THRESHOLD EFFECTS IN THE OPENNESS-PRODUCTIVITY GROWTH RELATIONSHIP: THE ROLE OF INSTITUTIONS AND NATURAL BARRIERS

By

SOURAFEL GIRMA, MICHAEL HENRY

AND

CHRIS MILNER

(GEP and School of Economics, University of Nottingham)

1ST DRAFT (PLEASE DO NOT QUOTE)

Paper Presented to the 27th Annual Conference of the International Economics Study Group, University of Bath
(13-15th September, 2002)

THRESHOLD EFFECTS IN THE OPENNESS-PRODUCTIVITY GROWTH RELATIONSHIP : THE ROLE OF INSTITUTIONS AND NATURAL BARRIERS

1. Introduction

Notwithstanding the oft cited measurement and econometric problems, there is still fairly widespread consensus that openness to international trade and institutional quality/efficiency impact positively on economic performance (e.g. North and Thomas, 1973; Knack and Keefer, 1995; Mauro, 1995; Hall and Jones, 1999; Rodrik, 2001). Indeed, with respect to institutions, the issue has been what aspects of institutions matter and how these institutional factors should be analysed. Similarly, the role of geography in explaining differences in economic performance across individual countries and between groups of countries has also been subjected to some empirical scrutiny (e.g. Gallup et al., 1999; Redding and Venables, 2000). Generally, the finding has been that favourable geographical factors are associated with higher per capita income growth.

Here we hypothesise that aspects of geography (transport costs) as well as institutions affect TFP growth through their favourable impact on trade; the productivity payoffs from openness or trade liberalisation being mediated by the quality of a country's institutions and the extent of the natural barriers it faces. We also postulate that there exists some critical level of both institutional quality and transport costs above and below which the positive contribution of openness to TFP growth differs. Specifically we argue that the productivity growth response to increased trade policy openness will be greater for those countries with higher quality institutions and lower 'natural' barriers to trade than those with lower quality institutions and higher 'natural' barriers.

The aim of this paper is therefore to test for such threshold effects and to identify the critical values for these thresholds in institutional quality and the level of natural barriers. We do so in the context of a cross-country TFP growth model, estimated econometrically for a panel of up to 83 countries for the period 1970-1989. The rest of this paper is organised as follows, Section 2 briefly reviews the empirical literature on the role of institutions (and transport costs) in fostering and/or hindering trade in particular, and economic performance in general. It then reviews previous research on threshold effects within the context of the openness-growth relationship. Section 3 details the different approaches we employ to model threshold effects. Section 4 describes the data (and their sources) used for our empirical analysis as well as the estimation method employed. Section 5 presents the results of our estimations while conclusions are presented in Section 6.

2. Threshold Effects in the Openness-Growth Relationship: A Review of the Literature

The hypothesis of a simple direct effect of institutions on TFP growth is well established in the empirical literature. Dawson (1998) and, Ayal and Karrass (1998) find that economic freedom affects economic growth through its direct effect on TFP. Similarly, Klein and Luu (2001), using frontier analysis, consider only a direct impact of economic freedom on technical efficiency. Others point also to indirect relationships between institutions and TFP. Both Dawson (1998) and, Ayal and Karrass (1998) also find that economic freedom affects growth through an indirect effect on investment (capital accumulation).

The argument advanced by "the new institutional economics" is that growth requires that the potential hazards of trade (shirking, opportunism, risk etc.) be controlled by institutions such as property rights, the rule of law, uniform commercial codes, standard weights and measures, organised financial markets and the like (North and Thomas, 1973; North, 1990 and 1991; Klein 2000). It is argued that these institutions reduce information costs, encourage capital formation and capital mobility, allow risks to be priced and shared, and facilitate co-operation. Similarly, Besley (1995) argues that institutions which facilitate economic transactions between individuals and firms enhance the gains from trade and therefore increase the potential return to investment. More than that, it is argued that countries with better institutions, more secure property rights, and less distortionary policies will invest more in physical and human capital, and will use these factors more efficiently to achieve a greater level of income (e.g. North and Thomas, 1973; North, 1981; and Jones, 1981). While Rodrik (1998) argues that societies that benefit the most from integration with the world economy are those that have the complementary institutions at home that manage and contain the conflicts that economic interdependence triggers.

In terms of the relationship between transport costs and trade, studies by Limão and Venables (1999) and Radelet and Sachs (1998) point to the negative correlation between transport costs and trade volumes. In fact IDB (2000) argues that in light of the wave of global trade liberalisation of the 1980s and 1990s, the effective protection provided by high transport costs represents a greater obstacle for some countries integrating successfully in the global economy than that provided by trade policy barriers (e.g. tariff and non-tariff barriers). They also argue that the huge differences in port efficiency between locations like Hong Kong, Singapore and Belgium, on the one hand, and some of the Latin American or African countries on the other, is only partly explained by differences in the physical infrastructure of ports. In their view, many of the least efficient ports are the consequence of an inadequate regulatory and institutional environment that impedes competition, fosters organised crime and slows the introduction of modern techniques of

cargo handling and port management. The end result is higher transport costs and a reduced volume of trade.

The notion of a threshold effect has long been the subject of inquiry in the empirical trade and growth literature[1] (see for example, Michaely, 1977; Tyler, 1981; Balassa, 1984; and Kavoussi, 1984); albeit as an appendage to the main export-growth hypothesis. Essentially, researchers sought to test the hypothesis that the effect of exports on economic growth differs between countries above or below the critical level of some observed variable: the threshold variable. The variable commonly used was the level of per capita income which proxied for the level of development. Evidence of such a difference was taken as the existence of a "threshold effect". According to Greenaway and Sapford (1994), the evidence from the early studies on the existence of a threshold effect is mixed.

In the traditional approach, the threshold procedure involves the splitting of one's sample into classes (groups) based on the value of the threshold variable. Among the studies finding evidence of a threshold effect (Michaely, 1977; Tyler, 1981; Kavoussi, 1984; Ram 1985; Moschos, 1989) all, excepting Moschos, simply divided their sample of developing countries into two groups – higher and lower income- on the basis of an exogenously determined level of per capita income. They then determined the effect of export growth on the economic performance of these two groups of countries by comparing the coefficient on exports from the two sets of estimates, in terms of their magnitude and significance. For instance, Michaely (1977) found that the positive correlation between economic growth and export growth was significant for the 23 higher income countries, but that the statistical significance for the lower-income group was "practically zero". Consequently, he concluded that "growth is affected by export performance only once countries achieve some minimum level of development" (p.52). A similar conclusion was reached by Tyler[2] (1981). Using the same exogenous sample splitting technique but a different estimation procedure, Kavoussi (1984) states that while "in low income countries too export expansion tends to be associated with better economic performance" (p.240), "the contribution of exports…. is greater among the [more advanced developing countries]" (p.242).

In contrast to previous researchers, Moschos (1989) employed a completely different technique for determining the existence or non-existence of a threshold level of development. He employed a switching regression technique whereby the critical switching point (threshold level) is

[1] Table 1 in Greenaway and Sapford (1994) lists some of the export and growth studies between 1977-1993 which also tested the threshold hypothesis.
[2] Though reaching a similar conclusion to Michaely (1977), Tyler used OLS to estimate a production function in contrast to the rank correlation methods used by Michaely.

arrived at from the data itself rather than it being determined exogenously. Based on this sample splitting methodology, Moschos found evidence of "the existence of a critical development level below and above which the responses of output growth to its determining factors differ substantially." (p.93). His results also suggested that the effect of export expansion on aggregate growth is stronger in the "low income" regime compared to the "high income" regime. Thus contradicting the previously held view that the effect of export expansion on growth is stronger among 'more advanced' developing economies compared to the 'less advanced' ones.

In a critique of the methodology employed in earlier studies, Moschos argued that the basic or critical level of development was chosen rather arbitrarily, with the splitting of the sample based on some ad hoc level of per capita income. Consequently, he argued that the results are likely to be sensitive to the choice of per capita income used as the critical level of development. Similarly, Hansen, in a series of papers on the subject of threshold regression analysis [see Hansen, 1999; Hansen, 2000 and; Caner and Hansen, 2001], criticises the use of ad hoc and arbitrary sample splitting in many areas of economic inquiry. Hansen (2000) noted that econometric estimators generated on the basis of such procedures may pose serious inference problems.

Recently, Miller and Upadhyay (2000) adopted a linear interaction approach for determining the existence of a threshold. The authors interacted a measure of the stock of human capital with a measure of openness (exports-to-GDP ratio) in their TFP regression. They found the coefficient of the interaction term to be positive and statistically significant, while those of the human capital stock and the measure of openness were negatively and positively significant respectively. Based on this finding, the authors concluded that countries must reach a critical level of openness before human capital contributes positively to TFP. Below this level of openness, the contribution of human capital to TFP is negative. When they subsequently divided their sample of countries into lower, middle and high-income groups, they found that only low income countries conformed to this "threshold effect".

