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Exchange rate volatilities and disaggregated bilateral exports of Malaysia to the United States: empirical evidence

Wong Hock Tsen[1]

Abstract This study examines the impacts of exchange rate volatilities on real total export and all the subcategories of real total export by standard international trade code (SITC) from 0 to 9 of Malaysia to the United States (US). Exchange rate volatilities are computed by the moving standard deviation with order three [MSD(3)] and estimated by the generalized autoregressive conditional heteroscedasticity (GARCH) model, more specifically the GARCH(1,1) model. The results of the autoregressive distributed lag (ARDL) approach show insignificant impacts of exchange rate volatilities on real total export in the level but some significant impacts of exchange rate volatilities on the subcategories of real total export in the first differences. There are more cases when exchange rate volatility estimated by the GARCH(1,1) model are found to have significant impact on exports. The significant impacts of exchange rate volatilities are found for some sectors of exports and can be negative or positive. Exporters of Malaysia shall improve their products through innovation and high technology and also to further diversify their exports in order to reduce the impact of exchange rate volatility.

Keywords Exchange rate volatilities · Exports · Malaysia · The United States ·
The moving standard deviation with order three [MSD(3)] · The generalized
autoregressive conditional heteroscedasticity (GARCH)

JEL Classification F31 · F14

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1 Introduction

Exchange rate volatility can cause uncertainty into exports. Exporters confront uncertainty of their costs and revenues because of the change of exchange rate. This might affect their revenues. Exporters, who are risk averse will avoid exchange rate volatility and thus will reduce their exports and perhaps will focus more on selling in the domestic market. On the other hand, some exporters might regard exchange rate volatility to be a risk that can result higher return and therefore these exporters increase their exports. However, there is no consensus on the impact of exchange rate volatility on export (Baek 2013, 2014). This recommends that the impact of exchange rate volatility on export should be assessed based on case by case basis. The impact of exchange rate volatility on export is shown to be different from industries. The use of disaggregated export data enables the impact of exchange rate volatility on export to be tested more accurately and can avoid the problem of aggregation bias in export data in testing the impact of exchange rate volatility on export, that is, a number of insignificant impacts of exports can be offset by a significant impact of export or an insignificant impact of export is offset by a number of significant impacts of exports (Bahmani-Oskooee and Hegerty 2007; Byrne et al. 2008; Fang et al. 2009; Ćorić and Pugh 2010; Bahmani-Oskooee and Harvey 2011; Verheyen 2012; Bahmani-Oskooee et al. 2013; Nishimura, and Hirayama 2013; Thorbecke and Kato 2013; Baek 2013, 2014; Bahmani-Oskooee et al. 2014; Wong 2014; Naknoi 2015).

This study examines the impacts of exchange rate volatilities on real total export and all the subcategories of real total export by standard international trade code (SITC) from 0 to 9 of Malaysia to the United States (US). The impacts of exchange rate volatilities on different categories of exports can be different because of different demand elasticities of exports (Caglayan and Di 2010). Conversely, the previous studies in the literature of the impact of exchange rate volatility on export mainly examine certain category or some categories of exports (Bahmani-Oskooee and Harvey 2011; Wong and Tang 2008, 2011; Bahmani-Oskooee et al. 2014). The data are monthly for the period from January, 2010 to December, 2014. The impact of exchange rate volatility on a specific category of export can be assessed more directly by using disaggregated data, that is, the sub-categories of real total export. The impact of exchange rate volatility on export could be different because monthly data are used rather than quarterly or yearly data. There is limited study on the impact of exchange rate volatility on disaggregated bilateral exports of Malaysia to the US. The US is an old and important trading country of Malaysia. In 2010, export of Malaysia to the US was Malaysian ringgit (RM) RM60,951 million or 9.5 per cent of total export of Malaysia and import from the US was RM56,259 million or 10.6 per cent of total import of Malaysia. In 2013, export of Malaysia to the US reduced to RM58,055 million or 8.1 per cent of total export of Malaysia and import from the US reduced to RM50,980 million or 7.9 per cent of total import of Malaysia. In 2013, the US is the fourth most important exporting country of Malaysia after Singapore, China and Japan. Exports of Malaysia to Singapore, China and Japan were about 14.0 per cent, 13.5 per cent and 11.1 per cent of total

export of Malaysia, respectively (MOF 2014). Exchange rate volatilities are computed by the moving standard deviation with order three [MSD(3)] and estimated by the generalized autoregressive conditional heteroscedasticity (GARCH) model, namely the GARCH(1,1) model, which is selected from a group of the autoregressive conditional heteroscedasticity (ARCH) models. This study provides some evidence of the impacts of exchange rate volatilities computed by a non-ARCH model and estimated by an ARCH model on real total export and the sub-categories of real total export. The impact of exchange rate volatility on export can be different because different measurements of exchange rate volatilities are used. Moreover, the selection of an ARCH model without considering other ARCH models may result in the selection bias of the ARCH model in the estimation of exchange rate volatility. The export demand model is estimated as a function of real exchange rate, real foreign demand and exchange rate volatility, where real export is expressed by export value divided by export price of respective export. In the literature of the impact of exchange rate volatility on export, real exports mainly are expressed by unit prices, that is, nominal exports divided by unit values (Bahmani-Oskooee et al. 2013, 2014). However, unit values of exports are not good proxies for export prices and can be biased because the bundles of export goods can change over time (Byrne et al. 2008; Bandt and Razafindrabe 2014). In some studies, real export of each commodity is expressed by nominal export of each commodity divided by aggregate export price index rather than by export price of respective commodity (Bahmani-Oskooee and Harvey 2011). The autoregressive distributed lag (ARDL) approach is used to assess the impacts of exchange rate volatilities on exports, which is currently a state of art of the estimation method. Moreover, the ARDL approach is able to examine the impacts of exchange rate volatilities in the levels and in the changes on exports.

2 Literature review

Bahmani-Oskooee and Hegerty (2007) provide a good literature review of the impact of exchange rate volatility on international trade. Wong (2014) presents a more recent discussion of the impact of exchange rate volatility on international trade. There are some studies on the impact of exchange rate volatility on export in Malaysia (Bahmani-Oskooee and Harvey 2011; Wong and Tang 2008, 2011). Bahmani-Oskooee and Harvey (2011) investigate the impact of real exchange rate volatility on international trade between the US and Malaysia, that is, the impact of real exchange rate volatility on 17 categories of industry in 3-digit level of the US importing industries from Malaysia and on 101 categories of industry in 3-digit level of the US exporting industries to Malaysia using the ARDL approach for annual data from the year 1971 to the year 2006. The 17 categories of industry in 3-digit level are 031, which is fish, fresh and simply preserved, 032, which is fish, in airtight containers, 053, which is fruit, preserved and fruit preparati, 075, which is spices, 099, which is food preparations, not elsewhere specified (n.e.s.), 231, which is crude rubber-including synthetic and reclaimed, 243, which is wood, shaped or simply worked, 292, which is crude vegetable materials, n.e.s., 581, which is plastic

materials, 631, which is veneers, plywood boards and other wood, 632, which is wood manufactures, n.e.s., 656, which is made-up articles, wholly or chiefly, 687, which is tin, 821, which is furniture, 841, which is clothing except fur clothing, 892, which is printed matter and 941, which is animals, n.e.s. including zoo animals, dogs. However, the study does not analyse all the categories of exports. The impact of exchange rate volatility on export can be different from sectors of exports. Real export of each commodity is expressed by nominal export of each commodity divided by aggregate export price index. Exchange rate volatility is computed by the standard deviation of the twelve monthly real bilateral exchange rates within a year. The results show that exchange rate volatility is found to have short-run impacts of about two-thirds of the industries and the impacts of exchange rate volatility continue into the long run in 38 of the US exporting industries and in 10 of the US importing industries. The main long-run determinants of exports are found to be the levels of economic activities in both countries.

Wong and Tang (2008) investigate the impact of exchange rate volatility on electrical exports of Malaysia, namely SITC 716, SITC 7415, SITC 772, SITC 773 and SITC 775 using the ARDL approach for quarterly data from quarter I, 1990 to quarter IV, 2001. SITC 716 is rotating electric plants and parts thereof. SITC 7415 is air-conditioning machinery comprising a motor-driven fan and elements of changing the temperature and humidity, parts thereof. SITC 772 is electrical apparatus, resistors, other than heating resistors; printed circuits; switchboard and control panels. SITC 773 is equipment for distributing electricity. SITC 775 is household-type electrical and non-electrical equipment. The study examines only the impact of exchange rate volatility on some categories in 3-digit level of SITC 7 and one category in 4-digit level of SITC 7. Exchange rate volatility is derived by the moving standard deviation with order four of real effective exchange rate of Malaysia. The results show that exchange rate volatility is found to have an adverse impact on electrical exports of Malaysia.

