Looking for a Break: Identifying transitions in growth regimes

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Looking for a Break: Identifying transitions in growth regimes

ABSTRACT

Economic growth in developing countries is characterised by frequent shifts in growth regimes. Following Pritchett (2000), there is a large empirical literature that has tried to identify the timing of these shifts in economic growth. Two distinct approaches have been developed by this literature. The first is a 'filter-based' approach that identifies growth breaks on the basis of subjectively defined rules, while the second approach is based on statistical structural break tests. The first approach is ad hoc and lacks consistency across studies, while the Bai-Perron method, which is the basis of the statistical approach, has low power and cannot discern true breaks in growth. In this paper, we propose a unified approach that combines the filter and statistical approaches and avoids the limitations of each approach. Applying our approach to comparable GDP per capita data for 125 countries for the period 1950–2010, we are able to identify a much larger number of plausible breaks in GDP per capita than a pure statistical approach. More importantly, our approach is able to identify more breaks from countries with volatile growth paths—and hence has a larger proportion of breaks from developing countries than other studies that use the pure statistical method of Bai-Perron.

Keywords: Economic growth, growth regimes, structural breaks, Bai-Perron

JEL codes: C18, O11, O47

1 INTRODUCTION

The persistent differences in living standards across countries in the world have been hard to explain (Lucas 1988). Attempts to do so have generated a voluminous literature on economic growth, both theoretical and empirical. The theoretical literature, both the 'first generation' neoclassical growth models and the 'second generation' endogenous growth theories, explain these differences as the result of dissimilar steady-state growth rates across countries (e.g. Aghion and Howitt 1992; Barro and Sala-i-Martin 1997; Lucas 1988; Mankiw et al. 1992; Romer 1986; 1990; Solow 1956). The empirical literature puts into practice the concept of the steady state by adopting long-run average growth rates of countries as the variable to be 'explained' (Barro 1991). However, in recent years, there has been a realisation that explaining growth by using arbitrarily chosen long-run average growth rates (by decades, for example) fails to take account of a very important 'stylised fact' of economic growth, i.e., while the growth process of 'developed' economies is well characterised by such a single long-run average growth rate (with a 'business cycle' around this trend), this is not true of most countries in the world, many of whom exhibit multiple structural breaks in growth rates (Rodrik 1999, 2003, Hausmann et al. 2006, Aizenman and Spiegel 2010). Therefore, long-run growth averages for a country may hide distinct periods of success and failure (Jones and Olken 2008). In fact, most developing countries experience distinct growth regimes (growth accelerations and decelerations or collapses) and frequently switch from one growth regime to another.

Clearly, moving away from explaining long-run growth averages to explaining transitions between growth regimes is the key to understanding economic growth (Kar et al. 2013). This necessitates the knowledge of the timing of the breaks in economic growth. This, however, is not straightforward. How do we know when growth is accelerating when in most low income countries, income movements are highly volatile, so a movement up or down may be transitory and not signal a shift in the growth rate? How do we identify a growth break which is an episode involving a significant change in growth rates, implying a transition from one growth regime to another? These questions have given rise to a growing literature. Early contributions attempted to show that long run growth averages were not able to capture the important breaks in economic growth. Easterly et al. (1993) showed that for most countries, medium term growth rates showed a lack of persistence, indicating that these countries transitioned between high and low growth regimes. Ben-David and Papell (1998) demonstrate that rather than growing at a steady state, most developed and developing countries have been through growth transitions. The seminal paper in this area was Pritchett (2000), which showed that a single average growth rate fitted over a long time period gives very poor statistical fits in a large number of countries, particularly developing nations. A set of recent studies has followed Pritchett (2000) and attempted to identify breaks in growth rates of GDP per capita for countries with comparable income data.

Two distinct approaches have been developed by this literature. The first is a 'filter-based' approach that identifies growth breaks on the basis of subjectively defined rules. Using this approach, Hausmann et al. (2005) study breaks that involve growth accelerations, Hausmann et al. (2006) study growth collapses, and Aizenman and Spiegel (2010) study takeoffs—periods of sustained high growth following periods of stagnation. The second approach is based on statistical structural break tests that uses estimation and testing procedures to identify growth breaks in terms of statistically significant changes in (average) growth rates. The studies that have adopted the 'statistical' approach have used the Bai-Perron methodology (1998) which locates and tests for multiple growth breaks within a time-series framework.

In the Bai-Perron method, first, an algorithm searches all possible sets of breaks (up to a maximum number of breaks) and determines for each number of breaks the set that produces the maximum goodness of fit. The statistical tests then determine whether the improved fit produced by allowing an additional break is sufficiently large, given what may be expected by chance (Jones and Olken 2008). Starting with a null of no breaks, sequential tests of k versus k+1 breaks allow one to determine the appropriate number of breaks.[1] Jones and Olken (2008) is the earliest contribution that used this approach to show that upbreaks are associated with very little increase in investment and substantial increase in trade, while downbreaks are associated with major declines in investment, increasing inflation, devaluation, and a rise in internal conflict. Kerekes (2011) is a similar study that finds that upbreaks associated with technological progress have happened only in developed countries, while the same in developing countries are the result of improvements in the efficiency of production. Downbreaks, on the other hand, are the result of slower capital accumulation and deteriorating efficiency levels. Berg et al. (2012) studies the duration of growth spells. They use the Bai-Perron approach to identify breaks and then put them through economic filters to identify 'meaningful' growth spells. They find that the duration of growth spells is positively affected by equality of income distributions, good democratic institutions, openness to trade, foreign direct investment, more sophisticated exports, and a stable macroeconomic environment.

Which of the two approaches does a better job in identifying growth breaks? In the paper, we argue that both approaches have serious shortcomings that call for a better alternative. The limitation of the filter-based approach is well known—the use of filters pre-determined by the researcher is ad hoc and leads to a lack of consistency in the identification of breaks across papers that use the filter-based approach. On the other hand, a significant shortcoming with the statistical approach is that it is limited by the low power of the Bai-

[1] Bai and Perron determine critical values for tests of various sizes and employ a trimming parameter, expressed as a percentage of the number of observations, which constrains the minimum distance between two breaks.

Perron test, which leads to the rejection of true breaks suggested by the behaviour of the underlying GDP per capita series. In addition, we argue that a common limitation of both approaches is that they are ahistorical, in that they do not account for previous growth breaks in the same country when identifying current ones. We show that by not doing so, both approaches miss changes in rates of economic growth of a significant magnitude.

