The US Trade Balance as it Relates to Domestic and Foreign Income and the Dollar Exchange Rate

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Abstract

To analyze the current relationship between the US trade deficit and the exchange rate over the past 20 years, the trade balance was divided into two components to model: imports and exports. Growth of imports and growth of exports were regressed on the variables of US gross domestic product and foreign domestic product and the real broad index exchange rate, and then again with the real index exchange rate lagged by 10 quarters. After regressions, the US imports component was found to have a strong, significant relationship with domestic GDP and a significant relationship with both the exchange rate and lagged exchange rate. The US exports component showed a statistically significant relationship with foreign GDP and the lagged exchange rate, but lacked a significant relationship with the un-lagged exchange rate.

Keywords: US trade deficit, US imports, US exports, J-curve relationship, exchange rate

Introduction

One underlying concern regarding the overall health of the US economy has been the sustainability of its burgeoning trade deficit. Research on the impact of record trade deficit volumes, such as $725.8 billion in the year 2005\(^1\), on the current economy is prolific and opinionated. A quick key word search in an economic database such as J-Stor results in many papers on this topic. Each one analyzes the deficit through a slightly different framework such as the elasticity of imports or immigration as a proxy for consumer tastes (Mann, 2005; pp. 6). Analysis of the two components of the trade deficit, imports and exports, will be helpful in considering the impact such a large deficit will have on the economy in the long run. The direction of the models in this paper is based loosely off the study conducted by Neil Ericsson and Jaime Marquez in 1993. In that study, they critically examined various trade balance forecasting models that were developed in the 1980’s. They noted a large variance in the predictions made by the different models. Some predicted future values of the trade balance differed by $150 billion or more (Ericsson, 1993; pp. 19). Ericsson and Marquez tested six models for their forecast encompassing capabilities in order to decrease this large variance. The models used in this study were inspired by two of the models used in their 1993 experiment. Ericsson’s and Marquez’s models are presented below:

\[
\ln(X_i) = X(P_{wE}E_t^f, Y_{dt}) + u_{1i} \quad (1)
\]

\[
\ln(M_i) = M(P_{mt}/P_t, Y_{dt}) + u_{2i} \quad (2)
\]

\(^1\) Bureau of Economic Analysis, 2005
where,

\[ P_m \text{ and } P_x \] are the prices of imports and exports

\[ E \] is the nominal exchange rate (domestic/foreign)

