Japan's Relative GDP and Positions in Services Trade:

Co-integration and Granger causality tests based on linear VEC models

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Abstract—**This study explores the nexus among the Japanese trade in services to world trade and the economic development. Assuming that the relationship is linear, short-run Granger causality indicates that the export position negatively Granger causes the Japanese GDP relative to the world; the relative GDP exerts positive effects on the import position, and the export Granger causes the import position with negative effects while Granger causality runs from the later to the former with positive effects, and; the relative GDP positively Granger causes the Japanese import position. In the long-run, Wald tests show that the co-integration relationship Granger causes both the relative GDP and the import position in services, and; both export and import positions Granger cause the relative GDP, and both the relative GDP and the export position Granger cause the Japanese import position, all with positive effects. The export position in services seems to be exogenous to the model system, probably because of the policy interference of export facilitation.**

Keywords—Japan; Granger causality; trade in services; relative GDP; time series analysis

I. INTRODUCTION

Developed countries are usually featured with larger shares of services industries in relation to their GDP and more trade in services. The services trade balance is directly included in a country's GDP [1-4] and the ways services are produced are often clean and friendly to environment [5-7]. Exports and imports in services, however, may have different effects on different country's sustainable economic development and growth in a same individual country at different stages [8].

The aim of this study is to empirically investigate Granger causality relationship among the Japanese trade position, including both export and import positions in services, and the changes in relative GDP which is measured by a country's GDP (gross domestic product) in relation to the world total GDP. We focus upon Japan because Japan has been a developed country for decades and the relative GDP had kept the second largest in the world until the year of 2010 when being surpassed by China [9]. Can the Japanese export and import positions in the world services trade improve the Japanese relative GDP? This puzzling question is to be answered by empirical evidences.

II. DATA AND METHODOLOGY

A. Basic Models

We assume that there exist linear relationships among the three variables in this study. Considering that we allow every variable to be dependent or endogenous, the basic models are

$$\begin{bmatrix} y_t \\ x_t \\ m_t \end{bmatrix} = \begin{bmatrix} c_{01} \\ c_{02} \\ c_{03} \end{bmatrix} + \begin{bmatrix} 0, a_{12}, a_{13} \\ a_{21}, 0, a_{23} \\ a_{31}, a_{32}, 0 \end{bmatrix} \begin{bmatrix} y_t \\ x_t \\ m_t \end{bmatrix} + \begin{bmatrix} \tau_1 \\ \tau_2 \\ \tau_3 \end{bmatrix} T + \begin{bmatrix} u_1 \\ u_2 \\ u_3 \end{bmatrix} \qquad (1)$$

where y stands for the Japanese relative GDP; x and m represent the Japanese export and import positions in world services trade; T expresses a deterministic linear time trend and u is the error term of the equation. c_{01}, c_{02} and c_{03} indicate the constant terms; a_{XX} are the coefficients, and u_1, u_2 and u_3 are the stochastic error terms of each equation. If further tests show that there is no constant term or no deterministic linear time trend in the optimal model specification, we revise the model(s) by imposing the restrictions of $c_{0X} = 0$ or $\tau_X = 0$.

B. Data Sources and Data Processing

We collected the data of the Japanese GDP (Y_j) and that of the world (Y_w) for 1980-2017 from the System of National Accounts (SNA) of United Nations Statistics Division, GDP and its breakdown are at current prices in US dollars (https://unstats.un.org/unsd/ amaapi/api/file/2). We thus obtain Japan's relative GDP by

$$y_{jt} = Y_{jt} / Y_{wt} = y_{jt} / \sum_{n=1}^{N} y_{nt} \qquad (2)$$

where y_{nt} is the individual country's GDP at time point t, and the subscript j and w stand for Japan and the world.

Data for Japan's trade in services are provided by UNTCAD (https://unctadstat.unctad.org/wds/ReportFolders/reportFolders.aspx). UNTCAD employs the classification of BPM5 for the period of 1980-2013 and that of BPM6 for 2005-2017. The change of classifications has made things difficult to obtain complete long time series. We obtained Japan's trade position in relation to that of the world by

$$x_{jt} = X_{jt} / X_{wt} = X_{jt} / \sum_{n=1}^{N} X_{nt} \qquad (3)$$

and the import position in the world services trade by

$$m_{jt} = M_{jt} / M_{wt} = M_{jt} / \sum_{n=1}^{N} M_{nt} \qquad (4)$$

where X_t is the value of exports and M_t is the imports. We investigated the consistent portion for the period of 2005-2013 and found that the differences in x_t and m_t are minimal for the year of 2010. This urged us to combine the data of 1980-2009 for BPM5 and 2010-2017 for BPM6 to obtain the long time series. Fig. 1 describes the time path of Japan's relative GDP and Fig. 2 describes that of the Japanese trade positions.

