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RE-TESTING LIQUIDITY CONSTRAINTS IN TEN ASIAN DEVELOPING COUNTRIES

This paper suggests that the strength or weakness of the economy can affect short-run consumption and consumer borrowing in the credit markets, and that these behavioural changes are key factors determining liquidity constraints. A nonlinear threshold model is developed, with the threshold variable of the real GDP growth dividing the model into two regimes: strong economy and weak economy. The model is used to test again for liquidity constraints on consumers in the ten Asian countries analyzed in Habibullah et al. (2006). Of the ten countries, seven are found to exhibit nonlinearity in their consumption data. This confirms that levels of economic growth affect the proportion of consumers who are liquidity-constrained. Weak economic growth is found to be associated with higher levels of liquidity constraints, and strong economic growth with lower levels of constraints.

JEL Classification Code: E21, E32, C22

Keywords: business cycle, liquidity constraints, permanent income hypothesis, threshold model

1. INTRODUCTION

There have been two main approaches to determining the proportion of liquidity-constrained consumers in an economy. The first is the Euler equation approach. This approach, which was proposed by Hall (1978), is based on the estimation of the intertemporal first-order condition for the optimal choice of a fully forward-looking representative consumer. The second is the error-correction model approach which was popularized by Davidson et al. (1978) and Hendry and von Ungern-Sternberg (1981).

Hall (1978) introduces into the Euler equation the assumptions that consumers are rational and forward-looking, and uses U.S. macroeconomic time series data to test the approach. He finds that regression of consumption on current income is not significant. This is consistent with the permanent income hypothesis/life cycle hypothesis (PIH/LCH). However, researchers examining data from other countries have found that consumption levels are strongly

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affected by current income. Hence, there is excess sensitivity to current income level among consumers, in contradiction to the expectations of the PIH/LCH.

Most of the literature discussing problems with the PIH/LCH has focused on liquidity constraints (see Flavin, 1985; Hayashi, 1987; Jappelli and Pagano, 1989, 1994; Zeldes, 1989; Campbell and Mankiw, 1989, 1990, 1991; Deaton, 1991). Liquidity constraints prevent consumers from adopting consumption strategies based on permanent income, and force them to consume based on their current level of income. Other issues have also been discussed. Hall and Mishkin (1982), Zeldes (1989), Runkle (1991) and Attanasio and Weber (1993) have noted the problem of aggregation bias when using macroeconomic data. Caballero (1990) and Carroll (1997) point out the phenomenon of precautionary saving. Baxter and Jermann (1999) note that home production and consumption have an inverse relationship with marketplace production and consumption. Flavin (1985, 1993) and Shea (1995) note that myopia is one of the characteristics of consumers. All of these factors are potential constraints which may cause a consumer's spending to be limited by their current income. This study focuses on liquidity constraints, and attempts to assess whether liquidity constraints affect the behaviour of consumers.

Generally, the ability of a consumer to borrow in the credit markets is an important index of whether the consumer is liquidity-constrained. Hayashi (1987) notes that transaction costs and asymmetries of information between borrowers and creditors are the cause of interest spread. Where the credit market is imperfect, the supply and demand sides of the capital markets possess different information, and a consumer's current income and income trend may be the key indices by which a lender decides whether or not to lend. Thus in a market with asymmetrical information, consumer borrowing may be limited; current income may be the primary factor determining levels of consumption.

The strength of the economy can have an impact on consumers' incomes, and thereby affect the ability of consumers to borrow in the credit markets. In a strong economy, there are more opportunities to work, and credit institutions make more positive assessments of the consumers' ability to repay debts. Lending policies become looser, and consumers are able to borrow the capital they need from credit organizations more easily. In a weak economy, financial institutions fear that economic problems will reduce consumers' ability to repay debts. They therefore adopt stricter lending policies to avoid generating bad debt, and borrowing becomes more difficult for consumers.

Davidson et al. (1978) and Hendry and Ungern-Sternberg (1981) were the first to measure liquidity constraints using an error correction model. More recently, Habibullah et al. (2006) have used a single-equation error-correction methodology to determine whether liquidity constraints exist in ten Asian countries (Indonesia, Malaysia, Myanmar, Nepal, Philippines, Singapore, South Korea, Sri Lanka, Taiwan and Thailand), and whether financial liberalization has reduced liquidity constraints. The study finds the lowest level of liquidity constraints in Taiwan, and the highest in Nepal. However, we believe that in an economy with imperfect credit markets that is affected by a business cycle of economic upturns and downswings, a linear (symmetrical) model is inappropriate. We therefore assume the level of liquidity constraints in a country may vary with the perfection of its credit markets and the strength of its economy.

Generally, there is some economic variation over the business cycle. This variation causes nonlinear changes (fluctuations, limited cycles) in other economic variables. Linear models, which ignore non-linear relations between variables, therefore inevitably produce skewed results. Unfortunately Davidson et al. (1978), Hendry and Ungern-Sternberg (1981) and Habibullah et al. (2006) all apply linear error-correction models to time series data, ignoring the possibility of nonlinear relations between variables. In this paper it is proposed that taking into account economic changes over the business cycle would alter the conclusions of Habibullah et al. (2006), because economic strength or weakness is a factor of the existence and level of liquidity constraints. We therefore introduce a nonlinear threshold model, with real GDP growth as the threshold variable. Two regimes are defined: strong economy and weak economy. Using this model, we reassess the existence and level of liquidity constraints in the ten Asian countries over a longer sample period than Habibullah et al. (2006). There have been many papers applying threshold models to related issues, e.g. Tsay (1989, 1998), Berthelemy and Varoudakis (1995), De Gregorio and Guidotti (1995), Hansen (1996, 1999), Chen et al. (2003), Huang and Yang (2004), Huang et al. (2005). These models address finance, production, price shocks, etc., and could easily be applied to the questions addressed in this paper.

The consumption patterns of seven of the ten countries (Indonesia, Philippines, Singapore, South Korea, Sri Lanka, Taiwan, and Thailand) show nonlinear features. A nonlinear model is developed for each of them, using economic growth as the threshold variable. Most of these models support the existence of liquidity constraints. This suggests that consumers do adjust their behaviour based on their current income, in contradiction to the PIH/LCH. This general conclusion is largely in accord with the findings of Habibullah et al. (2006). However, our results also show that there are more rigorous liquidity constraints when the economy is weak than when it is strong. That is to say, credit organizations are more conservative in their lending behaviour when the economy is weak, causing more demanding liquidity constraints.

The remainder of the paper is organized as follows. In Section 2, the theoretical background is discussed and the experimental model developed. Section 3 explains the results of the empirical tests. A conclusion follows in Section 4.

2. THEORETICAL BACKGROUND AND EMPIRICAL MODEL

2.1. Theoretical background

According to the PIH/LCH, the utility function of a rational consumer pursuing the greatest utility over their lifetime is as follows:

$$E_t \sum_{j=0}^{\infty} \left(\frac{1}{1+\delta} \right)^j U\left(C_{t+j}\right) \rightarrow \max \tag{1}$$

where E_t is the conditional expectation; C_t is actual consumption at time t; δ is the rate of subjective time preference (>0). $U(C_t)$ is the utility function at time t. Assuming constant relative risk-aversion (CRRA), $U(C_t)=C_t^{1-\alpha}/(1-\alpha)$, $\alpha>0$, $U'>0$, $U<0$. Consumers attempting to maximize their lifetime utility face the following budget constraints:

$$A_{t+j+1} = (1+r_{t+j})(A_{t+j} + Y_{t+j} - C_{t+j}) \tag{2}$$

A_t is real assets at time t; r_t is the real interest rate; and Y_t is real income.