However, there are inherent limitations to this type of approach (see Girma, 2002). The linear interaction term *a priori* restricts the externalities generated by openness to trade (e.g. improvements in the quality of human capital) to be monotonically increasing (or decreasing) with openness. It may be that after reaching the critical level of openness, human capital despite contributing positively to TFP may be doing so at a declining rate; that is the relationship between openness and human capital may be quadratic rather than linear. Further, the analysis does not allow the data itself to reveal the critical value of any threshold.

Before outlining our chosen methodology for determining threshold level(s) in the next section, we conclude this section by noting that in departing from the practice of an exogenous sample division we are also rejecting the implicit assumption that countries in the same group have the same institutional as well as transport cost structures. In our view, such an assumption seems implausible given the heterogenous nature of institutional and transport structures across countries.

3. Modelling TFP Growth and Threshold Effects

Base Model

The primary aim of the study is to investigate how the effects of openness on TFP growth may be influenced by the quality of a country's institutions and the natural barriers to its international trade . We specify first however a base model which incorporates only direct effects. In line with other cross-country empirical growth models (e.g. Rodrik, 1997; Edwards, 1998; Miller and Upadhyay, 2000), we hypothesise that the rate of national productivity growth depends on national policies, including trade policy or openness, and on initial conditions. It is assumed that more open economies have a greater capacity to absorb new ideas from the rest of the world, and a higher steady state level of knowledge. Initial conditions might for example include initial human capital, since this captures the country's capacity to innovate and absorb new ideas; lower initial human capital reducing this capacity and lowering the steady-state rate of knowledge accumulation (see Edwards, 1998). Here we include initial GDP which proxies both the initial human capital effect[3], and may also capture any conditional convergence effect. The sign on these combined effects is therefore ambiguous. In addition, we incorporate two additional (direct) hypotheses about firstly the productivity growth-enhancing effects of good national institutions and secondly the growth retarding effects of high 'natural' barriers to trade arising out of transport infrastructure deficiencies or geographical disadvantages of remoteness or landlockness. Thus the base model is:

$$TFPG_{it} = \alpha_0 + \alpha_1 GDP_{it}^{\ 0} + \alpha_2 OPEN_{it} + \alpha_3 INSTIT_{it} + \alpha_4 NATBARR_{it} + \mu_{it} \qquad (1)$$

where TFPG is the growth rate of total factor productivity; GDP^0 is the log of per capita GDP at the beginning of each five year period from 1970-89 and represents a country's initial conditions. OPEN is a variable proxying alternative measures of openness (trade distortion) and its behaviour is expected to be consistent with the hypothesis that more openness (less trade distortions) is associated with higher levels of TFP growth. INSTIT is a measure of institutional quality. NATBARR is a measure of international transport costs that a country incurs when engaging in

[3] The two variables are highly co-linear (r=0.80) in the present sample of countries.

international trade; μ is the disturbance term; *i* indexes the countries in our sample and *t* the time periods. Since our sample period, 1970-89, is divided into four five-year periods, namely 1970-74; 1975-79; 1980-84; 1985-89, *t* is defined over the values [1,2,3,4]. For example, when *t*=1, T= 1974 and GDP^{0}_{i1} refers to the level of income 1970.

The expected signs on our coefficients are: $\alpha_1 \gtreqless 0$; $\alpha_2 > 0$; $\alpha_3 > 0$ and $\alpha_4 < 0$

Augmented Model with Traditional Specification of Threshold Effects

The incorporation of linear interaction terms or the exogenous splitting of the sample is the traditional way in which threshold influences are investigated. Here we investigate both of these approaches, in order to compare with a more formal threshold model and to illustrate the limitations of the traditional approaches.

In the case of the interaction effects, we separately add the terms ($OPEN_{it} * NATBARR_{it}$) and ($OPEN_{it} * INSTIT_{it}$) to Equation (1). Thus the augmented models are as follows:

$$TFPG_{it} = \alpha_0 + \alpha_1 GDP^0_{it} + \alpha_2 OPEN_{it} + \alpha_3 INSTIT_{it} + \alpha_4 \left(OPEN_{it} * NATBARR_{it}\right) + \mu_{it} \qquad (2)$$

$$TFPG_{it} = \alpha'_0 + \alpha'_1 GDP^0_{it} + \alpha'_2 OPEN_{it} + \alpha'_3 NATBARR_{it} + \alpha'_4 \left(OPEN_{it} * INSTIT_{it}\right) + \mu'_{it} \qquad (2')$$

where the expected signs are: $\alpha_4 < 0$ and $\alpha'_4 > 0$.

In Equation (2) we hypothesise that higher natural barriers will reduce the benefits of increased (policy-induced) openness or trade liberalisation, since it will constrain the country's access to new ideas and/or increase the costs of accessing new ideas through international exchange. While in Equation $(2')$ the ability of a country to benefit from increased openness is hypothesised to be fashioned by the quality of its institutions, with the productivity growth return to openness increasing as institutional quality increases.

As an alternative to expecting there to be a continuous conditioning influence of institutions or natural barriers on the productivity growth impact of openness, one might hypothesise that the relationship between openness and productivity growth is constant among particular sub-sets of the sample of countries but varies between the sub-set of countries. Countries characterised as being represented by higher quality institutions or by lower natural barriers might for example be expected to benefit more from increased openness than other countries in the sample. For the current analysis the sample of countries is split in turn into HIGH, MEDIUM and LOW natural

barrier and institutional quality countries, with one-third (approximately) of the countries falling each time into each category. The revised estimating equations are therefore:

$$TFPG_{it} = \alpha_0 + \alpha_1 GDP_{it}^0 + \alpha_2 OPEN_{it} + \alpha_3 INSTIT_{it} + \alpha_4 NATBARR_{it} + \alpha_5 (OPEN_{it} * Dmednatbarr) + \alpha_6 (OPEN_{it} * Dhighnatbarr) + \mu_{it} \quad (3)$$

where *Dmednatbarr* is country dummy (=1) for countries with MEDIUM natural barriers; and *Dhighnatbarr* is country dummy (=1) for countries with HIGH natural barriers. The expected signs are:

either

α_5 and $\alpha_6 < 0$ (lower benefits of openness for all countries without LOW natural barriers)

or

$\alpha_5 = 0$ and $\alpha_6 < 0$ (lower benefits only for HIGH natural barrier countries)

and

$$TFPG_{it} = \alpha_0' + \alpha_1' GDP_{it}^0 + \alpha_2' OPEN_{it} + \alpha_3' INSTIT_{it} + \alpha_4' NATBARR_{it} + \alpha_5' (OPEN_{it} * Dlowinstit) + \alpha_6' (OPEN_{it} * Dmedinstit) + \mu_{it}' \quad (3')$$

where *Dlowinstit* is country dummy (=1) for countries with LOW quality institutions and *Dmedinstit* is country dummy(=1) for countries with MEDIUM quality institutions. The expected signs are:

either

α_5' and $\alpha_6' < 0$ (lower benefits of openness for all countries without HIGH quality institutions)

or

$\alpha_5' < 0$ and $\alpha_6' = 0$ (lower benefits of openness only for low institution quality countries)

Formal Threshold Model

Threshold regression models specify that individual observations can be divided into classes based on an observed variable. They allow us to determine whether regression functions are identical across all observations in a sample, or whether they fall into discrete classes. In our case,

we postulate that they are heterogenous; given our *a priori* belief that the effects of openness on TFP growth differ across countries based on the countries' institutional and infrastructural capabilities. We do not know, however, how the coefficients on the openness variables vary with institutional quality and transport costs. In light of this we employ the endogenous threshold regression techniques based on Hansen (2000) and estimate the unknown threshold or cut-off values. The standard econometric theory of estimation and inference is not valid, but Hansen (2000) provides an asymptotic distribution theory which enables one to make valid statistical inferences on the basis of threshold models.

For a single threshold, we could specify our estimating equations as :

$$TFPG_{it} = \gamma X_{it} + \beta_1 OPEN_{it} I\left(NATBARR_{it} \le \alpha\right) + \beta_2 OPEN_{it} I(NATBARR_{it} > \alpha) + \varepsilon_{it} \qquad (4)$$

$$TFPG_{it} = \gamma' X_{it} + \beta_1' OPEN_{it} I(INSTIT_{it} \ge \alpha') + \beta_2' OPEN_{it} I(INSTIT_{it} < \alpha') + \varepsilon_{it}' \qquad (4')$$

where I(.) is the indicator function and X is vector of other control variables for Equations (4) and $(4')$, and includes both threshold variables. We use Equation (4) to provide a brief insight of two main econometric and statistical problems that arise in the estimation of our formal threshold model. These same two problems and the procedures we adopt for resolving them apply to Equation $(4')$ in an analogous manner. The first is to jointly estimate the threshold value α and the slope coefficients γ, β_1, and β_2. The second is to test the null hypothesis of no threshold (i.e. $H_0 : \beta_1 = \beta_2$) against the alternative of a threshold regression model (i.e. $\beta_1 \neq \beta_2$).

