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**A BOUNDS TEST APPROACH TO THE STUDY OF LEVEL RELATIONSHIPS
IN A PANEL OF HIGH-PERFORMING ASIAN ECONOMIES (HPAES)**

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Abstract:

This study analyses long-run level relationships between total factor productivity (*TFP*) and a set of variables (the degree of openness of an economy, the different roles of government, and human capital) that are hypothesised as the major factors that drive *TFP* in the High-Performing Asian Economies (HPAEs).

We apply Pesaran, Shin and Smith's (2001) bounds test approach to the analysis of level relationships between *TFP* and its hypothesised determinants using panel data for five HPAEs (Indonesia, Malaysia, Singapore, South Korea and Thailand) and find evidence of a long-run relationship between *TFP* and our hypothesised determinants, irrespective of whether the regressors are $I(0)$ or $I(1)$.

Key words: total factor productivity, panel data analysis, high-performing Asian economies

JEL classification: O40, O50

1. Introduction

For over three decades from the 1960s to the 1990s, the remarkable economic performance of the high-performing Asian economies (HPAEs) was unparalleled in the world. This study analyses long-run level relationships between total factor productivity (*TFP*) and a set of variables (the degree of openness of an economy, the different roles of government, and human capital) that are commonly hypothesised as the major factors that drive TFP in five of the High-Performing Asian Economies (HPAEs) (Indonesia, Malaysia, Singapore, South Korea and Thailand). In examining the HPAEs' remarkable economic growth in the long-run, we look beyond factor accumulation, and focus instead on *TFP* growth, which has long been argued to be the ultimate determinant of long-run growth (see for instance Solow, 1956, Swan, 1956, Arrow, 1962, Uzawa, 1965, Romer, 1986, and Lucas, 1988).

There are three basic approaches to studying the determinants of *TFP*. First, *TFP* can be analysed within a single growth equation (e.g., Knight, Loayza and Villanueva, 1993). That is, by estimating a typical production function with the usual factor inputs, labour and capital, but with additional factors, e.g., openness and government policy indicators, that are assumed to affect growth via *TFP*. A second approach to studying the determinants of *TFP*, is to derive a measure of *TFP* from a growth accounting framework, and then regress *TFP* on some basic measures of initial conditions (i.e., initial level of income, life expectancy and years of schooling, as indicators of health and education); the external environment (i.e., the mean and standard deviation of the annual change in each country's terms of trade), some regional dummy variables and on various macroeconomic and trade policy indicators (i.e., budget balance, change in terms of trade, standard deviation of terms of trade, standard deviation of real exchange rate, and an openness indicator (e.g., Collins and Bosworth (1996) and Hall and Jones (1999)). Finally, in other empirical studies, such as Thomas and Wang (1993), Coe, Helpman and Hoffmaister (1997), and Miller and Upadhyay (2000), *TFP* estimates are first derived from typical production functions (i.e., *TFP* as residuals from production functions), and then

regressed on other variables, e.g. trade/openness and government policy indicators that are perceived to affect *TFP* growth.

In this study, we adopt the second approach to the analysis of *TFP* and its determinants and calculate *TFP* levels based on Hall and Jones' (1999) levels accounting study of productivity across a cross-section of 127 countries (details in Section 3). Throughout this study, analysis is directed at examining the levels of *TFP*, instead of *TFP* growth rates, because levels capture the relevant long-run relationships among the variables of interest (e.g. *TFP* and its determinants).

Panel econometric methods, specifically Im, Pesaran and Shin (2003) panel unit root tests, are used to test for panel unit roots. In addition, a bounds testing procedure developed by (Pesaran, Shin and Smith, 2001) is applied on panel data to identify long-run relationships among variables when the order of integration of the variables is uncertain.

This paper is organised as follows: Section 2 highlights the advantages of using panel data while Section 3 describes the model and data used in our analysis. Section 4 presents the unit root test results. Section 5 details the bounds testing strategy used in the analysis of level relationships and the results obtained, and Section 6 concludes.

2. Advantages of using panel data

There are several advantages of using panel data over pure cross-sectional or time-series data in the analysis of economic growth. First, the central focus in the study of growth, which is long-run steady-state growth, is basically an analysis of what happens to the variables of interest (e.g. GDP, labour, capital, etc.) over time. Time-series data have been argued to be essential in

providing more dynamic information than would otherwise be obtained when only cross-sectional data are used (Easterly, Loayza and Montiel, 1997).¹

Second, estimations that make use of time-series data (especially if there are not enough time-series observations) for a single group/country, are often subject to collinearity problems. The use of panel data provides the researcher with a larger data set and, consequently, additional information and increased degrees of freedom, which could be important in reducing collinearity among the explanatory variables. Moreover, by making use of information from time-specific and country-specific effects, the researcher is also better able to control for the effects of missing or unobserved variables (Hsiao, 1986).

