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Threshold and Interaction Effects in the Openness-Productivity Growth Relationship: The Role of Institutions and Natural Barriers

by

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

by

Sourafel Girma, Michael Henry, Richard Kneller and Chris Milner

Abstract

This paper explores heterogeneity in the openness-productivity growth relationship, specifically whether the productivity payoffs from openness or trade liberalisation are conditioned by the quality of a country's institutions and the extent of natural barriers. The paper endogenously searches for the type of heterogeneity; what variable might be used to capture the heterogeneity and with what level of certainty can we attach to it. Evidence is found to suggest there is a threshold in the effect of openness on growth that depends on the level of natural barriers but not institutions. These results are robust to the use of alternative indicators.

JEL classification: F43; O4; O1

Keywords: productivity growth, openness, heterogeneity, natural barriers, institutions

Outline

Non-Technical Summary

This paper explores whether the relationship between openness and productivity growth differs across countries (whether it is heterogeneous). Specifically, whether differences across countries are related to aspects of geography (transport costs) or institutions; the productivity payoffs from openness or trade liberalisation being conditioned by the quality of a country's institutions and the extent of the natural barriers it faces. There is strong evidence to suggest that institutional quality/efficiency and geography impact positively on economic performance, but the interaction between these variables and openness and productivity growth have not previously been formally tested.

The form of the heterogeneity and the variable that best captures it are explored in some depth in the paper. This approach has several econometric advantages over the approach adopted in the previous literature of an ad-hoc imposition of a heterogeneous relationship based on the researchers own biases.

The research is conducted into 83 countries for the period 1970-1989. We find a number of interesting results. For natural barriers there does appear to be heterogeneity in the openness-productivity growth relationship captured by this variable. Moreover, formal testing suggests that this heterogeneity is of a threshold type, there is a break in the relationship around specific critical values. Two thresholds are identified by the data, but only one has a confidence interval sufficiently small that we might consider it to be accurately identified. Interestingly the position of the single threshold is robust to alternative measures of openness to international trade, although the nature of the relationship differs. For one measure of openness used we find that countries with high natural barriers are less responsive to changes in trade openness than countries with low natural barriers. In contrast, when we use measures that might better reflect trade policy openness this relationship is reversed. It is now countries with high natural barriers that benefit most from a change in policy openness. These differences may account for different findings in the previous literature.

The work also contributes to a deeper understanding of why other researchers have found that being closed to trade is more costly to growth in Africa than elsewhere. Africa is a region with relatively high 'natural barriers'. However, the composition of the 'high' natural barriers group also suggests that factors other than physical geographical characteristics contribute to high barriers to trade. That is, while being landlocked and away from international markets is important,- the potential hazards of trade (shirking, opportunism, risk etc.) controlled by institutions covering property rights, the rule of law, commercial codes, organised financial markets and the like also play a role. This clearly has implications for government policy, and for the importance to a broad group of developing countries of improving infrastructure and efficiency in the international transport sectors.

Evidence for the general quality of institutions, rather than those that shape natural barriers, is much weaker. We find evidence of heterogeneity only for the policy based measured of trade, but the confidence interval placed round this single threshold is very large and therefore limits its use.

1. Introduction

The recent literature on openness and growth has brought into serious doubt the generality of the positive correlation found between these two variables by many earlier works (see in particular Harrison & Hanson, 1999; and Rodriguez & Rodrik, 2000). There are a number of reasons to expect, however, that these criticisms may themselves be non-robust. For example, Baldwin & Sbergami (2000) argue that the fragility of the relationship in the earlier literature is generated by the false imposition of a linear relationship between openness and growth. A linear relationship has no support beyond the most basic of theoretical models. By contrast, the notion of threshold effects in the openness-growth relationship has a long history in the empirical trade and growth literature (see for example, Michaely, 1977; Tyler, 1981; and Kavoussi, 1984).

In this paper we explore whether there is evidence for heterogeneity in the openness-productivity growth relationship that is related to aspects of geography (transport costs) as well as institutions; the productivity payoffs from openness or trade liberalisation being conditioned by the quality of a country's institutions and the extent of the natural barriers it faces. There is strong evidence to suggest that institutional quality/efficiency and geography impact positively on economic performance (e.g. Keefer and Knack, 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. The non-linear effects these variables might generate between openness and productivity growth have not previously been formally tested.

The form of these non-linearities and the appropriate means of modelling them are explored in some depth in the paper. This involves searching for the nature of the heterogeneity, whether it is best captured by interaction effects as in Miller & Upadhyay (2000) or thresholds as is Moschos (1989). In so doing we employ the endogenous search techniques outlined by Hanson (2000) to determine the critical values for any thresholds and the confidence interval surrounding these thresholds. Hansen (1999, 2000) criticises the exogenous imposition of thresholds on the basis that the econometric estimators generated from such procedures may pose serious inference problems. Moschos (1989) argues, in addition, that the results are likely to be sensitive to the choice of exogenous threshold point, albeit using a different methodology.

This research conducted in this paper is of a similar spirit to those using alternative methodologies to search for parameter heterogeneity in growth regressions, such as regression trees (see for example Durlauf et al., 2001 and Johnson & Takeyama, 2001). In terms of the methodology used it is most similar to Papageorgiou (2001). That paper is also of interest in that it uses trade as one of the threshold variables (along with income and human capital). It finds significant evidence of a threshold related to trade for middle income countries.

From our research into a cross-country TFP growth model, estimated econometrically for a panel of up to 83 countries for the period 1970-1989, we find a number of interesting results. For natural barriers we find that there does appear to be heterogeneity in the openness-productivity growth relationship captured by this variable. Moreover, formal testing suggests that this heterogeneity is of a threshold type, there is a break in the relationship around specific critical values. Two thresholds are identified by the data, but only one has a confidence interval sufficiently small that we might consider it to be accurately identified. Interestingly the position of the single threshold is robust to alternative measures of openness to international trade, although the nature of the relationship differs. In addition for one of the measures of openness used we find there is some sensitivity of the results to tests for endogeneity bias, although this relates to the position of the threshold not to its existence. For conventional measures of the volume of trade we find that countries with high natural barriers are less responsive to changes in trade openness than countries with low natural barriers. In contrast, we find that when we use measures that might better reflect trade policy openness this relationship is reversed. It is now countries with high natural barriers that benefit most from a change in policy openness.

For institutional quality the evidence that this matters for openness and productivity growth is much weaker. We find evidence of heterogeneity only for the policy based measured of trade, but the confidence interval placed round this single threshold is very large and therefore limits its use as a description of the data. Again for the policy-based measures of openness it is those countries with weak institutions that appear to benefit most from openness. Overall we conclude against the use of this variable as the threshold variable, arguing instead that the elements of institutional quality important for trade are better captured by the measure of natural barriers used.

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 or hindering trade and the impact of trade in growth. Section 3 sets up the modelling framework for exploring the openness-TFP growth relationship and 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 the conclusions are presented in Section 6.

2. The Influence of Institutions and Natural Barriers on the Openness-Growth Relationship

The hypothesis of a simple direct effect of institutions on TFP growth is well established in the empirical literature. Dawson (1998) finds that economic freedom affects economic growth through its direct effect on TFP and indirectly through its effect on investment. 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.

