Sovereign Credit Risk, Macroeconomic Dynamics, and Financial Contagion: Evidence from Japan*

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Proposed running head: Sovereign Credit Risk in Japan

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Abstract: We try to understand the nature of Japan's sovereign credit risk by examining the interaction between Japan's sovereign credit default swap (CDS) spreads and its financial indicators of macroeconomic fundamentals. We consider potential contagion from the global financial market, and allow for reverse causality between CDS spreads and macroeconomic fundamentals. We find strong evidence of contagion from global stock markets to Japan's credit market when Lehman brothers collapsed, while the European sovereign debt crisis only had temporary effects. We also show that several credit events, such as 2011 Tohoku earthquake and rating cuts by rating agencies, significantly raised volatility in Japan's sovereign CDS market.

Keywords: Credit default swap spread, Financial contagion, Japan, Regime switch

1 Introduction

Japan has long been characterized by high government debt. The high level of government debt has attracted extensive attention to Japan's sovereign credit risk. The international monetary fund (IMF, 2013) and other commentators are worrying that the mounting government debt eventually leads to a debt crisis in Japan which can damage the world economy.[1] This is not only because Japan is the world's third largest economy with its currency as an important international transaction vehicle, but also because a crisis in Japan can damage investors' confidence on government debt of many other heavily indebted industrial countries. In this paper, we investigate how the indicators of macroeconomic fundamentals affect Japan's sovereign credit default swap (CDS) spread.

The first purpose of this paper is to understand the nature of Japan's sovereign credit risk, which is not only of interest in itself, but also provides general implications for many other countries. As shown by Andritzky (2012), the Japanese government debt is mainly held by domestic owners. This feature makes the Japanese experience potentially useful for many developing countries that have adopted aggressive policies to increase their domestic debt share. Panizza (2008) shows that the weighted average share of domestic debts of all developing countries has reached 69% by 2005, and this share even exceeded 80% in East Asia and Pacific. One important motivation for increasing domestic holdings is to prevent future debt crises caused by external shocks and thus avoid financial contagion, since the investor base of domestic debts is often believed to be more stable (Panizza, 2008). This belief, however, lacks firm evidence and it still remains a question whether a high domestic debt share can actually help prevent financial contagion. Japan's experience can serve as exemplary evidence because of its long-existing large share of domestic debts. Particularly, by carefully examining the interaction between Japan's sovereign credit market and the global financial market, we can provide insights on whether limiting foreign borrowing can effectively prevent financial contagion.

Besides, the features of a high domestic debt share and large holdings by domestic financial institutions also make the Japanese experience indicative for developed countries under economic and financial distress. Andritzky (2012) shows that the investor base of government securities of many developed countries tends to shift towards domestic holders during the recent financial crisis. For example, the share of domestic debts in the euro area has increased sharply from 32.5% to 45% since 2008 (Source: Statistical Data Warehouse of the European Central Bank, hereafter SDW). This phenomenon is not occasional as similar shifts in the investor base were also observed historically in a wide range of developed countries during bad times, e.g. the Great Depression and World Wars (Abbas et al., 2014). Among the domestic holders, domestic financial institutions are the most important investors in Japan holding a large share of its government securities (Andritzky, 2012). This feature is also shared by many developed countries under economic and financial distress, whose domestic financial institutions usually pick up the holdings of government securities from non-residents in bad times (Abbas et al., 2014). A recent example is that the share of euro area government debts held by the local financial institutions has increased dramatically from 26% to more than 39% since the onset of the global financial crisis (Source: SDW). For these reasons, Andritzky (2012) suggests that the Japanese experience could provide useful implications for the future development of sovereign credit markets in the euro area countries during bad times.

Compared to directly studying the euro area countries, one advantage of studying the Japanese sample is that it provides a clearer identification of sovereign CDS determinants and financial contagion. In particular, the identification in euro area samples is complicated by the monetary union and investors' belief regarding a union-wide willingness of bailout. This is because the effects of economic fundamentals on CDS spreads are mixed with the uncertainty of political games between the union members on the bailout packages (Blommestein et al., 2012).

The second purpose of this paper is to make a methodological point that financial contagion, endogeneity, and policy shifts are three important issues that cannot be ignored in studying the interdependence between sovereign CDS spreads and macroeconomic fundamentals. We discuss these three issues in turn below. The first issue is financial contagion which is often defined as an increasing spillover effect during the turbulent period.[2] While the international spillover effect from the global financial market to a country's sovereign CDS market has been widely documented (Longstaff et al., 2011; Dieckmann and Plank, 2011; Fontana and Scheicher, 2010), few studies consider the time variation of this spillover effect. It is very likely that the global spillovers to Japan's market are much stronger in the turbulent period than in the tranquil period. Conventional regression analysis (single-regime specification) that assumes a constant spillover effect over periods may produce misleading results, because the estimated coefficient in the single-regime model reflects an "overall" spillover effect, and its insignificance (or significance) does not imply that periodically heterogenous effects are also insignificant (or significant). Besides this theoretical concern, examining the contagion effect is also useful for policy makers and investors. Existence of contagion suggests that they need to appropriately adjust their policies and strategies in different periods.

The second issue that is currently ignored by the sovereign CDS literature is endogeneity. In our context, endogeneity can arise from at least two sources. One is the potential feedback from Japan's sovereign credit risk to global financial markets due to Japan's international importance, and the other is the impact of sovereign default on the domestic economy. As the sovereign default risk increases, investors' expectations on domestic macroeconomic fundamentals may become worse. Such expectations can dampen investment and be materialized as real output costs (Sandleris, 2008; Brutti, 2011; Mendoza and Yue, 2012). Besides, the sovereign CDS market can also influence the local economies by changing asset prices and interest rates, because it affects the borrowing cost of countries (Delatte et al., 2012). Ignoring the endogeneity not only biases the estimates but also severely contaminates the contagion test (Forbes and Rigobon, 2002; Dungey et al., 2005; Pesaran and Pick, 2007).

Finally, to our best knowledge, no study has accounted for the effect of policy shifts on the sovereign CDS spread determination. In fact, several significant policy changes occurred in Japan during our sample period, especially in the financial crisis and after the great natural calamity. According to the Lucas critique, policy shifts can cause shifts in the behavior of economic agents. This means that a policy shift not only causes a regime switching in the determination process of Japan's sovereign CDS spread, but also a regime switching in the dynamic process of fundamental macroeconomic determinants. Omitting such a possibility can also bias the estimation results.

To address these three issues, we consider a regime-switching model with endogenous variables, and the regime switching is allowed in the dynamic processes of *both* CDS spreads and macroeconomic fundamentals. One advantage of using regime-switching models to capture contagion is that it does not require splitting the sample as in the conventional contagion models (see Dungey et al. (2005) for a recent survey), and thus we do not need a sufficiently long crisis period for estimation. This allows us to identify important events triggering a *temporary* but significant increase in market volatility, which is almost infeasible in the conventional contagion models. We estimate the model using a two-step maximum likelihood method proposed by Kim (2009). The idea of regime-switching analysis is related to Alexander and Kaeck (2008) who study the regime-dependent determinants of corporate CDS spread. We differ from them by considering the *sovereign* CDS spread, and addressing the issues of global spillover effect, endogeneity, and the Lucas critique.

Our work is also related with Beirne and Fratzscher (2013) and Aizenman et al. (2013) who examine the *macroeconomic* determinants of sovereign CDS spreads. We differ from these two studies by using the *financial* indicators of macroeconomic conditions rather than directly working with macroeconomic data. One advantage of using *financial* indicators to proxy the macroeconomic situations is that they can incorporate the potential impacts of future fundamentals due to the forward-looking behavior of investors. This is, however, infeasible when using macroeconomic data as noted by Aizenman et al. (2013). Besides, using financial indicators also allows us to make use of higher-frequency data to incorporate omitted information in lower-frequency models.