In spite of the advantages of using panel data, it has only been over the last decade that empirical studies of economic growth with panel data have appeared in the literature. This is most likely due to the fact that comparable data for a wide range of countries over several time periods have been difficult to obtain, and only with the availability of the Summers and Heston (1991) data set has work on growth empirics with panel data become more feasible.²

A critical aspect in the estimation of relationships that combine cross-sectional and time-series data lies in the specification of the model, i.e., the model should be specified in such a way that possible differences in behaviour across countries, as well as any differences in behaviour over time for any given country, are adequately captured. In estimating panel data models, it is also important to examine the time-series properties of the data, particularly with respect to the

¹ Other studies, however, e.g., Pesaran and Smith (1995), Phillips and Moon (1999) and Temple (1999) point out that pure cross-section regressions can produce consistent estimates of the average long-run effects.

² Atkinson and Brandolini (2001) however, question the quality and consistency of secondary data sets, and point out the importance of making sure that cross-country panel data sets do provide comparable data across countries.

orders of integration of the time-series data, and ideally apply appropriate unit root and cointegration tests for panel data.

3. The model and data

Based on the empirical literature on the economic growth experience of the HPAEs,³ and in the spirit of Collins and Bosworth (1996), Thomas and Wang (1993), Coe, Helpman and Hoffmaister (1997), and Miller and Upadhyay (2000), we hypothesise that openness (measured in terms of the taxes imposed on international trade), the different roles of government, and human capital are the major factors that drive *TFP* in the HPAEs:

$$TFP_{i,t} = \alpha_0 + \alpha_1 O_{i,t} + \alpha_{2,x} G_{i,x,t} + \alpha_3 H_{i,t} + \varepsilon_{it} \quad (1)$$

where,

$TFP_{i,t}$	=	represents total factor productivity in country i and time t
$O_{i,t}$	=	openness variable for country i and time t
$G_{i,x,t}$	=	government-related variable x for country i and time t
$H_{i,t}$	=	represents human capital in country i and time t

The approach used in this study to calculate *TFP* levels is based on Hall and Jones' (1999) (hereafter HJ) levels accounting study of productivity across a cross-section of 127 countries. Hall and Jones' (1999) *TFP* levels are available for a wide cross-section of countries but only for the year 1988. For the purposes of this study, we need to calculate *TFP* levels for a number of years. We follow Hall and Jones' (1999) levels accounting methodology, but exclude human capital from the underlying production function equation, i.e.,

³ See for example Wade (1990), Leipziger and Thomas (1993), Root (1996), and Warr and Nidhiprabha (1996) for studies on the role of government in the economic performance of the HPAEs; Chow (1987), Ahmad, Harnhirun and Yang (1997) for studies on openness and the East Asian economies; Campos and Root (1996), Islam and Chowdhury (1997) and Tipton (1998) for studies that emphasise the importance of human capital in the East Asian economies.

$$Y_{i,t} = K_{i,t}^\alpha (A_{i,t} L_{i,t})^{1-\alpha} \quad (2)$$

where the variables and parameters have the usual meanings. Re-writing equation (2) in terms of output per worker, $y \equiv Y/L$, and following Mankiw, Romer and Weil (1992) in decomposing y in terms of the capital-output ratio, the alternative levels accounting equation can be expressed as:

$$y_{i,t} = \left(\frac{K_{i,t}}{Y_{i,t}} \right)^{\alpha/(1-\alpha)} A_{i,t} \quad (3)$$

The *TFP* measure of total factor productivity is A in equation (3).

We take the y data from Summers and Heston's (1991), *Penn World Tables 5.6*. The other relevant data for calculating the *TFP* levels are taken from a later version of the Collins and Bosworth (1996) data set. We also use Collins and Bosworth's human capital data (*Human*), which is essentially a labour quality index that measures the quality of the workforce based on a 7% return to each additional year of schooling.

The specific role that governments played in the economic success of the HPAEs has been the subject of much debate. One possible reason for this is related to the way the government intervention variable is measured in previous studies. Much of the empirical work on the relationship between government and economic growth makes use of data on government expenditures, as a proportion of either total output or private investment, as a measure of government size or degree of government intervention in the country (e.g. Ram (1986), Kormendi and Meguire (1985), Barro (1991), Barro and Lee (1994), Evans (1997)). However, government expenditures alone can be poor representations of actual effects of government intervention on various sectors of the economy because government intervention takes several forms (e.g. tax concessions; setting of interest rates, foreign exchange rates, wage rates; subsidising education; direct public infrastructural investments, etc.), and not all interventions

necessarily involve any spending. Besides, money spent on different types of intervention may also produce different results. Another reason why government expenditure is a poor measure of government intervention relates to the way government expenditures are aggregated. It is more desirable to disaggregate government expenditures by type of expenditure (e.g. defence/military expenditures, education, social welfare, or public capital investments), because each type of government expenditure can affect different sectors of the economy differently (see for example, Kneller, Bleaney and Gemmell (1999) and Bleaney, Gemmell and Kneller (2001)). For instance, expenditures on education can lead to higher productivity growth, but public capital investments could crowd out private consumption and investment.

