Exchange Rate Nonlinearities in India’s Exports to the US

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Abstract

The investigation and estimation of effect of movements in exchange rate on the trade have been a major area of interest in international economics. This paper investigates the long run and short run non-linear relationship between Export Demand of India and Exchange Rate using monthly time series data for the period of 1993 to 2013. The issue of nonlinearity in export demand equations has been benignantly neglected in literature so far. Accordingly, this paper fills this gap and figures out if exports react to exchange rate changes in a nonlinear fashion. To tackle this issue, we apply newly developed nonlinear ARDL bounds testing approach of Shin (2011) and find that neglecting nonlinearities might be too restrictive. Our evidence points to the fact that exports react differently to appreciations and depreciations. More precisely, it seems as if exports respond stronger to appreciations than to depreciations.

1 Introduction

The relationship between exchange rate and exports is key research area in international empirical economics as exports are vital for any country’s Gross Domestic Product and also for maintaining the trade balance. Exports are a measure of a country’s trade in the world market and if exports appreciate at a faster rate as compared to imports the economy is said to be stable and progressive. At least since the mid 1940s economists tried to figure out what effect price or demand changes have got on exports or imports (Adler, 1945 or Chang, 1946). Nevertheless, this issue has not lost any of its attractiveness, as today there are still plenty of papers in this field of research with several open ended questions. However, the focus has somewhat changed in two aspects. Many researchers conducted study to estimate export and import demand equations for emerging Asian economies (Hossain, 2009 or Kumar, 2011) while some researchers focus on research dealing with trade and exchange rate volatility (Bahmani-Oskooee and Hegerty, 2007, Coric and Pugh, 2010 or Verheyen, 2012).

Exchange rate also plays a important role in country’s level of trade which is critical to most every free market economy in the world. For this reason, exchange rates are one of the most observed, studied and governmentally manipulated economic measures. There has been a lot of debate and discussions
in recent times due to rupee depreciation as compared to dollar, with politi-
cians and academicians worrying about the net trade balance. If currency of a
country falls in comparison to other currencies then the purchasing power of the
country in global market reduces. It also makes the economy unstable many a
times leading to a fall in Foreign Investment.

While early studies were based upon very simple econometric methods due
to lack of more sophisticated methods like cointegration etc. that are used in
today’s world. Even after the advancement in the methodology, nonlinearities in
the exchange were completely ignored. Our paper fills this gap in the literature.
It uses the recently presented nonlinear autoregressive distributed lag (NARDL)
model of Shin et al. (2011) which enables us to figure out whether exports react
differently to appreciations and depreciations, in the short- as well as in the
long-run. Hence, the main question is whether a nonlinear pattern between
exports and exchange rate changes can be identified.

The thought behind nonlinearities in the export demand could be understood
by following example; exports will not alter their prices to every change in the
exchange rate because if they make changes and when exchange rate returns
to its previous value then they have to take back these adjustments. Hence,
it’s not possible for exports to respond to every change in the exchange rate.
There may be a band of inaction where exporters do not react to exchange
rate changes. This argument holds especially in times of high exchange rate
volatility which applies for the evolution of the bilateral nominal exchange rate
of the euro against the US-

Another example in the favor of nonlinearities in exports demand is that ex-
porters could react to appreciations and depreciations differently. If exporters
try to maintain or gain market shares, appreciations could be absorbed at least
partly in exporters margins with the consequence that appreciations will not af-
fect exports that strong as one might expect. After considering these thoughts
we can reasonably argue to check whether if exchange rate nonlinearities in ex-
port demand equations exist. In order to do so, we will use a sample of bilateral
export data for India and US. Our results indeed suggest that neglecting non-
linearities in export demand functions might be too restrictive. Our evidence
points to the fact that exports react differently to appreciations and depreci-
ations. Moreover, it seems as if exports respond stronger to appreciations than
to depreciations.

The rest of the paper is organized as follows. The second section presents the
brief review of empirical literature. Section III outlines the econometric model
and exchange rate partial decomposition. Section IV elaborates on the data set
used and data conversions performed for econometric analysis. Section V de-
scribes about the NARDL methodology for detecting nonlinearities. Section VI
lays down the empirical results and inference from the estimation. Section VII
lays down the conclusion and discuss the economic interpretation of empirical
results.
2 Literature Review

In this section we review all the relevant past research work. As presented in the introduction, the investigation of export and import demand equations is a popular research topic. The export demand function in its traditional formulation incorporates the exchange rate and foreign demand of exports. However, the role of these export determinants is explained differently in the trade theories such as the theory of comparative advantage, the Keynesian trade multiplier and the new trade theory. Goldstein and Khan (1985) argue that the two general models of the trade dominating the empirical literature are the imperfect substitutes model and perfect substitutes model. But nonlinearities have more or less been neglected when estimating export or import demand equations with time series methods so far. However, there are especially theoretical models incorporating nonlinearities in international trade.