The times series show similar time paths, however, this is far less enough to draw reliable conclusions about the intrinsic relationship. We need meticulous tests to explore the nexus.
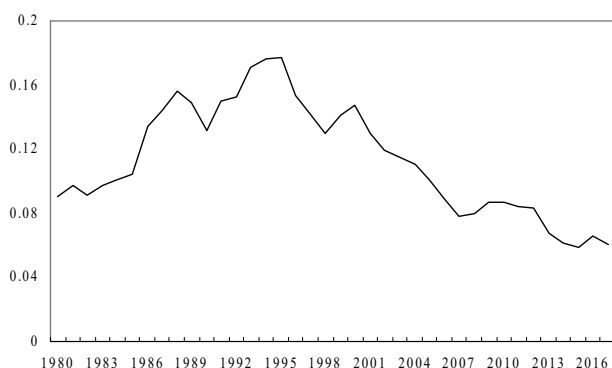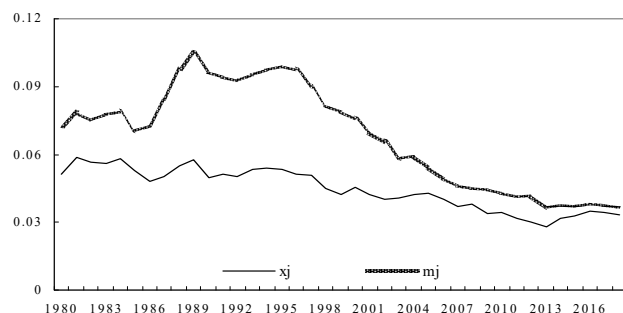

Fig. 1.   Japanese relative GDP.

Fig. 2.   Japanese trade position in services.

III. STATIONARITY TESTS AND COINTEGRATION TESTS

A. Unit Root Tests

OLS regression analysis requires variables to be stationary independent to estimate unbiased coefficients. We employed augmented Dickey-Fuller (ADF) unit root tests to examine the stationarity of the time series of y_{jt}, x_{jt}, and m_{jt}. Table I. reports the results for both level series and first differences.

ADF unit root test results show that the level series have unit roots while their first differences are stationary. The facts imply that the use of level series for OLS may suffer from the problem pseudo-regression. Co-integration and vector error correction analysis are adequate for Granger causality tests.

For the first problem, we made unrestricted vector auto-regression (VAR) models to select the optimal lag order p, and p-1 is the optimal lag order for co-integration and VEC models [11-12]. Table II. reports the VAR lag order selection results.

Each of the information criteria selects lag 2 as optimal for our VAR models, therefore the optimal lag interval is 1-1 for Johansen co-integration tests and the VEC models.

B. Co-integration Tests

For the second problem, Table III. summarizes the five possible model specifications with lag interval of 1-1.

TABLE I.   ADF UNIT ROOT TEST RESULTS

	Test type	ADF t-stats	Prob.		Test type	ADF t-stats	Prob.
y	N, N, 0	-0.5491	(0.4724)	Δy	N, N, 0	-4.4171	(0.0001)
x	N, N, 0	-1.1340	(0.2291)	Δx	N, 1, 0	-6.6126	(0.0000)
m	N, N, 0	-1.5554	(0.1113)	Δm	N, N, 0	-4.4908	(0.0010)

a.   Note: ① Prob. is for MacKinnon (1996) one-sided p-values of ADF t-statistics [10]; ② Δ refers for the first difference.

TABLE II.   VAR LAG ORDER SELECTION RESULTS

Lag	LogL	LR	FPE	AIC	SC	HQ
0	328.0566	NA	5.58E-13	-19.7004	-19.5644	-19.6546
1	401.8367	129.6742	1.1E-14	-23.6265	-23.0823	-23.4434
2	425.7206	37.63521*	4.56e-15*	-24.5285*	-23.5762*	-24.2081*
3	432.3271	9.2091	5.48E-15	-24.3835	-23.0230	-23.9257
4	443.0597	13.0093	5.32E-15	-24.4885	-22.7199	-23.8934
5	447.6751	4.7552	7.92E-15	-24.2227	-22.0460	-23.4903

b.   Note: ① LR: sequential modified LR test statistic (each test at 5% level); ②FPE: Final prediction error; ③AIC: Akaike information criterion; ④SC: Schwarz information criterion; ⑤HQ: Hannan-Quinn information criterion; ⑥ * indicates the lag order selected by the criterion.