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 covering property rights, the rule of law, commercial codes, organised financial markets and the like (North, 1991). 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, 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 a 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.

There have been a number of recent studies (Milner, 1997; Milner, Morrissey and Rudaheranwa, 2000) which have shown that trade policy liberalisation in specific low-income developing countries have only partially lowered the total barriers to trade from policy and 'natural' sources. Clearly the extent to which total barriers in different developing countries are lowered by a given trade policy liberalisation will depend upon the relative importance of natural and policy barriers, which in turn is fashioned by locational (remoteness, landlocked) and other (e.g. efficiency and competitiveness of international transport services) characteristics. It will also depend on whether policy and related barriers contribute to the total barriers in an additive or multiplicative sense. In the latter case for example, *ad valorem* border taxes may be applied to the international transaction – inclusive of valuation (i.e. c.i.f.) of traded goods. In which case a given reduction of border taxes on trade will lower the total barrier to trade more in a high than a low international transaction cost country. One might argue therefore that a given policy liberalisation will have more impact as far as opening up of the economy and the stimulation of productivity growth in a ‘high’ than ‘low’ natural barrier country. On the other hand, one may well expect the absolute level of post-liberalisation trade barriers to influence the extent to which there are international competitive and relative domestic incentive effects to raise productivity growth. In which case one would anticipate a greater productivity growth premium on increased policy openness in ‘low’ rather than ‘high’ natural barrier countries.

3. Modelling Threshold Effects

The notion of threshold effects has long been the subject of inquiry in the empirical trade and growth literature[1] (see for example, Michaely, 1977; Tyler, 1981; 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 Sapsford (1994), the evidence from the early studies on the existence of a threshold effect is mixed.

In the traditional approach (which we label the exogenous threshold literature), 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; 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

1 Table 1 in Greenaway and Sapsford (1994) lists some of the export and growth studies between 1977-1993 which also tested the threshold hypothesis.

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 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 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, 2000), 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. In the present context, an exogenous sample division also involves an 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.

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[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.

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. 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.

Formal Threshold Model

Given that the 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 need a base analytical framework within which to explore these relationships. 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 analytical framework is:

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

$$[\alpha_1 \gtreqless 0;\ \alpha_2 > 0;\ \alpha_3 > 0 \text{ and } \alpha_4 < 0]$$

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 liberalisation) 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 international trade; μ is the disturbance term; *i* indexes countries and *t* time periods.

We now extend this to allow for heterogeneity in the parameters governing the relationship between openness and productivity growth. In this paper we adopt a more structural approach to the modelling of heterogeneity than that used previously by considering the answer to a number of questions.

1. What form does the heterogeneity take?
2. With what variable might the heterogeneity be captured?
3. What level of confidence can we ascribe to the estimated heterogeneous relationship?

As outlined above there are strong *a-priori* grounds to expect that the heterogeneous relationship between openness and productivity growth is captured by differences in natural barriers to trade and institutional quality. Then using the endogenous threshold regression

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

techniques based on Hansen (2000) we determine whether this heterogeneity should be modelled as a threshold (against the null of no heterogeneity) or a linear interaction term (against the null of a threshold relationship). Finally, given all of the heterogeneous relationships are identified as being of the threshold type, what level of confidence can we ascribe to the position of the threshold. How confident can we be that any particular country lies above or below the threshold? Hansen (2000) has previously argued that this final point is an important element in the testing procedure. The standard econometric theory of estimation and inference is not valid, but Hansen (2000) provides an asymptotic distribution theory that enables one to make valid statistical inferences on the basis of threshold models.

To understand the problems associated with applying this technique, assume for simplicity that the openness-TFP growth relationship is captured by either of the single threshold equations below, where in equation (2a) natural barriers is the threshold variable and in the equation (2b) institutional quality the threshold variable:

$$TFPG_{it} = \gamma X_{it} + \beta_1 OPEN_{it} I\left(NATBARR_{it} \le \alpha\right) + \beta_2 OPEN_{it} I(NATBARR_{it} > \alpha) + \varepsilon_{it} \qquad (2a)$$

$$TFPG_{it} = \gamma' X_{it} + \beta_1' OPEN_{it} I(INSTIT_{it} \le \alpha') + \beta_2' OPEN_{it} I(INSTIT_{it} > \alpha') + \varepsilon_{it}' \qquad (2b)$$

In each equation I(.) is the indicator function and *X* is vector of other control variables for Equations (2a) and (2b), and includes both threshold variables. In the case of a threshold effect associated with natural barriers if for example $\beta_1 \ne \beta_2$, $\beta_1 > 0$ and $\beta_1 > \beta_2 > 0$; then the interpretation of this combination of results would be that there are higher productivity growth effects from openness for those countries with below the threshold level of natural barriers and lower, albeit positive, effects for those with above threshold level of barriers.

In estimation there are three steps: firstly, jointly estimate the threshold value α and the slope coefficients γ, β_1, and β_2. Secondly, 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. $\beta_1 \ne \beta_2$) and thirdly, to construct confidence intervals for α.

To estimate the parameters of the equation 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 off 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.

If a threshold effect is found (i.e. $\beta_1 \neq \beta_2$), then a confidence interval for the critical natural barrier level should then be formed. This will enable us to attach a degree of certainty as to which threshold a given country with a given level of transport costs (and institutional quality) is likely to lie. In this case one needs to test for the particular threshold value as: $H_o : \alpha = \alpha_0$. We require this confidence interval to be reasonably small, given countries within it cannot be confidently placed in either regime.

It should be noted that the test of the null hypothesis for forming the confidence interval is not the same as that for the second problem i.e. the test of no threshold effect. Under normality, the likelihood ratio test statistic $LR_n(\alpha) = n\frac{S_n(\alpha) - S_n(\hat{\alpha})}{S_n(\hat{\alpha})}$ is commonly used to test for particular parametric values. However, Hansen (2000) proves that when the endogenous sample-splitting procedure is employed, $LR_n(\alpha)$ does not have a standard χ^2 distribution. Consequently, he then derives the correct distribution function and provides a table of the appropriate asymptotic critical values[5].

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

[5] See Table I on page 582 of Hansen (2000).

Equation (2a) and (2b) assume that there exists only a single threshold. It is straightforward to extend the analysis to consider multiple thresholds and this is allowed for in the estimations.

Interaction Effects

Both exogenous and endogenous splitting assume discrete breaks in the influence of natural barriers or institutions in the openness-productivity growth relationship. In order to explore the possibility of continuous conditioning influences, we also estimate models that incorporate interaction terms. Separately adding the terms ($OPEN_{it} * NATBARR_{it}$) and ($OPEN_{it} * INSTIT_{it}$) to Equation (1), gives:

$$TFPG_{it} = \alpha_0 + \alpha_1 GDP_{it}^0 + \alpha_2 OPEN_{it} + \alpha_3 INSTIT_{it} + \alpha_4 \left(OPEN_{it} * NATBARR_{it}\right) + \mu_{it} \quad (3a)$$

$$TFPG_{it} = \alpha_0' + \alpha_1' GDP_{it}^0 + \alpha_2' OPEN_{it} + \alpha_3' NATBARR_{it} + \alpha_4' \left(OPEN_{it} * INSTIT_{it}\right) + \mu_{it}' \quad (3b)$$

A significant estimated coefficient of $\alpha_4 < 0$ imply that higher natural barriers continuously reduce the benefits of increased (policy-induced) openness or trade liberalisation by progressively constraining the country's access to new ideas and/or increasing the costs of accessing new ideas through international exchange. Similarly, $\alpha_4' > 0$ it would indicate that the ability of a country to benefit from increased openness is fashioned by the quality of its institutions incrementally, with the productivity growth return to openness increasing steadily as institutional quality increases.

