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THREE ESSAYS IN APPLIED ECONOMETRICS WITH APPLICATIONS TO INTERNATIONAL TRADE AND FINANCE

By

Patrice Whitely

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ABSTRACT

THREE ESSAYS IN APPLIED ECONOMETRICS WITH APPLICATIONS TO INTERNATIONAL TRADE AND FINANCE

By

Patrice Whitely

My dissertation consists of three essays in applied Econometrics with applications in the fields of Trade and International Finance. Chapters 1 and 2 investigate the relationship between openness and growth. This is an area which has received a great deal of attention from economists. The usual approach to investigating this relationship involves the specification of a structural model for gross domestic product (GDP) per capita with some measure of openness and other variables which are assumed to be exogenous. The weakness of this approach is the fact that openness may be endogenous. This may be as a result of simultaneity. Therefore the estimated coefficient of openness in such a model would be invalid. As such the goal of my paper is to identify the direction of Granger causality between openness and growth. Granger causality is a specific, testable definition of causality which does not involve the specification of a structural model. It is a statement about forecastibility and predictability. The concept of Granger causality is usually applied to time series data. However chapter 1 shows how this concept can be extended for use with panel data. I find that the direction of Granger causality for low and high income countries is from openness to growth.

Chapter 2 uses the popular 'Barro' regression to investigate the relationship between openness and growth. This involves running regressions of the growth rate of

income over a period of time on initial income as well as other control variables. This approach is used in order to address the issue of simultaneity between growth and openness. Openness at the beginning of the period cannot be caused income growth over the entire period. The 'Barro' methodology also allows me to measure the impact of openness on a country's growth rate as opposed to investigating the impact of openness on a country's GDP per capita as is usually done. I find that initial income, investment rates and initial openness all have an important impact on the rate at which a country grows.

Chapter 3 determines whether or not the popular monetary model of exchange rate determination describes exchange rate movements in Latin American countries. In the monetary model of exchange rate determination, the exchange rate is viewed as the value of one country's money supply against another. Initially there was some support for this model. However, subsequently these results have been invalidated by the discovery of the existence of a unit root in the exchange rate sequence. This led to studies trying to discover whether or not there exists a cointegrating or long run relationship between the exchange rate and the monetary fundamentals money supply and income. This paper investigates the applicability of the model to exchange rates in Latin America. Latin American countries are usually characterized by exchange rate volatility and high inflation. I find that despite the instability and volatility of exchange rates in these countries, there is still a long run relationship between the exchange rate and the fundamentals.

Dedicated to my mother, my sister and the memory of my father

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1.1 *Introduction*

This paper investigates the relationship between openness and growth. What is the direction of causality between openness and growth? The theory of comparative advantage tells us that countries benefit by specializing in and exporting the good that they can produce at a lower relative cost. However, in the real world does openness cause an increase in output? Does trade cause an increase in income? Or is it true that countries with higher incomes trade more? Does openness indicate future growth or does growth indicate future openness or are both of these true?

Statistics show that there is a correlation between trade and growth. According to a report[1] from the World Bank, in the last two decades, twenty-four less developed countries, (including China, India and Mexico), have become more integrated into the global economy. During that time period, these countries have doubled their ratio of trade to national income and in the 1990s their per capita Gross Domestic Product increased by an annual average of 5%. In less integrated countries, the ratio of trade to output has decreased, and the number of people below the poverty line has increased. Does this correlation between trade and growth imply causality? This is a complex question which economists have used various methods to try to answer.

The traditional approach to investigating the relationship between trade and growth involves the use of static structural models. This paper takes a different approach by applying the concept of Granger causality. I use this approach because the goal of this paper is to identify the direction of causality as defined in Granger (1969) between openness and growth and not to measure the impact of openness on growth. As I will

[1] "Globalization, Growth and Poverty", World Bank policy research report. December 2001

discuss in the literature review, this approach has been used in various fields of economics in order to address the issue of direction of causality. Granger causality tests are usually conducted using time series data. However, recent developments in econometric techniques now allow Granger causality tests to be applied to panel data sets. This study makes use of these techniques in order to identify the direction of Granger causality between openness and growth.

The paper is organized as follows: section 2 gives a review of the relevant literature. Section 3 defines the concept of Granger causality in its traditional time series setting. Section 4 discusses the extension of the concept to panel data. Section 5 describes the sample used. Section 6 outlines the methodology which was followed. Section 7 presents the results, section 8 discusses the results and section 9 summarizes the main findings of the paper in the form of a conclusion.

1.2 *Literature Review*

Does trade cause growth? Grossman and Helpman (1990) use an endogenous growth model to put forward the answer "it depends." It depends on whether or not trade forces the economy to direct resources to activities that generate growth (such as research and development, increasing product quality, and so on) or if it in fact diverts the economy from such activities.

In the traditional neoclassical growth model, the rate of growth of income per capita is unexplained. That is, growth is assumed to be exogenous to the model. As the name implies, the endogenous growth model endogenizes or explains growth. Growth is treated as a variable to be determined. Investment in physical and human capital has spillover effects which allow capital to exhibit non-decreasing returns to scale. Therefore sustained growth becomes a possibility.

Grossman and Helpman (1990) consider a two-sector, two-factor economy. They assume that the two factors, land and labour are available in fixed supplies. Output in each sector i is described by the following constant returns to scale production function:

$$X^i = KF^i(T^i, L^i) \quad i = 1,2 \tag{2}$$

where

T^i = amount of land used in sector i

L^i = amount of labour used in sector i

K = stock of knowledge capital (a public input)

They also assume that:

$$\dot{K} = bX^1 \tag{3}$$

where

$\dot{K}$ = growth rate of K

Using the Rybczynski Theorem they argue that an increase in the supply of the factor used intensively in sector 1 the knowledge generating sector will lead to an increase in growth while an increase in the supply of the factor used intensively in sector 2 will decrease growth. They then go on to discuss how trade and trade policy can change the relative supplies of the factors. Grossman and Helpman therefore conclude that the potential for less developed countries to benefit from international trade does exist but such trade gains are not automatic. They depend on whether or not trade leads to knowledge and technology transfers.

In this paper Grossman and Helpman also briefly mention product cycles or the 'North-South' theory of product development. This theory was first introduced in Vernon (1966) and was formally modeled in Krugman (1979). Grossman and Helpman (1991a) builds on earlier work to construct a product cycle model which features endogenous innovation and endogenous technology transfer. The product cycle theory states that product innovation takes place in the North while imitation takes place in the South. That is, the invention and initial manufacturing of a product occurs in the North. Over time, as the production methods become more standardized, they are copied by firms in the South. It is argued that innovation occurs in the North because these countries possess the research and development resources and technology necessary for the introduction of new products. The existence of lower wages in the South means that, after the technology has been successfully copied, the bulk of manufacturing and production takes place there. Of course as the South successfully copies the goods invented in the North and is able to produce and sell them at a lower price, this forces the North to introduce new products as well as improve the quality of existing products. Examples of goods that have followed this cycle include personal computers and consumer electronics.

Both Grossman and Helpman (1990) and (1991a) show that the potential exists for countries to benefit from trade. However the authors use the North-South theory of product development to suggest that less developed countries potentially stand to benefit the most from international trade. This is because trade allows them to have access to the technologies invented in the North. This implies that trade may have a greater impact on growth in low and middle income countries than it does in high income countries.

Grossman and Helpman (1991b), Feenstra (1990) and Matsuyama (1992), among others, have shown how trade can lead to a reduction in the long run growth rate of developing countries. They do so by using formal models of the 'infant industry' argument. These models illustrate that once real world market imperfections are taken into consideration, there is no reason to believe that trade will necessarily lead to growth.

Many empirical studies have been undertaken in order to quantify the impact of trade on growth. These studies usually proceed by running a cross-sectional regression of per capita income on some measure of trade or openness (such as the ratio of exports and/or imports to gross domestic product (GDP)), and other variables. These regressions usually identify a weakly positive relationship.

The main weakness of studies of this type is the fact that trade may be endogenous. As Elhanan Helpman (1988), Colin Bradford, Jr. and Naomi Chakwin (1993), Rodrik (1995 a), and several others point out, countries with high incomes (for reasons other than trade) may trade more. Therefore a positive coefficient on the trade variable may be reflecting the fact that growth causes trade and not necessarily the other way around. Furthermore, if there are endogeneity issues, the least squares estimator is biased and inconsistent. Frankel and Romer (1999) address the endogeneity issue by using an instrumental variables (IV) approach. A valid instrument should be uncorrelated with the unobservables that affect growth but correlated with the trade share. As such, Frankel and Romer use countries' geographic characteristics as instruments for trade. They argue that "it is difficult to think of reasons that a country's geographic characteristics could have important effects on its income except through their impact on trade." Frankel and Romer estimate the model:

$$\ln Y_i = a + bT_i + c_1 \ln N_i + c_2 \ln A_i + \mu_i \qquad (1)$$

where

i = country

N = population

A = area

T = trade share

Y = income

Using geographic characteristics as instruments for T_i they conclude that trade increases income. They believe that by using IV they have uncovered a causal effect of trade on income. Their paper suggests that there is no reason to believe that the positive correlation between trade and income comes about because countries whose incomes are high for other reasons, trade more. Therefore, Frankel and Romer would lead one to conclude that trade causes growth.

It has also been argued that another source of endogeneity is omitted variables. If the relationship between trade and growth is driven by the existence of omitted variables, then trade may be an endogenous variable. For example, countries with good institutions may grow faster. However, it could be that one of the reasons that this growth occurs is because of the impact of these institutions on trade. This would imply that one needs to isolate the effect of quality of institutions on growth by including it as an independent variable. Rodrik, Subramanian and Trebbi (2002) attempt to estimate the partial effects of trade and institutions using the same instrument for trade advocated in Frankel and Romer (1999). They conclude that the effect of institutions on growth is robust to the inclusion of trade as an explanatory variable, but the effect of trade on growth is not robust to the inclusion of institutions. This casts a new light on the findings of Frankel and Romer. It may be that the results of Frankel and Romer suffer from omitted variable bias. Rodrik et al. find that trade has a positive impact on institutions. It is therefore possible that the positive effect of trade on growth found by Frankel and Romer, is actually reflecting the impact of institutions on growth. Trade may have an indirect impact on growth through its impact on institutions. Rodrik et al (2002) highlights the unresolved nature of the trade and growth debate. It also illuminates the difficulty in specifying a model with truly exogenous explanatory variables. As is well known, if the explanatory variables in a model are not exogenous, the coefficient estimates are invalid. This is one reason why some papers have addressed the trade-growth debate by using the concept of Granger causality. The rationale behind using this approach will be discussed in detail in the next section.

As the title suggests, the goal of this paper is to identify the direction of 'causality' between openness and growth. Granger causality has been used to address the issue of direction of causality between several variables – money and output [for example, Hayo (1999)] United States (U.S.) and foreign equity market yields [for example, Cochran and Mansur (1991)] international trade and political conflict/cooperation [for example, Reuveny and Kang (1996)], among others. It is a concept that has been applied in fields from Macroeconomics to Finance to Trade. Several studies, for example, – Ahmad and Harnhirun (1996), Leichenko (2000), and Tao and Zestos (2002), use Granger causality tests to explore the relationship between trade and growth.

Tao and Zestos use annual time series data from 1948-1996 to analyze the causal relations between trade and GDP growth in the U.S. and Canada. They use the Granger causality test introduced in Engle and Granger (1987). This causality test requires cointegration. Informally, two variables are cointegrated if they move together over a long period of time. If two variables, X and Y, are cointegrated, causality from X to Y can be established not only from the joint significance of the coefficients of the lagged values of the X variable but also from the joint significance of the coefficient of the one-period lagged error term of the cointegrating equation of the two variables. As such, Tao and Zestos estimate the following vector error correction (VEC) model:

$$\Delta LGDP_t = a_1 + a_{LGDP} u_{t-1} + \sum_{i=1}^{r} a_{1i}\, \Delta LGDP_{t-i} + \sum_{i=1}^{s} b_{1i}\, \Delta L\exp ort_{t-i} +$$

$$\sum_{i=1}^{k} c_{1i}\, \Delta Limport_{t-i} + v_{1t} \qquad (2)$$

$$\Delta L\exp ort_t = b_2 + b_{L\exp ort} u_{t-1} + \sum_{i-1}^{r} a_{2i}\, \Delta LGDP_{t-i} + \sum_{i=1}^{s} b_{2i}\, \Delta L\exp ort_{t-i} +$$

$$\sum_{i=1}^{k} c_{2i}\, \Delta Limport_{t-i} + v_{2t} \qquad (3)$$

$$\Delta Limport_t = c_3 + c_{Limport} u_{t-1} + \sum_{i=1}^{r} a_{3i}\, \Delta LGDP_{t-i} + \sum_{i=1}^{s} b_{3i}\, \Delta L\exp ort_{t-i} +$$

$$\sum_{i=1}^{k} c_{3i}\, \Delta Limport_{t-i} + v_{3t} \qquad (4)$$

where:

$\Delta LGDP$ = growth rate of GDP

$\Delta L\exp ort$ = growth rate of exports

$\Delta Limport$ = growth rate of imports

u_{t-1} = one-period lagged error term of the cointegrating vector

Tao and Zestos conclude that for Canada causality exists in every possible direction. They argue that export growth generated the necessary foreign exchange to pay for imported goods, which led to domestic economic growth. For the U.S. causality was found from exports to GDP. They argue that since the U.S. dollar is widely accepted for international payments, there was no causality from imports to exports.

Ahmad and Harnhirun (1996) explore the causal relationship between exports and economic growth for the countries of the Association of South East Asian Nations (ASEAN) – Indonesia, Malaysia, the Philippines, Singapore and Thailand. They use annual data on exports and Gross National Product from 1966-1988. They specify a VEC model but since the variables in their study are not cointegrated, the error correction term is excluded from their causality tests. If the error correction term is excluded the Granger causality test becomes the standard Granger (1969) test. Ahmad and Harnhirun find that exports do not Granger cause GDP growth in any of the countries. However, they find Granger causality from economic growth to exports in all five countries.

Leichenko (2000) uses the standard Granger (1969) test to investigate causality between U. S. foreign exports and economic growth at the regional level. He finds general support for bidirectional causality between exports and economic growth but notes that there is variation among regions.

Rodriquez and Rodrik (1999) argue that the measure of "openness" used in many empirical studies does not accurately reflect the existence or lack thereof of trade barriers.

The authors conduct a review of four papers – Dollar (1992), Ben-David (1993), Sachs and Warner (1995) and Edwards (1998). Dollar (1992) uses two indices of 'outward orientation' – exchange rate distortion and real exchange rate variability. Sachs and Warner (1995) use a binary variable for their openness indicator. This variable takes on the value of 0 if the economy is closed according to any of five criteria and takes on the value of 1 otherwise. Rodriquez and Rodrik show that these methods do not accurately measure openness. They also argue that there is no evidence that these more complex measures improve on a simple measure such as trade-weighted tariff averages. They posit that this is a more direct indicator of trade restrictions. They also suggest that it might be more fruitful to look for more contingent relationships between trade policy and growth. That is, they propose asking if trade restrictions operate differently in low versus high income countries. If the implications of product cycle theories are correct then openness should have a larger impact on growth in developing countries than it does in developed countries.

1.3 *Granger Causality Testing*

(i) Discussion of Approach

What is causality? This paper uses an explicit, testable definition of causality that is introduced in Granger (1969). This is different from the standard meaning of causality. The usual way of testing for the standard cause and effect relationship, and measuring the impact of one variable on another involves the specification of a structural model. However, in order for the estimates from a structural model to be valid (that is, unbiased or consistent), the explanatory variables in the model must be exogenous. As discussed in the literature review, one of the main difficulties in investigating the relationship between openness and growth is the issue of endogeneity. This may arise either because of the simultaneous bias inherent in the relationship between the two or because of omitted variable bias.

When one fits a regression line, the existence of a relationship is assumed on the basis of economic theory. The objective is to measure the ceteris paribus impact of one variable on another. However this involves introducing the untestable concept of exogeneity. As was discussed in the literature review, specifying a structural model for income per capita makes the existence of exogeneity of the explanatory variables highly questionable. It is therefore not possible to conduct a 'controlled experiment' of the impact of trade on growth.

Granger (1969) introduces an alternative, explicit and testable definition of the word causality. Some authors including Leichenko (2000) and Ahmad and Harnhirun (1996) define causality as Granger causality. However, as Harvey (1981) points out, Granger's definition of causality is purely statistical and does not correspond to the cause and effect definition of causality in the philosophical sense. Granger's definition is limited in that it is a statement about predictability and forecastibility. However, it's strength is in the fact that it is explicitly and easily testable.

It is important to note that Granger causality is a weaker condition than the condition for exogeneity. Enders (1995) shows that it is possible for a series y_t to not Granger cause the series x_t , and yet x_t is not exogenous to y_t. This leads to the question, when does Granger causality imply standard causality? The answer is, when we have exogeneity. Hamilton (1994) argues that if $\{(x_t, y_t) : t = 1,2,...\}$ is a bivariate time series: if x_t Granger causes y_t and if nothing else Granger causes x_t, then it is possible to conclude that x_t causes y_t. As stated above, exogeneity is a stronger condition than Granger causality so if x_t Granger causes y_t, and if x_t is exogenous then x_t causes y_t. Similarly Enders (1995) shows that if x_t does not Granger cause y_t and y_t is exogenous then x_t has no impact on y_t. Therefore, in the final analysis, to answer the question of standard causality we will always need exogeneity. It is important to emphasize that Granger causality is not another way of answering the question of the existence of standard causality. It is asking a different question. It proposes a different definition of the concept of causality. It asks the question, 'does the forecast of y_t improve after taking account of past values of x_t, while controlling for past values of y_t?' It is also able to give a definitive answer to the question it asks. As such that is the definition of causality utilized in this paper.

In this paper, I use a rich panel data set in order to see what allowing variation, both across countries and over time, will illuminate about the relationship between openness and growth. Specifying a structural model for income per capita would require the use of instruments for both trade and institutions. Finding suitable instruments is always a challenge. The currently agreed upon instruments used in Rodrik, Subramanian and Trebbi (2002), for both trade and institutions, do not vary over time. Therefore it would be impossible to estimate their coefficients using fixed effects estimation. It would be difficult to find appropriate time-varying instruments that are available for all the countries in the sample, over all the years included in the sample. Therefore, as was previously discussed, the exogeneity of the explanatory variables would be highly questionable. Looking at Granger causality as opposed to standard causality overcomes these issues. It will be interesting to see what this method reveals about the relationship between trade and growth. Can past values of openness predict future values of growth, after controlling for past values of growth or do past values of growth serve as an indicator of future values of openness after controlling for past values of openness? Or are both of these true?

This paper extends Tao and Zestos (2002) and other papers that have used Granger causality to identify the direction of causality between trade and growth by using a rich panel data set with more recent data. The fact that using panel data increases estimation efficiency is well known. The use of panel data also overcomes the problem of lack of sufficient data for some countries. The version of the Granger causality test used by Tao and Zestos can only be used if the variables are cointegrated and is therefore somewhat restrictive. I use the standard F-test version of the Granger causality test extended for use with panel data. This is described in more detail in the following section.

In this paper, I also address the critique of Rodriquez and Rodrik (1999). I do so by using more direct measures of openness, which will be described in more detail in section 5. Rodriquez and Rodrik suggest using trade-weighted tariff averages. However due to the existence of non-tariff trade barriers, I think that trade percentage would be a more reliable, direct measure of openness. I also address the critique of Rodriquez and Rodrik by dividing the sample into groups according to income levels to see if the relationship between openness and growth is different in low versus middle versus high income countries.

The goal of this paper is not to measure the impact of openness on growth. The goal is to try to discern whether observed correlations between openness and growth are driven by the fact that openness Granger causes growth or by the fact that growth Granger causes openness or both. Looking at whether or not past values of openness help to predict future values of growth or vice versa will help in understanding the relationship between openness and growth.

(ii) Definition of Granger Causality

If $\{(x_t, y_t) : t = 1,2,\ldots\}$ is a bivariate time series, then x_t Granger causes y_t if

$$E(y_t \mid y_{t-1}, x_{t-1}, y_{t-2}, x_{t-2}, \ldots) \neq E(y_t \mid y_{t-i}, y_{t-2}, \ldots) \quad (5)$$

In other words, if, after we control for past information of y, past values of x help to predict y, then we say that x_t Granger causes y_t [2]. As the timing of the information sets implies, Granger causality is not a statement about contemporaneous causality. Its strength lies in the fact that it is fairly easy to test without additional assumptions.

Usually, a linear model is put forward for the more general expectation, $E(y_t \mid y_{t-1}, x_{t-1}, y_{t-2}, x_{t-2}, \ldots)$, and then a joint test of significance is carried out for the lags of x. With p lags of y and q lags of x, we have

$$E(y_t \mid y_{t-1}, x_{t-1}, y_{t-2}, x_{t-2}, \ldots) =$$

$$\alpha + \gamma_1 y_{t-1} + \ldots. + \gamma_p y_{t-p} + \beta_1 x_{t-1} + \ldots \beta_q x_{t-q} \quad (6)$$

Assuming that $\{(x_t, y_t) : t = 1,2,\ldots\}$ is a weakly dependent series – that is, satisfies the central limit theorem (and therefore the law of large numbers), we can use a Wald test of

[2] Causality from y to x is defined by reversing the two variables in the previous definition

$H_0 : \beta_1 = 0,\ldots,\beta_q = 0$. The standard F test (which is just a rescaled Wald statistic) or the usual Lagrange multiplier test, maintain homoskedasticity under the null:

$$Var(y_t \mid y_{t-1}, x_{t-1}, y_{t-2}, x_{t-2},\ldots) = \sigma^2, t = 1,2,\ldots \quad (7)$$

This, rules out structural change in the variance as well as autoregressive forms of heteroskedasticity such as autoregressive conditional heteroskedasticity (ARCH) and generalized ARCH (GARCH). The ARCH model was introduced by Engle (1982) while GARCH was introduced in Bollerslev (1986). In the ARCH model the conditional variance of the error term, rather than being constant, changes over time as an autoregressive function of the squared residuals. In the GARCH model the conditional variance of the error term has both autoregressive and moving average components. That is, the variance is a function of both the past squared residuals and past variances. Heteroskedasticity-robust versions of the F statistic are easy to obtain.

Sometimes it is useful to write the conditional expectation in (6) in error form:

$$y_t = \alpha + \gamma_1 y_{t-1} + \ldots + \gamma_p y_{t-p} + \beta_1 x_{t-1} + \ldots \beta_q x_{t-q} + u_t \quad (8)$$

where, necessarily, the error term satisfies

$$E(u_t \mid y_{t-1}, x_{t-1}, y_{t-2}, x_{t-2},\ldots) = 0 \quad (9)$$

The fact that past errors are a function of the conditioning set in (9) implies that the errors are appropriately serially uncorrelated. Therefore Granger causality tests do not have to be made robust to serial correlation.

1.4 *Panel Data Granger Causality Testing*

Consider the following model for x_t and y_t:

$$y_{it} = \alpha_i + \sum_{k=1}^{K} \gamma_i^{(k)} y_{it-k} + \sum_{k=1}^{K} \beta_i^{(k)} x_{it-k} + \varepsilon_{it} \tag{10}$$

for each individual $i = 1,...,N$ and $t = 1,....,T$ with $K \in N^*$ and $\beta_i = (\beta_i^{(1)},...\beta_i^{(k)})'$

With the usual assumptions, (mentioned above), it is possible to conduct a test for Granger causality by estimating equation (10) pooled across i and t. The null hypothesis would be:

$$H_0 : \beta^{(k)} = 0 \quad \forall k = 1...K$$

While the alternative hypothesis would be:

$$H_1 : \beta^{(k)} \neq 0 \quad \forall k = 1...K$$

In this case the standard F test is asymptotically valid. However, pooling in this manner does not allow heterogeneity across i. It assumes that the lagged coefficients are the same for each individual in the sample. It is possible to conduct panel Granger causality testing that overcomes this limitation. We start by making the following assumptions:

A (1) $\{(x_{it}, y_{it}) : t = 1,2...\}$ are weakly dependent for all i.