We then propose an approach that provides a unified framework for identifying breaks in economic growth drawing from filter-based and statistical approaches. We call this the fit and filter approach, as it involves identifying candidate breaks from the best fit to the data (Bai-Perron method) in the first stage and, in the second stage, the application of a filter to these candidate breaks to identify the chosen breaks. We then apply this approach to comparable GDP per capita data for 125 countries for the period 1950–2010. We show that our approach allows us to identify a far larger set of plausible breaks in economic growth from our sample of countries than a pure Bai-Perron approach. We discuss the difference in our results on growth breaks and those of other studies.

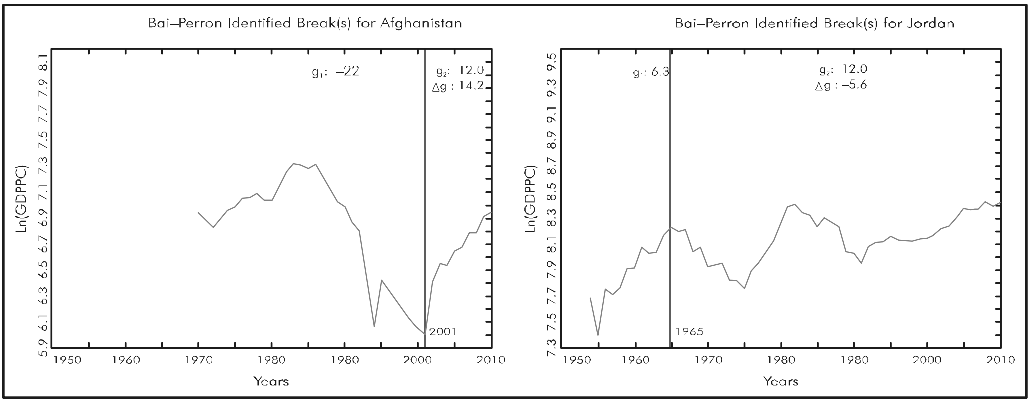
The rest of the paper is in four sections. In the next section (Section 2), we discuss the limitations of existing approaches to the identification of growth regimes. In Section 3, we propose our alternative approach. Section 4 applies our approach to Penn World Table GDP per capita purchasing power parity (PPP) data and compares our results with those of previous studies. Section 5 concludes.

2 THE LIMITATIONS OF FILTER-BASED AND STATISTICAL APPROACHES TO IDENTIFYING GROWTH BREAKS

In the filter based approach, each contribution has studied a single type of growth transition and defined them accordingly, rather than provide a single unified framework to identify all types of transitions. Thus, Hausmann et al. (2005) focus only on growth accelerations and define it as (1) increase in per capita growth rates by 2 percentage points or more; (2) sustained for at least eight years; and (3) the post-acceleration growth rate has to be at least 3.5 per cent per year. Hausmann et al. (2006), on the other hand, study only growth collapses and define these as episodes that start with a contraction of output per worker and end when output per worker again reaches the levels immediately preceding the decline. Similarly, Aizenman and Spiegel (2010) focus only on takeoffs, described as a transition from stagnation to high growth. Here, stagnation is defined as five-year periods with average per capita growth below 1 per cent, while significant growth is that exceeding 3 per cent over a minimum of five years, within 10 years of the stagnation period. The lack of a common framework in the filter-based approach is underlined by Hausmann et al. (2005) and Aizenman and Spiegel (2010), both dealing with upbreaks in growth, but defined in different ways. Hausmann et al. (2005, 2006), on the other hand, deal with upbreaks and downbreaks respectively, but do not have a common approach to them. To sum up, the shortcoming with this approach is that it fails to provide a unified framework that can be used to identify all types of growth transitions.

Studies using the statistical approach, on the other hand, are more comprehensive, in the sense that they identify all transitions—upbreaks and downbreaks. Thus, this approach scores over the filter-based approaches by providing a uniform technique to identify all growth transitions. A significant shortcoming with the statistical approach, however, is that it is limited by the low power of the Bai-Perron test. This implies that the approach may not be able to identify genuine breaks in the GDP per capita series, especially for countries where the series is highly volatile. This is known as the 'true negative' problem. Bai and Perron (2003) carry out some simulation exercises that confirm this problem conclusively. Jones & Olken (2008) and Kerekes (2011)—both based on the Bai-Perron method—have accepted this shortcoming and stressed that the set of breaks identified in their studies are a subset of the complete set of 'true' breaks. However, the problem is that the subset may not be a good representative of the complete set. This becomes clear from Figure 1 which shows the trajectory of output for Afghanistan (left panel) and Jordan (right panel).

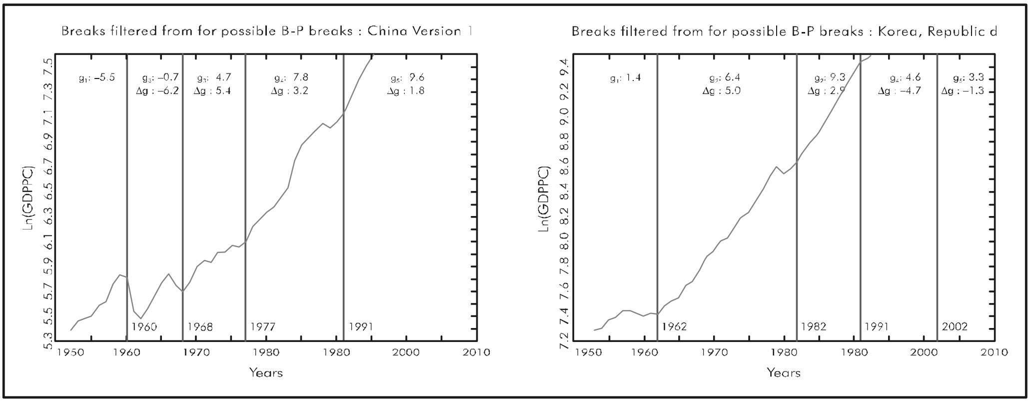
Figure 1 Countries with multiple turning points and their Bai-Perron identified breaks



In both the countries, it can be reasonably agued that there are more than one growth breaks. However, because of the high 'volatility' of output, the Bai-Perron test identifies only one break (represented by the black vertical line). In other words, particularly in those countries which have experienced large positive and negative growth breaks, this approach fails to identify them!

