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Maritime Business Cycles with Multiple Structure Changes

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Abstract : *In this paper we examined a novel extension of the convergence empirics for the maritime business cycle which considers structure breaks and/or changes. To provide theoretical justification, the convergence hypothesis uses the relaxed assumption to technology shocks. Based on the recent empirical results provided by Kim and Chang (2020), we consider nonlinear dynamics that capture the properties on structural changes in the equilibrium adjustment process. This approach bridges the gap between the theoretical framework and empirical specifications. In particular, we applied the convergence hypothesis to the multiple structure change model for the maritime business cycle. Our application to the maritime data showed support of the convergence hypothesis allowing multiple structure changes during the high volatile period and offers additional insight into the forecasting maritime business cycles.*

Key words : *maritime, business cycle, convergence, multiple structure change, forecasting*

1. Introduction

The growth of the world economy, represented by GDP(gross domestic product), is the most critical driver for shipping markets and this macroeconomic dynamics generate market conditions, which shape the output of the bargaining over current freight rates. To this textbook theory, it is generally described as maritime business cycles are caused by business cycles. However, in view of the co-movement, the cyclical movement in macroeconomic variables can affect volatility and transfer expectations to maritime business cycles. Thus, we need to clarify about which factor are the most important ones in order to relate the fluctuations in maritime business cycles.

In empirical investigation, when prior knowledge for testing procedure is unavailable, various testing strategies have been suggested so far. Recently the estimates with structural changes provided by Kim and Chang(2020) suggest necessity of novel specification for time series analysis to capture the fluctuations in maritime business cycle. In particular, Kim and Chang(2020) present a simple testing strategy that avoids burdensome for testing that is able to happen with other testing methods, and discusses how to apply prior knowledge about forecasting models.

In output growth models, theoretical framework for real business cycle has been of the primary area of economic growth and focused on the productivity/technology shocks, which includes random components in deterministic solution of convergence equation. In terms of convergence issue, the results obtained have been focused on different countries as the neoclassical prediction. However, the validity of such a prediction has been heavily questioned on empirics and modified the specification by introducing constant return to scale in the production function(Lucas, 1988; Barro, 1997; Barro and Sala-i-Martine, 2003). That is, debates on economic growth of convergence empirics and no changes in the underlying dynamics of output have dominated empirical researches on the issues during last decades. In particular, until now empirical specifications to the theory for cross section, panel and time series have been mainly performed under trend stationary assumption.

However, when the empirical models are highly sensitive to the disturbances in determination process, procedures commonly used are not fully appropriate for evaluating the models whose variables contain stochastic trends. To these empirical results from previous studies, we first examine theoretical specifications where technology is considered in stochastic framework. In order to clarify technology shock effects in business cycle model, we consider two types of exogenous shocks between permanent and temporary. When the technology shock has permanent effect irrespective of other macroeconomic factors such as labor shock, that is, composite shock is nonstationary. On the contrary, it is transitory effect if the shock is temporary. From the different specifications for technology shock, it is going to bridge the gap between theoretical framework and empirical

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specifications. In particular, it is consistent with unit root test with structural changes and provides theoretical justification for empirics. Along the same line of real business cycle theory, an investigation for a specified area such as maritime also has a critical meaning. Thus, this study is going to identify productivity/technology shock as a macroeconomic factor and empirically to evaluate its effects on economic convergence for maritime using time series data.

From the theoretical specification we derive structural change models for empirics. In particular, even though the balanced-growth in maritime occurs in the specification, technology/productivity is still assumed to be exogenously given constant rate of progress. In this view, substantiative difference in empirics lies in alternative specifications for technology/productivity, which can be compared by studying the different restrictions with dynamics implication. Hence we are going to investigate whether there exist equilibrium path that towards balanced growth with $I(1)$ process in technology/productivity shock, and if so, what characteristics to the balanced-growth in maritime show when technology/productivity shock is suitably considered.

To deal with stochastic approach in conjunction with empirical issues for maritime business cycle, this paper is going to attempt to consider following three issues: first, we examine the stochastic movement caused by technology/productivity effect and then compare stochastic technology/productivity, which follows $I(0)$ and $I(1)$ process as assumed in general approaches. This general equilibrium approach would be complementary to show the combined effect with stochastic technology. Second, to properly capture the technology/productivity shock with convergence equation, we will introduce suitable structural change models that is able to solve the main complication in estimating and testing the theory within time series context. Finally, the paper is going to provide the empirical evidence for maritime business cycles.