\[ M \text{ and } X \] are the volume of imports and exports, respectively

\[ Y^f \] is real foreign income

and

\[ Y^d \] is real domestic income

The gist of these models is the concept that imports are a function of domestic income, or gross domestic product, and the exchange rate. Likewise, exports are a function of foreign income, or foreign gross domestic product, and the exchange rate. The idea of analyzing the trade deficit by its two components, imports and exports, comes from post World War Two research conducted by Hans Adler. Running regressions on imports and exports separately allows for the possibility that the exchange rate or GDP may have a significant relationship with only one of the dependent variables, rather than both. If there is a significant relationship with only one of the variables, regressing each dependent variable individually against the independent variables will conveniently illustrate this. Using slightly modified versions of the models 1 and 2 above, this study analyzes the relationship between the volume of imports, exports and the exchange rate in the United States, as well as the lagged exchange rate. These models hope to determine if a relationship between the trade balance and exchange rate still exists. A few decades ago, a study on this topic would show a significant relationship between the strength of the dollar and the trade balance. For example, Marwah and Klein in 1996, examined the exchange rates and trade balances of Canada and the US for the seventies, eighties, and early nineties, and found evidence of J-curve lags in both countries’ data, where the trade deficit in the current period narrowed due to an increase in the strength of the US dollar from an earlier period. Specifically, their results indicated that the demand elasticity of US imports and the demand elasticity of their exports were greater than one, due to the Marshall-Lerner Condition. By this condition, if a nation’s demand elasticity for imports plus the foreign demand elasticity for a nation’s exports exceeds one, then devaluation of that nation’s currency will help alleviate the trade deficit. Conversely, if the nation’s demand elasticity for imports plus the foreign demand elasticity for their exports is less than one, then devaluation of the nation’s currency will worsen the trade deficit (Carbaugh, 2004; pp. 454). Because it is beyond the scope of this paper to measure the demand elasticities of US imports and exports, when analyzing the results, it is assumed that the demand elasticity for US imports plus the demand elasticity for US exports will sum greater than one, and that a current or lagged devaluation of the dollar will positively affect the trade deficit. Currently, however, some economists argue that this J-curve effect has started to diminish over the past ten to fifteen years. Considering the substantial size of the US trade deficit, the implications of a faltering relationship between the exchange rate and the trade balance are intriguing. Perhaps the factors that determine the size of the trade balance are not as straightforward as noting that the volume of imports should increase as the dollar strengthens, or that the volume of exports should increase as the dollar weakens. Over the past decade, the national savings rate in the US has dropped steeply; the marginal propensity to save is roughly estimated to be below 5 percent. This veering of the savings rate from its historical levels may also have a greater affect on the trade deficit. A drop in the level of savings means the level of domestic investment must be financed in part by foreign dollars to maintain the equilibrium between savings and investment in the economy. As a result foreign dollars from countries such as China have been back large amounts of domestic investment and this is a situation which doesn’t appear to be letting up any time in the near future. By including both domestic and foreign GDP variables as well as the exchange rate in the models, this paper attempts to capture both the domestic and international influences on the trade balance. In models 3 and 4 below, the logarithmic growth of US imports (exports) are a function of the logarithmic growth in income, US GDP (foreign GDP), and the natural log of the trade-weighted exchange rate.
\[
\begin{align*}
\ln M &= a + \hat{\beta}_1 \ln GDP^d + \hat{\beta}_2 \ln e \\
\ln X &= a + \hat{\beta}_1 \ln GDP^f + \hat{\beta}_2 \ln e
\end{align*}
\]
(3) (4)

Where,
- \(M\) is the volume of US imports (goods and services) in millions of USD
- \(X\) is the volume of US exports (goods and services) in millions of USD
- \(GDP^d\) is the US nominal gross domestic product in millions of USD
- \(GDP^f\) is the trade-weighted average of the nominal gross domestic products of Japan, Mexico, Canada, Germany, and the UK in millions of USD
- \(e\) is the real broad index value of the US dollar (base= March 1973)

If the variable, domestic income is found to have a positive relationship with imports, it may be that increased income and consumption (as savings decline) is the driving force behind the large trade deficit. If the exchange rate is found to have a positive relationship with imports, then we may conclude that a relationship between the trade balance and the dollar still exists. In the export model, exports are tested as a function of foreign income which has been trade-weighted, and the exchange rate. In a similar interpretation as before, if foreign GDP is found to be positively related to US exports, decreased foreign spending may be one of the causes of the widening deficit, due to decreased income with which to import, and if the exchange rate is found to have a negative relationship with US exports, a relationship between the dollar and the deficit may still exist.

Both of these models will also be regressed with a time lag of 10 quarters (2 ½ years) on the real broad index of the US dollar exchange rate to determine if there is a significant relationship between the volume of imports and exports and the exchange rate of a previous period. If the lagged broad index variable is found to be significant, this will indicate the trade balance is still experiencing a J-curve effect.

\[
\begin{align*}
\ln M &= a + \hat{\beta}_1 \ln GDP^d + \hat{\beta}_2 \ln e_{t-10} \\
\ln X &= a + \hat{\beta}_1 \ln GDP^f + \hat{\beta}_2 \ln e_{t-10}
\end{align*}
\]
(5) (6)

Where,
- \(M\) is the volume of US imports (goods and services) in millions of USD
- \(X\) is the volume of US exports (goods and services) in millions of USD
- \(GDP^d\) is the US nominal gross domestic product in millions of USD
- \(GDP^f\) is the trade-weighted average of the nominal gross domestic products of Japan, Mexico, Canada, Germany, and the UK in millions of USD
- \(e\) is the real broad index value of the US dollar time lagged by 10 quarters (base= March 1973)