We employ daily data over 2008–2012. Our results provide new insights into Japan's sovereign CDS market. First, we find that changes in the global stock market return have no significant impacts on Japan's sovereign CDS spread in tranquil times, but the impact is intensified and become strongly significant in turbulent times, suggesting the existence of financial contagion to Japan's sovereign CDS market. Second, we find that the probability of Japan's sovereign CDS market being in the turbulent regime is much higher when jump risk in the global stock market is high. This serves as another evidence of contagion. Third, our estimates show that the domestic stock market return and volatility have a significant impact on Japan's sovereign CDS spreads in tranquil times, but such an impact is dominated by the contagion from the global stock market in turbulent times. Finally, we exactly identify important events with temporary but significant impacts, such as the 2011 Tohuku earthquake and cuts of Japan's credit ratings by rating agencies. The consistency of our estimation results with the real world events suggests the importance of the three issues we consider and shows the advantages of our method.

The paper is organized as follows. Section 2 introduces the potential determinants of Japan's sovereign CDS spread. Section 3 describes the data. Section 4 introduces and estimates the regime-switching model, and Section 5 analyzes the sources that drive regime switching. We conclude in Section 6.

2 Determinants of Japan's sovereign CDS spread

The sovereign CDS spread reflects investors' expectations on a country's sovereign credit risk, and the probability of default is thought to be determined by the country's willingness (rather than ability) to repay.[3] The government decides whether to honor its debt typically based on a cost-benefit analysis using the information of the country's macroeconomic fundamentals, such as the level and volatility of the country's output. The literature has suggested a number of financial variables as indicators of those fundamentals, e.g. domestic stock market performance and various spreads (credit and term spreads) as indicators of domestic output (Longstaff et al., 2011; Dieckmann and Plank, 2011; Fontana and Scheicher, 2010; Jaditz et al., 1998; and Anderson and Vahid, 2001). Rational investors use these indicators to forecast the probability of a government's default, and the forecasts further determine the price of the sovereign CDS contract. In this section, we shall discuss several indicators as potential determinants of Japan's sovereign CDS spread.

First, we consider the domestic stock market return and volatility, which reflects the domestic economic performance. Domestic economic performance (state and volatility) can affect the CDS spread by influencing government's willingness to take fiscal reforms, and effective fiscal reforms are typically regarded as an important tool of reducing default risk. Particularly, when the domestic economy is weak and unstable, the policy maker is less willing to implement the reforms, because they can impose extra pressure on the distressed economy. Juessen et al. (2016) show that domestic fundamentals also matter in a framework where the government's ability to pay and the lender's willingness to lend determine default. We follow the literature and use the domestic stock market return and volatility to proxy the economic state and volatility, respectively. We expect that a low stock market return or high volatility is associated with a high sovereign CDS spread.

Second, we consider the nominal Yen-U.S. Dollar exchange rate. The Yen-U.S. Dollar exchange rate can affect Japan's CDS spread, because the strength of Yen reflects Japan's current economic situation and it also affects the external demand which further influences Japan's future economy.

Third, we consider the global market determinants. Longstaff et al. (2011) suggest that changes in the global stock and bond markets can explain a large part of sovereign CDS spread variation. Empirical studies on the European sovereign CDS market (Fontana and Scheicher, 2010; Dieckmann and Plank, 2011) find a similar result. We follow Longstaff et al. (2011) to use the U.S. stock and bond market returns to proxy the global market performance. The U.S. market returns are good proxies because the they embrace a large amount of information from the worldwide countries. Also, as the largest economy in the world, U.S. has an especially close connection with Japan in the field of economy, finance, military, technology, et al., and its economic and financial conditions influence Japan's economy to a large extent. Such an international spillover effect cannot be not fully captured by the *contemporary* domestic stock market return since the worldwide economic condition typically imposes impacts on the home economy *with lags*.

Another potential determinant of Japan's sovereign CDS spread is the U.S. treasury yield. A high treasury yield signals a high economic growth rate in U.S., which may positively influence Japan's economy, and further encourage Japanese government to repay.

We follow Longstaff et al. (2011) to include U.S. corporate bond spreads as additional candidate determinants. Those spreads may contain useful information about the global default risk premium. Moreover, they also contain information regarding the macroeconomic situation in the U.S. (Collin-Dufresne et al., 2001).

Finally, Longstaff et al. (2011) point out that various types of risk can potentially affect sovereign CDS pricing. We thus consider different measures of risk premiums in global financial markets as potential determinants of Japan's sovereign CDS spread. Again, we use the U.S. variables as proxies of the global variables.

3 Data

3.1 Dependent variable: Japan's sovereign CDS spread

A CDS contract can be taken as an insurance contract, more precisely a quasi-insurance instrument, against the credit event specified in the contract.[4] Its spread, expressed in basis points, is the insurance premium that protection buyers have to pay. For example, a CDS spread of 20 basis points means that the buyer of credit protection has to pay the seller an annual amount equal to 0.2% of the notional value of the reference debt obligation.[5] The CDS protection buyer pays the spread in exchange for a compensation from the protection seller when a credit event happens. The compensation can take two different forms. In a physical settlement, the protection seller pays the face value of the bond to the protection buyer in exchange for the defaulted bond. In a cash settlement, the protection seller pays the difference between the face value of the bond and its recovery value after the credit event. There are different credit events against which a sovereign CDS contract can insure. Here we focus on the CDS contracts on the credit event "complete restructuring", as this is the most popular credit event insured by a sovereign CDS contract. Following Longstaff et al. (2011), we consider the contract maturity of five years. The sample covers daily data of five-year government bond CDS spreads from September 15th, 2008 to October 10th, 2012 (Source: Datastream). Our sample excludes the observations before the collapse of Lehman Brothers because previous studies suggest a structural break occurred after Lehman Brothers collapses, see e.g. Dieckmann and Plank (2011) and Blommestein et al. (2012). We extend Longstaff et al.'s (2011) ending period from January 2010 to October 2012, which allows us to study the impacts of some important events, such as the Tohoku earthquake (March 2011) that created huge government deficit, and the rating cut of Japan's sovereign credit during 2011 and 2012.

A preliminary unit root analysis suggests that the time series of CDS spreads is nonstationary, and it is stationary after first-differencing (see Appendix A). Therefore, we shall use the first-differenced data to avoid spurious regression.

3.2 The covariates

The potential determinants of Japan's sovereign CDS spread are discussed in Section 2. When measuring the U.S. corporate bond spreads, we follow Longstaff et al. (2011) and distinguish between two bonds: the investment-grade corporate bonds and the high-yield corporate bonds. We also consider three types of risk premiums: the equity risk premium, volatility risk premium, and term premium. We provide the measures of these determinants as follow. All data are from Datastream if not particularly specified.