Because of asymmetries in the information available to lenders and borrowers in the credit markets, lenders cannot be certain of the future ability of borrowers to repay their debts. Lenders therefore select conservative lending strategies in order to guarantee their investments and to prevent moral hazard or adverse selection. They can make their assessments of potential borrowers only based on the information available to them at the time of the demand for capital. Shefrin and Thaler (1988) suggest that the current trend in a consumer's wealth is a major factor in whether she is able to obtain the finance she requires from the credit markets. Telmer (1993) and Lucas (1994) point out that the upper limit on the credit that consumers can obtain falls within a certain proportion (usually between 10% and 40%) of their current total incomes or individual incomes. Aiyagari (1994) defines the borrowing limit as the consumer's minimum income divided by the return on assets. Zhang (1997) follows Aiyagari (1994), but suggests that the rate of a consumer's income growth is another important factor in the limit on the credit they can obtain, as well as the consumer's minimum income divided by the return on assets. All of these papers agree that when borrowers and lenders have access to different information, consumers' current income and current income trends are important factors in the decision of the lender to lend or not. Consumers therefore face an upper limit to credit availability as follows:

$$A_{t+j+1} \geq -L_{t+j}(Y_{t+j}) \qquad j = 1,\ldots,\infty \tag{3}$$

where L_t is the credit limit at time t. In a credit market with information asymmetries, the credit limit conditions should be linked to current income and current income trends. Particularly where a consumer's current income is higher than previously, there will be relatively lax limits on their credit. One possible formula representing this form of credit constraint is: $L_{t+j}(Y_{t+j}) = kY_{t+j}(Y_{t+j}/Y_{t+j+1})^{\theta}$, where $k > 0$, $\theta \geq 1$. The key feature of this condition is that the credit constraint varies with income and income trend, so the credit constraints faced by consumers vary with time. This represents a clear departure from the assignment of a fixed credit limit in previous studies, including Aiyagari (1994) and Zhang (1997). Given this credit constraint condition, a consumer's optimum lifetime utility strategy must take into account credit constraints (L_t) as well as interest rates and their subjective time preference.

In reality, decisions on the granting of credit are closely linked to current income and current income trends, but Williamson (1987), Greenwald and Stiglitz (1993), and Gertler and Gilchrist (1994) all point out that the strength of the economy is also an important factor. When the economy is weak, lenders in the credit markets tend to be more conservative as they attempt to avoid a credit crunch. This conservatism is reflected in an increased emphasis on consumers' current income and current income trends. When the economy is growing strongly, lenders assume that borrowers' ability to repay debts will improve in the future, and decisions on lending are no longer limited by current income or current income trends. The condition (3) therefore only holds as a credit constraint for consumers during economic downturns.

$$A_{t+j+1} \geq -L_{t+j}(Y_{t+j}) \qquad q_{t+j} \leq \gamma \tag{4}$$

where q_t is an index of economic strength at time t; γ is the threshold value for a strong or weak economy. This represents the effect of the economy on consumer borrowing: credit limits only affect consumers' long-term consumption strategies when the economy is weak. In other words, when the economy is strong (the index is above the threshold value γ), consumers' optimum strategies for resource allocation will not be affected by limits on the availability of credit. Consumers pursuing their maximum lifetime utility will thus be limited only by the interest rate r and their subjective time preference δ. These consumers will make consumption decisions based on their permanent income. When the economy is weak, and the index is below the threshold value γ, consumers who attempt long-term allocation of resources will be restricted by liquidity constraints. Their strategy for optimum consumption will be limited not only by the interest rate r and their subjective time preference δ, but also by credit restrictions.

This discussion includes several testable hypotheses. One is that when the economy is strong, consumer borrowing is less restricted, and consumer behaviour will approximate more closely to the permanent income hypothesis. But when the economy is weak, credit limits will affect consumer behaviour by limiting consumers' ability to borrow. Under these circumstances, the PIH will not hold, and consumption will be strongly affected by current income.

However, Campbell and Mankiw (1990, 1991) present a different view. They assume that not every consumer in an economy is pursuing their maximum permanent utility. They divide consumers into two groups: the first group makes consumption decisions based on a “rule of thumb,” in which consumption is determined by current income, not permanent income; the other group pursues the maximum utility over their lifetime, and so makes consumption decisions based on their permanent income. However, the authors do not explain clearly why a single economy should contain two such markedly different groups of consumers, or why it should produce such sharply different consumption strategies.

2.2. Empirical model building

This paper still proposes that consumers rationally seek to maximize their utility, but we may discover current income having an effect on consumption time series data because of liquidity constraints. We also particularly consider the potential impact on consumer behaviour of information asymmetries in the credit markets, so the effect of overall economic performance on lending and borrowing in the credit markets is also incorporated into the model. This departs from the analysis in Habibullah et al. (2006), and should more accurately reflect consumer behaviour under liquidity constraints. Using a linear ECM and ARDL model, Habibullah et al. (2006) find liquidity constraints in all ten countries they examine.

In (4) the performance of the economy (whether the economic index is above or below the threshold value) determines whether consumer behaviour varies with current income. In our nonlinear threshold model, Δg_{t-d} is the threshold variable, incorporating a lag d. The threshold variable divides the economy into two regimes, in order to assess whether liquidity constraints exist, and whether there is any difference in a strong and weak economy. Real GDP growth is an appropriate threshold variable because it reflects the strength of the economy, and also meets the condition on threshold variables that they be stationary. The structure of the threshold error correction model (TECM) is as follows:

$$\Delta c_t = \begin{cases} \alpha_1 + \lambda_1 \Delta y_t + \sum_{j=1}^{p} \beta_{1j} \Delta y_{t-j} + \sum_{j=1}^{q} \phi_{1j} \Delta c_{t-j} + \delta_1 ecm_{t-1} + \varepsilon_{1t} & \text{if} \quad I(\Delta g_{t-d} > \gamma) \\ \\ \alpha_2 + \lambda_2 \Delta y_t + \sum_{j=1}^{p} \beta_{2j} \Delta y_{t-j} + \sum_{j=1}^{q} \phi_{1j} \Delta c_{t-j} + \delta_2 ecm_{t-1} + \varepsilon_{2t} & \text{if} \quad I(\Delta g_{t-d} \le \gamma) \end{cases} \tag{5}$$

where γ is the optimum threshold value, dividing the model into two regimes: regime 1, when $\Delta g_{t-d} > \gamma$, the economy is strong, and the dummy variable $I(\Delta g_{t-d} > \gamma) = 1$; otherwise it is 0; and regime 2, when $\Delta g_{t-d} \le \gamma$, the economy is weak, and the dummy variable $I(\Delta g_{t-d} \le \gamma) = 1$; otherwise it is 0. The error correction term ecm_{t-1} is $(c_{t-1} - a - by_{t-1})$. In (5), if δ_i (i=1,2) is significant and negative, this indicates that consumers adjust consumption in response to short-run changes in income, as well as to previous disequilibria $(c_{t-1} - a - by_{t-1})$, which can be interpreted as a feedback response to obtain a desired long-run condition. If there is no cointegration, then the error term ecm_{t-1} is deleted. The parameter λ_i is then used to measure the fraction of consumers who are liquidity-constrained (according to the Euler equation in Blundell-Wignal et al., 1995; Habibullah et al., 2006).