Wong and Tang (2011) examine the impact of exchange rate volatility on a category of exports of Malaysia, namely SITC 776 using the Johansen cointegration approach for quarterly data from quarter I, 1990 to quarter IV, 2001. SITC 776 is thermionic, cold cathode or photo-cathode valves and tubes; diodes, transistors and similar semiconductor devices; photosensitive semiconductor devices; light-emitting diodes; mounted piezoelectric crystals; electronic integrated circuits and microassembles; parts thereof. Exchange rate volatility is the moving standard deviation with order four of real effective exchange rate of Malaysia. The results show that exchange rate volatility is found to have both the long run and the short run impacts on semiconductor exports of Malaysia.

Fang et al. (2009) demonstrate that the impact of exchange rate volatility on export depends on the state of currency whether it is in depreciation or appreciation. The study amongst others reports that an increase in exchange rate volatility would lead to an increase in export during depreciation in Malaysia. Caglayan and Di (2010) report that there is little impact of real exchange rate volatility on international trade. The study finds that the impact of exchange rate volatility on export is significant only in about six per cent of the models estimated. Moreover,

the impact of real exchange rate volatility on international trade is found to be positive.

In a summary, real export of each commodity is expressed by nominal export of each commodity divided by aggregate export price index is frequently used in the literature of the impact of exchange rate volatility on export (Bahmani-Oskooee and Harvey 2011). Also, some categories of exports to the whole world rather than bilateral exports are usually examined (Wong and Tang 2008, 2011). Exchange rate volatility, which is expressed by a moving standard deviation rather than selected from a group of the ARCH models, is commonly used in the past studies (Wong and Tang 2008, 2011; Bahmani-Oskooee and Harvey 2011; Bahmani-Oskooee et al. 2014). There are not many studies to compare the impacts of exchange rate volatilities computed by a non-ARCH model and estimated by an ARCH model on exports. The low frequency data, namely yearly or quarterly data rather than monthly data are frequently used in the literature of the impact of exchange rate volatility on export. Generally, there are not many studies on the impact of exchange rate volatility on export in Malaysia.

3 Data and methodology

Real total export is the sum of export values of SITC from 0 to 9 divided by the total export price index (2005 = 100). SITC 0 is food and live animals. SITC 1 is beverages and tobacco. SITC 2 is crude materials, inedible, except fuels. SITC 3 is mineral fuels, lubricants and related materials. SITC 4 is animal and vegetable oils, fats and waxes. SITC 5 is chemicals and related products. SITC 6 is manufactured goods classified chiefly by material. SITC 7 is machinery and transport equipment. SITC 8 is miscellaneous manufactured articles. SITC 9 is commodities and transactions not classified elsewhere in SITC. Real exports of SITC from 0 to 9 are export values of SITC from 0 to 9 divided by the export price indexes of SITC from 0 to 9 (2005 = 100), respectively. Real exchange rate is RM against the US dollar exchange rate multiplied by the ratio of the consumer price index (CPI) of the US (2005 = 100) over the CPI of Malaysia (2005 = 100). Exchange rate volatilities are computed by the MSD(3) and estimated by the GARCH(1,1) model. Real foreign demand is expressed by the industrial production index of the US (2005 = 100). Total export, export values of SITC from 0 to 9 and the export price indexes were obtained from various issues of *Malaysia External Trade Statistics System*, Department of Statistics Malaysia. RM against the US dollar exchange rate was obtained from the website of Central Bank of Malaysia. The CPI of Malaysia was obtained from *Consumer Price Index*, Department of Statistics Malaysia. The CPI and the industrial production index of the US were obtained from the website of United Nations Economic Commission for Europe Statistical Database. The sample period is from January, 2010 to December, 2014. The length of the sample period is restricted by the availability of the monthly export price indexes in Malaysia.

Exchange rate volatility is unobservable in the market and therefore it must be estimated through its proxy using appropriate method. The MSD(3) is coumputed as follows:

$$\text{MSD}(3) = \left[(1/3) \sum_{i=1}^{3} (\ln e_{t+i-1} - \ln e_{t+i-2})^2 \right]^{1/2} \qquad (1)$$

where ln is logarithm and e is real exchange rate. The window of moving average is fixed to three since monthly data are used and therefore average of 3 months is a quarter. The window of moving standard deviation is arbitrary. A larger window size would introduce the problem of over smoothing and lack of degree of freedom in the estimation. A smaller window size may cause under smoothing. The moving standard deviation is employed because it is commonly used as a measurement of exchange rate volatility to examine the impact of exchange rate volatility on export. This measurement is said to be able to capture well of exchange rate volatility (Verheyen 2012; Nishimura and Hirayama 2013). However, it might not able to address the problem of volatility clustering, that is, high or low volatility is followed by high or low volatility.

The ARCH models are argued to be good in modelling the volatility clustering. The ARCH models are widely used to model the conditional variance of exchange rate (Nishimura and Hirayama 2013). An ARCH model can be presented as follows:

$$\ln e_t = \mu + \gamma_1 \ln e_{t-1} + \gamma_2 \ln e_{t-2} + u_t$$
$$u_t = \varepsilon_t \sqrt{\sigma_t}, \varepsilon_t | I_{t-1} \sim N(0, 1) \qquad (2)$$
$$\sigma_t^d = \omega + \sum_{i=1}^{p} \alpha_i (|u_{t-i}| + \theta_i u_{t-i})^d + \sum_{i=1}^{q} \beta_i \sigma_{t-i}^d$$

where u_t is a disturbance term, ε_t is a white noice stoachastic process, I_{t-1} is the past information set, d is the power term and σ_t is the conditional variance. In this study, the order of the lags in the mean equation is selected based on the Akaike information criterion (AIC). When $d = 2$, $p = 1$, $q = 0$ and $\theta_1 = 0$, the estimated model is the ARCH model or the ARCH(1) model. When $d = 2$, $p = 1$, $q = 1$ and $\theta_1 = 0$, the estimated model is the generalized autoregressive conditional heteroscedasticity (GARCH) or the GARCH(1,1) model. When $d =$ free, $p = 1$, $q = 1$ and $\theta_1 \neq 0$, the estimated model is the asymmetric power generalized autoregressive conditional heteroscedasticity (APGARCH) model or the APGARCH(1,1) model. When $d =$ free, $p = 1$, $q = 1$ and $\theta_1 = 0$, the estimated model is the power generalized autoregressive conditional heteroscedasticity (PGARCH) model or the PGARCH(1,1) model (Ding et al. 1993; Brooks et al. 2000). Finally, when $d = 2$, $p = 1$, $q = 1$, $\theta_1 = 0$, $\sigma_t^d = \ln \sigma_t^d$ and $|u_{t-i}| = \varphi u_{t-i} + \phi[|u_{t-i}| - \text{E}|u_{t-i}|]$, where E is the expectation operator and the estimated model is the EGARCH model or the EGARCH(1,1) model. The conditional variance models are estimated by the maximum likelihood estimators. The selection of an ARCH model from a group of the ARCH models with different distribution assumptions of the disturbance term, namely Gaussian, student's t and generalized error enables the estimation of volatility more precisely to be compared with the estimation of volatility from a certain ARCH model.

The results of the ARCH(1) model, the EGARCH(1,1) model, the PGARCH(1,1) model, the APGARCH(1,1) model and the GARCH(1,1) model, are reported in

Table 1 Exchange rate volatilities, January, 2010–December, 2014 ($\ln e_t = +\Upsilon_1 \ln e_{t-1} + \Upsilon_2 \ln e_{t-2} + u_t$, $\sigma_t^d = \omega + \alpha(|u_{t-1}| + \theta u_{t-1})^d + \beta \sigma_{t-1}^d$)

	ARCH(1)	EGARCH(1,1)	PGARCH(1,1)	APGARCH(1,1)	GARCH(1,1)
Mean equation					
μ	0.2496***	0.2202***	0.1894***	0.1588***	0.2470***
Υ_1	1.0946***	1.1363***	1.1698***	1.2460***	1.0797***
Υ_2	−0.3172***	−0.3343***	−0.3400***	−0.3889***	−0.2992***
Variance equation					
ω	0.0002***	−15.5001***	0.0054	0.0053	0.0003***
α	−0.1448	−0.2944	0.1222	0.1531	−0.1508*
β	–	−0.8471	0.5356	0.2951	−0.4271
θ	–	–	–	0.5472	–
Diagnostic tests					
AIC	−5.5576	−5.5187	−5.5036	−5.4863	−5.5592
SBC	−5.3444	−5.2701	−5.2549	−5.2021	−5.3460
LR	167.1697	167.0434	166.6046	167.1015	167.2164
ARCH	0.1602	0.0482	1.1106	1.1788	0.3513
Q(12)	12.118	8.7556	12.783	13.761	11.785
Q(24)	20.119	13.393	21.087	21.626	18.647

AIC is the Akaike information criterion. SBC is the Schwarz Bayesian criterion. LR is the log likelihood ratio. ARCH is the F-statistic for the ARCH test. Q(12) and Q(24) are the Ljung-Box statistics with the orders twelve and twenty four, respectively. *** (**, *) Denotes significance at the 1 % (5 %, 10 %) level

Table 1. The powers for the APGARCH(1,1) model and the PGARCH(1,1) model are fixed to unity. On the whole, the ARCH models with generalized error distribution except the GARCH(1,1) model with normal distribution are found to be the best among distributions of Gaussian, student's t and generalized error in terms of significance of the estimated coefficients and the large values of the log likelihood ratio, the AIC and the Schwarz Bayesian criterion (SBC). The ARCH tests, which are based on the F statistics for testing the disturbance term of the mean equations demonstrate all the estimated models have no ARCH effect and therefore the estimated models are said to be appropriate. Moreover, the Ljung-Box statistics with order twelve and twenty fourth, respectively show the stationary of the disturbance terms of the mean equations. Nevertheless, the log likelihood ratio of the GARCH(1,1) model is the largest, that is, 167.2164. Also, the absolute values of the AIC and the SBC of the GARCH(1,1) model are the largest, that is, 5.5592 and 5.3460, respectively. The coefficients of the mean equation and the variance equation of the GARCH(1,1) model are mostly found to be statistically significant. On the whole, exchange rate volatility estimated by the GARCH(1,1) model is selected from the ARCH models to examine the impact of exchange rate volatility on export.

