International Linkages of Business Cycles in a Two-Country Model: a Case with Trading and Financial Sectors

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Abstract

As a small economy, Taiwan's output is greatly affected by the output of foreign countries. However, not many studies have thoroughly discussed this issue. The purpose of our study is to explore the linkages of international business cycles. Since the United States seems to be the most important trading partner of Taiwan, it is included in our two-country model. The impact of the US economy on the economy of Taiwan is hypothesized to pass through two main channels: trading and financial sectors.

Keywords: Business cycles, Error correction model, International linkages, Taiwan.

JEL classification codes: C22, E32, O53

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1 Introduction

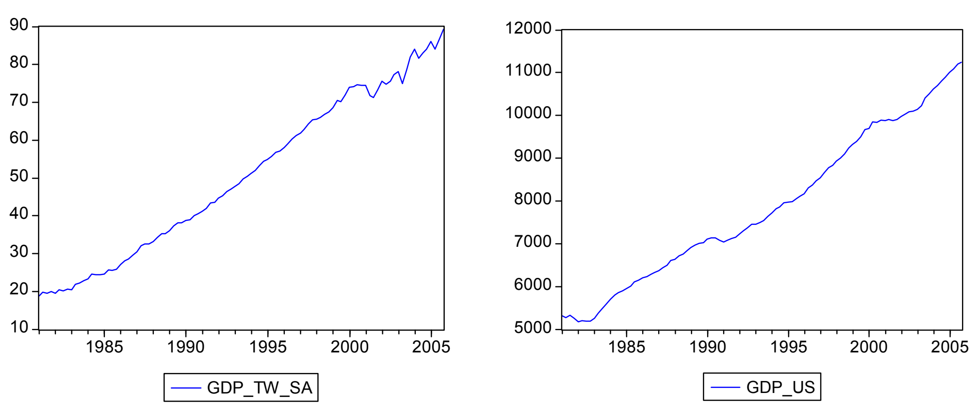
As a small economy, Taiwan's output is greatly affected by the output of foreign countries. However, not many studies have thoroughly discussed this issue. The purpose of our study is to explore the linkages of international business cycles. Since the United States seems to be the most important trading partner of Taiwan, and some of the existing literature shows apparent co-movement of US-Taiwan business cycles (Liang et al., 2005), the U.S. is included in our two-country model.

Most of the existing literature studying the international linkages of business cycles uses multi-national models. In doing so, regression analyses can measure the importance of the trading and financial channels (Otto et al., 2001). In this paper, we propose an alternative which would suit a two-country model. Some researches indicate that the trading and financial channels both play important roles in determining the international linkages of business cycles (Meyer, 2001; Brooks et al., 2003). Thus, the impact of the US economy on the economy of Taiwan is hypothesized to pass through two main channels: trading and financial sectors.

2 Evidence for a relation between the output of Taiwan and the U.S.

First, for a comparison, the real GDP time series of the U.S. and Taiwan are plotted from 1981Q1 to 2005Q4 (Figure 1). Except for the permanent shock of US output around 1990-91, the real GDP of the U.S. and Taiwan both increase in a similar pattern.

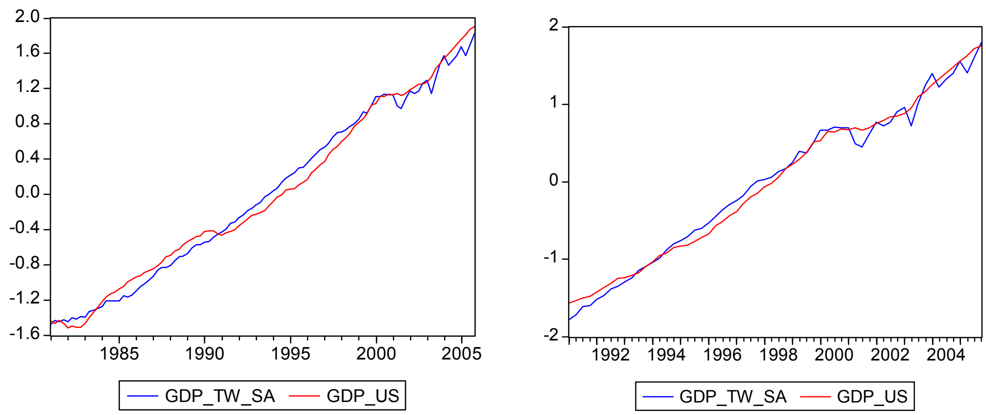
Figure 1 The real GDP of Taiwan (Left) and U.S. (Right)



Note: both the real GDP of Taiwan and the U.S. are seasonally adjusted, billion US$.