Apart from the shortcomings in the two approaches discussed above, there is another common lacuna. The approaches assume that any growth break is completely independent of past growth breaks—a completely ahistorical approach. In reality, however, it seems reasonable to assume that if a country has attained a large increase in growth rates, it becomes that much more difficult to increase growth rates again by a similar margin. Instead, many successful and 'miracle countries' have attained a second increase in growth rates that is much smaller, but have nonetheless played a very significant role in increasing the per capita growth rates to very high levels. Figure 2 depicts the growth experience of two 'miracle economies'—China (left panel) and Korea (right panel)—that confirm this phenomenon.

Figure 2 Smaller breaks that push growth rates to very high levels



In these graphs, we have estimated the four best breaks for the two countries using the same algorithm that is used in the first step (estimation of breaks) of the Bai-Perron approach. In the case of China, we find a larger increase in growth in 1977 (an increase of 3.2 per cent) that pushes up growth to 7.8 per cent, followed by a smaller increase in 1991 (an increase of 1.8 per cent) that pushes up growth to 9.6 per cent. Similarly, in the case of Korea, there is a large increase in growth in 1962 (an increase of 5 per cent) that pushes up growth to 6.4 per cent and a smaller increase in 1982 (an increase of 2.9 per cent) that pushes the growth rate to 9.3 per cent. Unfortunately, neither of the two existing approaches to the growth break literature is capable of identifying these smaller breaks as they do not take into account the nature of the previous break. It may be noted that while the above argument is in terms of upbreaks, the same logic holds for downbreaks as well. Any country that has experienced a large fall in growth rates may not experience another of the same magnitude, but even a smaller fall should be considered a break as it pushes down growth rates to crisis levels. Thus, for both upbreaks and downbreaks, the criteria for identifying breaks need to take into account the nature of the previous break.

In this paper, we propose an alternative approach to identifying growth breaks that takes care of the shortcomings described above. It contributes to the empirical literature on the identification of growth breaks by differing from the existing literature in three ways. First, we merge the filter-based and statistical approaches to provide a unified way of identifying growth breaks, both upbreaks (growth accelerations) and downbreaks (growth decelerations). In a sense, this approach unifies the filter-based approaches to a common framework. Secondly, we show that this approach is able to address better the 'true negative' problems of the statistical approach. Finally, we propose a filter that explicitly recognises a non-linearity in the growth process in that it is more difficult for countries to exhibit an upbreak following an upbreak or a downbreak following a downbreak. We show that by using a filter that takes into account this non-linearity, we are able to obtain a periodisation of growth regimes that are consistent with our historical understanding of economic growth across countries.

3 AN ALTERNATIVE APPROACH TO IDENTIFYING GROWTH TRANSITIONS

We start with the Bai-Perron technique, which is a two-step methodology where the first step estimates up to a given number of breaks and the second step sequentially tests for the optimal number of statistically significant breaks. It may be noted that the poor power of the Bai-Perron test can be attributed to the second step where the statistical testing procedure rejects a large number of 'true' breaks. In order to provide an identification mechanism that is more broad-based and captures a larger number of 'true' breaks, we propose an alternative two-step method. Here, the first step again uses the Bai-Perron estimation technique to identify potential breaks. However, the second step uses an 'economic filter' instead of a 'statistical procedure' to confirm the genuine breaks. As we shall see in the next section, this helps us to identify a far larger set of breaks from a sample of countries.

An important prerequisite for the first step is to determine the maximum number of breaks that is going to be estimated by the algorithm. In the Bai-Perron technique, this is partly determined by the minimum length of the growth regimes and partly by the length of data series that is available to the researcher. We estimate the potential breaks assuming that 'growth regime' lasts a minimum of eight years. One can use shorter or longer periods but shorter periods (e.g. three or five years) risk conflation with 'business cycle fluctuations' or truly 'short run' shocks (e.g. droughts). Longer periods (e.g. 10 or 12 years) reduce the number of potential breaks. The length of the output data series that is available in the Penn World Tables varies from country to country. This implies that we need to specify a maximum number of candidate breaks for each country depending on the length of the data series available. We postulate that a country with

(1) forty years of data (only since 1970) can have a maximum of two breaks;

(2) more than 40 years and up to 55 years (data since 1955) can have a maximum of three breaks; and

(3) more than 55 years (before 1955) can have a maximum of four breaks.

Based on these assumptions, the first step of our methodology uses the first step of the Bai-Perron technique to estimate the best 'potential' breaks for each country, where the number of breaks depend on the length of time series data that is available for the country. Once the 'potential' breaks have been estimated, the second step of our methodology uses a filter in order to confirm the genuine breaks.

There is an important distinction between our filters and those used by earlier studies (see Hausmann et al. 2005 or Aizenman and Spiegel 2010) that needs some clarification at this stage. We recognise a non-linearity present in growth dynamics—when a country has achieved a positive growth transition (an upbreak), it gets tougher to increase growth rates sufficiently to achieve another transition of a similar magnitude. Conversely, when a country has achieved a negative growth transition (a downbreak), it is tough to have another downbreak of a similar magnitude. We feel that a smaller increase in growth rates should be considered as an upbreak provided it follows another upbreak. The same logic applies for downbreaks. Based on this, our filters are as follows:

(1) In case of the first candidate break, since it is not known whether it follows an acceleration or deceleration, any change of more than 2 per cent (up or down) is counted as a growth break.

After that, the threshold depends on the previous history:

(2) If a candidate acceleration follows a previous deceleration or a candidate deceleration follows a previous acceleration, then to qualify as a genuine growth break, the absolute magnitude of the growth difference has to be 3 per cent.

(3) If, however, a candidate acceleration follows a previous acceleration or a candidate deceleration follows a previous deceleration, then a change of only 1 ppa (in absolute value) qualifies as a genuine break.