(2) The errors are homoskedastic. That implies:

$$Var(y_{it} \mid x_{it-1}, y_{it-1},...) = \sigma^2 \text{ (a constant)}$$

B $\{(x_{i1},...x_{iT}, y_{i1}....y_{iT})\}$ are independent across i.

It is then possible to test a Homogenous Non-Causality (HNC) Hypothesis where the null hypothesis is:

$$H_0 : \beta_i = 0 \quad \forall i = 1...N$$

While the alternative hypothesis is:

$$H_1 : \beta_i = 0 \quad \forall i = 1....N_1$$

$$\beta_i \neq 0 \quad \forall i = N_1 + 1, N_1 + 2, ...N$$

If the HNC hypothesis is not rejected, we can conclude that there is no causality for all individuals of the sample. If $N_1 = 0$, then $\beta_i \neq 0$ for all i and there is causality for all i. If $0 < N_1 < N$, then there are N_1 individuals with no causality from x to y and N - N_1 individuals with causality from x to y. If $N_1 = N$, we are back to the case of failing to reject the null hypothesis.

Consider the test statistic:

$$W^{HNC} = N^{-1} \sum_{i=1}^{N} W_{iT} \tag{11}$$

where

W_{iT} = individual Wald statistic for $H_0 : \beta_i = 0$.

Under the null hypothesis W_{iT} converges asymptotically to a chi-squared distribution, with K degrees of freedom, as $T \rightarrow \infty$, $\forall i = 1...N$ with:

$$E(W_{iT}) = K \quad \text{and} \quad V(W_{iT}) = 2K$$

Therefore by the Lindberg-Levy central limit theorem, under the null hypothesis:

$$Z^{HNC} = \sqrt{N/2K} * (W^{HNC} - K) \tag{12}$$

converges asymptotically to a standard normal distribution as $T \rightarrow \infty$ first and then $N \rightarrow \infty$.

The test involves taking the Wald statistic for individual Granger causality tests for individual groups and averaging them to form a statistic that is appropriate for panel data Granger causality testing. As such, we need two sets of assumptions. We need assumptions that guarantee that each W_{iT} converges asymptotically to a chi-squared distribution with K degrees of freedom as T→ ∞. We also need an assumption that allows us to apply the central limit theorem to the averaged statistic in order to guarantee that it converges asymptotically to the standard normal distribution as N → ∞.

The assumptions in group A imply that under H_0, W_{iT} converges asymptotically to a chi-squared distribution with K degrees of freedom as T → ∞. Adding assumption B implies that under H_0, Z converges asymptotically to a standard normal distribution as T → ∞ first and then N → ∞.

Hurlin (2004) argues that this approach can be extended to the case of fixed T by making adjustments to the first and second moments of W_{iT}. He does this by assuming normality in order to apply the Magnus (1986) theorem. However, the Magnus theorem requires strict exogeneity of the regressors, which clearly cannot hold in the model presented in equation (10). Nevertheless, in his paper, Hurlin conducts Monte Carlo experiments generating the model presented in equation (10) and computing the mean and variance of the Wald statistic. He compares these with the calculated moments based on the Magnus theorem and shows that the differences are negligible. As such I will make use of the statistic he proposes in his paper, which is outlined below.

For the case of fixed T, Hurlin asserts that by the Magnus Theorem, the second order moments of W_{iT} exist if and only if:

$$T > 5 + 2K$$

He then uses the Lyapunov central limit theorem to posit that:

$$Z^F = \frac{N^{1/2}[W^{HNC} - N^{-1}\sum_{i=1}^{N} E(W_{iT})]}{\sqrt{N^{-1}\sum_{i=1}^{N} Var(W_{iT})}} \tag{13}$$

converges asymptotically to a standard normal distribution as $N \to \infty$.

Applying the Magnus theorem he gets:

$$E(W_{iT}) = K * \frac{(T-2K-1)}{(T-2K-3)}$$

$$Var(W_{iT}) = 2K * \frac{(T-2K-1)^2 * (T-K-3)}{(T-2K-3)^2 * (T-2K-5)}$$

if and only if $T > 5 + 2K$

Using these values for $E(W_{iT})$ and $Var(W_{iT})$ Hurlin puts forward the following approximated standardized statistic:

$$Z^{FHNC} = \sqrt{\frac{N * (T-2K-5)}{(2*K)*(T-K-3)}} * [\frac{(T-2K-3)}{(T-2K-1)} W^{HNC} - K] \tag{14}$$

which converges asymptotically to a standard normal distribution as $N \to \infty$.

In the case of both N and T fixed Hurlin suggests that one can use the approximated standardized statistic z^{FHNC} and compute an approximation of the appropriate critical values $[c_{NT}(\alpha)]$ for a fixed N. Based on this he gets:

$$c_{NT}(\alpha) = z_{\alpha} \sqrt{N^{-1} Var(W_{iT})} + E(W_{iT}) \tag{15}$$

1.5 *Description of Data*

(i) Initial Measures

The sample is an unbalanced panel data set of 123 countries with a time span of 20-51 years (depending on data availability). I use annual data on openness and PPP adjusted constant gross domestic product (GDP) per capita obtained from the Penn World Tables. The measure of openness used by the Penn World Tables is total trade as a percentage of GDP. This is a standard measure of openness and is also used by organizations such as the International Monetary Fund. However in the next section, I give a detailed description of an alternative method of openness which was also used. Logs were taken of both series before unit root tests were done. Taking logs allows me to calculate the elasticity of trade with respect to openness and vice versa, in preliminary regressions.

When dividing the sample into groups according to income level, I use a balanced panel of 107 countries with 20 years of data from 1981-2000. Table 1.1 gives summary statistics for the percentage trade and GDP per capita variables in levels. All values are in 1996 dollars. As expected, the average income per capita increases steadily from the low income group to the high income group in both 1981 and 2000. In 2000, the average income for the low income group is $1,482.54, for the lower middle income group is $5,195.70, for the upper middle income group is $10,494.13, and for the high income group is $25, 083.01.

In 1981, the high income countries have the lowest average trade percentage, while over the low income to the upper middle income range, the average trade percentage increases. In 2000, there is a positive relationship between average trade percentage and income group, as the low income group has an average trade percentage of 84.2, the lower middle income group has an average trade percentage of 87.2, the upper middle income group has an average trade percentage of 87.9, and the high income group has an average trade percentage of 101.1. There is therefore some evidence that larger countries trade more.

Figure 1.1 is a diagram showing the relationship between income and trade in 1980 (the earliest year for which data is available for all 123 countries). It shows a slightly positive relationship between trade and income. Figure 1.2 illustrates that this positive relationship increases in 1996 (the latest year for which data was available for all 123 countries). This weakly positive relationship is reflected in the correlation between trade and income for all countries, which as table 1.2 illustrates, is 6%.

Figures 1.1 and 1.2 indicate that some of the trade percentage values are greater than 300. Figures 1.3 and 1.4 take a closer look at the values for trade percentage for each country in 1980 and 1996, respectively. As figure 1.3 shows, in 1980, one country has a trade percentage greater than 300. This country is Romania, with a trade percentage of 325. Four countries, Romania, Sao Tome and Principe, Singapore, and Luxembourg, have trade percentages greater than 200. As figure 1.4 illustrates, in 1996 Singapore is the only country with a trade percentage greater than 300. While Hong Kong, Equatorial Guinea, Guyana, and Luxembourg are the other countries with trade percentages greater than 200. Hong Kong, Singapore and Luxembourg are all classified as high income countries.

When the panel is divided into groups according to income levels, the correlation is the strongest in the high income group – 29%. The second largest correlation, 17%, is among the upper middle income countries. The low income countries have a correlation of 15%, while the lower middle income countries show the smallest degree of correlation between trade and income. The correlation for the middle income countries as a group is 6%.

As table 1.2 illustrates, there is also a weakly positive relationship between trade and growth ((income$_t$ – income$_{t-1}$)/ income$_{t-1}$). This correlation is strongest among the high income countries – 11.4%, and weakest among the low income countries – 0.46%. So there is also evidence that the relationship between trade and growth may differ across income groups.

(ii) Alternative Measure of Openness

The initial measure of openness used may not accurately reflect how open to trade an economy's borders are. As such, I also use the difference between the volume of trade predicted by the gravity model and the volume of trade that actually occurred, to determine how 'open' a country's economy is. The gravity model relates bilateral trade between countries to GDP, distance, and other factors that might affect trade barriers. The theory states that after controlling for size, trade between two regions is inversely related to their bilateral trade barrier relative to the average barrier of the two regions to trade with all their partners.

I use the following equation for the gravity model:

$$\ln X_{ij} = k_0 + k_1 \ln Y_i + k_2 \ln Y_j - k_3 \ln D_{ij} + k_4 CONT_{ij} + k_5 LANG_{ij} + k_6 FTA_{ij} + u_{ij} \qquad (16)$$

where:

X_{ij} = value of exports from country i to country j

Y_i = real GDP of country i

D_{ij} = distance between i and j

$CONT_{ij}$ = dummy variable which is 1 if i and j are contiguous

$LANG_{ij}$ = dummy variable which is 1 if i and j share a common language

FTA_{ij}[3] = dummy variable which is 1 if i and j share a common free trade agreement

This implies:

$$X_{ij} = \frac{Y_i^{k_1} Y_j^{k_2}}{D_{ij}^{k_3}} \exp(k_0 + k_4 CONT_{ij} + k_5 LANG_{ij} + k_6 FTA_{ij}) \quad (17)$$

We know that:

T_{ij} = total trade between i and j = $X_{ij} + X_{ji}$

Therefore:

$$T_{ij} = \frac{Y_i^{k_1} Y_j^{k_2} + Y_j^{k_1} Y_i^{k_2}}{D_{ij}^{k_3}} \exp(k_0 + k_4 CONT_{ij} + k_5 LANG_{ij} + k_6 FTA_{ij}) \quad (18)$$

T_i = total trade by country i = $\sum_j T_{ij}$

Therefore:

$$T_i = \sum_{j=1}^{107} \frac{Y_i^{k_1} Y_j^{k_2} + Y_j^{k_1} Y_i^{k_2}}{D_{ij}^{k_3}} \exp(k_0 + k_4 CONT_{ij} + k_5 LANG_{ij} + k_6 FTA_{ij}) \quad (19)$$

[3] A binary variable for common continent was used as a proxy for this variable

$= T_{iP}$

= trade predicted by the gravity model for country i

In order to calculate the predicted trade for each country, I therefore need estimates of $k1 \ldots k6$, which can be obtained by estimating equation (16). However estimating this equation requires data on bilateral trade for each country pair in the sample. I have data on total trade for each country. This data cannot be used to estimate a gravity model. Therefore I obtain the estimated coefficients by doing a survey of papers that have estimated gravity equations.

A number of empirical papers exploring the gravity model have been written. Several of them have focused on the impact of national borders, for example McCallum (1995) and Anderson and Van Wincoop (2001). Others have focused on using the gravity model to distinguish among different theoretical models, for example, Evenett and Keller (1998), Head and Ries (2000) and Feenstra, Markusen and Rose (2001).

The goal of Evenett and Keller (1998) is to use the gravity model to differentiate between the Heckscher-Ohlin theory and the Increasing Returns trade theory. As such, the version of the gravity model that they use focuses on the effect of own country GDP and trading partner GDP. They do not include variables such as common language and distance which, as shown in Feenstra, Markusen and Rose (2001), have an impact on trade flows. Furthermore, Evenett and Keller use a data set of 58 countries which consists of nearly all industrialized countries but relatively few less developed countries. Head and Ries focus on the U.S. and Canada. I use a balanced panel of 107 countries therefore I need to use estimates that were obtained using a larger data set.

Bergstrand (1985) presents typical gravity equation coefficient estimates for trade flows. The coefficients for 1965 and 1976 are presented in table 1.3. All variables except the dummies are in logarithms. The model used does not include common language, which is shown to be significant in Feenstra, Markusen and Rose (2001).

Therefore, the estimated coefficients used to construct the predicted trade measure are taken from Feenstra, Markusen and Rose (2001). This paper presents a comprehensive version of the gravity model including variables such as common language and distance which are not in the model used in Evenett and Keller (1998). Feenstra, Markusen and Rose also use a much wider data set – over 110 countries. The results of Feenstra, Markusen and Rose (2001) are generally consistent with the findings in Evenett and Keller (1998) and Head and Ries (2000).

Feenstra, Markusen and Rose get different coefficient estimates depending on whether trade is in differentiated or homogeneous products. I use the estimated coefficients for 1980 for both cases. These are reported in table 1.4. Since all the variables are in logs, the estimates are the elasticities of exports with respect to each independent variable. So, for example, the elasticity of exports of differentiated goods of a particular country with respect to its trading partner's GDP is 0.65. The estimated coefficients are similar to the typical gravity equation coefficient estimates presented in Bergstrand (1985). For example, the estimate on partner GDP presented in Bergstrand (1985) is 0.65 in 1965 and 0.69 in 1976.

The measure of openness I use is:

$$O_{it} = \ln T_{itA} - \ln T_{itP} \tag{20}$$

where T_{itP} = trade predicted for country i in year t

T_{itA} = actual trade for country i in year t

For every country in the sample, predicted trade is greater than actual trade. This means that the expected value of the error term in equation (19) cannot be zero, implying that equation (19) may not be a very good model for trade. However this problem may arise because the coefficients used to construct predicted trade were not estimated with the sample data used in this paper. As was previously mentioned, because of data limitations the estimated coefficients were obtained from Feenstra, Markusen and Rose (2001).

The above measure is constructed for 107 countries for the years 1982-2000. As table 1.5 illustrates the correlation between actual and predicted trade is very low (0.1, whether I use the estimates for trade in differentiated or homogeneous goods). However once both measures of openness (trade percentage and the measure based on the gravity model) are standardized and first differenced to achieve stationarity, the correlation between the measures of openness actually used in the Granger causality tests is quite high. When trade in differentiated products is assumed, the correlation is 0.9858. When the estimated coefficients for trade in homogeneous products are used, the correlation is 0.9807. These high correlations are reflected in figures 1.5 and 1.6 which are scatter diagrams of the different measures.

1.6 *Methodology*

First of all, a test for weak dependence must be conducted. As such, I use Choi's test statistic for panel unit roots. This statistic allows a great deal of flexibility. For example, it allows the number of time series to be different across groups. Choi (2001) introduces the inverse normal test. The test statistic is:

$$Z = \frac{1}{\sqrt{N}} \sum_{i=1}^{N} \Phi^{-1}(pi) \tag{21}$$

where Φ is the standard normal cumulative distribution function and

p_i is the p-value for a unit root test statistic for the i^{th} country

For all i, pi has a uniform distribution over the interval [0,1]. Therefore Z converges to a standard normal distribution as $T \to \infty$ first and then $N \to \infty$. As Choi (2001) shows, we can reject the null hypothesis that all the time series are unit root non-stationary when the test statistic is less than the critical value of the lower tail of the standard normal distribution. Choi's unit root test was conducted on the log of income and the log of trade. The unit root test statistic used for constructing Z was the augmented Dickey-Fuller test.

I then conduct a test for Granger causality by estimating equation (10) pooled across individuals and over time. This equation is estimated by using both openness and growth alternately as the dependent variables in the model. Next, I allow heterogeneity across i by testing the HNC hypothesis using both openness and growth as dependent variables in the model. I use both alternately because I am interested in discovering whether openness Granger causes growth or growth Granger causes openness or both. First I use the entire panel and therefore employ both the Z^{HNC} and the Z^{FHNC} statistic. Then I divide the data set into groups according to income levels. I classify the countries as high, upper middle, lower middle or low income based on the system used by the

World Bank[4] for 1987 (the earliest available year). I then test the HNC hypothesis for each group by computing the Z^{FHNC} statistic and using the appropriate critical values for the case of fixed N and T.

1.7 *Results*

(a) Using Trade Percentage to Measure Openness

(i) Unit Root Testing

For the income variable, I am unable to reject the null hypothesis that for every individual in the sample the series contains a unit root. I am able to reject this null hypothesis for the percentage trade variable. However, the p-values for the individual unit root tests are less than 0.05 for 12% of the countries in the sample. Since the alternative hypothesis in the Choi test is that at least one of the time series is stationary, the test is conducted using the difference of both variables. This time the null hypothesis is rejected for both variables and the p-values for the individual unit root tests are less than 0.05 for all the countries in the sample for both income and trade. Therefore the HNC hypothesis is tested using the difference in the log of both variables. Weak dependence is one of the assumptions that is necessary for the test statistic to converge to a standard normal distribution, and I now have evidence that the difference of both series is stationary, and therefore weakly dependent.

[4] For complete list of classifications see table 1.6

(ii) Preliminary Regressions

Table 1.7 illustrates a fixed effects regression of the differenced income variable (referred to as growth) on lags of both growth and the differenced trade variable. The differences are used because as the above section indicates they are stationary. The lagged impacts of trade on growth are all positive. The elasticity of growth with respect to trade after one year is 0.074. This decreases to 0.028 after three years, increases to 0.037 after four years and then falls to 0.026 after 5 years. Therefore the long run elasticity of growth with respect to trade is 0.21. A number of specifications with different numbers of lags were estimated. The results for five lags of the trade variable are shown because all five lags are significant at the 1% level. This implies that any impact that trade may have on growth is likely to be positive and that this impact declines over time. The lagged impact of growth on trade is positive. There is therefore further evidence that larger countries trade more.

The models shown in table 1.7 were estimated using ordinary least squares for each country in the sample individually. These results are illustrated in figures 1.7 and 1.8. Figure 1.7 illustrates the long run elasticity of growth with respect to trade for each country in the sample individually. For 94 of the 123 countries in the sample, the impact is positive. St. Lucia has the largest elasticity (1.169) while the smallest elasticity (in absolute value) belongs to St. Kitts and Nevis. Both countries are classified as middle income. The average long run elasticity is 0.167. Of the 29 countries for which the elasticity is negative, 41% of them were lower middle income. However the elasticity of growth with respect to trade is positive for most (71% of) lower middle income countries, including St. Lucia, the country with the highest elasticity.

When the elasticity of trade with respect to growth is examined for the individual countries, it is positive for 72 countries in the sample. As illustrated in figure 1.8, the country with the largest magnitude of elasticity is Burkina Faso, with an elasticity of -1.667. The country with the largest positive elasticity is Indonesia with an elasticity of 1.587. The country with the smallest elasticity (in absolute value) is Thailand with an elasticity of -0.0018. The average elasticity is 0.07. Once again, of the four income groups, the lower middle group has the largest percentage (31%) of the countries for which the elasticity is negative. However, yet again, for the majority of lower middle income countries (62%) the impact of growth on trade is positive. Overall, for the majority of countries in all income groups, the relationship between trade and growth is positive. However, the lower middle income group had the largest percentage of countries for which there was a negative relationship between growth and trade.

Table 1.8 shows the results of fixed effects regressions where the impacts of trade and growth are allowed to vary by income group. The results indicate that there is variation in these impacts across income groups. For example, the impact of trade on growth after one year is 0.048% lower for the middle income group than it is for the low income group. The impact of growth on trade after one year is 0.155% lower for upper middle income countries, than it is for low income countries. This is further evidence that the relationship between trade and growth may differ across income groups.

(iii) Panel Data Granger Causality Tests

I start by conducting an F test for the null of non-causality on the pooled data. I estimate the models of table 1.7 using fixed effects. As expected the null hypothesis of non-causality is rejected both from growth to trade and from trade to growth. As table 1.9 illustrates, going from trade to growth the test statistic is 33.05 and the p-value is 0. In testing the hypothesis from growth to trade, the statistic is 11.44 and the p-value is 0.007. Table 1.7 reports the models for trade and growth that fit the best (in terms of significance). As table 1.7 implies, an AR (1) model is most appropriate for both trade and growth.

Table 1.10 reports the results of the panel data Granger causality tests that allow heterogeneity across individuals. Using one lag, the HNC hypothesis can be rejected from trade to growth as well as from growth to trade, at the 5% level. In all cases the test statistic is greater, in absolute value, than the critical value. The same is true when the data set is restricted to a balanced panel with T = 20 for 107 countries. Therefore, it is necessary to attempt to identify a sub-group of countries for which there is no causality for all i. In other words, I attempt to identify N_1. In order to do so the panel of countries is divided into 4 groups according to income levels – low, lower middle, upper middle and high.

Table 1.11 shows that for all sub-groups, it is possible to reject the hypothesis from trade to growth. Going from growth to trade the HNC hypothesis cannot be rejected for the middle income group. This result is confirmed when the middle income group is divided into upper middle and lower middle income sub-groups. The

HNC hypothesis from growth to trade cannot be rejected for both groups. This implies that for middle income countries past values of growth do not help to predict future values of trade. This is not surprising when one recalls that the middle income group has the lowest correlation between income and trade. The non-rejection of the hypothesis implies that for middle income countries the direction of Granger causality is from trade to growth.

The tests are repeated dropping assumption A2 and making the statistics robust to heteroskedasticity. The tests are also repeated for K = 2 and K = 3. These results are reported in the appendix. An AR(1) model is most appropriate for both trade and growth.

(b) Alternative Measure of Openness

(I) Trade in Differentiated Products

(i) Unit Root Testing

The null hypothesis that every individual in the sample contains a unit root is rejected for the first difference of the openness variable. The p-values for the individual unit root tests on the first difference are less than 0.05 for 82% of the sample. Therefore the HNC hypothesis is tested using the first difference of the variable.

(ii) Preliminary Regressions

Table 1.13 illustrates the fixed effects regression of the growth variable on lags of both growth and the differenced openness variable. As was the case with the percentage trade measure, the coefficients on the lagged values of openness suggest that openness has a positive impact on growth. The elasticity of growth with respect to openness after one year is 0.087. With trade as the measure of openness, this elasticity is 0.074. Once again the elasticity decreases as the lag length increases. Table 1.13 also shows evidence that larger countries are more open. So once again the result is similar to that which is obtained with trade as the measure of openness.

The models shown in table 1.13 were estimated via OLS for each country in the sample individually. These results are illustrated in figures 1.9 and 1.10. Figure 1.9 shows the long run elasticity of growth with respect to openness. This impact is positive for 64% of the countries in the sample. Most of the countries for which the impact is negative are low income countries. The largest elasticity in absolute value belongs to Denmark with a value of -0.905. Argentina is the country with the largest positive long run effect. As figure 1.9 illustrates this value is 0.793. The average long run elasticity is 0.078 which is lower than the value obtained using trade (0.167). The country with the smallest elasticity in absolute value is the Netherlands, with an elasticity of -0.0019.

The average impact of growth on openness is 0.051. However the elasticity is negative for 57% of the countries in the sample. Of the four income groups the lower middle group has the largest percentage (38%) of the countries for which the elasticity is negative. This is also true when trade is used as the measure of openness.

Table 1.14 shows evidence that the impact of growth on openness varies across income groups. For example, the impact of growth on openness after one year is 0.45% higher for upper middle income countries than it is for low income countries.

(iii) Panel Data Granger Causality Tests

Table 1.9 shows the results of conducting an F test for the null of non-causality on the pooled data. I estimate the models of table 1.13 using fixed effects. The null hypothesis of non-causality from openness to growth is rejected even at the 1% level. The test statistic is 29.65 and the p-value is 0. Similarly the null hypothesis from growth to openness is also rejected. The F statistic is 26.05 and the p-value is 0. We see that the AR(1) model is most appropriate for the openness variable.

Table 1.11 shows that once again using one lag, the HNC hypothesis from openness to growth as well as from growth to openness can be rejected for the entire sample, at the 5% level. Going from openness to growth, the HNC hypothesis cannot be rejected for the low and high income groups, while the hypothesis from growth to openness cannot be rejected for the middle income group. This suggests that for the low and high income countries the direction of Granger causality is from growth to openness, while for the middle income countries the direction of Granger causality is from openness to growth.

