

Multiple Structural Breaks in Korea's Macroeconomic Data: An Application of the Lumsdaine and Papell Test*

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The Korean economy has undergone rapid economic growth and structural change since the early 1960s. Over this period of time it has been one of the fastest growing economies in Asia, but, more recently, has been vulnerable to external shocks which have contributed to major volatility in the economy. This paper employs quarterly time series data to endogenously determine the timing of major structural breaks for various macroeconomic variables in the Korean economy. The ADF (Augmented Dickey and Fuller) test and the LP (Lumsdaine and Papell, 1997) test are used to examine the time series properties of the data. The ADF test results provide no evidence against the unit root null hypothesis in all major macroeconomic variables under study. After accounting for the two most significant structural breaks in the data impacting on both the intercept and trend (model CC), results from the LP test indicate that the null of at least one unit root is rejected for some of the variables under investigation at the 10% level or better. The paper also goes further to shed some light on the implications of the Asian financial crisis on the Korean economy, as this is considered to be the most severe external shock to affect the economy in the recent past. Our preliminary empirical findings verify this, indicating that the dates of structural breaks in most cases point to the Asian financial crisis. However, using the LP approach it is shown that a second structural break can be identified, the timing of which depends on key policy changes or other factors contributing to economic turbulence in the Korean economy. The estimated two structural breaks were found to be statistically significant for all of the variables under investigation.

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1. INTRODUCTION

Few countries in history have attained economic development as rapidly as Korea (World Bank, 1993). In a single generation this poor nation, consisting primarily of subsistence farmers in the 1950s and early 1960s, experienced such rapid economic growth and structural change that it was transformed by 1996 into the world's largest producer of home appliances, the second largest producer of semi-conductor chips, the second largest ship builder, the fifth largest car maker, the eleventh largest economy in the world and the third largest in Asia, and the twelfth largest exporter and trading nation (Harvie and Lee, 2003a, 2003b). Per capita income doubled every eight years from the early 1960s rising from US\$80 to US\$10,000 by 1996 (Australian Department of Foreign Affairs and Trade, 1999; Harvie and Lee, 2003a, 2003b), and income remained relatively equally distributed. The country's attainment of OECD membership in December 1996¹⁾ signified the culmination of 35 years of extraordinary growth, and the economy's coming of age. Its model of economic development — state directed capitalism — became the envy of other developing economies. Despite it being one of the fastest growing economies in Asia, more recently, and barely a year after its accession to the OECD, the country experienced a traumatic financial and economic crisis (Park, 1998; Park and Song, 2000; Radelet and Sachs, 1998a, Radelet and Sachs, 1998b, Smith, 1998), exposing major structural weaknesses in both the production and financial sectors. The country had become particularly vulnerable to external shocks, which had contributed to major volatility in the economy.

In this context the paper employs quarterly time series data to endogenously determine the timing of major structural breaks for various macroeconomic variables in the Korean economy, extending work previously conducted by the authors on this issue (Harvie and Pahlavani, 2006, 2007). The ADF (Augmented Dickey and Fuller) test and the LP (Lumsdaine and Papell, 1997) test are used to examine the time series properties of the data.

¹⁾ An officially stated objective of the government in 1993.

The ADF test results provide no evidence against the unit root null hypothesis for all major macroeconomic variables under study. After accounting for the two most significant structural breaks in the data impacting on both the intercept and trend (model CC), results from the LP test indicate that the null of at least one unit root is rejected for some of the variables under investigation at the 10% level or better. The paper also goes further to shed some light on the implications of the Asian financial crisis on the Korean economy, as this external shock is considered to be the most severe shock that has affected the economy in the recent past. Our preliminary empirical findings provide further support for this, indicating that the dates of structural breaks in most cases point to the Asian financial crisis. However, of particular interest, and an extension to previously reported results (Harvie and Pahlavani, 2006, 2007), using the LP approach it is shown that a second structural break can be identified, the timing of which depends on key policy changes or other factors contributing to economic turbulence in the Korean economy. The estimated two structural breaks were found to be statistically significant for all of the variables under investigation.

