MS thesis

In economics

Explaining Structural Breaks in Growth Series

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Abstract

Despite the fact that almost all work on economic growth has centered around long-run average growth rates, growth is not a steady process. It is common that countries switch between periods of fast growth and periods of slow (or no) growth. In this research project I examine the transition between periods of fast growth and slow (or no) growth. I explain a model that describes the mechanism behind these drops. Empirically there are two main conclusions. First of all the group of countries where I identified a downward break is distributed near the middle between the high income countries and the low income. I argue that this is relevant for test of the convergence hypothesis. Secondly under this model the probability of such a switch is positively correlated with importance of manufacturing and negatively correlated with skilled labor force and the development of financial markets.

Contents

1. Introduction

Economic growth is what determines material well being; the difference between no growth and moderate growth rate over just a couple of decades can be the deciding factor for living standards. As Paul Collier (2007) wrote about the countries that did not share in the economic growth of the 20th century: "The countries at the bottom coexist with the twenty-first century, but their reality is the fourteenth century: civil war, plague, ignorance."

Despite the fact that almost all work on economic growth has centered around long-run average growth rates, growth is not a steady process. It is common for countries to switch between periods of fast growth and periods of slow or no growth. For example between 1971 and 1987 South Korea grew at an annual rate of 8.3%, but between 1988 and 2004 it contracted by an annual rate of -1.0%.

In this research project I examine the transition between periods of fast growth and slow (or no) growth. The underlying question that I hope to answer is why a country that is growing is sometimes unable to keep growing. I will try to identify what these countries have in common and understand the mechanism behind this.

In macroeconomics, one of the big issues is that of convergence, e.g. whether less developed countries are catching up with richer countries. This is commonly known as the convergence hypothesis. One of the first tests of convergence was done by Barro (1991) using the Penn-World Tables. He found that growth in the period 1960-85 was negatively related to the initial level of real per capita GDP if he included the initial level of human capital. As a proxy for human capital he used the initial primary and secondary enrollment rates. In most work, a distinction is made between β-convergence (economies that start out poorer tend to grow faster) and σ-convergence (the variance of income tends to fall over time). Bianchi (1997) tests for convergence by looking at the GDP distribution across countries in 1970, 1980 and 1989. He finds low mobility patterns of intra-distribution dynamics and increasing evidence for bimodality. These findings stand in sharp contrast with the convergence prediction for the overall sample. However, he finds that the variance of output per capita for the richer club of countries is falling, which shows convergence within that group. Quah (1996) describes a body of empirical research that tries to model directly the dynamics of the cross section distributions. One of the main results of this paper is that the GDP of the countries that have downward breaks between 1970 and 1995 were distributed in between the two peaks at the beginning of this time span. The question is not so much whether there is convergence, rather whether convergence is sustainable over a longer period. Also, a model that takes in structural breaks in growth could improve tests of the convergence hypothesis.

Another big question is which factors economic growth is correlated with. A vast literature uses cross-country regressions to search for empirical linkages between long-run average growth rates and a variety of economic policy, political, and institutional factors suggested by theory. As Levin and Renelt (1991) point out, over 50 variables have been found to be significantly correlated with growth in at least one regression. They argue that most conclusions from such regressions are fragile to small changes in the conditioning information set. Interesting examples of papers that look at this correlation include papers by Sachs and Warner (1995) that look at the role of natural resources, Levin (1997) that looks the role of financial institutions and Krueger and Lindahl (2001) that looks at the role of education. All of these papers look at average growth over at least 30 years, but growth is not a steady process. In this paper instead of looking at average growth over long period, I look at the breaks that happen in growth and what factors these breaks are correlated with.

2. Theoretical Framework

2.1 Nelson and Phelps' framework

Aghion and Hewitt (2009) distinguish between two frameworks for how human capital influences growth. The first one based on Lucas (1988) treats human capital as an input into the production function, similar to physical capital. The second, one based on Nelson and Phelps (1996), relates human capital influence on growth to two different aspects, i.e. directly through its ability to innovate and indirectly through its ability to facilitate technological adaptation.

It is within the Nelson-Phelps framework that I will work. It is the difference between how human capital affects these two aspects, e.g. innovation and technological adaptation that holds the key in understanding why countries go from a period of fast growth and slow. I will also allow other variables than education to affect innovation and adaptation, namely the structure of industries and financial development.

Nelson and Phelps (1966) state that "the rate at which the latest theoretical technology is realized in improved technological practice depends upon educational attainment and upon the gap between the theoretical level of technology and the level of technology in practice". Their model is

$$\frac{\dot{A}(t)}{A(t)} = \Phi(X) \cdot \frac{T(t) - A(t)}{A(t)},$$

(2.1)

where A is level of technology, T is theoretical level of technology and X are other relevant variables, such as education or financial development.

Assume exponential growth of T, that is

$$T(t) = T_0 e^{\lambda t}.$$

(2.2)

The solution to this is

$$A(t) = \left(A_0 - \frac{\Phi}{\Phi + \lambda}\right) e^{-\Phi t} + \frac{\Phi}{\Phi + \lambda} \mathrm{T}_0 \mathrm{e}^{\lambda t}$$

(2.3)

The equilibrium path of this solution is

$$A^*(t) = \frac{\Phi}{\Phi + \lambda} \mathrm{T}_0 \mathrm{e}^{\lambda t}$$

(2.4)

and the equilibrium gap is

$$\frac{\mathrm{T(t)} - A^*(\mathrm{t})}{A^*(\mathrm{t})} = \frac{\lambda}{\Phi(\mathrm{X})}$$

(2.5)

From equation 2.3 we see that in the long run the rate of increase in the level of technology, $\dot{A}/A$ will settle down to the value of λ. The speed with which it settles down to this value is an increasing function of Φ. If we set X as education we can assume that $\Phi'(X) > 0$ and from 2.5 it follows that the gap is a decreasing function of education.

Here we have the mechanism though which a country transitions between a period of fast growth and slow. If initially the technical level of a county is far behind the theoretical technical level then growth will be fast as the country moves toward its equilibrium path. But as it reaches its equilibrium path, it’s growth will slow down..

2.2 Vandenbussche, Aghion and Meghir’s expansion

Similar result can be explained from Vandenbussche, Aghion and Meghir (1996). Vandenbussche et.al expanded Nelson and Phelps this by looking at productivity growth functions of the form

$$\dot{\mathrm{A}}_{\mathrm{i,t}} = \mathrm{u_{i,n,t}}^{\sigma} \mathrm{s_{i,n,t}}^{\sigma-1} (\overline{\mathrm{A}}_{\mathrm{t-1}} - \mathrm{A_{t-1}}) + \gamma \mathrm{u_{i,n,t}}^{\phi} \mathrm{s_{i,n,t}}^{\phi-1} \mathrm{A_{t-1}}$$

(2.6)

where $\overline{A}$ is the best productivity, $u_{m,i,t}$ (resp. $s_{m,i,t}$) is the amount of unskilled (resp. skilled) labor used in imitation and $u_{n,i,t}$ (resp. $s_{n,i,t}$) is the amount of unskilled (resp. skilled) labor used in innovation., σ (resp. φ) is the elasticity of unskilled labor in imitation (resp.

innovation) and $\gamma > 0$ measures the relative efficiency of innovation compared to imitation in generating productivity growth. Since innovation is more dependent on skilled labor than imitation, they assume that the elasticity of skilled labor is higher in innovation activities than in imitation activities, i.e. < σ..