Data

The data are quarterly and cover the years 1985-2005. Nominal figures were used for all of the GDP data in the two regressions. The real exchange rate data were obtained from The Economic Report of the President, editions 2006-1986. From the years 1985-1996, the real Multi-lateral trade-weighted index was used for the value of the dollar. The base year for this index was the March, 1973 US dollar. Since this index was dissolved after 1998, the Broad index was used for the years 1997-2005 because the index included the exchange rates of Canada and Mexico, two important trading partners with the US. The figures for the volume of US imports and exports, US GDP, and the major trading partners’ GDP, were all obtained from the Organisation for Economic Co-operation and Development (OECD) data tables. The
figures for the foreign trade-weighted volume of GDP were derived from estimating the GDP’s of the top five importers of United States goods. Given the limited OECD data, Canada, Japan, and the United Kingdom (representing Western Europe), were used as proxies for the top importers from the time period of 1985-1993. Over the time period of 1994-2005, GDP figures for Canada, Mexico, Japan, Germany, and the United Kingdom were used to represent the top five importers of US goods. The foreign trade-weighted GDP was then calculated by multiplying the foreign country’s GDP by the percentage of US exports it received. That value was then multiplied by 100 and divided by the total percentage of exports the US sent to all 5 (or 3) countries. This was done for each of the 5 (or 3) countries, and then the values were summed up and divided by the number of countries to obtain the final average.

Results

All of the regression analysis was done at the 95% confidence level on the software program, Shazam. The models were subject to the basic statistical tests: the t-test, for significance of each individual coefficient, and the F-test, for significance of the overall model. The regression analysis also calculated the R² and adjusted R² values to give an indication of the explanatory power of the models, as well as the standard errors and p-values. Models 3 and 4 contain 81 degrees of freedom and models 5 and 6 contain 72 degrees of freedom, enough to assume the sample s have a normal distribution. Because of this, the critical t-value used in comparing all the observed t-values will be ± 1.96. The regressions were run multiple times using different regression techniques. The results of the first runs done through Ordinary Least Squares (OLS) are presented in equations 7-10 below.

\[
\begin{align*}
\ln M &= -9.28 + 1.42 \ln \text{GDP}^{d} + 0.11 \ln \epsilon \\
\text{t-ratios:} & (-30.50) (87.57) (2.35) \\
\text{Adj. R}^2 &= 0.99 \\
\text{Durbin-Watson} &= 0.24 \\

\ln X &= -7.96 + 1.60 \ln \text{GDP}^{f} - 0.25 \ln \epsilon \\
\text{t-ratios:} & (-3.19) (9.96) (-0.91) \\
\text{Adj. R}^2 &= 0.54 \\
\text{Durbin-Watson} &= 0.07 \\

\ln M &= -8.77 + 1.30 \ln \text{GDP}^{d} + 0.42 \ln \epsilon_{t-10} \\
\text{t-ratios:} & (-34.98) (59.65) (6.17) \\
\text{Adj. R}^2 &= 0.99 \\
\text{Durbin-Watson} &= 0.36 \\

\ln X &= -10.77 + 1.08 \ln \text{GDP}^{f} + 1.97 \ln \epsilon_{t-10} \\
\text{t-ratios:} & (-4.29) (5.47) (5.41) \\
\text{Adj. R}^2 &= 0.59 \\
\text{Durbin-Watson} &= 0.12
\end{align*}
\]