In order to show the similarity, transformed (standardized) data are used. Figure 2 shows that the patterns of these two series are very similar, especially in the sub period (1991Q1-2005Q4) depicted at the right.

Figure 2 Standardized data for the real GDP of Taiwan and U.S.



Note: the left figure is for the full period; the right figure is for the sub period.

Motivated by the fact that the patterns of the real GDP for the U.S. and Taiwan are highly similar, it is likely that there exists some long run and stable relationship between the two series. Statistically, it could be examined by a usual co-integration test. Table 1 shows the results for Johansen's co-integration test (Johansen, 1991). Using trace and max-eigenvalue calculations, the test indicates that there is co-integration of rank one.

Table 1 Co-integration test for the real GDP of Taiwan and U.S.

Hypothesized No. of CE(s)	Eigenvalue	Trace Statistic	5 Percent Critical Value	1 Percent Critical Value
None **	0.308902	22.28799	15.41	20.04
At most 1	0.001991	0.119584	3.76	6.65
Hypothesized No. of CE(s)	Eigenvalue	Max-Eigen Statistic	5 Percent Critical Value	1 Percent Critical Value
None **	0.308902	22.16841	14.07	18.63
At most 1	0.001991	0.119584	3.76	6.65

Note: *(**) denotes rejection of the hypothesis at the 5%(1%) level

3 Model and Empirical Results

3.1 Measuring the relationship of international business cycles in a two-country model

In Liang et al.'s (2005) paper, the authors focus on Taiwan and follow the approach of de Brouwer and Romalis (1996) who analyze the interaction of business cycles between two countries at the industry-level with an error-correction model. In the two-country model in this paper, the error-correction model is also utilized with a few extensions.

Since the existence of a long run relationship has been shown in the previous discussion, Engle and Granger's (1987) form of an error-correction model (ECM) can be derived to facilitate the discussion later. Specifically, a series named disequilibrium term, denoted $\{DE_t\}$, is defined as follows:

$$DE_t = y_t^{Taiwan} - \hat{\beta}_0 - \hat{\beta}_1 y_t^{US} , \tag{1}$$

where y^{Taiwan} and y^{US} are the real GDP of Taiwan and the U.S. respectively. Actually, $\{DE\}$ are the residuals of the regression of y^{Taiwan} on y^{US} and a constant term. Due to the long run stable relationship between the real GDP of Taiwan and the U.S., $\{DE\}$ should be a stationary process. Therefore, an autoregression (AR) approximation is utilized to model the $\{DE\}$ series. For simplification, an AR(1) specification is used to formulate this procedure,

$$DE_t = \rho \cdot DE_{t-1} + \varepsilon_t \quad , \tag{2}$$

where ε_t is white noise. Subtracting DE_{t-1} from both sides, equation (2) can be re-written as follows:

$$DE_t - DE_{t-1} = \Delta DE_t = (\rho - 1) \cdot DE_{t-1} + \varepsilon_t \quad . \tag{3}$$

Substituting equation (1) into equation (3), the following equation can be derived:

$$\Delta y_t^{Taiwan} - \hat{\beta}_1 \Delta y_t^{US} = (\rho - 1) \cdot \left(y_{t-1}^{Taiwan} - \hat{\beta}_0 - \hat{\beta}_1 y_{t-1}^{US} \right) + \varepsilon_t \quad . \tag{4}$$

From equation (4), the usual ECM form can be obtained,

$$\Delta y_t^{Taiwan} = \alpha \cdot \left(y_{t-1}^{Taiwan} - \hat{\beta}_0 - \hat{\beta}_1 y_{t-1}^{US} \right) + \hat{\beta}_1 \Delta y_t^{US} + \varepsilon_t \quad , \tag{5}$$

where $\alpha = \rho - 1$. Hence, the speed of the adjustment to disequilibrium between the real GDP of Taiwan and the U.S. is the absolute value of α. First, this study examines the data under this ECM framework. Next, we expand the ECM framework to measure the strength of the co-movement.