ΔCDS_{t-1}: To control for the persistence in the change of the sovereign CDS spread, we include the first-order lagged dependent variable (denoted by ΔCDS_{t-1}) as an explanatory variable.

sdri: Japan's stock market return, measured by the Dow Jones Total Market (DJTM) Japan total return index, a local-currency (Yen) return expressed in percentage point. Note that here we follow previous literature (Longstaff et al., 2011; Dieckmann and Plank, 2011) to use the total market return rather than just the headline index "NIKKEI". It is because the total market return contains more complete information about the aggregate economy. As noticed by Fontana and Scheicher (2010), changes in the domestic and global stock market returns are highly correlated with each other.[6] To avoid multicollinearity, we replace the domestic stock market return by the difference between the domestic and global stock market return, denoted by $sdri^r$.[7]

svol: Japan's stock market volatility, measured by the GARCH(1,1) volatility of the Japanese stock market return.

forex: Nominal Yen-U.S. Dollar exchange rate, measured by the amount of Yens per 100 U.S. Dollars. High *forex* means a depreciation of Yens against U.S. Dollars.

gstock: U.S. stock market return, measured by the Morgan Stanley Capital International (MSCI) United States total return index.

gbond: U.S. treasury yield with the constant maturity of five years.

ivbond: Investment-grade corporate bond spread in basis points. It is one of the measures of U.S. corporate bond spreads. Changes in the investment-grade yield spread are daily changes in the yield spread between BBB and AAA bond indexes.

hybond: High-yield corporate bond spread in basis points. It is a complementary measure of U.S. corporate bond spreads. Changes in high-yield spreads are daily changes in the yield spread between BB and BBB bond indexes.

pe: Equity risk premium. Changes in the equity premium are proxied by changes in the price-earning ratio for the S&P 100 index.

vix: The VIX index.[8] It is a measure of volatility risk premium since previous studies find it a good forecaster of the sovereign CDS spread.[9]

tp: Term premium, constructed in the same way as Longstaff et al. (2011). In particular, we obtain the term premium based on the estimated parameters of excess returns on five-year treasury bonds reported in Table 1 of Cochrane and Piazzesi (2005) and one- through five-year Treasury Strips.

4 Regime switching model analysis

4.1 Motivation and methodology

Conventional studies on the determinants of sovereign CDS spreads are based on the single-regime model (e.g., Longstaff et al., 2011; Dieckmann and Plank, 2011), assuming that the macroeconomic fundamentals are exogenous and have a constant effect on the sovereign CDS spread. As a preliminary analysis we follow this convention and examine the determinants of Japan's sovereign CDS spread using a linear regression model with different error specifications. The estimation results show that the lagged dependent variable, domestic stock market return, domestic stock market volatility, and the VIX index are significant in all models, while others are less robust. More details of the single-regime analysis are given in Appendix B.

The single-regime assumption, however, could be vulnerable in practice as the process of the CDS spread is highly likely to vary over different regimes. One important source of regime-switching is financial contagion. As we discussed in the introduction, financial contagion occurs when the international spillover from global financial markets to the Japanese sovereign CDS market intensifies in the turbulent period. Since Japan plays a crucial role in international finance and its financial market is closely related with the U.S. and European markets, it is likely that the international financial crises or significant financial events impose strong impacts on both the global and Japanese market, and thus the association between these two markets is greatly strengthened. This naturally suggests at least two regimes. In the tranquil regime, global financial market indicators have a relatively weak impact on Japan's sovereign CDS spread, but such an impact can become much stronger in the turbulent regime if contagion exists.

In the contagion literature, identification of splitting dates or breaking events (to separate non-crisis and crisis periods) is a non-trival issue, and there is no consensus. Conventional methods determine the splitting date according to the unconditional variance of the interested variable, i.e. Japan's CDS spread in our case. This approach is relatively arbitrary in the sense that one needs to determine the threshold value (to split the sample) and the following analysis largely depends on such a predetermined value. Also, the determination process is completely separated from the estimation process, which suffers from similar problems of pretesting, e.g. misleading variance estimates; see Danilov and Magnus (2004) for detailed discussions. Another problem of using the *unconditional* variance is that it does not capture investors' rationale and conditioning. An investor can adjust investment behavior based on the information available and reduce the uncertainty. Hence, a large unconditional variance does not always imply a turbulent regime.

To model the regime-dependent effect of CDS spread determinants and avoid the problems of using the unconditional variance, we employ a regime-switching model and propose to use the filtered probability of being in the turbulent regime as an indicator of the splitting date. The model allows the parameters to vary over different regimes, and the state of being in one regime is unobserved. If the effect of the global stock return is larger in the turbulent regime than in the tranquil regime, we could conclude the existence of contagion. Unlike conventional methods of contagion test, the regime-switching model requires neither the division of the sample nor a predetermined threshold value, and thus it avoids the arbitrariness, at least to some extent. One advantage of using filtered probability as an indicator of the splitting date is that the estimation and state identification is in one process, and the filtered probability is obtained from the estimation procedure conditional on the covariates. Therefore, it avoids the problems of using the unconditional variance. Besides, since the estimation uses the whole sample, we address the problems caused by a short post-crisis period, so that we can better capture the contagion.

It is worth noting that in our regime-switching framework the turbulent period concerns the Japanese market, instead of the global market where the contagion origins. This is different from conventional contagion studies which consider how one market's volatility affects its influence on other markets (Pericoli and Sbracia, 2003; Dungey et al., 2005). Intuitively, investors of Japan's sovereign credit market are likely to have a larger response to the changes in the *local* market than to the changes in other markets. We thus expect that the volatility of Japan's sovereign CDS spread play a more important role in investors' investment decisions than the volatility of other markets. Therefore, it makes more sense to study how the effect of determinants varies when the *local* market performs differently, and we shall use the estimated conditional volatility of Japan's CDS spread to differentiate the regimes.[10] Other potential sources of regime-switching include changes in government policy regimes, jump risk in the economy, etc.

Another crucial issue ignored by the previous single-regime analysis is endogeneity. Endogeneity can rise from two possible sources. One is the feedback from the credit risk to its domestic macroeconomic fundamentals. Particularly, it has been recognised by a number of theoretical works that a sovereign default can cause output fluctuations.[11] A rise in the sovereign credit risk can raise economic agents' expectation of an output loss and thus cause more fluctuations in investment and spending. Another potential source of endogeneity is the interaction between Japan's credit market and the global stock market. The contagion literature documents plenty of evidence of the two-way influence between countries' stock market, and it is possible that Japan's credit market and the global stock market also influence each other. The two sources of endogeneity will be formally tested in the next subsection. In the presence of endogenous variables, a standard maximum likelihood estimation (MLE) of a regime-switching model produces biased results, and the tests for contagion based on these estimates are therefore unreliable. The generalized method of moment (GMM) estimation of the simultaneous equations often causes an identification problem, because the division of sample increases the number of parameters which exceeds the number of moments (Dungey et al., 2005); See also Pesaran and Pick (2007) for discussions of the endogeneity issue in testing for contagion.

To address these two issues, we consider the following regime-switching model with endogenous variables

$$\Delta CDS_t = x_t'\gamma_{S_{1t}} + y_t'\beta_{S_{1t}} + e_t, \quad e_t \sim \text{i.i.d. } \mathrm{N}(0, \sigma^2_{e,S_{1t}}), \tag{1}$$

$$y_t = (I_m \otimes z_t')\delta_{S_{2t}} + v_t, \quad v_t \sim \text{i.i.d. } \mathrm{N}(0, \Sigma_{S_{2t}}) \tag{2}$$

where x_t contains covariates uncorrelated with e_t, y_t contains covariates correlated with e_t, z_t contains instrumental variables uncorrelated with e_t but correlated with y_t, and I_m is an $m \times m$ identity matrix with m being the dimension of y_t. S_{1t} and S_{2t} are unobservable state variables with the number of states J_1 and J_2, respectively.

$\otimes$ denotes the Kronecker product. Errors e_t and v_t are allowed to be correlated with each other.