When λ_i is significantly different from 0, there are liquidity constraints, and the PIH/LCH does not hold. This demonstrates that the impact of current income on consumer behaviour varies with economic performance. Habibullah et al. (2006) also find that there is no cointegration for some countries. They therefore use an ARDL model to test the effect of the error correction term on consumption. In this paper, a different test is used. Where there is no cointegration, we construct a threshold auto-regression (TAR) model for the test. The model proposed by Hansen (1996, 1999, 2000) is also used to carry out a test of linearity, to determine that a nonlinear model is applicable to the ten Asian nations. Before estimating TAR or TECM models, it is necessary to confirm the existence of a threshold effect, by testing the null hypothesis of a linear AR or ECM model, with the nonlinear TAR or TECM as the alternative hypothesis. Please see Appendix A for a detailed discussion of the estimation procedures.

2.3. Weak exogeneity of income in a nonlinear structure

Habibullah et al. (2006) add real exports per capita and total population figures to their model (equation (5), p. 2538), and test for the weak exogeneity of income (y_t). When the coefficient of the error correction term is 0, the weak exogeneity of income is taken to be demonstrated. However, we believe that where the data is nonlinear, this procedure is not sufficient to establish the weak exongeneity of incomes. We therefore develop a nonlinear autoregression based on (5):

$$\Delta y_t = \begin{cases} \pi_{01} + \sum_{i=1}^{p} \pi_{11} \Delta y_{t-1} + \sum_{i=1}^{p} \pi_{21} \Delta c_{t-1} + \sum_{i=1}^{p} \pi_{31} \Delta x_{t-1} + \sum_{i=1}^{p} \pi_{41} \Delta pop_{t-1} + \pi_{51} ecm_{t-1} + \omega_{1t}, \text{ if } \Delta g_{t-d} > \gamma \\ \pi_{02} + \sum_{i=1}^{p} \pi_{12} \Delta y_{t-1} + \sum_{i=1}^{p} \pi_{22} \Delta c_{t-1} + \sum_{i=1}^{p} \pi_{32} \Delta x_{t-1} + \sum_{i=1}^{p} \pi_{42} \Delta pop_{t-1} + \pi_{52} ecm_{t-1} + \omega_{2t}, \text{ if } \Delta g_{t-d} \le \gamma \end{cases} \quad (6)$$

x_t denotes real exports per capita; pop_t denotes total population. If $\pi_{51} = 0$, then incomes are weakly exogeneous when the economy is strong; if $\pi_{52} = 0$, then incomes are weakly exogeneous when the economy is weak. If there is no cointegration, then ecm_{t-1} will be deleted from (6).

3. DATA AND EMPIRICAL RESULTS

The ten Asian countries included in this study are the same as those in Habibullah et al. (2006): Indondesia, Malaysia, Myanmar, Nepal, Philippines, Singapore, South Korea, Sri Lanka, Taiwan, Thailand. The model is estimated country by country using annual data, with the sample period expanded to cover 1950-2006 (the sample period in Habibullah et al. (2006) is 1950 to 1994). Because of a lack of data, the sample period for some of the countries starts later. Table 1 shows the variables used, sample periods and sources of data for each country. The variables included are: (i) Real private consumption per capita, which serves as a measure of household consumption, represented by c_t. (ii) Real income per capita, as a measure of disposable income. Income is measured by GDP, represented by y_t. (iii) Real exports per capita, represented by x_t. (iv) Total population, represented by pop_t. All nominal variables are deflated using the Consumer Price Index (CPI) or GDP deflator. Data was collected from various issues of

International Financial Statistics, published by the International Monetary Fund. All variables were transformed into logarithms.

Table 1
Variables and sample periods

Variable	
c_t : real consumption per capita	
y_t : real income per capita	
x_t :real exports per capita	
pop_t : population	
Country	**Sample period**
Indonesia	1960~2006
Malaysia	1955~2006
Myanmar	1961~2004
Nepal	1975~2004
Philippines	1950~2006
Singapore	1960~2006
South Korea	1953~2006
Sri Lanka	1950~2006
Thailand	1950~2006
Taiwan	1951~2006

Notes: 1. Data for all of the countries except Taiwan was drawn from the International Financial Statistics database maintained by the International Monetary Fund. Data for Taiwan came from the National Statistics website of the R.O.C. See www.stat.gov.tw/mp.asp?mp=4.

2. Nominal values are adjusted using the CPI for most of the sample. However, real values for South Korea, Nepal, Thailand and Taiwan are calculated using the GDP deflator, because the sample period for these countries is shorter.
The base-year is 2000.

Source: own elaboration

Before estimating equation (5), we carried out unit root tests on income and consumption, and tested for cointegration between consumption and income. Both Augmented Dickey-Fuller (ADF) and Phillips and Perron (PP) tests for unit roots were used. Table 2 shows the results of the unit root tests. The results indicate that all the variables are integrated of order 1 (I(1)), in both the constant expressions and those with time-trend. We next tested for cointegration, to determine whether the long-run relationship between income and consumption is stationary.