(II) Trade in Homogeneous Products

(i) Unit Root Testing

The null hypothesis that every individual in the sample contains a unit root is rejected using the first difference of the openness measure. The p-values for the individual unit root tests are less than 0.05 for 83% of the sample. The HNC hypothesis is tested using the first difference of the variable.

(ii) Preliminary Regressions

Once again, the estimated coefficients on the lagged values of openness, suggest that a reduction in trade barriers leads to growth. The elasticity of growth with respect to openness, after one year, is 0.09. This decreases to 0.063 after two years. As table 1.15 shows, the coefficient of lagged growth implies that larger countries are more open. Table 1.16 illustrates evidence that the impact of growth on openness varies across income groups.

Figures 1.11 and 1.12 illustrate the results of estimating the models from table 1.15 for each country individually. The average long run elasticity of growth with respect to openness is 0.073. This elasticity is positive for 64% of the countries in the sample. Most of the countries for which the impact is negative are classified as low income. As is the case with trade in differentiated products the country with the largest elasticity is Denmark, while the country with the largest positive elasticity is Argentina.

The average elasticity of openness with respect to growth is positive (0.079). However, the impact is negative for approximately half (53%) of the countries in the sample. As the previous section indicated this is also the case with trade in differentiated products. Once again, the lower middle income countries account for the largest percentage (39%) of the countries for which the elasticity is negative.

(iii) Panel Data Granger Causality Tests

I conduct an F test for the null of non-causality on the pooled data. The null hypothesis of non-causality is rejected both from growth to openness and from openness to growth. In both case the p-value is 0. Once again an AR (1) model is most suitable for the openness variable.

Using one lag, the HNC hypothesis from openness to growth, as well as from growth to openness, can be rejected for the entire sample, at the 5% level. As table 1.11 shows, the hypothesis from openness to growth cannot be rejected for low, high, and upper middle income countries. The HNC hypothesis from growth to openness cannot be rejected for the high and middle income countries.

The results for the statistics that are robust to heteroskedasticity are reported in the appendix.

1.8 *Discussion of Results*

The results using trade percentage as the measure of openness indicate that the HNC hypothesis from openness to growth is rejected for all income groups. However using the alternative measures of openness the results are different. When trade in differentiated products is assumed, the HNC hypothesis from openness to growth cannot be rejected for the low and high income groups. This suggests that the alternative measure of openness may capture more complexity in the relationship between openness and growth than the simple measure does. With a sample of 107 countries, the assumption of trade in differentiated products is more plausible than the assumption of trade in homogeneous products. Moreover, as Feenstra, Markusen and Rose (2001) points out product differentiation is usually assumed when deriving the gravity equation.

Interestingly, the results using trade percentage as the measure of openness are the same as the results using the alternative measure of openness and assuming trade in differentiated goods when testing the HNC hypothesis in the opposite direction. In both cases the HNC hypothesis from growth to openness cannot be rejected for middle income countries only.

If the alternative measure of openness is accepted as being more accurate and if trade in differentiated products is assumed, the results suggest that the direction of Granger causality for low and high income groups is from growth to openness while the direction of Granger causality for middle income countries is from openness to growth. It may be that for high income countries, there are factors (other than openness) that are more important to predicting growth. Whereas low income countries may not have the resources needed to take advantage of the opportunities provided by openness. This would leave middle income countries as the only group for which the path of openness is useful for forecasting the path of growth. It may be that for these countries, the policies that helped them to achieve middle class status work together with openness to generate increases in the growth rate of GDP.

This is consistent with the North-South theory of product development. It may be that for the developed, high income countries of the North factors such as the research and development and technology, which they used to innovate, are more important for predicting future values of growth. Middle income countries have the resources and income needed to be able to imitate the products developed in the North. Openness provides the opportunity for this technology diffusion to occur and therefore leads to growth for these countries. On the other hand, low income countries may be too 'poor' to take advantage of the opportunities provided by openness. These countries may not possess the resources or levels of income required to undertake the costs of imitation. Therefore technology transfers may not occur. Grossman and Helpman (1990) argues that technology diffusion is not automatic. If these knowledge transfers do not occur, openness will not be important for predicting growth in low income countries.

The above findings are consistent with the findings of Ahmad and Harnhirun (1996) for Indonesia and Singapore. Indonesia is classified as a low income country while Singapore is classified as a high income country. The above results therefore suggest that for these two, openness does not Granger cause growth however causality in the opposite direction is statistically supported. However Ahmad and Harnhirun also found this result for Malaysia, the Philippines and Thailand which are all classified as lower middle income countries. The results of this paper suggest that for these countries openness may Granger cause growth. The difference in results may be attributed to the fact that Ahmad and Harnhirun investigate the relationship between exports and growth while I examine the relationship between openness and growth.

The results of this paper also differ from the findings of Tao and Zestos (2002). Tao and Zestos found that imports Granger cause growth in Canada, and that exports Granger cause GDP growth in Canada and the U.S. Both of these countries are classified as high income countries. Therefore the results of this paper using the alternative measure of openness imply that openness does not Granger cause growth for these countries. However the above findings of Tao and Zestos are consistent with the results of this paper using trade percentage to measure openness. When trade percentage is used to measure openness the HNC hypothesis from openness to growth is rejected for the high income group. This similarity in results makes sense since Tao and Zestos explore the relationship between trade and GDP growth.

1.9 *Conclusion*

This paper uses a novel approach to examine the relationship between trade and growth. It shows how the concept of Granger Causality can be extended to apply to panel data. A new test statistic allowing for variation across countries as well as across time is introduced. Hopefully, future work will put forward variants of this statistic that will allow the relaxation of some of the assumptions made.

Globalization is a powerful force that isn't going anywhere any time soon. Economies are becoming more and more open. The results of this paper imply that using a more complex measure of openness may reveal subtleties about the causal relationship between openness and growth that may not be obvious. It may be that trade predicts growth but openness may only predict growth for middle income countries. If the impact of trade is isolated, there is evidence that trade may Granger cause growth. However just opening up one's economy to trade by reducing trade restrictions etc. may not be a surefire way to achieve growth. Any open economy policy may need to be accompanied by other growth inducing policies if the benefits of openness are to be reaped. It is possible that low income countries may not be in a position to reap these benefits.

The findings of this paper are not inconsistent with the endogenous growth theory or with endogenous product cycle theory. It appears that whether or not openness 'causes' growth depends. Middle income countries seem to be the ones most likely to take advantage of the opportunities provided by openness. It may be that for these countries openness leads the economy to direct resources to activities such as research and development, increasing product quality etc. that stimulate growth. Middle income countries can benefit from openness by having access to a larger market for their goods, more advanced technology, increased variety, etc. Low income countries may not possess enough resources to take advantage of these opportunities and to use openness as an engine for growth.

The results of this paper are also not inconsistent with 'infant industry' theories. It may be that in low income countries, openness leads to the destruction of local industries that are too 'young' to survive against the competition from imported goods. In this case openness may lead to unemployment and dependence on foreign countries for goods.

This paper also highlights the fact that, as was suggested in Rodrik and Rodriquez (1999), the relationship between openness and growth differs according to income levels. This is important for development policy. The findings imply that emphasis on openness as a stimulus for growth is most relevant for middle income countries, such as South Africa, Korea, and Jamaica, for which the HNC hypothesis from openness to growth is rejected.

A fruitful area for future study is the causal relationships between innovation, trade and growth implied by the endogenous growth and endogenous product cycle theories. It would be interesting to see what panel data Granger causality testing reveals about the linkages among them.

Table 1.1 – Summary Statistics for Income and Trade

Sample Split	Year	Variable	No. of Observations	Mean	Standard Deviation
Full	1981	Income	107	6197.973	5778.212
		Trade		67.488	46.330
	2000	Income		9100.228	9334.541
		Trade		84.222	50.787
Low Income	1981	Income	31	1210.275	484.718
		Trade		60.777	38.884
	2000	Income		1482.541	975.360
		Trade		66.693	45.707
Lower Middle	1981	Income	36	3891.873	1563.458
		Trade		70.873	41.010
	2000	Income		5195.696	2783.269
		Trade		87.191	37.458
Upper Middle	1981	Income	18	7231.266	2374.847
		Trade		83.075	66.795
	2000	Income		10494.130	4218.728
		Trade		87.896	47.139
High Income	1981	Income	22	16154.290	2991.545
		Trade		58.650	43.402
	2000	Income		25083.010	5483.062
		Trade		101.059	71.555

Table 1.2 – Correlations

Sample Split	Income and Trade	Growth and Trade
Full	0.0612	0.0291
Low Income	0.1528	0.0046
Lower Middle	0.0008	0.0586
Upper Middle	0.1704	0.0049
Middle Income	0.0605	0.0349
High Income	0.2909	0.1138

Table 1.3 – Typical Gravity Equation Coefficients from Bergstrand (1985)

Independent Variables	1965 Values	1976 Values
Own GDP	0.80	0.84
Partner GDP	0.65	0.69
Distance	-0.72	-0.72
Common Border	0.61	0.74
EEC Dummy[5]	0.35	0.30
EFTA Dummy[6]	0.69	0.69

Table 1.4 – Estimated Coefficients from Feenstra, Markusen and Rose (2001)

Independent Variables	Differentiated Goods	Homogeneous Goods
Own GDP	1.06	0.54
Partner GDP	0.65	0.82
Distance	-1.04	-0.73
Common Border	0.06	0.05
Common Language	0.71	0.50
FTA	1.53	1.12

Table 1.5 – Correlations

Type of Good	Actual Trade and Predicted Trade	Stationary Versions of Trade Percentage and 'Openness'
Differentiated Products	0.139	0.9858
Homogeneous Products	0.132	0.9807

[5] EEC dummy = dummy variable equal to one if both countries are members of the European Economic Community, and zero otherwise

[6] EFTA dummy = dummy variable equal to one if both countries are members of the European Free Trade Area, and zero otherwise

Table 1.6 - Classification of Countries According to Income Levels

Low	Lower Middle	Upper Middle	High
Bangladesh	Angola	Algeria	Australia
Benin	Belize	Antigua	Austria
Burkina Faso	Bolivia	Argentina	Belgium
Burundi	Botswana	Barbados	Canada
Central African Rep.[1]	Cameroon	Brazil	Denmark
Chad	Cape Verde	Cyprus	Finland
China	Chile	Gabon	France
Comoros	Colombia	Greece	Hong Kong
Congo, Dem. Rep.[1]	Congo, Republic of	Hungary	Iceland
Equatorial Guinea	Costa Rica	Iran	Ireland
Ethiopia	Cote d`Ivoire	Korea, Rep.[1] of	Israel
Gambia, The	Dominica	Panama	Italy
Ghana	Dominican Republic	Portugal	Japan
Guinea	Ecuador	Romania	Luxembourg
Guinea-Bissau	Egypt	Seychelles	Netherlands
Guyana	El Salvador	St. Kitts & Nevis	New Zealand
Haiti	Fiji	Trinidad &Tobago	Norway
India	Grenada	Uruguay	Singapore
Indonesia	Guatemala	Venezuela	Spain
Kenya	Honduras		Sweden
Lesotho	Jamaica		Switzerland
Madagascar	Jordan		Taiwan
Malawi	Malaysia		United Kingdom
Mali	Mauritius		United States
Mauritania	Mexico		
Mozambique	Morocco		
Nepal	Namibia		
Niger	Nicaragua		
Nigeria	Papua New Guinea		
Pakistan	Paraguay		
Rwanda	Peru		
Sao Tome and Principe	Philippines		
Sierra Leone	Poland		
Sri Lanka	Senegal		
Tanzania	South Africa		
Togo	St. Lucia		
Uganda	St.Vincent[2]		
Zambia	Syria		
	Thailand		
	Tunisia		
	Turkey		
	Zimbabwe		

Notes:
1 Rep. = Republic
2 St. Vincent = St. Vincent & the Grenadines

Table 1.7 – Fixed Effects Estimation

Independent Variables	Growth	ΔTrade
growth_1	**0.039 (0.016)	***0.096 (0.028)
Δtrade_1	***0.074 (0.008)	***-0.057 (0.015)
Δtrade_2	***0.047 (0.008)	
Δtrade_3	***0.028 (0.007)	
Δtrade_4	***0.037 (0.007)	
Δtrade_5	***0.026 (0.007)	

Notes: standard errors are in parentheses
** denotes significance at the 5% level
***denotes significance at the 1% level

Table 1.8 – Fixed Effects Estimation with Interactions

Independent Variables	Growth	ΔTrade
growth_1	***0.041 (0.016)	***0.181 (0.041)
growth_1*lm		**-0.156 (0.063)
growth_1*um		**-0.155 (0.076)
growth_1*h		-0.169 (0.111)
ΔTrade_1	***0.088 (0.010)	***-0.052 (0.015)
ΔTrade_2	***0.047 (0.008)	
ΔTrade_3	***0.028 (0.007)	
ΔTrade_4	***0.037 (0.007)	
ΔTrade_5	***0.026 (0.007)	
ΔTrade_1*lm	***-0.048 (0.018)	
ΔTrade_1*um	-0.015 (0.021)	
ΔTrade_1*h	0.022 (0.045)	

Notes: standard errors are in parentheses
** denotes significance at the 5% level
***denotes significance at the 1% level

Table 1.9 - Pooled Granger Causality Test Results

	Openness to Growth		Growth to Openness	
Measure of Openness	F-statistic	P-Value	F-statistic	P-value
Trade Percentage	33.05	0.0000	11.44	0.0007
Gravity – Differentiated Products	29.65	0.0000	26.05	0.0000
Gravity – Homogeneous Products	30.58	0.0000	30.41	0.0000

Table 1.10 – Granger Causality Test - Unbalanced Panel – one lag

Statistic	Trade to Growth	Growth to Trade	Critical Value
Z^{FHNC}	7.908	4.310	1.650
Z^{HNC}	9.112	5.159	1.650

Table 1.11 – Granger Causality Test - Balanced Panel – one lag - Causality from Openness to Growth

Measure of Openness	All Countries	Low Income	Lower Middle	Upper Middle	Middle Income	High Income
Trade Percentage	6.551	2.887	4.429	3.596	5.692	2.101
Gravity – Differentiated Goods	2.184	*0.468	2.407	3.246	2.661	*0.092
Gravity – Homogeneous Goods	2.390	*0.564	2.455	*1.227	2.713	*0.357

Note * denotes non-rejection at the 5% level

Table 1.12 – Granger Causality Test - Balanced Panel – one lag - Causality from Growth to Openness

Measure of Openness	All Countries	Low Income	Lower Middle	Upper Middle	Middle Income	High Income
Trade Percentage	3.811	4.597	*1.167	*-0.550	*0.635	1.954
Gravity – Differentiated Goods	3.602	3.331	*1.512	*-0.260	*1.084	2.290
Gravity – Homogeneous Goods	3.251	4.195	1.750	*-0.028	* 1.413	*-0.023

Note * denotes non-rejection at the 5% level

Table 1.13 – Fixed Effects Estimation – Openness based on Trade in Differentiated Products

Independent Variables	Growth	Openness
growth_1	-0.037 (0.026)	***0.234 (0.046)
openness_1	***0.087 (0.014)	***-0.064 (0.024)
openness_2	***0.062 (0.013)	

Notes: standard errors are in parentheses
** denotes significance at the 5% level
***denotes significance at the 1% level

Table 1.14 – Fixed Effects Estimation with Interactions - Openness based on Trade in Differentiated Products

Independent Variables	Growth	Openness
growth_1	-0.037 (0.026)	***0.390 (0.060)
growth_1*lm		**0.265 (0.115)
growth_1*um		***0.448 (0.118)
growth_1*h		0.454 (0.235)
openness_1	***0.091 (0.019)	**-0.061 (0.024)
openness_2	***0.063 (0.013)	
openness_1*lm	0.027 (0.032)	
openness_1*um	-0.016 (0.034)	
openness_1*h	-0.024 (0.103)	

Notes: standard errors are in parentheses
** denotes significance at the 5% level
***denotes significance at the 1% level

Table 1.15 – Fixed Effects Estimation – Openness based on Trade in Homogeneous Products

Independent Variables	Growth	Openness
growth_1	-0.048 (0.026)	**0.246 (0.045)
openness_1	***0.090 (0.014)	***-0.058 (0.024)
openness_2	***0.063 (0.013)	

Notes: standard errors are in parentheses
** denotes significance at the 5% level
***denotes significance at the 1% level

Table 1.16 – Fixed Effects Estimation with Interactions - Openness based on Trade in Homogeneous Products

Independent Variables	Growth	Openness
growth_1	-0.050 (0.026)	***0.389 (0.059)
growth_1*lm		**0.248 (0.113)
growth_1*um		***0.418 (0.117)
growth_1*h		0.360 (0.232)
openness_1	***0.088 (0.019)	**-0.055 (0.024)
openness_2	***0.063 (0.013)	
openness_1*lm	0.021 (0.033)	
openness_1*um	-0.024 (0.035)	
openness_1*h	-0.087 (0.102)	

Notes: standard errors are in parentheses
** denotes significance at the 5% level
***denotes significance at the 1% level

Figure 1.1 – Relationship Between Income and Trade in 1980

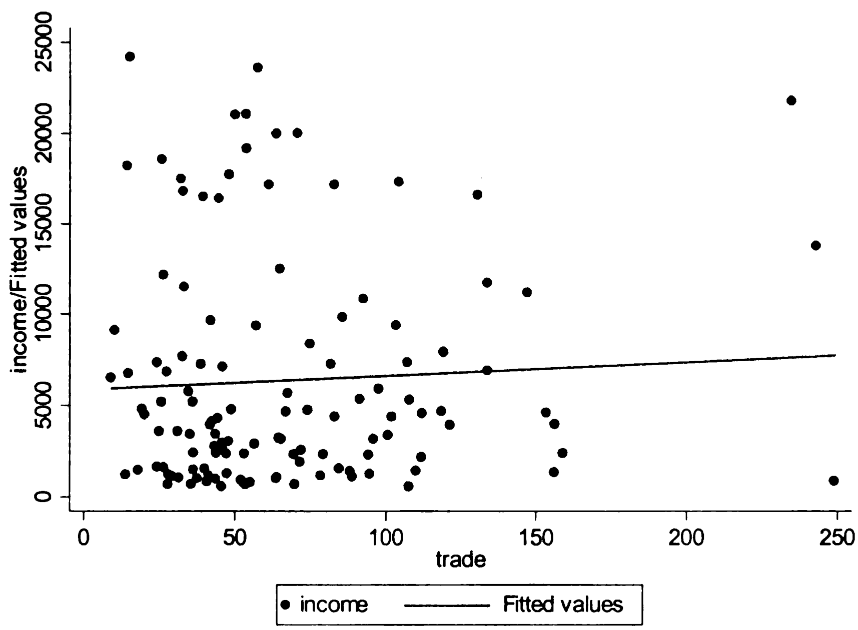


Figure 1.2 – Relationship Between Income and Trade in 1996

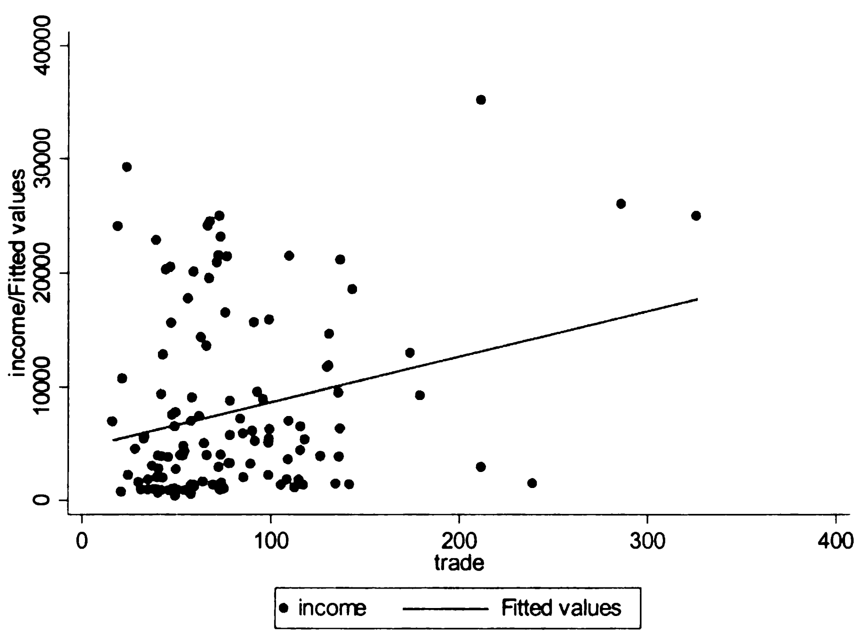
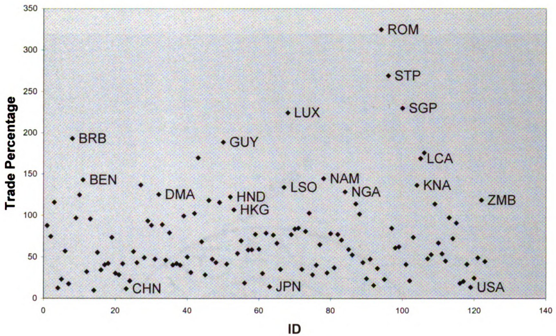