The explanatory variables of our regime-switching model contains ΔCDS_{t-1}, *sdri*^{r}, *svol*, *gstock*, *ivbond*, and *vix*, and they are all first-differenced. These variables are reported as relatively salient determinants according to the single-regime analysis (see Appendix B). We do not include the covariates that are insignificant in the single-regime model for two reasons. First, the insignificant covariates are either less relevant to Japan's sovereign CDS spread or highly correlated with those salient determinants already included. Including highly correlated variables results in a poorly specified model, causing the estimation not to converge. Another reason is that including insignificant covariates largely increases the number of parameters, and thus causes the "curse of dimensionality" and an efficiency loss. For example, we only include *ivbond* as the global bond market indicator because it is the only measure robustly significant in both GARCH and TGARCH models, and highly correlated with the other two measures (*gbond* and *hybond*). Simultaneously including all three measures can break down the estimation procedure. Similar reasons apply to the set of risk premium measures and domestic economic performance measures.

We note that the regime-switching model (1) differs from the standard linear regression in two main aspects. First, the parameters are allowed to vary over regimes which are not predetermined but specified after estimating the model. Second, model (1) and (2) explicitly take into account potential endogeneity. This allows us to investigate possible reverse causality from the CDS spread to domestic and global economic indicators. We also note that this model differs from the conventional instrumental-variable model in that the instrument equation (2) is allowed to vary over time, and the parameters of the governing equation (1) can be in a different regime from the parameters of the instrument equation (2) at time t, that is $S_{1t} \neq S_{2t}$. This extension from the conventional instrumental-variable model is important because the Lucas (1976) critique suggests that a shock affecting the process of the CDS spread (governing equation) can also influence the process of CDS spread determinants (instrument equation). However, a regime shift in the dynamic process of CDS spread given in (1) is typically associated with, but not always perfectly corresponds to the regime shift in the process of macroeconomic determinants. For example, a credit-market event may impose a much stronger effect on the process of CDS spread than on the process of domestic macroeconomic fundamentals; or a policy may drive domestic macroeconomic fundamentals to a turbulent regime, while the CDS spread responses to the regime shift with a lag.

To estimate (1) and (2), we employ the two-step maximum likelihood estimation proposed by Kim (2009). In the first step we estimate the instrument equation (2) using the Hamilton filter, a standard method for a regime-switching model. The second step estimates a transformed version of (1) based on the consistent estimates obtained in the first step, namely

$$\Delta CDS_t = x_t'\gamma_{S_{1t}} + y_t'\beta_{S_{1t}} + \hat{v}_t'\theta_{S_{1t}} + \omega_t, \quad S_{1t} = 1, 2, \tag{3}$$

where $\hat{v}_t$ is the first-step estimate for v_t, and $\omega_t \sim$ i.i.d $\mathrm{N}(0, \sigma^2_{\omega,S_{1t}})$. The regime-dependent variance $\sigma^2_{\omega,S_{1t}}$ is the conditional volatility of CDS spread in different regimes given explanatory variables, and it can be used to define tranquil and turbulent regimes. The standard error estimates are corrected to avoid the bias caused by the generated regressors. This two-step procedure suffers less from the curse of dimensionality since it "decomposes" the joint log likelihood into two components, each of which only contains the *marginalized* transition probability with fewer parameters than the joint transition probability (see Kim (2009) for detailed discussion). It also has a better finite sample performance than the joint maximum likelihood estimation, especially in the presence of weak instrumental variables. We consider two states for both S_{1t} and S_{2t}, i.e. $J_1 = 2$ and $J_2 = 2$. The two states correspond to two regimes (turbulent/crisis regime and tranquil/non-crisis regime) typically assumed in the contagion literature (see, e.g. Nason and Tallman, 2015).

From the small number of states, we also benefit a significant efficiency gain due to the reduction of dimensionality.[12]

4.2 Choosing instruments and testing for endogeneity

Appropriate instruments are prerequisite to estimate (1) and (2). We use the lagged values of endogenous variables as their own instruments. The exogeneity of such instruments is justified by the fact that the past values are not affected by the future. Then the question is which lag order we should use as instruments. Campbell and Mankiw (1991) point out that the first-order lag may not be appropriate due to potential measurement errors in the dependent variable, and they recommend to use the second or higher order lags. In our case, the second-order lag is neither satisfactory since the lagged dependent variable ΔCDS_{t-1} is included as an explanatory variable, causing potential multicollinearity.[13] Therefore, the third-order lag seems a natural choice. In particular, we instrument three potentially endogenous determinants (domestic stock returns, domestic stock market volatility, and global stock returns) by their third-order lags. One concern of using the third-order lags is whether they are strong instruments. We formally test the strength of these instruments based on the joint significance of first-step coefficient estimates, and it rejects the null hypothesis of no explanatory power. We also consider higher order lags as a robustness check. The results are hardly affected and available upon request.

Before we estimate the model, we first test the endogeneity of explanatory variables. A preliminary test for endogeneity is necessary because one additional instrumental variable gives rise to more than one extra parameters, depending on the number of states. In fact, unnecessary instruments not only hurt the efficiency, but also lead to a breakdown of the estimation due to a numerically near-singular covariance matrix. This suggests that we use instruments only when necessary. We employ the Wald-type test for endogeneity proposed by Kim (2009).

As we have discussed, there are two potential sources of endogeneity: the feedback from the CDS spread to domestic macroeconomic fundamentals and from the CDS spread to the global market indicators, and we shall test these two sources in turns. We first consider the endogeneity of domestic macroeconomic fundamentals. The Wald test for endogeneity gives $W = 123.9$ with p-value 0.000, which clearly rejects the null hypothesis of no endogeneity. This confirms the feedback effect from the sovereign credit risk to the macroeconomic dynamics in Japan, and thus instrumenting domestic explanatory variables is required. We then consider the feedback from Japan's sovereign CDS market to the global financial market. The endogeneity test suggests that there is no strong feedback effects from Japan's sovereign CDS market to the global stock market, and instrumenting the global stock return is not necessary, at least in our sample. Based on these results of endogeneity tests, we shall estimate the regime-switching model with only $\Delta sdri^r$ and $\Delta svol$ instrumented by their third-order lagged variables, and treat other explanatory variables exogenous.

4.3 Estimation results

TABLE 1

Table 1 presents the estimation results. We see a significant difference between the estimates in two regimes. In one regime the conditional standard deviation is $\sigma_{\omega,1} = 0.039$, four times more than that of the other regime ($\sigma_{\omega,2} = 0.009$). We take the regime with a larger conditional standard deviation as the turbulent regime, and the other as the tranquil regime. Four main findings are observed. First, the effect of the preceding CDS spread is rather modest in both regimes. One basis point change in the preceding CDS spread can only increase the current CDS spread by less than 0.1 basis point. The change of CDS spread is even less persistent in the tranquil regime than in the turbulent regime.

Second, the effect of domestic economic indicators on sovereign CDS spread differs in two regimes to a large degree. We see that the level and the volatility of domestic stock return both have a significant impact on Japan's sovereign CDS spread in the tranquil regime. One percent increase in domestic stock return is associated with a drop of the CDS spread by 0.432 basis points, and one unit (percentage point squared) decrease in the conditional variance of the domestic stock return leads to an even larger drop of the sovereign CDS spread by 4.110 basis points. This suggests that a good domestic economic situation can reduce investors' expected likelihood of sovereign default. However, when we consider the turbulent period, we see a rather different result: the effect of domestic economic indicators is much weaker and no longer significant. This finding contrasts with Longstaff et al. (2011) who show a significant impact of domestic variables in Japan, and it suggests that there may be other factors whose impacts dominate that of domestic variables in the turbulent period.