How does this method work in practice? We take a few country experiences to throw light on this issue. In the case of Brazil, the Bai-Perron procedure finds only one growth break in 1980 as statistically significant, separating growth of 4.8 per cent during 1950 to 1980 from growth of 0.7 per cent during 1980-2010. In our approach, the first step identifies four candidate break years: 1967, 1980, 1992, and 2002. In 1967, growth accelerated from 3.7 per cent (for 1950-67) to 6.3 per cent (for 1967-80). Since this is the first potential break and is above the 2 per cent threshold, we conclude that it is a genuine break. In 1980, growth decelerates from 6.35% to -1.1 per cent (for 1980-92), a deceleration of 7.4 per cent, and easily passes the 'deceleration following acceleration' threshold of 3 per cent. In 1992, growth accelerates from -1.1per cent to 1.4 per cent, a change of 2.5 per cent. However, as this is an acceleration following a deceleration, it would have to be above 3 per cent in order to pass the filter and hence, we do not include 1992 as a 'genuine' growth break. In 2002, growth accelerated again, this time to 2.5 per cent and since this was an acceleration, following a previous candidate acceleration, it only had to pass the 1 per cent threshold. So our procedure characterises Brazil's growth regimes as 'strong growth' of 3.7 per cent from 1950-1967, 'rapid growth' of 6.3 per cent from 1967 to 1980, 'stagnation' from 1980 to 2002, followed by 'strong growth' again from 2002 to 2010. Looking at the growth experience of Ghana, the Bai-Perron procedure finds only one statistically significant growth break, from a growth rate of 0.1 per cent from 1955–83 to a growth rate of 2.6 per cent from 1983–2010. Our method classifies all three of the candidate break years as breaks and hence has four growth regimes in Ghana. These are slow growth from 1955 to 1966 (g = 1.2 per cent), a burst of growth from 1966 to 1974 (g = 3.7per cent), a growth disaster from 1974 to 1983 (g = -4.5 per cent) and moderate growth from 1983 to 2010 (g = 2.6 per cent).

Our methodology clearly creates a richer description of the dynamics. This point is further illustrated by looking at country graphs. Figure 3 presents the growth breaks for Jordan corresponding to the Bai-Perron method (left panel) and our methodology (right panel). Our method correctly identifies all the four 'turning points' in Jordan's economic history as genuine breaks. In this sense, our method can be reasonably said to be able to identify a larger number of 'true negatives' compared to the BP technique. Interestingly, our method also performs better than the BP technique in avoiding problems of 'false positives', i.e., identifying breaks that are not 'true' breaks. This problem typically arises in countries with very smooth growth paths, where even small changes in average growth rates get identified as breaks in the BP framework. This point is illustrated in Figure 4 that depicts the output trajectory for Canada.

Figure 3 Growth breaks for Jordan: Bai-Perron versus Fit-and-Filter

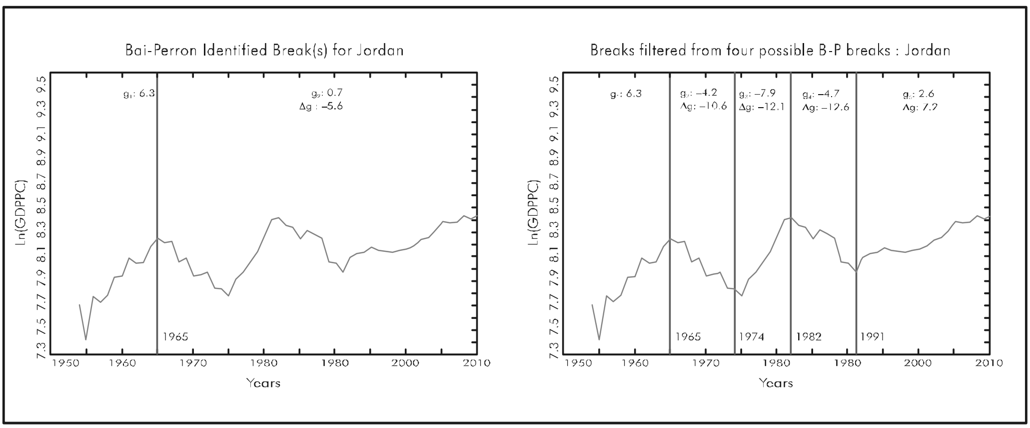
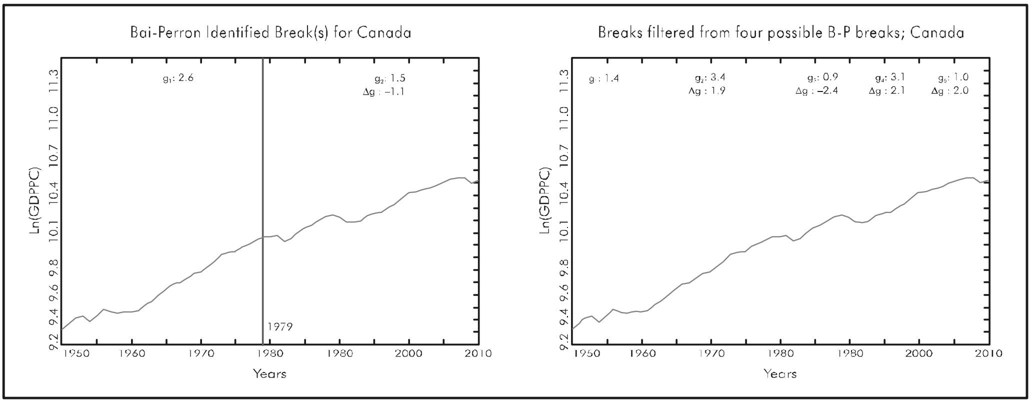


Figure 4 Growth breaks for Canada: Bai-Perron versus Fit-and-Filter



Here, we find the growth breaks for Canada corresponding to the BP method (left panel) and our methodology (right panel). The BP technique identifies 1979 as a break even though the difference in the growth rates before and after the break is only around 1 per cent. Our approach, however, rejects this case and returns a 'no-break' result for Canada.

4 APPLYING OUR APPROACH

How well does our methodology work with cross country output data? As we shall show in this section, our methodology identifies a significantly larger number of breaks than other studies that use some variant of the BP technique (Jones and Olken 2008; Kerekes 2011; Berg et al. 2012). We use per capita income growth data from the Penn World Table (PWT Version 7.1) which provides data from 1951 to 2010. Based on this data, Table 1 shows that our methodology identifies a total of 314 breaks (156 upbreaks and 158 downbreaks). Compared to this, Jones and Olken (2008) identify 73 breaks, Kerekes (2011) identifies 97 breaks and Berg et al. (2012) identify 174 breaks. Of course, our study has between 4 and 10 years' more data than these studies but that explains only a small part of the much larger number of breaks identified we have.[2] (See Table 2 for the number of breaks in the 2000s). What explains this difference?