Figure 1.3 - Trade Percentage in 1980



Note: For a complete list of country abbreviations and IDs see Table 17

Figure 1.4 - Trade Percentage in 1996

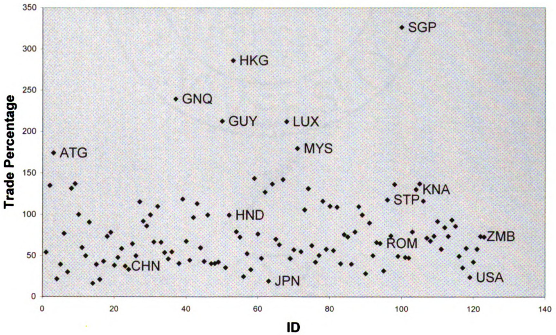


Figure 1.5 – Scatter Diagram of Values Used in Granger Causality Tests

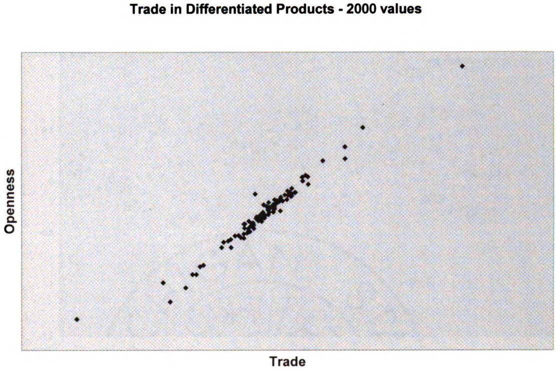


Figure 1.6 – Scatter Diagram of Values Used in Granger Causality Tests

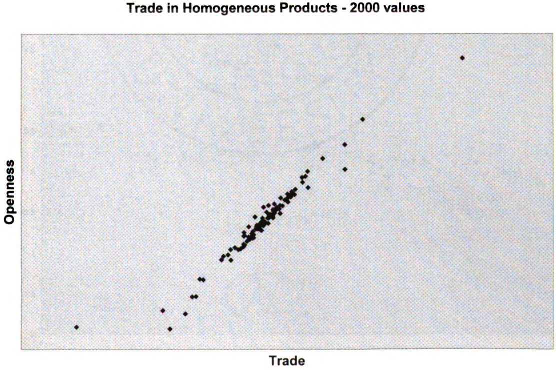


Figure 1.7 - LR Impact of trade on growth

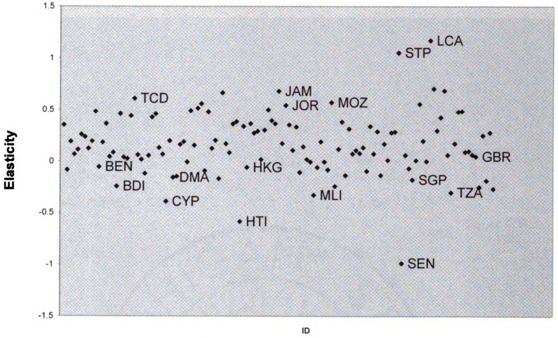


Figure 1.8 - Impact of Growth on Trade

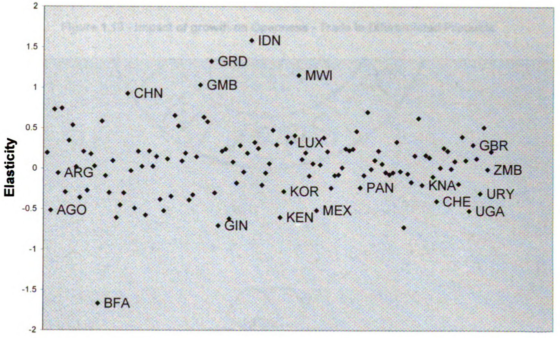


Figure 1.9 - LR Impact of Openness on Growth - Trade in Differentiated Products

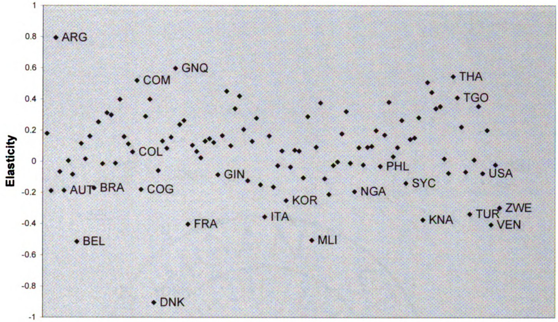


Figure 1.10 - Impact of growth on Openness - Trade in Diferentiated Products

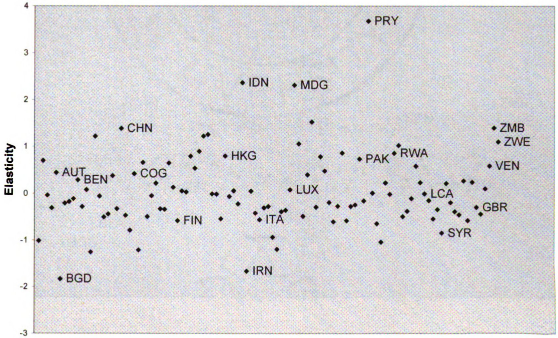


Figure 1.11 - LR impact of Openness on Growth - Trade in Homogeneous Products

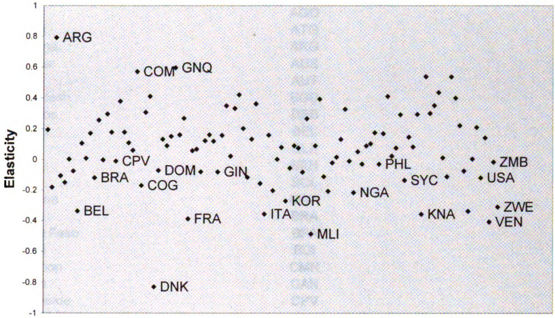


Figure 1.12 - Impact of growth on Openness - Trade in Homogeneous Goods

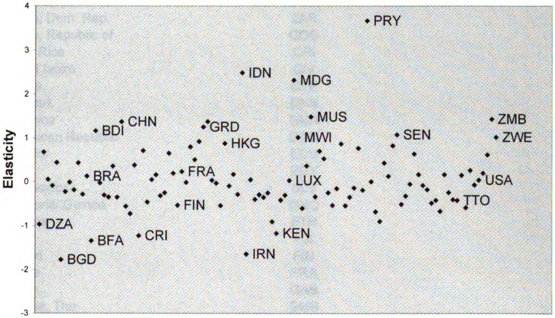


Table 1.17 – List of Country Codes and ID's

Country	Code	ID
Algeria	DZA	1
Angola	AGO	2
Antigua	ATG	3
Argentina	ARG	4
Australia	AUS	5
Austria	AUT	6
Bangladesh	BGD	7
Barbados	BRB	8
Belgium	BEL	9
Belize	BLZ	10
Benin	BEN	11
Bolivia	BOL	12
Botswana	BWA	13
Brazil	BRA	14
Burkina Faso	BFA	15
Burundi	BDI	16
Cameroon	CMR	17
Canada	CAN	18
Cape Verde	CPV	19
Central African Republic	CAF	20
Chad	TCD	21
Chile	CHL	22
China	CHN	23
Colombia	COL	24
Comoros	COM	25
Congo, Dem. Rep.	ZAR	26
Congo, Republic of	COG	27
Costa Rica	CRI	28
Cote d`Ivoire	CIV	29
Cyprus	CYP	30
Denmark	DNK	31
Dominica	DMA	32
Dominican Republic	DOM	33
Ecuador	ECU	34
Egypt	EGY	35
El Salvador	SLV	36
Equatorial Guinea	GNQ	37
Ethiopia	ETH	38
Fiji	FJI	39
Finland	FIN	40
France	FRA	41
Gabon	GAB	42
Gambia, The	GMB	43

Table 1.17 – List of Country Codes and ID's - Continued

Country	Code	ID
Ghana	GHA	44
Greece	GRC	45
Grenada	GRD	46
Guatemala	GTM	47
Guinea	GIN	48
Guinea-Bissau	GNB	49
Guyana	GUY	50
Haiti	HTI	51
Honduras	HND	52
Hong Kong	HKG	53
Hungary	HUN	54
Iceland	ISL	55
India	IND	56
Indonesia	IDN	57
Iran	IRN	58
Ireland	IRL	59
Israel	ISR	60
Italy	ITA	61
Jamaica	JAM	62
Japan	JPN	63
Jordan	JOR	64
Kenya	KEN	65
Korea, Republic of	KOR	66
Lesotho	LSO	67
Luxembourg	LUX	68
Madagascar	MDG	69
Malawi	MWI	70
Malaysia	MYS	71
Mali	MLI	72
Mauritania	MRT	73
Mauritius	MUS	74
Mexico	MEX	75
Morocco	MAR	76
Mozambique	MOZ	77
Namibia	NAM	78
Nepal	NPL	79
Netherlands	NLD	80
New Zealand	NZL	81
Nicaragua	NIC	82
Niger	NER	83
Nigeria	NGA	84
Norway	NOR	85
Pakistan	PAK	86
Panama	PAN	87

Table 1.17 – List of Country Codes and ID's - Continued

Country	Code	ID
Papua New Guinea	PNG	88
Paraguay	PRY	89
Peru	PER	90
Philippines	PHL	91
Poland	POL	92
Portugal	PRT	93
Romania	ROM	94
Rwanda	RWA	95
Sao Tome and Principe	STP	96
Senegal	SEN	97
Seychelles	SYC	98
Sierra Leone	SLE	99
Singapore	SGP	100
South Africa	ZAF	101
Spain	ESP	102
Sri Lanka	LKA	103
St. Kitts & Nevis	KNA	104
St. Lucia	LCA	105
St.Vincent & Grenadines	VCT	106
Sweden	SWE	107
Switzerland	CHE	108
Syria	SYR	109
Taiwan	TWN	110
Tanzania	TZA	111
Thailand	THA	112
Togo	TGO	113
Trinidad &Tobago	TTO	114
Tunisia	TUN	115
Turkey	TUR	116
Uganda	UGA	117
United Kingdom	GBR	118
United States	USA	119
Uruguay	URY	120
Venezuela	VEN	121
Zambia	ZMB	122
Zimbabwe	ZWE	123

What is the impact of Openness on Growth? A Panel Data Approach

2.1 *Introduction*

What is the impact of openness on growth? The benefits of openness have been touted since Adam Smith introduced the concept of absolute advantage. David Ricardo built on this concept to formalize the theory of comparative advantage. This theory states that countries can gain from trade by specializing in and exporting the good that they can produce at a lower relative cost. Openness provides opportunities for technology transfers, and increased domestic competition and efficiency resulting from international competition. However, in practice, do countries benefit from openness? Does openness lead to an increase in a country's growth rate? Does openness cause countries to grow faster?

The usual approach to investigating the relationship between openness and growth involves the specification of a cross sectional model for gross domestic product (GDP) per capita with some measure of openness and other variables on the right hand side of the equation. The argument is that if openness has a positive impact on GDP per capita then an increase in openness will lead to an increase in GDP per capita. Therefore these studies do not investigate the impact of openness on a country's growth rate. The weakness of this approach is that openness may be endogenous. This may be as a result of simultaneity. It is possible that countries with high incomes (for reasons other than trade) may trade more. To overcome the endogeneity issue I use an approach that is sometimes referred to as the 'Barro' regression, because of Barro's seminal paper. Barro (1991) investigates the concept of "conditional convergence" by running regressions of the growth rate of income over a period of time on initial income as well as other control variables. In this paper I use the Barro growth regression approach but I add initial openness as one of my explanatory variables. This overcomes the issue of simultaneity between growth and openness. Openness at the beginning of the period cannot be caused by the growth rate of income over the entire period.

Barro (2000) extends the traditional cross-sectional growth regression, popularized in Barro (1991) and Mankiw, Romer and Weil (1992), to panel data. This paper also uses panel data to take advantage of the information provided by considering variation both across countries and over time. The estimation techniques employed include pooled ordinary least squares (POLS), fixed effects (FE), and first differencing (FD), and instrumental variables versions of these. These techniques will be discussed in detail in section 3. The paper is organized as follows: section 2 reviews the relevant literature, section 3 discusses the methodology, section 4 describes the data, section 5 presents the results, and section 6 discusses the main findings of the paper in the conclusion.

2.2 Literature Review

The general framework for analysis used in Barro regressions is the following model:

$$g_{it} = k_{0t} + k_1 y_{i,t-j} + k_2 p_{i,t-j} + k_3 x_{it} + k_4 w_i + a_i + u_{it}, \quad i = 1,\ldots,N \tag{1}$$

where:

g_{it} = annual average growth rate of income = $\frac{y_{it} - y_{i,t-j}}{j}$

$y_{i,t-j}$ = log of initial period income

$p_{i,t-j}$ = primary variable of interest

x_{it} = vector of time varying explanatory variables

w_i = vector of time constant explanatory variables

a_i = time constant unobserved effect

u_{it} = idiosyncratic error term

N refers to the number of individuals in the sample and L is the length of the entire sample period. Some of the variables in x are measured as period averages while others are measured as initial period values.

In the earlier papers using this approach, for example, Barro (1991) and Mankiw, Romer and Weil (1992), the primary variable of interest is the lagged dependent variable. In more recent papers such as Barro (2000) and Dejong and Ripoll (2006), the primary variables of interest are inequality and tariffs respectively. Another feature of earlier papers, is the fact that they take a cross-sectional approach to estimating the model. In doing so they assume that the $x's$ and $w's$ control for all cross-country heterogeneity. Any unobserved heterogeneity is captured in the idiosyncratic error term so there is no need for a time constant fixed effect. These more recent papers take a panel approach to estimating (1) and therefore acknowledge the presence of the time constant unobserved effect. The different approaches to estimating equation (1) and the assumptions involved will be examined in more detail in section 3. This section discusses the motivations and findings of previous papers that have used the Barro regression.

Barro regressions have traditionally been used to explore the concept of convergence. Barro (1991) asks the question “do poor countries grow faster than rich countries?” He argues that neoclassical growth models, such as Solow (1956), Cass (1965), and Koopmans (1965), imply that a country’s per capita growth rate is negatively related to its initial level of income per person. Barro runs cross-sectional regressions of equation (1). He uses the annual average growth rate of per capita real GDP from 1960-1985, and from 1970-1985 as dependent variables. His primary variable of interest is lagged income. His $x's$ include government spending, and measures of human capital and political instability. His measures of human capital include secondary and primary school enrollment rates, the student-teacher ratio in primary and secondary schools and the adult literacy rate. He uses the period average for government spending and initial values for the enrollment rates. His sample includes 98 countries.

Barro finds support for "conditional convergence". He finds that given the human capital variables growth is negatively related to the initial level of per capita GDP. Poor countries grow faster than rich countries, but only for a given quantity of human capital.

Mankiw, Romer and Weil (1992) also test the predictions of the Solow growth model. They, too, include human capital as an explanatory variable. They argue that the augmented Solow model (which includes human capital) predicts that countries generally arrive at different steady state income levels. Therefore income per capita in any country converges to that country's steady state value. Thus, the Solow model predicts "conditional convergence". That is, convergence occurs only after one controls for the determinants of the steady state.

Mankiw, Romer and Weil (MRW) are primarily interested in the impact of initial period income on growth. Their $x's$ include investment, population growth, and school enrollment. They estimate the cross-sectional version of equation (1) over the period 1960 to 1985. Their three samples consist of 98, 75, and 22 countries. The coefficient of initial income is negative and statistically significant. They therefore argue that once one controls for differences in investment, population growth rates and human capital, convergence occurs. Thus using a slightly different set of control variables than the one used in Barro (1991) MRW also find evidence of conditional convergence.

Sachs and Warner (1995) also use cross-sectional growth regressions to explore the issue of convergence. They too find evidence of conditional convergence, but unlike Barro (1991) and MRW (1992) they argue that convergence is conditional on good policy choices. Specifically, they argue that these good policy choices include protecting private property rights and maintaining economic openness. A country is classified as having failed the property rights test if it is characterized by at least one of the following conditions:

(1) A socialist economic structure

(2) Extreme domestic unrest

(3) Extreme deprivation of civil or political rights

A country is classified as having failed the economic openness test if it possesses any of the following:

(1) A very large percentage of imports covered by quota restrictions

(2) A high percentage of exports covered by state export monopolies and state-set prices

(3) A socialist economic structure

(4) A black market premium on the official exchange rate of 20% or more

Their data set includes 117 countries over the years 1970-89. Sachs and Warner replicate the basic Barro (1991) regression of cross-country growth for their sample and time period including dummy variables for political and openness qualifications (1 for countries that fail and 0 for countries that pass). Therefore their primary variables of interest are these dummy variables. They found that political and openness non-qualifiers grow more slowly than the countries that passed the tests. They argue that this is evidence that the growth rate over this period was determined by policy choices.

Rodriquez and Rodrik (1999) question the measure of openness used in Sachs and Warner (1995). By dividing the binary openness variable into different variables based on each individual characteristic, they show that the significance of the openness dummy is being driven by the state monopoly on exports and the black market premium criteria. They then point out that the index for state monopoly on exports was taken from a World Bank study that only covered 29 African countries. Therefore non-African countries with restrictive export policies are not captured at all. They also argue that black market premia reflect a wide range of policy failures such as inflation pressures, high and growing levels of external debt, and no enforcement of rule of law, among others. They therefore conclude that the measure of openness used by Sachs and Warner does not reflect trade policy. On the contrary they argue that there is no evidence that complex binary measures such as the one used in Sachs and Warner (1995) do a better job of measuring openness than more direct measures.

As such this paper uses 2 direct measures of openness. The first one is the standard measure of openness used by institutions such as the international monetary fund (IMF) and the World Bank – trade percentage ((exports + imports)/GDP). The second is the difference between the amount of trade predicted by the gravity model and actual trade.

Levine and Renelt (1992) explore the issue of different authors using different control variables in growth regressions. They state that over 50 variables have been found to be significantly correlated with growth in at least one regression. They point out that economists who examine the relationship between fiscal policy measures and growth often ignore trade policy measures while those who explore the relationship between trade and growth often exclude fiscal policy variables. They examine whether the findings of such studies are robust to changes in the conditioning information set.

The methodology they use is extreme-bounds analysis (EBA). They test the robustness of coefficient estimates to changes in the control variables. They estimate the cross-sectional version of equation (1). They distinguish between 'I' variables, 'M' variables and 'Z' variables. 'I' variables are the set of variables always included in Barro regressions. The 'M' variable is the variable of interest and the 'Z' variables are a subset of variables chosen from a pool of variables identified as significant in past studies.

The data set covers the period 1960-1989 and includes 119 countries. The 'I' variables consist of the investment share of GDP, the initial level of real GDP per capita, the initial secondary-school enrollment rate and the average annual rate of population growth. They argued that of the 41 growth studies surveyed few included all of the above but most of them controlled for some subset.

Their main findings are that firstly no reliable, independent statistical relationship between a wide variety of macroeconomic indicators and growth exists. Secondly there is a positive and robust correlation between growth and the share of investment to GDP and thirdly the ratio of trade to output is robustly, positively correlated with the investment share.

Levine and Renelt highlight the difficulty in choosing which variables to include as explanatory variables. As was mentioned above they found that over 50 variables have been found to be correlated with growth. Since including 50 variables in a regression would result in a substantial loss in degrees of freedom and since it would be extremely difficult, if not impossible, to find data on all 50 variables for a large number of countries, one has to exercise discretion in choosing which variables to include in the information set. This decision of course will be guided firstly by the question being asked.

The findings of Levine and Renelt also provide guidance in this issue. They imply that the investment share should definitely be included in the information set. I would also argue that the complete set of 'I' variables should be included where possible. The 'I' variables were the variables that were included in most growth regressions. This would imply that they have been 'agreed upon' as being important for determining growth.

A more recent paper that has explored the issue of growth and convergence is Higgins, Levy, and Young (2006). They study growth and convergence using county level data from across the United States. Their data set includes 3,058 county level observations and covers 1970-1998. They estimate the cross-sectional version of equation (1). They include 41 conditioning variables such as area, percentage of Hispanics, school enrollment, percentage of the population below the poverty line, percentage of the population employed in finance, construction, and entertainment, among others. They are able to include so many independent variables because of the large number of observations and because they only include United States data.

The estimation techniques that they use are OLS and a procedure which they refer to as 3SLS-IV which was introduced in Evans (1997). They argue that the OLS procedures usually used require strong, unrealistic assumptions. However the technique introduced in Evans (1997) also requires strong unrealistic assumptions. This procedure and the assumptions will be discussed in detail in section 3. Higgins, Levy and Young find evidence of convergence and conclude that convergence rates are variable. For example, the Southern counties converge more than two and a half times faster than the counties in the Northeast.

Barro (2000) extends the traditional cross-sectional growth regression to panel data. Using a panel data set over three decades, 1965 to 1975, 1975 to 1985, and 1985 to 1995, Barro explores the relationship between inequality and growth. As his framework for analysis Barro uses the model in equation (1). Therefore his entire sample period is from 1965 to 1995. So in this case, $L = 30$, and $T = 3$. His sample size is 146 observations. His dependent variable is the growth rate of real per capita GDP and his independent variables include the period averages of the ratios of government spending and investment to GDP, the initial period value of years of schooling, and initial income, among others. Since he is interested in the relationship between inequality and growth, he also includes a measure of inequality, the Gini coefficient, as his primary variable of interest. The estimation technique that Barro uses is three stage least squares (3SLS) with mainly lagged values of the regressors as instruments. He finds that, ceteris paribus, changes in Gini coefficients for income inequality have no significant impact on economic growth. He concludes that overall there is little relation between income inequality and growth.

Dejong and Ripoll (2006) have also used a panel version of the growth regression. Using a panel data set of 60 countries from 1975-2000 they explore the contingent relationships between tariffs and growth. They split the data into 5 non-overlapping half decades. So, in their model, $L = 25$, $l = 5$, and $T = 5$. However, the dependent variable in their sample is logged per capita real GDP measured in 1980, 1985, ..., 2000. Their independent variables include lagged income, (for example when GDP in 1980 is the dependent variable, GDP in 1975 is an explanatory variable), proxies for human capital, ad valorem tariffs, investment as a percentage of real GDP and government expenditure as a percentage of GDP. They distinguish between stock variables measured at the beginning of the period and flow variables which are period averages. They classify lagged income and the human capital proxies as stock variables and tariffs, investment share, and government expenditure as flow variables. To capture contingencies in the relationship between tariffs and growth, they include as an explanatory variable the product of lagged income and tariffs. Alternately, they also include the product of tariffs and the 1975 income rankings. They also capture contingencies by dividing the data set into two sub-samples – one with high and upper middle income countries and the other one with lower middle and low income countries.

The authors use 4 different estimation techniques – generalized method of moments (GMM) systems, GMM difference, panel seemingly unrelated regression (SUR) and cross-sectional OLS. These techniques will be discussed in detail in section 3. Dejong and Ripoll conclude that tariffs have a significant and negative impact on growth among the world's rich countries but a positive and sometimes insignificant (depending on the estimation technique) impact on growth among the world's poor countries.

As a study of the relationship between openness and growth Dejong and Ripoll (2006) is limited. This is because of the existence of non-tariff trade barriers. I am interested in looking at the impact of openness, and not just one particular type of trade barrier, on growth. Therefore I use more comprehensive measures. Another limitation of Dejong and Ripoll (2006) is the fact that population growth is excluded as a control variable. As noted in MRW (1992) population growth is an important explanatory variable in the Solow growth model. Also as Levine and Renelt (1992) highlights, population growth is one of the variables that is included in most regressions and is therefore agreed upon by most economists as being an important determinant of GDP growth.

Dejong and Ripoll (2006) can also be criticized on the basis of one of their proxies for human capital. Their proxies for human capital include average years of secondary school for males and females over the age of 15 and log of life expectancy. It can be argued that life expectancy is not a very good measure of human capital. It is a better measure of the state of a country's health sector. Furthermore, as Levine and Renelt (1992) point out, the standard measure of human capital is school enrollment rates.

2.3 *Methodology*

Different estimation techniques can and have been used to estimate equation (1). This section provides a unified framework for the analysis of these techniques. The first approach that was employed was to estimate the equation over the entire time period L and therefore to use cross-sectional ordinary least squares (OLS). Consistency of these estimates requires the assumption that the independent variables control for all observable cross-country heterogeneity. Any unobservable factors are included in the idiosyncratic error term, which is assumed to have a conditional expectation of zero. In this case $j = L$ and initial income is measured at year 0 only. The model in equation (1) therefore becomes:

$$g_{it} = k_{0t} + k_1 y_{i,t-j} + k_2 p_{i,t-j} + k_3 x_{it} + k_4 w_i + u_{it}, \quad i = 1,\ldots,N \tag{2}$$

More recently papers such as Barro (2000) and Dijong and Ripoll (2006) have taken the approach of dividing the sample period L into sub-periods of length $l < L$. In this case $j = l$ and the result is a panel data set with N countries, and $T = \frac{L}{l}$ time periods. Using a panel data approach allows us to look at dynamic relationships. If it is assumed that there is no time constant unobserved heterogeneity, that is, a_i=0, then pooled OLS (POLS) can be used to estimate (2). Sequential exogeneity is required for consistent estimation of the coefficients of the explanatory variables. This assumption can be written as:

$$E(u_{it} \mid q_{it}) = 0, \; t = 1,\ldots,T \tag{3}$$

Where:

$$q_{it} = (y_{i,t-j}, p_{i,t-j}, x_{it}, w_i)$$

That is, we need to assume that the idiosyncratic error term is uncorrelated with the explanatory variables in the same time period.

If we acknowledge the existence of the time constant unobserved effect a_i then POLS leads to biased and inconsistent estimates. Fixed effects and FD are methods of dealing with the unobserved effect which do not require one to assume that it is uncorrelated with the explanatory variables. Both methods involve eliminating the fixed effect. However, for consistency of the estimates, they both require the assumption of strict exogeneity of the idiosyncratic error. This assumption is stronger than sequential exogeneity and can be written as:

$$E(u_{it} \mid q_{i1}, q_{i2}, \ldots, q_{iT}) = 0,\ t = 1, \ldots, T \tag{4}$$

Strict exogeneity means that the error term is uncorrelated with the explanatory variables in all time periods. The regressors in equation (1) cannot be strictly exogenous. This is because of the presence of the lagged dependent variable. Therefore if FE or FD are used as estimation techniques we need to be concerned about the endogeneity of $y_{i,t-j}$. One way to solve that problem is to use instrumental variables.