The OLS estimation results of the ECM in the sample period of 1991Q1-2005Q4 are provided below, where the number inside the parentheses denotes the standard error and the number inside the brackets denotes the t-ratio. It is clear that the coefficient of adjustment is -.35425 which is negative and significantly different from zero.

$$\begin{array}{lllll} \Delta y_t^{Taiwan} = -.35425 \cdot y_{t-1}^{Taiwan} & + \; .00371 \cdot y_{t-1}^{US} & + \; .00901 \cdot \Delta y_t^{US} & - 10.25345 & \\ \quad (.09892) & \quad (.00105) & \quad (.00349) & (3.24279) & (6) \\ \quad [-3.581] & \quad [3.529] & \quad [2.578] & [-3.162] & \end{array}$$

$\overline{R}^2$=0.17243, DW=2.00166

The usual ECM form is as follows:

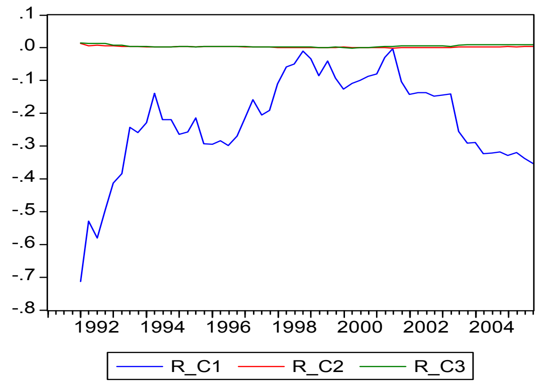
$$\Delta y_t^{Taiwan} = -.35425 \cdot \left(y_{t-1}^{Taiwan} + 28.94411 - .01047 \cdot y_{t-1}^{US} \right) + .00901 \cdot \Delta y_t^{US} \quad . \tag{7}$$

The level-terms in the parenthesis combine to form a disequilibrium term, and the negative coefficient of adjustment implies that whenever the output of Taiwan exceeds a equilibrium level which is supported by the output of the U.S., the output of Taiwan will fall next period to eliminate this disequilibrium.

A larger absolute value for the coefficient of adjustment implies a faster speed of adjustment. Since the coefficient of adjustment is negative, a larger absolute value for the coefficient of adjustment means that less time will be needed to take real GDP back to the long run equilibrium. If the coefficient of adjustment can be traced through time, a speed of adjustment series will be generated to be used as a measure of the proximity of international business cycles in the two-country model.

First, simple recursive OLS estimations by expanding the sample period over time might provide some insight in this direction. Figure 3 represents the recursive estimates of the explanatory variables in equation (6). The series of recursive estimates of the coefficient of adjustment is denoted by R_C1. In addition, R_C2 and R_C3 represent the output of the U.S. and the differenced output of the U.S., respectively. Note that R_C4 (a constant term) is not shown here to make the relative magnitudes of variations in the other variables clear. This figure indicates that the recursive estimates of α (R_C1), which measures the speed of adjustment for disequilibrium, are more volatile than other variables.

Figure 3 Recursive estimation for the ECM



From the previous discussion, the coefficient of adjustment is variable over time. The disequilibrium term is examined under a time-varying-parameter (TVP) model, in which the regression coefficient is time varying. This model is considered in the following two-stage procedure. First, the disequilibrium series can be generated in the usual way,

$$DE_t = y_t^{Taiwan} - \hat{\beta}_0 - \hat{\beta}_1 y_t^{US} .$$

This equation is the same as equation (1).

Next, the following state space form can be used to represent the dynamics of the model:

$$\begin{cases} DE_t = \rho_t \cdot DE_t + \varepsilon_{1,t} \\ \rho_t = \rho_{t-1} + \varepsilon_{2,t} \\ \varepsilon_{1,t} \sim NID(0, \sigma_1^2) \\ \varepsilon_{2,t} \sim NID(0, \sigma_2^2) \end{cases} . \tag{8}$$

In order to estimate the time-varying parameter, we apply the Kalman filter which is a recursive procedure for computing optimal estimates of the unobservable-state variable (Kim and Nelson, 1999). The prediction and updating steps in the basic filter can be used to calculate $\rho_{t|t-1}$. The results are represented in Table 2 and Figure 4.