For this reason, we include several measures of government in our analysis and disaggregate government expenditure into non-complementary and complementary expenditures. Government non-complementary expenditures (*Noncomp*) are those that are considered as not directly affecting the productivity of the private sector (e.g., general public services, defence, and social security and welfare). We hypothesise that this type of expenditure has a negative effect on *TFP*. On the other hand, government complementary expenditures (*Comp*) are those that are likely to complement private investment (e.g., health, education and economic services, including expenditures on research, roads, other transportation and communication services). We hypothesise that this type of expenditure has a positive effect on *TFP*.

We also include government revenues in our analysis, and following the same line of reasoning that different types of government revenue could affect the economy in different ways (see for example, Kneller et al. (1999) and Bleaney et al. (2001)), we also disaggregate our government revenue measures. In general, government revenue in this study is defined as the taxes received by the central government and, depending on how these taxes are spent, may or may not be positively associated with *TFP*. We are also concerned with how government affects the degree of openness in the economy; hence revenues are classified into domestic (*Domtax*) and

international tax revenues (*Tradetax*). We also use *Tradetax* as the proxy for the degree of openness of an economy. We opt to use *Tradetax* as the common practice of using trade volumes or trade shares and the rate of growth of exports as a proxy for openness is limited because exports are not necessarily related to trade policy. A country's trade regime can be heavily distorted, but still have high export growth rates (Edwards, 1997). Rodriguez and Rodrik (2000) provide a comprehensive assessment of the different measures of openness used in the empirical literature on openness and growth. They find that in many cases, the indicators used by researchers are problematic as measures of openness, or are often highly correlated with other sources of poor economic performance.

We tested for correlation among different measures of openness (*Tradetax*, the black market exchange premium and size of the trade sector) and found that they are significantly correlated with each other.⁴ Hence, even though there are different ways to measure the degree of openness, we expect that effect of openness on *TFP* will be approximately the same regardless of which particular measure is used, and so it is not necessary to include all of the openness variables in the same regression equation. What is of concern is choosing which one best measures the degree of openness of the economy for our purposes. Because of concerns regarding the reliability of data on black market exchange rate premiums and on the limitations of the use of the size of the trade sector as a proxy for openness, we opted to use *Tradetax* as our measure of openness.

Data for our government and openness indicators are taken from various issues of the IMF's *International Financial Statistics* (IFS) and *Government Finance Statistics* (GFS) yearbooks, and the Asian Development Bank's (ADB) *Key Indicators for Developing Member Countries*. In order to keep the panel balanced, the full set of panel data used in this study consists of time-

⁴ Results are available from the author on request.

series observations over the period 1973 to 1990, a total of 18 annual observations for five HPAEs: Indonesia, Malaysia, Singapore, South Korea and Thailand. The analysis is limited to these five HPAEs mainly because the International Monetary Fund's (IMF) *Government Finance Statistics* (GFS), the main source of our government-related variables, do not report data for the other two HPAEs: Hong Kong and Taiwan. Table 1 presents some basic descriptive statistics for the variables used in this paper.

Table 1
BASIC DESCRIPTIVE STATISTICS FOR THE VARIABLES

	Variables (in logs)					
	<i>lnTFP</i>	<i>lnTrade</i>	<i>lnDomtax</i>	<i>lnNoncomp</i>	<i>lnComp</i>	<i>lnHuman</i>
mean	8.393011	-3.43043	-2.03696	-2.54212	-2.43074	5.009262
median	8.540939	-3.01232	-2.0305	-2.5521	-2.45226	4.993886
std dev.	0.512616	1.093236	0.223276	0.268141	0.362183	0.116888

4. Panel unit root testing

Panel unit roots based on the Im, Pesaran and Shin (2003) (hereafter IPS) t -bar test for the more general case when the errors in the univariate time-series representation are serially correlated, for the logarithms of each of the variables' demeaned series, with and without trend, were carried out and the results are summarised in Table 2.⁵ We opt to use this more general specification of the IPS t -bar test, so as not to restrict the number of lagged terms (p_i) to be zero for all countries, and instead let p_i be determined based on the GS testing strategy to ensure that errors are uncorrelated.