By maximizing the profit function of the producers they find that

1) a marginal increase in higher education investment S enhances productivity growth all the more the closer the country is from the world technology frontier, that is

$$\frac{\delta^2 g_t}{\delta a\, \delta S} > 0$$

2) a marginal increase in lower education investment U enhances productivity growth all the less the closer the country is from the world technology frontier, that is

$$\frac{\delta^2 g_t}{\delta a\, \delta U} < 0$$

Now consider two countries, A and B, that have the same total stock of human capital and are the same distance from the frontier. The difference between the two countries being that country A has more skilled labor whereas country B's has more unskilled labor. Which of these two countries will grow faster? The answer is dependent on how close to the frontier they are. Under these results country A will grow faster if they are close enough to the frontier, country B will grow faster if they are further away from the frontier.

To understand the dynamics behind what happens when long run growth drops I add the assumption that the composition of human capital does not adapt as country gets closer to the frontier.

Now imagine we have a county that is quite far from the frontier whose labor force is mostly unskilled labor. Most of the population has primary or even secondary education but little tertiary or higher education. It is optimal for it to imitate technology rather than try to innovate. Using its pool of unskilled labor to imitate technology it is able to optimize its growth and work its way closer to the frontier. But as it gets closer to the frontier it would be better to have skilled labor and be able to innovate. Under our assumption that the composition does not adapt it is inevitable that its growth will slow down. This seems to be the main reason behind downward breaks.

2.3 Predictions

If in fact the reason behind the drop in growth is because a country was growing through imitation and is unable to switch to innovation as it gets closer to the technological frontier, then the following proposition should follow:

Proposition: *The probability of a downwards break in growth is*

1. *Increasing in closeness to the technical frontier*
2. *Increasing in importance of manufacturing*
3. *Decreasing in amount of skilled labor relative to unskilled*
4. *Decreasing in the development of financial markets*

As a country that bets on imitation to grow gets closer to the frontier there will be fewer ideas left to be (re)discovered. Therefore it stands to reason that the drop, if it happens, is more likely the closer to the technological frontier the country is.

In manufacturing there is a huge difference between imitation and innovation. Building a sewing factory or aluminum smelter is fundamentally different than developing a computer chip. Although technology plays a part in agriculture and in use of natural resources, the difference between innovation and imitation is not nearly as large as in manufacturing.

A country needs skilled labor to master advanced technologies. A country well endowed with skilled labor will be able to adapt as it gets closer to the frontier. In contrast a country with unskilled labor will not be able to adapt. So this drop is less likely to happen in a country with a lot of skilled labor relative to unskilled.

The development of financial markets and institutes matter for growth (see Levin 1997). It is reasonable to assume that financial development matters more in innovation than for imitation. Innovation is by nature a riskier endeavor and entrepreneurs need angel investors, stock markets and the ability to pay employees with options. In contrast, for imitation, a standard German style bank is sufficient to fund a factory.

3. Empirical results

3.1 Structural breaks

In appendix B is an overview of the main econometric methods that are used in structural change analysis. I define the growth rate in year t as

$$g_t = ln\left(\frac{rgdp_t}{rgdp_{t-1}}\right)$$

(3.1)

where rgdp is the GDP per capita in constant prices. I consider the following multiple linear regressions with m breaks[1]

$$g_t = r_j + \varepsilon_t, \;\; for\ t = T_{j-1} + 1, \dots, T_j$$

(3.2)

for j = 1,…,m+1. First consider sup F test discussed in appendix B.2. In figure 3.1 is a plot of the growth series for two counties as well as the F test statistics.

[1] It would be possible to consider a more complete model with different macro-economic independent variables. However the part of this research project will be to see what varables these breaks are correlated with. So using these varables both in the detection of breaks and in sequent correlations could cause simultaneous equation bias.

