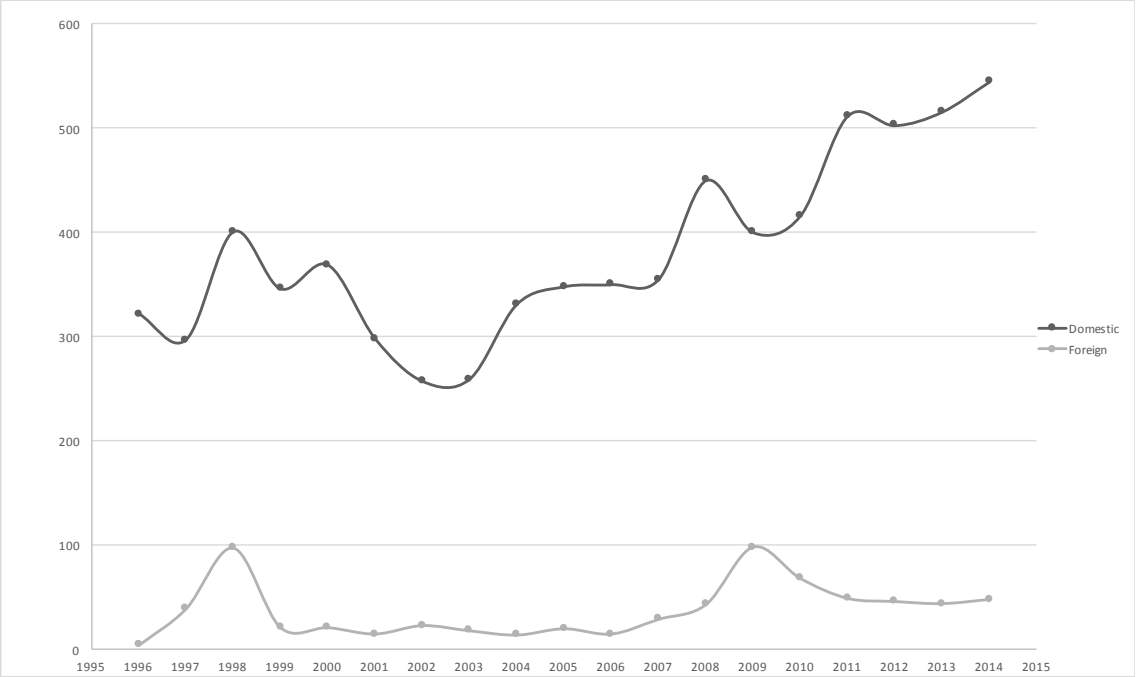
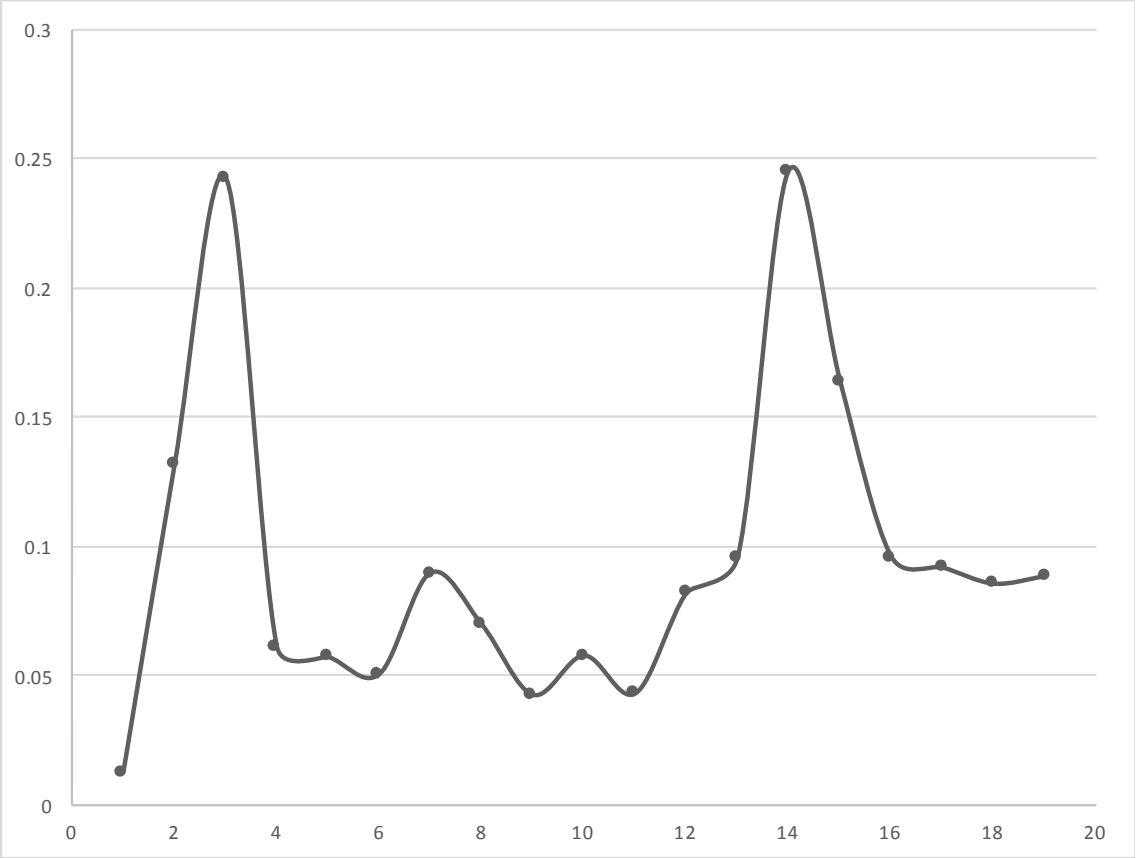