To address the first problem, we use the algorithm Hansen (2000) provides that searches over values of α sequentially until the sample splitting value $\hat{\alpha}$ is found[4]. Once found, estimates of γ, β_1 and β_2 are readily provided. The problem that arises in testing the null hypothesis of no threshold effect (i.e. a linear formulation) against the alternative of a threshold effect is that under the null hypothesis, the threshold variable is not identified. Consequently, classical tests such as the Lagrange Multiplier (LM) test do not have standard distributions and so critical values cannot be read of standard distribution tables. To deal with this problem, Hansen (2000) recommends a bootstrap procedure to obtain approximate critical values of the test statistics which allows one to perform the hypothesis test. We follow Hansen (2000) and bootstrap the p-value based on a likelihood ratio (LR) test.

In the case of a threshold effect associated with natural barriers one might expect that $\beta_1 \neq \beta_2$, and that $\beta_1 > 0$ and $\beta_2 < 0$; higher than average productivity growth effects from openness for those countries with below the threshold level of natural barriers and lower than average effects for those with above threshold level of barriers. Analogously in Equation $(4')$ the expected threshold effect would also be revealed by $\beta_1' > 0$ and $\beta_2' < 0$; higher than average productivity growth effects from openness for those countries with above the threshold level of institutional quality and lower than average effects for those with below threshold institutional quality.

4. Data And Estimation

Productivity Growth

Our empirical analysis begins with the measurement of total factor productivity (TFP) growth. To compute TFP growth, we use a combination of econometric estimation as well as growth accounting [see Senhadji (2000)]. Allowing for parameter heterogeneity across countries, we estimated a constrained Cobb-Douglas production function (without human capital) for each country. Following the recommendation of Pesaran and Smith (1995) we then averaged the capital and labour output elasticities by region and use these to compute individual country TFP growth rates. This procedure represents a middle ground between panel measures based on the assumption of homogeneity of production parameters for all countries and the individual country estimations which posit total heterogeneity across countries. Both of which have been subjected to criticism within and without the empirical growth literature (see for example Durlauf and Johnson, 1995; Lee, Pesaran and Smith, 1997; Temple, 1999; Baltagi and Griffin, 1997). Our measure allows for heterogeneity of production parameters but assumes that production technologies are the same for countries within the same regional grouping. We believe this assumption is plausible and is strengthened by the finding of Koop et al. (1995) that most of the variation in technical efficiency is between regional groupings rather than within them.

The data used to compute TFP growth were obtained from the World Bank's STARS database [see Nehru and Dhareshwar, 1993]. This data set contains data on GDP, physical and human capital stock, and the working age population for 93 developed and developing countries from 1950-1990.

Openness

[4] This is the value of α that minimises the concentrated sum of squared errors based on a conditional OLS regression.

Concerns have been raised over the ability of some openness/trade liberalisation measures to capture particular aspects of a country's trade policy (Edwards, 1998; Rodriguez and Rodrik,2000), as well as the suitability of a single measure of openness/trade liberalisation to adequately proxy something as complex and multi-faceted as a country's trade regime (Edwards, 1998; Greenaway et al., 1998). In line with the last two cited studies which use more than a single measure of openness/trade liberalisation, we employ three alternative measures of openness/trade liberalisation (distortion). These include the log of exports plus imports to GDP; the Sachs-Warner openness index (see Sachs and Warner, 1995); the log of the price level GDP in PPP prices, relative to the U.S. dollar exchange rate[5]. As a means of capturing the effect of a change in trade policy on TFP growth, we also used the change in the Sachs-Warner index. Data for our openness measures were obtained from the World Bank's World Development Indicators (WDI) CD ROM 2000, the Penn World Tables (Mark 5.6a) [updated by Summers and Heston in 1995] and Sachs and Warner (1995).

Institutional Quality

To assess the impact of institutional differences on TFP growth we use an index proxying the countries' Legal Structure and Property Rights. This index is a sub-component of the composite economic freedom of the world (EFW) index (2001) developed under the auspices of the Fraser Institute of Canada and constructed by James Gwartney, Robert Lawson and associates[6]. Specifically, Legal Structure and Property Rights measure: (a) legal security of private ownership rights/risk of confiscation, and (b) rule of law i.e. legal institutions, including access to non-discriminatory judiciary, that are supportive of the principles of the rule of law. A 0-10 scale is used to assign country ratings, with countries having a secure property rights structure receiving a higher rating.

Despite the use of a 11 point scale to determine individual country ratings, one significant advantage of our institutional measure is that it is constructed from data derived from quantitative (objective) measurements and not qualitative (subjective) assessments. Consequently, the data used to construct the index of legal structure and property rights are unlikely to be biased in favour of a positive relationship between this index and economic performance as would be the case if

---

[5] Miller and Upadhyay (2000) explains that this variable measures the local price of an identical basket of goods for all countries relative to the price in the U.S. Consequently, they referred to it as a measure of the local price deviation from PPP, with the U.S. as the reference country.

[6] Our use of Legal Structure and Security of Property Rights to proxy a country's institutional quality rather than the overall Economic Freedom index was informed by the fact that the former is the measure commonly used in the literature to proxy institutions (e.g. Barro, 1994; Knack and Keefer, 1995; Gwartney et al., 1998)

researchers tended to assign high legal structure and property rights ratings to more prosperous countries (see Klein and Luu, 2001).

The data are provided in 5 year intervals from 1970-1995, and for 1999 (our sample period extends from 1970 through 1989). Given that institutional arrangements are likely to change slowly through time and, thus the year to year variation may be rather small, then using data in 5 year periods may not be unreasonable[7]. In fact, similar reasoning was employed by Barro (1997) and Chong and Calderón (2000).

Natural Barriers

We use transport costs as our proxy for natural barriers. As noted by Milner et al., (2000) this measure conflates two barriers (natural barriers and infrastructure inefficiencies) into one. The natural component relates to the physical geographical factors like distance (from the coast and core markets) while infrastructure relates to roads, telephones, ports and general telecommunications.
Our measure of transport costs is the estimated average c.i.f./f.o.b. margins in international trade. The c.i.f./f.o.b. ratio measures, for each country, the value of imports (inclusive of carriage, insurance and freight) relative to their free on board value i.e. the cost of the imports and all charges incurred in placing the merchandise aboard a carrier in the exporting port. Data for this ratio were obtained from the International Monetary Fund's (IMF) International Financial Statistics (IFS) Yearbook (various years) for the period 1965-1990.

The c.i.f./f.o.b. measure is not without its drawbacks. The principal one is that it is prone to measurement error. For one thing, the ratio is a crude estimate undertaken by the IMF for countries that report the total value of imports at c.i.f. and f.o.b. values, which themselves contain some measurement error. Added to that, is the fact that some countries do not report these figures every year. Finally, the measure aggregates over all commodities imported[8]. However, three factors contribute to make the c.i.f./f.o.b. ratio our preferred measure of transport costs. First, the country coverage is broader than alternative measures. Second, a fairly lengthy time series exists for this ratio. Third, the c.i.f./f.o.b. ratio allows us to capture both the overland transport costs borne by landlocked countries as well as the international component (either air or marine or both) [see Milner et al (2000); Limão and Venables (1999)].

---

as well as the fact that some openness/trade liberalisation (distortion)- most notably the Sachs and Warner index- are used as a basis for constructing the latter.

[7] Though the assumption that institutional factors change slowly through time has been used by researchers, Rodrik (2000) points to some countries (Chile, Korea and China)where there have been instances of rapid and dramatic changes in institutions.

Summary statistics and the correlation matrix for the variables used in our estimation exercises are provided in Tables A1 and A2 respectively, in Appendix 1.

Estimation

To examine the relationships between TFP growth and openness/trade liberalisation (distortion); institutions and natural barriers we use Feasible GLS estimation of pooled cross-section and time series data. Our justification for using Feasible GLS estimation is largely based on the need to account for heteroscedasticity across countries within the framework of our panel estimations and also the fact that we don't know the nature of the scedastic function. We believe that it is plausible to assume that there will be some variation of scale in our broad cross-section of countries. That being the case, the variance of each country will differ and so one needs to take this into account in one's estimations.

Thus we allow for heteroscedasticity across countries but no autocorrelation either across or within countries[9]. Given that our data are in five-year periods, we believe that with only four time periods not accounting for autocorrelation will not fundamentally affect our estimation results. Finally, it should be noted that asymptotically the FGLS estimator is equivalent to the GLS estimator.

5. Results

Base Model

The GLS estimates for the base model incorporating only direct effects on TFP growth are reported in Table 1, for panels covering eighty three (83) countries or seventy eight (78) countries where the Sachs-Warner index of openness is used. Four alternative openness measures (equations a-d) are employed along with the proxies for institutional quality (INSTIT) and natural barriers (NATBARR). All of the openness measures have the expected sign, with significance at the 1% level; greater openness or liberalisation or reduced price distortion being associated with higher productivity growth. There is also support in these regressions for the expected direct effects of institutions and natural barriers.