Table 2. Unit-root tests

		ADF				PP			
		Level		first difference		level		first difference	
		Constant	Constant + Trend	Constant	Constant + Trend	Constant	Constant + Trend	Constant	Constant + Trend
Indonesia	y_t	-0.71[2]	-2.44[2]	-6.53[1]***	-6.48[1]***	-4.12[3]***	-13.10[4]***	-36.34[6]***	-34.52[6]***
	c_t	-4.97[0]***	-25.98[0]***	-33.49[0]***	-2.64[8]	-4.36[4]***	-17.22[4]***	-35.40[3]***	-34.5[3]***
Malaysia	y_t	0.35[0]	-3.95[1]**	-6.36[1]***	-6.30[1]***	0.43[3]	-3.74[1]**	-6.5[4]***	-6.53[4]***
	c_t	0.23[0]	-4.20[1]***	-5.62[0]***	-5.60[0]***	0.18[3]	-3.28[1]*	-5.47[5]***	-5.44[5]***
Myanmar	y_t	-1.92[1]	-7.37[0]***	-13.64[0]***	-13.36[0]***	-5.99[4]***	-7.37[3]***	-13.62[1]***	-13.36[0]***
	c_t	1.11[2]	-0.30[2]	-6.03[1]***	-6.39[1]***	0.56[2]	-1.14[1]	-6.79[1]***	-7.30[5]***
Nepal	y_t	0.30[4]	-1.90[2]	-2.34[3]	-7.57[1]***	1.04[1]	-1.69[1]	-8.26[3]***	-8.97[1]***
	c_t	0.43[1]	-3.31[4]*	-10.52[0]***	-10.49[0]***	0.52[14]	-4.55[1]***	-10.95[2]***	-10.74[1]***
Philippines	y_t	-2.16[1]	-2.69[1]	-6.09[0]***	-6.17[0]***	-1.95[3]	-2.25[2]	-6.05[3]***	-6.12[4]***
	c_t	-2.32[0]	-3.41[1]*	-6.22[0]***	-6.21[0]***	-2.27[1]	-3.46[0]**	-6.14[4]***	-6.13[4]***
Singapore	y_t	-1.08[1]	-1.42[1]	-4.89[0]***	-4.94[0]***	-1.40[1]	-1.20[2]	-4.90[1]***	-4.94[0]***
	c_t	-0.72[2]	-2.84[1]	-4.71[1]***	-4.68[1]***	-0.88[1]	-2.07[1]	-4.61[2]***	-4.54[3]***
South Korea	y_t	1.11[0]	-3.12[0]	-5.66[0]***	-5.77[0]***	0.86[3]	-3.05[3]	-5.70[3]***	-5.82[3]***
	c_t	1.43[4]	-2.73[0]	-4.13[3]***	-4.56[3]***	1.55[8]	-2.91[14]	-6.52[5]***	-6.96[10]***
Sri Lanka	y_t	0.77[0]	-1.94[3]	-7.03[0]***	-7.26[0]***	0.72[2]	-2.11[2]	-7.06[2]***	-7.27[2]***
	c_t	0.41[0]	-3.83[9]**	-7.13[0]***	-7.25[0]***	0.39[1]	-1.83[1]	-7.14[2]***	-7.25[2]***
Thailand	y_t	0.23[1]	-2.69[1]	-4.97[0]***	-4.97[0]***	0.29[4]	-2.33[3]	-4.95[2]***	-4.95[2]***
	c_t	0.80[0]	-2.53[1]	-6.62[0]***	-6.63[0]***	0.75[2]	-2.67[2]	-6.63[1]***	-6.64[1]***
Taiwan	y_t	-0.63[1]	-0.29[0]	-5.01[0]***	-5.01[0]***	-0.84[3]	-0.91[3]	-5.00[2]***	-5.00[2]***
	c_t	0.65[1]	-2.67[1]	-4.45[0]***	-4.54[0]***	0.48[4]	-1.81[3]	-4.47[3]***	-4.49[2]***

Notes: y_t refers to real private consumption per capita; c_t is real income per capita. For the augmented Dickey-Fuller test (ADF), the values in square brackets [ ] are the lag lengths determined using the Akaike information criterion (AIC). For the Phillips and Perron test (PP), the values in square brackets are the bandwidth obtained using the Bartlett kernel method. ***, **, and * denote statistical significance at the 1%, 5%, and 10% level, respectively. For critical values, please refer to MacKinnon (1996).

Source: own elaboration

Table 3 gives the results of the Engle-Granger test for cointegration. There is no cointegration for three of the countries (Philippines, South Korea, and Taiwan); the no cointegration null hypothesis is rejected for the other seven. Therefore, an ECM is used for short-run estimation for Indonesia, Malaysia, Myanmar, Nepal, Singapore, Sri Lanka and Thailand; for the Philippines, South Korea and Taiwan, an autoregression (AR) model is used.

Table 3
Engle-Granger cointegration test

	ADF		PP	
	Constant	Constant + Trend	Constant	Constant + Trend
Indonesia	-3.46[0]**	-3.10[0]	-3.18[3]**	-3.26[3]*
Malaysia	-4.14[1]***	-4.70[1]***	-3.78[3]***	-3.67[4]**
Myanmar	-3.87[2]**	-2.94[2]	-5.40[3]***	-5.26[2]***
Nepal	-3.82[2]**	-3.74[2]*	-3.88[4]***	-3.85[4]**
Philippines	-2.41[7]	-1.85[7]	-2.67[4]	-2.70[4]
Singapore	-3.52[1]**	-3.84[1]*	-2.58[3]*	-2.55[2]
South Korea	-2.50[0]	-1.99[0]	-1.94[7]	-1.76[8]
Sri Lanka	-3.70[0]**	-3.68[0]*	-3.62[4]***	-3.60[4]**
Taiwan	-1.88[1]	-1.78[2]	-0.89[0]	-0.82[5]
Thailand	-3.43[0]*	-3.66[0]*	-3.389[2]**	-3.272[3]*

Notes: The long-run equation can be represented as $c_t = a + by_t + e_t$. ***, **, and * denote statistical significance at the 1%, 5%, and 10% level, respectively. For ADF test, the critical values with no trend at the 1%, 5%, and 10% level are -4.094, -3.445, and -3.119; the critical values with trend at the 1%, 5%, and 10% level are -4.609, -3.951, and -3.623, please refer to Table 1 in MacKinnon (2010).

Source: own elaboration

Table 4 shows the results of the short-run ECM and AR model estimations. λ is significantly different from 0 for all ten countries, and falls between 0 and 1 for each country, with Myanmar the highest at 0.886, and Taiwan the lowest at 0.364. These linear estimations suggest that there are liquidity constraints in all ten countries, so the PIH does not hold. This result agrees with Habibullah et al. (2006), and suggests that consumption is excessively sensitive to current income.

Table 4

Results from error-correction and autoregressive models

	Indonesia	Malaysia	Myanmar	Nepal	Philippines
Model	ECM	ECM	ECM	ECM	AR
constant	0.012	-0.002	0.005	-0.001	0.004
	(1.15)	(-0.31)	(0.971)	(-0.11)	(1.189)
Δy_t	0.595***	0.666***	0.886 ***	0.802***	0.544***
	(4.20)	(6.14)	(10.71)	(5.55)	(7.399)
ecm_{t-1}	-0.126*	-0.459***	-0.790***	-0.487***	
	(-1.92)	(-4.21)	(-3.36)	(-3.49)	
Δc_{t-1}	0.045***	0.261***		-0.123	-0.049
	(3.20)	(5.50)		(-1.06)	(-0.541)
Δc_{t-2}		0.021		0.321**	0.036
		(0.37)		(2.52)	(0.410)
R^2	0.565	0.757	0.903	0.818	0.529
SER	0.049	0.027	0.036	0.014	0.021
DW	2.132	1.885	1.711	1.908	2.028
LM(1)	0.257	0.705	2.195	0.145	0.139
	[0.613]	[0.401]	[0.138]	[0.704]	[0.710]
ARCH(2)	1.178	0.631	0.755	1.231	0.221
	[0.555]	[0.730]	[0.686]	[0.540]	[0.895]
	Singapore	South Korea	Sri Lanka	Taiwan	Thailand
Model	ECM	AR	ECM	AR	ECM
constant	0.003	0.010	0.005	0.001	0.010
	(0.640)	(0.928)		(0.160)	(1.488)
Δy_t	0.614***	0.711***	0.846***	0.364***	0.661***
	(7.912)	(5.305)	(6.78)	(3.168)	(4.205)
ecm_{t-1}	-0.254***		-0.365***		-0.395**
	(-3.516)		(-4.05)		(-2.665)
Δc_{t-1}	0.500***	0.089		0.340***	0.065
	(4.071)	(0.780)		(2.863)	(0.397)
Δc_{t-2}		-0.206			-0.026
		(-1.809)			(-0.414)
Δc_{t-3}					
Δy_{t-1}	-0.322**			0.218*	-0.093
	(-2.430)			(1.685)	(-0.551)
R^2	0.728	0.399	0.575	0.439	0.654
SER	0.025	0.036	0.032	0.022	0.023
DW	1.938	2.227	1.677	2.121	1.971
LM(1)	0.653	2.528	3.530*	0.737	0.073
	[0.419]	[0.112]	[0.060]	[0.391]	[0.786]
ARCH(2)	8.887**	2.119	1.107	2.075	0.333
	[0.017]	[0.347]	[0.575]	[0.354]	[0.847]

Source: own elaboration

Notes: ecm_{t-1} is the error-correction term. SER and DW denote standard error of regression and Durbin-Watson statistic, respectively. LM(N) and ARCH(N) are Lagrange multiplier tests for N-order serial correlation and autoregressive conditional heteroskedasticity, all two tests are asymptotically distributed as Chi-square. Figures in parentheses () and square brackets [ ] are t-statistics and p-values, respectively. ***, **, and * denote statistical significance at the 1%, 5%, and 10% level, respectively.