The plot of exchange rate volatilities computed by the MSD(3) and estimated by the GARCH(1,1) model are given in Fig. 1. The discriptive statistics of exchange rate volatilites are given in Table 2. The patterns of the two exchange rate
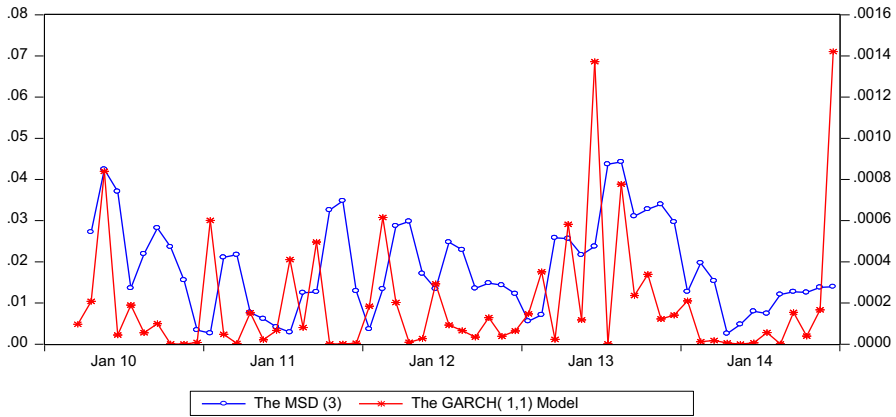
Fig. 1 Exchange rate volatilities computed by the MSD(3) and estimated by the GARCH(1,1) model, January, 2010–December, 2014

Table 2 The descriptive statistics of exchange rate volatility estimated by the MSD(3) and the GARCH(1,1) model, January, 2010–December, 2014

	MSD(3)	GARCH(1,1) Model
Mean	0.0185	0.0002
Median	0.0148	0.0001
Maximum	0.0443	0.0014
Minimum	0.0026	0.0000
SD	0.0111	0.0003
Skewness	0.5245	2.5326
Kurtosis	2.4668	9.6119
Jarque–Bera	3.2884	167.6533***

SD standard deviation

*** Denotes significance at the 1 % level

volatilities are about the same. The mean of exchange rate volatility computed by the MSD(3), that is, 0.0185 is larger than the mean of exchange rate volatility estimated by the GARCH(1,1), that is, 0.0002. The Jarque–Bera normality test is found to be insignificant for exchange rate volatility computed by the MSD(3) but significant for exchange rate volatility estimated by the GARCH(1,1) model. There is weak correlation between the two exchange rate volatilities, that is, 0.1164.

Kwiatkowski et al. (1992) propose a stationary test. The model is specified as follows:

$$y_t = \beta' d_t + \mu_t + u_t$$
$$\mu_t = \mu_{t-1} + \varepsilon_t, \ \varepsilon_t \sim iidN(0, \sigma_\varepsilon^2) \tag{3}$$

where d_t is the deterministic components, that is, constant or constant plus time trend, μ_t is a pure random walk with innovation variance σ_ε^2, u_t is stationary or heteroskedastic and ε_t is normally identically independently distributed with mean zero and variance σ_ε^2. The test statistic is the Lagrange multiplier (LM) test for testing the null hypothesis, that is, $H_0 : \sigma_\varepsilon^2 = 0$, which implies y_t is stationary and μ_t

is a constant against the alternative hypothesis, that is, $H_a : \sigma_\varepsilon^2 > 0$. The test statistic is specified as follows:

$$LM = T^{-2} \sum_{t=1}^{T} s_t^2 / \sigma_u^2 \tag{4}$$

where $s_t = \sum_{i=1}^{t} u_i$, u_t is the residual of a regression of y_t on μ_t and d_t and σ_u^2 is a consistent estimate of the long-run variance of u_t, that is, the sum of squared residual divided the sample size (T). The critical values can be obtained in the paper by Kwiatkowski et al. (1992).

The ARDL approach approach allows the regressors to be integrated of order zero [I(0)] and integrated of order one [I(1)] (Fuinhas and Marques, 2012). The unrestricted error correction model for the export demand model is specified as follows (Bahmani-Oskooee et al. 2014):

$$\Delta \ln x_t = \beta_{10} + \sum_{i=0}^{p} \beta_{11i} \ln e_{t-i} + \sum_{i=0}^{q} \beta_{12i} \ln y_{t-i}^* + \sum_{i=0}^{r} \beta_{13i} v_{t-i}$$
$$+ \sum_{i=1}^{s} \beta_{14i} \ln x_{t-i} + \beta_{15} \ln e_{t-1} + \beta_{16} \ln y_{t-1}^* + \beta_{17} v_{t-1} + \beta_{18} \ln x_{t-1} + u_{1,t} \tag{5}$$

where Δ is the first difference operator, x_t is real export, which is real total export or real exports of SITC from 0 to 9, respectively, e_t is real exchange rate, y_t^* is real foreign demand, v_t is exchange rate volatility computed by the MSD(3) or estimated by the GARCH(1,1) model and $u_{1,t}$ is a disturbance term. The F-statistic is computed to test the null hypothesis, H_0: $\beta_{15} = \beta_{16} = \beta_{17} = \beta_{18} = 0$ against the alternative hypothesis, H_a: $\beta_{15} \neq \beta_{16} \neq \beta_{17} \neq \beta_{18} \neq 0$. If the F-statistic falls outside the upper bound or it is denoted by I(1), the null hypothesis of no cointegration is rejected. If the F-statistic falls below the lower bound or it is denoted by I(0), the null hypothesis of no cointegration cannot be rejected. However, no conclusive inference can be made for the F-statistic falls inside the critical bounds, that is, between I(0) and I(1). The order of the lags in the unrestricted error correction model is selected based on the SBC or the AIC.

The ARDL approach for the export demand model can be estimated as follows:

$$\ln x_t = \beta_{20} + \sum_{i=0}^{p} \beta_{21i} \ln e_{t-i} + \sum_{i=0}^{q} \beta_{22i} \ln y_{t-i} + \sum_{i=0}^{r} \beta_{23i} v_{t-i}$$
$$+ \sum_{i=1}^{s} \beta_{24i} \ln x_{t-i} + u_{2,t} \tag{6}$$

where $u_{2,t}$ is a disturbance term. The order of the lags in the ARDL model is selected based on the SBC or the AIC. The error correction model of the ARDL approach can be estimated as follows:

$$\Delta \ln x_t = \beta_{30} + \sum_{i=0}^{p} \beta_{31i} \ln e_{t-i} + \sum_{i=0}^{q} \beta_{32i} \ln y_{t-i}$$

$$+ \sum_{i=0}^{r} \beta_{33i} v_{t-i} + \sum_{i=1}^{s} \beta_{34i} \ln x_{t-i} + \beta_{35} ec_{t-1} + u_{3,t} \tag{7}$$

where ec_{t-1} is the error correction term generated from Eq. (6) and $u_{3,t}$ is a disturbance term. In this study, the general to specific modelling strategy is used to find the error correction model. Initially, three lags of each first difference variable are used and sequentially variables, which are statistically insignificant and do not contribute substantially to the goodness of fit of the model, are excluded.

4 Results and discussions

The results of the Kwiatkowski, Phillips, Schmidt and Shin (KPSS) unit root test statistics are reported in Table 3. The KPSS unit root test statistics show that the variables are mostly non-stationary in their levels but become stationary after taking the first differences indicated by the KPSS unit root test statistic with the model included a constant only or the KPSS unit root test statistic with the model included a constant and a time trend except real exports of SITC 2, SITC 3, SITC 8, real foreign demand and exchange rate volatilities, which are stationary in level. Thus, variables in this study are mixture of I(0) and I(1) variables.