⁵ In the case where the errors in the different regressions contain a common time-specific component, IPS propose the same t -bar test, but with the individual test statistics based on cross-sectionally demeaned regressions. This approach, however, does not correct for specific dependencies in the errors involving, for instance, pairs of countries within the bigger group. In this study, we argue that demeaning is more appropriate compared to many other applications of the IPS test, because our group of countries, the

Table 2
RESULTS OF IPS PANEL UNIT ROOT TESTS

Variable (in logs)	\bar{t}_{NT}			
	Original		demeaned	
	trend	no trend	trend	no trend
$\ln TFP$	-1.6433	-0.4638	-2.3843	-1.2442
$\Delta \ln TFP$	-3.4682***	-2.9332***	-3.5269***	-3.4179***
$\ln Trade$	-3.118***	-1.2331	-3.1495***	-1.6024
$\Delta \ln Trade$	-5.2309***	-4.7682***	-4.1878***	-4.2349***
$\ln Domtax$	-2.4418	-2.1316*	-3.0038**	-1.9207
$\Delta \ln Domtax$	-3.6143***	-3.6220***	-4.0816***	-4.1627***
$\ln Noncomp$	-2.3272	-1.8816	-2.8581**	-1.9804
$\Delta \ln Noncomp$	-3.3163***	-3.3787***	-3.6006***	-3.7230***
$\ln Comp$	-2.1361	-2.8676**	-2.6676*	-3.0480***
$\Delta \ln Comp$	-5.0603***	-3.0433***	-4.0303***	-4.1045***
$\ln Human$	-9.1408***	-2.4764**	-8.0900***	-1.6362
$\Delta \ln Human$	-16.0225***	-10.7274***	-11.0288***	-8.6452***
critical values for \bar{t}_{NT}	1%: -3.13 (with trend) ; -2.50, (no trend)			
	5%: -2.82 (with trend); -2.19 (no trend)			
	10%: -2.67(with trend); -2.04 (no trend)			
***, ** and * reject the null of a unit root at the 1%, 5% and 10% significance levels, respectively.				

The \bar{t}_{NT} test results for the TFP series clearly show that the demeaned series, whether or not it is demeaned and/or includes a time trend, is non-stationary. For the other series however, the unit root test results are mixed, and a conclusive decision on the order of integration of the variables cannot be made.

The mixed results from the panel unit root tests based on IPS' t -bar statistics (\bar{t}_{NT}) fail to provide conclusive inference on the order of integration of the variables of interest. So, while we hoped that, by using panel data, inferences on the presence of unit roots would be more accurate, our results suggest otherwise.

HPAEs, aside from the fact that they are regionally connected, have also been hit by common shocks, e.g.

In our panel unit root tests, we find in favour of a unit root in several series that do not include a time trend in the univariate time-series representation. This result is not surprising as Perron (1988) and Elder and Kennedy (2000) note that if the series actually contains a trend, but this is erroneously omitted, unit root tests tend to be biased toward finding a unit root. On the other hand, including a trend term, when the series does not actually have one, reduces the power of the unit root test (but does provide a ‘similar’ test if $N \neq 0$). Since the consequences of over-fitting are “less harmful” than under-fitting (acknowledging that there is a trade-off between power and size of the tests), the unit root tests on the series with trend may be preferable.

Focusing on the panel unit root test results on the demeaned series with trend, we find that the \bar{t}_{NT} tests (assuming serially correlated errors) suggest that *TFP* is non-stationary, and the rest of the variables: *Tradetax*, *Domtax*, *Noncomp*, *Comp*, and *Human* are all $I(0)$. Note, however, that while we have decided that these results are “preferred” based on the reasons mentioned earlier, these are still considered quite fragile, especially since the actual data-generating structure of the variables of interest is unknown.

5. A bounds test approach to the analysis of level relationships

5.1 Pesaran et al.’s (2001) testing strategy

The results of the panel unit root tests show how sensitive unit root test results can be. There is still much uncertainty as to whether the variables of interest are actually $I(0)$ or $I(1)$. Given these results, a bounds test approach developed by Pesaran et al. (2001) for testing level

relationships could be useful because it can be applied irrespective of whether the regressors are $I(0)$ or $I(1)$.

For our purposes, we use Pesaran et al.'s bounds tests, based on standard F -statistics, to test the significance of the lagged levels of the variables within a univariate error-correction mechanism to determine long-run relations between TFP and our hypothesised determinants. The F -statistics have non-standard asymptotic distributions under the null hypothesis that there exists no level relationship, irrespective of whether the variables of interest are $I(0)$ or $I(1)$, and are analysed against two sets of critical value bounds that cover all possible classification of the regressors into purely $I(0)$, purely $I(1)$, or a mixture of $I(0)$ and $I(1)$ variables. If the computed F -statistic falls outside the critical band, a conclusive decision can be made without needing to know whether the regressors are $I(0)$ or $I(1)$. That is, if the computed F -statistic falls outside the lower critical band, we fail to reject the null hypothesis of no level relationship, and if the computed F -statistic falls outside the upper critical band, then we reject the null hypothesis and conclude that there exists a level relationship between our variables of interest. On the other hand, if the computed F -statistic falls within the bounds, then no conclusive inference can be made without first knowing the order of integration of the variables.