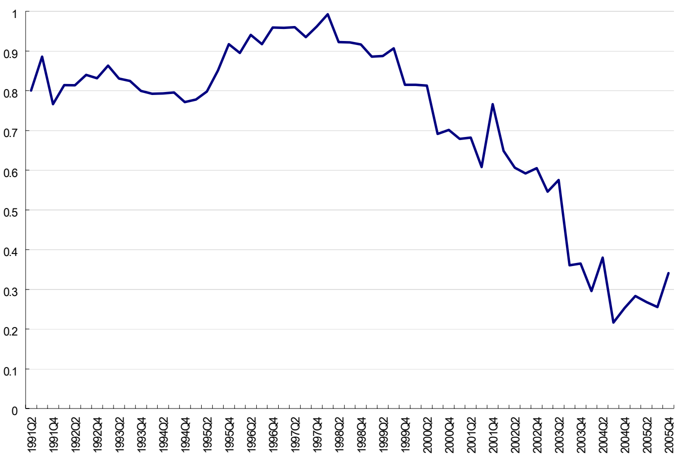
Table 2 Parameter estimates of the TVP model

σ_1	1.1056 (0.1151)
σ_2	0.0746 (0.0404)

Log Likelihood	-76.8176

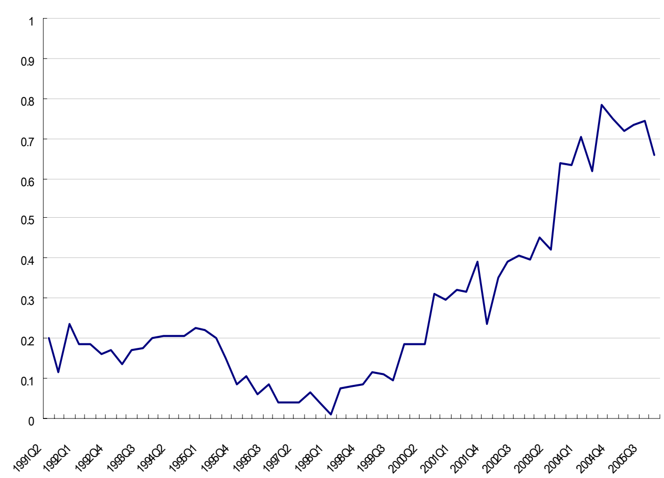
Note: Standard errors are in the parentheses.

Figure 4 Time-varying regression coefficient: ρ_t



Therefore, the implied time-varying speed of adjustment is the absolute value of ρ_t-1, which is plotted in Figure 5. $|\rho_t - 1|$ can be considered to be a measure of the strength of the relation of international business cycles in the two-country model. Specifically, we analyze it through the trading and financial channels.

Figure 5 Implied time-varying speed of adjustment, i.e. $|\rho_t - 1|$



3.2 Understanding the international linkages through the trading and financial channels

In Figure 6, the trade data of the U.S. and Taiwan indicate that the ratio between exports to the U.S. and the GDP of Taiwan is stable over time. The ratio between imports to the U.S. and the GDP of Taiwan, and the ratio of the total trade value between the U.S. and Taiwan over the GDP of Taiwan also show a similar pattern. Since the total trade value of Taiwan as a percentage of the GDP of Taiwan is increasing in the second half period, the ratio of the total trade value between the U.S. and Taiwan over the total trade value of Taiwan decreases in the same period.