The ARDL bounds testing approach and the long run coefficients of the ARDL approach are given in Table 4. Panels (a) and (b) present the results of the ARDL approach with exchange rate volatilities computed by the MSD(3) and estimated by the GARCH(1,1) model, respectively. The F statistics are found to be statistically significant except real export of SITC 5 when exchange rate volatility is estimated by the GARCH(1,1) model, which the F statistic falls in between I(0) and I(1) and therefore no conclusive conference can be made on real export and their determinants but it is said to be cointegrated in this study. On the whole, real exports and their determinants are said to be cointegrated. The coefficient of real exchange rate is found to be negative and statistically significant for real export of SITC 4 when exchange rate volatility is computed by the MSD(3). An increase in real exchange rate will lead to a decrease in real export. Contrarily, the coefficient of real exchange rate is found to be positive and statistically significant for real export of SITC 3 when exchange rate volatility is estimated by the GARCH(1,1) model. An increase in real exchange rate will lead to an increase in real export. The coefficients of real foreign demand are found to be positive and statistically significant except real exports of SITC 0, SITC 1, SITC 3, SITC 5 and SITC 9 when exchange rate volatility is computed by the MSD(3) and except real exports of SITC 0, SITC 1 and SITC 9 when exchange rate volatility is estimated by the GARCH(1,1) model. Thus, an increase in real foreign demand will lead to an increase in real export. The coefficient of exchange rate volatility is found to be positive and statistically significant only for real export of SITC 3, which exchange rate volatility is computed by the MSD(3) and real exports of SITC 2 and SITC3 when exchange rate

Table 3 The results of the Kwiatkowski, Phillips, Schmidt and Shin (KPSS) Unit Root Test Statistics

	No trend	Trend
$\ln x_{t,t}$	0.1916 (5)	0.1864(5)*
$\Delta \ln x_{t,t}$	0.1591(2)	0.0139(0)
$\ln x_{0,t}$	0.5312(5)**	0.1372(5)*
$\Delta \ln x_{0,t}$	0.0922(7)	0.0780(7)
$\ln x_{1,t}$	0.5185(4)**	0.0712(2)
$\Delta \ln x_{1,t}$	0.0406(3)	0.0317(3)
$\ln x_{2,t}$	0.0712(3)	0.0575(3)
$\Delta \ln x_{2,t}$	0.2325(3)	0.0710(6)
$\ln x_{3,t}$	0.2325(4)	0.0601(3)
$\Delta \ln x_{3,t}$	0.0444(2)	0.0410(2)
$\ln x_{4,t}$	0.5320(4)**	0.1863(2)**
$\Delta \ln x_{4,t}$	0.0670(6)	0.0666(6)
$\ln x_{5,t}$	0.6523(5)**	0.1882(4)**
$\Delta \ln x_{5,t}$	0.0775(3)	0.0354(3)
$\ln x_{6,t}$	0.8592(3)***	0.0615(2)
$\Delta \ln x_{6,t}$	0.0409(3)	0.0407(3)
$\ln x_{7,t}$	0.2530(5)	0.2143(5)**
$\Delta \ln x_{7,t}$	0.1993(5)	0.0541(6)
$\ln x_{8,t}$	0.1061(5)	0.0744(5)
$\Delta \ln x_{8,t}$	0.0827(2)	0.0567(3)
$\ln x_{9,t}$	0.4367(5)*	0.1129(5)
$\Delta \ln x_{9,t}$	0.0961(6)	0.0656(6)
$\ln e_t$	0.2245(5)	0.1948(5)**
$\Delta \ln e_t$	0.4192(6)*	0.0748(6)
$\ln y_t$	0.9693(6)	0.0561(3)
$\Delta \ln y_t$	0.0470(4)	0.0465(4)
$v_{1,t}$	0.0854(4)	0.0876(4)
$\Delta v_{1,t}$	0.0548(3)	0.0538(3)
$v_{2,t}$	0.1241(1)	0.0597(1)
$\Delta v_{2,t}$	0.1798(6)	0.0966(6)

$x_{t,t}$ is real total export. $x_{i,t}$ is real export of SITC i ($i = 0$–9). e_t is real exchange rate. y_t is real foreign demand. $v_{1,t}$ is exchange rate volatility computed by the MSD(3). $v_{2,t}$ is exchange rate volatility estimated by the GARCH(1,1) model. No trend is the KPSS test statistic estimated with the model included a constant only. Trend is the KPSS test statistic estimated with the model included a constant and a time trend. Values in the parentheses are the lags used in the estimation. *** (**, *) Denotes significance at the 1 % (5 %, 10 %) level

volatility is estimated by the GARCH(1,1) model. The coefficient of exchange rate volatility is found to be negative and statistically significant only for real export of SITC 0 when exchange rate volatility is estimated by the GARCH(1,1) model. An increase in exchange rate volatility would lead to a decrease or a decrease in real export.

The error correction models are reported in Table 5. Figure 2 displays the plots of cumulative sum of recursive residuals (CUSUM) and cumulative sum of squares of recursive residuals (CUSUMSQ). For exchange rate volatility computed by the MSD(3), the plots of cumulative sum of recursive residuals (CUSUM) and cumulative sum of squares of recursive residuals (CUSUMSQ) show no evidence of instability of the error correction models except the real exports of SITC 1, SITC 2, SITC 6 and SITC 9 models, which CUSUM shows stability of the error correction

Table 4 The results of the ARDL bounds testing approach for cointegration and the coefficients of the ARDL approach

(a) The MSD(3), F-statistics

	$x_{1,t}$	$x_{0,t}$	$x_{1,t}$	$x_{2,t}$	$x_{3,t}$	$x_{4,t}$
	9.9639***	4.5998**	9.3080***	11.9515***	19.7019***	20.6423***

	$x_{5,t}$	$x_{6,t}$	$x_{7,t}$	$x_{8,t}$	$x_{9,t}$
	4.5312**	14.0484***	11.0913***	4.8723**	10.3407***

	$\ln x_{1,t}$	$\ln x_{0,t}$	$\ln x_{1,t}$	$\ln x_{2,t}$	$\ln x_{3,t}$	$\ln x_{4,t}$
$\ln e_t$	3.0317 (1.1995)	4.3217 (0.6001)	10.8162 (1.5727)	−0.6644 (−0.2719)	−0.9837 (−0.1376)	−11.6098 (−2.1390)**
$\ln y_t^*$	1.5762 (2.6061)**	0.4534 (0.2620)	−1.9352 (−1.1815)	1.4128 (2.4100)**	1.0991 (0.6464)	4.3880 (3.3770)***
$v_{1,t}$	−4.4579 (−1.0125)	−10.7912 (−0.8500)	−12.0895 (−0.8632)	4.8370 (1.0514)	31.4833 (1.9367)*	−0.9915 (−0.1050)
Diagnostic tests						
LM	16.4600	16.6030	14.9711	12.3791	12.7699	14.5565
Reset	1.9732	2.0197	3.5638*	0.7108	0.3862	4.2408**
Normal	1.7845	1.4150	5.1382*	187.3440***	2.5230	2.0062
Hetero	0.3889	0.7338	0.0686	1.6793	0.0899	0.1484

	$\ln x_{5,t}$	$\ln x_{6,t}$	$\ln x_{7,t}$	$\ln x_{8,t}$	$\ln x_{9,t}$
$\ln e_t$	2.1642 (0.5570)	−0.3572 (−0.3019)	2.0850 (0.8691)	1.1964 (0.3135)	0.1898 (0.0279)
$\ln y_t^*$	1.0356 (1.1105)	1.7284 (6.0910)***	1.7163 (2.9847)***	1.6644 (1.8220)*	0.8664 (0.5312)
$v_{1,t}$	−10.8025 (−1.4480)	−1.7871 (−0.8025)	−2.4923 (−0.5775)	2.5174 (0.3305)	9.3660 (0.7311)
Diagnostic tests					
LM	12.0732	11.5625	14.9605	14.6690	6.9022
Reset	2.1889	0.0017	4.2143**	0.7526	0.0973
Normal	4.2357	29.8091***	1.2164	2.4954	1.2867
Hetero	1.4812	0.0034	5.3733**	1.8818	5.9645**

Table 4 continued

(b) The GARCH(1,1) model, F-statistics

	$x_{t,t}$	$x_{0,t}$	$x_{1,t}$	$x_{2,t}$	$x_{3,t}$	$x_{4,t}$
	9.2121***	4.2309*	10.2005***	12.6604***	21.7121***	17.2280***

	$x_{5,t}$	$x_{6,t}$	$x_{7,t}$	$x_{8,t}$	$x_{9,t}$
	3.3171	12.8253***	3.8993*	4.9471**	4.2778*