Baldwin (1990) presents a model which assumes the existence of sunk costs. As a result, he shows that the decision of a firm to enter or leave the market does not depend linearly on the exchange rate. Campa (2004) models the choice of a firm to serve the export market and if the firm decides to act as an exporter what volume it exports. His results suggest that although sunk cost hysteresis is prevalent for Spanish manufacturing firms, it does not seem to be related to exchange rate changes.

For establishing the short term and long term level relationships between variables first major contribution was made by Pesaran et. al 2001. they developed Autoregressive Distributed Lag Modeling (ARDL) approach for long run relationships. Narayan and Narayan (2005) estimated Fiji’s import demand function for sample period of 1970-2000 using ARDL to approach to cointegration and found the long run cointegration relationship between imports and its determinants. In which he found both the expenditure components and relative prices have positive impacts on import demand of fiji.

Pami Dua and Rajiv Ranjan (2011) developed a VAR and BVAR (Bayesian VAR) models for forecasting Re/US Exchange Rate. The monetary model developed in the study considered capital inflows, volatility of capital flows and central bank interventions to improve the accuracy of forecasts. A VECM analysis between export demands and factors was done by Sahabettin Gunes (2006). If a cointegration relationship can be found, this will indicate that there are no fundamental distortions of export demand distribution among the factors on the right hand side. The detailed short-run properties of the relationship among variables can be obtained from the VECM application.

R.T Baillie and T. Bollerslev (1994) study Based on Multivariate tests due to Johansen (1988, 1991) as implemented by Baillie and Bollerslev (1989a) reveal mixed evidence on whether a group of exchange rates are cointegrated. Further analysis of the deviations from the cointegrating relationship suggests that it possesses long memory and may possibly be well described as a fractionally integrated process. Hence, the influence of shocks to the equilibrium exchange rates may only vanish at very long horizons.

Abid Ali Shah et. al (2012) analyze the long and short run relationship
between the Karachi stock market index and a set of macro-economic variables using ARDL methodology and found that long run Co-integration relationship does exist between stock prices and the macro-economic variables such as date of inflation, exchange rate and interest rates.

However nonlinearities in exchange rates are estimated due to major contribution by the Shin (2011) in which he developed NARDL approach and by using this approach we are able to establish short term as well as long term relationships in the co-integration framework. Florian Verheyen (2012) with the use NARDL approach for bilateral export data for 12 EMU countries and US suggested that exports react differently to appreciations and depreciations. More precisely, he found exports respond stronger to depreciations than to appreciations.

Logan T. Lewis (2012) in his study on Menu Cost and Trade flows found that if local prices do not respond to exchange rates, then trade flows will also not respond. Results from his study suggest that while complementarity in price setting and sticky prices can explain pricing patterns, some other short-run friction is needed to match actual trade flows and there is evidence of an asymmetric response to exchange rate changes.

Yin-Wong Cheung et al. (2012) study the real effective exchange rate (REER) effects on the share of exports of Indian non-financial sector firms for the period 2000-2010. They find out that there has been a strong and significant negative impact from currency appreciation and currency volatility on Indian firms’ export shares. They further add compared with those exporting goods, firms that export services are more affected by exchange rate fluctuations. They conclude that exports react to appreciations more rather than depreciations.

Kannebly Jr. (2008) uses cointegration model derived from the hysteresis model of and Belke and Goecke (2001, 2005) to identify whether there is evidence of hysteresis in Brazilian exports. He finds nonlinear behavior of exports with regard to the adjustment to the long-run equilibrium. However, by construction his model allows only for short-run asymmetry. In contrast, new methodology developed by Shin allows us to take the path which distinguish short- and long-run asymmetry which is less restrictive.

Belke, Goecke and Guenther (2009) estimate “pain thresholds” for German exports. According to their results, a time variable play area exists in which one cannot observe strong reactions of exports to exchange rate fluctuations. Their estimates point to a pain threshold for German exports of 1.55 ¥/€ in 2009 which implies that if the euro appreciates against the dollar beyond this value, one should expect a significant drop of German exports. In a follow-up study, Belke, Goecke and Guenther (2012) perform an analysis for German exports on SITC product category level. They identify several export categories for which they analyzed the impact of exchange rate fluctuations.

All the theoretical studies and results give an indication of existence of nonlinearities in exchange rate. However, to the best of our knowledge an approach which distinguishes between appreciations and depreciations, in the short- as well as the in long-run has not been applied to trade functions for India - US.
3 Model Specification

To investigate the existence of the nonlinearities with respect to the exchange rate for India exports to the US we employ the newly developed nonlinear ARDL framework of Shin et al. (2011). The NARDL approach is a generalization of the ARDL bounds testing approach of Pesaran et al. (2001) which allows for estimating asymmetric long-run as well as short-run coefficients in a cointegration framework.