Please refer to the Appendix to view the residual plots (Figures I-IV) and program output for each model. Just a cursory glance will make it apparent that there is some correlation showing up in the stochastic error terms in the imports and exports models. Shazam provides the Durbin-Watson statistic which is a general test for autocorrelation in a regression. Using 84 observations and 2 explanatory variables, the upper and lower bounds for the Durbin-Watson test were \(d_L = 1.600\) and \(d_U = 1.696\) for models 7 and 8. Using 75 observations and 2 explanatory variables for models 9 and 10, the upper and lower bounds for the Durbin-Watson test were \(d_L = 1.571\) and \(d_U = 1.680\). The Durbin Watson provides the bounds for which (if the observed Durbin Watson value falls in between) the null hypothesis of no positive or negative autocorrelation is rejected, and the evidence of positive or negative autocorrelation is concluded. In this case, all of the models’ Durbin Watson statistics fell between 0 and their respective lower bounds,
which is evidence to reject the null hypothesis. Therefore, it is concluded that all 4 models contain positive autocorrelation such that “correlation between members of series of observations ordered in time” exists (Gujarati, 2003; pp. 442). The positive autocorrelation might be attributed to the fact that the gross domestic product is an independent variable in the models. This variable would be greatly affected by the business cycle of each country, and has an overall upward trend over the long term, thus due to inertia, autocorrelation exists in each model (Gujarati, 2003; pp. 443). Although using the OLS method on these regressions will still yield results that are consistent and unbiased, the presence of autocorrelation will cause the OLS estimators to be inefficient. As a result, the $t$-statistics and $F$-statistics calculated for the models will be unreliable (Gujarati, 489).

Given such strong trends in the residual plots, it was also necessary to test for heteroscedasticity in the error variance. It seems likely that the error variances in each model would be non-constant, again due to the use of gross domestic product as an independent variable. The trend of GDP growth tends to increase over time, hence the variance of GDP measurements may also increase over time. On the other hand, it can be argued that over the time period 1985-2005, data collecting techniques to measure the GDP and exchange rate index have improved, and the variances for each measurement have decreased over time. Either way, White’s General Heteroscedasticity Test (Gujarati, 2003; pp. 413), can be used as a basic indicator for determining if heteroscedasticity is present in the models or not. The test requires that the squared residuals be regressed against the explanatory variables in the models, the squared values of the explanatory variables and the product of the explanatory variables. White’s test is presented in equation 11:

$$u_i(\hat{)}^2 = \alpha_1 + \alpha_2X_{2i} + \alpha_3X_{3i} + \alpha_4X_{2i}^2 + \alpha_5X_{3i}^2 + \alpha_6X_{2i}X_{3i} + \epsilon_i$$  \hspace{1cm} (11)

Once the regression for equation 11 was run, the $R^2$ value was obtained for each model. Next, the $R^2$ values were multiplied by the number of observations. The resulting values are test statistics which follow the $X^2$ distribution. The degrees of freedom are the number of explanatory variables measured by the test model. The critical $X^2$ at $\alpha = 0.05$ and 5 degrees of freedom was found to be 11.07. Using this as the standard, the null hypothesis of no heteroscedasticity was rejected for all models as can be observed in Table I.

<table>
<thead>
<tr>
<th>Model</th>
<th>$R^2$ value</th>
<th>$X^2$ value</th>
<th>Reject Null</th>
</tr>
</thead>
<tbody>
<tr>
<td>Model 7</td>
<td>0.16</td>
<td>13.12</td>
<td>Yes ($X^2_{crit} = 11.07$)</td>
</tr>
<tr>
<td>Model 8</td>
<td>0.64</td>
<td>53.64</td>
<td>Yes ($X^2_{crit} = 11.07$)</td>
</tr>
<tr>
<td>Model 9</td>
<td>0.15</td>
<td>11.59</td>
<td>Yes ($X^2_{crit} = 11.07$)</td>
</tr>
<tr>
<td>Model 10</td>
<td>0.70</td>
<td>52.82</td>
<td>Yes ($X^2_{crit} = 11.07$)</td>
</tr>
</tbody>
</table>