	$\ln x_{t,t}$	$\ln x_{0,t}$	$\ln x_{1,t}$	$\ln x_{2,t}$	$\ln x_{3,t}$	$\ln x_{4,t}$
$\ln e_t$	2.8643 (1.2736)	5.8259 (0.9547)	4.8635 (0.8632)	−1.8130 (−0.5240)	17.9091 (2.1849)**	−11.6098 (−2.1390)**
$\ln y_t^*$	1.6029 (2.9472)***	0.1022 (0.0695)	−0.5696 (−0.4180)	1.6713 (2.0128)*	−3.3850 (−1.7020)*	4.3880 (3.3770)***
$v_{2,t}$	−64.1094 (−0.4210)	−1305.0 (−1.9205)*	618.6703 (1.4232)	967.2442 (2.5153)**	1174.7 (1.8244)*	−0.9915 (−0.1050)
Diagnostic tests						
LM	15.2061	12.5353	17.5546	5.6320	10.9877	6.6912
Reset	1.1243	2.4543	3.9092**	0.0085	0.0872	5.1048**
Normal	2.1124	0.8652	5.6429*	24.9296***	4.5745	4.8841*
Hetero	0.3335	0.2107	0.2596	7.5201***	0.2739	0.1130

	$\ln x_{5,t}$	$\ln x_{6,t}$	$\ln x_{7,t}$	$\ln x_{8,t}$	$\ln x_{9,t}$
$\ln e_t$	−1.5080 (−0.3912)	−0.0799 (−0.0747)	2.3304 (1.0752)	−1.6073 (−0.6217)	1.9588 (0.3039)
$\ln y_t^*$	1.8698 (2.0079)*	1.6555 (6.4024)***	1.6504 (3.1483)***	2.3038 (3.6956)***	0.4855 (0.3119)
$v_{2,t}$	274.7312 (1.0063)	−2.3451 (−0.0308)	−55.1159 (−0.3608)	−178.4770 (−0.9600)	−293.0890 (−0.6280)
Diagnostic tests					
LM	11.1996	11.0797	14.1335	19.1445*	8.6231
Reset	2.4041	0.0686	3.8564*	0.9557	0.0396

Table 4 continued

	ln $x_{5,t}$	ln $x_{6,t}$	ln $x_{7,t}$	ln $x_{8,t}$	ln $x_{9,t}$
Normal	7.7170**	34.6599***	0.5814	1.2420	1.0137
Hetero	1.2408	0.2152	4.5026**	4.8250**	3.6229*

$x_{t,t}$ is real total export. $x_{i,t}$ is real export of SITC i ($i = 0$–9). e_t is real exchange rate. y_t^* is real foreign demand. $v_{1,t}$ is exchange rate volatility computed by the MSD(3). $v_{2,t}$ is exchange rate volatility estimated by the GARCH(1,1) model. LM is the Lagrange multiplier test of disturbance serial correlation. Reset is the test of functional form. Normal is the test of the normality of disturbance. Hetero is the test of heteroscedasticity. The critical values of the lower bound [I(0)] and the upper bound [I(1)] at the 1, 5 and 10 % levels are I(0) = 4.29, I(1) = 5.16, I(0) = 3.23, I(1) = 4.35 and I(0) = 2.72, I(1) = 3.77, respectively (Pesaran et al. 2001). Values in parentheses are the t-statistics. *** (**, *) Denotes significance at the 1 % (5 %, 10 %) level

Table 5 The results of the error-correction models

(a) The MSD(3)

	$\Delta \ln x_{t,t}$	$\Delta \ln x_{0,t}$	$\Delta \ln x_{1,t}$	$\Delta \ln x_{2,t}$	$\Delta \ln x_{3,t}$	$\Delta \ln x_{4,t}$
Constant	0.0029 (0.2978)	−0.0135 (−0.5382)	0.0464 (0.5787)	0.0340 (0.7803)	0.1212 (0.8372)	0.0051 (0.1344)
$\Delta \ln e_t$	—	−0.9808 (−0.5819)	—	—	—	—
$\Delta \ln e_{t-2}$	−0.0912 (−0.1312)	—	—	—	−0.4661 (−0.0467)	—
$\Delta \ln e_{t-3}$	—	—	7.5236 (1.4343)	6.2077 (2.0868)**	−29.3337 (−3.0301)***	1.4811 (0.5724)
$\Delta \ln y^*_t$	—	3.6473 (1.9774)*	—	—	—	—
$\Delta \ln y^*_{t-3}$	−0.1500 (−0.2306)	—	−10.1761 (−1.8260)*	−9.1220 (−3.0333)***	—	−2.8205 (−1.0649)
$\Delta v_{1,t}$	2.4015 (2.3334)**	−4.8070 (−1.7330)*	14.5639 (1.7809)*	−9.2295 (−2.0394)**	−21.2839 (−1.3759)	−17.8612 (−3.7900)***
$\Delta v_{1,t-2}$	—	—	—	—	—	−11.5202 (−2.4911)**
$\Delta v_{1,t-3}$	—	−6.2250 (−2.3968)**	—	—	—	—
$\Delta \ln x_{j,t-1}$	−0.6141 (−4.7195)***	—	—	—	—	−0.6218 (−4.5671)***
$\Delta \ln x_{j,t-2}$	−0.3039 (−2.4255)**	—	—	—	—	−0.3134 (−2.6809)**
ec_{t-1}	−0.2302 (−2.8464)***	−0.2074 (−2.6733)**	−0.6337 (−5.0425)***	−1.0262 (−7.5119)***	−1.0548 (−8.0563)***	−0.4137 (−3.1580)***
Diagnostic tests						
Adj. R²	0.3937	0.1878	0.3987	0.5518	0.5998	0.5811
LM	17.0386	10.1896	9.5532	8.0764	9.1931	14.1319
Reset	0.0039	0.8366	3.7179*	0.2512	1.5665	5.8562**
Normal	2.2385	2.5090	0.3753	82.1827***	2.7972	0.3486
Hetero	1.4762	0.6319	1.3841	0.0225	0.2259	0.0171

	$\Delta \ln x_{5,t}$	$\Delta \ln x_{6,t}$	$\Delta \ln x_{7,t}$	$\Delta \ln x_{8,t}$	$\Delta \ln x_{9,t}$
Constant	0.0087 (0.2760)	0.0078 (0.3502)	0.0009 (0.0084)	−0.0013 (−0.1014)***	0.0221 (0.5168)
$\Delta \ln e_t$	3.6114 (1.6073)	—	—	—	−5.1337 (−1.6437)
$\Delta \ln e_{t-1}$	—	—	—	—	5.6647 (1.8087)*

Table 5 continued

	Δ ln $x_{5,t}$	Δ ln $x_{6,t}$	Δ ln $x_{7,t}$	Δ ln $x_{8,t}$	Δ ln $x_{9,t}$
Δ ln e_{t-2}	–	–	−1.2750 (−1.7571)*	–	–
Δ ln e_{t-3}	–	1.3869 (0.8570)	–	−1.5365 (−1.7376)*	−3.1498 (−1.0603)
Δ ln y^*_t	−2.6168 (−1.1428)	–	1.0091 (1.3478)	0.9589 (1.0034)	–
Δ ln y^*_{t-1}	–	–	–	–	−4.5266 (−1.2250)
Δ ln y^*_{t-2}	–	–	–	–	−5.8286 (−1.6094)
Δ ln y^*_{t-3}	–	−1.9019 (−1.2540)*	–	–	–
Δ ln $v_{1,t}$	–	–	–	–	8.7491 (1.7573)*
Δ ln $v_{1,t-1}$	−4.9632 (−1.4286)	–	–	–	−6.3068 (−1.1321)
Δ ln $v_{1,t-2}$	–	–	2.9860 (2.7613)***	2.9443 (2.1066)**	–
Δ ln $v_{1,t-3}$	–	3.1638 (1.4118)	–	–	−9.2504 (−1.7113)*
Δ ln $x_{ji,t-1}$	−0.1929 (−1.4335)	–	−0.4133 (−3.6052)***	−0.3559 (−2.8036)***	−0.2676 (−1.8626)*
Δ ln $x_{ji,t-3}$	–	0.1616 (1.7345)*	–	–	–
ec_{t-1}	−0.3499 (−2.6127)**	−1.1066 (−7.9406)***	−0.2858 (−3.3073)***	−0.2592 (−2.8353)***	−0.1995 (−1.8545)*
Diagnostic tests					
Adj. R^2	0.2646	0.5730	0.4078	0.3191	0.2283
LM	8.9173	10.5898	15.9492	10.8001	10.8678
Reset	1.2358	2.9545*	1.0369	0.0399	3.2620*
Normal	1.9625	17.1468***	0.0084	2.5397	7.0753**
Hetero	0.0044	0.0018	0.2987	1.5032	0.3783

(b) The GARCH(1,1) model

	Δ ln $x_{1,t}$	Δ ln $x_{0,t}$	Δ ln $x_{1,t}$	Δ ln $x_{2,t}$	Δ ln $x_{3,t}$	Δ ln $x_{4,t}$
Constant	0.0029 (0.2864)	−0.0060 (−0.2485)	−0.0532 (−0.7095)	0.0434 (0.9709)	−0.0089 (−0.0622)	0.0278 (0.6651)
Δ ln e_{t-1}	–	−0.8915 (−0.5528)	18.1097 (2.9167)***	–	–	−5.5757 (−1.7957)*