Florian Verheyen(2012) used the conventional export demand equations in which exports is a function of exchange rates and foreign demand. We use two different versions to identify whether it is real exchange rate or nominal exchange rate that matters for exports. We use two different versions of export demand equations. Thus, the basic export demand function can be written as:

\[ X_t = f(Y_t, R_t, P_t) \]

- \( X \) = Exports by India
- \( R \) = Real Exchange Rate between India and US
- \( Y \) = Foreign demand for Exports
- \( P \) = Relative Price (Price in US / Price in India)

Two different specifications of the export demand function will be as follows:

\[ X_t = AR_t^\alpha Y_t^\beta \quad \text{(1a)} \]
\[ X_t = BE_t^\gamma P_t^\delta Y_t^\xi \quad \text{(1b)} \]

Thus, in first equation, exports \( X \) are determined by the real bilateral exchange rate \( R \), foreign demand \( Y \) and a constant \( A \). The exponents represent the elasticities of exports with respect to the real exchange rate and foreign demand, respectively. In second equation, in order to distinguish between the exchange rate and the price effect we include the nominal bilateral exchange rate \( E \) and relative prices \( P \) separately. The exponents again correspond to the elasticities and \( B \) is the usual constant term.

Taking logs of above Equations yields the supposed long-run relationship between exports and its determinants which will be tested in the following empirical investigation. Thereby lower case letters denote logarithms.

\[ x_t = a + \alpha r_t + \beta y_t \quad \text{(2a)} \]
\[ x_t = b + \gamma e_t + \delta p_t + \xi y_t \quad \text{(2b)} \]

However, both specifications assume that the influence of each determinant is linear which might be too restrictive. For example, one could suppose that exports react differently to appreciations and depreciations or to large and small

\( x \)
exchange rate movements due to hysteresis or strategic pricing effects. For example, one could imagine that the destination country would not switch to other trading partners with each appreciation of the exporter’s currency because such behavior would imply searching and negotiation costs. As an alternative mechanism, exporters may decide to pass-through depreciations of the domestic currency while they fix prices denominated in foreign currencies in case of domestic currency appreciations in order to increase their market shares. In addition, such a pattern may only be observed over the short-but not over the long-run. To account for these possible nonlinearities in export demand functions we apply the NARDL framework of Shin et al. (2011).

As a first step, the original exchange rate series is decomposed into its positive and negative partial sum: \( r_t = r_0 + r_t^+ - r_t^- \). Thereby, each partial sum captures the effect of either appreciations or depreciations. Precisely, the partial sums are computed as follows:

\[
\begin{align*}
  r_t^+ &= \sum_{i=1}^t \Delta r_t^+ = \sum_{i=1}^t \max(\Delta r_t, 0) \quad 3a) \\
  r_t^- &= \sum_{i=1}^t \Delta r_t^- = \sum_{i=1}^t \min(\Delta r_t, 0) \quad 3b)
\end{align*}
\]

For our analysis, the threshold for changes of the exchange rate is set to zero. One thing we need to note that with this decomposition, exchange rate series contains negative values also so one cannot use logs for the exchange rate variable as the log of a negative number is not defined. Accordingly, for the NARDL model, all but the exchange rate series will be incorporated in logs. Therefore, we cannot interpret the coefficients of the exchange rate series as elasticities. However, we are able to figure out if nonlinearities with respect to the long-run exist. Furthermore, a one unit change in our exchange rate series roughly corresponds to a one percent change because the exchange rate series hover around one. Accordingly, the magnitude of our exchange rate coefficients should be comparable to conventional elasticities.

These decompositions can then be included in the export demand functions (2a) and (2b) which gives for the one threshold case as follows:

\[
\begin{align*}
  x_t &= a + \alpha_1 r_t^+ + \alpha_2 r_t^- + \beta y_t \quad 4a) \\
  x_t &= b + \gamma_1 e_t^+ + \gamma_2 e_t^- + \delta p_t + \xi y_t \quad 4b)
\end{align*}
\]

As foreign demand should stimulate exports, we expect a positive value for \( \beta \) and \( \xi \), respectively. The coefficient for relative prices should enter equations with negative sign. All exchange rate coefficients, i.e. the \( \alpha_1 \) and \( \gamma_1 \) coefficients should be negative as theory suggest an inverse relationship between the exchange rate and exports. Remember that an increase in the exchange rate series refers to a depreciation of the INR against the US-$ because exchange rate series is defined as local currency over foreign currency. If the exchange rate coefficients for the one threshold case (Equations (4a) and (4b)) differ significantly from
each other, one could take this as an indication of strategic pricing.