We apply Pesaran et al.'s bounds testing strategy to our pooled data-set consisting of five cross-sections (i.e., the five HPAEs), and 18 time-series observations (i.e., annual from 1973 to 1990). We are unable to fully exploit the advantages of panel characteristics in our analyses because of the small size of our panel data, and we have to assume homogeneity across our cross-section of countries and pool our data, treating these as coming from one long time-series. We take extreme care to ensure that our data are arranged in such a way that all the observations for each country are together. It is also important to specify the lagged variables

appropriately in order to keep the lagged variables of a country in the cross-section separate from the lag values of the next country in the cross-section.

One advantage of using panel data over pure cross-section or time-series estimation, is that, in principle, the use of panel data will allow the researcher to exploit the dynamics from the cross-sections. However, because our panel is small, i.e., the number of time-series observations is small for each country, we are unable to exploit more fully the possible heterogeneity of the underlying economic relationships; instead we assume a common structure across the five countries and apply Pesaran et al.'s bounds testing strategy. If, however, these differences do matter and are not randomly distributed, then these differences need to be properly accounted for in our *TFP* equation. The simplest way of doing so is by including dummy variables for each of the countries in our panel data set.

We begin our bounds tests by selecting the optimal length of the ARDL model using a general to specific (GS) testing strategy similar to that suggested by Campbell and Perron (1991) and Hall (1994).⁶ Once the optimal length for the distributed lagged difference for each variable in the model is determined, we then compute the *F*-statistic and test it against Pesaran et al.'s critical value bounds. If a level relationship is established, we then analyse the coefficients of the long-run relations. We also supplement our analyses with diagnostic tests.

We present in the next two sections the results of our estimations. In the first set of results, we assume that all the countries in our panel data possess similar structural characteristics and have been subjected to common shocks. We also assume that structural differences among the

⁶ Although we recognise that a pre-testing problem may be inherent in such an approach, we opt to determine the optimal lag length first, before testing for the existence of the level relationship, mainly because we do not want to compromise the degrees of freedom available, given the limited number of time-series observations we have in our pooled data-set.

HPAEs in our panel do not affect TFP , or if they do, these effects are randomly distributed with zero mean. In the second set of results, we assume that, these differences do matter and are not randomly distributed, so we include dummy variables for each of the countries in our panel data set.⁷

5.2 Bounds test for the existence of level relationships in a TFP equation

Due to the short span of time-series data available for each country in our panel, we set the highest order of the lags in our ARDL model at $p_{max} = 5$. The error correction version of our ARDL (5, 5, 5, 5, 5, 5) model in the variables TFP , $Tradetax$, $Domtax$, $Noncomp$, $Comp$ and $Human$, where these variables are as previously defined, is given by:

$$\Delta \ln TFP_{it} = \alpha_0 + \alpha_1 \ln TFP_{it-1} + \alpha_2 X_{it-1} + \sum_{p=1}^5 \alpha_3 \Delta Z_{it-p} + \alpha_4 \Delta X_{it} + u_{it} \quad (1)$$

where,

$$X_{it} = (\ln Tradetax_{it}, \ln Domtax_{it}, \ln Noncomp_{it}, \ln Comp_{it}, \ln Human_{it})'$$

$$Z_{it} = (\ln TFP_{it}, \ln Tradetax_{it}, \ln Domtax_{it}, \ln Noncomp_{it}, \ln Comp_{it}, \ln Human_{it})'$$

$$= (\ln TFP_{it}, X'_{it})'$$

$$\alpha_0 = \text{is an intercept term, representing the structural similarities between countries}$$

$$\alpha_k = k = 1, \dots, K, \text{ are vectors of slope coefficients, assumed to be constant over time and countries.}$$

⁷ Country-specific trend terms could also have been included in our general equation to allow for possible influences of trends in the data. However, to avoid losing valuable degrees of freedom, given our small panel data set, we have instead re-estimated our general equation using de-trended variables. In de-trending the variables though, we are in effect forcing the variables for each country to have zero means; hence we are practically throwing away any long-run information from whatever cross-country variation there may be. Because of these reservations, the results of the estimation of the general equation using de-trended variables are not presented here. Results are available on request from the author.

and the subscripts i and t denote country and time respectively. We assume, at least initially, that the countries in our panel have common structural characteristics, and that individual country differences have no significant effect on TFP or, if they do, these effects are randomly distributed with zero mean. Ideally, country-specific trend terms should be included in our regression equation. However, because there are only five cross-sections in the data set and the number of annual observations for each country is also limited (i.e., $t = 18$), including country-specific trend terms is not feasible since it would lead to further loss in degrees of freedom.