Although the incorporation of interactive terms provides an opportunity to capture continuous conditioning influences, it also needs to be recognised that it allows for the possibility of sign changes on the relationships between openness and productivity growth. If $\alpha_4 < 0$, then there would be a level of natural barriers beyond which the model predicts openness to have a negative impact on productivity growth. This is a different type of threshold to the ones considered in the earlier models, and perhaps a threshold that one does not wish to allow the possibility of on *a-priori* grounds.

To test the linear interaction model specified in equation (3a) against the endogenous threshold model equation (2a) we augment equation (3a) to reflect the one specified in (2a). We thus specify:

$$TFPG_{it} = \alpha_0 + \alpha_1 GDP_{it}^0 + \alpha_2 OPEN_{it} + \alpha_3 INSTIT_{it} + \alpha_4 (OPEN_{it} * NATBARR) \quad (4)$$
$$+ \alpha_5 OPEN_{it} I(NATBARR \leq \gamma) + \alpha_6 OPEN_{it} I(NATBARR > \gamma) + u_{it}$$

Equation (4) is a special case of equation (2a) if we constrain α_4 to be the same in the two regimes. This has no effect on the distribution theory underlying the endogenous model of (2a) (see Hansen, 1999). Failure to reject the null hypothesis of no threshold effects implies that $\alpha_5 = \alpha_6$ and that the linear interaction model better captures the observed heterogeneity in the openness-productivity growth relationship.

More complex interaction relationships might be considered using as similar testing procedure. However, given that we reject the linear interaction model in favour of the simpler threshold model, we do not explore those possibilities in this paper.

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 individual country estimations that posit total heterogeneity across countries. Both of these alternatives methodologies have been subjected to criticism (see for example Durlauf and Johnson, 1995; Lee, Pesaran and Smith, 1997; Temple, 1999). 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 83 developed and developing countries from 1950-1990.

Openness

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 this argument we use three alternative measures of openness/trade liberalisation. These are the log of exports plus imports to GDP - labelled OPEN1; a collection tax ratio for which we follow Rodriguez and Rodrik (2000) in multiplicatively expressing import and export duties as a proportion of total trade[6] labelled OPEN2; and the log of the price level GDP in PPP prices, relative to the U.S. dollar exchange rate (multiplied by minus 1)[7] – labelled OPEN3. OPEN2 is multiplied by minus one so that so that there are common expected signs on the relationship between our alternative openness/liberalisation variables and productivity growth. Data for our openness measures were obtained from the World Bank's World Development Indicators (WDI) CD ROM 2000, and the Penn World Tables (Mark 5.6a) (updated by Summers and Heston in 1995).

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

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[6] The formula used by see Rodriguez and Rodrik (2000) for the collection ratio is [(1+ mdut)x(1+xdut) – 1]/(X+M) where mdut are import duties and xdut are export duties.

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. Principally that 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 intercontinental component (either air or marine or both) (see Milner et al, 2000; Limão and Venables, 1999).

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[9]. 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 secure property rights structure receiving a higher rating.

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[7] Miller and Upadhyay (2000), (without multiplying by minus 1) use this variable as a measure of price distortion i.e. the local price deviation from PPP, with the U.S. as the reference country.

[8] 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] 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) 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.

Despite the use of an 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 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[10]. Barro (1997) and Chong and Calderón (2000) have previously employed similar reasoning.

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.[11] Further, asymptotically the FGLS estimator is equivalent to the GLS estimator.

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

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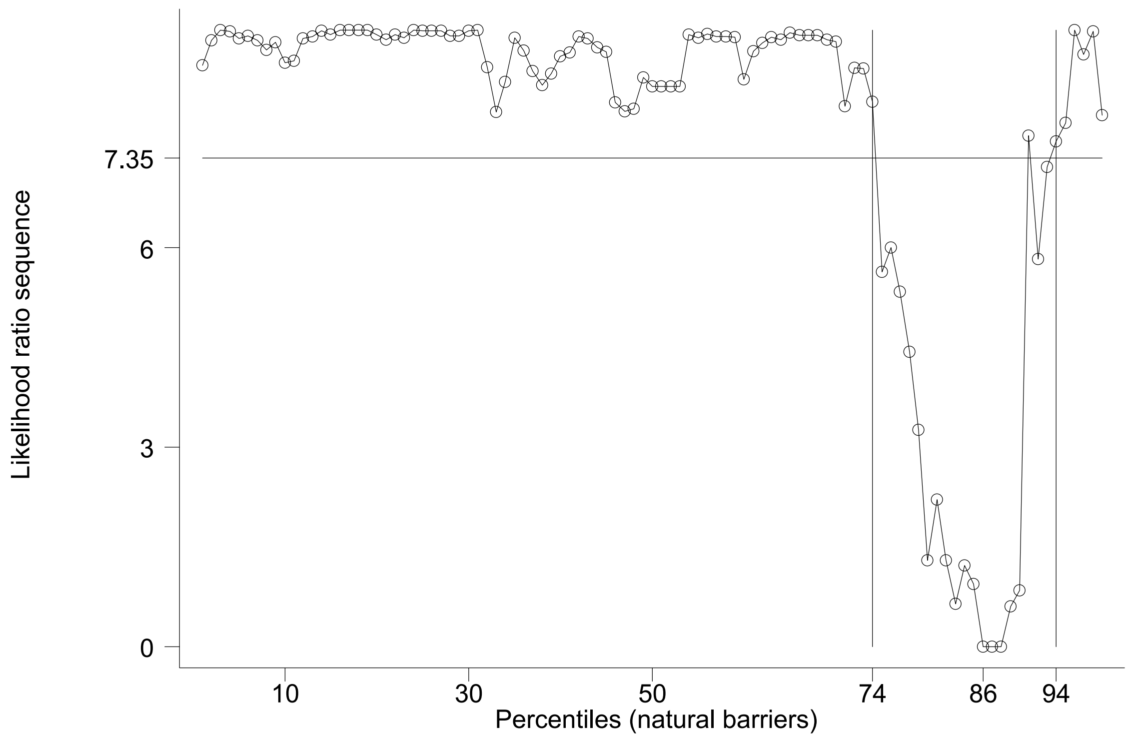
[10] Though the assumption that institutional factors change slowly through time has been used by researchers, Rodrik (2000) points to some countries (Chile, Korea and China) where there have been instances of rapid and dramatic changes in institutions.

5. Results

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 3) identified two statistically significant cut-off values. The first of the identified thresholds (the upper thresholds) corresponds to a NATBARR value of 1.15 (or the 86th percentile) with a bootstrapped p-value[12] of 0.045. Denoting the percentiles of the natural barriers variable (NATBARR) by α, the 95% confidence interval for the threshold estimates is obtained by plotting the likelihood ratio sequence in α, LR (α), against α and drawing 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.