The primary purpose of this paper is to employ the Lumsdaine and Papell (LP) (1997) test to examine the existence and significance of structural breaks in major macroeconomic series of the Korean economy, using quarterly data covering the period 1980Q1-2006Q4. The detection of structural breaks within these time series will present new and novel evidence of the impact of institutional and regulatory change during this important period for the Korean economy. The macroeconomic series of the Korean economy examined are the natural logs of annual observations on: real GDP, gross national income, private consumption, government consumption, Gross Fixed Capital Formation, total exports, total imports, consumer price index, money supply and exchange rate.

The remainder of the paper proceeds as follows. Section 2 briefly discusses the theoretical underpinnings of the LP test procedure. Section 3 presents the empirical results of the ADF and LP tests using data series for key macroeconomic data. Finally, section 4 provides some concluding remarks.

2. THE LUMSDAINE AND PAPELL TEST PROCEDURE IN THE PRESENCE OF POTENTIAL MULTIPLE STRUCTURAL BREAKS

The issue of structural change is of considerable importance in the analysis of macroeconomic time series. Structural change occurs in many time series for any number of reasons, including economic crises, changes in institutional arrangements, policy changes and regime shifts. An associated problem is that of testing the null hypothesis of structural stability against the alternative of a one or two-time structural break. Most importantly, if such structural changes are present in the data generating process, but not allowed for in the specification of an econometric model, results may be biased towards the erroneous non-rejection of the non-stationarity hypothesis (Perron, 1989; Perron, 1997; Leybourne and Newbold, 2003). The economic content of such a result is to incorrectly conclude that the series under investigation has a stochastic trend. This in turn implies that any shock — whether demand, supply, or policy-induced — to the variable will have effects on the variable into the very long run. It is, therefore, very important to allow for the presence of a structural break in the data so as to more reliably conduct the test of non-stationarity.

Conventionally, dating of the potential break is assumed to be known *a priori*. Test statistics are then constructed by adding dummy variables representing different intercepts and slopes, thereby extending the standard Dickey-Fuller procedure (Perron, 1989). However, this standard approach has been criticized, most notably by Christiano (1992), who has argued that this approach invalidates the distribution theory underlying conventional testing.

In response, a number of studies have developed different methodologies for endogenising dates, including Zivot and Andrews (ZA, 1992), Perron (1997), Lumsdaine and Papell (1997) and Bai and Perron (2003). These have shown that by endogenously determining the time of structural breaks, bias in the usual unit root tests can be reduced. Perron and Vogelsang (1992) and

Perron (1997) have proposed a class of test statistics which allows for two different forms of a structural break: namely, the Additive Outlier (AO) model, which is more relevant for series exhibiting a sudden change in the mean (the crash model), and the Innovational Outlier (IO) model, which captures changes in a more gradual manner through time. Perron (1997, p. 356), for example, argues that "... if one can still reject the unit-root hypothesis under such a scenario it must be the case it would be rejected under a less stringent assumption."

Many practitioners use the Augmented Dickey-Fuller (ADF) test to examine time series properties of the data. For the sake of comparison, the ADF regression is presented in the following equation

$$\Delta y_t = \mu + \beta t + \alpha y_{t-1} + \sum_{i=1}^k c_i \Delta y_{t-i} + \varepsilon_t, \quad (1)$$

where y_t is the time series being tested, t is a time trend variable, Δ denotes the first difference operator, and k is the number of lags which are added to the model to ensure that residuals, ε_t , are white noise. The Schwartz Bayesian information criterion (BIC) is used to determine the optimal lag length or k .