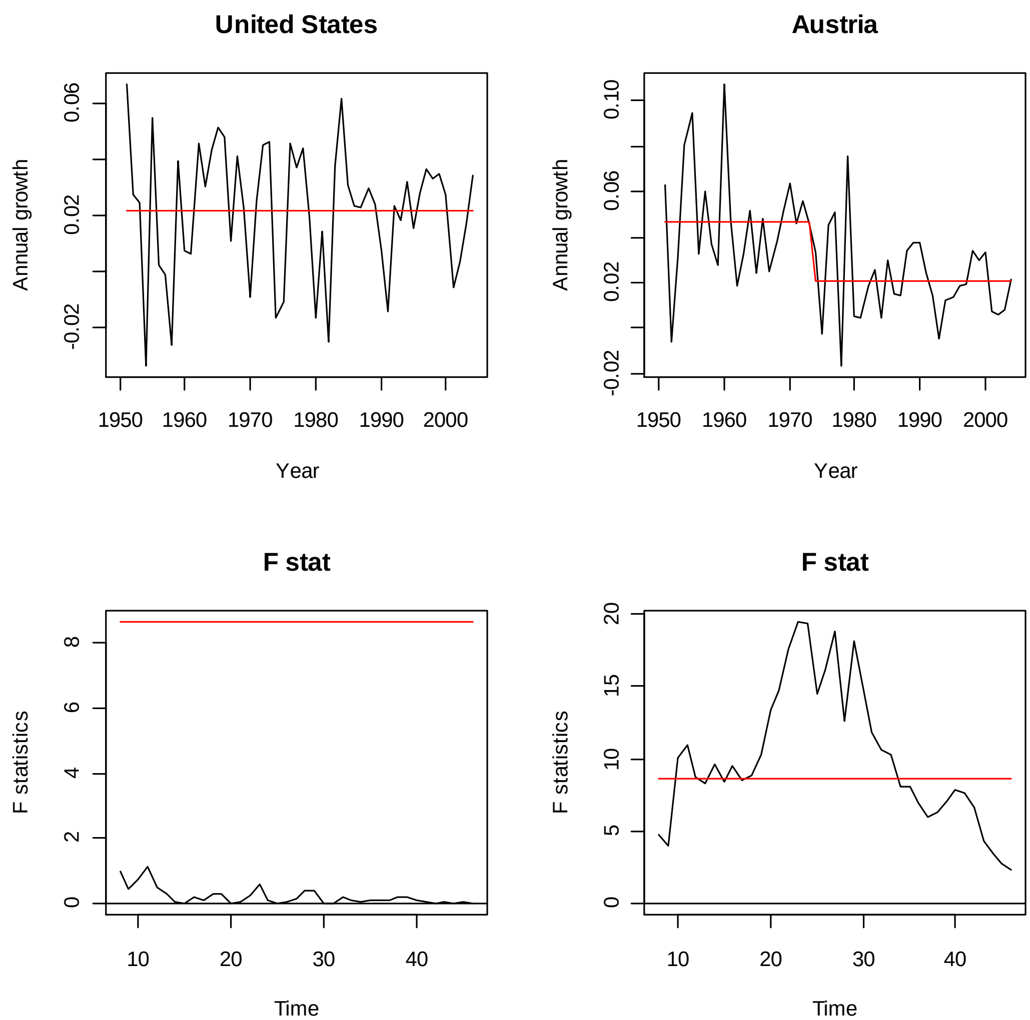

Figure 3.1: Growth series and Fstat for two countries. In the left country (United States) the F-stat for all possible breakpoints is less then the 1% critical value and we can fit it without a breakpoint. In the right country (Austria) the F-stat for is higher than the 1% critical value and a piece wise fit is better.

The 1% critical value for the sup F test for a time series of length 54 (corresponding to the years 1951 to 2004) is 8.2. Out of 156 growth series 48, or 30%, have sup F test statistic higher than the 1% critical value. In the absence of structural breaks no more than 2 growth series would be expected to be higher.

There is no reason to assume that having only one break should be the rule. In order to estimate the number of structural breaks, consider again the information criteria method discussed in appendix B.5. An example of the use of BIC is in figure 3.2. In the lower pictures is a plot of BIC and the sum of squared residuals for different number of breakpoints. In the upper pictures is a plot of the growth series as well as the least square fit of the multiple linear regressions model with m break points, where m is the number of breakpoints that minimizes the Bayesian information criterion.

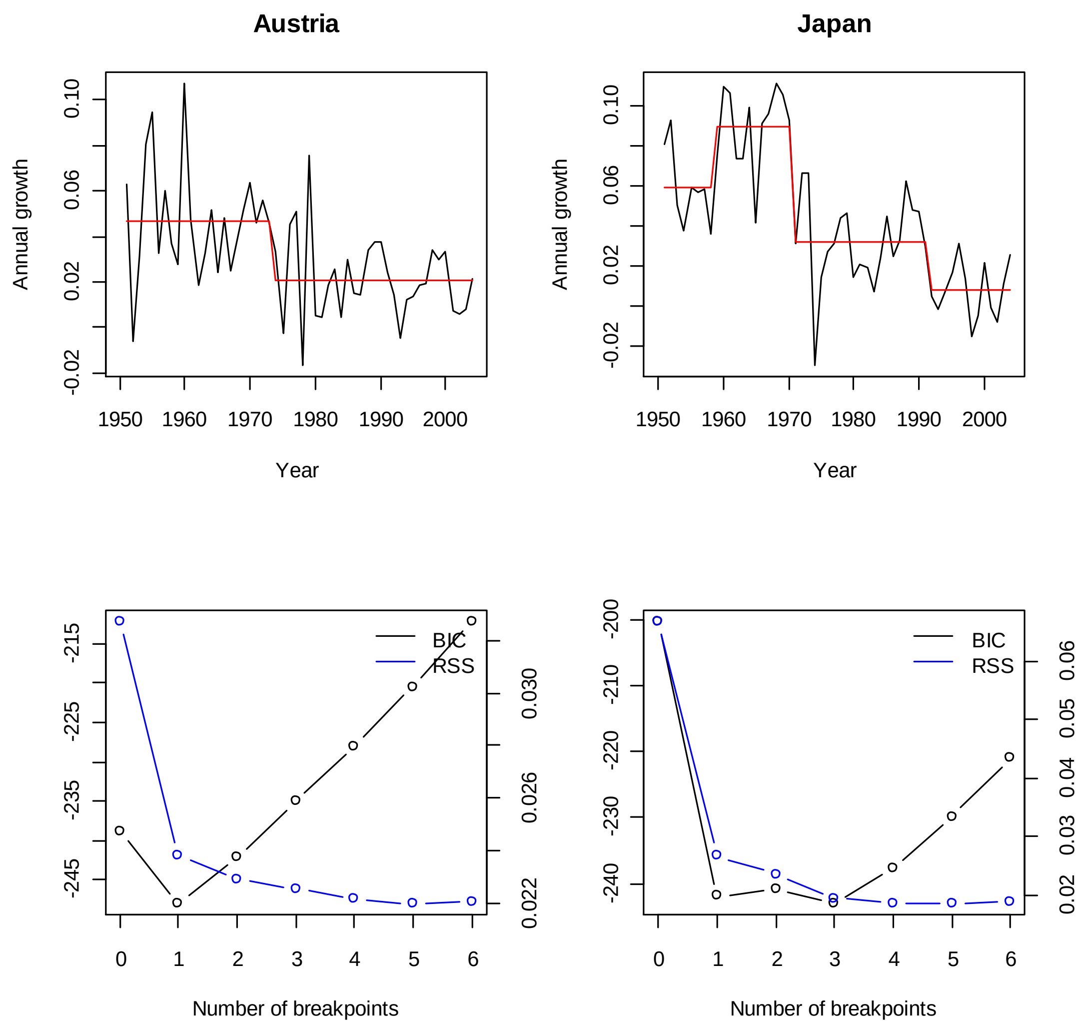

Figure 3.2: Growth series and Bayesian Information Criterion (BIC) as a function of number of breakpoint for two different countries. In the left country (Austria) the BIC has a minimum one breakpoint, but in the right country (Japan) the BIC has a minimum with three breakpoints. In both cases we use the minimum to decide the number of breakpoints in the piecewise constant fit (upper row).

Using the Bayesian Information Criterion (BIC) criteria on the 156 countries 99 do not have a structural break, 36 have one structural break, 18 have two structural breaks and 3 have three structural breaks.

In this project I am mainly interested in downward structural breaks. Of the 156 countries 45 have one downward break and 1 has two downward breaks. All downward structural breaks where between 1970 and 1995.

3.2 Density distributions

As earlier stated, of 156 countries, 46 had at least one downward break in the years between 1970 and 1995. Now question is: what distinguishing factors countries with these breaks have? In order to shed some light on this question I looked at density distribution of a number of variables for countries with a downward break and compared to the density distribution for countries without such a break. In all kernel density estimations I use a Gaussian kernel and Silverman's 'rule of thumb' to choose the bandwidth, see Silverman (1986)

Before we look at the these plots I want to add one caveat: When examining graphs other then GDP we have to keep in mind that these variables are correlated, and more importantly almost all of these variables are highly correlated with national income. But each graph only plots one variable so omitted variable bias is almost certain. A difference between the distribution of a country with a break and one without can point to what variables are interesting but drawing conclusions from these graphs is difficult. See chapter 3.3. for a regression that takes this into account.