Our GS testing strategy to determine the appropriate length of the distributed lag begins by estimating equation (1). The last lagged difference term of the regressor with the least significant coefficient is deleted, and the equation is re-estimated until all the last lagged difference terms of the regressors are all significant. This results in the choice of an ARDL (0, 0, 3, 0, 3, 0) specification. The computed F-statistic for testing the hypothesis that there exists no level relationship between TFP and the explanatory variables in our equation ($\alpha_2 = 0$) is $F(6,52) = 1.0956$.⁸ This indicates that the hypothesis that there exists no level relationship in our TFP equation is not rejected. In this case, Pesaran et al. do not recommend proceeding with the estimation of the error-correction form of our ARDL (0, 0, 3, 0, 3, 0) TFP equation, and from this we find hardly any evidence of a long-run relationship between TFP and our explanatory variables. To the extent that this ECM had been meaningful, analysis of the level relationships using the ECM form would have allowed us to examine more directly the dynamics that exist between changes in TFP and its hypothesised determinants.

5.3 Bounds test for the existence of level relationships in a TFP equation *with* country-specific dummy variables

⁸ The appropriate critical value bounds from Pesaran et al. are (2.12, 3.23), (2.45, 3.61) and (3.15, 4.43) at 90%, 95% and 99% significance levels respectively.

In order to allow for differences in structural characteristics, we have included dummy variables for each of the countries in our panel data set. Thus, our *TFP* equation with dummy variables is given as:

$$\begin{aligned} \Delta \ln TFP_{it} = & \alpha_1 \ln TFP_{it-1} + \alpha_2 X_{it-1} + \sum_{p=1}^5 \alpha_3 \Delta Z_{it-1} + \alpha_4 \Delta X_{it} \\ & + \sum_{j=1}^5 \alpha_5 D_{jt} + u_{it} \end{aligned} \quad (2)$$

where the variables and parameters are as previously defined, and the D_{jt} s are dummy variables,⁹ such that:

$$D_{jt} = \begin{cases} 1 & \text{for observations for country } j \quad (j = 1, \dots, 5) \\ 0 & \text{otherwise} \end{cases}$$

Following the same GS testing strategy to determine the optimal length of the distributed lag in our ARDL *TFP* equation, we arrive at an ARDL (1, 5, 3, 3, 2, 1) *TFP* equation. We then estimate the ECM form of this equation and present the results in Table 3. Table 4 presents diagnostic test results.

The computed *F*-statistic for the ARDL (1, 5, 3, 3, 2, 1) *TFP* equation with dummy variables, $F(6,29) = 5.0990$, clearly falls outside Pesaran et al.'s upper critical value bounds,¹⁰ Thus, the null hypothesis of no level relationship in our *TFP* equation with dummy variables for each HPAE, is rejected, irrespective of whether the variables are all I(0) or all I(1) or a mixture of I(0) and I(1).

Our estimates also show that three of the six explanatory variables in levels (*TFP*, *Noncomp* and *Comp*), are highly statistically significant. The lagged levels of *TFP* and *Noncomp* appear to

⁹ There are five dummy variables included in equation (2) because it does not include an additional/separate constant variable.

¹⁰ In this case, these are (2.12, 3.23), (2.45, 3.61) and (3.15, 4.43) at 90%, 95% and 99% significance levels respectively. We recognise that for our new equation, where our intercept term is effectively

have a significant negative influence on the change in *TFP* ($\ln\Delta TFP$), while the lagged level of *Comp* appear to have a significant positive effect. The *Domtax*, *Tradetax* and *Human* lagged level variables have no significant effect.

Of the differenced variables, only those of *Noncomp* and *Comp* are found to be statistically significant. The coefficient of the change in *Noncomp* points to a negative influence on the change in *TFP*, while the coefficient of the change in *Comp* indicates a positive influence.

Our testing strategy that started with choosing the optimal length of the distributed lag ensured that, at least the last lagged difference term of each variable is statistically significant. It is interesting to note, however, that while the levels of *TFP* and *Noncomp* indicate a negative influence on the change in *TFP*, we find that the lagged changes of these variables, generally positively affect the change in *TFP*. In the same way, while the levels of *Domtax* and *Comp* are positive influences on the change in *TFP*, their lagged changes have the opposite (negative) effect. This seems to indicate that some level variables may initially have a positive (e.g. *Domtax* and *Comp*) or negative (e.g. *Noncomp*) effect on the change in *TFP*, but after some time, have a reverse effect.