Third, we also observe a large difference in the effect of the global stock market in two regimes. In the tranquil regime the global stock market seems to have no obvious effects on Japan's CDS spread. The effects, however, become significant and strongly negative in the turbulent regime, and one percent increase of global stock market return is associated with 0.209 basis points decrease of Japan's CDS spread. This explains the insignificant effect of domestic economic variables in the turbulent regime, because the spillover effect from the global market dominates the domestic effect in this regime. This is intuitive because in the turbulent regime with great uncertainty in the domestic market, domestic economic indicators are less reliable and investors may use more information from outside Japan to infer the credit risk. Therefore, the global market indicators play a more important role in the turbulent regime. This result again differs from Longstaff et al. (2011) and our single-regime analysis (see Appendix B), both of which report an insignificant global stock market effect. We argue that the insignificance is partly because of the ignorance of heterogeneity in different regimes. In fact, the (insignificantly) positive effect in the tranquil regime and (significantly) negative effect in the turbulent regime can offset, leading to an ambiguous overall effect. Such a heterogeneous effect of the global stock market return implies the existence of financial contagion from the global market to Japan's credit market. Most existing literature on financial contagion focuses on the contagion among stock markets, but few on the contagion from a stock market to a credit market. We complement this literature by providing a Japanese evidence. Potential transmission channels of such contagion can be from the global stock market to Japan's stock market and then to Japan's credit market, from the global stock market to global credit markets and then to Japan's credit market, et al., and we leave further investigation of transmission channels for future research.

Our finding of the existence of financial contagion provides an important policy implication. As noted by Panizza (2008) and Andritzky (2012), there is a recent trend in many developing and euro area countries to substitute foreign debts by domestic debts. The main motivation is to avoid financial crises triggered by external shocks as external sources of funding are believed to be more volatile. However, our results suggest that financial contagion can still happen even if the majority of debts are held by locals. Therefore, simply restricting foreign investment in government debts is not sufficient to prevent adverse foreign shocks from damaging domestic financial markets, and more attention should be paid to better macroeconomic and fiscal management.

Finally, we see that the volatility risk premium, measured by VIX index, can significantly raise the market-perceived credit risk in Japan under both regimes. The size of such an effect is larger in the turbulent regime than in the tranquil regime, providing another evidence of contagion.

5 Drivers of the regime switching

We have seen that there is a clear regime difference in the conditional volatility of Japan's CDS spread, and the effects of its determinants significantly vary over different regimes. In this section, we investigate what drives such a regime switching. This is related to the issue of identifying different regimes of the sample. Conventional methods determine the splitting date according to the unconditional variance of the interested variable, which causes various problems, such as arbitrariness and lack of conditioning (see discussions in Section 4.1). Figure 1 depicts the filtered probability and the squared daily changes in the CDS spread. It shows that a high probability of being in the turbulent regime is often but not always accompanied by a large daily change in the CDS spread. We propose to use the filtered probability of being in the turbulent regime as an indicator of splitting dates. The filtered probability $\tilde{p}_t$ is the likelihood of being in the turbulent regime conditional on information up to time t. It can avoid the problems of using the unconditional variance because it does not require a predetermined threshold value, and is obtained from the estimation procedure (conditional on the covariates). Therefore, we expect that the inference based on the filtered probability is more reliable.

FIGURE 1

5.1 Drivers from financial markets

According to Alexander and Kaeck (2008), the regime switching in the sovereign CDS spread may be caused by jump risk in the stock market and changes in the determinants of the CDS spread. To investigate this, we regress the filtered probability on the squared daily changes in Japan's CDS spread, jump risk in the stock market, and the candidate determinants of Japan's sovereign CDS spread discussed in Section 2. Formally, we follow Alexander and Kaeck (2008) to estimate the following model:

$$\tilde{p}_t = \frac{1}{1 + \exp(-\alpha_0 - X'_{t-1}\alpha_1)}, \tag{4}$$

where X_{t-1} is a vector of lagged explanatory variables. To measure the jump risk in the stock market, we use the difference between 30-day VIX and 3-month VIX. This is motivated by the fact that a decrease in short-term volatility compared with long-term volatility indicates a lower likelihood of downward jumps in equity prices over the short-term than over the longer term (Alexander and Kaeck, 2008). We shall denote the jump risk at time t by JR_t.

TABLE 2

The estimation results are given in columns (1)–(4) in Table 2. The standard deviations we report are Newey-West estimatesbecause a preliminary LM test for serial correlation rejects the null hypothesis of no serial correlation with a p-value 0.000. Among the candidate explanatory variables, the previous day's squared change in the sovereign CDS spread ($dcds^2$), domestic stock market volatility ($svol$), and jump risk in the global stock market (JR) are the most robust. They are always significant at the one percent level.

The local and global stock market returns ($sdri^r$ and $gstock$) and the global corporate bond spreads ($ivbond$ and $hybond$) are significant at the ten percent level when the exchange rate, U.S. treasury bill rate, and the risk premium measures are included in the regression (column (1)). However, the exchange rate ($forex$), U.S. treasury bill rate ($gbond$), and the risk premium measures (pe, tp, and vix) are not significant even at the ten percent level. Excluding those redundant variables from the regression, the local and global stock market returns are no longer significant, while the investment grade corporate bond yield becomes more significant (column (2)).

In the most parsimonious model (column (4)), there are four significant explanatory variables that drive the regime switching: $dcds^2$, $sdri^r$, $ivbond$, and JR. In particular, an increase in the squared sovereign CDS change makes the next day more probable to be in the turbulent regime. This is generally in line with Figure 1; Higher domestic stock market volatility leads to a lower filtered probability, and a higher investment grade corporate bond spread in the global market also corresponds to a lower filtered probability. This reflects a "flight to quality" effect. A flight of liquidity from Japan's stock market and the global bond market to Japan's sovereign credit market can increase Japan's stock market volatility and global corporate bond market spread but reduce the volatility in Japan's sovereign credit market. Higher jump risk in the global stock market raises the filtered probability, which means that jump risk in the global stock market is a source of jump across regimes in the Japanese sovereign CDS market. This serves as another evidence of contagion from the global stock market to the Japanese sovereign CDS market.

Figure 2 plots the filtered probability and jump risk. It is obvious that the turbulent regime happens most frequently in the period right after the collapse of Lehman Brothers. In this period, jump risk in the global stock market reached its peak. This signals that the collapse of Lehman Brothers is an important trigger of contagion. One dramatic example for the impact of Lehman's failure is that Japan's ministry of finance encountered a problem to issue 128.7 billion Yen government debt which was bid by Lehman in a previous auction.[14] The global financial crisis also triggered policy reactions. On December 8th 2009, the Japanese government announced a 7.2 trillion Yen stimulus package. This policy temporarily caused a regime switching in the sovereign CDS market, and we see the filtered probability jumped to 0.9852 at that time and kept more than 0.5 for one month (see Figure 2).