The rest of this investigation start from identifying convergence hypothesis and empirical methodologies that have been used in the previous investigation. In section 2 we mainly present that there is some correspondence between definition and methodologies. We then present the model and critical issues of previous studies. In section 3 we provide the theoretical specifications for empirics and then provide basis for the empirical testing model. Finally in section 5 we provide concluding remarks with summary of estimation results.

2. Theoretical Framework for Output Growth

The information revealed by the conventional linearized analysis has been well developed but there may be still insufficient to yield definitely conclusive estimation results in several aspects. In particular, even though the time series analysis generally supports a variant of the conditional convergence hypothesis, those have shown the fact that unit roots in economic growth rate and no change in the underlying dynamics seem to be stylized facts that cannot go together. Hence we are going to extend time series properties and examine the effect caused by stochastic technology shock.

Based on the economic growth framework with technology $A_t = A_0 e^{gt}$, labour $L_t = L_0 e^{nt}$, capital per person $k_t = K_t / A_t L_t$, output per person $y_t = Y_t / A_t L_t$ and the capital evolution in terms of per person $k_{t+1} = (1-\delta) k_t + s f(k_t)$, we start to illustrate how first order difference equation derived. Using the definition to linearize around the steady state, k^*, we take first-order approximation to $f(\,\bullet\,)$ evaluated at k^*,

$$\hat{k} = \left(\frac{k - k^*}{k^*} \right) = \ln\left(\frac{k}{k^*} \right)$$

where $\ln(\hat{k} + 1) = \hat{k}$. Hence, linearization of capital evolvement in the steady state follows that

$$\hat{k}_{t+1} = a_1 \hat{k}_t \tag{1}$$

where $a_1 = (1-\delta) + s f_k(k^*)$. We then linearize Cobb-Douglas production function, $y_t = k^\alpha$ around the steady state, y^* and k^*.

$$\hat{k}_t = b_1 \hat{y}_t \tag{2}$$

The equation (2) may be substituted back into (1) to generate the first order difference equation

$$\hat{y}_t = a_3 \hat{y}_{t-1} \tag{3}$$

where the parameter a_3 is the function of a_1 and b_2 and $\hat{y}_t = (y_t - y^*)/y^*$. The technology/productivity disturbance was assumed to be included in error term. If the technology/productivity shock is independently distributed through time, then the error term is predicted to be a moving average of the independent shocks, A_t. However, even though one allow for the possibility that the disturbance to the regression equation (3) may be composed of a moving average of independent shocks, the residual of the regression of y_t on y_{t-1} would have unit root. In particular, most applications of β-convergence account for this fact by subsumed trend or $i.i.d.$(identically independently distributed) assumption. Hence we will show how a linear difference equation can be used to model the properties of the disturbance to the production technology in a way that provides a plausible representation of the time series properties of the data.

We examine technology/productivity effect in two categories. The first one is when the technology/productivity A_t to the system have a transient, diminishing effect in the process, $I(0)$ case. The second case is $I(1)$ process with permanent effect. We compare both cases as follows:

Case 1) $A_t \sim I(0)$

When exogenous shock, A_t, is given by $A_t = A_0 + gt + e_t$, which is assumed to represent $I(0)$ process of technology shock and $e_t \sim i.i.d.$. To match the model with the data, we rewrite the definition of $\hat{y}_t$ and approximation then implies,

$$\hat{y}_t = \ln\left(\frac{Y_t}{L_t}\right) - gt - \ln y^* A_0$$[1]

where $\ln(Y_t/L_t)$ is the logarithm of output per capita. Using equation (3) and the definition for labour, $L_t = L_0 e^{nt}$ we arrive at a representation of the linearized stochastic model,

$$\ln Y_t = (1+\beta)\ln Y_{t-1} + \beta(n+g)t - (1+\beta)(n+g) + de_t \qquad (4)$$

$$e_t = v_t + c_3 v_{t-1}$$

where $a_3 = (1+\beta)$. As shown in the equation(4), the structural form of exogenous growth model with $I(0)$ technology shock is consistent Dickey-Fuller test with drift and linear trend. Hence the question reduces to whether Y_t has a unit root. In addition the concept actually implies within convergence but the researches have extended across convergence as well. In particular, the stochastic approaches based on time series properties generally support a variant of conditional convergence hypothesis, though the results have been produced by univariate approaches. However, empirical results by Quah(1996), Bernard and Durlauf(1996), Evans and Karras(1996), Bliss(1999), Hobijn and Franses(2000), Michelacci and Zaffaroni(2000) show that the output growth in steady state is close to unit root process.