For the *Tradetax* and *Human* variables, it appears that it takes some time before their effects on the change in *TFP* are manifested, i.e. between three to five period lagged changes for *Tradetax*, and a one-period lagged change in *Human*.

In terms of the dummy variables for each of the HPAEs, we find that none of these is statistically significant. However, a joint (*F*-) test on the significance of the country-specific dummy variables (H_0 : α_5 's are all = 0 against H_1 : at least one of the α_5 's are $\neq 0$) indicate that at

disaggregated into country-specific dummy variables, the critical values we use to test our hypothesis may be affected; hence we use these critical values with some reservation.

least some of the coefficients of the dummy variables are significantly different from zero. This implies that country-specific characteristics do affect our *TFP* equation. Such a result may be better confirmed by applying the same bounds test for each individual country over time. However, because there are not enough time-series data available for the HPAEs, it is not feasible to apply the same bounds test on the individual HPAEs at this point.

We find that our regression equation fits reasonably well and also performs well against a series of diagnostic tests. Diagnostic tests for normality of error terms, heteroskedasticity and model mis-specification for the ECM form of the ARDL (1, 5, 3, 3, 2, 1) *TFP* equation with dummy variables indicate that the errors are normally distributed and in general, do not suffer from heteroskedasticity and mis-specification problems. Overall, we consider the results of our estimation reasonably reliable.

Table 3

ERROR CORRECTION FORM OF THE ARDL (1, 5, 3, 3, 2, 1) TFP EQUATION
(DEPENDENT VARIABLE: $\Delta \ln TFP_{it}$, 1973-1990)

Regressor	Coefficient	Standard error	t-ratio
$\ln TFP_{it-1}$	-0.502	0.130	-3.866***
$\ln \Delta TFP_{it-1}$	0.262	0.151	1.737*
$\ln Tradetax_{it-1}$	-0.000	0.049	-0.001
$\ln \Delta Tradetax_{it}$	0.054	0.059	0.919
$\ln \Delta Tradetax_{it-1}$	0.116	0.080	1.449
$\ln \Delta Tradetax_{it-2}$	-0.055	0.093	-0.591
$\ln \Delta Tradetax_{it-3}$	0.186	0.076	2.450**
$\ln \Delta Tradetax_{it-4}$	-0.004	0.0778	-0.058
$\ln \Delta Tradetax_{it-5}$	0.099	0.052	1.909*
$\ln Domtax_{it-1}$	0.250	0.146	1.710
$\ln \Delta Domtax_{it}$	0.128	0.116	1.109
$\ln \Delta Domtax_{it-1}$	0.047	0.116	0.410
$\ln \Delta Domtax_{it-2}$	-0.005	0.107	-0.051
$\ln \Delta Domtax_{it-3}$	-0.274	0.128	-2.145**
$\ln Noncomp_{it-1}$	-1.224	0.302	-4.057***
$\ln \Delta Noncomp_{it}$	-0.508	0.116	-4.396***
$\ln \Delta Noncomp_{it-1}$	0.652	0.185	3.525***
$\ln \Delta Noncomp_{it-2}$	0.427	0.124	3.435***
$\ln \Delta Noncomp_{it-3}$	0.349	0.103	3.402***
$\ln Comp_{it-1}$	0.540	0.158	3.416***
$\ln \Delta Comp_{it}$	0.244	0.081	3.004***
$\ln \Delta Comp_{it-1}$	-0.219	0.105	-2.081*
$\ln \Delta Comp_{it-2}$	-0.156	0.083	-1.881*
$\ln Human_{it-1}$	0.201	0.411	0.488
$\ln \Delta Human_{it}$	-5.112	3.843	-1.330
$\ln \Delta Human_{it-1}$	-11.973	4.628	-2.587**
D1	1.959	2.083	0.940
D2	2.254	2.169	1.039
D3	2.304	2.129	1.083
D4	2.489	2.292	1.086
D5	1.531	2.068	0.740
$R^2 = 0.7531 \quad \bar{R}^2 = 0.4976 \quad F\text{-statistic (6,29)} = 5.0990***$			

Notes:

***, ** and * reject the null hypothesis at 1%, 5% and 10% levels respectively.

Table 4
 DIAGNOSTIC TEST RESULTS
 FOR THE ERROR CORRECTION FORM
 OF THE ARDL (1, 5, 3, 3, 2, 1) *TFP* EQUATION

Null hypothesis	Test statistics	Conclusion
Jarque-Bera LM test for normality of errors	0.820 (2)	Fail to reject H_0
Homoskedasticity		
$(\varepsilon_i)^2$ on \hat{Y}_i	7.580*** (1)	Reject H_0
$(\varepsilon_i)^2$ on $[\hat{Y}_i]^2$	1.347 (1)	Fail to reject H_0
$(\varepsilon_i)^2$ on $\ln[\hat{Y}_i]^2$	0.670 (1)	Fail to reject H_0
$(\varepsilon_i)^2$ on X	35.001 (30)	Fail to reject H_0
$\ln[(\varepsilon_i)^2]$ on X	30.424 (30)	Fail to reject H_0
$ \varepsilon_i $ on X	33.544 (30)	Fail to reject H_0
Correct specification		
RESET (2)	4.417* (1, 28)	Reject H_0
RESET (3)	2.437 (2, 27)	Fail to reject H_0
RESET (4)	1.566 (3, 26)	Fail to reject H_0

Notes:

Numbers in parentheses are degrees of freedom.