INSTIT has a positive sign in all the equations , and is significant at the 1% level in all the equations except equation (b). This latter result may be a consequence of the manner of

[8]Frankel (1997), Limao and Venables (1999) and, before them, Moneta (1959) provide a fuller discussion on the problems associated with the c.i.f./f.o.b. data.

[9] We also estimated our base model allowing for autocorrelation within panels assuming both a common AR (1) coefficient for all panels as well as panel specific AR(1) coefficient. Generally, our results matched those obtained from assuming no autocorrelation.

construction of the Sachs-Warner index (OPEN2), and the use of information on institutional characteristics in its construction. NATBARR also has a negative sign in all the estimations, with significance at the 1% level in three cases and at the 5% level in the case of equation (b).

Table 1: GLS REGRESSIONS OF DETERMINANTS OF TFP GROWTH

DEPENDENT VARIABLE TFP GROWTH				
INDEPENDENT VARIABLES	**(a)**	**(b)**	**(c)**	**(d)**
GDP^0	-0.00690***	-0.00741***	-0.00516***	-0.00581***
	(5.54)	(7.15)	(4.18)	(3.96)
OPEN1(X+M/GDP)	0.00844***			
	(6.21)			
OPEN2(SW)		0.01759***		
		(8.37)		
OPEN3			-0.01059***	
			(6.48)	
ΔOPEN2(ΔSW)				0.01095***
				(2.70)
INSTIT	0.00133***	0.00047	0.00262***	0.00268***
	(2.81)	(1.11)	(6.41)	(5.55)
NATBARR(c.i.f./ f.o.b)	-0.05023***	-0.02971**	-0.05369***	-0.05095***
	(3.15)	(2.19)	(3.33)	(2.91)
PERIOD==2(1975-79)	-0.00852***	-0.00810***	-0.00279	
	(3.37)	(4.11)	(1.16)	
PERIOD==3(1980-84)	-0.02364***	-0.01961***	-0.02032***	-0.01458***
	(11.33)	(13.11)	(10.33)	(8.06)
PERIOD==4(1985-89)	-0.00894***	-0.00775***	-0.00662***	-0.00189
	(4.53)	(5.77)	(3.37)	(1.00)
Observations	253	243	253	197
Number of countries	83	78	83	78

NOTES:
Absolute value of z-statistics in parentheses.* significant at 10%; **significant at 5%; *** significant at 1%.

OPEN1 is the log of the share of exports plus imports in GDP (%); OPEN2 is the Sachs and Warner (1995) openness index; OPEN3 is the log of the price level GDP (%)in PPP prices, relative to the U.S. dollar exchange rate. INSTIT is an index of Security of Property Rights. NATBARR is a

measure of international transport costs and is proxied by the c.i.f./f.o.b ratio.

The consistency of the support for the hypothesised direct effects across the alternative measures of openness is encouraging for two reasons. Firstly, it offers some accommodation for the criticisms that may be made over trying to capture the multi-faceted concept of policy openness in a simple summary measure. Secondly, it reduces the concerns arising from any co-linearity between openness and institutions or natural barriers. For example in equation (a) one may legitimately point to the fact that a trade to GDP measure of openness incorporates aspects both of policy and functional openness, with natural barriers being one influence on functional openness.

In these, as in all the subsequent estimations, initial GDP (GDP^0) consistently has a negative coefficient with a high level of significance. For this set of countries and time periods we consistently have support for the conditional convergence hypothesis, or at least for conditional convergence effects swamping any technological absorptive capability effect.

Adding Linear Interaction Terms

Initially the full specification of the augmented models (specifications 2 and 2′ from Section 3) were estimated. Given some implausible signs on the direct effects and on the threshold values (i.e. where ∂TFPG/∂NATBARR or ∂TFPG/∂INSTIT switched from zero to positive), possibly associated with induced co-linearity problems, the model(s) were estimated with the direct effect (NATBARR in Table 2 and INSTIT in Table 3) excluded.

The results in Table 2 are consistent with natural barriers having indirect effects, via the influence of openness, on TFP growth. The pattern of signs and significance on all the direct relationships are as in the base results (Table 1), except for the change in the openness/Sachs-Warner index used to proxy liberalisation [in equation (d) of Table 2]. The interaction terms OPEN1(2)(3)*NATBARR are consistently negative with significance at the 1% level [except equation (b) at the 10% level]. This finding is consistent with the view that as natural barriers increase the positive effect of openness on productivity growth steadily decreases, [or in equation (c) with the idea of the negative effect of price distortions on productivity growth steadily increasing]. By imposing a continuous (and linear) relationship or an indirect effect of natural barriers on TFP growth, we do allow for the possibility of a specific type of threshold; namely we allow for the critical or threshold value of NATBARR where the growth effects of openness switch from being positive to

being negative. It is only in the case of equation (a) in Table 2 that the critical value of NATBARR is feasible or falls within the actual sample range of values for this variable. Modelled in this manner, openness has positive but declining productivity growth effects up to a c.i.f.–f.o.b. ratio of 1.129 and beyond this threshold value of NATBARR increasingly negative growth effects.

Again in Table 3 there is some support for institutions having indirect effects via openness on TFP growth. The alternative openness measures, initial GDP and natural barrier variables have the expected signs with strong significance. The interaction term also has the expected positive sign in equations (a) and (c). Thus modelled in this way [equation (a)] increases (falls) in institutional quality increase (reduce) productivity growth benefits of openness. Alternatively [equation (c)], increases (falls) in institutional quality reduce (increase) the productivity losses associated with distortions. For the other two estimations [equations (b) and (d)], which use the Sachs-Warner index, there is however either no support for an indirect effect for institutions [equation (b)] or the unexpected sign [equation (d)].

Although there is support for indirect effects in estimations (a) and (c), there is no possibility of a threshold effect (as defined above) in equation (a) for any feasible (positive) measure of institutional quality. In the case of equation (c), the positive value the institutional quality index has to reach before the beneficial effect of reducing distortions disappears is beyond the upper limit of the index. But this, in any case, would be a rather non-credible threshold to hypothesise. One would expect distortions reduction to be productivity growth enhancing at all levels of institutional quality. Similarly, one would not expect increased openness to actually reduce (long-term) productivity growth at any level of natural barriers. Rather it would be more credible to argue that the productivity growth response to increased openness may be different for groups of countries with different levels of natural barriers; 'lower' natural barrier countries tending to have greater positive responses to increased openness than 'higher' natural barrier countries. Such thresholds between 'higher' and 'lower' indexed countries (indexed in terms of natural barriers or institutional quality) might be imposed (exogenously) upon the data or explored endogenously within the data itself.

Table 2: GLS REGRESSIONS WITH LINEAR INTERACTIONS BETWEEN OPENNESS AND NATURAL BARRIERS

DEPENDENT VARIABLE TFP GROWTH				
INDEPENDENT VARIABLES	**(a)**	**(b)**	**(c)**	**(d)**
GDP^0	-0.00692***	-0.00771***	-0.00523***	-0.00402***
	(5.46)	(8.60)	(4.37)	(3.67)
OPEN1(X+M/GDP)	0.07457***			
	(3.90)			
OPEN2(SW)		0.06807***		
		(2.61)		
OPEN3			-0.00935***	
			(6.17)	
ΔOPEN2(ΔSW)				-0.20963**
				(2.44)
INSTIT	0.00123**	0.00039	0.00244***	0.00287***
	(2.57)	(1.00)	(5.90)	(9.22)
OPEN1*NATBARR	-0.06603***			
	(3.46)			
OPEN2*NATBARR		-0.04488*		
		(1.88)		
OPEN3*NATBARR			-0.01849***	
			(3.96)	
ΔOPEN2*NATBARR				0.19889***
				(2.67)
PERIOD==2(1975-79)	-0.00883***	-0.00847***	-0.00325	
	(3.50)	(4.74)	(1.36)	
PERIOD==3(1980-84)	-0.02365***	-0.02042***	-0.02056***	-0.01519***
	(11.34)	(15.64)	(10.52)	(9.40)
PERIOD==4(1985-89)	-0.00920***	-0.00798***	-0.00695***	-0.00162
	(4.71)	(6.45)	(3.59)	(0.97)
Observations	253	243	253	197
Number of countries	83	78	83	78

NOTES:
Absolute value of z-statistics in parentheses.* significant at 10%; ** significant at 5%; *** significant at 1%.

OPEN1 is the log of the share of exports plus imports in GDP (%); OPEN2 is the Sachs and Warner (1995) openness index; OPEN3 is the log of the price level GDP (%)in PPP prices relative to the U.S. dollar exchange rate. INSTIT is an index of Security of Property Rights. NATBARR is a measure of international transport costs and is proxied by the c.i.f./f.o.b ratio.