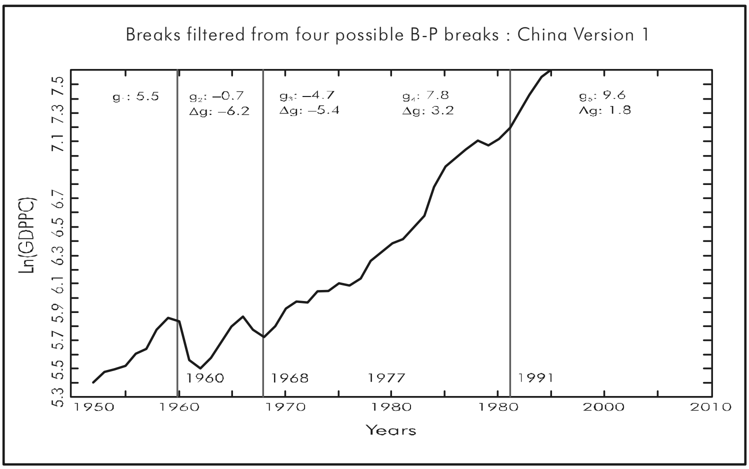
There are two salient features of our methodology that enable it to identify more breaks than approaches based on the Bai-Perron method. The first is that 'genuine' breaks are defined by the magnitude of the change in growth rate before and after the break. This enables us to identify breaks every time there is a certain change in the average growth rates between two periods. The Bai-Perron method would identify the same as a break only

2 Jones and Olken (2008) use PWT 6.1 with data from 1950 to 2000 while Kerekes (2011) uses PWT 6.2 with data ranging from 1950 to 2004. Berg et al. use PWT 6.2 and augment the data till 2006 using World Economic Outlook Database.

if the change in growth rate is statistically significant. Thus, breaks on volatile growth paths do not get easily identified by the Bai-Perron approach, even if the volatility is itself a result of the growth break. The second important feature in our approach that helps in identifying more breaks is—as discussed earlier—an explicit recognition of a non-linearity in growth dynamics, i.e., a positive growth transition makes it tougher to achieve another positive growth transition of the same magnitude. Conversely, a negative growth transition makes it tougher to have another negative growth transition of the same magnitude. In terms of our definition of breaks, this manifests itself in terms of different filters for the candidate breaks, depending on the nature of the last actual break. More specifically, any acceleration can be counted as a genuine break even if it is only one percentage point higher than the last growth regime, provided the last regime was also the result of an acceleration. This allows us to identify a number of breaks at relatively higher levels of growth, while these are missed by the Bai-Perron technique. For a developing nation, the critical importance of these transitions from high to higher growth rates (arguably, these are the real 'miracles') can hardly be overemphasised.

The growth dynamics of China is a good example to highlight the points discussed above in more details. Figure 5 shows the per capita output of China between 1950 and 2010.

Figure 5 Identifying growth breaks in China



Based on variants of the Bai-Perron technique, Jones and Olken (2008), Kerekes (2011) and Berg et al. (2012) all identify a single break in China's growth—1978 for Jones and Olken and 1977 for the other two studies. Our methodology, on the other hand, identifies three additional breaks which are 1960, 1968 and 1991, apart from 1977. Historically, all these years are recognised as growth breaks. The 'Great Leap Forward' was initiated by Mao slightly before 1960 leading to a disastrous famine and stagnation of the economy for the next few years. The average growth fell from 5.5 per cent to -0.7 per cent, a change of 6.2 per cent. The 'leap' ended around 1968 and this restored growth to the Chinese economy. In the following years, the growth rate rose again to about 5.4 per cent. The year 1977 is associated with the shift to Deng Ziaoping and a more market friendly approach. This was the beginning of the 'Chinese Miracle' and growth rose to around 7.8 per cent. Finally, around 1991, the present phase of Chinese globalisation took off and China became the fastest growing economy of the world with growth rates close to 9.6 per cent.

Why did the Bai-Perron techniques fail to identify 1960, 1968, or 1991? The BP technique correctly identified 1977–78 as the most significant break in Chinese growth. Having identified this break, however, it found 1960 and 1968 were not statistically significant to be identified as breaks, largely due to the volatility of the data during the Great Leap Forward. Our methodology, on the other hand, could identify these breaks due to the changes in growth rates that they brought about. What about 1991? The growth post 1991—as everybody who has studied China knows—is a tremendous achievement for the Chinese economy. But the increase in growth rate from 7.8 per cent to 9.6 per cent was not very large and, hence, did not show up as a break based on the Bai-Perron technique. Our approach, with its explicit recognition that an acceleration can count as a break even with an increase in one percentage point provided it follows another acceleration, could identify 1991 as a 'genuine' break.

Apart from developing techniques that can identify more and more 'genuine' breaks, the literature on growth transitions also focus on the distribution of these breaks—between upbreaks and downbreaks, over decades and across continents. In the rest of this section, we look at these issues. Table 1 gives upbreaks and downbreaks (actual breaks and percentage) based on our methodology (FF) and for other studies that use variants of the Bai-Perron technique. The table also presents the breaks that are generated by using the Bai-Perron technique on our data (BP-). The table indicates that our sample of breaks contains a significantly higher proportion of upbreaks compared to the other studies. This result, however, seems to have more to do with the change in the dataset rather than the change in methodology as we find that the BP technique (see KPRS-BP) also generates a relatively higher proportion of upbreaks for our database. Overall, there is an almost equal proportion of upbreaks and downbreaks based on our methodology.

Table 1 Upbreaks, downbreaks, and total breaks

Break Type	FF	BP-	Jones and Olken	Kerekes	Berg et al.
Upbreaks	156	59	30	39	78
Upbreaks as % of total breaks	49.7	47.2	41.1	40.2	44.8
Downbreaks	158	66	43	58	96
Downbreaks as % of total breaks	50.3	52.8	58.9	59.8	55.2
Total breaks	314	125	73	97	174

The distribution of breaks over the decades has been a theme of recurring interest in the literature. Ben David and Papell (1998) was an early contribution that showed that while most of the breaks (downbreaks) in the developed world were in the 1970s, those in the developing countries were mostly in the 1980s. Other studies have also looked into this issue. Table 2 presents a comparison of the upbreaks, downbreaks and total breaks over the decades for our study vis-à-vis others that have used the Bai-Perron technique. The figures in square brackets represent upbreaks and downbreaks as percentage of total breaks in that decade. The figures in round brackets represent total breaks in a decade as a percentage of total breaks for the whole period. Most of the other studies find that breaks were concentrated in the 1970s and 1980s with the highest proportion of breaks in the 1970s.