FIGURE 2

5.2 Drive of the Tohoku earthquake and agencies' rating cuts

On Friday March 11th 2011, the most powerful earthquake in Japan's history hit the country. The earthquake triggered powerful tsunami which caused nuclear accidents. The market expected that those events will generate extra fiscal costs. As a result, Japan's sovereign CDS spread increased by 15 basis points immediately on the next weekday (March 14th), and on March 15th the CDS spread further increased by another 27 basis points. This earthquake and related disasters are another important drivers of the regime switching. We can see from Figure 2 that the filtered probability of being in a turbulent regime was only 0.039 on the date when the earthquake hit (March 11th). However, the probability jumped to 0.422 on the coming Monday, and to 0.999 on Tuesday. Then it kept close or equal to 1 for two weeks. Such a turbulent regime ended on April 26th 2011 when the filtered probability dropped to 0.363. We point out the only exception during this period occurred on March 17th 2011 when the filtered probability was only 0.220. This is partly because on March 16th Yen reached its top level since World War II and stock prices slumped around the world. As liquidity fled to safer government securities, the sovereign credit market temporarily calmed down.[15]

Rating agencies cut Japan's sovereign credit ratings several times in 2011 and 2012. On January 27th 2011, S&P cut Japan's long-term credit rating by one notch to AA−, but this rating action seems to have a limited impact on the volatility in Japan's sovereign CDS market. The filtered probability was only 0.065 on that date. One reason is that the other two major rating agencies, Moody's and Fitch, reaffirmed their sovereign credit ratings on Japan, which calmed down the market. Another important reason is that this rating cut may have been anticipated by investors. They expected the rating cut because they had noticed the mounting debt, aging population, and persistent deflation, which are stated reasons for S&P's rating cut. Moody's cut of Japan's sovereign rating on August 24th 2011 also had an insignificant impact on the sovereign CDS market. The filtered probability of being in the turbulent regime was only 0.097. This was also because the rating cut was well anticipated by the market.[16] By contrast, the rating cut by Fitch Ratings on May 22nd 2012 is shown to have a strong impact on the market volatility. On that date, Fitch cut Japan's local-currency rating by one level and the foreign-currency rating by two levels. The filtered probability jumped to 0.787, a relatively higher level than the preceding dates (see Figure 2). The reason for the strong impact of Fitch's action is that most strategists were worried about the European debt crisis and took Japan's government bonds as safe havens at that time. Hence, Fitch's rating cut was a great surprise to them, resulting in great uncertainty in Japan's credit market.[17]

5.3 Contagion from the European sovereign debt crisis?

Besides the collapse of Lehman Brothers, another important international crisis in our sample period is the European sovereign debt crisis. A natural question is whether there is contagion from the European sovereign CDS market to Japan's sovereign CDS market. To answer this question, we add the iTraxx SovX Western Europe index, a sovereign CDS index of western European countries, as a covariate in the regime-switching model (1) and test its significance. This index covers the a wide range of European countries including the Eurozone region, Denmark, Norway, Sweden, and United Kingdom, and therefore it reflects the market-perceived sovereign credit risk in the western European countries. We find that this index is insignificant in either the turbulent regime (t-ratio = 1.415) or the tranquil regime (t-ratio = 1.411). We also test whether this index significantly affected the filtered probability, and we find no significant effects again (t-ratio = 1.368). These results suggest no significant *systematic direct* influence from the European debt crisis to Japan's sovereign CDS market. However, it does not exclude *temporary indirect* effects of the debt crisis through global financial markets. For example, on May

10th 2010, euro area offered a one trillion Dollar rescue package to save the Euro. This package unleashed an initial rally in international stock markets[18], and further affected Japan's sovereign CDS market. But the positive effect was not stable, and the stock price declined on May 13th 2010, resulting in an increase in bond prices.[19] Our model precisely captures this event by reporting a change of the filtered probability from 0.005 to 0.960 on May 10th 2010, and the probability remains above 0.900 until May 20th 2010.

6 Conclusion

Existing studies on the sovereign CDS spread typically assume that macroeconomic fundamentals are exogenous and have a constant impact on the CDS spread over time. These assumptions mean that there is no financial contagion and reverse causality from the CDS spread to macroeconomic fundamentals. We show that ignoring financial contagion and reverse causality can produce misleading results. We focus on Japan's credit market, and examine the determinants of Japan's sovereign CDS spread, explicitly taking into account financial contagion and endogeneity. We employ daily data from September 15th, 2008 to October 10th, 2012, and estimate a regime-switching model with endogenous variables. Our method has several advantages. It is more flexible than the conventional sample-splitting contagion models; it allows us to identify the events with a temporary but significant effect; and it can capture how the dynamic process of Japan's sovereign CDS spread is affected by policy shifts.

Our empirical results provide new insights on the sovereign credit market in three aspects. First, we provide empirical evidence of significant feedbacks from sovereign credit risk to domestic macroeconomic fundamentals, confirming the theoretical literature on the output costs of sovereign default and also suggesting the importance of the endogeneity issue. Second, we find a strong contagion effect from the global stock market to Japan's sovereign credit market. The domestic market enters a more turbulent regime when jump risk in the global stock market is high. Under this regime, the global stock market return has a much stronger spillover effect on Japan's sovereign CDS spread than in the tranquil regime. The contagion effect is so strong that it dominates the effect of the domestic stock return that is only significant in the tranquil period. The finding of financial contagion to Japan provides an important policy implication for many countries that are also increasing their domestic debt share, since it suggests that simply restricting foreign borrowing is not enough to prevent financial crises triggered by external shocks. Finally, we find that, besides the financial contagion, the dynamic process of Japan's CDS spread is also affected by policy shifts.

Further investigation suggests that several events play important roles in Japan's sovereign credit market. For example, the 2011 Tohuku earthquake (March 11th, 2011) and Fitch's rating cuts (May 22nd, 2012) triggered a temporary increase in sovereign CDS market volatility. However, the rating cuts by S&P (January 27th, 2011) and Moody's (August 24th, 2011) did not bring the market into the turbulent regime. Besides, we see a significant impact of the collapse of Lehman brothers on Japan's sovereign CDS spread, while the European sovereign debt crisis only had temporary effects.

One advantage of the country-specific study is that it allows us to carefully investigate the sources of the regime switching or contagion and match them to important economic events occurred to this country. Contagion, output costs of sovereign defaults, and policy-induced reactions of investors are general issues which are also likely to exist in other countries than Japan. Our empirical findings suggest that ignoring these issues in the sovereign CDS analysis may lead to our unawareness of important facts.

Notes

[1]http://www.spiegel.de/international/world/massive-japanese-sovereign-debt-could-become-global-problem-a-875641.html

[2]See Forbes and Rigobon (2001) for a detailed discussion on the definition of financial contagion.

[3]A comprehensive review of this literature is provided by Panizza et al. (2009). See also Reinhart and Rogoff (2009) for a detailed discussion on the sources of sovereign defaults.

[4]See Pan and Singleton (2008) and Dieckmann and Plank (2011) for a detailed description of the sovereign CDS contract.

[5]The reference debt is the senior sovereign bond denominated in U.S. Dollar.

[6]We regress changes in the global market on the changes in the domestic market, and find the similar result (t-ratio $= -4.055$).

[7]The differencing can have a nonlinear effect on the estimates of the regime-switching model, so that the near-singular covariance matrix can be avoided.

[8]VIX is the symbol for the Chicago Board Options Exchange Market Volatility Index, a measure of market expectations of near-term stock market volatility conveyed by the stock index option prices.

[9]See, for example, Pan and Singleton (2008) and Fontana and Scheicher (2010).

[10]This differs from the smooth transition model with volatility being the threshold variable because the regimes are specified after we estimate the model. The advantages of using the conditional volatility will be discussed in details in Section 5.

[11]See Sandleris (2008), Brutti (2011), Mendoza and Yue (2012), Panizza et al. (2009) for a recent survey on sovereign default and output.

[12]Increasing the number of possible states from two to three increases the dimension of the transition matrix from 12 to 72.

[13]This is very important since estimating the model with the second-order lag incurs a convergence problem.

