Trade as a Threshold Variable for Multiple Regimes

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Abstract. This paper employs the data-sorting method developed by Hansen (2000) which allows the data to endogenously select regimes using different variables. It is shown that openness, as measured by the trade share to GDP, is a threshold variable that can cluster middle-income countries into two distinct regimes that obey different statistical models. Our result suggests that openness may not be as crucial in the growth process of low and high-income countries but it is instrumental in identifying middle-income countries into high and low-growth groups.

Keywords: Endogenous splitting; Threshold variables; Openness; Growth

JEL classification: C13; C21; O47

*I thank Bruce E. Hansen for making his programs available to me and for his valuable comments.

"... we can use measures of foreign trade and openness to help explain the clustering of middle-income economies into high-growth and low-growth groups."

Costas Azariadis (1996)

1. Introduction

The relationship between openness and growth is at the center of lively discussions amongst economist. On the one hand, recent work by Sachs and Warner (1995), Edwards (1998) and Frankel and Romer (1999), just to name a few, assigns an important role of trade and openness to economic growth. On the other hand, there exists a fair amount of scepticism about this relationship, both on theoretical and empirical grounds, as summarized in Rodríguez and Rodrik (2000).

Some evidence in favor of a positive openness-growth relationship is obtained by plotting the cross-country average annual growth rate of trade volume against the average annual growth rate of per capita GDP from 1960 to 1993. The relationship that emerges is clearly positive indicating that a component of the growth performance of many economies maybe associated with an increase in trade intensity. However, for the same time period, the trade intensity in many rapidly growing countries, like Japan, has been declining. Moreover, the majority of sub-Sahara African countries have exhibited trade intensity increases while having virtually no growth. This evidence suggests that the relationship between openness and growth is far from simple.

This paper examines an alternative way by which openness maybe influencing economic performance. Following Durlauf and Johnson (1995) (DJ) and more recently Hansen (2000) we employ a data-sorting method which allows the data to endogenously select regimes using different variables. We show that openness, as measured by the ratio of trade volume to GDP, is a threshold variable that can cluster middle-income countries into two regimes that obey different statistical models. This finding is in favor of theoretical models in which trade and openness is a plausible source of multiple equilibria such as Trejos (1992), Azariadis (1996, pp.464-465) and Ferreira and Trejos (2000).

2. Estimation

In this section we follow Hansen (2000) to search for multiple regimes in the data by using, in addition to initial per capita output (y_{1960}) and initial literacy rates (LIT), trade shares (TS) as a possible threshold variable. The advantage of Hansen's methodology over the regression-tree methodology used in DJ is that it is based on an asymptotic distribution theory. Unlike the regression-tree approach, Hansen's method can test the statistical significance of regimes selected by the data.[1]

In line with most empirical growth literature, we consider the following regression equation:

$$\log y_{i,1985} - \log y_{i,1960} = a_0 + a_1 \log y_{i,1960} + a_2 \log s_{ik} + a_3 \log s_{ih} + a_4 \log(n_i + g + \delta) + \varepsilon_i, \quad (1)$$

where y_i is per capita GDP for country i, s_k is physical capital investment (investment share to GDP), s_h is human capital investment (secondary-school enrollment of working-age population), n is population growth, $g + \delta = 0.05$ as in Mankiw, Romer, Weil (1992), and ε is a random error term.

The country-sample (96 countries) and data (real GDP, working-age population, average share of real investment, secondary-school enrolment rates and adult literacy rates) are from DJ.[2] Data on trade shares defined as the ratio of imports plus exports to real GDP in 1985, are from PWT-5.6 (series: OPEN).[3]

Since Hansen's theory allows for one threshold for each threshold variable, we proceed by selecting among the three threshold variables (y_{1960}, LIT, TS) by employing the heteroskedasticity-consistent Lagrange Multiplier test for a threshold obtained in Hansen (1996). Our first round of threshold model selection obtains the following p-values: 0.270 for trade share, 0.168 for literacy rate and 0.080 for initial per capita output. These results indicate that there maybe a sample split based on initial per capita output. As shown in Hansen (2000), the threshold value occurs at \$863 and the asymptotic 95% confidence set is $[\$594, \$1794]$. This threshold value divides our entire sample of 96 countries into a low-income group with 18 countries and a high-income group with 78 countries.