The Zivot and Andrews (1992) and Perron (1997) Innovational and Additive Outlier models, however, capture only one (the most significant) structural break in each variable. Considering only one endogenous break may not be sufficient, and it could lead to a loss of information particularly when, in reality, there is more than one break (LP, 1997). On this same issue, Ben-David *et al.* (2003) argued that "just as failure to allow for one break can cause non-rejection of the unit root null by the Augmented Dickey-Fuller test, failure to allow for two breaks, if they exist, can cause non-rejection of the unit root null by the tests which only incorporate one break" (2003, p. 304). LP introduced a new procedure to capture two structural breaks. They argued that a unit root test that accounts for two structural breaks (if significant) is more powerful than those which only allow for one single break.

As an extension of the Zivot and Andrews (1992) test (model C), Lumsdaine and Papell (1997) use a modified version of the ADF test which is augmented by two endogenous breaks as follows

$$\begin{aligned} \Delta y_t = & \mu + \beta t + \theta DU1_t + \gamma DT1_t + \omega DU2_t + \psi DT2_t \\ & + \alpha y_{t-1} + \sum_{i=1}^k c_i \Delta y_{t-i} + \varepsilon_t, \end{aligned} \quad (2)$$

where $DU1_t = 1$ if $t > TB1$ and otherwise zero; $DU2_t = 1$ if $t > TB2$ and otherwise zero; $DT1_t = t - TB1$ if $t > TB1$ and otherwise zero; and finally $DT2_t = t - TB2$ if $t > TB2$ and otherwise zero.

Two structural breaks are allowed in both the time trend and the intercept and this model is referred to as the CC model (similar to the Zivot and Andrews C model, which only captured one break point) in the literature. The two indicator dummy variables (i.e. $DU1_t$ and $DU2_t$) capture structural changes in the intercept at time $TB1$ and $TB2$, respectively. The other two dummy variables (i.e. $DT1_t$ and $DT2_t$) capture shifts in the trend variable at time $TB1$ and $TB2$, respectively.²⁾

The optimal lag length (k) is determined based on the general to specific approach (the t -test) suggested by Ng and Perron (1995). The “trimming region,” in which we have searched for $TB1$ and $TB2$, cover the $0.05T$ - $0.95T$ period. We have selected the break points ($TB1$ and $TB2$) based on the minimum value of the t statistic for α . Using annual time series data, LP (1997) and Ben-David *et al.* (2003) have assumed the lag length (k) to vary up to $K_{\max}=8$.

²⁾ While the LP approach is one of the most advanced methods to endogenously detect one or two significant structural breaks in a time series, it is unable to identify multiple (more than two) structural breaks.

3. EMPIRICAL RESULTS

In order to examine the time series properties of selected macroeconomic data for the Korean economy, we first use the ADF test during the period 1980Q1-2006Q4. As expected the null hypothesis of a unit root in all variables under investigation cannot be rejected at the 5% significance level. The ADF test results are not reported here but are available from the authors upon request. Since macroeconomic variables in the Korean economy can be reasonably anticipated to be subject to structural breaks, the ADF test is considered biased towards not rejecting the unit root. A more recent study by Harvie and Pahlavani (2006) employs the Innovational Outlier and Additive Outlier models and quarterly data for the Korean Economy to conclude that, after allowing for one structural break, the non-stationarity of the same series remained unchanged. It is of interest to see how the unit root results can be affected if we allow for the existence of two structural breaks in the data. The remainder of the paper examines this important issue.

By applying the LP (Lumsdaine and Papell, 1997) testing procedure in the presence of two endogenously determined structural breaks, we found some interesting results.³⁾ Based on the LP test the empirical results obtained and presented in table 1 indicate that five out of the ten macroeconomic variable time series become stationary at the 5% significance level. In other words the LP test results are somewhat mixed as five out of the 10 variables, i.e.