Figure 6 Some ratios of trading data

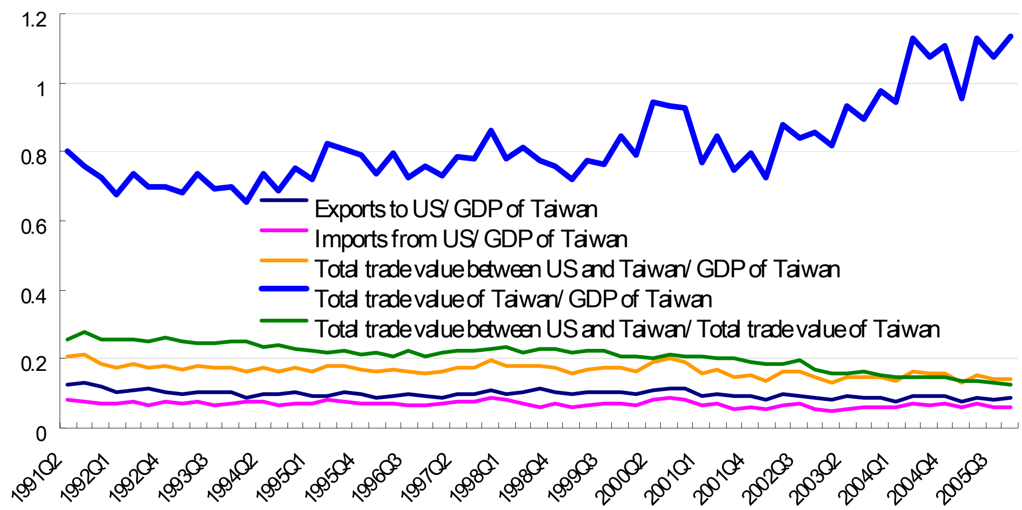
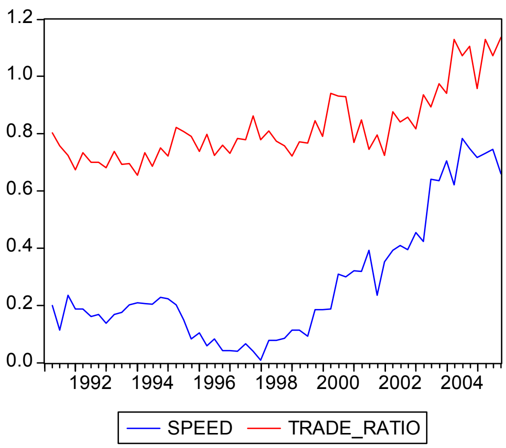
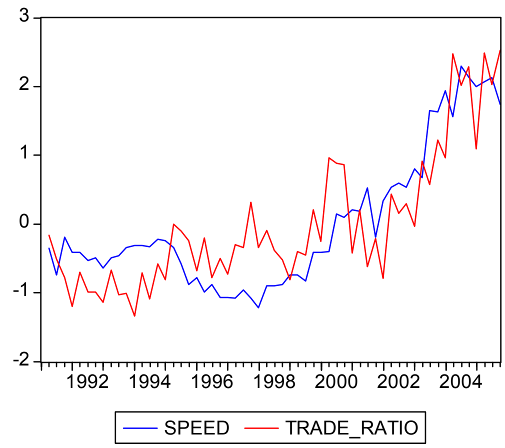


Figure 7 compares the trade ratio constituted by the ratio of the total trade value between the U.S. and Taiwan over the total trade value of Taiwan and the speed of adjustment between Taiwan and US output by using original and standardized data. A common pattern of these two series is that they both increase in the second half of the sample period. The results of a simple regression of the speed of adjustment on the trade ratio are tabulated in first three rows of Table 3 which indicate that the trade ratio has a significant effect in explaining the variation of the speed of adjustment. The trade ratio used here is the total trade value of Taiwan as a percentage of the GDP of Taiwan. One explanation for this is that the U.S. in the whole international trade environment plays an important leading character as a final demander. So, the total foreign trade of Taiwan may be affected by the U.S. through direct or indirect ways.

Figure 7 Trade ratio and the speed of adjustment (original and standardized data)





Note: trade_ratio is the ratio between the total trade value of Taiwan and the GDP of Taiwan

As for the financial channel, this paper examines two indicators (interest rate difference, stock return difference) which measure the strength of financial integration. Specifically, the interest rate difference represents the absolute value of the difference between the federal funds rate in the U.S. and the overnight interest rate in Taiwan. The stock return difference is measured by the absolute value of the difference between the year-over-year (YOY) return of the S&P500 index and the YOY return of the Taiwan-weighted stock index. Figure 8 shows these two measures for financial integration between the U.S. and Taiwan. Both measures show decreasing patterns in the sample period.

The results of a simple regression of the speed of adjustment on the interest rate difference are tabulated in the fourth and fifth rows of Table 3 which indicate that there is no significant evidence that the interest rate difference has an effect in explaining the variation of the speed of adjustment. The results of the speed of adjustment on the stock return difference are tabulated in the sixth and seventh rows of Table 3 which indicate that the stock return difference has a significant effect in explaining the variation of the speed of adjustment. This negative coefficient implies that the integration of international financial sectors will increase the speed of adjustment.

The estimation results with other combinations of regressors are shown in the rest of Table 3. Combing the trading and financial sectors, the trading sector seems to play a more important role on the speed of adjustment. The coefficient is positive and significant. The coefficients for financial sectors are both insignificant.