Table 5 continued

(b) The GARCH(1,1) model

	$\Delta \ln x_{t,t}$	$\Delta \ln x_{0,t}$	$\Delta \ln x_{1,t}$	$\Delta \ln x_{2,t}$	$\Delta \ln x_{3,t}$	$\Delta \ln x_{4,t}$
$\Delta \ln e_{t-2}$	−0.4777 (−0.6410)	–	−13.4563 (−2.2008)**	–	–	6.2968 (2.0281)**
$\Delta \ln e_{t-3}$	–	–	12.4537 (2.3045)**	6.6518 (2.0832)**	−17.8062 (−1.8795)*	–
$\Delta \ln y^{*}_{t}$	–	2.2547 (1.3995)	–	–	–	–
$\Delta \ln y^{*}_{t-2}$	−0.7516 (−1.1096)	–	15.6355 (2.7281)***	–	–	−5.0876 (−1.7078)*
$\Delta \ln y^{*}_{t-3}$	–	−147.5647 (−2.1656)**	497.8011 (2.5843)**	−7.6032 (−2.3906)**	−12.7797 (−1.2859)	–
$\Delta \ln v_{2,t}$	–	–	–	–	647.9012 (1.9124)*	–
$\Delta \ln v_{2,t-1}$	–	–	–	−336.1722 (−2.1417)**	–	–
$\Delta \ln v_{2,t-2}$	62.7486 (1.7117)*	–	–	−282.3873 (−2.1793)**	–	–
$\Delta \ln v_{2,t-3}$	69.4715 (1.8799)*	–	–	–	–	67.3517 (0.6139)
$\Delta \ln x_{j,t-1}$	−0.4181 (−3.5500)***	–	−0.6617 (−5.3916)***	−0.8372 (−6.4733)***	–	−0.4207 (−3.4227)***
ec_{t-1}	−0.2551 (−2.9843)***	−0.2164 (−3.3391)***	–	–	−1.1572 (−9.1467)***	−0.4463 (−2.9771)***
Diagnostic tests						
Adj. R^2	0.3383	0.1482	0.4487	0.5275	0.6351	0.4813
LM	16.7316	13.4371	16.3267	10.2549	8.4331	15.9800
Reset	0.0212	0.8958	8.8325***	0.2413	0.0719	3.8402*
Normal	1.1851	0.5739	1.9160	53.8847***	1.9916	0.9214
Hetero	0.4109	0.2371	1.3225	0.0025	0.1034	1.4605

	$\Delta \ln x_{5,t}$	$\Delta \ln x_{6,t}$	$\Delta \ln x_{7,t}$	$\Delta \ln x_{8,t}$	$\Delta \ln x_{9,t}$
Constant	0.0083 (0.2471)	−0.0306 (−1.1914)	−0.0043 (−0.4163)	0.0552 (1.9022)*	−0.0068 (−0.0188)
$\Delta \ln e_{t}$	–	–	–	–	−7.2441 (−2.5772)**
$\Delta \ln e_{t-1}$	–	–	–	0.9893 (1.0302)	8.5692 (3.0940)***
$\Delta \ln e_{t-2}$	–	–	−1.6129 (−2.0063)*	–	−5.9668 (−2.2884)**

Table 5 continued

	$\Delta \ln x_{5,t}$	$\Delta \ln x_{6,t}$	$\Delta \ln x_{7,t}$	$\Delta \ln x_{8,t}$	$\Delta \ln x_{9,t}$
$\Delta \ln e_{t-3}$	−0.7568 (−0.3212)	−1.8615 (−1.2305)	–	–	–
$\Delta \ln y^*_t$	−1.3526 (−0.5201)	3.7610 (2.1255)**	–	–	0.4012 (0.1561)
$\Delta \ln y^*_{t-1}$	–	3.4817 (1.8441)*	–	–	–
$\Delta \ln y^*_{t-2}$	–	2.9708 (1.7118)*	1.2289 (1.6984)*	1.1219 (1.2291)	–
$\Delta v_{2,t}$	182.9466 (1.6881)*	–	–	–	–
$\Delta v_{2,t-1}$	95.5630 (0.7856)	−107.1242 (−1.7567)*	−46.3912 (−1.4784)	−61.649 (−1.5239)	–
$\Delta v_{2,t-2}$	–	–	–	–	296.8979 (3.0210)***
$\Delta v_{2,t-3}$	–	–	63.8387 (2.1703)**	74.8018 (1.9023)*	–
$\Delta \ln x_{j,t-1}$	−0.2063 (−1.4221)	–	−0.4166 (−3.6967)***	−0.3540 (−2.7504)***	−0.2280 (−1.8185)*
ec_{t-1}	−0.3106 (−2.4080)**	−1.1300 (−8.0752)***	−0.3005 (−3.3463)***	−0.2276 (−2.2073)**	−0.1852 (−1.9757)*
Diagnostic tests					
Adj. R^2	0.1731	0.5585	0.3936	0.2576	0.3365
LM	11.0954	7.6281	10.4964	10.7166	9.4337
Reset	0.7063	5.3863**	0.0821	0.0140	0.0026
Normal	6.6992**	37.3635***	0.7635	4.4369	0.8904
Hetero	0.0221	0.0013	0.5527	1.9539	0.3448

$x_{t,t}$ is real total export. $x_{i,t}$ is real export of SITC i ($i = 0–9$). $x_{j,t-1}$ is lag of real total export or real export of SITC i ($i = 0–9$). e_t is real exchange rate. y^*_t is real foreign demand. $v_{1,t}$ is exchange rate volatility computed by the MSD(3). $v_{2,t}$ is exchange rate volatility estimated by the GARCH(1,1) model. ec_{t-1} is the error correction term. Adj. R^2 is the adjusted R^2. LM is the Lagrange multiplier test of the disturbance term serial correlation. Reset is the test of functional form. Normal is the test of the normality of the disturbance term. Hetero is the test of heteroscedasticity. Values in parentheses are the t-statistics. *** (**; *) Denotes significance at the 1 % (5 %, 10 %) level
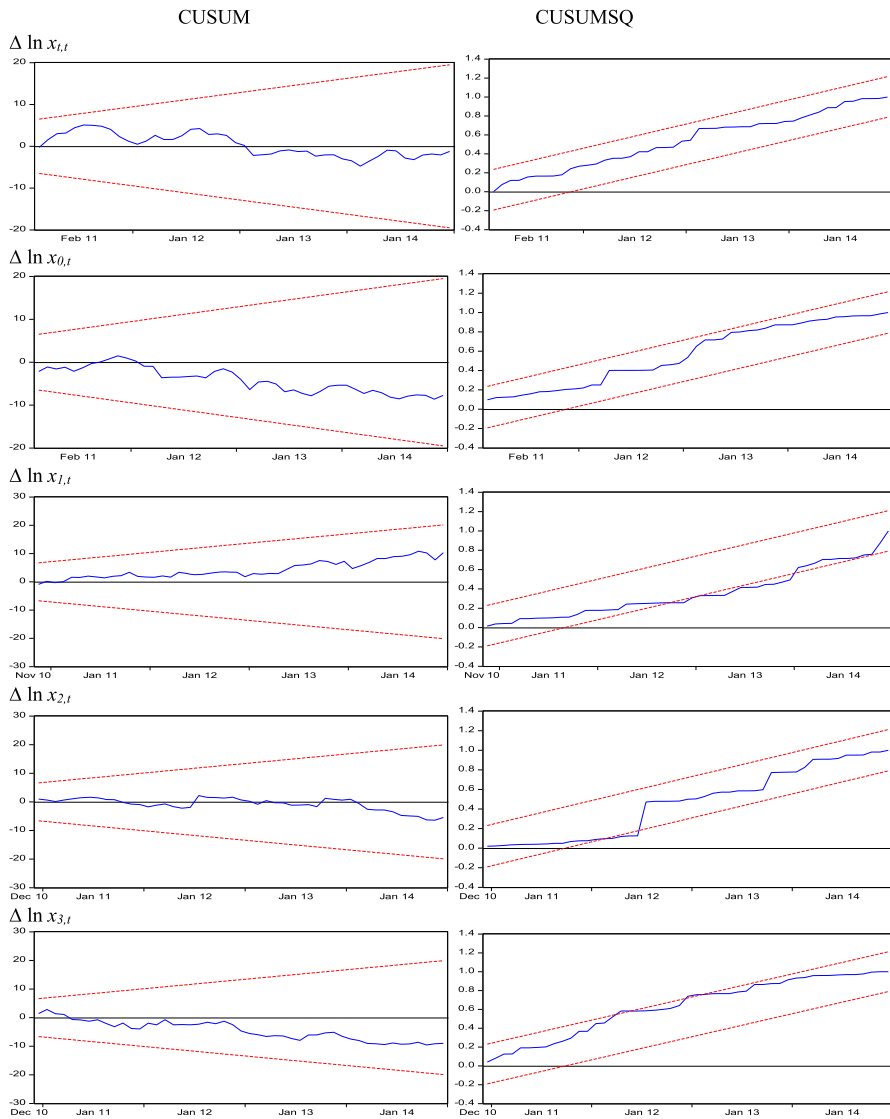
(a) The MSD(3)