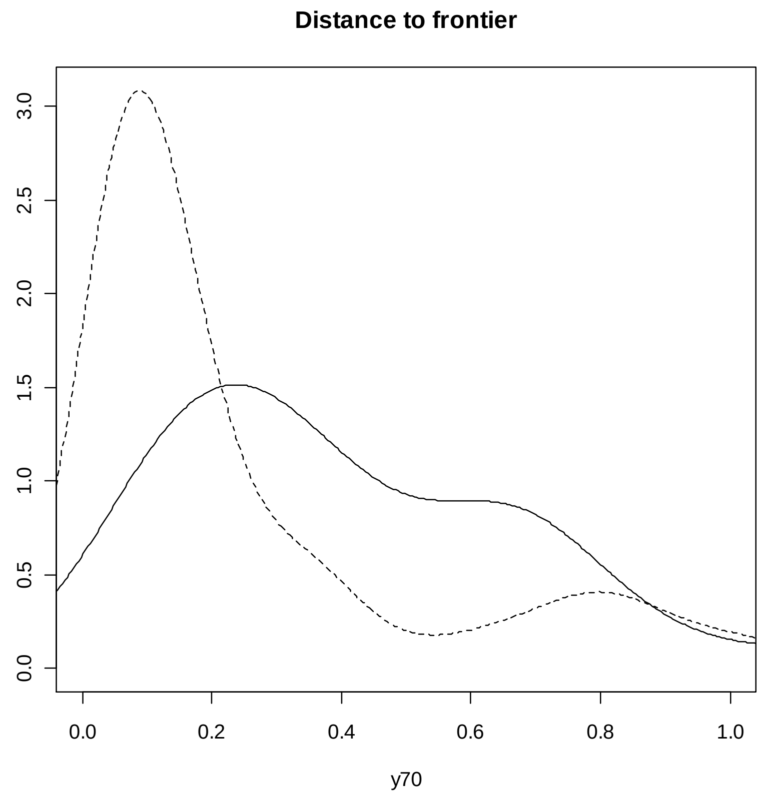

Figure 3.3: Density distribution of rgdp relative to the United States 1970 for countries with a downward break (solid line) compared with countries without a downward break (dashed line). The group of countries where we identified a downward break is distributed near the middle between the poor countries on the left and the rich countries on the right.

In figure 3.3 we see the rgdp relative to the United States 1970 for countries with a downward break compared with countries without a downward break.

The density distribution of the countries without a break is similar to the density distribution described in Bianchi (1997). We see two groups, the poor countries on the left (top at 0.08) and the rich countries on the right (top at 0.79). If we split between the groups in the minimum, then the split is in 0.54 and p = 0.83 is in the poor group. The group of countries where we identified a downward break is distributed near the middle between the poor countries on the left and the rich countries on the right. In this density plot we also see two modes though they are not as distinct, a poor group with a top at 0.24, a rich with a top at 0.62 and p = 0.66 is in the poor group.

Both Quah (1996) and Bianchi (1997) tackle the problem of convergence by looking at how the distribution of income evolves over time. The middle income countries are arguably the most important because they are the ones that are moving between groups. Therefore I argue that since downward breaks are concentrated in the middle income, taking them into account can improve the analysis of Quah and Bianchi. For example one of the results of Bianchi is that “a process of vanishing of the middle class appears to have taken place in the 1980s, thus reverting a tendency of opposite sign in the 1970s.” This result supports that, in that it is the middle class of countries that a downward break in growth is concentrated.

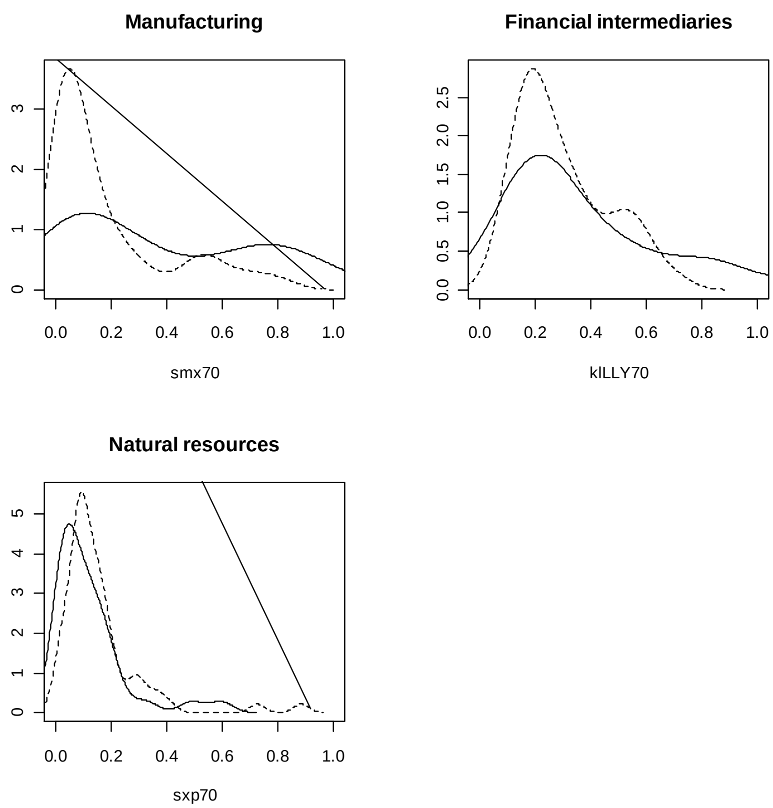

Figure 3.4: Density distribution of importance of manufacturing, natural resources and the financial system 1970 for countries with a downward break (solid line) compared with countries without a downward break (dashed line)

In figure 3.4 is a plot of the density distributions for the importance of manufacturing, natural resources and financial development. As expected[2] countries with a break seem to

[2] see chapter 2.3

be on average more dependent on manufacturing. However contrary to what I expected counties with a break tend to have a more developed financial system. The importance of natural resources does not seem to be relevant regarding breaks.