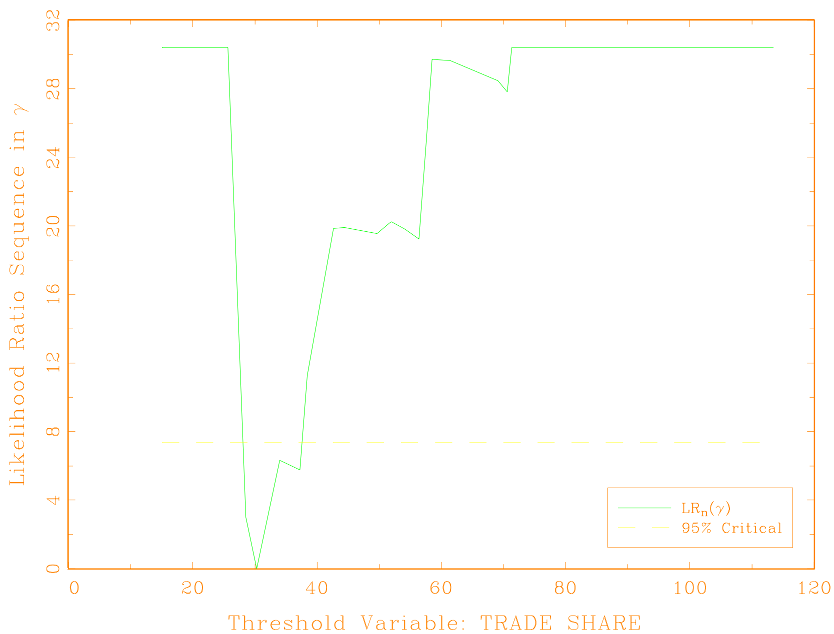
Our second round of threshold model selection involves the 78 countries with per capital output above \$863 and obtains the following p-values for our three threshold variables: 0.552 for trade share, 0.055 for literacy rate and 0.146 for per capita output. These results indicate a possible sample split based on literacy rates. The threshold value occurs at 45% and the asymptotic 95% confidence set is $[19\%, 57\%]$. The literacy-rate threshold variable splits the high-income subsample

[1] For a detailed discussion on the statistical theory for threshold estimation in the regression context, see Hansen (2000).

[2] With the exception of the adult literacy rates that are from the World Bank's *World Report*, all of the data used in DJ are from the Real National Accounts constructed by Summers and Heston (1988).

[3] Trade shares in our country sample vary dramatically from 13.16% in Burma to 318.07% in Singapore. The complete dataset used in this paper is presented in the appendix. The GAUSS programs used to determine the thresholds are available by the author upon request.

Figure 1: Threshold Variable Confidence Interval



of 78 countries into two further groups; the low-literacy group with 30 countries and the high-literacy group with 48 countries.

In the third round, we obtain our key finding. In this round we try spliting the high-income-low-literacy subsample with 30 countries (income above $863 and literacy rate below 45%). The p-values obtained from the three alternative threshold models are, 0.033 for trade share, 0.121 for literacy rate and 0.105 for initial per capita output, indicating that there may be a sample split based on trade shares. Figure 1 presents the normalized likelihood ratio sequence $LR_n^*(\gamma)$ statistic as a function of the trade shares. The least-squares estimate γ is the value that minimizes the function $LR_n^*(\gamma)$ which occurs at $\hat{\gamma} = 30.27\%$. The asymptotic 95% critical value (7.35) is shown by the dotted line and where it crosses $LR_n^*(\gamma)$ displays the confidence set $[28.53\%, 37.23\%]$. This threshold divides our subsample of 30 countries into a high-income-low-literacy-low-trade group with 8 countries and a high-income-low-literacy-high-trade group with 22 countries. Notice that our third splitting is the most significant (at the 3.3% level) indicating strong evidence in favor of trade shares as a threshold variable among middle-income countries.