Table 2 Distribution of breaks over the decades

Break type	FF	Jones and Olken	Kerekes	Berg et al.
1950s				
Upbreaks	10 [71.4]	4 [80]	5 [100]	6 [85.7]
Downbreaks	4 [28.6]	1 [20]	0 [0]	1 [14.3]
Total breaks	14 (4.5)	5 (6.8)	5 (5.2)	7 (4.0)
1960s				
Upbreaks	22 [50]	7 [100]	10 [66.7]	11 [64.7]
Downbreaks	22 [50]	0 [0]	5 [33.3]	6 [35.3]
Total breaks	44 (14.0)	7 (9.6)	15 (15.5)	17 (9.8)
1970s				
Upbreaks	22 [26.5]	5 [15.6]	3 [9.4]	13 [21.3]
Downbreaks	61 [73.5]	27 [84.4]	29 [90.6]	48 [78.7]
Total breaks	83 (26.4)	32 (43.8)	32 (33.0)	61 (35.1)
1980s				
Upbreaks	40 [51.3]	8 [44.4]	9 [31]	21 [41.2]
Downbreaks	38 [48.7]	10 [55.6]	20 [69]	30 [58.8]
Total breaks	78 (24.8)	18 (24.7)	29 (29.9)	51 (29.3)
1990s				
Upbreaks	39 [63.9]	6 [54.5]	12 [75]	27 [71.1]
Downbreaks	22 [36.1]	5 [45.5]	4 [25]	11 [28.9]
Total breaks	61 (19.4)	11 (15.1)	16 (16.5)	38 (21.8)
2000s				
Upbreaks	23 [67.6]	0 [-]	0 [-]	0 [-]
Downbreaks	11 [32.4]	0 [-]	0 [-]	0 [-]
Total breaks	34 (10.8)	0 (0.0)	0 (0.0)	0 (0.0)

They also find that a significant majority of the breaks in these two decades were downbreaks, particularly in the 1970s. Our results also confirm that around half the breaks for the whole period came from these two decades. This proportion is somewhat lower than those in the other studies because about 10 per cent of our breaks are in the 2000s, while other studies did not identify any breaks in this period due to data limitations. Interestingly, contrary to other studies, our results find that during the eighties, upbreaks are a majority rather than downbreaks.

Are there regional factors playing a role in growth breaks? The literature deals with this issue by looking at the distribution of breaks across continents. Table 3 presents the upbreaks, downbreaks, and total breaks across the continents for our study as well as those from other studies. The figures in square brackets represent upbreaks and downbreaks as a percentage of total breaks for that continent. The figures in round brackets represent total breaks for a continent as a percentage of total breaks for the whole world. Jones and Olken (2008) and Kerekes (2011), both using standard Bai-Perron techniques, identify a quarter of the breaks in Europe, with another quarter of breaks coming from Africa. The relatively large proportion of breaks from Europe is partly due to the nature of the Bai-Perron technique, which picks up breaks far more easily when countries have very steady growth rates (this is true of most of Europe). The variant used by Berg et al. (2012) is not so susceptible to this problem. Our results show a far lower proportion of breaks from Europe (and North America) and a far higher one from Africa. The proportion of upbreaks and downbreaks in Africa is also more evenly matched in our results compared to other studies that had a predominance of downbreaks. Another interesting result from our study is that both Asia and South America have proportionately more upbreaks compared to the other studies. In South America, this results in a majority of the breaks being upbreaks while downbreaks were a significant majority in the other studies.

To sum up, using our methodology, we are able to identify a much larger number of breaks. There is a larger proportion of upbreaks in our results, but that seems to be more due to having more recent data—a period when more countries experienced upbreaks. Our approach is able to identify more breaks from countries with volatile growth paths and hence has a larger proportion of breaks from developing countries, compared to other studies that use the BP technique. It also identifies a number of breaks that increase growth rates of countries from 'high' to 'higher', indicative of 'miracle growth'.

Table 3 Distribution of breaks across the continents

Break type	FF	Jones & Olken	Kerekes	Berg et al.
Asia				
Upbreaks	39 [59.1]	9 [56.3]	10 [50]	24 [51.1]
Downbreaks	27 [40.9]	7 [43.8]	10 [50]	23 [48.9]
Total breaks	66 (21.0)	16 (21.9)	20 (20.6)	47 (27.0)
Europe				
Upbreaks	14 [33.3]	5 [27.8]	8 [32]	7 [31.8]
Downbreaks	28 [66.7]	13 [72.2]	17 [68]	15 [68.2]
Total breaks	42 (13.4)	18 (24.7)	25 (25.8)	22 (12.6)
North America				
Upbreaks	19 [48.7]	6 [50]	7 [41.2]	14 [46.7]
Downbreaks	20 [51.3]	6 [50]	10 [58.8]	16 [53.3]
Total breaks	39 (12.4)	12 (16.4)	17 (17.5)	30 (17.2)
South America				
Upbreaks	21 [56.8]	1 [25]	4 [36.4]	6 [42.9]
Downbreaks	16 [43.2]	3 [75]	7 [63.6]	8 [57.1]
Total breaks	37 (11.8)	4 (5.5)	11 (11.3)	14 (8.0)
Africa				
Upbreaks	59 [49.2]	8 [38.1]	9 [40.9]	25 [45.5]
Downbreaks	61 [50.8]	13 [61.9]	13 [59.1]	30 [54.5]
Total breaks	120 (38.2)	21 (28.8)	22 (22.7)	55 (31.6)
Oceania				
Upbreaks	4 [40]	1 [50]	1 [50]	2 [33.3]
Downbreaks	6 [60]	1 [50]	1 [50]	4 [66.7]
Total breaks	10 (3.2)	2 (2.7)	2 (2.1)	6 (3.4)

5 CONCLUSIONS

Economic growth in developing countries is characterised by 'boom and bust' growth and frequent shifts in growth regimes from stagnant or declining growth to accelerations in growth and back again to decelerating growth. Following Pritchett (2000), there is a large empirical literature that has tried to identify the timing of these shifts in economic growth and periodisation of the GDP per capita data of developing countries into distinct growth regimes. The literature can be classified as using either one of two distinct approaches,

3 HPR only calculates upbreaks using a filter-break approach and so is not strictly comparable to other studies, including ours, all of which use a statistical approach or a combination of a statistical plus filter approach.

namely, the 'filter-based' approach and the 'statistical break test-based' approach. The 'filter' approach identifies growth changes as 'breaks' on the basis of a subjectively defined threshold of the magnitude of the change in growth before and after a break (e.g. Hausmann, Pritchett and Rodrik 2005).[5] The 'statistical' approach uses estimation and testing procedures (the BP test) that identify growth breaks in terms of statistically significant changes in (average) growth rates (e.g. Jones and Olken 2008, Berg et al. 2012, Kerekes 2011). The essential difference between 'filter based' and 'statistical' approaches comes in the second stage of deciding which of the 'candidate' break years identified by choosing years that maximising a test statistic (or equivalently, minimising the sum of squared errors under constraints) represents a 'true' break.