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[11] 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.

Figure 1: 95% percent confidence interval for upper threshold on natural barriers (OPEN1).

In Table B1 in Appendix B we list the natural barrier values for each country in each of the four time periods, ordered by their value in period 1 (1970-1974), to show for each country its position in the low natural barrier group, the confidence interval or the high natural barrier group.[13] Given the location of the threshold it is of no surprise that most countries are located in the class which have low natural barriers, some 67 of the 83 countries have two or more observations in the low natural barrier group.

As the Table also suggests the confidence interval for OPEN1 and natural barriers is reasonably tight. Only 17 of the 83 countries have at least two of the four 5-year period observations within the 74^{th} to the 94^{th} percentiles[14]. There is therefore, not much uncertainty about the location of the threshold. It follows however that the number of countries that we can reasonably sure fall into the high natural barrier class is relatively small, only 9 countries have at least 2 observations in this group. This highlights the importance of including confidence intervals around the threshold estimate. Included in the high natural barrier group are mostly African and Latin American countries, for example Ethiopia, Rwanda, Peru and Paraguay.

The second threshold identified (the lower threshold) corresponds to a NATBARR value of 1.075, or the 33^{rd} percentile. It is marginally significant with a bootstrapped p-value of 0.098. In contrast to the first threshold estimate, the 95% confidence interval for this threshold is wide and encompasses most of the region below the first threshold. Consequently, we are less sure in this case as to where the "true" value at which the break-point in the parameter lies. Below we consider the effect of this uncertainty on the slope estimate based on this lower threshold value when discussing our regression results.

To determine whether the results obtained and conclusions drawn on the basis of the first measure of trade openness (OPEN1) are robust to alternative measures of openness/trade

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[12] All of the bootstrapped p-values in our endogenous threshold analysis are generated using 1000 bootstrap replications.

[13] Given the lack of a confidence interval for the second threshold we assume there exists only one threshold for this variable.

liberalisation, we employ two policy oriented measures, OPEN3 and OPEN2. Using natural barriers as the threshold variable and OPEN2 as the measure of policy openness, we again find two thresholds. The first, the upper threshold, corresponds to a NATBARR value of 1.1462 (or 79th percentile). The bootstrapped p-value is 0.002. The second, the lower threshold, has a NATBARR value of 1.1110 (or 58th percentile). However, this threshold is statistically insignificant since it has a bootstrapped p-value of 0.325. This suggests that in this case we have a single, rather than a double, threshold model. The 90% confidence interval for the significant threshold estimate (Figure 2) is derived in an analogous manner to the one shown in Figure 1. Figure 2 shows that in terms of percentiles, the confidence interval for the threshold estimate is [p(68), p(91)]. The corresponding natural barriers values are given by NATBARR $\in$ [1.1214, 1.1772]. The countries that fall in each threshold and the confidence interval are listed in the remaining columns of Table B1 in Appendix B.

Although we are less certain about the "true" value of the threshold relative to the confidence interval shown in Figure 1, the confidence interval in Figure 2 is still reasonably tight; less than a quarter of the 78 countries having at least two observations lying in the interval. Additionally, there is considerable overlap in the countries located in the confidence bands shown in Figures 1 and 2, respectively (see Appendix B). An examination of Table B1 shows that most of the countries with two and three observations lying within the interval shown in Figure 1, have all four of their natural barriers values located in the interval shown in Figure 2. Therefore while there is a slight increase in the uncertainty with which some countries can be placed in the high natural barrier and low natural barrier group, in general the results appear reasonably robust to the measure of openness used. There are now 7 countries that can be confidently placed into the high natural barrier group (Paraguay and Bolivia drop out because a lack of data on OPEN2).

[14] When we consider countries with at least one observation falling within the confidence interval, the number increases to 26.

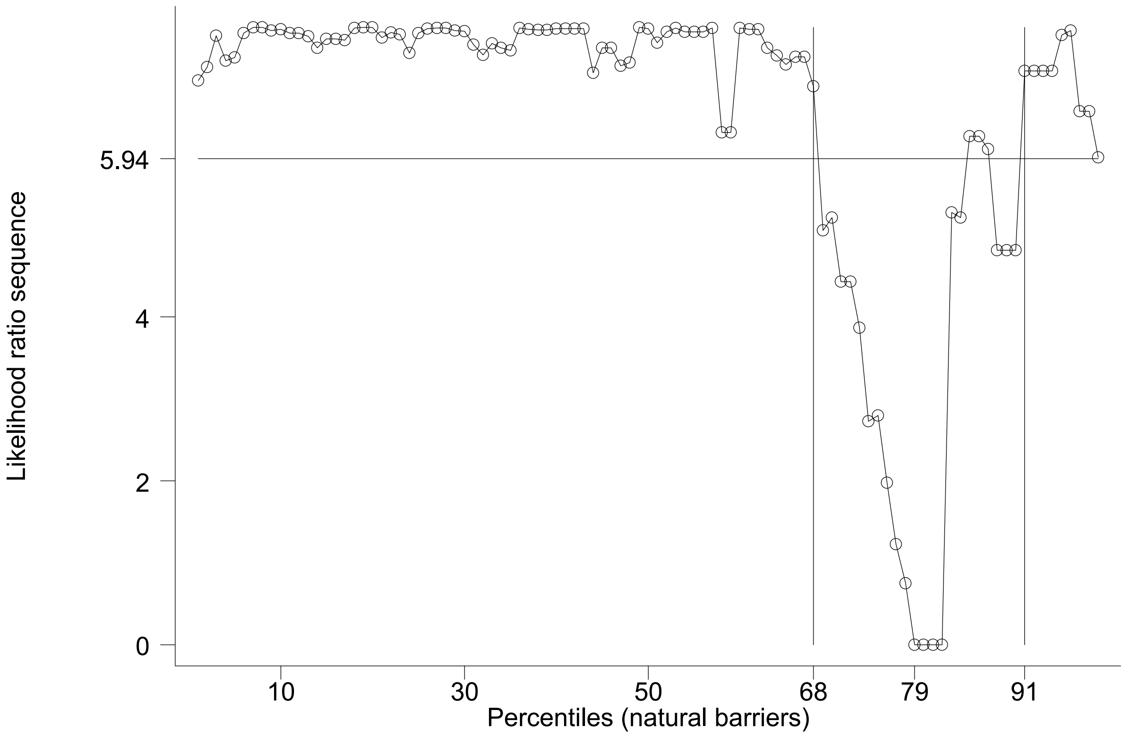

Figure 2: 90% percent confidence interval for the upper threshold on natural barriers (OPEN2).

Table 1 reports OLS estimates of TFP growth regressions for the double threshold model based on OPEN1, and the single threshold model based on OPEN2. In regression (a), the coefficients on the variables GDP^0 and INSTIT have the expected signs and achieve significance at the 1% and 5% levels respectively. Given that the mean value of INSTIT for the sample is 5.655 log points and its standard deviation 2.793 log points (approximately the average institutional quality difference between Korea and the Philippines), then the estimated coefficient for this variable implies that, *ceteris paribus*, a one standard deviation increase in INSTIT from its mean leads to a 0.6% average annual increase in TFP growth[15]. To the extent that initial GDP is capturing conditional convergence effects, i.e. out of steady state behaviour, then these are long-run (and not short-run) effects. The coefficient on NATBARR has the unexpected sign but without significance. There is therefore no direct effect of natural barriers on TFP growth, and only an indirect role in mediating the openness-TFP growth relationship.