We have tried to further split the high-income-high-literacy rate group of 48 countries but none

Table 1: Four Regimes Obtained by Hansen's Threshold Regression Estimation

Regime 1:	$y_{i,1960} \leq \$863$	(18 countries)
Regime 2:	$y_{i,1960} > \$863$; $LIT_{i,1960} \leq 45\%$; $TS_{i,1985} \leq 30.27$	(8 countries)
Regime 3:	$y_{i,1960} > \$863$; $LIT_{i,1960} \leq 45\%$; $TS_{i,1985} > 30.27$	(22 countries)
Regime 4:	$y_{i,1960} > \$863$; $LIT_{i,1960} > 45\%$	(48 countries)

Notes: LIT denotes literacy rates and TS denotes trade shares.

of the bootstrap test statistics were significant and therefore no further splitting was possible with the existing threshold variables. We have also checked the robustness of these three variables (y_{1960}, LIT, TS) by examining a list of other possible threshold variables suggested in the theoretical literature of multiple equilibria and growth; these include corruption (data from Mauro 1995), inflation, and political instability (data from Sachs and Warner 1995). None of the bootstrap test statistics for these variables were statistically significant at any round of the selection process.

Table 1 illustrates the four regimes whereas Table 2 presents the countries in each regime determined by our threshold estimation. The countries in each regime compare well with those identified by the regression-tree approach in DJ (1995 p.374). Like DJ we obtain four regimes, however these regimes are identified with different threshold variables. Our main difference is twofold: first their regimes 3 and 4 are clustered into our Regime 4; that is we do not obtain a statistically significant threshold for splitting the high-income-high-literacy rate countries using per capita output. Second, their Regime 2 is, in our work, divided into two regimes (Regime 2 and Regime 3) based on the countries' trade shares.

Next, we turn our attention to the estimation of equation (1) for the four regimes. Table 3 presents estimates for each regime in the unrestricted and restricted models.[4] The heterogeneity of the coefficient estimates across regimes is evident. Starting with the unrestricted model, point estimates on initial income level ($\log y_{1960}$) vary from -0.657 and significant at the 1% level for Regime 1, to 0.652 and significant at the 5% level for Regime 2. The coefficient estimate on physical capital investment ($\log s_k$) is 0.099 but insignificant for Regime 3, and 0.834 and highly significant for Regime 4. Finally, estimated coefficients on human capital investment ($\log s_h$) range from 0.018 but insignificant for Regime 1 to 0.589 and highly significant for Regime 3.

[4]The restricted model imposes the constraint that the coefficient on $\log(n_i + g + \delta)$ is equal in magnitude and opposite in sign to the sum of the coefficients on $\log s_{ik}$ and $\log s_{ih}$.

Table 2: Country Classification in Four Regimes

	Regime 1	Regime 2	Regime 3	Regime 4	
1	B. Faso	Bolivia	Algeria	Argentina	Mexico
2	Bangladesh	Ghana	Angola	Australia	N. Zealand
3	Burma	Guatemala	Benin	Austria	Netherlands
4	Burundi	India	Cameroon	Belgium	Nicaragua
5	C. Afri. Rep.	Mozambique	Chad	Brazil	Norway
6	Ethiopia	Nigeria	Congo	Canada	Panama
7	Liberia	Somalia	Egypt	Chile	Paraguay
8	Malawi	Sudan	Haiti	Colombia	Peru
9	Mali		Honduras	Costa Rica	Philippines
10	Mauritania		I. Coast	Denmark	Portugal
11	Nepal		Indonesia	Dom. Rep.	S. Africa
12	Niger		Jordan	Ecuador	S. Korea
13	Rwanda		Kenya	El Salvador	Singapore
14	Sierra Leone		Morocco	Finland	Spain
15	Tanzania		Pakistan	France	Sri Lanka
16	Togo		Papua N. G.	Greece	Sweden
17	Uganda		Senegal	Hong Kong	Switzerland
18	Zaire		Syria	Ireland	Thailand
19			Tunisia	Israel	Tri. & Tobago
20			Turkey	Italy	U.K.
21			Zambia	Jamaica	U.S.A.
22			Zimbabwe	Japan	Uruguay
23				Madagascar	Venezuela
24				Malaysia	W. Germany