Case 2) $A_t \sim I(1)$

Alternatively, the analysis is taken by the fact that technology shock have a permanent effect on the production. We establish endogenous shock $A_t = A_{t-1} + g + e_t$ where technology/productivity follows $I(1)$ process. Then we derive

$$\hat{y}_t = \ln\left(\frac{y_t}{y^*}\right) - 1$$

Approximation implies that

$$\hat{y}_t = \ln\left(\frac{Y_t}{L_t}\right) - \ln y^* A_t$$

Using the approximation (3) and the definition $L_t = L_0 e^{nt}$ linearized stochastic model is as follow:

$$\ln Y_t = (1+\beta)\ln Y_{t-1} + b + de_t \qquad (5)$$

$$e_t = v_t + c_3 v_{t-1}$$

where $v_t = \ln y^* A_t$, $a_3 = (1+\beta)$ and $b = (1-a_3)\ln y^*$. Comparing with the equation(4), the linearized structural form with I(1) technology shock includes only intercept in Dickey-Fuller test.

Summing up, the exogenous model equation(4), which is considering technology shock as given, could address differences in output whenever decreasing marginal productivity of capital is attained in growth model. On the contrary, persistent technology shock framework, equation(5) deliver sustained positive per capita growth in the long-run. That is, both of cases clearly show the effect of technology shock in convergence equation. In particular, when the technology shock follows $I(0)$ process, the model has both trend and intercept but the convergence equation with $I(1)$ technology shock only includes intercept. As briefly summarized in equation(4) and (5), we find exogenous technology shock generate trend but persistent effect caused by the technology shock exclude trend.

Hence, for empirical specification to consider technology shocks in maritime, we need to consider the structural changes in drift and trend of Dickey-Fuller type tests. To reinforce our point in evaluating convergence hypothesis on maritime business cycles, we need to extend main feature of convergence empirics.

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1) $\hat{y}_t = \left(\frac{y_t}{y^*}\right) - 1 = \left(\frac{\frac{Y_t}{A_0 e^{gt} L_t}}{y^*}\right) - 1 = \left(\frac{\frac{Y_t}{L_t}}{y^* A_0 e^{gt}}\right) - 1$

3. Empirical Specification

The earliest structural change model for the empirics was suggested by Chow (1960), which are for stationary variables and a single break. Perron(1989) has then proposed a modified Dickey-Fuller test for a unit root with three different specifications with deterministic and trend component where a known structural break is assumed to be given. From these results, Perron(1989) developed a testing procedure involving Dickey-Fuller type modified regressions with dummy variables to ensure consistent tests for stationarity in the presence of structure breaks at time $a < T_B < T$. He considers following four unit root null hypothesis,

Model 0: deterministic trend without structural change

$$Y_t = a_0 + b_0 t$$

Model I: level shift

$$Y_t = a_0 + a_1 DU_t + b_t \quad \text{where} \quad DU_t = \begin{cases} 1 & \text{if} \quad t > T_B \\ 0 & \quad\quad t \le T_B \end{cases}$$

Model Ⅱ: joint broken trend

$$Y_t = a + b_0 t + b_1 DT_t \quad \text{where} \quad DT_t = \begin{cases} t - T_B & \text{if} \quad t > T_B \\ 0 & \quad\quad t \le T_B \end{cases}$$

Model Ⅲ: locally disjoint broken trend

$$Y_t = a_0 + a_1 DU_t + b_0 + b_1 DT_t \quad \text{where} \quad DT_t = \begin{cases} 1 & \text{if} \quad t > T_B \\ 0 & \quad\quad t \le T_B \end{cases}$$

where Model(I) allows a change in the level of the series, Model(II) admits a change in the trend, and Model(III) includes both changes. While the Perron(1989) allows for a break under the null and the test requires the pre-test specification of a date for the structural break. In his empirical applications Perron(1989) makes the decision as to when the break took place from visual inspection of the data. Having estimated the appropriately modified model for a time series Y_t, the test for a unit root is the t statistic on Y_{t-1}. These test statistics depend on the location of the structural break, and Perron(1989) derived their asymptotic distributions under the null hypothesis and for different break dates.