Table 3: GLS REGRESSIONS WITH LINEAR INTERACTIONS BETWEEN OPENNESS AND INSTITUTIONS

DEPENDENT VARIABLE TFP GROWTH				
INDEPENDENT VARIABLES	**(a)**	**(b)**	**(c)**	**(d)**
GDP^0	-0.00608***	-0.00721***	-0.00555***	-0.00054
	(4.84)	(7.34)	(4.10)	(0.47)
OPEN1(X+M/GDP)	0.00740***			
	(4.09)			
OPEN2(SW)		0.01894***		
		(5.41)		
OPEN3			-0.01224***	
			(6.38)	
ΔOPEN2(ΔSW)				0.02336***
				(3.11)
NATBARR(c.i.f./f.o.b)	-0.04738***	-0.03482***	-0.05021***	-0.03801**
	(3.01)	(2.59)	(3.09)	(2.04)
OPEN1*INSTIT	0.00025**			
	(2.06)			
OPEN2*INSTIT		-0.00000		
		(0.00)		
OPEN3*INSTIT			0.00060***	
			(5.90)	
ΔOPEN2*INSTIT				-0.00345*
				(1.84)
PERIOD==2(1975-79)	-0.00955***	-0.00947***	-0.00304	0.01153***
	(3.77)	(5.43)	(1.22)	(8.41)
PERIOD==3(1980-84)	-0.02422***	-0.02125***	-0.02009***	
	(11.54)	(19.47)	(9.93)	
PERIOD==4(1985-89)	-0.00943***	-0.00945***	-0.00656***	0.01282***
	(4.74)	(12.40)	(3.23)	(10.16)
Observations	253	243	253	197
Number of countries	83	78	83	78

NOTES:
Absolute value of z-statistics in parentheses. * significant at 10%; ** significant at 5%; *** significant at 1%.

OPEN1 is the log of the share of exports plus imports in GDP (%); OPEN2 is the Sachs and Warner (1995) openness index; OPEN3 is the log of the price level GDP (%)in PPP prices relative to the U.S. dollar exchange rate. INSTIT is an index of Security of Property Rights. NATBARR is a measure of international transport costs and is proxied by the c.i.f./f.o.b ratio.

Exogenous Sample Splitting

The results for what effectively splits the sample of countries into first 'HIGH', 'MEDIUM' and 'LOW' natural barrier countries and secondly 'HIGH', 'MEDIUM' and 'LOW' institution quality countries are reported in Tables 4 and 5 respectively. Consider Table 4 first. The pattern of results on the direct terms is largely as in the base results, except for a coefficient on a liberalisation proxy (the change in Sachs-Warner index) in equation (d) which is not significantly different from zero. In the case of the interaction terms, openness proxies interacted with dummies used to split the sample, there are no combinations of signs on the two interaction terms in each equation which are in line with the priors. The α_6 coefficient of Equation 4 in Section 3 is never negative with significance. Indeed in Equation (d) in Table 4 it is positive with significance, albeit where the liberalisation variable is itself not significantly different from zero.

Though both α_5 and α_6 are negative in equations (b) and (c), only the estimate for α_5 in equation (c) is separately significant. There is evidence here that increased distortions reduce TFP growth more for medium natural barrier countries, but not strong support for a similar effect for high natural barrier countries. Jointly the coefficients are, however, different from zero. In the case of equation (a) both α_5 and α_6 are positive and significant in the case of α_5, but here the joint test indicates that they are not different from zero. There is therefore only limited evidence for the hypothesised threshold effects of natural barriers on the effects of openness on productivity growth using the thresholds imposed here.

The results for the indexing of the split on the basis of the quality of countries' institutions (Table 5) is overall more in line with the priors discussed in Section 3. The equations using Sachs-Warner based measures [equations (b) and (d)] have interaction terms that are either both insignificant [equation (b)] or both have the unexpected sign [equation (d)]. In the latter case, one might argue that the results point to the greater need for openness in the low and medium institution quality countries than the high quality countries to achieve positive growth effects. Similarly in equation (d) in Table 4, greater openness might be more needed by high natural barrier countries than other countries to induce TFP growth. The results of in equations (a) and (c) are more in line with the alternative hypotheses proposed in this paper that the ability to reap the productivity growth benefits of openness are contingent upon the institutional quality (directly) and the extent of natural barriers (inversely). In equation (c), both low and medium quality institution countries experience greater productivity declines for increases in distortions relative to high quality institution countries (i.e. $\alpha_5' < 0$ and α_6'<0), while in equation (a) $\alpha_5' < 0$ and $\alpha_6' = 0$, with lower productivity growth benefits of increased openness for low quality institution countries only.

Table 4: GLS REGRESSIONS WITH LINEAR INTERACTIONS BETWEEN OPENNESS AND HIGH & MEDIUM NATURAL BARRIER COUNTRY DUMMIES

DEPENDENT VARIABLE TFP GROWTH				
INDEPENDENT VARIABLES	**(a)**	**(b)**	**(c)**	**(d)**
GDP^0	-0.00597***	-0.00758***	-0.00508***	-0.00572***
	(4.61)	(7.02)	(4.94)	(4.09)
OPEN1(X+M/GDP)	0.00725***			
	(4.62)			
OPEN2(SW)		0.01873***		
		(7.21)		
OPEN3			-0.01282***	
			(10.21)	
ΔOPEN2(ΔSW)				-0.00415
				(0.39)
INSTIT	0.00133***	0.00036	0.00255***	0.00248***
	(2.70)	(0.83)	(6.64)	(5.95)
NATBARR(c.i.f./f.o.b)	-0.05859***	-0.02814**	-0.05730***	-0.05613***
	(3.44)	(2.02)	(3.00)	(3.13)
OPEN1*MEDNATBARR	0.00001*			
	(1.82)			
OPEN1*HIGHNATBARR	0.00001			
	(1.38)			
OPEN2*MEDNATBARR		-0.00052		
		(0.23)		
OPEN2*HIGHNATBARR		-0.00325		
		(0.94)		
OPEN3*MEDNATBARR			-0.00119**	
			(2.08)	
OPEN3*HIGHNATBARR			-0.00020	
			(0.30)	
ΔOPEN2*MEDNATBARR				0.01083
				(0.89)
ΔOPEN2*HIGHNATBARR				0.02414**
				(2.22)
PERIOD==2(1975-79)	-0.00897***	-0.00837***	-0.00247	
	(3.53)	(4.17)	(1.05)	
PERIOD==3(1980-84)	-0.02386***	-0.01961***	-0.02082***	-0.01342***
	(11.31)	(12.90)	(10.67)	(7.98)
PERIOD==4(1985-89)	-0.00936***	-0.00772***	-0.00646***	-0.00033
	(4.71)	(5.64)	(3.31)	(0.19)
Observations	253	243	253	197
Number of countries	83	78	83	78
chi2Test,OPEN1*HIGHNATBARR= OPEN1*MEDNATBARR=0	3.62			
prob>chi2	0.16			
chi2Test,OPEN2*HIGHNATBARR= OPEN2*MEDNATBARR=0		0.89		
prob>chi2		0.64		
chi2Test,OPEN3*HIGHNATBARR= OPEN3*MEDNATBARR=0			5.05	
prob>chi2			0.08	
chi2Test,ΔOPEN2*HIGHNATBARR =ΔOPEN2*MEDNATBARR=0				7.51
prob>chi2				0.02

NOTES: Absolute value of z-statistics in parentheses. * significant at 10%; ** significant at 5%; *** significant at 1%.

OPEN1 is the log of the share of exports plus imports in GDP (%); OPEN2 is the Sachs and Warner (1995) openness index; OPEN3 is the log of the price level GDP (%)in PPP prices, relative to the U.S. dollar exchange rate. INSTIT is an index of Security of Property Rights. NATBARR is a measure of international transport costs and is proxied by the c.i.f./f.o.b factor.

HIGHNATBARR refers to countries categorised as having high natural barriers (i.e. a c.i.f./f.o.b. factor greater than the 66.67 percentile); MEDNATBARR refers to countries categorised as having medium natural barriers (i.e. a c.i.f./f.o.b. factor greater than the 33.333 percentile but less than or equal to the 66.67 percentile. The reference group consist of those categorised as having low natural barriers(i.e. a c.i.f./f.o.b. factor less than or equal to the 33.333 percentile).