Thus, all models showed evidence that the error variance was non-constant. Since this condition exists within the data, the OLS estimators will be inefficient and no longer have minimum variance. Again, this indicates that the $t$-statistics and $F$-statistics calculated by OLS will be inaccurate, although, they will still remain unbiased and consistent (Gujarati, 2003; pp. 396). The regressions were run again by generalized least squares method (GLS) to correct for heteroscedastic error. The results of the models found are listed below:

$$\ln M = -9.25 + 1.42 \ln GDP^d + 0.11 \ln e$$ \hspace{1cm} (12)

t-ratios: (-30.34) \hspace{1cm} (87.96) \hspace{1cm} (2.40)

$R^2$: 0.99
\[ \ln X = -8.76 + 1.62 \ln GDP^f - 0.26 \ln e \] (13)
\[ t\text{-ratios: } (-3.23) \quad (10.04) \quad (-0.95) \]
\[ R^2: 0.54 \]

\[ \ln M = -8.76 + 1.30 \ln GDP^d + 0.41 \ln e_{t-10} \] (14)
\[ t\text{-ratios: } (-34.96) \quad (60.22) \quad (6.17) \]
\[ R^2: 0.99 \]

\[ \ln X = -11.16 + 1.11 \ln GDP^f + 1.95 \ln e_{t-10} \] (15)
\[ t\text{-ratios: } (-4.43) \quad (5.62) \quad (5.32) \]
\[ R^2: 0.59 \]

Correcting for heteroscedasticity, it can be seen that the values of the \(t\)-statistics and coefficients change only slightly. However, the values should be efficient and the variances at a minimum using this technique.

**Conclusion**

Using the results found under the regressions correcting for heteroscedasticity, it is observed that a very strong, positive statistical relationship exists between the natural log of the volume of imports and the natural log of domestic GDP, while a statistical relationship also exists between the volume of imports and the current real exchange rate. This relationship between imports and the exchange rate improves when the exchange rate is lagged by a period of 2 ½ years, indicating a J-curve effect is still in existence. The impressive positive relationship between domestic income and volume of imports implies that it is an increase in income, rather than an increase in purchasing power parity due to exchange rates, that is driving the boom in US imports. A positive statistical relationship also exists between the natural log of the volume of exports and the natural log of foreign GDP and the natural log of the exchange rate when it is lagged by 10 quarters. The economic impact of these results are that the volume of US exports over a 20 year period depends on both the income of the US’s foreign trading partners and the lagged broad index rate. A 1 percent increase in the natural log of exports depends upon an increasing factor of 1.11 in foreign GDP and 1.95 in the real broad index. This again implies that income makes a difference in the volume of US exports that foreign countries buy, since exports increase even in the face of an increasing lagged broad index. If this seems counter-intuitive, keep in mind that the ‘quick and dirty’ method used to trade-weight the foreign GDP in this paper results in a very rough estimate of the foreign GDP variable. Broad estimations were made regarding the percentage of exports sent to the major trading countries of the US over the last 20 twenty years. Because of this, the foreign GDP data may have an unpredictable influence on the export regression model. From the results, it appears the driving force behind the rise in import volume is mainly due to increases in US GDP with some aid from the current exchange rate as well as the J-curve effect. The driving force behind export volume depends on both foreign income and only exchange rate fluctuations from previous periods.
References


Appendix

Output for Model 7

R-SQUARE = 0.9899     R-SQUARE ADJUSTED = 0.9896
VARIANCE OF THE ESTIMATE-SIGMA**2 = 0.22517E-02
STANDARD ERROR OF THE ESTIMATE-SIGMA = 0.47452E-01
SUM OF SQUARED ERRORS-SSE= 0.18239
MEAN OF DEPENDENT VARIABLE = 13.707
LOG OF THE LIKELIHOOD FUNCTION = 138.372