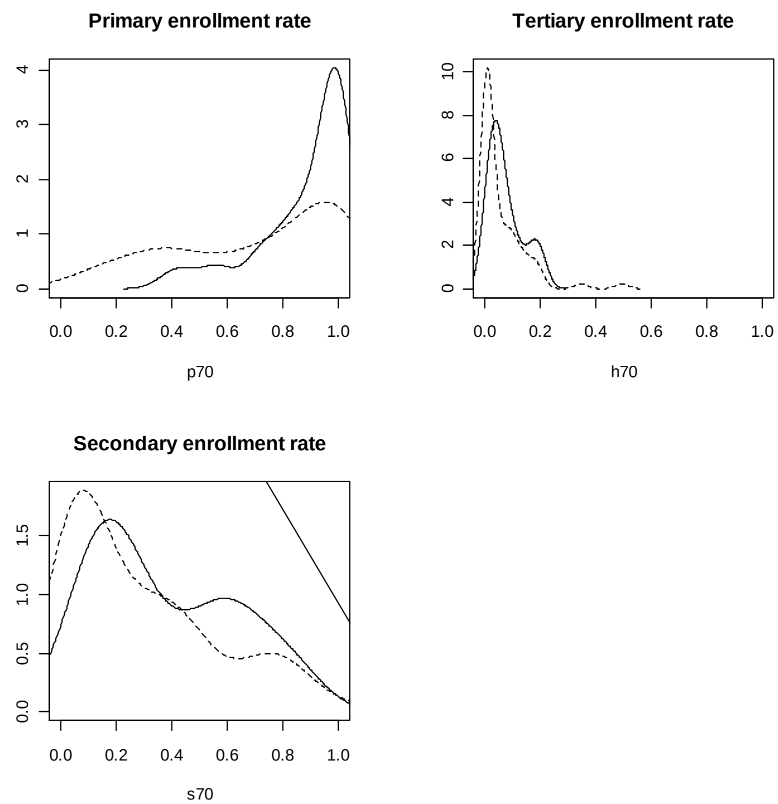

Figure 3.5: Density distribution of gross enrollment rates 1970 for countries with a downward break (solid line) compared with countries without a downward break (dashed line)

In figure 3.5 is a plot of the density distributions for primary, secondary and tertiary enrolment rates. On average the countries with a break seem to be better educated then the countries without. This is in contrast with our predictions. But as mentioned above we are only plotting one variable so we have to be careful of omitted variable bias[3].

3.3. Logit regression

As earlier mentioned under the model for downward breaks I propose the probability of a downward break should be

[3] I discuss this in more detail in chapter 3.3.1.

1. *Increasing in closeness to the technical frontier*
2. *Increasing in importance of manufacturing*
3. *Decreasing in amount of skilled labor relative to unskilled*
4. *Decreasing in the development of financial markets*

In order to test this I did a regression on the probability of a downward regime change in the growth series on a number of macroeconomic variables.

As a proxy for distance to the technological frontier I use rgdp relative to the United States (y).

As a proxy for the importance of manufacturing I used the share of manufacturing exports in total exports (smx70).

There is not one obvious answer the question of how the specify the composition of human capital. Therefore, I decided to use 3 different specifications: 1) enrollment rates, 2) fraction of population that has attained primary, secondary or tertiary education and 3) average years of primary/secondary and tertiary education. In the specification with enrollment rates I look at the correlation between values 1970 and the presence of a downward break in the time period between 1970 and 2000. In the specification with education attained and average years of education I look at the correlation between values at the start of the 5 year periods 1960-64, 1965-69, … , 2000-04 and presence of breaks it said 5 year period. The reason being that enrollment rates are a better indicator of human capital over a longer time period, while education attained and average years of education is a better indicator of human capital in the short run.

In King and Levin (1993) they consider four different variables that measure the development of financial markets. I decided to use one of these variables, e.g. the ratio of the liabilities of financial intermediaries plus currency in circulation to gdp (klLLY70).

3.3.1 First specification: enrollment rates

In this specification I use enrollment rates in 1970. I define the variables p70, s70 and h70 as the gross enrollment rates in the relevant age groups for primary, secondary and tertiary school resp.

I estimate model 3.3:

$$logit(br_i) = \beta_0 + \beta_y y70_i + \beta_{smx} smx70_i + \beta_p p70_i + \beta_s s70_i + \beta_h h70_i + \beta_{\mathrm{klLLY70}} \mathrm{klLLY70}_i + \epsilon_i$$

(3.3)

where br_i is whether I have identified a downward break in country i in the time span between 1969 and 2000 using the BIC method discussed earlier. The independent variables are from 1970.

In Levin and Renelt's (1991) analysis of cross-country growth regressions they found that only a few findings can withstand slight alterations to the list of explanatory variables. They test for robustness by estimating the model

$$logit(br_i) = \beta_0 + \beta_M M + \beta_Z Z + \epsilon_i$$

(3.4)

where M is the variables of interest[4] and Z is a subset of variables from a pool of variables that are potentially important. I use this technique to test for robustness using the following variables in Z:

1. Composition of GDP. I include investment share of gdp (k_i) and government share of GDP (k_g). Consumption share of gdp is omitted because of co-linearity.
2. Importance of natural resources in the economy. I use share of exports of primary products in total exports (sxp70) as a proxy for this.
3. Country group. I include a dummy variable for Africa and for OECD countries.

The results are in Table 3.1.

[4] In our case M of course being: Closeness to frontier, Importance of manufacturing, Education and Financial development.

	regr 1		regr 2		regr 3		regr 4		regr 5	
y70	4,59	*	5,23	**	6,14	*	4,94	**	6,68	*
	(1,85)		(2,01)		(2,67)		(1,83)		(2,85)	
smx70	4,72	***	4,69	**	4,08	**	5,30	***	4,98	**
	(1,40)		(1,43)		(1,54)		(1,60)		(1,79)	
p70	5,64	**	5,50	**	5,41	**	5,88	**	5,67	*
	(1,92)		(1,94)		(1,90)		(2,20)		(2,29)	
s70	-7,70	**	-9,05	**	-8,38	**	-10,40	**	-12,38	**
	(2,97)		(3,31)		(3,25)		(3,49)		(4,06)	
h70	-7,28		-7,70		-9,73		-10,02		-13,18	
	(5,82)		(6,36)		(6,73)		(6,86)		(8,65)	
klLLY70	0,20		-0,19		0,28		-0,28		-0,74	
	1,50		(1,54)		1,48		1,51		(1,60)	
ki70			4,32						4,56	
			(3,72)						(4,12)	
kg70			0,88						1,72	
			3,41						(3,68)	
sxp70					-3,41				-1,85	
					(3,89)				(4,43)	
AFRICA							-2,00	*	-2,10	*
							(0,91)		(0,95)	
OECD							0,92		1,07	
							(1,12)		(1,28)	
(Intercept)	-5,03	***	-5,37	**	-4,34	**	-4,03	*	-4,15	.
	(1,45)		(1,64)		(1,58)		(1,70)		(2,17)	

Table 3.1: Logit regression on the probability of a downward break in the time period between 1970 and 1995. Independent variables are all from 1970. Std. dev. in parenthesis, significant codes: 0 ***, 0.001 ** , 0.01 *, 0.05 .

The probability of downwards structural change in the growth series is positively associated with both closeness to the frontier (in reg.1 a 1% increase in y corresponds to a dp = 1.03% increase in probability) and with importance of manufacturing (dp = 1.06).