4 Data and Variables

This study employed India-US export monthly data from Jan-1993 to Dec-2013. Exports data series is collected from the CEIC database and consists of bilateral exports from India to the US measured in INR mn. Exports data are disaggregation at the 2 digit level. We applied the Census X12-procedure\(^1\) to deseasonalize nominal exports. For real exports, we follow Grier and Smallwood (2007) and use consumer price indices because no comparable export price series are available. US demand for Indian exports is proxied by US-Industrial Production Index. Export Price is proxied by Consumer Price Index (CPI) because no other export prices were available. Relative price is calculated as US CPI divided by the India CPI and is collected from the OECD database. The GDP and the CPIs are already seasonally adjusted. The nominal exchange rate series measured as units of domestic currency to one unit of foreign currency stem from OECD database. In order to get bilateral real exchange rates, we multiplied the bilateral nominal exchange rate series with our relative price measure. Therefore, an increase of our exchange rate series corresponds to a depreciation of India’s currency.

5 Estimation Methodology

The paper uses the newly developed nonlinear ARDL framework of Shin et al. (2011) to investigate whether there are nonlinearities with respect to the exchange rate for India exports to the US. The NARDL approach is a generalization of the ARDL bounds testing approach of Pesaran et al. (2001) which allows for estimating asymmetric long-run as well as short-run coefficients in a cointegration framework. One of the important features of this test is that it is free from unit root pre-testing and can be applied regardless of whether variables are I(0) or I(1). In addition, ARDL & NARDL technique efficiently determines the cointegrating relation in small sample. The short run and long-run parameters with appropriate asymptotic inferences can be obtained by applying OLS to NARDL with an appropriate lag length. Following Shin (2011) an NARDL representation of equation 4a) and 4b) can be written as:

\(^1\)Census X12- Procedure : Seasonal adjustment of a series is based on the assumption that seasonal fluctuations can be measured in the original series \((O_t,t = 1, \ldots, n)\) and separated from the trend cycle, trading-day, and irregular fluctuations. The seasonal component of this time series, \(S_t\), is defined as the intrayear variation that is repeated constantly or in an evolving fashion from year to year. The trend cycle component, \(C_t\), measures variation due to the long- term trend, the business cycle, and other long-term cyclical factors. The trading-day component, \(D_t\), is the variation attributed to the composition of the calendar. The irregular component, \(I_t\), is the residual variation. Many economic time series are related in a multiplicative fashion \(O_t = S_t \times D_t \times C_t \times I_t\) and others are related in an additive fashion \(O_t = S_t + D_t + C_t + I_t\). A seasonally adjusted time series, \(C_t \times I_t\) or \(C_t + I_t\), consists of only the trend cycle and irregular components.
\[
\Delta x_t = \Pi + \theta_1 x_{t-1} + \theta_2 r_t^+ + \theta_3 y_{t-1} + \sum_{j=1}^m \nu_j \Delta x_{t-j} + \sum \left( \delta_{t-k}^+ \Delta r_{t-k}^+ + \delta_{t-k}^- \Delta r_{t-k}^- \right) + \sum_{l=0}^a \rho_l (\Delta y_{t-l} + u_t)
\]

Where, \( \Delta \) is the first difference operator, \( \Pi \) is the drift component and \( u_t \) the usual white noise residuals. The coefficients \((\theta_1 - \theta_2)\) represent the long-run relationship whereas remaining expressions with summation sign \( \nu_j \), \( \delta_{t-k}^+ \), \( \delta_{t-k}^- \) and \( \rho_l \) represent the short term dynamics of the model.

This Equation nests the linear ARDL model presented in Pesaran et al. (2001) for the case of \( \theta_2 = \theta_3 = \theta_4 = 0 \). Thus, equation is less restrictive than a linear model. For this test, as its distribution is non-standard, Pesaran et al. (2001) tabulate critical values. The bound test developed by Pesaran, Shin and Smith (2001) is used to examine the existence of the long-run relationship among the variables in the system. This test is based on Wald or F-statistic and follows a non-standard distribution. To check whether a cointegrating relationship exists, one has to test the null hypothesis \( \theta_1 = \theta_2 = \theta_3 = \theta_4 = 0 \) in the Equation. Pesaran, Shin and Smith (2001) provide two sets of critical values in which lower critical bound assumes that all the variables in the ARDL are I(0) and upper critical bound assumes I(1). Then, the null hypothesis of cointegration can be rejected if the calculated F-statistics is greater than the upper bound critical values. If the F-statistics is below than the lower critical bound then null hypothesis cannot be rejected, indicating no cointegration among the variables. If it lies within the lower and upper bounds, the result is inconclusive. After examining the cointegration, long run coefficients are calculated by estimating the model with the appropriate lag orders based on the Schwarz Information Criteria (SIC).