Fig. 2 The Plots of Cumulative Sum of Recursive Residuals (CUSUM) and Cumulative Sum of Squares of Recursive Residuals (CUSUMSQ)

models but CUSUMSQ shows marginal instability of the error correction models at the 5 per cent level. For exchange rate volatility estimated by the GARCH(1,1) model, the plots of CUSUM and CUSUMSQ show no evidence of instability of the error correction models except the real export of SITC 1, which CUSUM shows stability of the error correction model but CUSUMSQ shows marginal instability of the error correction model at the 5 per cent level. The adjusted coefficients of
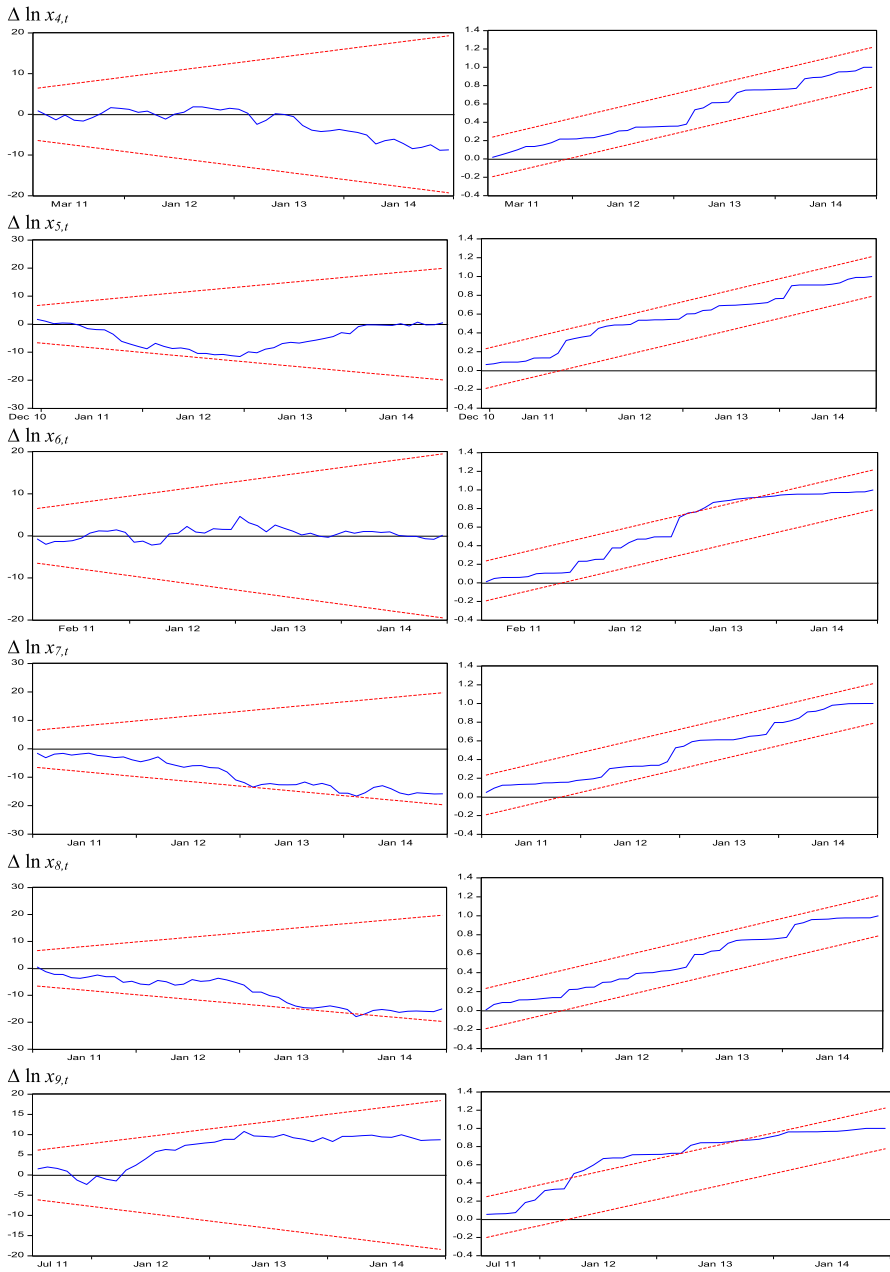
Fig. 2 continued

determination (R^2) are in the range of 0.1878 for the SITC 0 model to 0.5998 for the SITC 3 model when exchange rate volatility is computed by the MSD(3) and in the range of 0.1482 for the SITC 0 model to 0.6351 for the SITC 3 model when
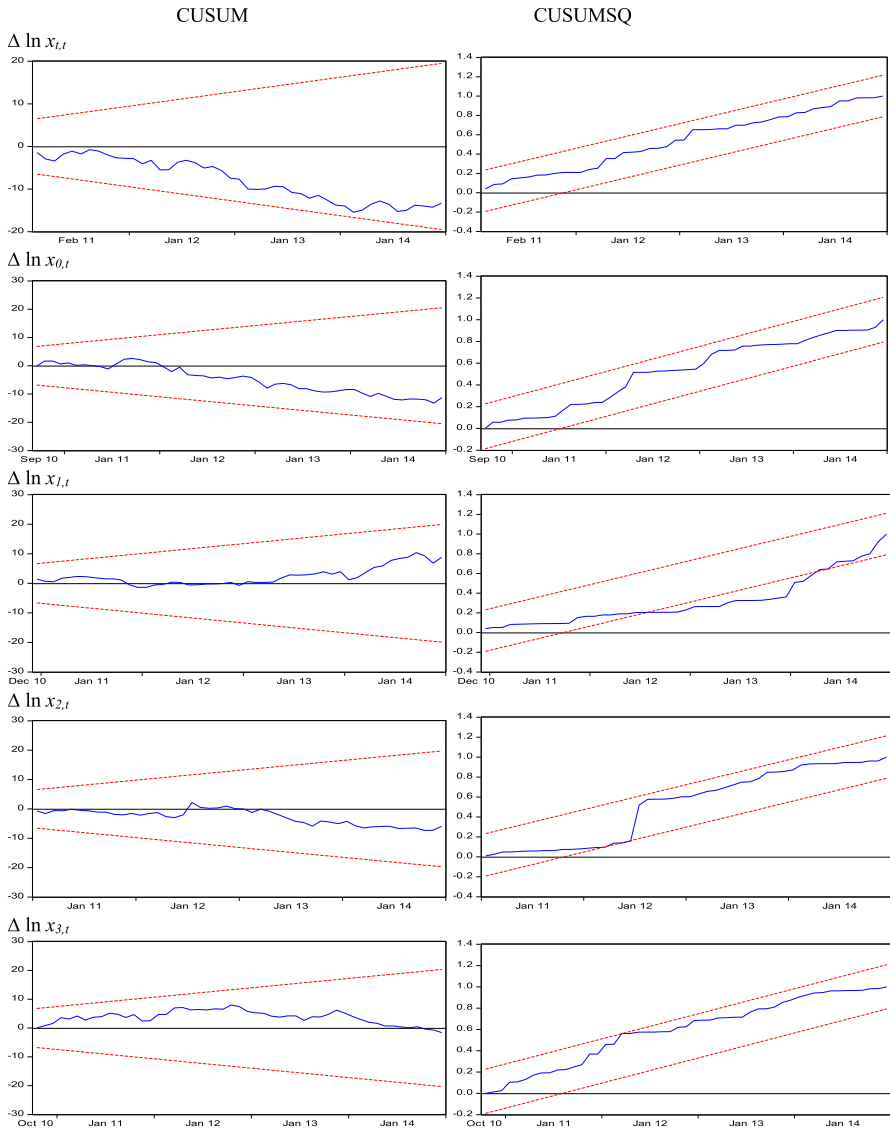
(b) The GARCH(1,1) Model