There may also be concern about the endogeneity of the x_{it} variables. If, for example, the growth rate of GDP has an impact on investment or government spending, the estimates of these variables would be biased and inconsistent. One approach to solving this problem is to use initial values for these variables. Another possible solution is to use instrumental variables. Possible instruments for the endogenous variables include lagged values of the regressors. Any time constant explanatory variables can also be used as instruments for the lagged dependent variable.

As discussed in the literature review, Higgins, Levy, and Young (2006) estimate a cross-sectional version of equation (1) using data from 1970-1998 on initial output and other conditioning variables. However the estimation technique they use is not OLS. Instead, they use a methodology introduced in Evans (1997). Evans argues that the assumption that the conditioning variables control for all cross-country heterogeneity is too strong.

The technique introduced in Evans (1997) starts with the cross-sectional variant of the model in equation (1). This is then differenced to give the following:

$$\Delta g_{it} = c_0 + k_1 \Delta y_{i,t-j} + v_{it} \tag{5}$$

It should be noted that the above equation is only true if all of the conditioning variables are constant over time. Instrumental variables is then used to estimate equation (5). Lagged values of the $x's$ and the $p's$ as well as the $w's$ can be used as instruments. The estimates from that regression are used to construct:

$$r_{it} = g_{it} - k_1^{*} y_{i,t-j} \tag{6}$$

Then r_{it} is regressed on $x_{it}, p_{i,t-j}$ and w_i as follows:

$$r_{it} = d_1 + k_2 p_{i,t-j} + k_3 x_{it} + k_4 w_i + e_{it} \tag{7}$$

Evans (1997) shows that OLS gives consistent estimators of k_2, k_3, and k_4. The weakness of the above method however is the highly unrealistic assumption that all of the conditioning variables are constant over time. While the $w's$ are constant over time, the $x's$ and the $p's$ vary. Therefore, I will not use this method.

DeJong and Ripoll (2006) use a panel data growth regression approach. The estimation techniques they use are generalized method of moments (GMM) systems, GMM difference, panel seemingly unrelated regression (SUR) and cross-sectional OLS. GMM is a method of applying instrumental variables to a system of equations. DeJong and Ripoll use the GMM dynamic panel (systems) estimator developed by Arrellano and Bover (1995) and Blundell and Bond (1998). They estimate the following version of equation (1):

$$y_{it} = k_{0t} + (1 + k_1) y_{i,t-j} + k_2 p_{it} + k_3 x_{it} + a_i + u_{it} \tag{8}$$

They use lagged differences of the variables on the right hand side of the above equation as instruments. Of course the consistency of the resulting estimates requires the assumption that there is no correlation between the differences of the regressors and the unobserved country specific effect. Their primary variable of interest is ad valorem tariffs. Their $x's$ include three proxies for human capital measured at the beginning of the period and investment share and government share measured as period averages.

The GMM difference estimator they use was developed in Arellano and Bond (1991). This involves estimating the first difference of equation (8) and using lagged levels of the explanatory variables as instruments. The rationale behind this technique is to take account of the unobservable fixed effect and any possible endogeneity. The third estimation technique used by Dejong and Ripoll is panel SUR. They specify separate regressions for each half decade and the covariance structure of the error term is allowed to vary across equations. As they point out, this is closely related to the random effects estimator. Of course this requires the assumption that the unobserved effect is uncorrelated with the explanatory variables. The final technique that DeJong and Ripoll use is cross-sectional OLS. This is the most popular estimation technique used in growth regressions.

I begin my analysis by estimating the cross-sectional variant of equation (1) using data from 1981-2000. That is, I start by assuming that $L = j = 20$, and estimate the equation using OLS. I then divide the entire sample period L into $T = 4$ sub-periods each of length $l = 5$. The result is a panel data set with $N = 107$ countries and $T = 4$ time periods. The first estimation technique I use for the panel data set is POLS. This technique ignores the presence of the time constant unobserved effect a_i, but only requires sequential exogeneity of the explanatory variables for consistency. I then use both FE and FD. Since these techniques require strict exogeneity, the presence of the lagged dependent variable is a problem. This can be solved using values of y prior to 1985 or any time constant explanatory variables as instruments for $y_{i,t-j}$.

The primary variable of interest in this paper is openness. The x_{it} variables include investment share, government spending and population growth. The time constant variable in the model is area. There may be concern about feedback from growth to the investment share and government spending. As such when using FD and FE I use instruments for these variables. As instruments I use lagged values. That is, I use values of the variables prior to 1986. For example, when T = 2, I use the 1982 values as instruments, and when T = 3, I use the 1983 values as instruments.

Another possible estimation technique involves running separate regressions for each time period using instruments for initial income, investment and government spending, and using the fitted values as instruments for initial income. The rationale behind running separate regressions to get the fitted values is to take advantage of the fact that as more recent data is used more instruments become available. For example when T = 2, instruments for initial income, investment and government spending include values of these variables prior to 1986, while when T = 4 the instruments include values of these variables prior to 1996. This approach is similar to the one put forward in Arellano and Bond (1991).

2.4 *Description of Data*

The sample is a balanced panel data set of 107 countries with data from 1981-2000. I use data on PPP adjusted constant GDP per capita, investment share of GDP, government share of GDP, openness and population obtained from the Penn World Tables (PWT). The measure of openness used by the PWT is total trade as a percentage of GDP. The alternative measure of openness used was constructed as the difference between the amount of trade predicted by the gravity model and actual trade. For details see Whitely (2006). Data on area was obtained from the Centre D'Etudes Prospective et D'Informations Internationales database.

Table 2.1 gives summary statistics for GDP per capita in 1981, and the growth rate of GDP from 1981 to 2000 ((GDP in 2000 – GDP in 1981)/GDP in 1981). Not surprisingly the average value for initial income increases steadily from 1,210 for low income countries to 16,154 for high income countries. All values are expressed in terms of 1996 dollars. The value for the growth rate over the period also increases from low income to lower middle income to higher middle income to high income countries. This provides preliminary evidence against convergence. Richer countries appear to have grown faster over the period. I do a more formal test for convergence when I conduct regression analysis.

Table 2.2 shows the 1981 values for trade share, investment share of GDP, and the share of government expenditure in GDP. The trade share is highest among the upper middle income countries (83%) and lowest among the high income countries (59%). The investment share is highest among the high income countries (23%) and lowest among the low income countries (10%). Interestingly, the low income countries have the highest value for the share of government expenditure in GDP (24.6%). The upper middle income countries rank a close second with 24.2% and the high income countries have the lowest value (15.5%). It seems that the low income countries have the highest level of government involvement in the economy. This can be viewed as evidence that less government intervention and a 'laissez-faire' attitude are better for the economy than more government intervention.

Table 2.3 shows the correlation between trade in 1981 and growth over the entire sample period. For the full sample this correlation is 0.14. The correlation between initial trade and growth is positive for all except the low income countries. The highest correlation between trade and growth is among the high income countries (0.653). The positive correlation between trade and growth is reflected in figure 2.1. Table 2.3 also shows the correlation between initial income and growth. There is evidence of convergence among the high and upper middle income countries only. Overall the correlation between initial income and growth is positive. This overall relationship is illustrated in figure 2.2.

2.5 *Results*

Table 2.4 shows the results of estimating equation 1 by cross-sectional OLS, POLS, FE and FD. Once a panel data approach is used initial openness becomes statistically significant at the 1% level. This is true no matter which of the three estimation techniques is used. The coefficient on initial openness is 0.02 using POLS, 0.03 using FE and 0.04 using FD. This would imply that a 1 percentage point increase in openness would increase growth by approximately 0.03 percentage points. The coefficient on initial income is consistently negative and statistically significant at the 1% level in all three cases. In the cross-sectional approach it is significant at the 5% level. Using both FE and FD the elasticity of growth with respect to initial income is approximately -0.1. This is similar to the coefficient of initial income in Barro (2000). The coefficient using the cross-sectional version of the model is similar to the estimates on initial income found in Barro (1991). The coefficient on investment is consistently positive and statistically significant in all cases. They imply that a 1 percentage point increase in investment would result in a 0.19 percentage point increase in growth.

Table 2.5 illustrates the results when values of income prior to 1985 are used as instruments for lagged income. In this case the number of time periods is 3. Using both FE-IV and FD-IV initial openness, initial income, and investment are all significant. Once again the coefficient on initial openness is approximately 0.03, and the coefficient on investment is 0.2. The coefficient on initial income is -0.1 using FD-IV and 0 using FE-IV. When the coefficients are standardized, the results indicate that a 1 standard deviation increase in openness increases the growth rate by 0.658 standard deviations using FD-IV and by 0.384 standard deviations using FE-IV. A 1 standard deviation increase in income decreases the growth rate by approximately 4.046 standard deviations while a 1 standard deviation increase in investment increases the growth rate by 0.564 standard deviations using FD-IV and 0.624 standard deviations using FE-IV. However, as table 2.6 illustrates once lagged values are used as instruments for initial income, investment share and government spending, all the variables become insignificant using both FE-IV and FD-IV.

Table 2.7 shows the results of running separate regressions for each time period using instruments for initial income, investment and government spending, and using the fitted values as instruments for initial income. The results are almost identical to the ones obtained using FE and FD without taking the endogeneity of lagged income into consideration. The coefficient on initial openness is 0.03 using FE and 0.04 using FD. Initial openness, initial income, and investment are all significant at the 1% level. The coefficient on initial income is approximately -0.2 while the coefficient on investment is 0.15. In this case the standardized coefficients show that a 1 standard deviation increase in openness increases growth by approximately 0.492 standard deviations using FE-IV and 0.68 standard deviations using FD-IV. A 1 standard deviation increase in initial income decreases growth by around 7.95 standard deviations while a 1 standard deviation increase in investment increases growth by around 0.4 standard deviations. So once again, the relative impacts of openness and investment are similar.

Table 2.8 shows the results of re-running the regressions using initial values for all variables and income prior to 1985 as instruments for lagged income when FE and FD are used. All the panel data estimation techniques show that openness is positive and statistically significant at the 1% level. Once the fixed effect is taken into consideration the coefficient is 0.04. The coefficient on initial income is only significant using FD-IV. The elasticity in this case is -0.1. Using FE-IV all other explanatory variables are insignificant.

The regressions in tables 4-6 are re-run adding the interaction between openness and initial income. The results are generally consistent with the previous findings. Overall, openness, initial income and investment are significant at the 1% level. The coefficient on the interaction term showed that the impact of openness on growth does in fact depend on the level of income. Tables 2.9 and 2.10 illustrate that as the level of income increases by 1 percentage point the impact of growth on openness decreases by 0.02 percentage points. Therefore the effect of openness on growth decreases as income increases. The elasticity of growth with respect to income is still approximately -0.1% and the coefficient on investment is still in the range 0.14 – 0.17. As table 2.11 illustrates once again when instruments are used for income, investment, and government spending nothing is significant at the 5% level.

The regressions in tables 4-8 are also re-run using the alternative measure of openness described in section 4. In this case openness is the difference between the amount of trade predicted by the gravity model and the amount of trade that actually occurs. Two different scenarios are investigated. In the first case, trade is assumed to be in differentiated products and in the second case trade is assumed to be in homogeneous products. The subscript 1 refers to trade in differentiated products while the subscript 2 refers to trade in homogeneous products. Generally the results for the two different cases are similar to each other and they are also similar to the results using openness measured as trade percentage.

As tables 2.12 and 2.13 illustrate once again initial openness, initial income, and investment are significant at the 1% level once FE and FD are used and without controlling for the endogeneity of any of the variables. Once again the elasticity of growth with respect to income is approximately -0.1, and the coefficient of openness is approximately 0.03, while the coefficient on investment is consistently 0.2. As before when only the endogeneity of income is taken into consideration, the three 'usual suspects' are all significant at the 1% level using FD. As table 2.14 shows, FD implies that a 1 percentage point increase in openness will lead to a 0.03 percentage point increase in growth while a 1 percentage point increase in investment will lead to a 0.2 percentage point increase in growth. Yet again the elasticity of growth with respect to income is -0.1% . Not surprisingly, the beta coefficients imply that investment and openness have a similar relative impact. As is the case when trade percentage is used to measure openness, when instruments are used for income, investment and government spending, nothing is significant.

Table 2.16 shows the results of using fitted values as instruments for income. In this case both FE and FD show that initial income and initial openness are significant (at the 1 % level in most cases). However the magnitudes of the coefficients of both variables are slightly higher than they are in the previous cases. The coefficient on initial openness is around 0.04 and the coefficient on initial income ranges from -0.3 to -0.2. Investment is only significant at the 10% level and its coefficient is slightly lower (0.1). The same general pattern of results is obtained when initial values are used for investment and government spending and lagged values of income are used as instruments for initial income. These results are in the appendix. The appendix also shows the results of including the interaction between initial openness and initial income using the alternative measure of openness. Once again the same pattern of results holds. Overall the results are remarkably robust to estimation technique, measure of openness, and the inclusion of the interaction term.

Table 2.17 shows the impact on the annual average growth rate of a 10 percentage point increase in openness. To get the figures I use the values of the coefficients for openness and the interaction term from table 10 as well as the values for initial income from table 1. It implies that a 10 percentage point increase in openness will increase the annual average growth rate by 0.32 percentage points for the entire sample using FD-IV. Using FE-IV the effect on the full sample is insignificant. Both estimation techniques indicate that as the income level decreases, the impact of openness on growth increases. Using FE-IV the effect of openness on growth becomes significant only once the income grouping becomes lower middle class while using FD-IV openness has a significant impact on growth even for the upper middle income countries. In both cases the magnitude of the impact increases as the income level decreases. The results imply that a 10 percentage point increase in openness will increase the annual average growth rate by approximately 0.65 percentage points among low income countries.

These findings appear to contradict the findings of DeJong and Ripoll (2006). They find that the marginal impact of tariffs on growth is decreasing in initial income. Specifically, using the results of the GMM Difference estimator DeJong and Ripoll argue that a 10 percentage point increase in tariff rates increases average annual growth by 0.181% among low income countries, decreases growth by 0.353% among lower middle income countries, by 0.839% among upper middle income countries and by 0.123% among high income countries. Using the GMM Systems estimator they argue that a 10 percentage point increase in tariff rates increases average annual growth by 1.309% among low income countries, by 0.366% among lower middle income countries, decreases growth by 0.492% among upper middle income countries and by 1.182% among high income countries.

However it should be noted that of the results mentioned above only the impact of tariffs on growth for low income countries using the GMM Systems estimator is significant at the 5% level or lower. For all other effects the p-value is > 0.05. In some cases the p-values are as high as 0.8 or 0.9. When DeJong and Ripoll run the regression with the interaction term between tariffs and initial income the coefficients on both the tariff rate and the interaction term are insignificant at the 5% level using all 4 estimation techniques. Only using GMM Systems estimation are these coefficients significant at the 10% level. This might lead one to argue that DeJong and Ripoll actually find that tariffs have no effect on openness. The strength of their conclusions is therefore questionable.

Mankiw, Romer and Weil (1992) show that the annualized rate of convergence λ solves:

$$k_1 = -[1 - \exp(-\lambda j)] \tag{9}$$

Using the value for k_1 (the coefficient of lagged income) of -0.1, which is obtained in the vast majority of regressions, the implied λ in this paper is 0.02. Mankiw, Romer and Weil (1992), Barro and Sala-i-Martin (1995) and Barro and Sala-i-Martin (2003) also find convergence rates of 0.02. This means that only 2% of the gap between a country's initial income level and its long run or steady state value is eliminated each year. Mankiw, Romer and Weil argue that a convergence rate of 2% means that the economy reaches halfway to steady state in around 35 years. Higgins, Levy and Young (2006) find convergence rates, for all counties within the United States, of 0.024% using OLS and 0.066% using 3SLS. DeJong and Ripoll (2006) find convergence rates varying from 0.99% to 2% using OLS, panel SUR, and GMM Systems estimation. However, using GMM Difference estimation they find a much higher convergence rate of 9%.

This paper finds support for conditional convergence. Once differences in investment, government spending, population growth, and openness are taken into consideration, lower income countries appear to grow faster than higher income countries. Moreover, the rate of convergence found in this paper is similar to the values found in other well-known papers investigating the issue of convergence.

2.6 *Discussion and Conclusions*

This paper provides evidence that initial income, investment rates and initial openness have an important effect on the rate at which countries grow. The significance and sign of the estimate of initial income is supportive of the theory of conditional convergence which is based on the augmented Solow model. An approximate annual convergence rate of 2% is found. Economic theory has long recognized investment as an engine of growth. Table 2.2 illustrates that the high income countries have the highest investment rates while the low income countries have the lowest. This implies correlation between investment and growth. The results of the regression analysis suggest a causal relationship between investment and growth.

The goal of this paper is to examine the relationship between openness and growth. Openness is found to have a positive impact on growth especially for low income countries. The results suggest that for these countries a 10 percentage point increase in openness will increase the annual average growth rate by 0.65 percentage points. This increase while plausible does appear to be a bit large. This may be because it includes the impact of human capital, which is not explicitly controlled for. Human capital is excluded as an explanatory variable because one way in which openness may influence growth is through its impact on human capital. It may be the case that openness increases human capital through the transfer of knowledge and technology, and human capital increases growth. The impact of openness on growth found in this paper is not independent of the impact of human capital investment.

The findings of this paper are important from a policy perspective. I apply relatively advanced panel data estimation techniques to the traditional 'Barro' regression and not only do I still find evidence of convergence, and evidence that openness has an impact on growth, I also find evidence that the impact of openness varies across income groups. It seems that openness is not important as an engine of growth for high income countries. Openness may provide opportunities for middle and low income countries to grow at a faster rate through knowledge transfers, investment in research and development, increase in product quality caused by competition, among others. However it appears that for high income countries emphasis on openness as a growth policy tool is ill-advised.

This is consistent with life cycle theories of product development. These theories state that innovation occurs in the high income developed countries of the North while imitation takes place in the low-wage developing countries of the South. This implies that middle and low income countries have the potential to benefit the most from openness. This is because openness provides these countries with access to the technologies developed in high income countries. Given that transfers of technologies, ideas, and processes occur, openness leads to growth for low and middle income countries. High income countries may be advised to focus on the development of technology and cutting edge products as a means for achieving growth.

The results of this paper are remarkably robust to estimation technique and measure of openness used. This gives a certain level of confidence in the findings. It seems that once investment rates, population growth, initial income levels, and government spending are controlled for, openness can increase growth among low income countries. However, the results do not imply that openness is a 'magic pill' that will automatically confer developed country status on low income countries. Instead they imply that an open economy policy combined with an emphasis on investment growth, and stable economic policies can result in an increase in growth. They imply that trade restricting policies may not be beneficial to low income countries in the long run. It may be better for these countries to focus on taking advantage of the opportunities provided by trade by investing in research and development and improvement of product quality so that they will be more competitive on the international market. Trade provides an opportunity for less developed economies to learn from more developed countries through technology transfers. Trade helps to make the processes, ideas and human capital in rich countries available to lower income countries. While I do find evidence of a positive impact of openness on growth, I also find evidence of a positive impact of investment on growth. This implies that any open economy policy should be accompanied by an emphasis on investment in order to assist countries in achieving a faster growth rate.

Table 2.1 – Summary Statistics

Sample Split	Variable	Observations	Mean	Std. Dev.
Full	Initial Income	107	6198	5778
	Growth		0.374	0.513
High Income	Initial Income	22	16154	2992
	Growth		0.578	0.346
Upper Middle	Initial Income	18	7231	2375
	Growth		0.506	0.585
Lower Middle	Initial Income	36	3892	1563
	Growth		0.331	0.480
Low	Initial Income	31	1210	485
	Growth		0.202	0.557

Notes: Initial income is measured as PPP adjusted constant GDP per capita in 1981 using 1996 as the base year. Growth is the annual average growth rate of income from 1981-2000.

Table 2.2 – Summary Statistics

Sample Split	Variable	Observations	Mean	Std. Dev.
Full	Trade	107	0.675	0.463
	Investment		0.169	0.081
	Government		0.225	0.123
High Income	Trade	22	0.587	0.434
	Investment		0.230	0.045
	Government		0.155	0.092
Upper Middle	Trade	18	0.831	0.668
	Investment		0.216	0.084
	Government		0.242	0.136
Lower Middle	Trade	36	0.709	0.410
	Investment		0.165	0.066
	Government		0.240	0.129
Low	Trade	31	0.608	0.389
	Investment		0.101	0.062
	Government		0.246	0.113

Notes: Trade is measured as (exports + imports)/GDP. Investment and government spending are also measured as ratios with respect to GDP.