In order to determine whether consumption is affected by information asymmetries in the credit markets and the strength of the economy, it is necessary to test for nonlinear features in the model. Table 5 reports the results of the linearity tests, using Δg_{t-d} as the threshold variable, with a null hypothesis of linearity. There was insufficient data to develop both linear and nonlinear models for Nepal, but the null hypothesis is rejected for seven countries: Indonesia, Philippines, Singapore, South Korea, Sri Lanka, Taiwan, and Thailand. For these countries, it is therefore necessary to develop nonlinear models. The lag *d* for Indonesia and Thailand was 3; for South Korea and Taiwan, 2; for the Philippines, Singapore and Sri Lanka, 1. This means that in the Philippines, Singapore and Sri Lanka, short-run nonlinear adjustments to consumption correlate with the previous year's real economic growth. The reaction time is fairly short. For the other four countries, the reaction time is two or three years. Comparing the threshold values for each country, Singapore's is the largest at 0.119; South Korea's is the smallest at 0.045. Singapore therefore needs fairly fast growth to reach the threshold for a "strong economy"; in South Korea, slower growth is sufficient.

Table 5
Linearity test

	Indonesia	Malaysia	Myanmar	Nepal	Philippines
Type of model	ECM	ECM	ECM	-	AR
F-statistic	3.654*	2.275	3.469	-	3.783*
	(0.099)	(0.466)	(0.163)	-	(0.078)
Lag (d)	3	2	2	-	1
Lag (γ)	0.101	0.097	0.049	-	0.051
	Singapore	**South Korea**	**Sri Lanka**	**Taiwan**	**Thailand**
Type of model	ECM	AR	ECM	AR	ECM
F-statistic	4.194**	5.019**	4.303*	3.662*	3.543*
	(0.048)	(0.029)	(0.072)	(0.093)	(0.070)
Lag (d)	1	2	1	2	3
Lag (γ)	0.119	0.045	0.080	0.115	0.077

Source: own elaboration

Notes: Values in the parentheses are the p-values of the chi-square statistics. ** and * denote statistical significance at the 5% and 10% level, respectively.

These results suggest that information on past economic performance (expressed as the lag *d* and the value of the threshold variable) is sufficient to cause asymmetry in the behaviour of consumers. This confirms that it is necessary to consider the restrictions on consumer lending determined by the strength of the economy. An analysis which uses only a linear model to determine relationships between variables may result in skewed results. Figure 1 shows consumption for each country plotted against the strength of the economy. The white regions represent years of a strong economy; grey years represent a weak economy. Of the seven countries plotted, six have more years of weak economy than strong. The exception, South Korea, has more years of strong economy because it has a particularly low threshold value between weak and strong economies.

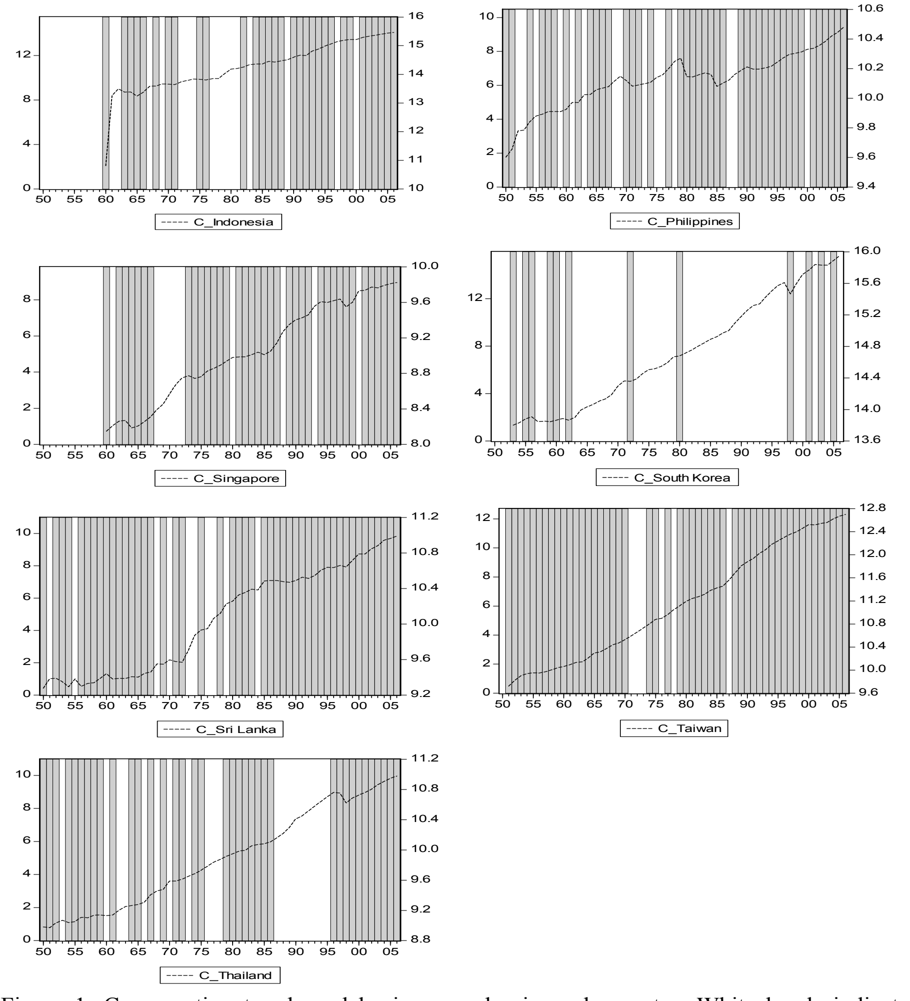

Figure 1. Consumption trends and business cycles in each country. White bands indicate strong economy, grey bands indicate weak economy.
Source: own elaboration