[14]http://in.reuters.com/article/2008/09/17/lehman-japan-bonds-idINT8697920080917

[15]http://www.bloomberg.com/news/2011-03-16/japan-s-government-bonds-may-advance-as-record-yen-dims-recovery-prospects.html

[16]http://www.bloomberg.com/news/2011-08-24/moody-s-japan-downgrade-clashes-with-s-p-in-u-s-as-jgbs-steady.html

[17]http://online.wsj.com/article/SB10001424052702303610504577419700029425564.html

[18]http://www.reuters.com/article/2010/05/10/us-eurozone-idUSTRE6400PJ20100510

[19]http://www.reuters.com/article/2010/05/13/markets-bonds-idUSN1327243220100513

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Table 1: Regime switching model results

	Turbulent	Tranquil
constant	-0.001	0.001
	(0.002)	(0.001)
ΔCDS_{t-1}	0.087**	0.055
	(0.041)	(0.059)
$sdri^r$	-0.041	-0.432***
	(0.118)	(0.096)
$svol$	0.010	4.110***
	(0.159)	(0.347)
$gstock$	-0.209**	0.007
	(0.101)	(0.081)
$ivbond$	0.725	0.314
	(1.173)	(0.866)
vix	0.135*	0.101*
	(0.074)	(0.057)
p_{ii}	0.889	0.867
σ_ω	0.039	0.009

Notes:

1. Standard errors in parentheses. ***, **, * denote significance at one, five, and ten percent level respectively.
2. p_{ii} denotes the probability of staying in the same regime in the next period as in the current period.

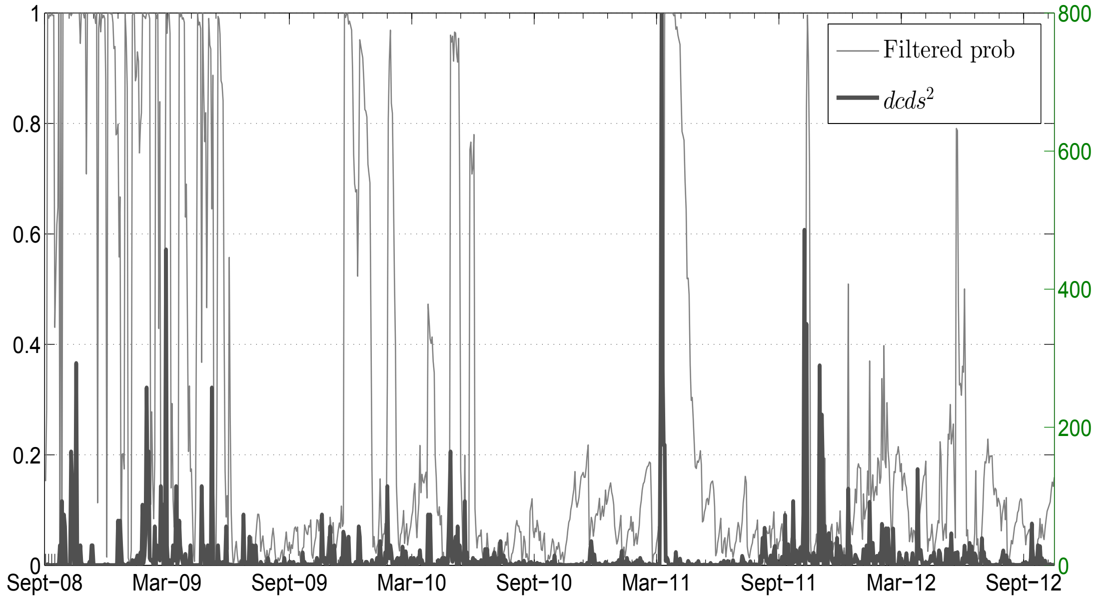
Table 2: Drivers of the regime switching

	(1)	(2)	(3)	(4)
$dcds^2$	0.011***	0.011***	0.013***	0.013***
	(0.004)	(0.004)	(0.003)	(0.002)
forex	0.094			
	(0.118)			
$sdri^r$	−0.073*	−0.013		
	(0.039)	(0.033)		
svol	−0.583***	−0.767***	−0.996***	−1.074***
	(0.189)	(0.220)	(0.232)	(0.133)
gstock	−0.102*	−0.039		
	(0.054)	(0.049)		
gbond	1.310			
	(1.099)			
ivbond	−0.565*	−0.754**	−0.773**	−0.793**
	(0.340)	(0.377)	(0.392)	(0.345)
hybond	0.014*	0.015*	0.011*	
	(0.007)	(0.008)	(0.008)	
pe	0.145			
	(0.132)			
tp	0.607			
	(0.394)			
vix	−0.048			
	(0.034)			
JR	0.234***	0.227***	0.227***	0.232***
	(0.043)	(0.041)	(0.040)	(0.021)

Notes:

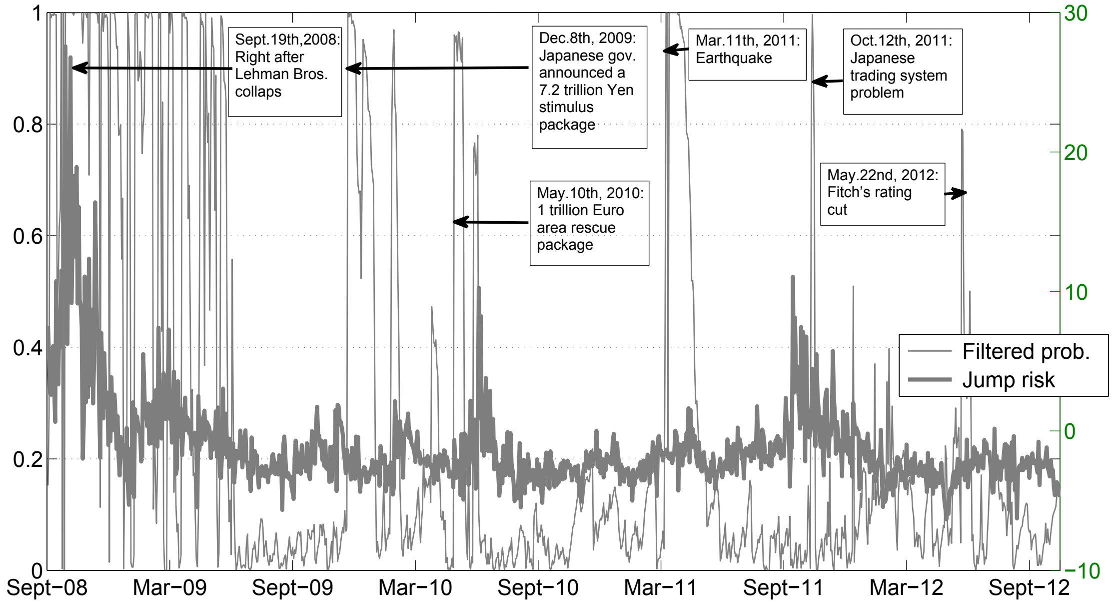
1. The dependent variable is the filtered probability of being in the turbulent regime.
2. Heteroscedasticity-autoregression consistent standard errors in parentheses. ***, **, * denote significance at one, five, and ten percent level, respectively.

Figure 1: Filtered probability and squared daily CDS spread change



Notes: Filtered prob is the filtered probability of being in the turbulent regime. $dcds^2$ is the squared daily CDS spread change.

Figure 2: Filtered probability and jump risk in the global stock market



Appendix A

This appendix presents some univariate time series analysis of Japan's CDS spreads. As the price of CDS insurance contract, the CDS spread is likely to be nonstationary. To verify this, we formally test the stationarity using three popular unit-root tests: Adjusted Dicky-Fuller (ADF) test, Phillips-Perron (PP) test, and Elliott, Rothenberg and Stock (ERS) test.