The short-run dynamics of the model is analyzed by using unrestricted Error Correction Model based on the assumption made by Pesaran, Shin and Smith (2001). Thus, the error correction version of the NARDL model pertaining to the central export equation can be expressed as:

\[
\Delta x_t = \Pi + \lambda EC_{t-1} + \sum_{j=1}^m \nu_j \Delta x_{t-j} + \sum_{k=0}^a (\delta_{t-k}^+ \Delta r_{t-k}^+ + \delta_{t-k}^- \Delta r_{t-k}^-) + \sum_{l=0}^a \rho_l (\Delta y_{t-l} + u_t)
\]

Where, \( \lambda \) is the speed of adjustment parameter and EC is the residuals that are obtained from the estimated cointegration model of equation 4a). The EC term is defined as: \( EC_{t-1} = x_{t-1} - \gamma_1 r_{t-1}^+ - \gamma_2 r_{t-1}^- - \gamma_3 y_{t-1} \). Where, \( \gamma_1 = -(\frac{\delta_{k}^+}{\delta_{k}^-}), \gamma_2 = -(\frac{\delta_{k}^+}{\delta_{k}^-}),\gamma_3 = -(\frac{\delta_{k}^+}{\delta_{k}^-}) \) are the OLS estimators obtained from the equation 5a). The coefficients of the lagged variables provide the short-run dynamics of the model covering the equilibrium path. The error correction coefficient (\( \lambda \)) is expected to be less than zero and its significance implies the cointegration relation among the variables. In order to check the performance of the model which examines the serial correlation, functional form, normality
Table 1: Results of ADF Test

<table>
<thead>
<tr>
<th>Variables (After First Difference)</th>
<th>ADF Statistic</th>
<th>1% CV</th>
<th>5% CV</th>
<th>Optimal LAG</th>
</tr>
</thead>
<tbody>
<tr>
<td>Log (Real Exp)</td>
<td>-17.889 (0.00)</td>
<td>-3.997</td>
<td>3.429</td>
<td>4</td>
</tr>
<tr>
<td>Log (Nominal Exp)</td>
<td>-17.801 (0.00)</td>
<td>-3.997</td>
<td>3.429</td>
<td>4</td>
</tr>
<tr>
<td>Nominal R_pos</td>
<td>-12.856 (0.00)</td>
<td>-3.997</td>
<td>3.429</td>
<td>4</td>
</tr>
<tr>
<td>Nominal R_neg</td>
<td>-12.856 (0.00)</td>
<td>-3.997</td>
<td>3.429</td>
<td>1</td>
</tr>
<tr>
<td>Real R_pos</td>
<td>-14.371 (0.00)</td>
<td>-3.997</td>
<td>3.429</td>
<td>1</td>
</tr>
<tr>
<td>Real R_neg</td>
<td>-13.101 (0.00)</td>
<td>-3.997</td>
<td>3.429</td>
<td>1</td>
</tr>
<tr>
<td>Log (Relative Price)</td>
<td>-10.159 (0.00)</td>
<td>-3.997</td>
<td>3.429</td>
<td>2</td>
</tr>
<tr>
<td>Log (Industrial Prod.)</td>
<td>-3.785 (0.02)</td>
<td>-3.997</td>
<td>3.429</td>
<td>2</td>
</tr>
</tbody>
</table>

6 Empirical Results

The results are shown in Table 1 to 6. Thereby, we generally estimate models with the real exchange rate as regressor as well as models using the nominal exchange rate and relative prices. As mentioned before, all model variables are in logarithms except the exchange rate series.

In order to apply the cointegration analysis, the order of cointegration of the variables under study need to be examined in the first step since the ARDL or NARDL technique can be applied only if the order of integration of the variables is less than two. Thus, this study has employed the Augmented Dickey-Fuller (ADF) test to examine the order of integration of the variables. The selection of lag length used for this test is based on Schwarz Information Criterion. The results of ADF test are reported in Table 1.²

Table 1 depicts that all the variables under study are stationary in the first difference. Since all the variables are integrated of order one or I(1), the NARDL approach to cointegration can be used in order to examine the relationship between variables under analysis. The optimal number of lags in the equation 5a) is calculated by SIC and shown in Table 1.

The long term relationship between variables has been examined by calculating F-statistics with appropriate lag. The F-statistics is calculated by applying Wald tests which imposes zero value restriction to the coefficient of level variables with one period lag. The calculated F-statistics and Critical values at 1% significance calculated from Pesaran, Shin and Smith (2001) are reported in Table 2.