Figure 8 Financial Link Measures

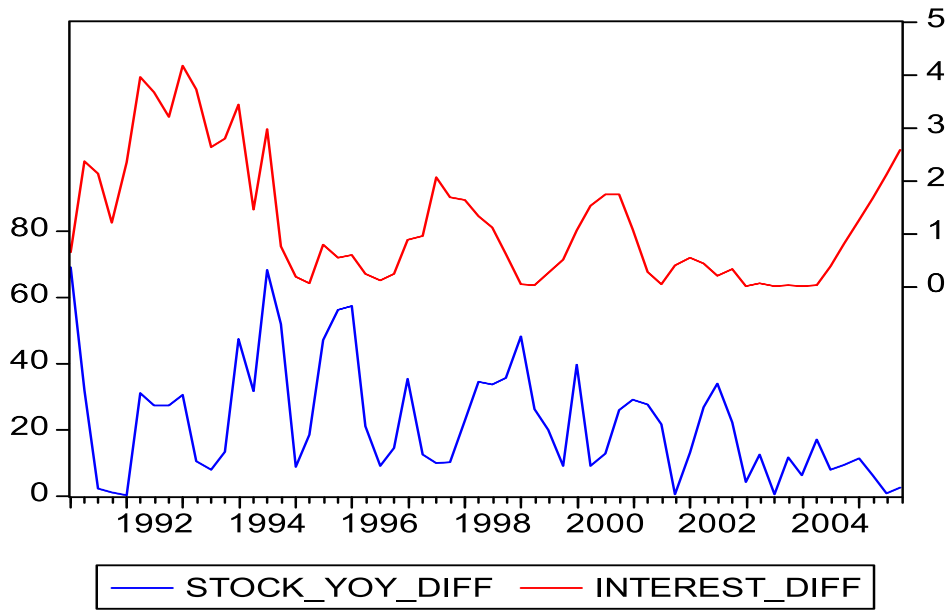


Table 3 Regressing Adjustment Speed on Various Regressor Set involving Financial Link Measures

Variable	Coeff.	Std. Error	t-Statistic	Prob.		
Trade_ratio	1.408	0.143	9.834	0.000	Adj. R-squared	0.623
Constant	-0.880	0.119	-7.400	0.000	Durbin-Watson	0.952
Interest rate diff.	-0.036	0.024	-1.472	0.146	Adj. R-squared	0.020

Constant	0.321	0.041	7.746	0.000	Durbin-Watson	0.084
Stock return diff.	-0.005	0.002	-3.313	0.002	Adj. R-squared	0.147
Constant	0.393	0.044	8.932	0.000	Durbin-Watson	0.288
Trade_ratio	1.336	0.156	8.582	0.000	Adj. R-squared	0.625
Stock return diff.	-0.001	0.001	-1.155	0.253	Durbin-Watson	0.966
Constant	-0.792	0.141	-5.611	0.000		
Trade_ratio	1.342	0.162	8.282	0.000	Adj. R-squared	0.618
Interest rate diff.	0.003	0.016	0.163	0.871	Durbin-Watson	0.972
Stock return diff.	-0.001	0.001	-1.141	0.259		
Constant	-0.800	0.152	-5.268	0.000		

4 Conclusions

As a small economy, Taiwan's output is greatly affected by the output of foreign countries. The purpose of this paper is to offer some additional insight on the co-movement of the output of the U.S. and Taiwan. This study explores the possible linkages of international business cycles under a two-country model aimed at U.S. and Taiwan. The impact of the US economy on the economy of Taiwan is hypothesized to pass through two main channels: trading and financial sectors. Specifically, this paper extends the ECM framework to derive an implied time-varying speed of adjustment whose absolute value could be considered as a measure of the strength of the relationship between international business cycles in the two-country model.

The empirical results reveal that the trade ratio has a significant effect in explaining the variation of the speed of adjustment. The trade ratio used here is the total trade value of Taiwan as a percentage of the GDP of Taiwan. One explanation for this is that the U.S. in the whole international trade environment plays an important leading character as a final demander. So, the total foreign trade of Taiwan may be affected by the U.S. through direct or indirect ways. As for the financial channel, stock return difference is used to measure the strength of financial integration. The empirical results regressing the speed of adjustment on the stock return difference indicate that the stock return difference has a significant effect in explaining the variation of the speed of adjustment. This negative coefficient implies that the integration of international financial sectors will increase the speed of adjustment.

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