³⁾ Computationally the determination of more than one structural break (even two) is very cumbersome. Attempts to apply such methods in the presence of multiple breaks can yield conflicting results. Further research to refine procedures and resolve such inconsistencies are required. Moreover, as Ben-David and Papell (1997) note, tests that allow for multiple structural breaks are restricted to stationary and non-trending data, which is not the case for the variables under investigation in this research. It can be argued that a procedure allowing for multiple structural breaks would perhaps be more appropriate to the Korean economy, but the data would need to be more longer term, or at least obtained monthly, rather than quarterly. Considering the short time span of the data used in this paper, justification of more than two breaks for each variable is overly difficult and not appropriate. The period of our study is 1980Q1-2006Q4, and for this period considering only two significant structural breaks is quite reasonable. Unfortunately, there is no available quarterly data for the longer period (e.g. 1960-2008). We would like to extend our thanks to an anonymous referee for the need to provide such clarification in the context of the present study.

Table 1 Estimating the Time of Structural Breaks by Using the Umsdaine and Papell Test

$$\Delta y_t = \mu + \beta t + \theta DU1_t + \gamma DT1_t + \omega DU2_t + \psi DT2_t + \alpha y_{t-1} + \sum_{i=1}^K c_i \Delta y_{t-i} + \varepsilon_t$$

Description	Symbol	K	TB1	TB2	t-Statistic for α	Correspond Break Time
GDP at 1995 Constant Price	Ln(<i>GDP</i>)	8	1995:02	1998:01	-7.483*	<i>TB1</i> : Business cycle peaked in 1995, construction and infrastructure boom <i>TB2</i> : Asian financial crisis – economic downturn
Gross National Income at Current Price	Ln(<i>GNI</i>)	8	1994:03	1998:01	-7.997*	<i>TB1</i> : Expansionary government policy, equipment and infrastructure boom <i>TB2</i> : Asian financial crisis – economic downturn
Private Consumption at Current Price	Ln(<i>Pc</i>)	5	1993:03	1997:04	-6.339	<i>TB1</i> : Anti inflationary stabilization measures of 1990-91 produced a sharp decline in investment and consumption spending <i>TB2</i> : Asian financial crisis – financial turbulence.
Government Consumption at Current Price	Ln(<i>Gc</i>)	5	1997:04	2001:04	-5.058	<i>TB1</i> : Asian financial crisis-collapse of the won, IMF financial assistance sought and related tightening of monetary and fiscal policy <i>TB2</i> : Tech wreck, global slowdown, semi-conductor price crash aftermath
Gross Fixed Capital Formation at Current Price	Ln(<i>GFCF</i>)	4	1994:02	1998:01	-9.94*	<i>TB1</i> : Equipment and infrastructure investment boom <i>TB2</i> : Asian financial crisis – economic downturn

Total Export (US\$)	$\text{Ln}(X)$	3	1985:01	2001:01	-6.152	<i>TB1</i> : Reduced inflation, improved competitiveness and productivity <i>TB2</i> : Tech wreck, global slowdown, semi-conductor price crash.
Total Imports (US\$)	$\text{Ln}(IM)$	8	1994:02	1998:01	-8.449*	<i>TB1</i> : Expansionary government policy; opening of domestic markets (through lower tariffs) to increased foreign competition, increased spending on imported capital goods, industrial materials and consumer goods. <i>TB2</i> : Asian financial crisis – economic downturn
Consumer Price Index	$\text{Ln}(CPI)$	6	1996:01	1998:04	-4.644	<i>TB1</i> : Price stability became the government's primary focus. Stable agricultural prices, increased competition from imports and subdued consumer spending from a growth slowdown contributed to low inflation particularly in the second half of 1996. <i>TB2</i> : Recovery from the Asian financial and economic crisis
Money Supply at Current Price	$\text{Ln}(M_s)$	8	1991:02	1997:04	-6.344	<i>TB1</i> : Anti-inflationary stabilization measures aimed at reducing strong domestic demand (construction and investment spending in particular). <i>TB2</i> : Asian financial crisis – financial turbulence
Exchange Rate (National Currency per US\$)	$\text{Ln}(ER)$	3	1991:01	1997:04	-7.023*	<i>TB1</i> : Strong economic growth; rapid growth of imports; investment and consumer (industrial materials and consumer goods) boom; trade and current account blowout. <i>TB2</i> : Asian financial crisis – financial turbulence

Notes: 1) The critical values at 1, 5 and 10% are -7.34, -6.82 and -6.49, respectively (Lumsdaine and Papell, 1997). 2) * Indicates that the corresponding null is rejected at the 5% level. 3) The optimal lag length (k) is determined by the general to specific method (the t -test) and $K_{\max}=8$.