Both approaches have inherent weaknesses. The weakness of the filter-based approach is in the ad hoc nature of how the filter is set and the lack of consistency in the studies that use this approach. Due to this limitation, more recent studies use the statistical approach that rely on the BP test for identifying multiple structural breaks in a time-series. The weakness of the BP methodology is that it has low statistical power, leading to rejection of structural breaks even when they are 'true' breaks. Moreover, since the statistical power of the test is dependent on the underlying volatility of the GDP per capita series, the BP procedure may 'reject' the null and identify as a 'true' break a shift in growth rates an acceleration from g=1 to g=3.5, Dg=2.5 in one country and 'fail to reject' a break of exactly the same magnitude in another country with higher volatility.

We propose a unified approach to the identification of breaks in economic growth and the periodisation of growth regimes that combines the filter-based and statistical approaches, and that also takes into account past growth episodes in identifying growth breaks. We argue that this approach avoids the problems observed in filter-based and statistical approaches. Applying our approach to comparable GDP per capita data for 125 countries for the period 1950-2010, we are able to identify a much larger number of plausible breaks in GDP per capita than a pure statistical approach. More importantly, our approach is able to identify more breaks from countries with volatile growth paths and hence has a larger proportion of breaks from developing countries, compared to other studies that use the pure statistical method of Bai-Perron. We are also able to identify a number of breaks that increase growth rates of countries from 'high' to 'higher' indicative of 'miracle growth'.

Our approach allows the growth experiences of countries to be classified into periods of growth accelerations and periods of growth decelerations (in a companion paper, we calculate the magnitude of growth in each of the growth episodes : see Karet al. 2013). In this paper, we do not propose an explanation of why we see the frequent occurrences of regime transitions in the growth experiences of many countries. But our paper sets the stage for what needs to be explained in a theory of economic growth—by providing a characterisation of the timing of these transitions.

Appendix 1 Complete list of growth breaks by fit-and-filter method

Country	Break Dates	Nature of Breaks
	ASIA	
Afghanistan	1986	Down
Afghanistan	1994	Up
Bangladesh	1967	Up
Bangladesh	1982	Up
Bangladesh	1996	Up
Cambodia	1982	Up
Cambodia	1998	Up
China	1960	Down
China	1968	Up
China	1977	Up
China	1991	Up
Hong Kong	1981	Down
Hong Kong	1994	Down
Hong Kong	2002	Up
India	1993	Up
India	2002	Up
Indonesia	1968	Up
Indonesia	1996	Down
Iran	1976	Down
Iran	1988	Up
Iraq	1979	Down
Iraq	1991	Up
Israel	1967	Up
Israel	1975	Down
Japan	1959	Up
Japan	1970	Down
Japan	1991	Down
Jordan	1965	Down
Jordan	1974	Up
Jordan	1982	Down

Complete list of growth breaks by fit-and-filter method (contd.)

Country	Break Dates	Nature of Breaks
Jordan	1991	Up
Korea, Rep. of	1962	Up
Korea, Rep. of	1982	Up
Korea, Rep. of	1991	Down
Korea, Rep. of	2002	Down
Laos	1979	Up
Laos	2002	Up
Lebanon	1982	Up
Lebanon	1991	Up
Malaysia	1970	Up
Malaysia	1979	Down
Malaysia	1987	Up
Malaysia	1996	Down
Mongolia	1982	Down
Mongolia	1993	Up
Nepal	1983	Up
Oman	1985	Down
Pakistan	1960	Up
Pakistan	1970	Down
Philippines	1959	Down
Philippines	1977	Down
Philippines	1985	Up
Singapore	1968	Up
Singapore	1980	Down
Sri Lanka	1959	Up
Sri Lanka	1973	Up
Sri Lanka	1981	Down
Syria	1981	Down
Syria	1989	Up
Syria	1998	Down
Taiwan	1962	Up

Complete list of growth breaks by fit-and-filter method (contd.)

Country	Break Dates	Nature of Breaks
Taiwan	1994	Down
Thailand	1958	Up
Thailand	1987	Up
Thailand	1995	Down
Vietnam	1989	Up
EUROPE		
Albania	1982	Down
Albania	1992	Up
Austria	1979	Down
Belgium	1959	Up
Belgium	1974	Down
Bulgaria	1988	Down
Bulgaria	1997	Up
Cyprus	1967	Down
Cyprus	1975	Up
Cyprus	1984	Down
Cyprus	1992	Down
Denmark	1958	Up
Denmark	1969	Down
Finland	1974	Down
Finland	1985	Down
Finland	1993	Up
Finland	2001	Down
Greece	1960	Up
Greece	1973	Down
Hungary	1978	Down
Ireland	1958	Up
Ireland	1979	Down
Ireland	1987	Up
Ireland	2002	Down
Italy	1974	Down

Complete list of growth breaks by fit-and-filter method (contd.)

Country	Break Dates	Nature of Breaks
Italy	1990	Down
Italy	2001	Down
Netherlands	1974	Down
Poland	1979	Down
Poland	1991	Up
Portugal	1964	Up
Portugal	1973	Down
Portugal	1985	Up
Portugal	2000	Down
Romania	1978	Down
Romania	1986	Down
Romania	1994	Up
Spain	1974	Down
Switzerland	1974	Down
Turkey	1958	Down
United Kingdom	1981	Up
United Kingdom	2002	Down
NORTH AMERICA		
Costa Rica	1958	Down
Costa Rica	1979	Down
Costa Rica	1991	Up
Cuba	1984	Down
Cuba	1995	Up
Dominican Republic	1960	Down
Dominican Republic	1968	Up
Dominican Republic	1976	Down
Dominican Republic	1991	Up
El Salvador	1978	Down
El Salvador	1987	Up
Guatemala	1962	Up
Guatemala	1980	Down

Complete list of growth breaks by fit-and-filter method (contd.)