[15] Multiplying the standard deviation by the coefficient and finding the exponential of this product gives the percentage change.

Our major finding in regression (a) is that there are positive and significant TFP growth benefits associated with openness for ‘low’ (NATBARR < 1.075) and ‘medium’ natural barriers[16] countries (1.075=<NATBARR< 1.15). In contrast, the growth benefit for ‘high’ natural barriers countries (NATBARR>= 1.15) from openness is not significantly different from zero. In other words, countries with high natural barriers (transport costs) receive no (or insignificant) TFP growth benefits associated with openness relative to the other two groups of countries. These results tend to support similar evidence from the exogenous threshold literature (Michaely, 1977; Tyler, 1981; Kavoussi, 1984), albeit where these papers impose one or more thresholds on the data.

The mean value of OPEN1 for the entire sample is 3.881 log points. Thus controlling for other variables, regression (a) suggests that the TFP growth effect at the mean level of trade openness is 3.1 percentage points per annum for countries with ‘low’ natural barriers[17]. The comparative figure for the ‘medium’ natural barriers countries is 2.5 percentage points. In short, the message conveyed by regression (a) is that the predicted productivity growth payoff from increased openness differs for groups of countries based on the regime in which they are located, countries in the regime below the lower threshold or critical level of natural barriers receiving the highest productivity growth benefits from openness.

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[16] Recall that we are using the c.i.f.-f.o.b. ratio as a proxy for natural barriers. The c.i.f.- f.o.b. ratio is itself a proxy measure for transport costs incurred through engaging in international trade.

[17] The TFP growth effect for countries below the lower threshold value is the product 3.881* 0.00799 = 0.0310.

Table 1: Endogenous Threshold Regression Estimates with OPEN1 and OPEN2

DEPENDENT VARIABLE: TFP GROWTH[1]			
Openness Variable	**(a)** *Trade Share (OPEN1)*	*Openness Variable*	**(b)** *Collected Tax Ratio (OPEN2)*
GDP^0	-0.00953 (2.86)***	GDP^0	-0.01073 (2.34)**
INSTIT	0.00221 (2.08)**	INSTIT	0.00346 (2.29)**
NATBARR	0.00378 (0.14)	NATBARR	-0.01104 (0.42)
BELOW LOWER THRESHOLD *OPEN1*I(NATBARR < 1.075)*	***0.00799*** ***(3.16)****	***BELOW THRESHOLD*** *OPEN2*I(NATBARR < 1.1462)*	***0.00024*** ***(0.35)***
INTER-THRESHOLDS *OPEN1*I(1.075=< NATBARR <1.15)*	***0.00641*** ***(2.23)****		
ABOVE UPPER THRESHOLD *OPEN1*I(NATBARR >= 1.15)*	***0.00248*** ***(0.58)***	***ABOVE THRESHOLD*** *OPEN2*I(NATBARR>= 1.1462)*	***0.00477*** ***(3.23)****
PERIOD==2	-0.00927 (2.00)**	PERIOD==2	-0.00111 (0.21)
PERIOD==3	-0.02611 (6.08)***	PERIOD==3	-0.01798 (3.82)***
PERIOD==4	-0.01160 (2.99)***	PERIOD==4	-0.00259 (0.61)
Constant	0.05059 (1.33)	Constant	0.09063 (1.64)
Observations R-squared Number of countries	253 0.25 83	Observations R-squared Number of countries	201 0.21 78

NOTES:

1. Estimates of threshold values are based on least squares estimation (see Hansen, 2000).
2. Absolute value of (robust)t-statistics in parentheses * significant at 10%; ** significant at 5%; *** significant at 1%.
3. 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. OPEN2 is the log of the collected taxes ratio (CTR) calculated using the multiplicative formula of Rodriguez and Rodrik (2000).

Given the relatively wide confidence interval associated with the low/medium natural barrier threshold (value 1.075) and thus degree of uncertainty about the location of the threshold parameter, the slope coefficient associated with this lower threshold value (though not ‘invalid’) is a less precise estimate of the population parameter. This is because some countries classified as belonging to the 'lower' natural barriers group may rightfully belong to the 'medium' natural barriers group and vice versa. However, the standard errors are calculated under the mistaken assumption that the threshold is precisely known, when in fact it is not. This means that they understate the uncertainty of the threshold value[18]. The similarity of the point estimate for the two groups perhaps providing some intuition of why this might be the case. The reader thus needs to bear this caveat in mind with regards to our predicted differentiated TFP growth effects from increased openness for the 'low' as opposed to the 'medium' natural barrier group, but we can have greater confidence regarding the higher TFP growth returns from increased openness to low and medium barrier countries collectively over that of high natural barrier countries.

Regression (b) in Table 1 provides results for the TFP growth regression based on the single threshold value of 1.1462 for OPEN2 (trade tax collection ratio) as the measure of trade liberalisation. All of the variables controlling for direct effects have the expected signs. However, only the variables GDP^{0} and INSTIT have statistical significance; both being significant at the 5% level. Once again we find that natural barriers has no significant direct effect on TFP growth. For INSTIT, the results indicate that a one standard deviation increase in this index (Legal Structure and Property Rights) above its mean level is associated with approximately a 1% increase in the average annual rate of productivity growth over a 5-year period.

Regression (b) does not identify a significant TFP growth-enhancing effect for the increased openness or reduced distortion measure for the group of countries below the natural barrier threshold, rather it finds a greater growth-enhancing effect for the group of countries above the threshold (i.e. with high natural barriers). This would appear to contradict the finding in regression (a) that countries with low natural barriers are more responsive to trade, but is consistent with evidence from Moschos (1989). One possible explanation for this combination of results is that the alternative openness proxies capture alternative influences of trade and trade policy on TFP growth, and these alternative channels of influence are differentially affected by natural barriers. At 'high' levels of natural barriers it appears to be important to reduce trade tax distortions, especially given that there may be interactive or multiplicative influences of trade taxes and natural barriers.

[18] Based on e-mail correspondence with Professor Bruce Hansen.

In many developing countries, for instance, import duties are levied on the c.i.f. (or international trade cost-inclusive) value of imports. Lowering import duties for 'high' natural barrier (i.e. 'high' trade cost) countries will in this context bring about larger reductions in the overall distortion between world and domestic prices, and have greater effects at the margin on competition between home and foreign suppliers. By contrast, these results show that actual increases in total trade's share of GDP have a positive productivity growth effect for 'low' natural barrier countries. Here it may be that the capacity of countries to absorb (or imitate) technological improvements embodied in trade goods is greater where trade expansion is not as highly skewed towards less trade-cost intensive goods.