The Jarque-Bera and heteroskedasticity tests are χ^2 distributed and the RESET tests are F-distributed under their respective null hypotheses.

***, ** and * reject the null hypothesis at 1%, 5% and 10% levels, respectively.

So far, we have only presented the results of the ECM form of the ARDL (1, 5, 3, 3, 2, 1) *TFP* equation. Earlier we mentioned that the ECM form allows a better insight into the dynamics involved in our *TFP* representation. However, from this, we can also obtain the implied long-run level relationship between *TFP* and the other variables. Solving our general ECM equation with dummy variables and trend (equation (2)), for $\ln TFP$ gives the long-run relationship between *TFP* and our hypothesised determinants as:

$$\ln TFP_{it} = \gamma X_{it} + \varepsilon_t, \text{ where } \gamma = - \begin{pmatrix} \alpha_2 \\ \alpha_1 \end{pmatrix} \quad (3)$$

and substituting the results from our ECM estimation, we have (*t*-statistics are in parentheses):¹¹

$$\begin{aligned} \ln TFP = & -0.0001 \ln Tradetax + 0.4971 \ln Domtax - 2.4370 \ln Noncomp \\ & (-0.0006) \quad (1.7445) \quad (-4.8941) \\ & + 1.0747 \ln Comp + 0.3995 \ln Human + \varepsilon_t \\ & (5.0331) \quad (0.4855) \end{aligned} \quad (4)$$

In analysing the level relationships, we find that the level estimates of *Domtax*, *Noncomp* and *Comp* are statistically significant. Both *Domtax* and *Comp* appear to have a positive effect on the *TFP* level, while *Noncomp* appears to have a highly statistically significant negative effect. The coefficients of the levels of *Tradetax* and *Human* are not statistically significant.

6. Summary and conclusions

In this study, we attempt to provide further insight as to what factors essentially drive *TFP* in five HPAEs using panel data. Recent panel unit root tests developed by IPS (2003) are applied to determine the time-series properties of the data. However, the results of our panel unit root tests, as well as the individual unit root tests performed in this study, provide no conclusive evidence on the order of integration of the variables of interest.

To overcome this situation and enable us to proceed with our analysis, we turn to the bounds testing approach to the analysis of level relationships developed by Pesaran et al. (2001). The main advantage of this testing strategy is that it can be applied irrespective of whether the variables of interest are I(0) or I(1), therefore avoiding difficulties associated with unit root

¹¹ Since the small-sample distribution of the level relationship is unknown, the *t*-statistics reported (obtained from non-linear tests) should be interpreted with caution.

testing (such as those mentioned previously). We use pooled data from five HPAEs and treat these as coming from one long time-series.

If we allow for country-specific effects in our regression equation (i.e., ARDL (1, 5, 3, 3, 2, 1) *TFP* equation) (equation (4)), we find strong evidence of a long-run relationship between *TFP* and our hypothesised determinants, irrespective of whether the regressors are I(0) or I(1). Both the ECM estimation of the underlying ARDL *TFP* equation and the implied level relationship indicate that the levels of the two types of government expenditure variables, *Noncomp* and *Comp*, are highly statistically significant influences on *TFP*. As hypothesised, the level estimates of *Noncomp* have a negative effect of *TFP* levels, while *Comp* levels have a positive effect. The level estimates of *Domtax*, also have a statistically significant (though to a slightly lesser degree) positive effect on *TFP* levels.

The information on the long-run relationship between the variables from this model suggests the importance of these variables in explaining *TFP* levels in the HPAEs, particularly the two types of government expenditure. Taken at face value, the sign and statistical significance of the coefficients on these government expenditure variables indicate what the effects are of different types of government expenditure on *TFP* levels. Expenditures on general public services, defence, and social security and welfare, which make up our *Noncomp* variable, adversely affect *TFP* levels. On the other hand, expenditures on health, education and economic services, including expenditures on research, roads, other transportation and communication services, which make up our *Comp* variable, positively affect *TFP*. Although appropriate policy decisions cannot be made simply on the basis of the statistical significance of these variables, the information from this study may prove useful as a starting point in developing policies that could help improve *TFP* levels in the HPAEs.

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