Table 6. Results from threshold model

Variable	Indonesia	Philippines	Singapore	S. Korea	Sri Lanka	Taiwan	Thailand
Model	TECM	TAR	TECM	TAR	TECM	TAR	TECM
Regime1							
constant	0.002	0.017	-0.020	0.013	0.029***	0.013***	-0.014
	(0.247)	(6.829)	(-0.264)	(1.084)	(2.597)	(4.541)	(-1.341)
Δy_t	0.549***	0.323***	0.329***	0.639**	0.799***	0.097	0.739***
	(7.653)	(7.593)	(4.535)	(2.301)	(4.266)	(1.314)	(8.549)
ecm_{t-1}	-0.278***		-0.158		0.247		0.336
	(-3.111)		(-0.667)		(0.778)		(0.959)
Δc_{t-1}	-0.125	-0.291***	0.307	0.033		0.861***	-0.377
	(-1.044)	(-4.459)	(1.053)	(0.170)		(16.330)	(-1.631)
Δc_{t-2}		0.143**		-0.096			-0.154
		(2.019)		(-0.611)			(-1.475)
Δy_{t-1}			0.268			-0.048**	0.864***
			(0.518)			(-2.441)	(3.277)
Regime2							
constant	0.016	0.000	-0.002	0.005	0.000	-0.001	0.021***
	(0.792)	(-0.027)	(-0.693)	(0.623)	(0.053)	(-0.154)	(4.777)
Δy_t	0.678***	0.627***	0.755***	0.791**	0.851***	0.407**	0.450***
	(3.219)	(4.268)	(8.342)	(2.029)	(6.164)	(2.344)	(4.583)
ecm_{t-1}	-0.083		-0.273***		-0.452***		-0.580***
	(-0.860)		(-4.190)		(-4.184)		(-3.487)
Δc_{t-1}	0.036**	-0.005	0.376**	-0.251**		0.158	0.245
	(2.416)	(-0.060)	(2.310)	(-2.010)		(1.172)	(1.234)
Δc_{t-2}		-0.082		-0.715**			0.080
		(-0.714)		(-2.663)			(1.175)
Δy_{t-1}			-0.398***			0.351*	-0.296
			(-3.324)			(1.760)	(-1.611)
H_0: $\lambda_1 = \lambda_2$	0.457	3.577*	15.21***	0.116	0.047	2.811*	7.025***
	[0.498]	[0.058]	[0.000]	[0.735]	[0.827]	[0.093]	[0.008]
H_0: $\delta_1 = \delta_2$	1.580		0.219		3.945**		5.265**
	[0.208]		[0.639]		[0.047]		[0.021]
R^2	0.621	0.633	0.802	0.470	0.660	0.571	0.765
SER	0.048	0.019	0.023	0.035	0.030	0.020	0.020
DW	2.128	1.792	1.860	2.337	1.824	1.825	1.980
LM(1)	0.339	0.756	1.773	4.749	0.778	0.895	0.002
	[0.561]	[0.385]	[0.412]	[0.191]	[0.378]	[0.344]	[0.961]
ARCH(2)	1.920	0.616	1.773	4.252	0.118	2.056	1.247
	[0.383]	[0.735]	[0.412]	[0.119]	[0.943]	[0.358]	[0.536]

Notes: ecm_{t-1} is the error-correction term. SER and DW denote standard error of regression and Durbin-Watson statistic, respectively. We utilize the chi-square distribution to test the hypotheses H_0: $\lambda_1 = \lambda_2$ and H_0: $\delta_1 = \delta_2$. LM(N) and ARCH(N) are Lagrange multiplier tests for N-order serial correlation and autoregressive conditional heteroskedasticity, both tests are asymptotically distributed as chi-square. Figures in parentheses () and square brackets [ ] are t-statistics and p-values, respectively. ***, **, and * denote statistical significance at the 1%, 5%, and 10% level, respectively.

Source: own elaboration

Based on the results in Table 5, a TECM is applicable to Indonesia, Singapore, Sri Lanka and Thailand; for the Philippines, South Korea and Taiwan, a threshold auto-regression (TAR) model is applicable. Table 6 reports the estimates of thresholds calculated using equation (5). In regime 1 (growth in average income is faster than the threshold level), the estimated value of the parameter λ_1 is significantly positive for all of the countries except Taiwan. In regime 2 (growth in incomes is slower than the threshold level), the estimated value of the parameter λ_2 is significantly positive for all of the countries. These estimated values confirm that there are liquidity constraints acting. The LM(1) and ARCH(2) diagnostic tests shown in Table 6 confirm that the residuals in the model do not display autocorrelation or heteroskedasticity.

For Indonesia, Singapore, Sri Lanka and Thailand, we also tested the significance of the adjustment coefficient δ_i (i=1, 2), in order to determine whether short-run imbalances in consumption could return to long-run equilibrium by adjustment of the error correction term. The results reported in Table 6 show that in regime 1, this is true only of Indonesia; in regime 2, it is true of Singapore, Sri Lanka and Thailand. This result suggests that short-run imbalances in Singapore, Sri Lanka and Thailand tend to occur during periods of economic weakness. The reason may be government intervention during periods of economic weakness, when the government implements growth policies in order to bring consumption back to its long-run equilibrium level.

Additionally, we test whether the restrictions $\lambda_1 = \lambda_2$ and $\delta_1 = \delta_2$ hold in model (5). The rejection of H_0: $\lambda_1 = \lambda_2$ means that in the two regimes, the liquidity constraint ratios are different because of the different economic status. The rejection of H_0: $\delta_1 = \delta_2$ tells that the adjustment velocity of the economy from the short-run disequilibrium to the long-run equilibrium varies with the economic status in the two regimes. The test result shows that the hypothesis $\lambda_1 = \lambda_2$ could not be rejected in Indonesia, Korea, and Sri Lanka, which indicates that the liquidity constraint ratios are the same in the two regimes in these three countries. In other words, in the three countries, the economic status cannot impact the liquidity constraint. As to the four countries in which the hypothesis $\lambda_1 = \lambda_2$ is rejected, it means that the liquidity constraint can be affected by the economic status. For the test result of the hypothesis $\delta_1 = \delta_2$, it cannot be rejected in Indonesia and Singapore, which mean that the economic status does not impact the adjustment velocity of the error correction term. In Sri Lanka and Thailand, the hypothesis is rejected. The economic significance of above findings can be summarized as follows. In different countries, the liquidity constraints can be the same or different in the two regimes. For countries that have the short-run error correction adjustment mechanisms, the adjustment velocity can be the same or different. The difference may originate from unique consumption behaviours and economic backgrounds of individual countries.

Because of the cointegration in the data for Indonesia, Singapore, Sri Lanka and Thailand, it is possible to test for weak exogeneity of incomes in these countries. The results are reported in Table 7. In regime 1, the error correction factor coefficient π_{51} is significantly different from zero in Singapore, Sri Lanka and Thailand, demonstrating the weak exogeneity of incomes. Because incomes and consumption are not cointegrated in the Philippines, South Korea and Taiwan, income is not weakly exogenous, but strongly exogenous. In regime 2, the results are not significant for any of the countries, suggesting that there is no weak exogeneity of incomes during periods of economic weakness. We suggest that when changes during the business cycle create information asymmetries in the credit markets, these asymmetries affect the level of liquidity constraints on consumers. The results presented in this paper indicate that incomes are weakly exogenous during periods of strong economic growth, while the results found by Habibullah et al. (2006) using a linear model appear in the periods of weak growth in our nonlinear model. This shows that results obtained using a linear model are liable to be skewed or incomplete. We also used linear ECM and AR models to estimate (6). Of the ten countries, six showed no cointegration, so income is strongly exogenous. For Sri Lanka and Thailand, the error correction term was significant, indicating no weak exogeneity; for Indonesia and Singapore, income is weakly exogenous. These results are generally in agreement with those of Habibullah et al. (2006), i.e. income is exogenous (please contact the authors for the complete results).