To further determine whether the threshold model is the most appropriate for adequately modelling heterogeneity in the openness-TFP growth relationship we undertook a direct test of the linear interaction model specified in equation (3a) against the endogenous threshold model equation (2a). Using OPEN1 as our measure of openness/trade liberalisation, our sequential testing for thresholds identified two significant threshold values, thus rejecting the linear interaction model specified in (3a) and by implication the results from Miller & Upadhyay (2000). Reassuringly, the threshold values (both in terms of percentiles and c.i.f.-f.o.b. ratios) correspond identically to that obtained earlier within the formal threshold framework. Similarly, we only obtained a confidence interval (95%) for the upper threshold value of 1.15 (86^{th} percentile). This finding clearly suggests that the endogenous threshold model better captures the conditioning influences of natural barriers on the openness-TFP growth relationship.

Thresholds were also explored on the final policy based measure of openness, OPEN3. The endogenous sample splitting procedure identified two statistically significant threshold values. The first corresponds to a natural barrier (NATBARR) value of 1.1496 (or 80^{th} percentile) with a bootstrapped p-value of 0.064. The second threshold occurs at NATBARR=1.075 (or the 24^{th} percentile) with a bootstrapped p-value of 0.014.

The confidence intervals at conventional levels for both thresholds are however very wide, indicating that there is considerable uncertainty as to where the threshold values lie. Therefore, we take our finding of two significant thresholds as evidence of the existence of thresholds but that the data are not informative about their exact location. We note, however, the threshold values (if not the percentiles) of NATBARR when we use OPEN3 as our measure of openness, are almost identical to those obtained from the use of OPEN1.

As indicated above, when the threshold value is imprecisely estimated this carries over to the slope coefficient that is "interacted" with the imprecisely estimated threshold value. This should therefore be borne in mind for the regression results shown in Table 2. Regression (a) reports OLS estimates for a TFP growth regression based on the double threshold model. Interestingly we find positive openness effects for all groups of natural barriers, but with the magnitude of the effect increasing as we move over thresholds to higher levels of natural barriers. Again therefore for a policy based measure of trade openness we find greater returns to reduced distortions for high natural barrier countries, this would appear to support the interpretation of the results made above. Note that the 'high' natural barriers group of countries include a mix of coastal countries (e.g. Tanzania, Kenya, Peru, Ecuador); island economies (e.g. Jamaica, Mauritius, Madagascar) and landlocked countries (e.g. Bolivia, Mali, Malawi, Rwanda and Zambia). This clearly suggests that factors other than being landlocked or being located far away from core markets also determine high transport costs[19] (see Radelet and Sachs, 1998; Limao and Venables, 1999; Gallup et al. 1999; IDB, 2000). As the latter authors argue, other key determinants of transport costs are the quality of a country infrastructure (roads, rail, ports and telecommunications) and the regulatory and institutional environment (e.g. transparency of customs procedures, efficiency of the bureaucracy etc.) governing international trade.

[19] Among our group of high natural barrier (transport costs) countries four – Dominican Republic, Haiti, Jamaica and Mauritius- were listed by Radelet and Sachs (1998) as having 100% of their populations residing within 100km of the coast, as well as being among the top 15 exporters of non-primary manufactured goods by developing countries between 1965-90.

Table 2: Endogenous Threshold Regression Estimates with OPEN3 and OPEN2

DEPENDENT VARIABLE: TFP GROWTH[1]			
	(a)		**(b)**
Openness Variable	*Price Distortion (OPEN3)*		*Collected Tax Ratio (OPEN2)*
GDP^0	-0.00551 (1.41)		-0.01273 (2.70)***
INSTIT	0.00251 (2.46)**		0.00271 (1.67)*
NATBARR	0.00263 (0.12)		-0.06773 (2.19)**
BELOW LOWER THRESHOLD *OPEN3*I(NATBARR < 1.075)*	***0.01217*** ***(2.15)*****	***BELOW THRESHOLD*** *OPEN2*I(INSTIT < 7.145)*	***0.00253*** ***(1.81)****
INTER THRESHOLDS *OPEN3*I(1.075=< NATBARR <1.15)*	***0.01452*** ***(2.45)*****		
ABOVE UPPER THRESHOLD *OPEN3*I(NATBARR >= 1.15)*	***0.01768*** ***(3.19)******	***ABOVE THRESHOLD*** *OPEN2*I(INSTIT >= 7.145)*	***-0.00107*** ***(1.32)***
PERIOD==2	-0.00719 (1.58)		-0.00068 (0.12)
PERIOD==3	-0.02430 (5.72)***		-0.01891 (4.05)***
PERIOD==4	-0.01236 (3.12)***		-0.00311 (0.71)
Constant	0.10070 (2.89)***		0.17674 (2.88)***
Observations R-squared Number of countries	253 0.26 83		201 0.20 78

NOTES:

1. Estimates of threshold values are based on least squares estimation (see Hansen, 2000).
2. Absolute value of (robust)t-statistics in parentheses * significant at 10%; ** significant at 5%; *** significant at 1%.
3. OPEN3 is the log of the price level GDP (%) in PPP prices, relative to the U.S. dollar exchange rate. All other variables are as defined for Table 1.

It can reasonably be argued that the extent to which a country is integrated into the world economy and productivity growth are simultaneously determined (see Acemoglu et al., 2001; Rodrik et al., 2002). Causality runs from growth to openness and the reverse. Two methods of dealing with endogeneity have typically been adopted in the empirical growth literature. The first involves using lagged values of the suspected endogenous regressor(s) and the second, the use of instrumental variable estimation, where the suspected endogenous regressors are instrumented by a separate set of variables that are correlated with the endogenous right hand side variable but not the dependent variable. While the latter approach might be considered the 'first best' solution, the difficulty in finding suitable instruments along with the complexity of applying this technique whilst simultaneously estimating thresholds (see Caner and Hansen, 2001) led us to choose the former approach to gauge the extent of the problem, ignored so far in the existing literature. In addition this allows us to incorporate into the endogenous sample splitting framework of Hansen (2000) without altering the estimation procedure upon which it is premised.

The number and the position of any thresholds along with the confidence interval around these values were re-estimated in the same manner as above but using the lagged values of the trade share (OPEN1) and the collected tax ratio (OPEN2). It is clear from this set of results that controlling for the possible effects of endogeneity when searching for threshold effects of openness on productivity growth is important, at least for some measures of openness. According to the results for the lag of OPEN1, there exists a single threshold level occurring at the 51st percentile which corresponds to a c.i.f.-f.o.b. ratio of 1.10. The position of the threshold for this measure of openness is somewhat lower than that found before, and in contrast to previous results no confidence interval could be established for this threshold. Therefore, we conclude that while it is difficult to determine the exact location of any threshold outside of that for contemporaneous effects, evidence remains for the existence of threshold effects.

For lagged values for OPEN2 greater robustness is found, evidence of a single threshold with a reasonably tight confidence interval is uncovered. Moreover, the critical threshold level both in terms of percentile (80th) and value (1.1496) is almost identical to that obtained using contemporaneous values of OPEN2, while the confidence interval [p (67), p (91)] around the threshold value is identical.

Using Institutional Quality as the Threshold Variable

Unlike natural barriers, when we search for evidence of threshold effects between trade openness and productivity growth using measures of institutional quality no such a relationship emerges. Using OPEN1 a threshold level of institutional quality at the 6th percentile was identified, but it was statistically insignificant based on the bootstrapped p-value. According to this result, to the extent trade openness is correlated with productivity growth this relationship is linear.