The evidence in favor of cointegration is quite strong. Based on our nonlinear approach, the hypothesis of no cointegration is rejected for both models. This is a first piece of evidence that focusing on linear cointegration is too restrictive. Regarding the implied long-run coefficients which can be obtained by dividing the coefficients of the lagged level regressors by the negative of the coefficient of ²The numbers within the parentheses are the p-values.
Table 2: F-Statistics and Critical Values

<table>
<thead>
<tr>
<th>Regressor</th>
<th>Coefficient</th>
<th>t-stat.</th>
<th>Standardized Coeff.</th>
</tr>
</thead>
<tbody>
<tr>
<td>RealR+</td>
<td>-0.0031(0.00)</td>
<td>-2.82</td>
<td>-0.270</td>
</tr>
<tr>
<td>RealR-</td>
<td>-0.0022(0.00)</td>
<td>-2.75</td>
<td>-0.403</td>
</tr>
<tr>
<td>LogIP</td>
<td>1.2293(0.00)</td>
<td>8.58</td>
<td>0.339</td>
</tr>
<tr>
<td>Constant</td>
<td>1.2293(0.00)</td>
<td>29.58</td>
<td></td>
</tr>
</tbody>
</table>

RMSE = 0.0524, R – sq = 0.78, F = 52.33(0.00), No. of obs. = 240

The overall fit seems reasonable as we estimate very simple and general export demand models. The $R^2$ takes value more than 0.75 for both the model which shows good fit of model and data. Table 3 shows the long run coefficients of the export demand equation with real exchange rate. The coefficients of the Real r+, Real r- and logIP are statistically significant at 95% significance level. The coefficient of Log(IP) has the expected positive sign and implies the higher elasticity of exports with respect to foreign demand, that is if the US-Industrial Production Index increases by the 1%, India’s exports to US will increase by 1.22% in the long run.

Table 4 shows the long run coefficients of the export demand equation with nominal exchange rate. The coefficients of the Nominal r+, Nominal r- and log(IP) are statistically significant at 95% significance level while coefficient of LogRelP is not significant. The coefficient of Log(IP) has the expected positive sign and implies the higher elasticity of exports with respect to foreign demand,

<table>
<thead>
<tr>
<th>Regressor</th>
<th>Coefficient</th>
<th>t-stat.</th>
<th>Standardized Coeff.</th>
</tr>
</thead>
<tbody>
<tr>
<td>NominalR+</td>
<td>-0.0084(0.00)</td>
<td>4.35</td>
<td>0.169</td>
</tr>
<tr>
<td>NominalR-</td>
<td>-0.0094(0.00)</td>
<td>-6.66</td>
<td>-0.447</td>
</tr>
<tr>
<td>LogIP</td>
<td>1.6187(0.00)</td>
<td>18.23</td>
<td>0.359</td>
</tr>
<tr>
<td>LogRelP</td>
<td>0.3999(0.19)</td>
<td>1.31</td>
<td>0.103</td>
</tr>
<tr>
<td>Constant</td>
<td>1.2293(0.00)</td>
<td>15.95</td>
<td></td>
</tr>
</tbody>
</table>

RMSE = 0.0550, R – sq = 0.79, F = 42.33(0.00), No. of obs. = 240

Table 4: Long-Run Coefficients for Export Equation for Nominal Ex. Rate
<table>
<thead>
<tr>
<th>Variable</th>
<th>Estimated Coefficients</th>
<th>Variable</th>
<th>Estimated Coefficients</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\Delta \text{LogREXP}_{t-1}$</td>
<td>-0.57(0.00)***</td>
<td>$\Delta \text{RealR}_{t-1}$</td>
<td>0.004(0.03)***</td>
</tr>
<tr>
<td>$\Delta \text{LogREXP}_{t-2}$</td>
<td>-0.24(0.00)***</td>
<td>$\Delta \text{LogIP}_{t-1}$</td>
<td>1.96(0.12)</td>
</tr>
<tr>
<td>$\Delta \text{LogREXP}_{t-3}$</td>
<td>0.39(0.62)</td>
<td>$\Delta \text{LogIP}_{t-1}$</td>
<td>0.41(0.59)</td>
</tr>
<tr>
<td>$\Delta \text{LogREXP}_{t-4}$</td>
<td>-0.01(0.00)***</td>
<td>$\Delta \text{LogIP}_{t-2}$</td>
<td>1.38(0.67)**</td>
</tr>
<tr>
<td>$\Delta \text{RealR}^+$</td>
<td>0.002(0.08)*</td>
<td>$\text{ECM}_{t-1}$</td>
<td>-0.249(0.00)***</td>
</tr>
<tr>
<td>$\Delta \text{RealR}^{**}$</td>
<td>0.005(0.04)**</td>
<td>Constant</td>
<td>0.003(0.09)*</td>
</tr>
</tbody>
</table>