In regards to the composition of human capital, I find positive association with enrollment in primary school (dp = 1.26) and negative association with enrollment in secondary (dp = -1.73%) and tertiary school (dp = -1.63%).

In Vandenbussche et.al (1996) they found that countries with higher tertiary education continue to grow even close to the frontier. Under the model for downward breaks I propose these results support their findings. If countries with higher tertiary education continue to grow even close the frontier, then they should be less likely to experience a drop in growth as they get closer to the frontier.

Barro (1991) found that growth in the period 1960-85 was negatively related to the initial level of real per capita GDP if he included the initial level of human capital. As a proxy for human capital he used the initial primary and secondary enrollment rates. He found that growth was positively related to both primary and secondary enrollment rates. Krueger and Lindahl (2001) found that “education [is] statistically significantly and positively associated with subsequent growth only for the countries with the lowest level of education”. It is difficult to compare my results to those of Barro; it is the low income countries that drive Barro’s correlation while it is the middle class of countries that are driving my results.

Note that although countries with breaks have on average higher tertiary enrolment rates (see fig 3.5), β_h is still negative, e.g. higher tertiary education lowers the chance of a break. Though this seems a paradox, it is understandable because of the simple fact that tertiary education is positively correlated with both closeness to the frontier (correlation = 0.67) and importance of manufacturing (correlation = 0.54).

I do not find a significant correlation with financial development.

These results are robust to addition of other variables. Surprisingly, of them, only AFRICA is significant, with negative association.

3.3.2 Second Specification: education attained (fractions)

In this specification I look at the fraction of the population that has attained a given level of education. I group together attained and completed. Because of co-linearity I skip no education. This gives us three independent variables from the seven categories in Barro-Lee, e.g. lp, ls and lh as the fraction of the adult population whose highest level of education is attained some or completed primary, secondary and tertiary resp.

I estimate the model 3.5:

$$logit(br_{ij}) = \beta_0 + \beta_y y_{ij} + \beta_{smx} smx_i + \beta_p lp_{ij} + \beta_s ls_{ij} + \beta_h lh_{ij} + \beta_{\mathrm{klLLY70}} \mathrm{klLLY70}_i + \epsilon_{ij}$$

(3.5)

where br_{ij} is whether I have identified a downward break in country i in the 5 year time span j. The variables lp, ls, lh and y are from the first year of the 5 year time span, smx70 and kILLY70 is from 1970.

I tested the sensitivity of my results the same method as in the first specification. In addition to the 3 groups of variables in Z in the first specification, I added current account deficit and overall balance.

The results are in Table 3.2.

	regr 1		regr 2		regr 3		regr 4		regr 5		regr 6	
y	1,77	*	1,44		2,40	*	2,15	**	1,24		2,56	
	(0,86)		(1,00)		(1,13)		(0,82)		(1,63)		(2,48)	
smx70	1,82	*	1,88	*	1,12		2,27	**	4,14	**	4,65	**
	(0,81)		(0,81)		(0,99)		(0,87)		(1,28)		(1,65)	
lp	1,36		0,99		1,04		1,75		3,74	*	4,70	*
	(0,99)		(1,02)		(1,06)		(1,13)		(1,82)		(2,12)	
ls	-2,61		-2,91		-2,96		-2,26		-3,73		-3,56	
	(2,28)		(2,36)		(2,38)		(2,29)		(3,59)		(3,50)	
lh	-12,00	.	-11,63	.	-12,94	.	-12,19	.	-14,19		-12,22	
	(6,58)		(6,64)		(6,63)		(6,76)		(8,66)		(9,12)	
klLLY70	-0,25		-0,52		-0,38		-0,18		-3,18	*	-2,69	.
	0,92		(0,98)		(0,94)		(0,86)		(1,44)		(1,46)	
ki			3,73	.							1,49	
			(2,02)								(5,29)	
kg			-0,24								-0,70	
			2,49								(4,60)	
sxp70					-3,81						-2,94	
					(3,20)						(5,52)	
AFRICA							-0,35				0,56	
							(0,74)				(1,16)	
OECD							-0,93				-1,87	
							(0,67)				(1,28)	
OverallBalance									28,28	**	18,53	
									(10,89)		(12,57)	
CurrentAccount									1,98		2,28	
									(7,67)		(10,19)	
(Intercept)	-3,71	***	-3,97	***	-3,00	***	-3,92	***	-4,11	***	-4,93	*
	(0,54)		(0,80)		(0,76)		(0,78)		(0,92)		(2,06)	

Table 3.2: Logit regression on the probability of a downward break in a five year time period. Std. dev. in parenthesis, significant codes: 0 ***, 0.001 ** , 0.01 *, 0.05 .

As in the first specification I find positive association with proximity to the frontier (in regression 1 a 1% increase in y corresponds to a dp = 0.08% increase in the risk of a downward break in the next 5 years) and with manufacturing (dp = 0.09).

I find positive association with primary school education (dp = 0.06) and negative association with secondary (dp = -0.12) and tertiary (dp = -0.57). The negative association with tertiary education is stronger than with secondary. These results are consistent with the results from the first specification.

Finally unlike the first specification, I find negative association with financial development (dp = -0.01).

These results are robust to addition of other variables. Of the additional variables used to test for robustness, the overall balance parameter is statistically significant. The probability of a downward break is positively associated with a surplus. A large surplus is an indicator of a credit boom (IMF (2004)), and credit booms usually follow a period of depressed growth.

3.3.3 Third Specification: years of education

In this specification I estimate average total years of primary/secondary and tertiary education[5]. This allows the stocks of unskilled and skilled labor to vary independently. There are seven categories in BL[6], so I define the following variables:

$$YearT = (p_6 + p_7)n_6 + p_7 n_7 \tag{3.6}$$

and

$$YearPS = \sum_{i=1}^{7}\left(\sum_{j=1}^{i} p_j\right) n_i \tag{3.7}$$

where p_i is the fraction of the population in category of schooling attainment i and n_i is the number of extra years of education which an individual in category i has accumulated over an individual in category i - 1. We have $(n_1, n_2, n_3, n_4, n_5, n_6, n_7) = (0, 3, 3, 3, 3, 2, 2)$. The variable YearsT (YearsPS) represents the number of years of tertiary (primary/secondary) education of the average adult in the population. With these assumptions, a college graduate contributes 12 years to YearsPS and 4 years to YearsT

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[5] Here I am following the same method of estimating average total years of primary/secondary and tertiary education as in Vandenbussche, Aghion and Meghir (1996)

[6] e.g. no schooling, some primary, primary attained, some secondary, secondary attained, some tertiary and tertiary attained.