TABLE III.   SUMMARY OF CO-INTEGRATION TEST RESULTS

Data Trend:	None	None	Linear	Linear	Quadratic
Test Type	No Intercept No Trend	Intercept No Trend	Intercept No Trend	Intercept Trend	Intercept Trend
Trace	1	0	1	0	0
Max-Eig	1	0	0	0	0

a.   Note: Critical values based on MacKinnon-Haug-Michelis (1999) [13].

The results of trace statistics and that of max-Eigen value are inconsistent. More tests need to be conducted before we can finally select the optimal co-integration as well as the VEC model specification, with purposes of further conducting the short-run and long-run Granger causality tests.

C. Vector Error Correction Models

Optimal specification for VEC models should be consistent to that of the co-integration. We estimated the five possible VEC models with lag interval of 1-1. Table IV. presents the evaluation indicators for each of the possible individual models.

Both Akaike information criterion (AIC) and Schwarz criterion (SC) select model I as the optimal. Comparing model I and model III, which is suggested optimal by trace statistics as shown in table III., we confirm that model I is optimal.

The estimation of the optimal VEC models is

$$\begin{bmatrix} \Delta y_t \\ \Delta x_t \\ \Delta m_t \end{bmatrix} = \begin{bmatrix} -0.282 \\ 0.03563 \\ 0.27053 \end{bmatrix} \varepsilon_{t-1} + \begin{bmatrix} 0.593,-1.536,-0.467 \\ 0.036,-0.326,0.2488 \\ 0.183,0.7851,0.5547 \end{bmatrix} \begin{bmatrix} \Delta y_t \\ \Delta x_t \\ \Delta m_t \end{bmatrix} \quad (5)$$

where ε_{t-1} is the lagged residual of the co-integration equation

$$y_t = -0.0471 x_t + 1.6843 m_t + \varepsilon_t \quad (6)$$

IV. GRANGER CAUSALITY TESTS

The estimation of the VEC models enabled us to perform Granger causality tests to explore the dynamic inter-dependence of our model system, in which each series is firstly assumed endogenous and has chance to act as the dependent before rejecting the null hypothesis of exogeneity.

A. Short-run Granger Causality Tests

Short-run Granger causality test focus on whether a lagged independent improves the explanatory power of the model while keeping other conditions unchanged. In other words, that implies whether the restriction of the coefficient being equal to zero, for an independent coefficient, reduces the explanatory power or not. For the value of short-run effects, we used the estimated coefficients of the lagged differences in the VEC models as proxies [14, 15].

Table V. shows the short-run Granger causality test results. As shown, each of the time series is endogenous, or is determined by other factors in the VEC model system. Specifically, there is a short-run Granger causality running from the Japanese export position (x) to the relative GDP with negative effects; the import position (m) Granger causes the export position (x) with positive effects at marginal significance level of 10%, but export position (x) negatively Granger causes the import position (m), and; the import position has positive short-run effects on the Japanese relative GDP (y) significantly at 1% confidence level.

B. Long-run Granger Causality Tests

Long-run Granger causality tests involve examining the long-run equilibrium relationship or the error correction term (ε_{t-1}) in the VEC models. This study conducted Wald joint-tests

on the individual coefficient together with that of ε_{t-1}. Basing on the VEC models, we employed the convergence value of the generalized impulse-response function to be the proxy for an individual variable's long-run effect on the dependent variable [16-18]. We found the values converged at 30 periods after the impulse, and took the response values at the 30th period as the long-run effects, as per the impulse-response functions. Table VI. reports the long-run Granger causality test results.