$R^2 = 0.39$ $R_{adj}^2 = 0.38$ $F = 11.87(0.00)$ $RootMSE = .03201$

Table 5: ECM Representation of NARDL Model with Real Ex. rate

<table>
<thead>
<tr>
<th>Variable</th>
<th>Estimated Coefficients</th>
<th>Variable</th>
<th>Estimated Coefficients</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\Delta \text{LogNEXP}_{t-1}$</td>
<td>-0.59(0.00)***</td>
<td>$\Delta \text{LogIP}$</td>
<td>1.35(0.08)*</td>
</tr>
<tr>
<td>$\Delta \text{LogNEXP}_{t-2}$</td>
<td>-0.24(0.00)***</td>
<td>$\Delta \text{LogIP}_{t-1}$</td>
<td>0.03(0.46)</td>
</tr>
<tr>
<td>$\Delta \text{LogNEXP}_{t-3}$</td>
<td>0.05(0.49)</td>
<td>$\Delta \text{LogIP}_{t-2}$</td>
<td>1.10(0.09)*</td>
</tr>
<tr>
<td>$\Delta \text{LogNEXP}_{t-4}$</td>
<td>-0.01(0.93)</td>
<td>$\Delta \text{LogRelativeP}_{t-1}$</td>
<td>-0.14(0.78)</td>
</tr>
<tr>
<td>$\Delta \text{NominalR}^+$</td>
<td>-0.001(0.49)</td>
<td>$\Delta \text{LogRelativeP}_{t-2}$</td>
<td>0.76(0.54)</td>
</tr>
<tr>
<td>$\Delta \text{NominalR}^-$</td>
<td>-0.006(0.02)**</td>
<td>$\text{ECM}_{t-1}$</td>
<td>-0.179(0.00)***</td>
</tr>
<tr>
<td>$\Delta \text{NominalR}^-$</td>
<td>-0.09(0.08)**</td>
<td>Constant</td>
<td>0.009</td>
</tr>
</tbody>
</table>

$R^2 = 0.37$ $R_{adj}^2 = 0.35$ $F = 9.33(0.00)$ $RootMSE = .03262$

Table 6: ECM Representation of NARDL Model with Nominal Ex. rate

that is if the US-Industrial Production Index increases by the 1%, India’s exports to US will increase by 1.61% in the long run. Also it is evident from both the table is that long run coefficients of the r+ and r- are not equal so linear restriction on the exchange would be too restrictive. Sign of Real r- is negative which shows that appreciation of domestic currency has negative impact on exports and by looking at standardized coefficients it is evident that exports respond more to appreciations than to depreciations.

The estimation of error correction model is shown in Table 5 and Table 6. Table 5 show that estimated lagged error correction term ($ECM_{t-1}$) is negative and statistically significant, implying cointegration among the variables: exports from India to US and its determinants chosen under study. The absolute value of the coefficient of the error correction term (0.249) implies that about 24.9% of the disequilibrium in real exports from India is adjusted towards equilibrium monthly. For example, if the real exports from India exceeds its long-run relationship with other variables in the model, then the export from India as a function of real exchange rate and foreign demand adjusts downwards at the rate of 24.9% monthly. Similarly Table 6 show that estimated lagged error correction term ($ECM_{t-1}$) is negative and statistically significant, implying cointegration
among the variables. The absolute value of the coefficient of the error correction term (0.179) implies that if the nominal exports from India exceed its long-run relationship with other variables in the model, then the export from India as a function of nominal exchange rate, relative price and foreign demand adjusts downwards at the rate of 17.9\% monthly. Thus, US demand might be the major driver of India exports and exchange rate movements are of minor importance.

7 Conclusion

Many empirical studies have estimated the elasticities of different final export demand components with respect to the exports because of their importance in trade policy formulation. But all the work has accounted only linearity in the exchange rate in export demand equation hence in this paper we have tried to estimate nonlinearities in export demand equation. We improve on the existing literature by incorporating the newly developed NARDL approach of Shin et al. (2011). This approach allows testing for nonlinearities both in the short- and in the long-run which might give indications of strategic pricing and nonlinearities in exchange rate.

The empirical analysis is carried out for bilateral export demand relationships of India with the US for January 1994 until Dec 2013. The bound test shows that there exists cointegration among the variables. Results show that exports are determined in the long-run by foreign demand, exchange rates and relative prices. The long-run coefficients have got the expected sign, are of reasonable magnitude and statistically significant. Regarding nonlinearities our evidence points to the fact that assuming linearity in export demand functions might be too restrictive. Thereby, the one threshold model that distinguishes exchange rate effects between appreciations and depreciations delivers plausible results. If exchange rate nonlinearities are detected, it seems to be that exports respond stronger to appreciations than to depreciations. A reason for this might be that firms perform strategic pricing in international trade to gain or maintain market shares.

8 Appendix : Derivation of ARDL and NARDL approach

Consider the ARDL(p,q) model

\[ \varphi(L)y_t = \alpha_0 + \alpha_1 t + \beta(L)x_t + u_t \]

where \( \varphi(L) = 1 - \sum_{j=1}^{\varphi} \psi_j L^j \), and \( \beta(L) = \sum_{j=0}^{q} \beta_j L^j \) and \( u_t \) are standard errors.