I estimate the model 3.8:

$$logit(br_{ij}) = \beta_0 + \beta_y y_{ij} + \beta_{smx} smx_i + \beta_{PS} YearsPS_{ij} + \beta_T YearT_{ij} + \beta_{\mathrm{klLLY70}} \mathrm{klLLY70}_i + \epsilon_{ij} \quad (3.8)$$

where br_{ij} is whether I have identified a downward break in country i in the 5 year time span j. The variables YearsPS, YearsT and y are from the first year of the 5 year time span, smx70 and klLLY70 is from 1970.

I used the same method and variables as in the second specification to test for robustness.

The results are in Table 3.3.

	regr 1		regr 2		regr 3		regr 4		regr 5		regr 6	
y	1,70	*	1,39		2,52	*	1,86	*	1,40		2,79	
	(0,83)		(0,96)		(1,14)		(0,80)		(1,61)		(2,37)	
smx70	1,65	*	1,75	*	0,89		1,85	*	3,05	**	2,80	*
	(0,77)		(0,78)		(0,94)		(0,79)		(1,09)		(1,34)	
YearsPS	-0,03		-0,08		-0,09		0,01		-0,03		0,00	
	(0,15)		(0,16)		(0,17)		(0,16)		(0,25)		(0,25)	
YearsT	-4,83	*	-4,41	*	-4,75	*	-5,33	*	-5,16	.	-5,55	.
	(2,06)		(2,10)		(2,08)		(2,13)		(2,79)		(2,83)	
klLLY70	-0,12		-0,46		-0,27		-0,20		-2,39	.	-2,12	
	(0,88)		(0,96)		(0,90)		(0,85)		(1,37)		(1,38)	
ki			4,00	*							-0,88	
			(1,92)								(5,06)	
kg			-0,83								-1,03	
			(2,41)								(3,80)	
sxp70					-4,32						-3,19	
					(3,15)						(4,94)	
AFRICA							-0,77				-0,66	
							(0,69)				(0,99)	
OECD							-0,64				-1,42	
							(0,68)				(1,27)	
OverallBalance									28,08	**	20,83	.
									(10,22)		(11,93)	
CurrentAccount									-1,31		-3,16	
									(6,73)		(8,90)	
(Intercept)	-3,26	***	-3,48	***	-2,50	***	-3,11	***	-2,97	***	-2,31	
	(0,43)		(0,70)		(0,66)		(0,59)		(0,66)		(1,60)	

Table 3.3: Logit regression on the probability of a downward break in a five year time period. Std. dev. in parenthesis, significant codes: 0 ***, 0.001 ** , 0.01 *, 0.05 .

As before I find positive association with proximity to the frontier (in regression 1 a 1% increase in y corresponds to a dp = 0.08% increase in the risk of a downward break in the next 5 years) and with manufacturing (dp = 0.08).

I did not see any association with years of primary/secondary education. I found negative association with years of tertiary education (dp = -0.23).

As in the second specification, and unlike the first, I find a negative association with financial development, though it is neither statistically significant nor robust.

These results are robust to addition of other variables. As in the second specification, OverallBalance is positively correlated with the probability of a downward break.

4. Conclusions

It is common for countries to switch between periods of fast growth and periods of slow or no growth. In this paper I have examined this transition. I explain it by noting that low income countries can grow fast by importing technology. However as they close the gap between themselves and richer counties there are fewer technologies left to import and the only way to sustain growth is to develop advanced technology themselves. If they are unable make this shift, a drop in growth is inevitable.

Empirically there are two result of note. First of all the GDP of countries where I identified a downward break is distributed between the poor and rich countries. Secondly that these breaks tend to happen mainly close to the technical frontier, in countries with high importance of manufacturing and low (levels of secondary and tertiary education) human capital.

Appendix A: Data description

For my data set I combine data from 4 sources.

GDP data is from the Penn World Tables 6.2 (Heston, Summers and Aten 2006). I define the growth rate in year i as $g_i = \ln(rgdp_i / rgdp_{i-1})$ where rgdp is the real GDP per capita in constant prices.

As a proxy for distance to the technological frontier I use rgdp relative to the United States (y). Penn World Table splits the GDP into investment share of rgdp (ki), government share of rgdp (kg) and consumption share of GDP (kc)

Educational information from the Barro Lee data set. Barro Lee has enrollment rates for primary, secondary and higher education. For amount of education attained, Barro-Lee has 7 groups (no education, some primary attained, primary completed, some secondary attained, some higher education attained, higher education completed).

Information about importance of manufacturing, natural resources and the financial system is from Sachs (1995). As in their work I decided to use share of exports of primary products in gnp (sxp70), the share of manufacturing exports in total exports (smx70) and the ratio of the liabilities of financial intermediaries plus currency in circulation to gdp (klLLY70). These variables are only available for 1970.

Trade deficit is from IMF's international financial statistical databases. I include 2 numbers, Current Account and Overall Balance (keys 78CBDZF and 78ALDZF respectively). These numbers are scaled with respect to GDP.

Appendix B: Structural changes – models and methods

In this chapter is an overview of the main econometric methods that can be used to test for and estimate the date of structural breaks.

B.1 Single known breakpoint

In order to test whether a point is a break point we use the well known Chow test that is discussed in most introductory econometrics textbooks, see for example Greene (). We consider the following linear regression model with one breakpoint

$$y_t = \begin{matrix} x_t'\beta_1 + \varepsilon_t, \;\; for\ t = 1, \dots, T' \\ x_t'\beta_2 + \varepsilon_t, \;\; for\ t = T' + 1, \dots, T \end{matrix}$$

(1)

In this model y_t is the observed independent variable, x_t is a $(p \times 1)$ vector of covariates, β_1, β_2 are the corresponding $(p \times 1)$ vectors of regression coefficients and ε_t is the disturbance. The breakpoint $T' \in (1, \dots, T)$ is treated as known.

The null hypothesis that T' is not a breakpoint is equivalent to $\beta_1 = \beta_2$. Let RSS be the sum of squared residual from the regression of over the whole period, RSS_1 the sum of squared residuals for a regression over $t = 1, \dots, T'$ and RSS_2 the sum of squared residuals for a regression over $t = T' + 1, \dots, T$. The relevant test statistic is

$$F = \frac{RSS - (RSS_1 + RSS_2)}{(RSS_1 + RSS_2)} \cdot \frac{T - 2k}{k}$$

(2)

Here k is the number of regressors in each regression or in our case 1. Under the null hypothesis this test statistic is distributed like the F-distribution with k and T-2k degrees of freedom.