Source: The Bank of Korea (2007), Korea National Statistical Office (<http://kosis.nso.go.kr>).

$\ln(Pc)$, $\ln(Gc)$, and $\ln(X)$, $\ln(CPI)$, and $\ln(Ms)$ are not stationary, while the remaining variables contain a unit root. Given the fact that all of the estimated coefficients for the indicator and dummy variables are statistically significant for all of the variables under investigation, one can argue that the two endogenously determined structural breaks identified are indeed statistically significant. The corresponding time of the endogenously determined structural breaks (*TBs*) for each variable are shown in the middle columns of table 1, and possible explanations for each of these are provided in the last column of table 1. We also find that the reported *t*-statistics in table 1 for α are significant in all cases.

It is interesting to note that the most significant endogenously determined structural breaks for the variables under investigation closely correspond to the Asian financial and economic crisis of 1997-1998.⁴⁾ It can be observed that one of the most significant structural breaks for all of the variables under investigation, with the exception of total exports, occurred in 1997Q4, the height of the financial crisis, or 1998Q1 which can be characterized as the quarter in which there was a severe economic downturn triggered by the financial turmoil, or in 1998Q4 when the economy was experiencing signs of recovery from the economic crisis. There is no obvious second major structural break that commonly impacted upon all or most of the variables under investigation, but rather this is variable dependent.

The last column in table 1 presents a tentative summary of key policy changes, internal and external events and crises that can explain the two structural breaks for all the variables listed. In the case of real GDP the two major structural breaks identified occurred in 1995Q2 and 1998Q1 respectively. In the case of *TB1* economic growth recovered strongly in 1994 and 1995 due to: the implementation of an expansionary economic plan under the new government led by Kim Young Sam; the opening of domestic

⁴⁾ Harvie and Pahlavani (2006), by applying the Innovational Outlier (IO) and Additive Outlier (AO) models for the same variables, concluded that, after allowing for one structural break, the majority of endogenously determined structural breaks coincided with the effects of the financial and economic crisis of 1997-1998. They find that GDP, GNI, GFCF, IM, CPI, ER, CUR and IR all experienced structural breaks during 1997Q4 and 1998Q1.

markets to increased foreign competition; the liberalization of foreign capital inflows; a strong export performance assisted by a high yen which gave Korean exporters a competitive advantage over Japanese exporters; a boom in construction and domestic infrastructure investment; and steadily rising private consumption. The business cycle peaked in 1995 but by 1995Q4 the economy began to enter a downward phase of the business cycle, and the economy began to slow in 1996 and 1997 from a rapid decline in consumption and investment expenditure and particularly weak export growth in 1996. For *TB2*, the financial crisis of 1997Q4 triggered a traumatic economic downturn in 1998Q1.

Gross National Income appears to have benefitted from the expansionary government policy implemented at this time (*TB1*) as well as from the equipment and infrastructure boom. As for the case of real GDP it was adversely affected by the financial crisis of late 1997 and subsequent severe economic downturn in 1998Q1 (*TB2*). Private consumption expenditure experienced a sharp downturn in the second half of 1993 as a consequence of the anti inflationary measures of 1990-1991 (*TB1*), but subsequently led the recovery of the economy from 1994. The onset of the financial crisis in 1997Q4 contributed to a collapse of consumer confidence and spending (*TB2*).

Government consumption spending was also subject to a shock at the height of the financial crisis in 1997Q4, when IMF financial assistance was sought, requiring a tightening of both monetary and fiscal policy (*TB1*). A second break is found to have occurred in 2001Q4, a period characterized by a global economic slowdown and shortly after the so called “tech wreck” and related crash in semi-conductor prices (*TB2*).