<table>
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<tr>
<th>VARIABLE</th>
<th>ESTIMATED</th>
<th>STANDARD ERROR</th>
<th>T-RATIO</th>
<th>PARTIAL STANDARDIZED ELASTICITY</th>
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<tr>
<td>LNUSAGDP</td>
<td>1.4231</td>
<td>0.1625E-01</td>
<td>87.57</td>
<td>0.995</td>
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<tr>
<td>LNRE</td>
<td>0.10551</td>
<td>0.4489E-01</td>
<td>2.351</td>
<td>0.253</td>
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<td>CONSTANT</td>
<td>-9.2795</td>
<td>0.3043</td>
<td>-30.50</td>
<td>0.9907</td>
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</table>

Figure I. Residual Plot for Model 7: Imports
Output for Model 8

R-SQUARE = 0.5505  R-SQUARE ADJUSTED = 0.5394
VARIANCE OF THE ESTIMATE-SIGMA**2 = 0.85336E-01
STANDARD ERROR OF THE ESTIMATE-SIGMA = 0.29212
SUM OF SQUARED ERRORS-SSE= 6.9122
MEAN OF DEPENDENT VARIABLE = 13.481
LOG OF THE LIKELIHOOD FUNCTION = -14.2947

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<th>STANDARD ERROR</th>
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<th>P-VALUE</th>
<th>CORR. COEFFICIENT</th>
<th>AT MEANS</th>
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<td>LNFORGDP</td>
<td>1.5994</td>
<td>0.1606</td>
<td>9.960</td>
<td>0.000</td>
<td>0.742</td>
<td>0.7444</td>
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<tr>
<td>LNRE1</td>
<td>-0.24916</td>
<td>0.2742</td>
<td>-0.9086</td>
<td>0.366</td>
<td>-0.0679</td>
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<tr>
<td>CONSTANT</td>
<td>-7.9643</td>
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<td>-3.186</td>
<td>0.002</td>
<td>0.5908</td>
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Figure II. Residual Plot for Model 8: Exports
Output for Model 9

R-SQUARE = 0.9914  R-SQUARE ADJUSTED = 0.9911
VARIANCE OF THE ESTIMATE-SIGMA**2 = 0.1497E-02
STANDARD ERROR OF THE ESTIMATE-SIGMA = 0.3869E-01
SUM OF SQUARED ERRORS-SSE = 0.10779
MEAN OF DEPENDENT VARIABLE = 13.619
LOG OF THE LIKELIHOOD FUNCTION = 139.020

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<th>STANDARD ERROR</th>
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<td>LNDGDP</td>
<td>1.3011</td>
<td>0.2181E-01</td>
<td>59.65</td>
<td>0.000</td>
<td>0.990</td>
<td>0.9256</td>
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<tr>
<td>LNRE_10</td>
<td>0.41643</td>
<td>0.6747E-01</td>
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<td>CONSTANT</td>
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<td>0.000</td>
<td>-0.972</td>
<td>0.0000</td>
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Figure III. Residual Plot for Model 9: Imports with lagged real broad index variable
Output for Model 10

R-SQUARE = 0.6024  R-SQUARE ADJUSTED = 0.5914
VARIANCE OF THE ESTIMATE-SIGMA**2 = 0.68912E-01
STANDARD ERROR OF THE ESTIMATE-SIGMA = 0.26251
SUM OF SQUARED ERRORS-SSE= 4.9617
MEAN OF DEPENDENT VARIABLE = 13.417
LOG OF THE LIKELIHOOD FUNCTION = -4.58009

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<th>P-VALUE</th>
<th>CORR. COEFFICIENT</th>
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<tr>
<td>LNFGDP</td>
<td>1.0827</td>
<td>0.1981</td>
<td>5.466</td>
<td>0.000</td>
<td>0.542</td>
<td>0.4569</td>
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<tr>
<td>LNRE_10</td>
<td>1.9671</td>
<td>0.3636</td>
<td>5.410</td>
<td>0.000</td>
<td>0.538</td>
<td>0.4522</td>
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<tr>
<td>CONSTANT</td>
<td>-10.765</td>
<td>2.508</td>
<td>-4.292</td>
<td>0.000</td>
<td>0.451</td>
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Figure IV. Residual Plot for Model 10: Exports with lagged real broad index variable