B.2 Single unknown breakpoint

We know consider a test for structure change with *unknown* change point. The following test was set forth by Andrews (1993). Consider the parametric model indexed by the parameter β_t

$$y_t = x_t' \beta_t + \varepsilon_t, \;\; for\ t = 1, \dots, T$$

(3)

The null hypothesis of parameter stability is

$$H_0: \beta_t = \beta_o\ for\ all\ t = 1,2, \dots, T$$

(5)

For the alternative hypothesis consider a one-time structural change alternative with change point $T' \in (q, \dots, T-q)$. The alternative hypothesis is given by

$$H_{1T}(T'): \beta_t = \begin{matrix} \beta_1(T') & for\ t = 1, \dots, T' \\ \beta_2(T') & for\ t = T'+1, \dots, T \end{matrix}$$

(6)

For a normal linear regression model (with the regression parameters β_t) and known change point T', one can form the F test statistic and corresponding F test discussed above. Constructing a test when T' is not given is complicated by the fact that the parameter T' only appears under the alternative hypothesis but not under the null. Therefore tests constructed with T' treated as a parameter does not possess the standard large sample asymptotic distribution. We adopt a common method used in scenarios like this and look at test statistic of the form

$$\sup_{T'} W_T(T'), \sup_{T'} LM_T(T')\ \ and\ \ \sup_{T'} LR_T(T')$$

(7)

where W, LM, LR are the Wald, Lagrange multiplier and likelihood-ratio test statistics and T' is a pre-specified subset of $[1, \dots, T]$. In the case of a normal linear regression model W, LM and LR test statistics are equivalent to the F statistic. So in the case where the parameter T' is unknown we are interested in the test statistic

$$\sup_{T'} F(T')$$

(8)

Andrews (1993) described the asymptotic distribution of this test statistic and provided critical values.

B.3 Multiple structural change models

We know consider the following multiple linear regressions with m breaks (m+1 regimes)

$$y_t = x_t' \beta_j + \varepsilon, \quad for\ t = T_{j-1} + 1, \dots, T_j \tag{9}$$

for j = 1,…,m+1. We use the convention that $T_1 = 0$ and $T_{m+1} = T$. The breakpoints $\{T_j\} = (T_1, \dots, T_m)$ are explicitly treated as unknown. We assume that the minimum size of a regime (e.g. $T_i - T_{i-1}$) is q . The purpose is to estimate the unknown regression coefficients together with the break points when T observations of (y_t, x_t) are available. Here I follow the method set forth in Bai and and Perron (2003)

The system (9) can be expressed in matrix form

$$Y = X\,\bar{\beta} + \mathrm{E} \tag{10}$$

with $Y = (y_1, \dots, y_T)'$, $X = (x_1, \dots, x_T)'$, $\mathrm{E} = (\varepsilon_1, \dots, \varepsilon_T)'$ and $\bar{\beta} = diag(\beta_1, \dots, \beta_{m+1})$ is the matrix that diagonally partitions β at $(T_1, \dots, T_m)$.

The method of estimation considered is based on the least square principle. For each m-partition $(T_1, \dots, T_m)$, the least square estimate $\hat{\beta}$ is obtained by minimizing the sum of squared residuals

$$(Y - X\beta)'(Y - X\beta) = \sum_{j=1}^{m+1} \sum_{t=T_{i-1}+1}^{T_i} \left(y_t - x_t' \beta_j\right)^2 \tag{11}$$

Let $\hat{\beta}(\{T_j\})$ denote the estimate based on the given m-partion $\{T_j\}$. Substituting this estimate of the regression parameter into the objective function (11) and let $RSS(\{T_j\})$ denote the resulting residual sum of squares. The estimated breakpoints $\{\hat{T}_j\} = (\hat{T}_1, \dots, \hat{T}_m)$ are such that minimize the residual sum of squares, e.g.

$$\{\hat{T}_j\} = \underset{\{T_j\}}{\operatorname{argmin}}\ RSS(\{T_j\})$$

(12)

where the minimization is taken over all partitions such that $T_i - T_{i-1} \geq q$.

B.4 Estimating the number of breaks – A test of m versus m+1 breaks

Usually we do not have any prior knowledge of the number of breaks. In order test for number of breaks, Bai and Perron (1998) proposed a test for m vs. m+1 number of breaks.

As they point out, ideally one would like to base the test on the difference between the sum of squared residuals obtained from a multiple structural change model with m breaks and one with m+1 breaks. However the limiting distribution of this test statistic is difficult to obtain. They therefore propose a different strategy.

First assume we have the multiple structural change model with m breaks defined by (9). For this model we estimate the breakpoints $\{\hat{T}_j\} = (\hat{T}_1, \ldots, \hat{T}_m)$ by a global minimization of the sum of squared residual. Then proceed by testing each of the m+1 segments $(\hat{T}_{j-1} + 1, \ldots, \hat{T}_j)$ for the presence of an additional break. We reject the null hypothesis of m breaks for the alternative of (m+1) breaks if the minimum sum of squared residuals with an additional break is sufficiently smaller than the sum of squared residuals of the m break model. Or more formally define

$$RSS_m = RSS(\{T_j\})$$

(13)

as the sum of squared residuals of the m break model and

$$RSS_{m+1} = \min_{j \in [1, m+1]} \inf_{\tau \in \Lambda_j} RSS(\hat{T}_1, \ldots, \hat{T}_{j-1}, \tau, \hat{T}_j, \ldots, \hat{T}_m)$$

$$\Lambda_j = \{\tau | \hat{T}_{j-1} < \tau < \hat{T}_j\}$$

(14)

as the (minimum) sum of squared residuals of the (m+1) alternative break models. The test statistic is defined as

$$F(m+1|m) = (RSS_m - RSS_{m+1})/\hat{\sigma}^2$$

(15)

where $\hat{\sigma}^2$is a consistent estimate of σ^2. Bai and Perron (1998) described the asymptotic distribution of this test statistic and provided critical values.

B.5 Estimating the number of breaks – Information criteria

An alternative way of estimating the number of breaks is by considering an information criterion. Yoa (1988) suggested the use of Bayesian Information Criterion (BIC) and Lie et.al. (1997) propose a modified Schwarz criterion (LWZ).

We again consider the following multiple linear regressions with m breaks (m+1 regimes)

$$y_t = x_t' \beta_j + \varepsilon_t, \ \ for\ t = T_{j-1} + 1, \dots , T_j \tag{16}$$

here we assume m is unknown. The Bayesian information criterion for a model with m breaks is

$$BIC(m) = \ln(\hat{\sigma}_\varepsilon^2) + \frac{k}{T}\ln(T) \tag{17}$$

where $\hat{\sigma}_\varepsilon^2$ is an estimate of the variance of the m-break model and k is the number of free parameters to be estimated. If β_j are $(p \times 1)$ vectors then $k = m + (m+1)p$. We then chose the m that minimizes $BIC(m)$.

In Perron (1997) he simulated the behavior of three information criteria: Akaike's information criterion (AIC), Bayesian Information Criterion (BIC) and modified Schwarz criterion (LWZ). He looked at how well these three criteria performed in estimating the number of breaks in the trend function of a series in the presence of serial correlation. The result was the AIC performed very badly. BIC and LWZ performed well without the presence of serial correlation, but overestimated the number of breaks when serial correlation was introduced.

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