Country	Break Dates	Nature of Breaks
Guatemala	1988	Up
Haiti	1972	Up
Haiti	1980	Down
Haiti	1994	Up
Honduras	1970	Up
Honduras	1979	Down
Jamaica	1961	Down
Jamaica	1972	Down
Jamaica	1986	Up
Jamaica	1994	Down
Mexico	1981	Down
Mexico	1989	Up
Nicaragua	1967	Down
Nicaragua	1979	Up
Nicaragua	1987	Down
Nicaragua	1995	Up
Panama	1959	Up
Panama	1982	Down
Panama	2002	Up
Puerto Rico	1972	Down
Puerto Rico	1982	Up
Puerto Rico	2000	Down
Trinidad & Tobago	1961	Down
Trinidad & Tobago	1980	Down
Trinidad & Tobago	1989	Up
Trinidad & Tobago	2002	Up
SOUTH AMERICA		
Argentina	1977	Down
Argentina	1985	Up
Argentina	1994	Down
Argentina	2002	Up
Bolivia	1958	Up
Bolivia	1977	Down
Bolivia	1986	Up

Complete list of growth breaks by fit-and-filter method (contd.)

Country	Break Dates	Nature of Breaks
Brazil	1967	Up
Brazil	1980	Down
Brazil	2002	Up
Chile	1968	Down
Chile	1976	Up
Chile	1986	Up
Chile	1997	Down
Colombia	1967	Up
Colombia	1994	Down
Colombia	2002	Up
Ecuador	1970	Up
Ecuador	1978	Down
Ecuador	1999	Up
Guyana	1981	Down
Guyana	1990	Up
Paraguay	1971	Up
Paraguay	1980	Down
Paraguay	1989	Down
Paraguay	2002	Up
Peru	1959	Up
Peru	1967	Down
Peru	1981	Down
Peru	1992	Up
Uruguay	1977	Down
Uruguay	1985	Up
Uruguay	1994	Down
Uruguay	2002	Up
Venezuela	1977	Down
Venezuela	1985	Up
Venezuela	2002	Up
AFRICA		
Algeria	1971	Up
Algeria	1979	Down
Algeria	1994	Up

Complete list of growth breaks by fit-and-filter method (contd.)

Country	Break Dates	Nature of Breaks
Angola	1993	Up
Angola	2001	Up
Benin	1978	Up
Benin	1986	Down
Benin	1994	Up
Botswana	1973	Down
Botswana	1982	Up
Botswana	1990	Down
Burkina Faso	1971	Up
Burkina Faso	1979	Down
Burundi	1992	Down
Burundi	2000	Up
Cameroon	1976	Up
Cameroon	1984	Down
Cameroon	1994	Up
Central African Republic	1986	Down
Central African Republic	1996	Up
Chad	1971	Down
Chad	1980	Up
Chad	2000	Up
Congo, Dem. Rep.	1958	Down
Congo, Dem. Rep.	1974	Down
Congo, Dem. Rep.	1989	Down
Congo, Dem. Rep	2000	Up
Congo, Republic of	1976	Up
Congo, Republic of	1984	Down
Congo, Republic of	1994	Up
Cote d'Ivoire	1978	Down
Egypt	1965	Down
Egypt	1976	Up
Egypt	1992	Down
Ethiopia	1969	Down
Ethiopia	1983	Down
Ethiopia	1992	Up

Complete list of growth breaks by fit-and-filter method (contd.)

Country	Break Dates	Nature of Breaks
Ethiopia	2002	Up
Gabon	1968	Up
Gabon	1976	Down
Gabon	1987	Up
Gambia, The	1982	Down
Gambia, The	1995	Up
Ghana	1966	Up
Ghana	1974	Down
Ghana	1983	Up
Ghana	2002	Up
Guinea	2002	Down
Guinea-Bissau	1970	Down
Guinea-Bissau	1981	Up
Guinea-Bissau	1997	Down
Kenya	1967	Down
Lesotho	1970	Up
Lesotho	1978	Down
Lesotho	1986	Up
Liberia	1994	Up
Liberia	2002	Down
Madagascar	1974	Down
Madagascar	2002	Up
Malawi	1964	Up
Malawi	1978	Down
Malawi	2002	Up
Mali	1974	Up
Mali	1986	Down
Mauritania	1968	Down
Mauritania	1976	Down
Mauritania	2002	Up
Mauritius	1963	Down
Mauritius	1971	Up
Mauritius	1979	Down
Morocco	1960	Up

Complete list of growth breaks by fit-and-filter method (contd.)

Country	Break Dates	Nature of Breaks
Morocco	1968	Down
Morocco	1977	Down
Morocco	1995	Up
Mozambique	1976	Down
Mozambique	1986	Up
Mozambique	1995	Up
Namibia	1974	Down
Namibia	1985	Up
Namibia	2002	Up
Niger	1968	Down
Niger	1979	Down
Niger	1987	Up
Nigeria	1960	Down
Nigeria	1968	Up
Nigeria	1976	Down
Nigeria	1987	Up
Rwanda	1981	Down
Rwanda	1994	Up
Rwanda	2002	Down
Senegal	1973	Up
Sierra Leone	1970	Down
Sierra Leone	1990	Down
Sierra Leone	1999	Up
Somalia	1978	Down
South Africa	1981	Down
South Africa	1993	Up
Sudan	1978	Down
Sudan	1996	Up
Swaziland	1978	Down
Swaziland	1989	Down
Tanzania	1971	Down
Tanzania	2000	Up
Togo	1969	Down
Togo	1979	Down

Complete list of growth breaks by fit-and-filter method (contd.)

Country	Break Dates	Nature of Breaks
Togo	1993	Up
Tunisia	1972	Down
Tunisia	1981	Down
Uganda	1961	Up
Uganda	1969	Down
Uganda	1980	Up
Uganda	1988	Up
Zambia	1967	Down
Zambia	1975	Down
Zambia	1983	Up
Zambia	1994	Up
Zimbabwe	1968	Up
Zimbabwe	1983	Down
Zimbabwe	1991	Down
Zimbabwe	2002	Up
OCEANIA		
Australia	1961	Up
Australia	1969	Down
Fiji	1979	Down
Fiji	1988	Up
Fiji	2000	Down
New Zealand	1958	Up
New Zealand	1974	Down
Papua New Guinea	1973	Down
Papua New Guinea	1984	Up
Papua New Guinea	1993	Down

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