Gross fixed capital formation experienced its two major structural breaks in 1994 and 1998. *TB1* occurred in 1994Q2, a period associated with an equipment and infrastructure boom in the economy. The Asian financial crisis, and subsequent economic crisis, then had a severe impact upon investment spending, in line with the severe economic downturn in 1998Q1 (*TB2*).

Total exports are the only macroeconomic variable not to have experienced a structural break during the period of the financial and economic crisis. The empirical results indicate that these occurred in 1985 and 2001. *TB1* occurred in 1985Q1, the only period outside the 1990s to have exerted an impact on the variables emphasized in this study. This is a period associated with a sharp increase in Korea's exports linked to reduced inflation and greater emphasis on enhancing competitiveness and productivity in the Korean manufacturing sector, as a result of market oriented economic reforms in the early 1980s and movement away from the failed heavy and chemical industries drive of the 1970s. *TB2* occurred in 2001Q1, a period associated with a global economic slowdown, the so called "tech wreck" and associated semi conductor price crash. All of which exerted an adverse effect on Korea's semi conductor exports, of which it was a major global exporter.

Total imports experienced two structural breaks. *TB1* occurred in 1994Q2, a period characterized by expansionary government policy; an opening of domestic markets through lower tariffs to increase foreign competition, increased spending on imported capital goods, industrial materials and consumer goods. *TB2* occurred in 1998Q1 as the economy went into a severe economic downturn, resulting in a significant reduction in imports.

As for the consumer price index and inflation, the two structural breaks identified are found to have occurred in 1996 and 1998. *TB1* was found to have occurred in 1996Q1, a period in which the focus of policy was on price stability, where agricultural prices remained stable, there was increased competition from imports and subdued consumer spending from a growth slowdown. All of these contributed to low inflation. *TB2* occurred in 1998Q4 when the recovery of the economy was well underway in the wake of the financial and economic crisis.

The money supply experienced two structural breaks. *TB1* occurred in 1991Q2 when the government's anti-inflationary stabilization measures were underway aimed at reducing strong domestic demand from construction and investment spending in particular. *TB2*, not surprisingly, occurred in 1997Q4,

at the height of the financial crisis, with the objective of stabilizing the economy and the exchange rate.

The exchange rate (won per US\$) experienced two structural breaks. *TB1* occurred in 1991Q1 when, due to strong economic growth, rapid import growth and a current account blowout, the currency noticeably weakened. Not surprisingly, *TB2* occurred at the height of the financial crisis in 1997Q4.

4. CONCLUDING REMARKS

This paper has used quarterly time series data for ten major macroeconomic variables for the Korean economy covering the period 1980Q1-2006Q4, to endogenously determine the two most important years when structural breaks occurred for these variables. For this purpose we used both the ADF test and the LP (Lumsdaine and Papell, 1997) test to make robust conclusions about the time series properties of the data. It was found that according to the ADF test none of the variables under investigation is stationary. However, after allowing for two structural breaks, the LP test results indicate that the unit root null hypothesis is rejected at the 5% level for five out of the ten variables. Most of the structural breaks are associated with the 1997 financial and economic crisis, plus variable specific events that have been influenced by specific government policies or other relevant events.

This study sheds some important light on the issue of structural breaks in key macroeconomic time series data for the Korean economy, which, during the period of the 1990s, was subject to major economic turbulence. This needs to be allowed for in the construction and estimation of macroeconomic models of the Korean economy, or for the estimation of relationships between specific macroeconomic variables in the economy. As the results from the LP test have indicated, non allowance for structural breaks in such time series, the exogenous imposition of dummy variables to capture structural breaks in the data, or indeed the endogenous determination of only

one structural break, can lead to model misspecification and spurious results. Since non-stationarity testing with multiple structural breaks may yield conflicting results to conventional ADF tests, future work should, therefore, concentrate on such a clearer refinement.

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