Disparity in coefficient estimates across regimes in the restricted model is as large as in the unrestricted model. The estimated share of physical capital α, varies from 0.06 but insignificant for Regime 3 to 0.413 and highly significant for Regime 1. Human capital shares are substantially different across regimes too, ranging from 0.014 but insignificant for Regime 1 to 0.349 and highly significant for Regime 3.[5]

Heterogeneity of coefficient estimates is particularly striking between Regime 2 and Regime 3 (both in the unrestricted and restricted regressions) which are clustered according to the trade threshold variable. This reinforces our finding that more open middle-income economies obey a

[5]Computing the shares of labor input across regimes obtains: 0.802 for Regime 1, 0.617 for Regime 2, 0.591 for Regime 3, and 0.553 for Regime 4. This result is consistent (even though not as strong in magnitude) with DJ's observation that labor shares decline with economic development. In a recent paper, Duffy and Papageorgiou (2000) have used panel data techniques to estimate a two-factor Constant Elasticity of Substitution (CES) aggregate production function specification for a cross-section of 82 countries over a period of 28 years. They find that the elasticity of substitution and therefore the capital share is increasing with economic development, which is consistent with the declining labor shares across regimes obtained here.

Table 3: Cross-Country Regressions for the Four Regimes

Specification	Regime 1	Regime 2	Regime 3	Regime 4
Unrestricted				
Constant	4.312**	−8.584	3.979**	4.310***
	(1.627)	(5.736)	(1.874)	(0.965)
$\log y_{1960}$	−0.657***	0.652**	−0.395**	−0.395***
	(0.218)	(0.204)	(0.147)	(0.061)
$\log s_k$	0.228***	0.603	0.099	0.834***
	(0.072)	(0.280)	(0.190)	(0.139)
$\log s_h$	0.018	0.027	0.589***	0.095
	(0.097)	(0.143)	(0.101)	(0.135)
$\log(n+g+\delta)$	−0.295	−2.063	−0.598	−0.418
	(0.337)	(1.775)	(0.462)	(0.270)
s.e.e.	0.368	0.230	0.254	0.289
Adj. R^2	0.36	0.32	0.69	0.54
Restricted				
Constant	4.434***	−4.094**	3.719***	3.221***
	(1.558)	(1.195)	(1.065)	(0.562)
Implied α	0.184***	0.324***	0.060	0.413***
	(0.053)	(0.113)	(0.108)	(0.061)
Implied β	0.014	0.059	0.349***	0.034
	(0.077)	(0.059)	(0.072)	(0.076)
s.e.e.	0.220	0.204	0.247	0.291
Adj. R^2	0.41	0.46	0.71	0.53
Obs.	18	8	22	48

Notes: α and β are the shares of physical and human capital respectively. Standard errors are given in parentheses. The standard errors for α and β were recovered using standard approximation methods for testing nonlinear functions of parameters. White's heteroskedasticity correction was used. *** Significantly different from 0 at the 1% level. ** Significantly different from 0 at the 5% level. * Significantly different from 0 at the 10% level.

model that is significantly different from that in more closed middle-income economies.

It is well-known in the literature that cross-country level regressions, such as ours, maybe subject to a list of econometric problems; two potentially serious problems are the omitted-variable error and the endogeneity error. DJ (pp.371-372, Table III) examined the possibility of omitted-variable error showing that evidence of multiple regimes is robust to the addition of a set of 13 control variables. Since our threshold estimation includes trade shares, there are legitimate concerns about potential endogeneity problems between trade and growth. Put differently, it maybe that income affects the level of openness and not the reverse. Frankel and Romer (1999) show that correcting for endogeneity problems by using instruments obtained from geographical components of countries, yields a stronger positive effect of trade on economic growth.