The results presented in this paper can be summarized in the following way. (1) Tests demonstrate cointegration for Indonesia, Singapore, Sri Lanka and Thailand. (2) Taking real economic growth as the threshold variable, data from seven of the ten countries display nonlinear behaviour in their short-run consumption. The progression of the business cycle from a strong to weak economy affects consumer behaviour. (3) Applying a nonlinear model shows that the strength of the economy affects the level of liquidity constraints, with stronger liquidity constraints when the economy is weak than when it is strong. (4) Testing weak exogeneity of incomes in a nonlinear model, we find that the results in Habibullah et al. (2006) only reflect the situation during periods of weak economic growth. During periods of strong economic growth, incomes are still weakly exogenous for some countries.

Table 7. Test for weak exogeneity of income in nonlinear model

	Indonesia	Philippines	Singapore	S. Korea	Sri Lanka	Taiwan	Thailand
Model	TECM	TAR	TECM	TAR	TECM	TAR	TECM
Regime 1							
constant	-0.211 (-1.156)	-0.073 (-0.799)	-0.014 (-0.145)	0.046* (1.870)	0.175* (1.826)	-0.359 (-0.806)	-0.040 (-0.573)
Δy_{t-1}	-0.770 (-1.456)	-0.307 (-1.497)	-4.052** (-2.515)	0.492*** (3.107)	1.442*** (4.817)	2.869 (0.769)	0.763 (0.991)
Δy_{t-2}	-0.328 (-0.624)		3.126*** (2.789)	0.211 (0.692)			
Δc_{t-1}	1.280* (1.865)	0.701 (1.497)	0.749* (1.738)	-0.499*** (-2.896)	-1.487*** (-7.573)	0.940** (2.650)	0.116 (0.294)
Δc_{t-2}	0.677 (1.042)				-1.950*** (-6.342)		
Δexp_{t-1}	-0.072 (-0.592)	0.015 (0.450)	0.049 (0.178)	-0.084 (-1.227)	0.073 (0.637)	0.819*** (3.996)	-0.027 (-0.211)
Δpop_{t-1}	11.041 (1.406)	3.074 (1.508)	13.775*** (3.005)	-0.070 (-0.069)	-5.784 (-1.663)	-6.809** (-2.495)	1.711 (1.040)
ecm_{t-1}	0.101 (0.724)		-1.680*** (-4.898)		3.909*** (8.215)		-0.633* (-1.758)
Regime 2							
constant	-0.071 (-1.295)	0.000 (0.006)	0.096 (3.500)	0.025 (1.599)	0.027 (1.291)	0.041*** (4.488)	0.048*** (4.649)
Δy_{t-1}	-0.014 (-0.047)	0.123 (0.375)	0.040 (0.160)	0.284 (1.582)	0.435 (1.277)	0.627*** (3.111)	-0.013 (-0.044)
Δy_{t-2}	-0.306** (-2.868)		-0.018 (-0.097)	0.039 (0.170)			
Δc_{t-1}	0.113 (0.730)	0.154 (0.469)	0.433 (1.735)	0.134 (1.088)	-0.148 (-0.628)	-0.231 (-1.251)	0.173 (0.640)
Δc_{t-2}	0.234** (2.313)				0.035 (0.213)		
Δexp_{t-1}	0.017 (0.251)	-0.046 (-0.749)	-0.081 (-1.066)	-0.068* (-1.760)	-0.045 (-0.473)	-0.042 (-0.844)	0.085 (1.052)
Δpop_{t-1}	7.406** (2.552)	0.516 (0.358)	-2.578** (-2.186)	0.401 (0.773)	-0.056 (-0.060)	-0.113 (-0.289)	-0.806 (-1.607)
ecm_{t-1}	-0.075 (-0.891)		-0.072 (-0.304)		0.190 (1.433)		-0.181 (-0.987)
R^2	0.395	0.104	0.437	0.263	0.432	0.233	0.389
SER	0.072	0.043	0.048	0.037	0.036	0.027	0.033
DW	2.224	1.876	1.971	1.959	2.153	1.866	1.970
LM(1)	2.260 [0.133]	0.948 [0.330]	0.040 [0.841]	0.005 [0.945]	1.325 [0.250]	1.357 [0.244]	0.016 [0.900]
ARCH(2)	0.344 [0.842]	4.549 [0.208]	0.552 [0.759]	1.069 [0.586]	1.549 [0.461]	4.118 [0.128]	0.123 [0.940]

Notes: ecm_{t-1} is the error-correction term. SER and DW denote standard error of regression and Durbin-Watson statistic, respectively. LM(N) and ARCH(N) are Lagrange multiplier tests for N-order serial correlation and autoregressive conditional heteroskedasticity, both tests are asymptotically distributed as chi-square. Figures in parentheses () and square brackets [ ] are t-statistics and p-values, respectively. ***, **, and * denote statistical significance at the 1%, 5%, and 10% level, respectively.

Source: own elaboration

4. CONCLUDING REMARKS

The existence of liquidity constraints between income and consumption is generally seen as one possible reason why the PIH/LCH might not hold. In an early paper, Hayashi (1987) points out that there are asymmetries of information between lenders and borrowers. However, he was unable to find an appropriate model to test this result. Habibullah et al. (2006) do not consider the effects of the business cycle and incomplete information in the credit markets on liquidity constraints. They are able to confirm the existence of liquidity constraints in the ten countries they survey, but cannot provide an adequate explanation of consumer behaviour. In this paper, we suggest that the level of economic growth is a key factor in both short-run consumption and borrowing in the credit markets, and this causes changes in the level of liquidity constraints. Based on this idea, we develop a nonlinear model using real economic growth as the threshold variable, and reassess the ten countries examined by Habibullah et al. (2006). We find that in seven of the countries, liquidity constraints are affected by the business cycle, and that liquidity constraints are stronger during periods of weak economic growth than during periods of strong growth.

We also include the exogenous variables, net exports and total population, in the models, to test whether income is exogenous to consumption. When the economy is weak, financial institutions tend to be conservative in their lending policies, so in many countries the hypothesis that income is exogenous to consumption is supported. This result agrees with those of Habibullah et al. (2006). However, during periods of strong economic growth, when financial institutions maintain looser lending policies, the data for five countries indicate that consumption affects income, and that there is feedback between the two. This result was not found by Habibullah et al. (2006).

The contributions of this paper are therefore as follows. (i) Methodologically, we incorporate the business cycle and information asymmetries in the credit markets to develop a nonlinear model, and use this model to test the level of liquidity constraints. (ii) The empirical results presented in this paper extend those of Habibullah et al. (2006) by adding to their model the effects of information asymmetries on consumer behaviour. (iii) Finally, for policymakers, the objective of policy is to increase short-term stability in consumption. Appropriate intervention by the government could prevent economic swings causing major variation in consumption patterns, and could reduce or even eliminate variation in liquidity constraints over the business cycle.