Fig. 2 continued

exchange rate volatility is estimated by the GARCH(1,1) model. The estimated models are mostly fulfil the conditions of no-autocorrelation, no functional form and normality and homoscedasticity of the disturbance term. For exchange rate volatility computed by the MSD(3), real exports of SITC 1 and SITC 4, which no functional form of the disturbance term is rejected, real export of SITC 2, which normality of
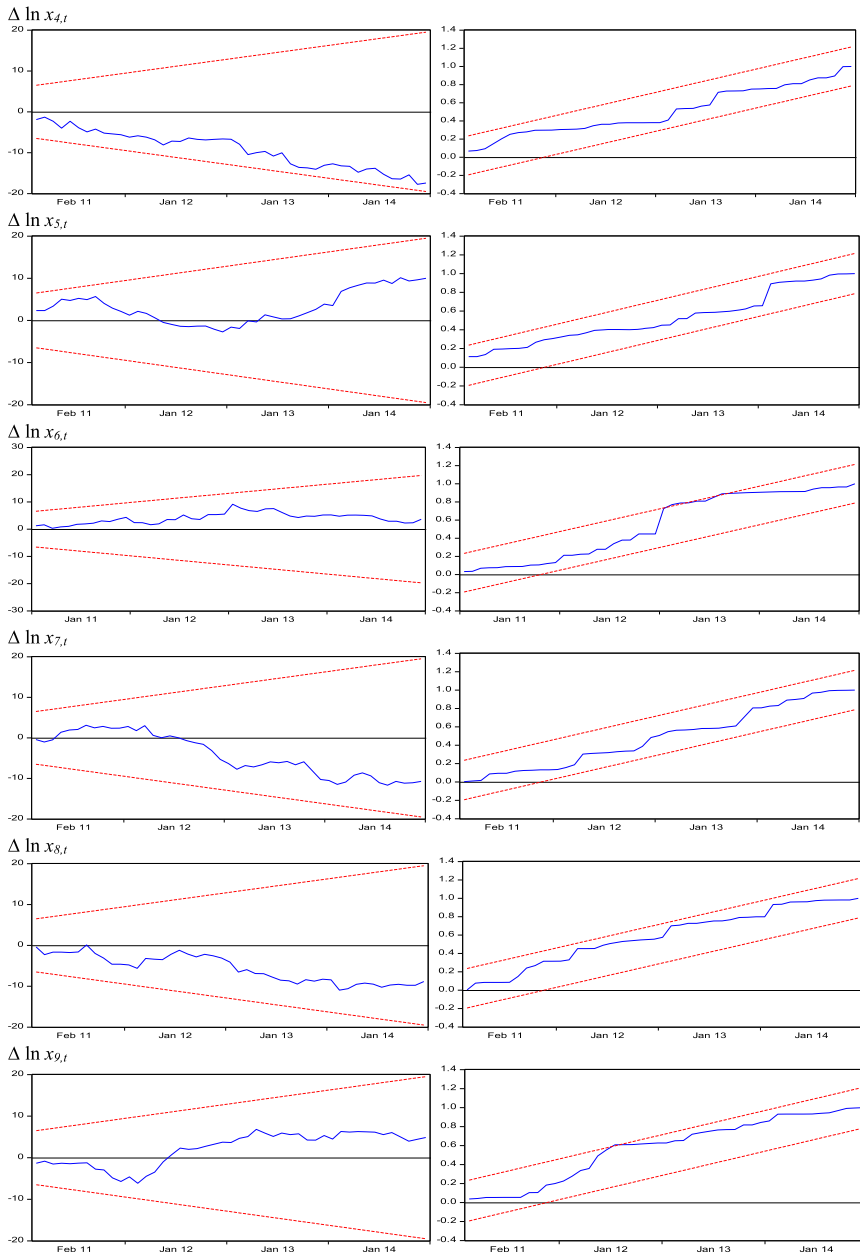
Notes: $x_{t,t}$ is real total export. $x_{i,t}$ is real export of SITC i ($i = 0$ - 9). The lines denote significance at the 5% level.

Fig. 2 continued

the disturbance term is rejected and real exports of SITC 6 and 9, which no functional form and normality of the disturbance term are rejected. For exchange rate volatility estimated by the GARCH(1,1) model, real exports of SITC 1 and

SITC 4, which no functional form of the disturbance term is rejected, real exports of SITC 2 and SITC 5, which normality of the disturbance term is rejected and real export of SITC 6, which no functional form and normality of the disturbance term are rejected. The coefficients of the one lag of error correction terms are found to have the expected negative signs and statistically significant. Moreover, the values of the one lag of error correction terms are less than one except real exports of SITC 2, SITC 3 and SITC 6 when exchange rate volatility is computed by the MSD(3) and real exports of SITC 3 and SITC 6 when exchange rate volatility is estimated by the GARCH(1,1) model, which the values of the one lag of error correction terms are close to one, respectively. On the whole, there are equilibrium relationships among the variables in the estimated models.

The coefficients of exchange rate volatility computed by the MSD(3) are all found to be statistically significant except real exports of SITC 3, SITC 5 and SITC 6. The coefficients of exchange rate volatility estimated by the GARCH(1,1) model are all found to be statistically significant except real export of SITC 4. The impacts of exchange rate volatilities are found to be negative and positive. Thus, some sectors of exports are found to be more sensitive to exchange rate volatility whilst some sectors of exports are found to be less sensitive to exchange rate volatility. Furthermore, some sectors of exports response negatively to exchange rate volatility whilst some sectors of exports response positively to exchange rate volatility.

This study finds that there is no evidence of exchange rate volatility on real total export of Malaysia to the US in the level but some evidence of exchange rate volatility on the sub-categories of real total export in the level. Moreover, the significant impacts of exchange rate volatilities on exports are mainly found in the first differences of exports. Conversely, Caglayan and Di (2010) report that there is little effect of exchange rate volatility on sectoral trade flows for both advanced and emerging economies. The finding that exchange rate volatility to have significant impact on exports is consistent with the findings such as Bahmani-Oskooee and Harvey (2011) and Wong and Tang (2008, 2011). The use of exchange rate volatility estimated by the GARCH(1,1) model in the estimation produces about the same conclusion as the use of exchange rate volatility computed by the MSD(3). However, there are more cases of exports, where the impact of exchange rate volatility estimated by the GARCH(1,1), are found to have significant impacts on exports compared with the impact of exchange rate volatility computed by the MSD(3) on exports. Furthermore, the impact of exchange rate volatility is found to be different from sectors of exports. Real exports of SITC 0, SITC 2 and SITC 3 are found to be more sensitive to exchange rate volatility when exchange rate volatility is estimated by the GARCH(1,1) model as the coefficients of exchange rate volatility are found to be statistically significant on real exports both in the level and the first differences. The impact of exchange rate volatility on export can be negative or positive. An increase in exchange rate volatility will lead to a negative or positive impact on some exports of Malaysia to the US. Byrne et al. (2008) report that exchange rate volatility is found to have significant negative impacts for different sectors of exports. The adverse impacts of exchange rate volatility are mostly found for exports of differentiated goods. Jaussaud and Rey (2012) argue that the impact of exchange rate volatility on export differs from sectors of exports

because companies from different sectors of exports do not react in the same way to exchange rate volatility. Firms in the imperfect market structure do not revise much their export prices and margins compared with firms in the perfect market structure. As a result, the impact of exchange rate volatility should be different from sector of export. This study finds that real foreign demand is mostly found to have significant impact on real export in the level. An increase in real foreign demand will lead to an increase in real export. In some cases, the coefficients of real exchange rate are found to be negative. Hence an increase in real exchange rate would lead to a decrease in real export.

There is no evidence of the impact of exchange rate volatility on real total export could be due to the exchange rate policy and its management implemented in Malaysia are satisfactory to avoid the adverse impact of exchange rate volatility on export. Malaysia adopts a managed floating exchange rate (IMF 2014). Central Bank of Malaysia might intervene in the exchange rate market in the short run but in the long run likely would let the exchange rate market to determine the value of RM, which is pegged against a basket of currencies. In the short run, small and medium exporters shall be given more convenience to access the forward and future markets. Thus, it is less costly for small and medium exporters to hedge their risk of uncertainty from exchange rate volatility. In the long run, the forward and future markets shall be further developed with the use of the state of art of technology in the transaction and more forward and future instruments shall be introduced. Currently, the economy of the US is not very impressive. In the short run, an effective marketing approach shall be adopted to aggressively promote exports of Malaysia in the US and also to other countries such as in Association of Southeast Asian Nations Economic Community (AEC) (MOF 2013). AEC would provide an extensive potential export market to exporters of Malaysia. Exporters through diversification of their export markets would reduce exposure of exchange rate volatility. Diversification shall have tendency to reduce risks including risk of exchange rate volatility. The economic recovery in the US in the future will bring to better prospects of exports of Malaysia to that country. In the long run, exporters of Malaysia shall continue to improve their products through innovation and high technology. The high quality products shall be less sensitive to the price change including exchange rate volatility.

5 Concluding remarks

This study examines the impact of exchange rate volatility on real total export and all its sub-categories namely real exports of SITC from 0 to 9. Exchange rate volatilities are computed by the MSD(3) and estimated by the GARCH(1,1) model. The GARCH(1,1) model is found to be the best model for estimating exchange rate volatility among the ARCH models of the ARCH(1) model, the GARCH(1,1) model, the PGARCH(1,1) model, the APGARCH(1,1) model and the EGARCH(1,1) model. Real export, real exchange rate, real foreign demand and exchange rate volatility are found to be cointegrated. There is no evidence that exchange rate volatility to have significant impact on real total export but some

evidence of exchange rate volatility to have significant impact on the sub-categories of real total export. Exchange rate volatility is mostly found to have a significant impact on real exports in the first differences. There are more categories of exports when exchange rate volatility estimated by the GARCH(1,1) model are found to be significant. The significant impact of exchange rate volatility differs from sectors of exports. Moreover, the significant impact of exchange rate volatility can be negative or positive. The impact of exchange rate volatility on export is about the same with the use of different measurements of exchange rate volatility. Export sector creates more high paying employment opportunities. This can help to achieve the vision of Malaysia to become a high income country.

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