Even when we use the policy-based measures of openness the evidence is not strong for institutions. Using the countries' Legal Structure and Security of Property Rights as the measure of institutional quality and OPEN2 as the measure of trade policy, we identified one significant threshold level. This occurs at a value of INSTIT = 7.145 (or 67th percentile). The corresponding bootstrapped p-value is 0.035. However, we are again unable to generate a confidence interval at conventional levels for this threshold due to the width of the interval. Again the results should be viewed with caution.

Regression (b) in Table 2 shows estimation results for the two regimes suggested by the threshold value of INSTIT and OPEN2. The finding of a direct TFP growth effect for the threshold variable, albeit a weak one, in this analysis represents a departure from previous results when we used NATBARR as the threshold variable. It suggests that in addition to mediating the openness-TFP growth relationship, there are direct TFP growth benefits associated with high institutional quality. The coefficient on the institution quality variable indicates that a one standard deviation increase of this variable away from its mean results in an average increase in TFP growth of 0.76% over the period.

The main finding is that for countries characterised by high institutional quality (i.e. those at or above the threshold value of 7.145) there are no significant TFP growth effects resulting from increased openness or reduced distortions. In contrast, increased policy openness/liberalisation is shown to increase TFP growth for countries below the threshold level of institutional quality. This is an unexpected finding since one might expect that institutional quality was a positive conditioning influence, with high quality institutions more likely to make openness effective. Rather this result suggests that increased openness is only needed to increase TFP growth where the quality of a country's institutions is relatively poor. Note, of course, that this conclusion holds only to the extent that the coefficients on the imprecisely defined threshold variables are relatively robust.

Indeed, the fact that the difference between the effect of openness differs statistically for high/low quality institution countries also highlights the dangers of exogenously imposing thresholds onto the regression. Exogenously setting the threshold (and assuming one managed to chose a value that was close to that estimated endogenously above) might lead to the false conclusion that the quality of institutions mediates the relationship between openness and productivity-growth. Making the same conclusion from the endogenous threshold methodology would not be possible.

We also experimented with other measures of openness with institutional quality as the threshold variable. Using OPEN3 we found one statistically significant threshold at INSTIT= 6.921 (or 63rd percentile) with a bootstrapped p-value of 0.018. It was not possible to ascribe a confidence interval for this threshold variable however. The results from estimations of TFP growth regressions (not reported) showed, unlike when we used OPEN2, that high institutional quality countries do have positive TFP growth effects from increased policy openness. These are, however, lower than those experienced by low institutional quality countries.

We repeated the same testing methodology applied above to compare the threshold model (2b) with the linear interaction model (3b) where institutional quality is the conditioning influence on openness (OPEN2). Again we can reject the interaction model in favour of the threshold model.

6. Conclusions

In this paper we ask the question of whether the dependence of the correlation between openness to international trade and growth to the measure of openness and sample of countries used found by Rodriguez & Rodrik (2000) and Harrison & Hanson (1999) is caused by non-linearity. If so, what causes the nature of the relationship to change across countries and what form does the heterogeneity take.

There is support for the hypothesis that there is a critical level of natural barriers (proxied by transport costs) above and below which the contribution to TFP growth from openness differ. We find that this relationship depends on the measure of openness used however. For instance, based on trade share as a percentage of GDP we uncover evidence that 'high' natural barriers countries receive lower or insignificant TFP growth benefits from increased openness relative to countries below this upper threshold. Alternatively, using the policy-based (trade tax) measures of openness/liberalisation, ‘high’ natural barrier countries are predicted to experience TFP growth benefits linked to reductions in trade taxes as a proportion of GDP, while countries below the threshold are predicted to experience no significant TFP growth effects. In this regard this work contributes to a deeper understanding of why other researchers (eg Block, 2001) have found that being closed to trade is more costly to growth in Africa than elsewhere. Africa is a region with relatively high ‘natural barriers’. These differences in the nature of the threshold effects may account for differences in the nature of the productivity growth-openness relationship when trade performance and policy-based indicators of openness have been used in the previous literature. The composition of the ‘high’ natural barriers group of countries suggest that factors other than physical geographical characteristics also contribute to high transport costs. This clearly has implications for government policy, and for the importance to a broad group of developing countries of improving infrastructure and efficiency in the international transport sectors. While the finding of threshold effects is robust to test of endogeneity, most noticeably for the policy based measure, it was not possible to accurately pin-point the location of threshold effects for the trade-GDP ratio. Although this suggests that future research into the source of these differences are warranted, we are still able to conclude that accounting for heterogeneity in the openness-productivity growth relationship using the techniques adopted in this paper will yield additional insights.

We find some evidence also of threshold level(s) based on natural barriers when using the alternative policy-based openness measure (OPEN3), and weak evidence that institutional quality affects the correlation between productivity growth and openness. In both instances there is imprecision over the location of the thresholds. Consequently, the slope coefficients based on the estimated thresholds are not necessarily accurately measured. While one possible conclusion from the result for institutions might be that institutional quality does not mediate the effects of openness, to the extent that measure of natural barriers used in this paper includes the effects of institutional quality this conclusion is likely to prove premature. Instead we conclude that the general quality of the institutional framework does not appear to be important for the openness-productivity growth relationship (there are direct effects from this variable), but there are likely to be specific aspects of institutional quality related to the level of natural barriers that are important.

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APPENDIX A

Table A1: Summary Statistics				
Variable	*Mean*	*Std. Deviation*	*Minimum*	*Maximum*
TFPG	0.002	0.032	-0.165	0.163
GDP^0	7.921	1.018	5.694	9.905
OPEN1	3.881	0.608	1.934	5.935
OPEN2	0.381	0.470	0	1
OPEN3	-4.108	0.451	-5.750	-2.548
OPEN2	-2.703	2.326	-6.786	6.593
INSTIT	5.655	2.793	0	10
NATBARR	1.113	0.065	1.006	1.667

Table A2 : Correlation Matrix								
	TFPG	*GDP^0*	*OPEN1*	*OPEN2*	*OPEN3*	*OPEN2*	*INSTIT*	*NATBARR*
TFPG	1.0000							
GDP^0	0.0065	1.0000						
OPEN1	0.1227	0.1755	1.0000					
OPEN2	0.2912	0.6205	0.2606	1.0000				
OPEN3	0.1515	-0.6908	-0.1322	-0.4742	1.0000			
OPEN2	0.0707	0.6716	0.2950	0.5494	0.5576	1.0000		
INSTIT	0.1347	0.7057	0.1521	0.6053	0.5450	-0.6048	1.0000	
NATBARR	-0.1085	-0.5585	-0.0688	-0.4023	-0.4168	0.4074	-0.4029	1.0000