3. Conclusion

This paper proposes an alternative way by which openness maybe affecting growth. It is shown that openness, as measured by the trade share to GDP, is a threshold variable that can cluster middle-income countries into two distinct regimes that obey different statistical models. Our result suggests that openness may not be as crucial in the growth process of high and low-income countries but it is instrumental in clustering middle-income countries into high and low-growth groups. Our finding is consistent with, and provides evidence in favor of a small but growing class of theoretical papers that view openness as a potential source of multiple equilibria. In a more general sense, our finding is in agreement with Durlauf and Johnson (1995), Liu and Stengos (1999) and Durlauf (2001) in that the constant coefficient linear model assumptions made in standard growth regressions are not supported by the data.

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Data Appendix

Country	GDP/L_{1960} (ths. US$)	GDP/L_{1985} (ths. US$)	Inv. Share (inv./GDP)	Schooling (% sec. sch.)	$Literacy_{1960}$ (% of pop.)	Trade Share (trd. vol./GDP)
Algeria	2485	4371	24.1	4.5	10.0	49.7
Angola	1588	1171	5.8	1.8	5.0	69.1
Argentina	4852	5533	25.3	5.0	91.0	17.1
Australia	8440	13409	31.5	9.8	100.0	35.3
Austria	5939	13327	23.4	8.0	99.0	81.3
B. Faso	529	857	12.7	0.4	2.0	52.4
Bangladesh	846	1221	6.8	3.2	22.0	25.8
Belgium	6789	14290	23.4	9.3	99.0	151.3
Benin	1116	1071	10.8	1.8	5.0	77.0
Bolivia	1618	2055	13.3	4.9	39.0	30.3
Brazil	1842	5563	23.2	4.7	61.0	19.3
Burma	517	1031	11.4	3.5	60.0	13.2
Burundi	755	663	5.1	0.4	14.0	30.8
C. Afri. Rep.	838	789	10.5	1.4	7.0	65.2
Cameroon	889	2190	12.8	3.4	19.0	57.7
Canada	10286	17935	23.3	10.6	99.0	54.5
Chad	908	462	6.9	0.4	6.0	61.4
Chile	5189	5533	29.7	7.7	84.0	53.9
Colombia	2672	4405	18.0	6.1	63.0	26.3
Congo	1009	2624	28.8	3.8	16.0	112.8
Costa Rica	3360	4492	14.7	7.0	90.0	63.2
Denmark	8551	16491	26.6	10.7	99.0	73.0
Dom. Repub.	1939	3308	17.1	5.8	65.0	64.2
Ecuador	2198	4504	24.4	7.2	68.0	47.6
Egypt	907	2160	16.3	7.0	26.0	52.0
El Salvador	2042	1997	8.0	3.9	49.0	52.2
Ethiopia	533	608	5.4	1.1	15.0	34.1
Finland	6527	13779	36.9	11.5	99.0	57.5
France	7215	15027	26.2	8.9	99.0	47.2
Ghana	1009	727	9.1	4.7	27.0	21.3
Greece	2257	6868	29.3	7.9	81.0	54.0
Guatemala	2481	3034	8.8	2.4	32.0	24.9
Haiti	1096	1237	7.1	1.9	15.0	38.4
Honduras	1430	1822	13.8	3.7	45.0	54.2
Hong Kong	3085	13372	19.9	7.2	70.0	209.5
I. Coast	1386	1704	12.4	2.3	5.0	78.2
India	978	1339	16.8	5.1	28.0	15.0
Indonesia	879	2159	13.9	4.1	39.0	42.7
Ireland	4411	8675	25.9	11.4	98.0	118.8
Israel	4802	10450	28.5	9.5	84.0	85.8
Italy	4913	11082	24.9	7.1	91.0	46.1
Jamaica	2726	3080	20.6	11.2	82.0	131.9
Japan	3493	13893	36.0	10.9	98.0	25.5
Jordan	2183	4312	17.6	10.8	32.0	113.5
Kenya	944	1329	17.4	2.4	20.0	51.7
Liberia	863	944	21.5	2.5	9.0	79.6
Madagascar	1194	975	7.1	2.6	50.0	31.0
Malawi	455	823	13.2	0.6	25.0	54.1