Table 5: GLS REGRESSIONS WITH LINEAR INTERACTIONS BETWEEN OPENNESS AND LOW & MEDIUM QUALITY INSTITUTION COUNTRY DUMMIES

DEPENDENT VARIABLE TFP GROWTH				
INDEPENDENT VARIABLES	**(a)**	**(b)**	**(c)**	**(d)**
GDP^0	-0.00661***	-0.00726***	-0.00644***	-0.00583***
	(5.08)	(6.68)	(5.30)	(4.07)
OPEN1(X+M/GDP)	0.00971***			
	(6.71)			
OPEN2(SW)		0.01768***		
		(5.95)		
OPEN3			-0.00666***	
			(3.16)	
ΔOPEN2(ΔSW)				-0.03235
				(1.56)
INSTIT	-0.00005	0.00054	-0.00000	0.00284***
	(0.07)	(1.00)	(0.00)	(6.19)
NATBARR(c.i.f./f.o.b)	-0.05253***	-0.02958**	-0.05815***	-0.04926***
	(3.34)	(2.15)	(3.81)	(2.85)
OPEN1*LOWINSTIT	-0.00284**			
	(2.54)			
OPEN1*MEDINSTIT	-0.00104			
	(1.42)			
OPEN2*LOWINSTIT		0.00285		
		(0.60)		
OPEN2*MEDINSTIT		-0.00030		
		(0.13)		
OPEN3*LOWINSTIT			-0.00483***	
			(3.79)	
OPEN3*MEDINSTIT			-0.00272***	
			(3.61)	
ΔOPEN2*LOWINSTIT				0.04920**
				(2.32)
ΔOPEN2*MEDINSTIT				0.04151*
				(1.91)
PERIOD==2(1975-79)	-0.00873***	-0.00808***	-0.00263	
	(3.37)	(3.59)	(0.99)	
PERIOD==3(1980-84)	-0.02389***	-0.01879***	-0.02113***	-0.01437***
	(11.32)	(10.58)	(9.55)	(8.32)
PERIOD==4(1985-89)	-0.00916***	-0.00689***	-0.00623***	-0.00173
	(4.75)	(4.27)	(2.91)	(0.95)
Observations	253	243	253	197
Number of countries	83	78	83	78
chi2 test, OPEN1*LOWINSTIT = OPEN1*MEDINSTIT =0	8.07			
Prob.>chi2	0.02			
chi2 test, OPEN2*LOWINSTIT= OPEN2*MEDINSTIT =0		0.61		
Prob.>chi2		0.74		
chi2 test, OPEN3*LOWINSTIT = OPEN3*MEDINSTIT =0			14.90	
Prob.>chi2			0.00	
chi2 test, ΔOPEN2*LOWINSTIT =ΔOPEN2*MEDINSTIT =0				6.00

Prob.>chi2				0.05

NOTES:
Absolute value of z-statistics in parentheses.* significant at 10%; ** significant at 5%; *** significant at 1%.

OPEN1 is the log of the share of exports plus imports in GDP (%); OPEN2 is the Sachs and Warner (1995) openness index; OPEN3 is the log of the price level GDP (%)in PPP prices, relative to the U.S. dollar exchange rate. INSTIT is an index of Security of Property Rights. NATBARR is a measure of international transport costs and is proxied by the c.i.f./f.o.b ratio.

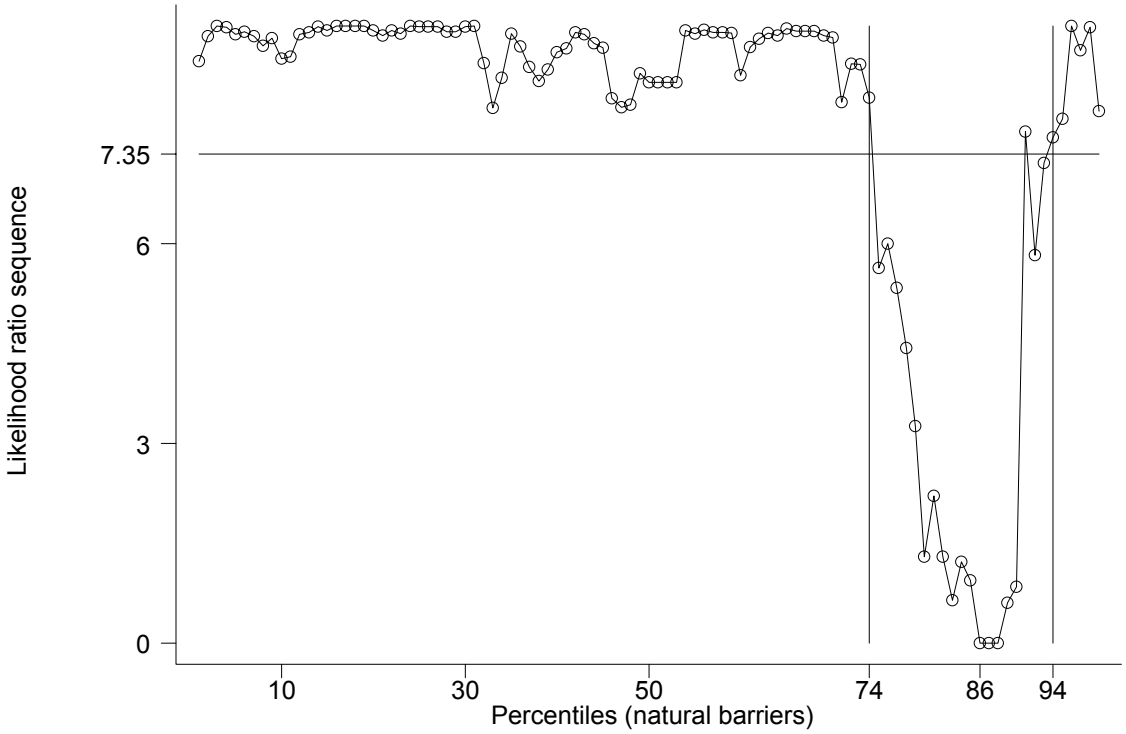
LOWINSTIT refers to countries categorised as having low institutional quality (i.e. a value for Security of Property Rights less than or equal to the 33.333 percentile); MEDINSTIT refers to countries categorised as having a medium level of institutional quality (i.e. a value for Security of Property Rights greater than the 33.333 percentile but less than or equal to the 66.67 percentile). The reference group consists of those categorised as having high quality institutions (i.e. a value for Security of Property Rights greater than the 66.67 percentile).

Any conclusions drawn above on the basis of this particular exogenous splitting of the sample need to be subject to a health warning. There has been no attempt to see if there is a convenient clustering of countries or to assess from other research whether there is an appropriate degree of homogeneity of the country groupings. The robustness of the results and the magnitude and significance of specific interaction terms may be sensitive to the arbitrarily selected splits.

Endogenous Splitting Using Formal Threshold Model

Taking natural barriers as the threshold identifying variable, Hansen's (2000) endogenous threshold modelling technique (set out in Section 4) identified two statistically significant cut-off values. The first corresponds to NATBARR = 1.15 (or 86^{th} percentile) with a bootstrapped p-value of 0.045. Denoting by α the percentiles of the natural barriers variable (NATBARR), the 95% confidence interval for the threshold estimates is obtained by plotting the likelihood ratio sequence in α, LR (α), against α and draw a flat line at the critical value (e.g. the 95% critical value is 7.35.). The segment of the curve that lies below the flat line will be the confidence interval of the threshold estimate. Figure 1 below illustrates how the 95% confidence interval for the first threshold which is NATBARR $\in$ [1.1214, 1.163] or in terms of percentiles [p (74), p (94)] is obtained.

Figure 1:
95% percent confidence interval for first threshold


Likelihood ratio sequence
7.35
6
3
0
10
30
50
74
86
94
Percentiles (natural barriers)

The second threshold is identified as NATBARR = 1.075 which corresponds to the 33rd percentile. It is marginally significant at p= .098. Its 95% confidence interval, however, is very wide and almost encompasses the whole region below the first threshold. Table 6 reports estimates from a number of TFP growth regressions, based on the two threshold values. It reports on a range of alternative estimations that incorporate the threshold values but use only one of the openness measures (OPEN1). We initially allow for the direct effects also of natural barriers on productivity growth. The variables GDP^{0} , INSTIT and OPEN1 generally have the expected sign and achieve significance at 1% or 5% level. We do not find a direct effect for natural barriers but do find the expected signs on the two "interaction" terms for those countries with natural barriers (c.i.f.-f.o.b. ratio) of less than 1.075 and greater than or equal to 1.15. For the former group there is evidence of a weakly significant greater growth effect from openness, and for the latter group a generally strong significant lower growth effect. Given the wide confidence interval on the low natural barrier country grouping, we focus on the 'high' natural barrier grouping. While the productivity growth response coefficient on marginal increases in openness is 0.007 in several of the estimations (including GLS), the response coefficient for the countries identified as having a c.i.f.-f.o.b. ratio of over 1.15 (see Appendix 2) is 0.001 to 0.002 lower.

Using the endogenously identified threshold values from above, we also explored the influence of the other openness measures on productivity growth. Given the unexpected results on the liberalisation proxy (change in OPEN2), we excluded this from the re-estimations. In the case of the Sachs-Warner index (OPEN2) we again found neither of the thresholds to be significant (not reported). However, with OPEN3 we again found the analogous significant threshold effects identified for OPEN1. These are reported in Table 7, in the same manner as Table 6. Across all the estimation methods we find a significant (1% or 5%) positive effect for 'low' natural barrier countries; that is the productivity growth-reducing effects of increased distortions are lower for the low natural barrier countries. While there is a significant additional negative effect (of varying degrees of significance) associated with increased distortions for countries having high natural barriers (greater than or equal to 1.15).