Using the decomposition \( \beta(L) = \beta(1) + (1 - L)\beta^*(L) \), where \( \beta(L) = \sum_{j=0}^{q} \beta_j, \beta^*(L) = \sum_{j=0}^{q-1} \beta_j L^j \) and \( \beta^*_j = -\sum_{j=1}^{q} \beta_j, (1.1) \) can be rewritten as
\[ \varphi(L)y_t = \alpha_0 + \alpha_1 t + \beta' x_t + \sum_{j=0}^{q-1} \beta_j^+ \Delta x_{t-j} + u_t; \beta = \beta(1) \]  

1.2

Similarly, \( \varphi(L) = \varphi(1) + (1-L)\varphi^*(L) \), where \( \varphi(1) = 1 - \sum_{i=1}^{p} \varphi_i \), and \( \varphi(L) = \sum_{j=0}^{p} \varphi_j^* L^j \)

and \( \varphi_j^* = -\sum_{i=j+1}^{p} \varphi_i \)

\[ \varphi(1)y_t = \alpha_0 + \alpha_1 t + \beta' x_t + \sum_{j=0}^{q-1} \beta_j^+ \Delta x_{t-j} - \varphi^*(L) \Delta y_t + u_t \]  

1.3

Also from 1.1, we obtain

\[ \Delta y_t = (\varphi(L))^{-1}(\alpha_1 + \beta' (L) \Delta x_t + \Delta u_t) \]

Central Equation \( y_t = \mu_0 + \delta t + \theta' x_t + \sum_{j=0}^{q-1} \theta_j^+ \Delta x_{t-j} - \kappa_u t \)  

1.4

Where \( \theta(L) = \frac{\bar{\theta}(L)}{\varphi(L)} \) and \( \bar{\theta}(L) = \theta(1) + (1-L)\theta^*(L) \), where \( \theta^*(L) = \sum_{j=0}^{\infty} \theta_j^* L^j \)

and \( \theta_j^* = -\sum_{i=j+1}^{\infty} \theta_i \) and \( \kappa_u = \sum_{j=q}^{\infty} \theta_j^* e_{t-j} + (\varphi(L))^{-1} u_t \)

The asymmetric long run regression equation can be written as

\[ y_t = \beta^+ x_t^+ + \beta^- x_t^- + u_t \]  

2.1

\[ \Delta x_t = v_t \]  

2.2

where \( y_t \) and \( x_t \) are scalar I(1) variables, and \( x_t \) is decomposed as \( x_t = x_0 + x_t^+ + x_t^- \) where \( x_t^+ \) and \( x_t^- \) are partial sum processes of positive and negative changes in \( x_t \):

\[ x_t^+ = \sum_{i=1}^{t} \Delta x_i^+ = \sum_{i=1}^{t} \max(\Delta x_i, 0) \]  

2.3

\[ x_t^- = \sum_{i=1}^{t} \Delta x_i^- = \sum_{i=1}^{t} \min(\Delta x_i, 0) \]  

2.4

Now we consider a nonlinear ARDL(p,q) model:

\[ y_t = \sum_{j=1}^{p} \varphi_j y_{t-j} + \sum_{j=0}^{q} (\theta_j^+ x_t^+ + \theta_j^- x_t^-) + e_t \]  

2.5

where \( x_t \) is a k*1 vector of multiple regressors defined such that \( x_t = x_0 + x_t^+ + x_t^- \), \( j \) is the autoregressive parameter, and \( \theta_j^+ \) and \( \theta_j^- \) are the asymmetric distributed-lag parameters, and \( e_t \) is an iid process with zero mean and constant variance.

Following Cesarean et al. (2001), it is straightforward to rewrite (2.5) in the error correction form as:
\[
\Delta y_t = \rho y_{t-1} + \theta^+ x^+_{t-1} + \theta^- x^-_{t-1} + \sum_{j=1}^{p-1} \gamma_j \Delta y_{t-j} + \sum_{j=0}^{q-1} \left( \psi^+_j \Delta x^+_{t-j} + \psi^-_j \Delta x^-_{t-j} \right) + \xi_t
\]

\[
\Delta y_t = \rho \tau_{t-1} + \sum_{j=1}^{p-1} \gamma_j \Delta y_{t-j} + \sum_{j=0}^{q-1} \left( \psi^+_j \Delta x^+_{t-j} + \psi^-_j \Delta x^-_{t-j} \right) + \xi_t
\]

where \( \rho = (\sum_{j=0}^{p-1} \varphi_j) \) and \( \gamma_j = \sum_{i=-j+1}^{i=p-1} \varphi_i \) are the associated asymmetric long-run parameters.

9 References