Data Appendix (continued)

Country	GDP/L_{1960} (ths. US$)	GDP/L_{1985} (ths. US$)	Inv. Share (inv./GDP)	Schooling (% sec. sch.)	$Literacy_{1960}$ (% of pop.)	Trade Share (trd. vol./GDP)
Malaysia	2154	5788	23.2	7.3	53.0	104.7
Mali	737	710	7.3	1.0	3.0	73.6
Mauritania	777	1038	25.6	1.0	5.0	141.6
Mexico	4229	7380	19.5	6.6	65.0	25.7
Morocco	1030	2348	8.3	3.6	14.0	58.5
Mozambique	1420	1035	6.1	0.7	11.0	18.4
N. Zealand	9523	12308	22.5	11.9	99.0	65.3
Nepan	833	974	5.9	2.3	9.0	31.3
Netherlands	7689	13177	25.8	10.7	99.0	118.8
Nicaragua	3195	3978	14.5	5.8	90.0	36.6
Niger	539	841	10.3	0.5	1.0	51.3
Nigeria	1055	1186	12.0	2.3	15.0	28.5
Norway	7938	19723	29.1	10.0	99.0	86.0
Pakistan	1077	2175	12.2	3.0	15.0	34.0
Panama	2423	5021	26.1	11.6	73.0	71.0
Papua N. Gui.	1781	2544	16.2	1.5	29.0	94.5
Paraguay	1951	3914	11.7	4.4	75.0	49.6
Peru	3310	3775	12.0	8.0	61.0	39.4
Philippines	1668	2430	14.9	10.6	72.0	45.8
Portugal	2272	5827	22.5	5.8	62.0	78.0
Rwanda	460	696	7.9	0.4	16.0	30.7
S. Africa	4768	7064	21.6	3.0	57.0	55.4
S.Korea	1285	4775	22.3	10.2	71.0	67.9
Senegal	1392	1450	9.6	1.7	6.0	70.6
Sierra Leone	511	805	10.9	1.7	7.0	19.2
Singapore	2793	14678	32.2	9.0	83.0	318.1
Somalia	901	657	13.8	1.1	2.0	25.6
Spain	3766	9903	17.7	8.0	87.0	43.5
Sri Lanka	1794	2482	14.8	8.3	75.0	62.9
Sudan	1254	1038	13.2	2.0	13.0	21.3
Sweeden	7802	15237	24.5	7.9	99.0	69.0
Switzerland	10308	15881	29.7	4.8	99.0	77.7
Syria	2382	6042	15.9	8.8	30.0	37.2
Tanzania	383	710	18.0	0.5	10.0	21.0
Thailand	1308	3220	18.0	4.4	68.0	51.2
Togo	777	978	15.5	2.9	10.0	105.5
Tri. & Tabago	9253	11285	20.4	8.8	93.0	61.9
Tunisia	1623	3661	13.8	4.3	16.0	71.3
Turkey	2274	4444	20.2	5.5	38.0	44.4
U.K.	7634	13331	18.4	8.9	99.0	56.9
U.S.A.	12362	18988	21.1	11.9	98.0	18.0
Uganda	601	667	4.1	1.1	35.0	22.5
Uruguay	5119	5495	11.8	7.0	94.0	47.9
Venezuela	10367	6336	11.4	7.0	63.0	40.8
W. Germany	7695	15297	28.5	8.4	99.0	61.5
Zaire	594	412	6.5	3.6	31.0	53.2
Zambia	1410	1217	31.7	2.4	29.0	77.0
Zimbabwe	1187	2107	21.1	4.4	39.0	56.4