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APPENDIX A

THE ESTIMATION PROCESS OF THE THRESHOLD AUTOREGRESSIVE MODEL

The threshold of the threshold autoregressive (TAR) model is specified as variables. The regimes of the TAR model are divided by the threshold variable whose value is greater than (less than or equal to) a threshold value. For instance, a uni-variate bi-regime TEC (TAR) model with lagged *p* periods can be expressed as:

$$\mathrm{y_t} = \phi_{0,1} + \phi_{1,1} y_{t-1} + \ldots\ldots + \phi_{p,1} y_{t-p} + \varepsilon_t \qquad \textit{if}\ \ \mathrm{y_{t\text{-}d}} > \gamma \tag{A.1}$$

$$= \phi_{0,2} + \phi_{1,2} y_{t-1} + \ldots\ldots + \phi_{p,2} y_{t-p} + \varepsilon_t \qquad \textit{if}\ \ y_{t\text{-}d} \le \gamma \tag{A.2}$$

where p denotes the number of lagged periods; y_{t-d} is the threshold variable; d denotes the number of delay periods; γ is the threshold value. The error term ε_t follows the iid process: $E(\varepsilon_t | \Omega_{t-1}) = 0$ and $E(\varepsilon_t^2 | \Omega_{t-1}) = \sigma^2$, where Ω_{t-1} is the information set containing last period information. The model says that when the value of the threshold variable is greater than the threshold value, the regression model is equation (A.1); when the value of the threshold variable is less than or equal to the threshold value, then the regression model is equation (A.2). The threshold value γ minimizing the estimated variance of the TAR model among all γ's, is endogenously determined by the model, and is called the optimal threshold value. Under the assumption that ε_t follows the normal distribution, the bi-regime TEC (TAR) model could be derivated as:

$$y_t = (\phi_{0,1} + \phi_{1,1} y_{t-1} + \ldots.. + \phi_{p,1} y_{t-p}) I(y_{t-d} > \gamma) \\ + (\phi_{0,2} + \phi_{1,2} y_{t-1} + \ldots.. + \phi_{p,2} y_{t-p}) I(y_{t-d} \leq \gamma) + \varepsilon_t \ , \qquad \text{(A.3)}$$

where $I(.)$ is an index function. $I(.) = 1$ when a certain regime holds; I(.) = 0, otherwise. Equation (A.3) can be re-written as

$$y_t = \phi_1' x_t I(y_{t-d} > \gamma) + \phi_2' x_t I(y_{t-d} \leq \gamma) + \varepsilon_t \ , \qquad \text{(A.4)}$$

where $\phi_j = (\phi_{0,j}, \phi_{1,j}, \ldots, \phi_{p,j})'$, j = 1, 2, and $x_t = (1, y_{t-1}, \ldots, y_{t-p})'$. Given γ, $\phi = (\phi_1', \phi_2')'$ can be estimated with OLS method.

One could apply the grid search method to find the optimal threshold value of the TEC (TAR) model. The grid search method obtains the structural change point by minimizing the sum of squared errors (SSE). It is known that

$$\hat{\phi}(\gamma) = (\sum_{t=1}^{n} x_t(\gamma) x_t(\gamma)')^{-1} (\sum_{t=1}^{n} x_t(\gamma) y_t), \qquad \text{(A.5)}$$

where $x_t(\gamma) = (x_t' I(y_{t-1} > \gamma), x_t' I(y_{t-1} \leq \gamma))'$; the error term $\hat{\varepsilon}_t(\gamma) = y_t - \hat{\phi}(\gamma)' x_t(\gamma)$ and the error term variance $\hat{\sigma}^2 = \sum_{t=1}^{n} \hat{\varepsilon}_t(\gamma)^2 / n$. By minimizing this variance, one could obtain the threshold value. That is,

$$\hat{\gamma} = \mathbf{arg\,min}\, \hat{\sigma}^2(\gamma). \qquad \text{(A.6)}$$

The $F(\hat{\gamma})$ statistic of Chan and Tong (1990) could be utilized to test the existence of the threshold. The null hypothesis is that the model is linear; that is, $\phi_1 = \phi_2$. The alternative hypothesis is $\phi_{i,1} \neq \phi_{i,2}$. The $F(\hat{\gamma})$ statistic can be expressed as

$$F(\hat{\gamma}) = n(\frac{\tilde{\sigma}^2 - \hat{\sigma}^2}{\hat{\sigma}^2}), \qquad \text{(A.7)}$$

where $\tilde{\sigma}^2$ is the residual variance under the null hypothesis; $\tilde{\sigma}^2 = \sum_{t=1}^{n} \tilde{\varepsilon}_t^2$, where $\tilde{\varepsilon}_t = y_t - \hat{\phi}' x_t$. The $F(\hat{\gamma})$ statistic follows the chi-square distribution with p + 1 degrees of freedom. If the value of the $F(\hat{\gamma})$ statistic is greater than the cirtical value $\chi^2_{(p)}$, it means that the threshold exists and one has to employ the nonlinear model to perform the estimation.

The linearity test of the TEC (TAR) model is different from regular hypothesis tests. Under the null hypothesis that there is no threshold effect, since the threshold variable cannot be identified, the asymptotic distribution of regular test statistics, such as the LM statistic and the Wald statistic, is not the chi-squre distribution anymore, but the non-standard and non-similar distributions influenced by the nuisance parameter. In this case, it is very difficult to obtain the large-sample critical values.

To overcome this problem, Hansen (1996) proposes a solution to transfer the test statistic by using the asymptotic distribution. The transferred statistic is called the asymptotic p-value and asymptotically follows the (0, 1) uniform distribution under the null hypothesis. In this way, the test statistic could avoid the impact from the nuisance parameter. However, since the asymptotic distribution function cannot be directly obtained, Hansen (1996) utilizes the bootstraping simulation to obtain the p values that can be used to approach the true p values. Hansen (1996) also proposes the supremum LM (SupLM) statistic to conduct the linearity test.[1] Under the null hypothesis, since the threshold variable cannot be identified, Hansen (1996) presumes a threshold variable $q_{t-d} \in [\gamma_L, \gamma_U]$, where d = 1, 2, …, k. The statistic of this assumed threshold variable is

$$SupLM = \sup_{\gamma_L \le q_{t-d} \le \gamma_U} LM(q_{t-d}) .$$

Since the limit distribution of this statistic is unknown, Hansen (1996) utilizes the bootstraping simulation to obtain the statistic.

In this paper, the delay periods of all models (TAR and TECM) are chosen by the following method. First, we utilize the Akaike information criterion (AIC) to find the maximum delayed period (lag = p) of the linear model. The advantage of the AIC is that it is very consistent and that it can be used to avoid the problem that the empirical results vary with delayed periods for the linear models. Then, we conduct the Hansen linearity test and estimate the bi-regime threshold model to obtain a set of p, d, and γ values. By changing the value of d (not greater than p), we could get a variety of linearity test results and threshold model estimation results. With these results, we could obtain the optimal threshold model from the models (with

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[1]Hansen (1996) constructs the statistic $\tilde{\kappa}_n(\gamma_1, \gamma_2) = \frac{1}{n}\sum_{t=1}^{n} \tilde{s}_t(\gamma_1)\hat{s}_t(\gamma_2)'$ $\tilde{\kappa}_n$.

This statistic is very close to the LM statistic when involving the null hypothesis.

different d and γ combinations) that reject the null hypothesis.[2]

Even though the threshold model allows for different delay periods in different regimes ($p_1 \neq p_2$), to compare the estimation results of the linear and nonlinear models, we still use the same delay periods to avoid confusions. In addition, we do try different delay periods in different regimes in the estimation and find that there is a slight difference with the estimation results listed in our tables. Therefore, we use the same delay periods in the two regimes ($p_1 = p_2$).

[2] We use the RATS software to conduct the tests and estimations.