TABLE IV. VEC MODEL SPECIFICATION SELECTION RESULTS

Model specification	I	II	III	IV	V
Co-integration Equation	No Intercept	Intercept	Intercept	Intercept	Intercept
VAR	No Trend	No Trend	No Trend	Trend	Trend
Determinant residual covariance (dof adj.)	3.32E-15*	3.29E-15	3.37E-15	3.32E-15	3.45E-15
Determinant residual covariance	2.33E-15	2.31E-15	2.15E-15	2.12E-15	2E-15
Log likelihood	453.2283	453.3947	454.6645	454.9547	456.0132
Akaike information criterion	-24.3460*	-24.2997	-24.2591	-24.2197	-24.1674
Schwarz criterion	-23.6862*	-23.5959	-23.4674	-23.3840	-23.2437

b. Note: ① VEC models are composed of two parts: the co-integration equation and the VARs. The model specifications of I to V list all the five possible combinations; ② the asterisks indicate the selection results by the selection criteria

TABLE V. SHORT-RUN GRANGER CAUSALITY TEST RESULTS

Dependent Independent	Δy_t		Δx_t		Δm_t	
	Chi	SE	Chi	SE	Chi	SE
Δy_{t-1}	——	——	0.3670 (0.5446)	0.0306	6.8960*** (0.0086)	0.1831
Δx_{t-1}	6.0405** (0.0140)	-1.5356			7.8366*** (0.0051)	-0.7851
Δm_{t-1}	1.1446 (0.2847)	-0.4671	3.0734* (0.0796)	0.2488	——	——

c. Note: ① Chi stands for Chi-square statistics; ② in parenthesis are the probabilities of the Chi-square statistics; ③ SE indicates short-run effects which sum up the lagged coefficients ④ "*", "**" and "***" denotes significance levels of 10%, 5% and 1% respectively.

TABLE VI. LONG-RUN GRANGER NON-CAUSALITY TEST RESULTS

Dependent Independent	Δy_t		Δx_t		Δm_t	
	F	LE	F	LE	F	LE
ε_{t-1}	9.0742*** (0.0050)	——	1.3754 (0.2495)		0.4155 (0.5238)	——
$\varepsilon_{t-1}, \Delta y_{t-1}$	——	——	1.0720 (0.3543)		4.0144** (0.0278)	0.0062
$\varepsilon_{t-1}, \Delta x_{t-1}$	7.7090*** (0.0019)	0.0042			4.0915** (0.0262)	0.0026
$\varepsilon_{t-1}, \Delta m_{t-1}$	4.6830** (0.0164)	0.0150	1.9182 (0.1634)		——	——

d. Note: ① F indicates F-statistics with degree of freedom of (1, 23) for ε_{t-1} and (4, 23) for the lagged differences of each individual independent variable combined with ε_{t-1}; ② in the parenthesis are the joint-probabilities of F-statistics; ③ LE stands for the long-run effect.

We find that

- the long-run equilibrium relationship (ε_{t-1}) and both Japan's trade positions in world services trade are Granger causes of the relative GDP (Δy_t), and both the export and import positions have positive long-run effects;

- there are long-run Granger causality running from the Japanese relative GDP (Δy_t) and the export position in

services trade (Δx_t) to the import position (Δm_t), with positive long-run effects at 5% significance level, and;

- none of the variables Granger causes the Japanese export position (Δx_t), implying that the export position or x_t is exogenous to the VEC model system.

V. CONCLUSION

Using yearly time series of the Japanese trade in services and relative GDP in relation to the world GDP for the period of 1980 to 2017, we examined the nexus among the variables.

ADF unit root test results show that the three time series are one-order integrated and further co-integration test summary indicates multiple possible long-run equilibrium relationships. We selected the optimal lag interval and model specification for Johansen co-integration and vector error correction models.

Basing on the estimation of the optimal VEC models, we conducted both short-run and long-run Granger causality tests. The test results, however, are somewhat different.

We find that:

- The Japanese export position in services trade has negative effect upon the relative GDP in the short-run while the long-run effect is positive, implying that the services exports may facilitate the Japanese domestic economic growth, but only in the long-run.

- The import position Granger causes the export position with positive effects in the short-run, but there is no Granger causality from the import position to the export position in the long-run. In other words, the causal relationship is limited in the short-run. Besides, the Japanese export position seems to be exogenous or independent in the long-run.

- The Japanese export position in world trade in services Granger causes the Japanese import position with negative effects, while the long-run effect is significantly positive though the extent is very slight.

The different short-run and the long-run effects are puzzling but interesting. The results and conclusions about the Japanese experiences are thought worthy for both developed countries and developing countries, to make adequate policies in services trade to improve the national income.

This study revealed the empirical evidences but the theoretical framework are left untouched. Future research may focus on the socio-economic features to study the intrinsic relation of the structural changes in Japan's macro-economy. This research hereby calls for further empirical study and theoretical research on the topic to explain the Japanese short-run and the long-run puzzles.

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