Table 2.3 - Correlations

Sample Split	Trade and Growth	Initial Income and Growth
Full	0.136	0.199
High Income	0.653	-0.412
Upper Middle	0.228	-0.299
Lower Middle	0.282	0.019
Low	-0.366	0.106

Notes: Correlations are between trade percentage and the annual average growth rate of income from 1981-2000 and the GDP per capita in 1981 and the average annual growth rate from 1981-2000

Table 2.4 – Estimation Results (T = 4)

Regressor	Cross-Sectional	POLS	Fixed Effects	First-Difference
Initial Openness	0.00338 (0.00344)	***0.01674 (0.00535)	***0.03295 (0.00587)	***0.0399 (0.01054)
log (Initial Income)	**-0.0055 (0.0023)	***-0.0065 (0.0023)	***-0.0687 (0.0069)	***-0.1175 (0.0101)
Population Growth	***-0.8603 (0.210)	**-0.6336 (0.279)	0.2938 (0.239)	0.3806 (0.2435)
log (Area)	-0.0009 (0.0009)	0.0001 (0.0007)		
Investment	*0.12224 (0.02621)	***0.16197 (0.02983)	***0.18249 (0.03046)	***0.19439 (0.04636
Government	-0.00183 (0.01454)	-0.01336 (0.01319)	-0.03885 (0.0256)	-0.05558 (0.03318)

Notes: the Huber/White/Sandwich standard error estimates are in parentheses
*denotes significance at the 10% level
** denotes significance at the 5% level
***denotes significance at the 1% level

Table 2.5 – IV Estimation Results (T = 3) – using instruments for y only

Regressor	FE-IV	FD-IV
Initial Openness	**0.02429 (0.00988)	***0.04164 (0.00729)
log (Initial Income)	-0.0089 (0.0551)	***-0.1006 (0.0272)
Population Growth	0.2782 (0.3259)	0.3429 (0.2253)
Investment	***0.2187 (0.0533)	***0.19778 (0.0364)
Government	-0.04439 (0.05128)	*-0.05831 (0.03158)

Notes: standard errors are in parentheses
*denotes significance at the 10% level
** denotes significance at the 5% level
***denotes significance at the 1% level

Table 2.6 – IV Estimation – using instruments for y, I and G

Regressor	FE-IV	FD-IV
Initial Openness	0.07292 (0.05523)	0.09354 (0.21103)
log (Initial Income)	-0.0528 (0.0904)	-0.1350 (0.2252)
Population Growth	0.2148 (0.4830)	0.3147 (1.999)
Investment	-0.16597 (0.52329)	-0.32372 (2.72143)
Government	-0.24416 (0.22855)	-0.27837 (0.54198)

Notes: standard errors are in parentheses
*denotes significance at the 10% level
** denotes significance at the 5% level
***denotes significance at the 1% level

Table 2.7 – Estimation Results - using different reduced forms for each time period

Regressor	FE-IV	FD-IV
Initial Openness	***0.03112 (0.00933)	***0.04299 (0.01135)
log (Initial Income)	***-0.1534 (0.0402)	***-0.2418 (0.0653)
Population Growth	0.4144 (0.3108)	0.4782 (0.3063)
Investment	***0.1465 (0.04817)	***0.14765 (0.05685)
Government	0.04138 (0.04474)	0.03538 (0.05601)

Notes: standard errors are in parentheses
*denotes significance at the 10% level
** denotes significance at the 5% level
***denotes significance at the 1% level

Table 2.8 – Estimation Results with Initial Values and using instruments for y only

Regressor	Cross-Sectional	POLS	FE-IV	FD-IV
Openness	0.00107 (0.0052)	***0.01606 (0.00552)	***0.03643 (0.01065)	***0.04036 (0.0096)
log (Income)	0.0028 (0.0019)	-0.0012 (0.0020)	-0.0488 (0.0674)	***-0.1375 (0.0332)
log (Population)	***0.0050 (0.0017)	***0.0041 (0.0012)	-0.0048 (0.0698)	**-0.1101 (0.0477)
log (Area)	***-0.0051 (0.0010)	***-0.0028 (0.0009)		
Investment	*0.04894 (0.02714)	***0.12206 (0.03372)	0.07927 (0.05122)	***0.10926 (0.03531)
Government	-0.00115 (0.01622)	-0.00367 (0.01343)	-0.02826 (0.03253)	**-0.05839 (0.02391)

Notes: the Huber/White/Sandwich standard error estimates are in parentheses
*denotes significance at the 10% level
** denotes significance at the 5% level
***denotes significance at the 1% level

Table 2.9 – Estimation of equation 1 with interaction term

Regressor	Cross-Sectional	POLS	Fixed Effects	First-Difference
Initial Openness	***-0.07835 (0.02443)	0.03629 (0.03374)	***0.18603 (0.03764)	**0.16325 (0.07266)
Log (Initial Income)	***-0.01164 (0.00306)	-0.00501 (0.00273)	***-0.05082 (0.00805)	***-0.11563 (0.01044)
Openness*log(Income)	***0.00996 (0.00284)	-0.00223 (0.00359)	***-0.01814 (0.00441)	*-0.0148 (0.00849)
Population Growth	***-0.85799 (0.18160)	**-0.66377 (0.27754)	*0.43595 (0.23569)	*0.40966 (0.23642)
Log (Area)	-0.00031 (0.00084)			
Investment	***0.13111 (0.02838)	***0.15806 (0.02697)	***0.15158 (0.00031)	***0.17328 (0.0407)
Government	0.00214 (0.01491)	-0.01543 (0.01336)	*-0.0452 (0.02502)	*-0.05697 (0.03403)

Notes: the Huber/White/Sandwich standard error estimates are in parentheses
*denotes significance at the 10% level
** denotes significance at the 5% level
***denotes significance at the 1% level

Table 2.10 – IV Estimation using instruments for y only with interaction

Regressor	FE-IV	FD-IV
Intial Openness	***0.29947 (0.08321)	***0.19443 (0.05256)
Log (Initial Income)	0.04280 (0.06844)	***-0.08014 (0.02955)
Openness*log (Income)	***-0.03262 (0.00999)	***-0.0186 (0.00626)
Population Growth	0.50062 (0.34084)	*0.39117 (0.22473)
Investment	***0.14248 (0.0532)	***0.16965 (0.03727)
Government	-0.06654 (0.05659)	*-0.0602 (0.0316)

Notes: standard errors are in parentheses
*denotes significance at the 10% level
** denotes significance at the 5% level
***denotes significance at the 1% level

Table 2.11 – IV Estimation using instruments for y, I and G with interaction

Regressor	FE-IV	FD-IV
Initial Openness	*0.5679 (0.3065)	0.45997 (1.26222)
Log (Initial Income)	-0.02933 (0.09736)	-0.10658 (0.20474)
Openness*log (Income)	*-0.05612 (0.02835)	-0.04178 (0.11418)
Population Growth	0.80493 (0.70375)	0.47086 (2.89942)
Investment	-0.53513 (0.76411)	-0.63825 (4.23981)
Government	-0.15075 (0.26704)	-0.34075 (0.53806)

Notes: standard errors are in parentheses
*denotes significance at the 10% level
** denotes significance at the 5% level
***denotes significance at the 1% level

Table 2.12 – Estimation of equation 1 using alternative measure of openness

Regressor	Cross-Sectional	POLS	Fixed Effects	First-Difference
Grav_Open1[a]	0.00038 (0.00197)	0.00252 (0.00177)	***0.02879 (0.00528)	***0.03565 (0.00882)
Log (Initial Income)	**-0.00548 (0.00228)	**-0.00565 (0.00232)	***-0.07278 (0.00701)	***-0.12483 (0.01091)
Population Growth	***-0.84594 (0.21342)	*-0.52377 (0.28253)	0.29978 (0.23961)	0.37872 (0.24383)
Log (Area)	*-0.00132 (0.00072)	***-0.00187 (0.00051)		
Investment	***0.12255 (0.02986)	***0.18164 (0.03575)	***0.20189 (0.02908)	***0.21092 (0.05122)
Government	-0.00151 (0.01548)	-0.00606 (0.01363)	-0.03729 (0.02564)	-0.05064 (0.03327)

Notes: [a]Grav_Open1 represents the difference between trade predicted by the gravity model and actual trade assuming that trade is in differentiated products.
the Huber/White/Sandwich standard error estimates are in parentheses
*denotes significance at the 10% level
** denotes significance at the 5% level
***denotes significance at the 1% level

Table 2.13 - Estimation of equation 1 using alternative measure of openness

Regressor	Cross-Sectional	POLS	Fixed Effects	First-Difference
Grav_Open2[a]	0.00296 (0.00246)	***0.00706 (0.0023881)	***0.02931 (0.00530)	***0.03573 (0.00882)
Log (Initial Income)	**-0.00567 (0.00227)	***-0.00679 (0.00239)	***-0.07703 (0.00713)	***-0.12949 (0.01097)
Population Growth	***-0.88232 (0.21802)	**-0.55055 (0.27486)	0.32988 (0.23912)	*0.39659 (0.24041)
Log (Area)	**-0.00155 (0.00073)	***-0.00248 (0.00055)		
Investment	***0.11804 (0.03052)	***0.17175 (0.03647)	***0.20099 (0.02905)	***0.21165 (0.05131)
Government	0.00159 (0.01568)	-0.00272 (0.01355)	-0.0378 (0.02562)	-0.05226 (0.03352)

Notes: [a]Grav_Open2 represents the difference between trade predicted by the gravity model and actual trade assuming that trade is in homogeneous products.
the Huber/White/Sandwich standard error estimates are in parentheses
*denotes significance at the 10% level
** denotes significance at the 5% level
***denotes significance at the 1% level

Table 2.14 – Results using Alternative Openness Measures and instruments for y only

Regressor	FE-IV1[a]	FE-IV2[b]	FD-IV1	FD-IV2
Initial Openness	**0.02174 (0.00869)	0.01488 (0.01152)	***0.03565 (0.00624)	***0.03468 (0.00642)
Log (Initial Income)	-0.01105 (0.05579)	-0.00938 (0.05984)	***-0.10926 (0.02606)	***-0.11246 (0.02579)
Population Growth	0.31218 (0.32245)	0.32892 (0.32762)	0.34503 (0.22468)	0.36077 (0.22423)
Investment	***0.22729 (0.05271)	***0.24454 (0.06006)	***0.21823 (0.03684)	***0.22206 (0.03794)
Government	-0.0466 (0.05024)	-0.04384 (0.04985)	*-0.05216 (0.03136)	-0.05325 (0.03136)

Notes: [a]1 represents trade in differentiated products.
[b]2 represents trade in homogeneous products
standard errors are in parentheses
*denotes significance at the 10% level
** denotes significance at the 5% level
***denotes significance at the 1% level

Table 2.15 – Results using Alternative Openness Measures and instruments for y, I & G

Regressor	FE-IV1[a]	FE-IV2[b]	FD-IV1	FD-IV2
Initial Openness	0.05407 (0.03660)	0.05207 (0.04051)	-0.10517 (0.58634)	-0.16540 (1.12136)
Log (Initial Income)	-0.04688 (0.08480)	-0.05843 (0.09269)	0.08066 (0.67593)	0.15203 (1.33141)
Population Growth	0.29935 (0.50614)	0.36554 (0.52650)	-0.90295 (2.54671)	-1.11286 (4.56906)
Investment	-0.09105 (0.45774)	-0.10491 (0.46748)	2.18672 (7.37938)	2.83551 (13.57584)
Government	-0.25847 (0.22142)	-0.2456 (0.22365)	-0.26283 (1.39469)	-0.1255 (2.52184)

Notes: [a]1 represents trade in differentiated products.
[b]2 represents trade in homogeneous products
standard errors are in parentheses
*denotes significance at the 10% level
** denotes significance at the 5% level
***denotes significance at the 1% level

Table 2.16 – Estimation Results – using different reduced forms for each time period

Regressor	FE-IV1[a]	FE-IV2[b]	FD-IV1	FD-IV2
Initial Openness	***0.03627 (0.01039)	***0.04167 (0.01170)	***0.04479 (0.01273)	***0.05328 (0.01336)
Log (Initial Income)	***-0.20754 (0.07841)	***-0.19593 (0.05922)	**-0.32881 (0.13972)	***-0.28581 (0.09047)
Population Growth	0.50124 (0.36607)	0.50689 (0.34234)	0.52247 (0.39365)	0.54241 (0.33780)
Investment	*0.11867 (0.06482)	*0.11414 (0.06122)	0.12248 (0.08225)	*0.11942 (0.07162)
Government	0.06417 (0.0625)	0.04933 (0.05117)	0.07074 (0.08665)	0.04206 (0.06356)

Notes: [a]1 represents trade in differentiated products.
[b]2 represents trade in homogeneous products
standard errors are in parentheses
*denotes significance at the 10% level
** denotes significance at the 5% level
***denotes significance at the 1% level

Table 2.17 – Effect on Average Growth Rate of a 10 Percentage point Increase in Openness

Sample Split	FE	FD
Full Sample	0.14614 (0.11190)	***0.31997 (0.07701)
High Income	-0.16634 (0.17473)	0.14179 (0.11234)
Upper Middle	0.09591 (0.11909)	***0.291323 (0.08076)
Lower Middle	***0.29784 (0.10187)	***0.40647 (0.07264)
Low	***0.67919 (0.15506)	***0.62393 (0.10539)

Notes: Using the coefficient estimates for openness and openness-income interaction from table 10, this table shows the impact on growth (measured in annual percentage terms) of a 10-percentage-point increase in trade. The values for the log of income were taken from table 1.
***denotes significance at the 1% level

Figure 2.1 - Relationship Between Initial Trade and Growth

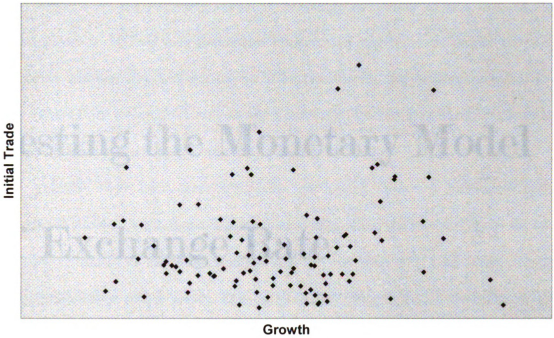
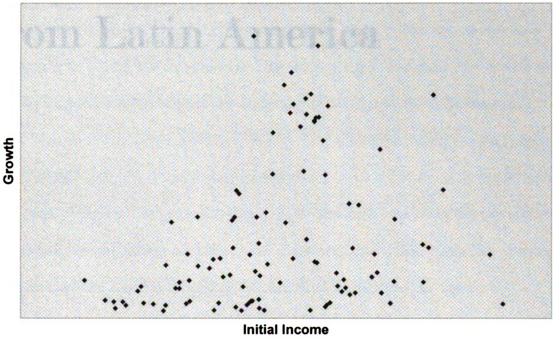


Figure 2.2 - Relationship Between Initial Income and Growth



Testing the Monetary Model of Exchange Rate Determination: Evidence from Latin America

3.1 *Introduction*

Since 1980 the monetary model of exchange rate determination has been the dominant one in the field of international finance. The appeal of the model lies in the convincing intuition on which it is based. Within this model, the exchange rate is viewed as the value of one country's money supply against another. Since its introduction several papers have been written in an attempt to determine its validity.

Initially, there was some support for this model. However, subsequent papers were able to identify weaknesses in the evidence supporting the model. One of the most damaging criticisms of the initial findings was the discovery of the existence of a unit root in the exchange rate sequence. This led to studies trying to discover whether or not a cointegrating relationship exists between the exchange rate and the monetary fundamentals. At first, the consensus was that the exchange rate and the fundamentals in the model are not cointegrated. However more recent papers, using different techniques to increase the power of the cointegration tests, suggest that the model may be appropriate as a long run phenomenon. That is, they imply that there may in fact be a cointegrating relationship between the exchange rate and the monetary fundamentals.

The papers that have previously been written testing the validity of the monetary model of exchange rate determination have focused on its applicability to industrialized first world countries. The goal of this paper is to determine whether or not this model is appropriate for describing exchange rate movements for Latin American countries. Countries in Latin America are usually characterized by exchange rate instability.

Exchange rate regimes are usually classified as fixed or flexible. However, in the real world there are a variety of different exchange rate systems which involve varying degrees of government participation in foreign exchange markets. According to a 2004 USAID Fiscal Reform Project Report exchange rate regimes can be classified as follows: "fixed–rate regimes", "intermediate regimes" and "flexible regimes". "Fixed-rate regimes" include currency unions, dollarized regimes, currency boards and fixed pegs. "Intermediate regimes" include horizontal bands, crawling pegs and crawling bands, while "flexible regimes" include managed and independent floats.

Over the sample period, the 15 countries analyzed have experienced a variety of different exchange rate systems from fixed exchange rates to crawling bands to managed floating to free floating. Some of these countries have experienced periods of frequent devaluations and currency crises. For example, Mexico experienced currency crises in 1976, 1982 and 1986. Eight out of the fifteen countries experienced a change in the actual currency used by the economy over the sample period. For example, in September 1975 in Chile the escudo was replaced by the Chilean peso at a rate of 1 peso to 1000 escudos. These changes in currency were usually driven by high inflation.

The issue being investigated in this paper is whether or not, in these countries characterized by exchange rate volatility, the value of the exchange rate can be described by relative money supplies and relative output levels. For these countries that are usually plagued by high inflation and whose currencies are not heavily traded on the world market, is there a cointegrating relationship between the exchange rate and the monetary fundamentals?

Economic theory tells us that despite the volatility in the exchange rate movements, there should be a long run relationship between the exchange rate between two countries and their relative money supplies and relative output levels. The monetary approach implies that countries with relatively restrictive monetary policies and/or relatively rapid increases in growth will experience an appreciation in their exchange rate. The monetary model is founded on the quantity theory of money which states that if a country increases its money supply faster than its growth rate of gross domestic product (GDP), then its prices will rise. Higher prices will then lead to a depreciation of the currency as the country's goods become less competitive in international markets. Despite the fact that Latin American countries usually experience high exchange rate volatility and high inflation rates and in spite of the fact that Latin American currencies are not widely traded in international foreign exchange markets, the above analysis should still hold.

The paper will proceed as follows: Section 2 provides an introduction to the monetary model. Section 3 presents the literature review. Section 4 outlines the methodology which will be followed in this paper. Section 5 provides a description of the data. Section 6 summarizes the results and section 7 highlights the main contributions of this paper in the form of a conclusion.

3.2 *The Monetary Model*

The monetary model of exchange rate determination is based on three relationships. These are the uncovered interest rate parity (UIRP) condition, purchasing power parity (PPP), and the money demand function for real balances.

The UIRP condition describes the relationship between domestic and foreign interest rates and the current and expected future spot exchange rate. It can be expressed as:

$$i_t - i_t^* = E_t \Delta s_{t+1} \quad (1)$$

where i_t = the domestic interest rate

s_t = log of the nominal spot exchange rate (domestic cost of foreign currency)

* denotes the foreign country

This equation implies that the interest rate differential is equal to the expected rate of change of the currency. The country with the higher interest rate has the currency that is expected to depreciate.

PPP is an extension of the law of one price to a basket of goods. The law of one price states that the price of a good in one country should be equal to the price of the same good in another country once the two prices are expressed in terms of the same currency. The extension to a basket of goods is usually done using the consumer price index or wholesale price index. PPP can be expressed as:

$$s_t = p_t - p_t^* \quad (2)$$

where p_t = log of the price level in the domestic country

The money demand function can be expressed as:

$$m_t - p_t = a_1 y_t - a_2 i_t \quad (3)$$

Where m_t = log of money supply

y_t = log of real output

a_1 and a_2 are both assumed to be positive. A similar equation can be written for the foreign country:

$$m_t^* - p_t^* = a_1 y_t^* - a_2 i_t^* \qquad (4)$$

Note that the parameters of the money demand function are the same for both home and foreign. This assumption is not a necessary one but it simplifies the analysis.

Combining equations (1) – (4) we get the monetary model. The first step is to solve equations (3) and (4) for p_t and p_t^*, respectively, and then substitute the resulting expressions into equation (2). This gives:

$$s_t = (m_t - m_t^*) + a_2(i_t - i_t^*) - a_1(y_t - y_t^*) \qquad (5)$$

Equation (1) is then substituted into the above expression to give:

$$s_t = b_0 + b_1(m_t - m_t^*) + b_2(y_t - y_t^*) + u_t \qquad t = 1,\ldots,T \qquad (6)$$

The error term comes from the uncovered interest rate parity condition which states that the currency with the higher interest is expected to have the currency depreciation. The expectation in equation (1) gives rise to the error term.

We expect $b_1 = 1$ and $b_2 < 0$.

3.3 *Literature Review*

One of the earliest papers testing the validity of the monetary model is Frankel (1979). Frankel estimates a model of the form:

$$s_t = c_0 + (m_t - m_t^*) + c_2(y_t - y_t^*) + c_3(i_t - i_t^*) + c_4(\pi_t - \pi_t^*) + \varepsilon_t \qquad (7)$$

where π_t = rate of inflation in domestic country

He anticipates $c_2 < 0$, $c_3 < 0$, and $c_4 > 0$. Note that this equation is slightly different from the model presented in equation (6). This is because Frankel derives and estimates the real interest rate differential version of the model. Frankel, rather than accept the UIRP, tests the validity of it. He concludes that it holds as a long run phenomenon.

He estimates the model using OLS and the Cochrane-Orcutt (C.O.) procedure. He concludes that when the above equation is estimated for the mark/dollar rate from July 1974-February 1978, the evidence is supportive of the monetary model. The signs of the coefficients were as he had hypothesized.

One of the main objections to Frankel's conclusion is the fact that when he used the C.O. procedure, his estimate of ρ was very close to one (0.99). This raises the question of non-stationarity of s_t and casts doubt on his findings.

Subsequent papers were therefore focused on determining whether or not there exists a long run relationship between the nominal exchange rate and its fundamentals, that is, whether or not the exchange rate and the monetary fundamentals are cointegrated. The findings have been inconclusive. MacDonald and Taylor (1993) find evidence of cointegration between the exchange rate and its fundamentals in a forward looking monetary exchange rate model for the United States (U.S.) $-DM over the period 1976-1990. However, Sarantis (1994) uses the same approach to conclude the opposite with data for the pound-sterling exchange rates of the U.S., Germany, Japan and France for the years 1973-1990. Other studies that have found little evidence of a long-run relationship using data from the post-Bretton Woods float include Meese (1986), Baillie and Selover (1987), McNown and Wallace (1989), Baillie and Pecchenino (1991) and Sarantis (1994).

Groen (2000) argues that previous papers have failed to find evidence of cointegration because of the availability of a short time span of data for the post Bretton

Woods float. Engle and Granger (1987) show that the power of cointegration tests increases with the time span of data used. Two approaches have been taken to increase the power of cointegration tests. The first approach involves using panel data, while the second approach involves using a long time span of data.

The first approach was utilized by Groen in his 2000 paper. He uses a panel version of the Engle and Granger cointegration test with quarterly data over the period 1973:1-1994:4 for monetary fundamentals and bilateral exchange rates with respect to both the U.S. \$ and the German DM. The sample includes the following 14 industrialized, first world countries: Australia, Austria, Canada, Finland, France, Germany, Italy, Japan, the Netherlands, Norway, Spain, Sweden, Switzerland and the United Kingdom.

Groen starts by estimating the following model using OLS on the pooled time series data:

$$s_{it} = b_{0,i} + \sum_{s=2}^{4} x_{is} d_{is} + b_1 (m_{it} - m_{it}^{*}) + b_2 (y_{it} - y_{it}^{*}) + \mu_{it} \qquad (8)$$

where $i = 1, \ldots, N$

$t = 1, \ldots, T$

d_{is} = seasonal dummies

The asterisks in the above equation refer to both the U.S. and Germany since he uses them both alternately as numeraire currencies. He anticipates $b_1 = 1$, $b_2 < 0$ and μ_{it} stationary with mean zero.

In his second stage he tests the estimated residuals of (8) using Levin and Lin's (1992) panel unit root tests. That is, he applies a panel augmented Dickey-Fuller regression to the residuals and conducts a one-sided t-test for the coefficient of the lagged residuals. The results for the 14 country panel were supportive of the monetary model for both numeraire countries. Groen was able to reject the null hypothesis at the 5% level or lower. The cointegrating vector on the U.S. $ panel was (b_1, b_2) = (0.66, -1.34) and for the DM panel it was (b_1, b_2) = (0.92, -1.82). The residuals were found to be stationary. Groen concludes that on a pooled time series level there is cointegration between the exchange rate and the fundamentals of the monetary model.

Rapach and Wohar (2002) use the second approach to increase the power of the cointegration test. They test the long run monetary model using annual data for 14 industrialized countries spanning the late 19th or early 20th century to the late 20th century. The countries included in their sample are Australia, Belgium, Canada, Denmark, Finland, France, Italy, the Netherlands, Norway, Portugal, Spain, Sweden, Switzerland, and the United Kingdom. They find support for a simple form of the long run monetary model in over half of the countries considered. For those countries, they estimate a vector error-correction model to uncover the short run dynamics.

They start by examining the integration properties of the three series. They then estimate equation (6). They also estimate a simpler form of the model by imposing the restrictions $b_1 = 1$ and $b_2 = -1$. To discover how long run equilibrium is restored between the nominal exchange rates and the monetary fundamentals, they estimate a bivariate vector error-correction model in s_t and f_t where $f_t = (m_t^* - m_t) - (y_t^* - y_t)$.

Rapach and Wohar point out that the panel cointegration test in Groen (2000) requires one to accept that the monetary model is appropriate for each member of the entire panel. However, in their paper they find that the monetary model is inappropriate for some of the countries that were included in Groen's panel. They therefore conclude that while there is some support for the long-run monetary model, this support may have been overstated by Groen.

Another approach that authors have used to test the validity of the monetary model involves evaluating its forecasting performance. This work tests the hypothesis that the foreign exchange market is not efficient and is therefore predictable. Meese and Rogoff, in their seminal 1983 paper, show that out-of-sample forecasts based on the monetary model do not beat the forecasts generated by a random walk for the U.S. dollar rates of Germany, Japan and the United Kingdom for the period 1976-2001. However Mark (1995) and Chinn and Meese (1995) find evidence that error correction terms, based on monetary models, do accurately forecast U.S. $ exchange rates for countries including Germany, Canada, and Japan within a time span of 1973-1991. On the other hand, Groen (1999), in doing further analysis of the results of Mark and Chinn and Meese, observes a break down in forecasting performance when he uses data for a longer time period (1973-1994).

3.4 *Methodology*

The goal of this paper is to determine the relevance of the monetary model for Latin American countries. I start by using OLS to estimate the model described in equation (6). I then test each of the series to determine their integration properties. The next step is to determine whether or not there exists a long run relationship between the exchange rates and their fundamentals.

I conduct Engle and Granger cointegration tests for each country within the sample. Then, following Groen (2000) I conduct a panel version of the Engle and Granger cointegration test. I use fixed effects on the pooled time series data to estimate the following model:

$$s_{it} = b_{i0} + b_1(m_{it} - m_{it}^*) + b_2(y_{it} - y_{it}^*) + u_{it} \quad , i = 1,...., N , \; t = 1,...., T \qquad (9)$$

Then I apply newly developed panel cointegration techniques to the residuals. The results from the two approaches are compared to determine the applicability of the monetary model to exchange rates in Latin America.