Table 3: Unit root tests of Japan's sovereign CDS spread

	ADF	PP	ERS
Original series			
Test statistics	-2.879	-2.949	-2.113
1% critical value	-3.967	-3.967	-3.480
5% critical value	-3.414	-3.414	-2.890
10% critical value	-3.239	-3.129	-2.570
First-differenced series			
Test statistics	-20.906	-32.734	-20.906
1% critical value	-3.436	-3.436	-2.567
5% critical value	-2.864	-2.864	-1.941
10% critical value	-2.568	-2.568	-1.616

The results of unit root tests are summarized in Table 3. All three tests accept the unit root hypothesis for the original series, confirming the nonstationarity of Japan's sovereign CDS spread. They also suggest that the series is stationary after first-differencing. This univariate analysis suggests that we should use the first-differenced data to avoid spurious regression.

Appendix B

We carry out a single regime analysis to examine the determinants of Japan's CDS spreads, assuming all covariates are exogenous. In addition to the covariates listed in the paper, we also consider an alternative measure of volatility risk premium, namely the VIX index minus a measure of realized volatility for the S&P 100 index, and we denote it as vp. The main results are not affected by considering this alternative measure, while the estimated coefficient of vp itself is much less significant than that of *vix* (see Table 4), suggesting that *vp* may not be a good measure in our case. We consider the linear regression model with three different assumptions on ϵ_t: (1) Independent and identically distributed, (2) Generalized Autoregressive Conditional Heteroskedasticity (GARCH): $\sigma_t^2 = a + b\epsilon_{t-1}^2 + c\sigma_{t-1}^2$, where σ_t^2 is the conditional variance, and (3) Threshold Generalized Autoregressive Conditional Heteroskedasticity (TGARCH): $\sigma_t^2 = a + b_1\epsilon_{t-1}^2 + b_2\epsilon_{t-1}^2 I_{t-1} + c\sigma_{t-1}^2$, where I_t is an indicator variable that takes value one if $\epsilon_t < 0$.

Table 4 presents the results of the three models. We find that the lagged dependent variable, domestic stock market return, domestic stock market volatility, and the VIX index are significant in all models. The estimates of these robust determinants are in line with our theoretical expectation (see Section 2 of the paper) that Japan's sovereign default risk depends on the performance of domestic and global economies. The sovereign default risk is relatively low when the domestic economy is performing well while it is relatively high when domestic and global economy are volatile. Comparing columns (O.1) and (O.2) we see that *vix* better explains Japan's sovereign CDS spread than *vp*. This result also holds in the GARCH and TGARCH model.

We then look at the less robust determinants. Japanese Yen's exchange rate against U.S. Dollar is significant and robust based on least square estimation, but not in GARCH and TGARCH model. In the latter two models the exchange rate is weakly significant if the domestic stock market return is *not* in the model, but insignificant when the domestic stock market return is included. This suggests that the exchange rate and domestic stock market return contain largely similar information in explaining the Japan's sovereign CDS spread, e.g. information on the domestic economy; The U.S. treasury bond yield is significant in the OLS and GARCH model but not in TGARCH. Since the reported TGARCH variance equation in Table 4 shows a threshhold effect in the variance specification, we cannot conclude the U.S. treasury bond yield as a robust and significant determinant; The investment-grade

Table 4: Single regime model results

	(O.1)	(O.2)	(G.1)	(G.2)	(TG.1)	(TG.2)
ΔCDS_{t-1}	0.064**	0.061*	0.163***	0.153***	0.146***	0.141***
	(0.032)	(0.032)	(0.038)	(0.038)	(0.041)	(0.041)
forex	−0.423***	−0.374**	−0.020	−0.001	−0.073	−0.057
	(0.171)	(0.054)	(0.115)	(0.116)	(0.118)	(0.118)
$sdri^r$	−0.275***	−0.249***	−0.273***	−0.244***	−0.215**	−0.195***
	(0.053)	(0.054)	(0.041)	(0.041)	(0.043)	(0.043)
svol	0.300***	0.278***	0.417***	0.310***	0.445***	0.340***
	(0.102)	(0.100)	(0.102)	(0.122)	(0.133)	(0.133)
gstock	−0.070	−0.077	−0.027	−0.045	0.036	0.016
	(0.071)	(0.070)	(0.059)	(0.059)	(0.062)	(0.064)
gbond	−3.850**	−3.057*	−2.467*	−1.766*	−1.785	−1.283
	(1.580)	(1.607)	(1.086)	(1.060)	(1.038)	(1.038)
ivbond	0.424	0.458	0.834**	0.879**	0.778**	0.795**
	(0.641)	(0.639)	(0.392)	(0.379)	(0.415)	(0.410)
hybond	0.002	0.002	0.001	0.000	-0.001	-0.001
	(0.010)	(0.009)	(0.007)	(0.007)	(0.007)	(0.007)
pe	−0.275	−0.265	−0.111	−0.107	−0.049	−0.052
	(0.170)	(0.169)	(0.176)	(0.172)	(0.179)	(0.176)
tp	−0.824	−0.869	−0.719**	−0.683**	−0.597	−0.563
	(0.549)	(0.548)	(0.346)	(0.335)	(0.338)	(0.337)
vp	0.000		0.001		0.001	
	(0.001)		(0.001)		(0.001)	
vix		0.116**		0.116***		0.105***
		(0.049)		(0.029)		(0.030)

GARCH Variance equation

(G.1) $\sigma_t^2 = \underset{(0.072)}{0.730^{***}} + \underset{(0.030)}{0.279^{***}}\epsilon_{t-1}^2 + \underset{(0.022)}{0.691^{***}}\sigma_{t-1}^2$

(G.2) $\sigma_t^2 = \underset{(0.078)}{0.738^{***}} + \underset{(0.029)}{0.275^{***}}\epsilon_{t-1}^2 + \underset{(0.023)}{0.691^{***}}\sigma_{t-1}^2$

TGARCH Variance equation

(TG.1) $\sigma_t^2 = \underset{(0.073)}{0.713^{***}} + \underset{(0.056)}{0.415^{***}}\epsilon_{t-1}^2 - \underset{(0.051)}{0.263^{***}}\epsilon_{t-1}^2 I_{t-1} + \underset{(0.025)}{0.696^{***}}\sigma_{t-1}^2$

(TG.2) $\sigma_t^2 = \underset{(0.076)}{0.723^{***}} + \underset{(0.053)}{0.402^{***}}\epsilon_{t-1}^2 - \underset{(0.048)}{0.253^{***}}\epsilon_{t-1}^2 I_{t-1} + \underset{(0.025)}{0.698^{***}}\sigma_{t-1}^2$

Notes:

1. Columns (O.1) and (O.2) give least square estimates, (G.1) and (G.2) the GARCH estimates, and (TG.1) and (TG.2) the TGARCH estimates.
2. All variables are first differenced.
3. Standard errors in parentheses. ***, **, * denote significance at one, five, and ten percent level, respectively.

corporate bond spread is significant in the more efficient GARCH and TGARCH model, and thus likely to be a salient determinant.

Finally, we report the insignificant variables. The high-yield corporate bond spread is not significant in any model. Neither are all measures of the global risk premium except *tp* that is weakly significant in the GARCH model.

This single-regime analysis, although not conclusive, provides a preliminary insight on what determinants could be prominent and salient, which further helps select important covariates for the regime-switching analysis.