Table 6: Endogenous Threshold Regression Estimates with OPEN1					
	(a)	**(b)**	**(c)**	**(d)**	**(e)**
	OLS	**OLS with Robust Standard Errors**	**Panel Random Effects**	**Panel Fixed Effects**	**GLS with Panel (hetero.)**
GDP^0	-0.010	-0.010	-0.010	-0.068	-0.007
	(4.46)***	(2.86)***	(4.03)***	(5.66)***	(5.88)***
INSTIT	0.002	0.002	0.002	0.000	0.001
	(2.79)***	(2.05)**	(2.58)***	(0.12)	(2.81)***
NATBARR	0.015	0.015	0.016	0.018	0.007
	(0.43)	(0.62)	(0.42)	(0.34)	(0.34)
OPEN1 (X+M/GDP)	0.007	0.007	0.008	0.035	0.007
	(2.44)**	(2.32)**	(2.44)**	(3.75)***	(5.18)***
OPEN1*I(NATBARR < 1.075)	0.002	0.002	0.002	0.003	0.001
	(1.56)	(1.80)*	(1.72)*	(1.54)	(1.74)*
OPEN1*I(NATBARR >= 1.15)	-0.005	-0.005	-0.005	0.001	-0.004
	(3.20)***	(2.24)**	(2.86)***	(0.24)	(4.17)***
_IPERIOD_2 (1975-79)	-0.009	-0.009	-0.010	-0.007	-0.009
	(1.86)*	(2.00)**	(2.04)**	(1.27)	(3.95)***
_IPERIOD_3 (1980-84)	-0.025	-0.025	-0.024	-0.007	-0.024
	(5.83)***	(5.80)***	(5.79)***	(1.17)	(11.93)***
_IPERIOD_4 (1984-89)	-0.011	-0.011	-0.010	0.007	-0.009
	(2.59)**	(2.79)***	(2.42)**	(1.18)	(4.71)***
Constant	0.040	0.040	0.035	0.396	0.028
	(0.86)	(1.04)	(0.71)	(3.47)***	(1.05)
Observations	253	253	253	253	253
R-squared	0.26	0.26		0.34	
Number of countries			83	83	83

NOTE:
Absolute value of t-statistics in parentheses
*significant at 10%; ** significant at 5%; *** significant at 1%.

OPEN1 is the log of the share of exports plus imports in GDP(%);INSTIT is an index of Security of Property Rights. NATBARR is a measure of international transport costs and is proxied by the c.i.f./f.o.b ratio.

Table 7: Endogenous Threshold Regression Estimates with OPEN3					
	(a)	**(b)**	**(c)**	**(d)**	**(e)**
	OLS	**OLS with Robust Standard Errors**	**Panel Random Effects**	**Panel Fixed Effects**	**GLS with Panel (hetero)**
GDP^0	-0.00551	-0.00551	-0.00503	-0.05915	-0.00418
	(2.25)**	(1.41)	(1.79)*	(4.95)***	(3.87)***
INSTIT	0.00251	0.00251	0.00244	0.00112	0.00213
	(3.23)***	(2.46)**	(2.90)***	(0.94)	(5.38)***
NATBARR	0.00263	0.00263	0.00613	0.04294	0.01270
	(0.07)	(0.12)	(0.16)	(0.83)	(0.64)
OPEN3	-0.01452	-0.01452	-0.01712	-0.03026	-0.01159
	(3.25)***	(2.45)**	(3.45)***	(3.77)***	(6.58)***
OPEN3*I(NATBARR < 1.075)	0.00235	0.00235	0.00291	0.00377	0.00156
	(2.47)**	(2.87)***	(2.67)***	(2.16)**	(3.12)***
OPEN3*I(NATBARR >= 1.15)	-0.00316	-0.00316	-0.00310	-0.00116	-0.00380
	(2.19)**	(1.69)*	(1.95)*	(0.48)	(5.64)***
PERIOD==2(1975-79)	-0.00719	-0.00719	-0.00724	0.00210	-0.00491
	(1.43)	(1.58)	(1.55)	(0.41)	(2.09)**
PERIOD==3(1980-84)	-0.02430	-0.02430	-0.02236	0.00011	-0.02167
	(5.63)***	(5.72)***	(5.59)***	(0.02)	(11.37)***
PERIOD==4 (1984-89)	-0.01236	-0.01236	-0.01122	0.00817	-0.00832
	(2.89)***	(3.12)***	(2.80)***	(1.45)	(4.31)***
Constant	0.10070	0.10070	0.10182	0.54962	0.06828
	(2.12)**	(2.89)***	(1.98)**	(4.87)***	(2.74)***
Observations	253	253	253	253	253
R-squared	0.26	0.26		0.34	
Number of countries			83	83	83

NOTES:
Absolute value of t-statistics in parentheses
* significant at 10%; ** significant at 5%; *** significant at 1%.

OPEN3 is the log of the price level GDP (%)in PPP prices, relative to the U.S. dollar exchange rate. INSTIT is an index of Security of Property Rights. NATBARR is a measure of international transport costs and is proxied by the c.i.f./f.o.b factor.

6. Conclusions

It is now commonly recognised that the growth effects of similar trade liberalisations or increases in trade policy openness have been markedly different. Similarly, it is now commonly argued that trade policy reforms to increase openness will be much more beneficial in terms of their long-term growth effects if prior or complementary reforms to improve the functioning of institutions and the quality of a country's infrastructure. These indirect or conditioning influences of institutions and features of geography are often investigated in the empirical growth literature by incorporating linear interaction terms into standard growth equations or by estimating empirical growth models for different sets of countries, with the split based arbitrarily on standard development criteria (e.g. per capita incomes). We also initially explore our present hypothesised threshold effects in this standard manner. But we find the results to be unsatisfactory, either failing to capture the specific type of thresholds we are interested in or not offering very robust evidence.

When however, we search for the threshold endogenously using a formal threshold model we do in the case of natural barriers find evidence of a critical and feasible threshold. For those 'high' natural barrier countries with a c.i.f.-f.o.b. ratio of greater than 1.15 there are positive TFP growth benefits of increased openness, but these are smaller than those for the 'low' natural barrier countries. This finding is also robust across a range of estimation methods, and appears also to be present for alternative proxies of openness.

Further work is required to explore the robustness of this finding for the alternative openness proxies by employing them in the formal threshold model at the initial stage of estimating the threshold value. A similar analysis is required also to explore endogenously for thresholds in the institutions-openness relationship.

REFERENCES

Acemoglu, Daron, Simon Johnson, and James A. Robinson (2001). "The Colonial Origins of Comparative Development: An Empirical Investigation", *American Economic Review*, Vol. 91, pp. 1369-1401.

Ayal, E.B. and G. Karras (1998), "Components of Economic Freedom and Growth: An Empirical Study", *The Journal of Developing Areas* 32 (spring); 327-338,.

Balassa, Bela (1984). Adjustment to External Shocks in Developing Countries. *World Bank Staff Working Papers*, 472. World Bank, Washington D.C.

Baltagi, Badi H. and Mark J. Griffin (1997). "Pooled Estimators Versus Their Heterogeneous Counterparts in the Context of the Dynamic Demand for Gasoline." Journal of Econometrics, 77, 303-327.

Barro, Robert J. (1994). "Democracy and Growth." NBER Working Paper No. 4909, NBER.

Barro, Robert J. (1997). Determinants of Economic Growth: A Cross Country Empirical Study. *MIT Press*, Cambridge, MA.

Besley, Timothy (1995). "Property Rights and Investment Incentives: Theory and Evidence from Ghana." *Journal of Political Economy*, October, 103:5, 903-937.

Caner, M. and B.E.Hansen (2001). "Instrumental Variable Estimation of a Threshold Model." available at http://www.ssc.wisc.edu/~bhansen/papers/ivtar.html.

Carlsson, Fredrik and Susanna Lundström (2001), "Economic Freedom and Growth: Decomposing the Effects", Working Paper in Economics #33, Department of Economics, Göteborg University.

Chong, Alberto and César Calderón (2000), "Causality and Feedback Between Institutional Measures and Economic Growth" Economics and Politics, Vol. 12.

Dawson, John W. (1998). "Institutions, Investment, and Growth: New Cross-Country and Panel Data Evidence." *Economic Inquiry*, Vol. XXXVI, 603-619.

Durlauf, Steven and Paul Johnson, (1995). "Multiple Regimes and Cross-Country Growth Behaviour," *Journal of Applied Econometrics*, 10:4, pp. 365-384.

Edwards, Sebastian (1998). "Openness, Productivity and Growth: What Do We Really Know?" *The Economic Journal*, 108: pp.383-398.

Gallup, John L., Jeffrey D. Sachs, and Andrew D. Mellinger, (1999). "Geography and Economic Development". Harvard Center for International Development Working Paper No. 1 (March).

Girma, Sourafel. (2002). "Geographical Proximity, Absorptive Capacity and Productivity

Spillovers from FDI: A Threshold Regression Analysis." Forthcoming *GEP Working Paper*,. University of Nottingham.

Greenaway, David and David Sapford. (1994). "What Does Liberalisation Do for Exports and Growth?" *Welwirtschaftliches Archiv,* pp. 152-174.

Greenaway, David., Wyn Morgan, and Peter Wright (1998). "Trade Reform, Adjustment and Growth: What Does the Evidence Tell Us?". *Economic Journal*, 108 (September), 1547-1561.