Panel Data Cointegration Testing

In recent years, the area of panel data cointegration has received a great deal of attention from economists. Several articles have explored the concept of extending cointegration testing to panel data[7]. The main approach that has been taken is to apply panel data unit root testing to the estimated residuals from a first stage regression. According to Pedroni (1999), in panels with homogeneous cointegrating vectors, if the regressors are assumed to be strictly exogenous, raw panel data unit root tests can be applied to the estimated residuals. Pedroni (1999) states "an interesting special case holds such that residual based tests for the null of no cointegration have distributions that are asymptotically equivalent to raw panel unit root tests if and only if the regressors are exogenous". Therefore following Groen (2000), I apply Levin and Lin's unit root test to the estimated residuals of (6). However, while Groen uses the 1992 version of Levin and Lin's test, I use the revised version in Levin, Lin and Chu (2002). The tests suggested in

[7] For a comprehensive summary see Banerjee (1999)

Levin et al (2002) are more relevant for panels of moderate size and are therefore more appropriate for me.

Levin et al (2002) test the null hypothesis that each individual time series contains a unit root against the alternative hypothesis that each time series is stationary. As both N and T approach infinity, the test statistic has a limiting normal distribution. However, Monte Carlo simulations showed that the normal distribution provides a good approximation to the empirical distribution of the test statistic in small samples. Levin et al also showed that panel cointegration tests have dramatically more power than separate unit root tests on each individual time series.

The test statistic introduced in Levin et al (2002) is:

$$t_d = \frac{\hat{d}}{STD(\hat{d})} \tag{10}$$

where $\hat{d}$ is the estimate from the regression:

$$\tilde{e}_{it} = d\,\tilde{v}_{it-1} + \tilde{u}_{it} \tag{11}$$

and

$$\tilde{e}_{it} = \frac{\hat{e}_{it}}{\hat{s}_{ui}} \qquad \tilde{v}_{it} = \frac{\hat{v}_{it-1}}{\hat{s}_{ui}} \tag{12}$$

where $\hat{s}_{ui}$ is the regression standard error in:

$$\Delta y_{it} = c_i y_{it-1} + \sum_{i=1}^{p_i} k_{iL}\, \Delta y_{it-L} + u_{it} \tag{13}$$

and $\hat{e}_{it}$ and $\hat{v}_{it-1}$ are the residuals from the regressions of Δy_{it} and y_{it-1} on Δy_{t-L} ($L=$ $1,\ldots,p_i$), respectively. $\{y_{it}\}$ is the stochastic process observed for the panel of individuals, $i=1,\ldots,N$ and each contains $t=1,\ldots,T$ time series observations.

Pedroni (1999) introduces panel cointegration tests that allow the regressors to be endogenous. This is particularly useful in this case because as discussed in the next section, the sample period includes fixed exchange rate regimes. For the monetary model to hold over that time span, one or both of the fundamentals must have adjusted to maintain the fixed rate, implying that the explanatory variables are not exogenous. He computes the asymptotic distributions and critical values for residual based tests of the null of no cointegration in panel data allowing multiple regressors and including specific fixed effects and time trends. In order to test the null hypothesis H_0: "all of the individuals of the panel are not cointegrated" against the alternative hypothesis H_1: "all of the individuals are cointegrated", Pedroni starts with the model:

$$y_{i,t} = a_i + d_i t + b_{1i}x_{1i,t} + b_{2i}x_{2i,t} + \ldots + b_{Mi}x_{Mi,t} + e_{i,t} \tag{14}$$

for $t=1,\ldots,T$; $i=1,\ldots,N$; $m=1,\ldots,M$

His panel t-statistic which he argues is analogous to the Levin and Lin panel unit root statistic applied to the estimated residuals of a cointegrated regression is:

$$Z^*_{tN,T} = \left(\tilde{s}^{*2}_{N,T} \sum_{i=1}^{N}\sum_{t=1}^{T} \hat{L}^{-2}_{11i}\, \hat{e}^{*2}_{i,t-1}\right)^{-\frac{1}{2}} \sum_{i=1}^{N}\sum_{t=1}^{T} \hat{L}^{-2}_{11i}\, \hat{e}^{*}_{i,t-1}\, \Delta \hat{e}^{*}_{i,t} \tag{15}$$

Where

$$\tilde{s}^{*2}_{N,T} = \frac{1}{N}\sum_{i=1}^{N} \hat{s}^{*2}_{i} \tag{16}$$

$$\hat{s}^{*2}_{i} = \frac{1}{T}\sum_{t=1}^{T} \hat{v}^{*2}_{i,t} \tag{17}$$

and

$\hat{v}^{*}_{it}$ is the residual from:

$$\hat{e}_{i,t} = \hat{h}_i \hat{e}_{i,t-1} + \sum_{k=1}^{K_i} \hat{h}_{i,k} \Delta \hat{e}_{i,t-k} + \hat{u}_{i,t} \tag{18}$$

and

$\hat{e}_{i,t}$ is the residual from (13)

$$\hat{L}^{2}_{11i} = \frac{1}{T}\sum_{t=1}^{T} \hat{c}^{2}_{i,t} + \frac{2}{T}\sum_{s=1}^{k_i}\left(1 - \frac{s}{k_i+1}\right) \sum_{t=s+1}^{T} \hat{c}_{i,t}\hat{c}_{i,t-s} \tag{19}$$

Where $\hat{c}_{i,t}$ is the residual from:

$$\Delta y_{i,t} = \sum_{m=1}^{M} \hat{b}_{mi} \Delta x_{mi,t} + \hat{c}_{i,t} \tag{20}$$

Pedroni shows that the asymptotic distribution for the panel t-statistic can be expressed in the form:

$$\frac{Z^{*}_{tN,T} - E\sqrt{N}}{\sqrt{v}} \rightarrow \mathrm{N}(0,1) \tag{21}$$

E and v are functions of the moments of the underlying Brownian motion functions. Pedroni calculates the values for E and v depending on the number of regressors and whether or not constants or trends have been included in the regression.

I use the Pedroni test because, unlike the Levin and Lin test, it allows endogeneity. This test is also appropriate for this case because it allows the number of regressors to be greater than one. Pedroni assumes that the researcher has in mind a particular relationship among the variables and is only interested in knowing whether or not the variables are cointegrated. In my case the 'particular relationship' of course is the monetary model.

3.5 *Description of Sample*

The sample consists of three different panels. The first panel includes 15 Latin American countries from 1967 – 2000. Figures 3.1 – 3.15 show the movements in the exchange rates for each of these countries in alphabetical order. The second panel contains the same 15 Latin American countries over the period 1981 – 2000. The 15 Latin American countries included in the sample are Argentina, Bolivia, Brazil, Chile, Colombia, Costa Rica, Ecuador, Guyana, Jamaica, Mexico, Nicaragua, Peru, Trinidad and Tobago, Uruguay, and Venezuela. The third panel consists of 7 countries over a longer time period, 1957 – 2000. These 7 countries – Brazil, Colombia, Costa Rica, Ecuador, Nicaragua, Peru, and Venezuela were chosen based on data availability. It will be interesting to see if using a longer time span but a smaller group of countries, will change the results.

In the early 1980's most Latin American countries started moving from "intermediate regimes" such as crawling pegs to "flexible regimes" such as managed or dirty floating. For example, figure 3.10 illustrates movements in the Mexican peso from 1967 – 2000. In the early 1980's the peso starts to exhibit more movement than it had in previous years. In fact, in 1976, the peso moved to a managed floating regime. As figure 3.4 illustrates, after the mid 1970's, the Chilean peso started experiencing more volatility.

In 1975, the Chilean peso experienced a series of depreciations. In 1977, a policy of pre-announced devaluation was adopted. The exchange rate was fixed in 1979. However by 1982, the system had changed to a dirty float. In 1983 there was a sharp depreciation (which coincided with a fall in real GDP), so a crawling peg was established until 1985. From 1985-1997 the exchange rate was left to float within two predetermined bands. The bands were widened to 12.5% in 1997. In that same year, Chile's exchange rate system was classified as managed floating. In 1999 the classification was changed to independent floating. Chile's experience from 1967 – 2000 is a good example of the exchange rate regime volatility experienced by most Latin American countries over the same period.

This volatility in the exchange rate movements may be difficult to see in the graphs because of the changes to the currencies used over the sample period. Table 3.1 shows the coefficient of variation (cv) for all 15 countries over different time periods. It illustrates that for all countries except Chile and Jamaica the cv over the last 20 years of the sample is greater than the cv over the first 14 years of the sample. The most extreme case is Uruguay which moves from a cv of 0.051 from 1967-1980 to a cv of 436420.4 from 1981-2000. For most of the countries the cv over the last 14 years of the sample is greater than the cv over the first 14 years of the sample. It should be noted that for Jamaica the cv over the first 11 years of the sample is 0.129 implying that more volatility started occurring around 1978. For Chile the cv over the first 6 years is 0.0298. The exchange rate for that country started becoming more volatile around 1973.

Of the 15 countries in the sample, Argentina and Ecuador are the only ones that by the end of the sample period had moved to "fixed-rate regimes". In the 1990's Argentina fixed its peso to the U.S. dollar. However in 2002 Argentina unpegged the peso from the U.S. dollar. In 2000 Ecuador made the conversion to dollarization. As such, the U.S. dollar is currently the official currency of Ecuador.

The sample of Latin American countries includes three Caribbean territories – Guyana, Jamaica and Trinidad and Tobago. As figures 3.8, 3.9, and 3.13 and table 3.1 illustrate they share the characteristic of experiencing greater movement in their exchange rates from the 1980's onwards. However over the period 1967 – 2000 these countries experienced less volatility in their exchange rate regimes than the other Latin American countries. All three countries currently have a floating exchange rate regime. However the Trinidad and Tobago dollar (TTD) was not floated until 1993. In 1972, the TTD was pegged to the pound sterling. In 1976, it was pegged to the U.S. dollar (USD) at a rate of 2.4 TTD to 1 USD. By 1985 the new peg was 3.6 TTD to 1 USD. In 1988, the rate was devalued to 4.25 TTD to the USD.

As was mentioned in the introduction, for eight countries within the sample – Argentina, Bolivia, Brazil, Chile, Mexico, Nicaragua, Peru, and Uruguay – there were changes in the currency used over the sample period. As figures 3.1 to 3.4, 3.10 to 3.12, and 3.14 illustrate these countries appear to have a currency valued at $0 to 1 US$ at the beginning of the sample period. While these values are very small, none of them is actually zero. In these countries high inflation rendered the currency useless at some point or points in time, so the currency was changed. All exchange rates are expressed in terms of the current currency of the country.

For example, in Argentina, the currency is currently the peso, (formally called the peso convertible). However in 1967 the currency was the peso moneda nacional. In 1970 this was replaced by the peso ley at a rate of 1 peso ley to 100 pesos moneda nacional. In 1983 the peso argentino replaced the peso ley at a rate of 1 to 10,000. In 1985 the austral replaced the peso argentine at a rate of 1 austral for 1000 pesos. In 1991 the peso replaced the austral at a rate of 1 to 10,000. In the final analysis one peso would be worth 10,000,000,000,000 pesos moneda nacional today.

Colombia, Costa Rica, Ecuador, Guyana, Jamaica, Trinidad and Tobago and Venezuela experienced no change in their currency over the sample period. For example, the sucre was the currency of Ecuador between 1884 and 2000. Ecuador is currently a dollarized economy. It will be interesting to see if the individual results will be different for this group of countries. A priori I would not expect them to be. The relationship between the exchange rate and the monetary fundamentals should still hold despite changes in currency.

The data on exchange rates and money supply was obtained from the International Monetary Fund's International Financial Statistics website. All exchange rates are expressed in terms of current currency per US$. The money supply data is the seasonally adjusted sum of currency outside banks plus demand deposits. It is the measure of money usually referred to as M1. The data on income was obtained from the Penn World Tables. Income is measured as PPP adjusted constant GDP.

3.6 *Results*

(a) Preliminary Analysis

The first step is to estimate the model using OLS. The results for panel 1 are illustrated in table 3.2. Both the heteroskedasticity robust and the Newey-West standard errors are reported. The two sets of standard errors are very similar implying that there may not be much serial correlation present in the model. Using the first panel, for all 15 countries except Colombia b_1 is statistically significant at the 1% level. In fact in all cases the p-value is zero. For 13 countries b_1 is approximately 1. However, for Trinidad and Tobago b_1 is 0.46 and for Ecuador b_1 is -4.4. Formal statistical testing shows that the hypothesis that b_1 is equal to 1 cannot be rejected at the 5% level for Chile, Costa Rica, Jamaica, Mexico, and Venezuela using the first panel.

The coefficient of relative GDP is significant at the 1% level for 10 countries. In some cases the p-value is zero. For Jamaica, b_2 is significant at the 5% level. For Mexico, b_2 is significant at the 10% level, whereas b_2 is not significant for Guyana, Venezuela and Brazil. In 8 of the 10 countries for which b_2 is significant, it is also negative. However, for Colombia, Nicaragua and Ecuador b_2 is positive.

Overall the results of the OLS estimation are quite supportive of the monetary model. The general pattern is $b_1 = 1$ and $b_2 < 0$. Table 3.2 also reports the coefficient from an AR(1) regression of the residuals of each country. The evidence here is mixed.

The root ranges from as low as 0.14 for Chile to as high as 0.97 for Ecuador. Interestingly the results for Chile are quite supportive of the monetary model while the results for Ecuador are not. Colombia is another country for which the root is close to one and the results are not supportive of the model. Casual inspection of the roots implies that there is evidence of cointegration for some countries and no cointegration for others. More formal tests of cointegration are conducted later.

The results for the second panel of countries show the same general pattern. The coefficient of relative money supply is significant at the 1% level for every country except Trinidad and Tobago and Colombia. In fact for each of these 14 countries except Ecuador, the p-value is zero. For all 14 countries except Chile and Ecuador b_1 is approximately 1. For Chile b_1 is 1.6 and for Ecuador b_1 is -1.5. Formal statistical testing shows that the hypothesis that b_1 is equal to 1 cannot be rejected at the 5% level only for Jamaica and Venezuela. The coefficient of GDP is significant at the 1% level for 8 countries. In some cases the p-value is zero. For Brazil and Guyana it is significant at the 5% level. However for Costa Rica, Jamaica, Nicaragua, Trinidad and Tobago, and Venezuela, b_2 is not significant (even at the 10% level). In all cases where b_2 is significant it is also negative.

Using the third panel for all 7 countries the p-value on b_1 is zero. For all countries except Ecuador b_1 is approximately 1. For Ecuador b_1 is -4.17. Formal statistical testing shows that the hypothesis that b_1 is equal to 1 cannot be rejected at the 5% level for Costa Rica and Venezuela. Only for Nicaragua and Venezuela is b_2 not significant at the 1%

level. For Nicaragua it is significant at the 10% level while for Venezuela it is not significant at all.

Dickey-Fuller (DF) and augmented Dickey-Fuller (ADF) tests are conducted for each series. A trend term is included where necessary for the relative money supply and GDP series based on both visual inspection and formal statistical testing. The results of the formal unit root tests for the first panel are illustrated in tables 3.3-3.5. They indicate that the exchange rate series is I(1) for every country except Brazil. For Brazil the test results imply that the series is I(2). The unit root tests on relative GDP imply that for every country except Brazil the series are I(1). For Brazil the results indicate that relative GDP is stationary. The results for money supply are more mixed. For 9 countries the series is I(1). For 5 countries – Bolivia, Brazil, Nicaragua, Peru, and Uruguay, the series is I(2) and for Colombia the series is I(0).

Using the third panel the unit root tests indicate that for all 7 countries except Brazil and Nicaragua all three series are I(1). Once again for Brazil the exchange rate and relative money supply series are both I(2). However in this case relative GDP is I(1). For Nicaragua as is the case with the first panel, both the exchange rate and relative GDP are I(1). A comparison of the results for the two panels indicates that of the 7 countries in panel three the results differ for Colombia and Peru. Using a longer time span all three series are I(1) for Colombia while using the shorter time span, the relative money supply sequence is stationary and relative GDP and the exchange rate are I(1). For Peru using the longer time span all three series are I(1) while panel 1 indicates that only the exchange rate series and relative GDP are I(1).

The results of the D-F test show the orders of integration based on a mechanical performance of the test. However in time series analysis most macroeconomic variables are I(1). An inspection of the root of relative GDP series for Brazil shows that the value of 0.84 is similar to the value for other countries that are found to be I(1). Furthermore it is higher than the root for countries such as Costa Rica, Guyana, and Venezuela for which the D-F test implies that the series is I(1). Therefore I treat all three series as I(1) for all countries and conduct cointegration tests on the residuals from the monetary model for all countries. It is possible that the D-F test concludes that some of the series are not I(1) because of the small sample size or because of type 1 or type 2 errors.

Fixed effects is used on the pooled time series data to estimate equation (9). As table 3.6 indicates, for all three panels the results are generally supportive of the monetary model. For panels 1 and 2 the p-values for both relative money and relative GDP are zero. Using the third panel the p-value for relative money supply is zero while relative GDP is significant at the 10% level. In all cases b_1 is approximately 1 and b_2 is negative. Using panels 1 and 3 the null hypothesis that b_1 is equal to 1 cannot be rejected at the 5 % level.

I apply a panel version of the Engle and Granger procedure to the residuals from the fixed effects regression. As table 3.7 illustrates for panel 1 the t-statistic is -8.82 and a regression of the residuals on their lagged values shows that the root is 0.71. The critical values for the Engle and Granger test cannot be used in this case because the procedure is being applied to panel and not time series data. However the high t-statistic and the size of the root imply that the residuals may be stationary. There is therefore preliminary evidence that the panel data implies that there is a long run relationship between the exchange rate and the fundamentals. The results using panel 2 show even more evidence of co-integration. In this case the t-statistic is -10.21 and the root is 0.48. Panel 3 shows the weakest support for co-integration. However it should be noted that when Colombia, Ecuador and Venezuela, the three countries for which the model fits most poorly, are excluded from this panel the root falls from 0.976 to 0.72.

To find out the order of integration of the panel data I use Choi's test for panel unit roots. Choi (2001) introduces the inverse normal test. The test statistic is:

$$Z = \frac{1}{\sqrt{N}} \sum_{i=1}^{N} \Phi^{-1}(pi) \qquad (22)$$

where Φ = standard normal cumulative distribution function and

p_i = p-value for a unit root test statistic for country i

The null hypothesis is that all the time series are unit root non-stationary while the alternative hypothesis is that at least one of the time series is stationary. Using the first panel the null hypothesis cannot be rejected at the 5% level for all three series. When the test is conducted on the first difference of each series the null hypothesis is rejected and the p-value for the individual unit root tests is less than 0.05 for the majority of countries in the sample. This implies that each series is I(1).

Using panel 3 the null hypothesis cannot be rejected for the money supply and GDP series. The null hypothesis is rejected for the first difference of all three variables and the p-values are less than 0.05 for most of the countries in the sample. Once again this is evidence that each series is I(1).

(b) Formal Cointegration Testing

I use the two-step Engle and Granger procedure to conduct cointegration tests on the individual countries. Since there are two explanatory variables in the model I obtain the critical values from Engle and Yoo (1987). As table 3.8 shows the null hypothesis of no cointegration is rejected for Argentina, Bolivia, Chile, Nicaragua, Trinidad and Tobago, and Uruguay using the first panel. Using the second panel the hypothesis is rejected for all of the above countries as well as Guyana and Mexico. For panel 3 the hypothesis can only be rejected for Costa Rica. Additionally table 3.8 shows that for Brazil, Jamaica and Peru, even though the Engle and Granger test formally shows no cointegration, the t-statistic for these countries is not as low as it is for Colombia, Ecuador and Venezuela. So there is evidence of a long run relationship between the exchange rate and the fundamentals. A comparison with table 3.2 shows that the countries for which cointegration is found all have residuals with roots of 0.41 or lower. For the countries for which the hypothesis of no cointegration could not be rejected the roots are all above 0.41. A comparison with table 3.2 also shows that the results of the OLS estimation for the countries for which a long run relationship exists are supportive of the monetary model. For countries such as Colombia and Ecuador where the results are unsupportive of the model the null hpothesis of no cointegration cannot be rejected.

The first panel data cointegration test that I apply is the Levin et al test. It should be noted that this test is only valid if the regressors are exogenous. I apply the test to the residuals from the fixed effects regression. The results of this test indicate that the null hypothesis of no cointegration can be rejected. As table 3.9 shows, for panel 1 the test statistic is -3.95 implying that the null hypothesis that the residuals are non-stationary for every individual in the panel can be rejected. For panels 2 and 3 the test statistics are -4.62 and -1.92 respectively. So this test implies that there is a long run relationship between the exchange rate and the fundamentals. As implied by the individual test results the rejection of the null hypothesis is strongest for panel 2 and weakest for panel 3. Panel 2 has the largest number of countries for which the hypothesis of no cointegration is formally rejected. Recall that for panel 3 formal evidence of cointegration is only found for Costa Rica. It is therefore not surprising that the Levin et al test shows that the null hypothesis can only be rejected at the 5% level. For panels 1 and 2, it is rejected at the 1% level.

Table 3.9 also illustrates the results of the Pedroni test. Using all three panels the null hypothesis of no cointegration for each member of the panel can be rejected even at the 1% level in favour of the alternative hypothesis that for each country there exists a cointegrating vector. Once again the rejection of the null hypothesis is strongest for panel 2 and weakest for panel 3. So the Pedroni test also implies that there is in fact a long run relationship between the exchange rate and the fundamentals. This along with the results of the fixed effects regression implies that the monetary model holds as a long run phenomenon.

(c) Error Correction Model

If a set of variables is cointegrated, their short term movements must be influenced by the deviation from the long run relationship. This leads to the concept of an error correction model. Error correction models describe how the variables respond to short term deviations in order to restore equilibrium. The following trivariate vector error correction model in s_t, $m_t - m_t^*$, and $y_t - y_t^*$ is estimated for each country for which evidence of cointegration is found:

$$\Delta s_t = k_1 + k_s u_{t-1} + k_{11} \Delta s_{t-1} + k_{12} \Delta (m_{t-1} - m_{t-1}^*) + k_{13} \Delta (y_{t-1} - y_{t-1}^*) + e_{st} \quad (23)$$

$$\Delta (m_t - m_t^*) = k_2 + k_m u_{t-1} + k_{21} \Delta s_{t-1} + k_{22} \Delta (m_{t-1} - m_{t-1}^*) + k_{23} \Delta (y_{t-1} - y_{t-1}^*) + e_{mt} \quad (24)$$

$$\Delta (y_t - y_t^*) = k_3 + k_y u_{t-1} + k_{31} \Delta s_{t-1} + k_{32} \Delta (m_{t-1} - m_{t-1}^*) + k_{33} \Delta (y_{t-1} - y_{t-1}^*) + e_{yt} \quad (25)$$

A maximum lag length of 1 is used because additional lags are insignificant. The above model is estimated for Argentina, Bolivia, Chile, Nicaragua, Trinidad and Tobago and Uruguay for panel 1, all of the above countries as well as Guyana and Mexico for panel 2 and Costa Rica for panel 3. The results for panel 1 are illustrated in table 3.10. On the basis of the results of the Pedroni test, the panel version of the above model is also estimated. These results are illustrated in table 3.11.

Table 3.10 illustrates that for Argentina, Nicaragua, and Trinidad and Tobago, it is relative GDP that adjusts to restore the long run equilibrium. For Bolivia, the opposite result holds. That is, for that country it is the exchange rate and relative money supply that adjust to restore the long run equilibrium. The results suggest that when there is a gap between the exchange rate and the fundamentals both the exchange rate and the money supply adjust to reduce the exchange rate, that is, appreciate the currency and restore equilibrium. For Chile it is the relative money supply only that does the adjusting. For Uruguay, none of the adjustment parameters are significant. This implies that the variables may not in fact be cointegrated. However, this may just be due to a statistical error. The results for Uruguay are quite supportive of the model and the root of the residuals is 0.38. Table 3.11 shows that panel 2 implies that money supply does the adjusting.