APPENDIX B

Table B1: Natural Barrier Value by Country and Time

Country	OPEN1 Time Period				OPEN2 Time Period			
	1	2	3	4	1	2	3	4
Switzerland	1.017	1.026	1.020	1.010		1.026	1.020	1.010
Norway	1.026	1.026	1.023	1.030		1.026	1.023	1.030
Austria	1.029	1.032	1.041	1.047	1.029	1.032	1.041	
Canada	1.030	1.026	1.025	1.025	1.030	1.026	1.025	1.025
Belgium	1.042	1.042	1.031	1.031		1.042	1.031	1.031
Ireland	1.050	1.050	1.050	1.050	1.050	1.050	1.050	1.050
Mexico	1.050	1.051	1.048	1.046		1.051	1.048	1.046
Denmark	1.057	1.032	1.046	1.044		1.032	1.046	1.044
Tunisia	1.057	1.063	1.063	1.072		1.063	1.063	1.072
Germany	1.058	1.035	1.031	1.026	1.058	1.035	1.031	1.026
U.S.A.	1.062	1.060	1.047	1.044	1.062	1.060	1.047	1.044
Netherlands	1.063	1.057	1.056	1.056	1.063	1.057	1.056	
Singapore	1.068	1.063	1.060	1.060				
France	1.069	1.043	1.052	1.036		1.043	1.052	1.036
Cameroon	1.069	1.091	1.100	1.100		1.091	1.100	1.100
Finland	1.070	1.049	1.049	1.045		1.049	1.049	1.045
Israel	1.074	1.074	1.077	1.080	1.074	1.074	1.077	1.080
Sweden	1.075	1.064	1.021	1.023	1.075	1.064	1.021	1.023
New Zealand	1.077	1.089	1.082	1.082	1.077	1.089	1.082	1.082
Italy	1.083	1.073	1.069	1.069	1.083	1.073	1.069	1.069
South Africa	1.083	1.075	1.078	1.088		1.075	1.078	1.088
Malaysia	1.083	1.106	1.107	1.105	1.083	1.106	1.107	1.105
Algeria	1.085	1.098	1.099	1.102				
Trinidad & Tob.	1.085	1.072	1.098	1.111		1.072	1.098	
China	1.090	1.090	1.090	1.090				1.090
Australia	1.092	1.094	1.121	1.093	1.092	1.094		1.093
Pakistan	1.096	1.096	1.095	1.095	1.096	1.096	1.095	1.095
Nigeria	1.097	1.108	1.107	1.107		1.108	1.107	1.107
Great Brit.	1.097	1.072	1.068	1.044	1.097	1.072	1.068	1.044
Panama	1.098	1.104	1.115	1.127		1.104	1.115	1.127
Sierra Leone	1.099	1.099	1.125	1.136		1.099	1.125	1.136
Egypt	1.099	1.106	1.111	1.111		1.106	1.111	1.111
El Salvador	1.099	1.085	1.108	1.110				
S. Korea	1.100	1.071	1.072	1.056		1.071	1.072	1.056
Myanmar	1.100	1.100	1.100	1.100	1.100	1.100	1.100	1.100
Guatemala	1.101	1.099	1.083	1.106		1.099	1.083	
Spain	1.102	1.076	1.058	1.060		1.076	1.058	1.060
Nicaragua	1.106	1.109	1.069	1.115		1.109	1.069	1.115
Morocco	1.106	1.136	1.131	1.099		1.136	1.131	1.099
Guyana	1.107	1.101	1.100	1.100		1.101	1.100	1.100
Sudan	1.107	1.101	1.097	1.066	1.107	1.101	1.097	
Cyprus	1.107	1.109	1.109	1.102		1.109	1.109	1.102
Turkey	1.109	1.053	1.053	1.057	1.109	1.053	1.053	1.057
Thailand	1.110	1.112	1.110	1.108		1.112	1.110	1.108

Uganda	1.110	1.110	1.111	1.110	1.110	1.110	1.111	1.110
Iraq	1.110	1.111	1.110	1.110				
Sri Lanka	1.111	1.111	1.111	1.111		1.111	1.111	1.111
Costa Rica	1.112	1.111	1.109	1.107		1.111	1.109	1.107
Venezuela	1.112	1.119	1.110	1.110	1.112	1.119	1.110	1.110
Honduras	1.114	1.101	1.104	1.148	1.114	1.101	1.104	
Philippines	1.114	1.087	1.075	1.068		1.087	1.075	1.068
Malta	1.115	1.111	1.109	1.111	1.115	1.111	1.109	1.111
Portugal	1.115	1.105	1.102	1.103				
Cote d'Ivoire	1.116	1.173	1.235	1.244			1.235	1.244
Bangladesh	1.117	1.119	1.127	1.109	1.117	1.119	1.127	1.109
Mozambique	1.120	1.120	1.120	1.120				
Indonesia	1.121	1.130	1.120	1.120	1.121	1.130	1.120	1.120
Jordan	1.122	1.123	1.124	1.124	1.122	1.123	1.124	1.124
Brazil	1.127	1.105	1.090	1.094			1.090	1.094
Iceland	1.128	1.100	1.100	1.100		1.100	1.100	1.100
Greece	1.130	1.130	1.130	1.130		1.130	1.130	1.130
Ghana	1.134	1.096	1.069	1.069		1.096	1.069	1.069
Senegal	1.135	1.125	1.144	1.144	1.135	1.125	1.144	
Colombia	1.136	1.110	1.110	1.097	1.136	1.110	1.110	1.097
Kuwait						**1.147**	1.154	1.153
Chile	1.143	1.135	1.086	1.091		1.135	1.086	1.091
Malawi	1.145	1.136	1.135	1.667		1.136	1.135	1.667
Kenya	1.147	1.154	1.157	1.163		1.154	1.157	1.163
Zimbabwe	**1.150**	**1.150**	**1.150**	**1.150**		1.150	1.150	1.150
Ecuador	1.151	1.135	1.152	1.138		1.135	1.152	1.138
India	1.152	1.127	1.117	1.117			1.117	1.117
Tanzania	1.153	1.149	1.176	1.176		1.149	1.176	1.176
Haiti	1.156	1.166	**1.150**	**1.150**		1.166	1.150	1.150
Iran	1.158	1.176	1.160	1.160		1.176	1.160	1.160
Dominican Rep.	1.160	**1.150**	**1.150**	**1.150**	1.160	1.150	1.150	1.150
Jamaica	1.161	1.178	1.142	1.139		1.178	1.142	1.139
Mauritius	1.168	1.193	1.170	1.115		1.193	1.170	1.115
Zaire	1.169	1.159	1.160	1.160				
Japan	1.172	1.114	1.080	1.078		1.114	1.080	1.078
Uruguay	1.177	1.100	1.075	1.048		1.100	1.075	1.048
Paraguay	1.177	1.196	1.163	1.144				
Bolivia	1.182	1.099	1.146	1.161				1.161
Ethiopia	1.192	1.218	1.175	1.186	1.192	1.218	1.175	1.186
Zambia	1.197	1.202	1.277	1.006		1.202	1.277	1.006
Madagascar	1.227	1.257	1.205	1.205		1.257	1.205	1.205
Peru	1.239	1.200	1.200	1.200		1.200	1.200	1.200
Rwanda	1.254	1.342	1.435	1.436		1.342	1.435	1.436
Argentina	1.259	1.106	1.105	1.090			1.105	1.090
Mali	1.259	1.392	1.429	1.429		1.392	1.429	1.429

Notes:

1. Light grey squares indicate observations in the lower threshold group
2. Medium grey squares when observations lie in the uncertainty range (the confidence interval)
3. Dark grey squares when observation lie in the upper threshold group; white squares indicate missing data for the openness variable
4. Bold squares indicate the location of the estimated threshold value.