Gwartney, J.D., R. Lawson and R.G. Holcombe (1998). The Size and Functions of the Government and Economic Growth. *Joint Select Committee Study*, Washington.

Gwartney, J.D., Charles Skipton , and R. Lawson, (2001). *Economic Freedom of the World: 2001 Annual Report*, The Fraser Institute, Vancouver. Data retrieved from http://www.freetheworld.com .

Hall, Robert E. and Charles I. Jones (1999). "Why Do Some Countries Produce So Much More Output per Worker than Others?". *Quarterly Journal of Economics*, 114:1, 83-116.

Hansen, Bruce E. (1999). "Threshold Effects in Non-Dynamic Panels: Estimation, Testing, and Inference." *Journal of Econometrics* 93, pp. 345-368.

Hansen, Bruce E. (2000). Sample Splitting and Threshold Estimation , *Econometrica* , 68 pp.575-603.

Inter-American Development Bank (IDB) [2000]. *Economic and Social Progress in Latin America*. Inter-American Development Bank.

International Monetary Fund. *International Financial Statistics Yearbooks,* various years.

Jones, Eric L. (1981). The European Miracle : Environments, Economics and Geopolitics in the History of Europe and Asia. *Cambridge, UK: Cambridge University Press*.

Kavoussi, Rostam M. (1984). "Export Expansion and Economic Growth: Further Empirical Evidence." *Journal of Development Economics*, Vol. 14, pp. 241-250.

Keefer, Phillip and Stephen Knack (1995). "Institutions and Economic Performance: Cross-Country Tests Using Alternative Institutional Measures." *Economics and Politics*, November, pp. 207-27.

Klein, Peter G. (2000). "New Institutional Economics." In Boudewin Bouckeart and Gerrit De Geest, eds., *Encyclopaedia of Law and Economics*. Cheltenham, U.K.: Edward Elgar, pp. 456-89.

Klein, Peter G. and Hung Luu (2001). "Politics and Productivity." available at http://www.terry.uga.edu/economics/facpages/klein.html

Koop, Gary, Jacek Osiewalski, and Mark Steel. (1995). "Measuring the Sources of Output

Growth in a Panel of Countries." CORE Discussion Paper No. 9542.

Lee, Kevin., M.H. Pesaran and R. Smith (1997). "Growth and Convergence in a Multi-Country Empirical Stochastic Solow Model," *Journal of Applied Econometrics*, 12, 357-92.

Limao, Nuno and Anthony J. Venables (1999). "Infrastructure, Geographical Disadvantage and Transport Costs", mimeo London School of Economics.

Mauro, Paola. (1995). "Corruption and Growth." Quarterly Journal of Economics (August), 681-712.

Michaely, Michael. (1977). "Exports and Growth: An Empirical Investigation", Journal of Development Economics 4, 49-53.

Miller, Stephen M. and Mutki P. Upadhyay (2000). "The Effects of Openness, Trade Orientation, and Human Capital on Total Factor Productivity" *Journal of Development Economics,* Vol. 69, pp. 399-423.

Milner, Chris R., Oliver Morrisey, and Nicodemus Rudaheranwa. (2000). "Policy and Non-Policy Barriers to Trade and Implicit Taxation of Exports in Uganda". *Journal of Development Studies*.

Moneta, Carmellah (1959). "The Estimation of Transport Costs in International Trade." *Journal of Political Economy* (February), 41-58.

Moschos, Demetrios.(1989). "Export Expansion, Growth and the Level of Economic Development: An Empirical Analysis", Journal of Development Economics 30, 93-102.

Nehru, Vickram. and Ashok Dhareshwar (1993), "A New Database on Physical Capital Stock: Sources, Methodology and Results", *Revista de Analisis Economico* 8, pp. 37-59.

North, Douglas C. (1981). *Structure and Change in Economic History*. New York: W.W. Norton & Co.

North, Douglas C. (1990). *Institutions, Institutional Change and Economic Performance*. Cambridge: Cambridge University Press.

North, Douglas C. (1991). "Institutions." *Journal of Economic Perspectives* 5: 97-112.

North, Douglas C., and Robert Paul Thomas (1973). *The Rise of the Western World: A New Economic History*. Cambridge: Cambridge University Press.

Pesaran, M. Hashem and Ron Smith (1995), "Estimating Long-Run Relationships from Dynamic Heterogeneous Panels", *Journal of Econometrics*, 68, pp. 79-113.

Radelet, Stephen and Jeffrey Sachs (1998), "Shipping Costs, Manufactured Exports and Economic Growth", mimeo Harvard Institute for International Development.

Ram, Rati. (1985). "Exports and Economic Growth: Some Additional Evidence." *Economic Development and Cultural Change*.

Redding, S. and A.J. Venables. (2000). "Economic Geography and International Inequality." LSE, Centre for Economic Policy Research. mimeo.

Rodriguez, Francisco and Dani Rodrik (2000), *"Trade Policy and Economic Growth: A Skeptic's Guide to the Cross-National Evidence"* Macroeconomics Annual 2000, Ben Bernanke and Kenneth Rogoff, eds., MIT Press for NBER.

Rodrik, Danny. (1997). "TFPG Controversies , Institutions, and Economic Performance in East Asia." *NBER Working Paper* 5914.

Rodrik, Danny. (1998)."Where Did All The Growth Go? External Shocks, Social Conflict, And Growth Collapses.
Downloadable
from http://ksghome.harvard.edu/~.drodrik.academic.ksg/papers.html.

Rodrik, Danny. (2000). "Trade Policy Reform as Institutional Reform". Paper prepared for a Handbook on *Developing Countries and the Next Round of WTO Negotiations*
downloadable
from http://www//ksghome.harvard.edu/~.drodrik.academic.ksg/papers.html.

Rodrik, Danny.(2001). "Institutions, Integration, and Geography: In Search of the Deep Determinants of Economic Growth" in Rodrik ed. *Analytic Country Studies on Growth.* Downloadable
from http://www//ksghome.harvard.edu/~.drodrik.academic.ksg/papers.html.

Sachs, Jeffrey and Andrew Warner (1995). 'Economic Reform and the Process of Global Integration', *Brookings Papers on Economic Activity*, Vol. 1, pp. 1-118.

Senhadji, Abdelhak (2000), "Sources of Economic Growth: An Extensive Growth Accounting Exercise", *IMF Staff Papers*, Vol. 47, # 1, pp. 129-158.

Summers, R. and A. Heston (1995). The Penn World Table (Mark 5.6a), Electronic Dataset.

Temple, Johnathan (1999). "The New Growth Evidence," *Journal of Economic Literature* 37: 112-156.

Tyler, W.G.(1981). "Growth and Export Expansion in Developing Countries: Some Empirical Evidence", Journal of Development Economics 9, 121-130.

World Bank (1993). World Bank STARS Database. Washington, D.C.: World Bank.

World Bank (2000). 2000 *World Development Indicators* (CD ROM). Washington, D.C.: World Bank.

APPENDIX 1

Table A1: Summary Statistics				
Variable	Mean	Std. Deviation	Minimum	Maximum
Total Factor Productivity Growth	0.002	0.032	-0.165	0.163
Log of Initial GDP	7.921	1.018	5.694	9.905
Log of Exports plus Imports to GDP (X+M/GDP)	3.881	0.608	1.934	5.935
Sach & Warner Index	0.381	0.470	0	1
Log of Price Level GDP (PPP Prices)	4.108	0.451	2.548	5.750
Change in Sachs & Warner Index	0.028	0.194	-0.800	1
Legal Structure & Security of Property Rights	5.655	2.793	0	10
C.I.F./F.O.B. Ratio	1.113	0.065	1.006	1.667

Table A2 : Correlation Matrix								
	TFPG	Log Initial GDP	Log (X+M)/ GDP	S & W Index	Log of Price Level GDP (PPP)	Change in S & W Index	Legal Structure & Security of Property Rights	C.I.F./F.O.B. Ratio
TFPG	1.0000							
Log Initial GDP	0.0286	1.0000						
Log (X+M)/GDP	0.1743	0.2214	1.0000					
S & W Index	0.3407	0.6361	0.3298	1.0000				
Log of Price Level GDP (PPP)	-0.1504	0.6499	0.1513	0.4510	1.0000			
Change in S & W Index	0.1085	-0.0507	-0.0086	0.1780	-0.0871	1.0000		
Legal Structure & Security of Property Rights	0.1655	0.6876	0.2527	0.6079	0.4894	-0.0506	1.0000	
C.I.F./F.O.B. Ratio	-0.1286	-0.5678	-0.1005	-0.4150	-0.4074	-0.0363	-0.4022	1.0000

APPENDIX 2

List of countries with a c.i.f.-f.o.b. ratio greater than or equal to 1.15

Cote d'Ivoire
Dominican Republic
Ethiopia
Haiti
Iran
Jamaica
Kenya
Kuwait
Madagascar
Mali
Mauritius
Malawi
Peru
Paraguay
Rwanda
Tanzania
Zaire
Zambia