Figure 6 Percentage of foreign to domestic factors in Fed minutes 1996-2014



Appendix

The Wilcoxon Signed-Rank Test

The method of non-parametric Signed-Rank Test was proposed by F. Wilcoxon (1945). Assume that one selects independent random samples of X_1 and X_2 observations from two populations I and II, then combines both selected samples X_1 + X_2 = X observations and ranks them. If the observations were from identical populations, the rank sums for the samples should be more or less proportional to the sample sizes X_1 and X_2. For example, if X_1 and X_2 were equal, the sample sums should be nearly equal (Mendenhall et al, 1986).

The null hypothesis H_0 assumes that there has no difference between two sample groups. Choose observations of any pair of the federal funds rate paths given in Table 1, we can get two groups of data shown in the following matrix.

	Rank j			
Group i	1	2	…	38
1	$X_{1,1}$	$X_{1,2}$	…	$X_{1,38}$
2	$X_{2,1}$	$X_{2,2}$	…	$X_{2,38}$

(A1)

Where $X_{i,j}$ is the j's observation from group i. The sample period is from 2000.01 to 2009.01, and the total number of observations for each group is N=38. The testing procedure is as follows:

1) As for j=1, 2…38, calculate $|X_{1.j}-X_{2.j}|$ and $\text{sgn}(X_{1.j}-X_{2.j})$. sgn(.) is the sign function. When $X_{1.j}-X_{2.j}>0$, sgn(.) = 1; when $X_{1.j}-X_{2.j}<0$, sgn(.) = -1; when $X_{1.j}-X_{2.j}=0$, sgn(.) = 0.

2) Rank the paired samples in the ascending order of $|X_{1.j}-X_{2.j}|$, from low value to high value. If $|X_{1.j}-X_{2.j}|=0$, then delete the sample. As for the data sets of this study, this problem does not exist.

3) Attach the numbers of rank to the paired samples. The minimum is 1 and the maximum is 38. Denote the number of rank by R_j.

4) Calculate Wilcoxon statistic T:

$$T = \left| \sum_{j=1}^{38} \left[sgn\left(X_{1.j} - X_{2.j}\right). R_j \right] \right| \tag{A-2}$$

5) Calculate the standardized statistic Z:

$$Z = \frac{T - 0.5}{\sigma_T} \tag{A-3}$$

where:

$$\sigma_T = \sqrt{\frac{N(N+1)(2N+1)}{6}} \tag{A-4}$$

If $N \geq 10$, then Z follows a standard normal distribution. Compare Z with the critical value $Z_{0.05}$ under the standard normal distribution. If $Z > Z_{0.05}$, the null hypothesis can be rejected at 5 percent level; otherwise, the null hypothesis cannot be rejected.