On the contrary, the Perron(1989) and Zivot and Andrews(1992) argue when the break is treated as endogenous, Perron's conclusions are inconsistent. Zivot and Andrews(1992) insist that, while Perron(1989) assumes abrupt exogenous change, the effects caused by such events are realized from the underlying data generating process. Hence a more appropriate null hypothesis than that employed by Perron(1989) would be of a unit root series excluding any structural change. When an endogenous event causes structural change, the proper unit root testing procedure should take account of the fact that break points in the testing regressions are data dependent, and they should not as in the Perron test be imposed in the evidence of pre-test visual analysis. Zivot and Andrews(1992) develop a unit root testing of procedure with the null hypothesis of a unit root with drift where the break time is determined by the given data.

Perron and Yabu(2009a) recently propose that the extension to the more general case are presented in equation(6).

$$Y_t = X_t \Psi + u_t \tag{6}$$

for $t = 1, ..., T$ where $u_t \sim i.i.d.$, X_t is a $(r \times 1)$ vector of deterministic components, and Ψ is a $(r \times 1)$ vector of parameters,

$$X_t = \begin{cases} DU_t \\ DT_t \\ (DU_t, DT_t)' \end{cases}, \qquad \Psi_t = \begin{cases} a_0 \\ b_0 \\ (a_0, b_0)' \end{cases}$$

where u_t is the residuals from a regression of Y_t on X_t.

The estimates of considered in equation(6) are obtained from the OLS and generate second-stage regression,

$$\Delta \hat{u}_t = \alpha \hat{u}_{t-1} + \sum_{i=1}^{p} \phi \Delta \hat{u}_{t-i} + \hat{\epsilon}_t \tag{7}$$

The GLS estimates are provided by Ordinary Least Squares (OLS) to the regression

$$(1 - \hat{\alpha}_{MS} L)\, Y_t = (1 - \hat{\alpha}_{MS} L) X_t \Psi + (1 - \hat{\alpha}_{MS} L) u_t$$

for $t = 2, ..., T$ and $X_t := [1, t, DT(\lambda)]$. The estimates employ bias correction for the lest-squares estimate, $\hat{\alpha}_{MS}$, with the specifications. That is, the truncated version of the bias-corrected estimate, $\hat{\alpha}_{MS}$, is still super-efficient under a local unit root, i.e. $T(1 - \hat{\alpha}_{MS})$ when $\alpha = 1 + c/T$. Perron and Yabu (2009a, 2009b) denote the resulting Wald test by $W_{RQF}(\lambda)$ where the subscript RQF stands for Robust Quasi Feasible GLS,

$$W_{RQF}(\lambda) = [R(\tilde{\Psi} - \Psi)]' [\hat{h} R(X'X) R'] [R(\tilde{\Psi} - \Psi)]$$

where $\hat{h}_v = T^{-1} \Sigma_{t=1}^{T} \hat{v}_t^2 + T^{-1} \Sigma_{t=1}^{T} \omega(j,m) \Sigma_{t=1}^{T} \hat{v}_t \hat{v}_{t-j}$, $s^2 = T^{-1} \Sigma_{t=1}^{T} \hat{u}_t^2$ and $v_t = (1 - \hat{\alpha}_{MS} L) u_t$. When we have no prior knowledge for model specifications, the specification need the new test statistics with structural breaks for the function. The test statistics are based on a Feasible Quasi Generalized Least Squares procedure with a super-efficient estimate of the sum of the autoregressive parameters α.

4. Empirical Results for Marine Industry

Prior to test our conjecture that the BDI for maritime business cycle is approximated by multiple structural changes, Kim and Chang(2020) displays the full period from Jan. 3. 1985 to Apr. 30. 2020 and shows multiple breaks in the series. In particular, the estimates show that the BDI and the rate of change has shown 4 times abrupt changes in Sep. 2003, Apr. 2007, Oct. 2008 and Dec 2010. To exclude contaminated series, Kim and Chang(2020) additionally consider nonstationary subsample period 2000:01 - 2010:12 after the effects caused by asian financial crisis are alleviated. As shown in Kim and Chang(2020), it reveals global shipping market has been experienced drastic changes in the rate of growth during the period.

Table 1 Results of linear unit root tests

		Model	ADF[2]	
			t^{ADF}	p
full sample period	BDI	C	-3.84***	5
		C/T	-3.76***	5
	ΔBDI	C	-12.25***	1
		C/T	-12.26***	1
subsample period (Jan.2000 - Dec.2010)	BDI	C	-2.51	1
		C/T	-2.53	1
	ΔBDI	C	-5.89***	1
		C/T	-5.88***	1

Note: C, C/T include drift and drift with trend. *,**,*** denote 10%, 5% and 1% significant levels respectively.

To document whether such changes are significant, we employ weekly dataset for the same periods and test the series with full and subsample periods that includes 4 structural breaks respectively. The results of the standard ADF tests are not able to reject the null in full sample period, while the tests for subsample period reject the null. Table 1 provides interesting empirical results. That is, it is not very sensitive the structure change effect for the full sample period but shows significant role for the subsample period.

To the nonlinear adjustment process, our investigation based on the work of Perron and Yabu (2009a and 2009b) for the FGLS that is a super-efficient estimator for the parameter estimates. As shown in previous, the resulting Wald test statistic is consistent with a chi-square limit distribution for both $I(0)$ and $I(1)$ cases asymptotically. To improve the finite sample properties of the tests, we employ the OLS estimator proposed by Roy and Fuller (2001) and correct the bias. The results are presented in Table 2. Our method selects the four structure changes as being significant, while the linear-based ADF method fails to find statistical significance.

Table 2 Results of multiple structure change test

		Model Ⅲ- W_{RQF}	
		$\hat{n}$	LM
subsample period	BDI	4	6.7782**

Note: $\hat{n}$ represent number of structural changes. *,**,*** denote 10%, 5% and 1% significant levels respectively.

While linear form based analysis do not show discontinuity in the form of a level shift, using Model III may be more appropriate to crudely account for the gradual nature of the change in slope. For global shipping market the evidence in favor of a change in the trend function is very strong with test statistics having W_{RQF} well below 5%. Table 2. also shows the estimates of the number of breaks. For the series, the number of breaks are consistent and the effect from changes in series are different comparing with the results from the linear model.

For full sample period, the empirical examination in the present paper provide evidence to the convergence of maritime business cycles even in the linear form based analysis. On the contrary, as suggested by theoretical framework, we find nonlinear approaches are suitable when there exist persistent technology shock effect and/or high volatility caused by economic crisis in the series. This would provide further insight into whether the maritime do

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2) ADF (Augmented Dickey-Fuller) test,

$$\Delta y_t = a + bt + \beta y_{t-1} + \sum_{i=1}^{p} \gamma_i \Delta y_{t-i} + \epsilon_t$$

experience output convergence in terms of multiple structural changes and what cause structure changes.

5. Concluding Remarks

In terms of empirical aspects, structural change models recently provide efficient estimation that is able to be systematically interpreted and has implications from the nonlinear approaches, even though there still exist unsolved problems. In contrast to the empirical development, theoretical support to clarify what generate nonlinear dynamics are still vague. In particular, while convergence hypothesis on the output growth have been mainly considered theoretical framework, the empirical results from linear form based analysis are still questioned. The univariate analysis for nonstationary time series against stationary has been a core of time series econometrics. However, there still exist power of the test and nonlinearity problem. The early stage of the relevant literature was in the examination of the linear form based model and implicitly ignore any possibilities about nonlinearity in the series. Thus present investigation has tried to tightly bridge the gap between theoretical justification and empirical specifications for nonlinear approaches.

Recently Kim and Chang(2020) provide novel empirical estimates for BDI as a representative indicator of maritime. However, the estimates only provide the number of breaks and time in maritime business cycles based on the BS(binary segmented) method. In this study, to extend their contribution, we first try to derive and provide the proof of structure changes based on the technology shock effects in convergence hypothesis. Secondly, in terms of econometric specifications for structural changes and/or break, we employ efficient estimation method suggested by Perron and Yabu(2009a and b) for the multiple structural changes with BS method. In this research, we combine both frameworks in one test procedure.

To provide theoretical justification of multiple structure changes in global shipping market, we employ convergence hypothesis with relaxed assumption and find different specifications depending on the technology shock, which supports structure changes in the trend. In particular, it is tightly linked with stochastic theory. For full sample period, the empirical examination presents the evidence to the convergence of maritime business cycles in the linear form based analysis. However, more specified analysis with subsample period indicates that maritime over the highly fluctuated periods strongly rejects the unit root hypothesis and support multiple structure changes. It is consistent with theoretical implication when there exist mixed technology shock effects in maritime business cycles.

Our application to the maritime data shows support of convergence hypothesis allowing multiple structure changes and offers additional insights into the forecasting maritime business cycles. That is, we confirm maritime business cycles there may exist nonlinearities and need to extend forecasting framework in view of supporting multiple structure changes. Therefore, the future studies to predict maritime business cycle should consider these nonlinear processes carefully.

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