3.7 *Discussion and Conclusions*

In the vein of papers like Groen (2000) and Rapach and Wohar (2002) this paper continues to find support for the monetary model. Like those authors I show that the existence of a long run relationship between the monetary fundamentals and the exchange rate may not be as statistically unsupported as it once seemed. However unlike those authors I focus on the exchange rate movements of Latin American countries rather than industrialized first world countries. The contribution of this paper is to show that the current consensus about the validity of the monetary model of exchange rates for high income developed countries holds for the countries of Latin America. That is, like Rapach and Wohar (2002) I show that panel data methods may overstate the support for the model because they force one to accept that it holds (or doesn't hold) for each individual unit in the panel.

The Pedroni test shows that the hypothesis that there is no cointegration for each member of the panel can be rejected. The cointegrating vectors for panels 1, 2, and 3 are (1.01, -1.32), (0.95, -4.57), and (1.02, -0.44) respectively. The coefficients are correctly signed and reasonably sized. This would lead one to accept the monetary model as an explanation for exchange rate movements among Latin American countries. The individual country analysis on the other hand shows strong support for the model for

Argentina, Bolivia, Chile, Costa Rica, Guyana, Mexico, Nicaragua, Trinidad and Tobago and Uruguay. There is weaker support for the model for Brazil, Jamaica and Peru. However there are other countries such as Colombia and Ecuador for which not only can the null hypothesis of no cointegration not be rejected but for which the coefficient estimates are not supportive of the model.

This leads to the question of why the model fits so well for countries like Argentina and Bolivia and yet so poorly for others like Colombia and Ecuador. Rapach and Wohar (2002) find support for the model for countries such as France and Italy but also find that it does not hold for countries like Denmark and Sweden. They argue that the failure of the model is caused by instability in the long run relationship between relative price levels and fundamentals for those countries. However as Diaz (2004) shows, that is not a likely explanation. Diaz (2004) examines how well the monetary model describes exchange rates in Mexico from 1945-2002. Diaz tests the monetary model as well as two of its building blocks, the money demand function and PPP over the entire sample as well as over two non-overlapping sub-samples. He shows that even though the relationships upon which the model is based changed over time the model still described exchange rate movements over the entire sample. He therefore argues that instabilities in the fundamentals do not provide an explanation for the failure of the model.

This paper shows that the model holds for countries such as Chile which as described in section 5 experienced a great deal of volatility in exchange rate movements over the sample period. The model is also a good fit for countries such as Argentina which experienced several changes in the actual currency used over the sample period.

Similarly the model describes exchange rate movements in countries such as Mexico and Uruguay quite well, despite the fact that they have the largest coefficients of variation over the sample periods 1967-2000 and 1981-2000 respectively. Therefore instability and volatility do not provide explanations for the failure of the model in some countries.

It is interesting to note that in Colombia where there is no evidence of a long run relationship between the exchange rate and the fundamentals there is some question about the accuracy of the official money supply statistics. This is because a number of transactions are conducted in U.S. dollars. This is mainly caused by the presence of the illegal drug trade. Cocaine accounts for about 25% of that country's foreign exchange earnings. U.S. dollars are used by foreign exchange earners. Ecuador is another country for which the model fits poorly. Currently Ecuador is a dollarized economy. Dollarization officially occurred in 2000. However even before the local currency was officially demonetized, the country was already heavily dollarized. There is therefore once again the concern that the official money supply data does not reflect that which is actually occurring in the economy.

It is therefore possible that for these countries there is a long run relationship between the exchange rate and the fundamentals but the model appears to fit poorly because of inaccurate data. If the data does not reflect what is happening in the economy we will not find evidence of this relationship even if it does exist. Another possible explanation is that for countries such as Colombia and Ecuador, the monetary model does hold as a long run phenomenon. However the speed of adjustment for these countries is so slow that it would take a much longer time span of data to find evidence of this relationship.

It should also be noted that Ecuador and Colombia are both members of the Andean Community (CAN) and have been since 1969. Venezuela was a member of the CAN from 1973-2006. The CAN and Mercorsur are the two main trading blocs of South and Central America. Peru and Bolivia are also members of the CAN. However it should also be noted that Venezuela and Ecuador are among Colombia's top 3 export partners while Columbia and Venezuela are among Ecuador's top 4 import partners. It seems that Colombia, Ecuador and Venezuela do a great deal of trading amongst themselves. The results imply that the model fits poorly for these three countries. This may be due to factors arising from the large volume of trade that occurs among these countries that are having an impact on exchange rate movements in these countries.

Whether or not any of the above explanations hold true, this paper shows that the monetary model describes exchange rate movements in Latin American countries just as well as it describes exchange rate movements in first world industrialized economies. This paper shows that there is evidence that the simple monetary model is appropriate even for countries characterized by exchange rate volatility, that are plagued by high inflation and whose currencies are not heavily traded on the world market. In spite of these features it is still possible to find a long run relationship between the exchange rate and the fundamentals.

Future work may benefit from finding a way to test the accuracy of official data for less developed countries that possess a prominent black market for foreign currency or that regularly conduct transactions in foreign currency. Research on less developed countries generally speaking is handicapped by data availability. Another area of interest is the relationship between exchange rates and growth. If there is a long run relationship between the exchange rates and the monetary fundamentals and if these variables respond to short run deviations from the equilibrium, insight on the relationship between exchange rates and growth can have important policy implications. It would also be interesting to investigate the impact of trade integration on exchange rates. Some research, for example, Hooper and Kohlhagen (1978) and Rose, Lockwood and Quah (2000), has looked at the impact of exchange rates on trade volumes but it would be interesting to see how the volume of trade between countries influences their exchange rate movements.

Figure 3.1 - The Exchange Rate in Argentina

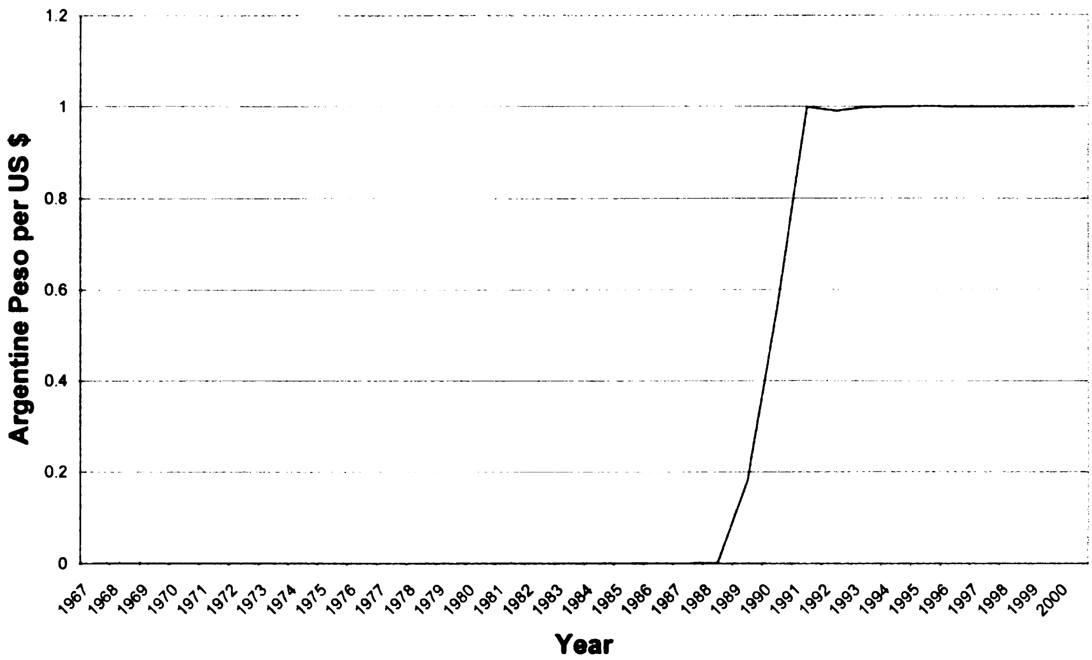


Figure 3.2 - The Exchange Rate in Bolivia

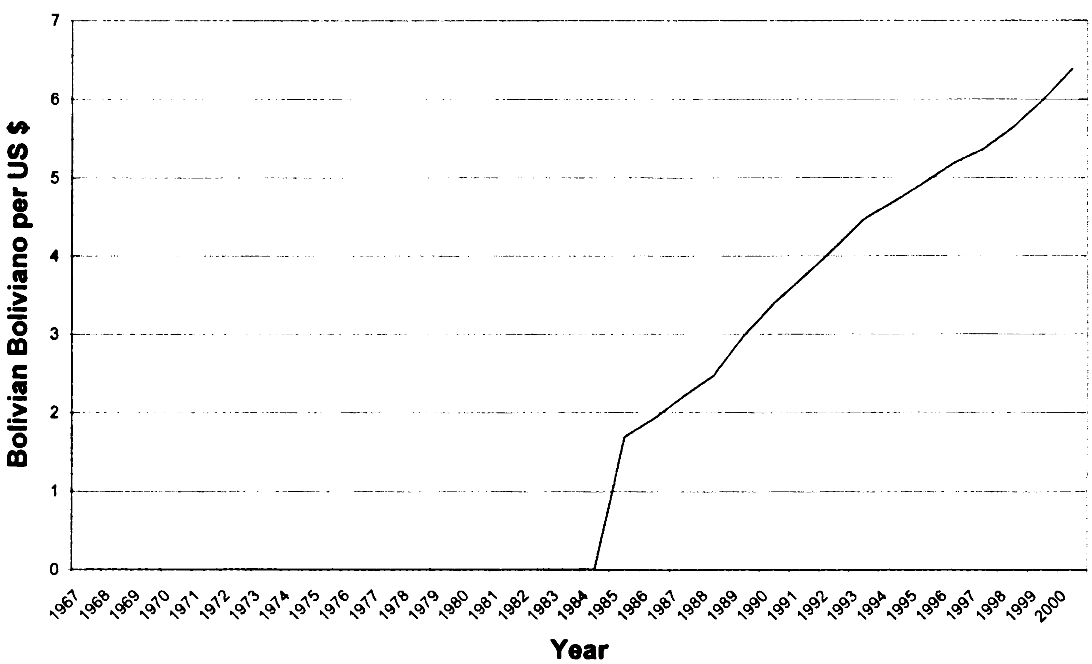


Figure 3.3 - The Exchange Rate in Brazil

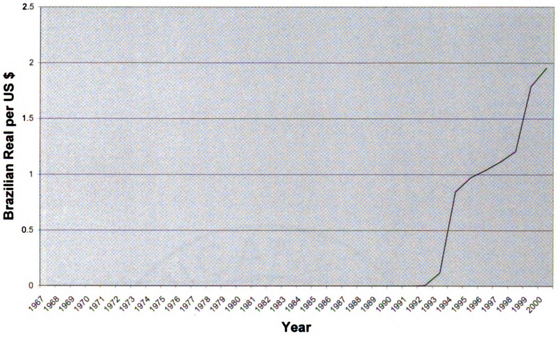


Figure 3.4 - The exchange rate in Chile

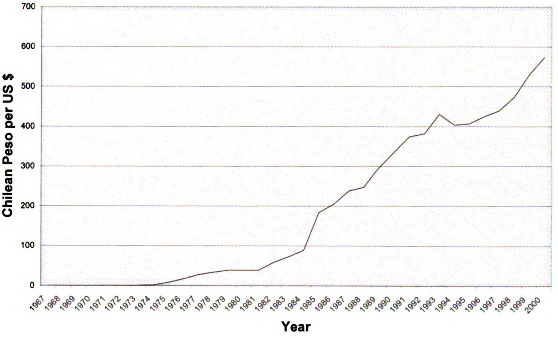


Figure 3.5 - The exchange rate in Colombia

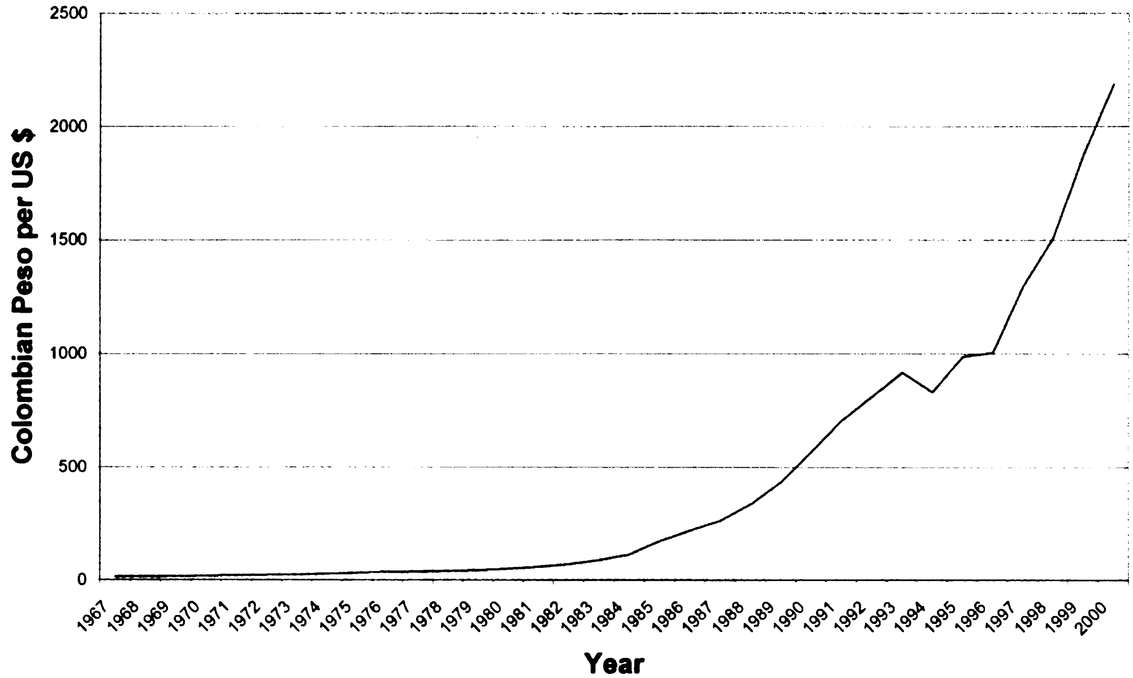


Figure 3.6 - The Exchange Rate in Costa Rica

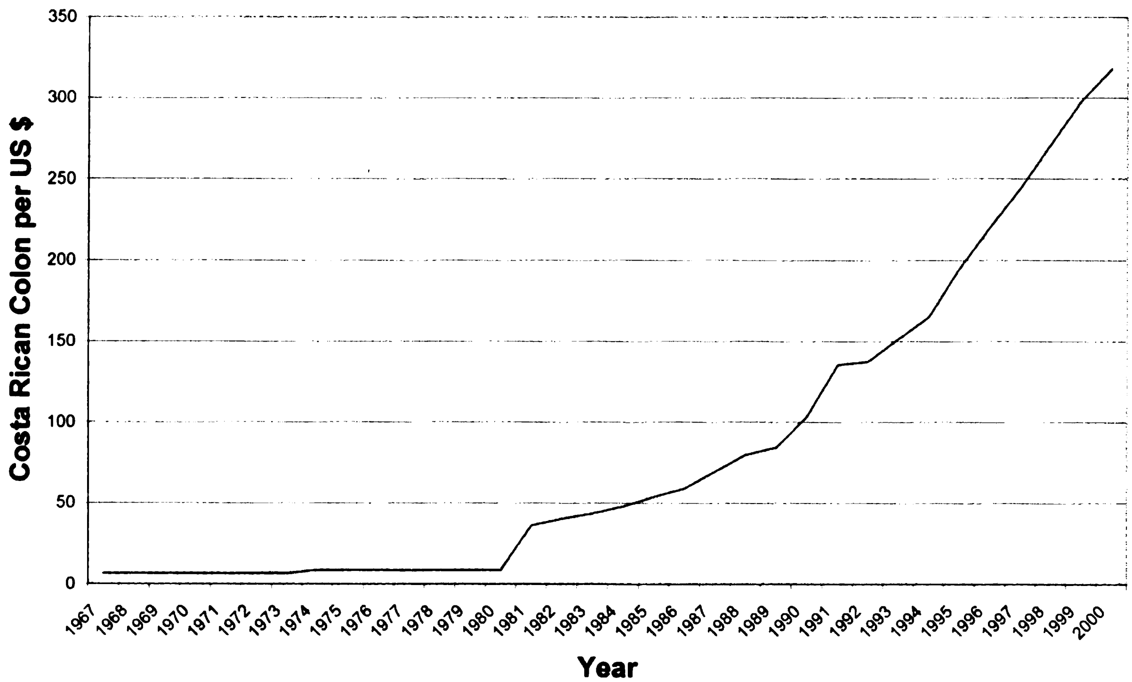


Figure 3.7 - The Exchange Rate in Ecuador

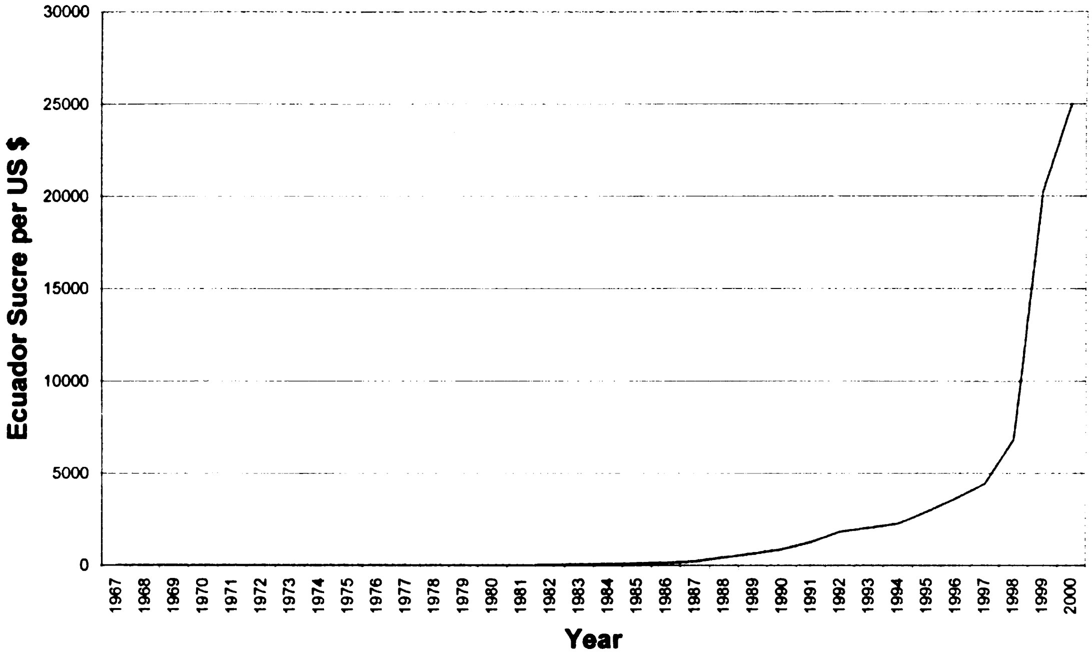


Figure 3.8 - The Exchange Rate in Guyana

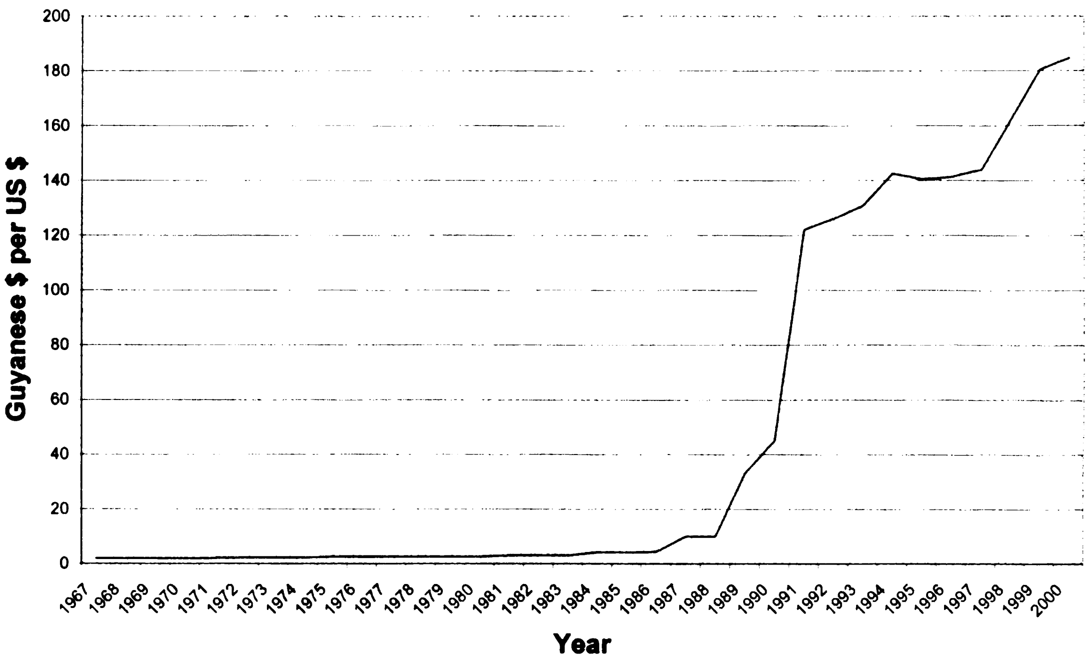


Figure 3.9 - The Exchange Rate in Jamaica

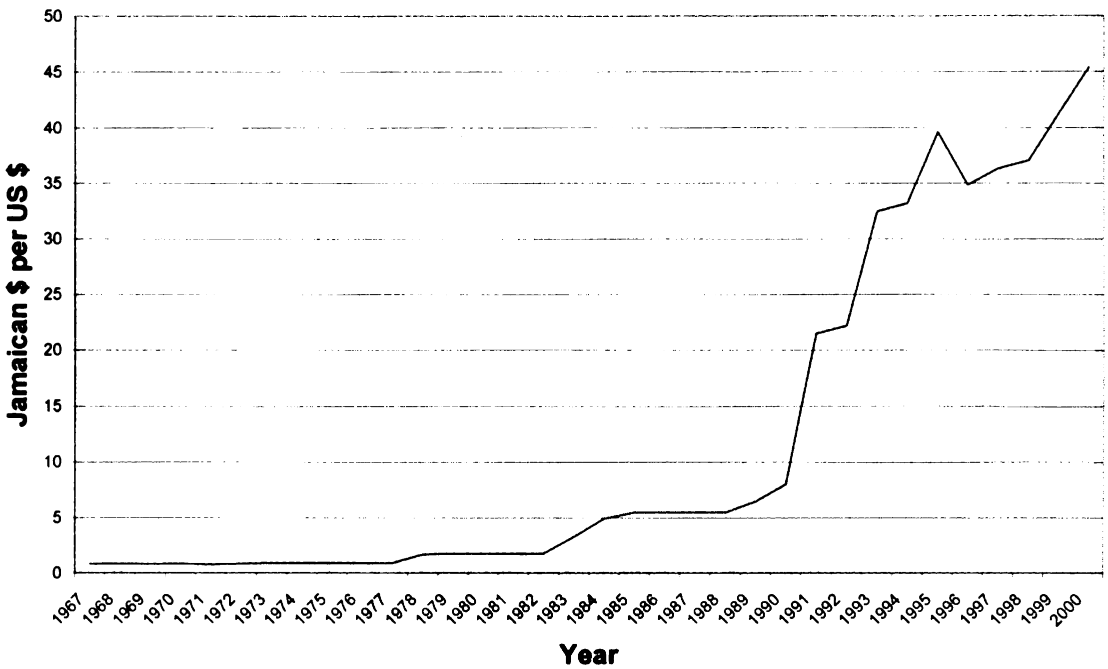


Figure 3.10 - The Exchange Rate in Mexico

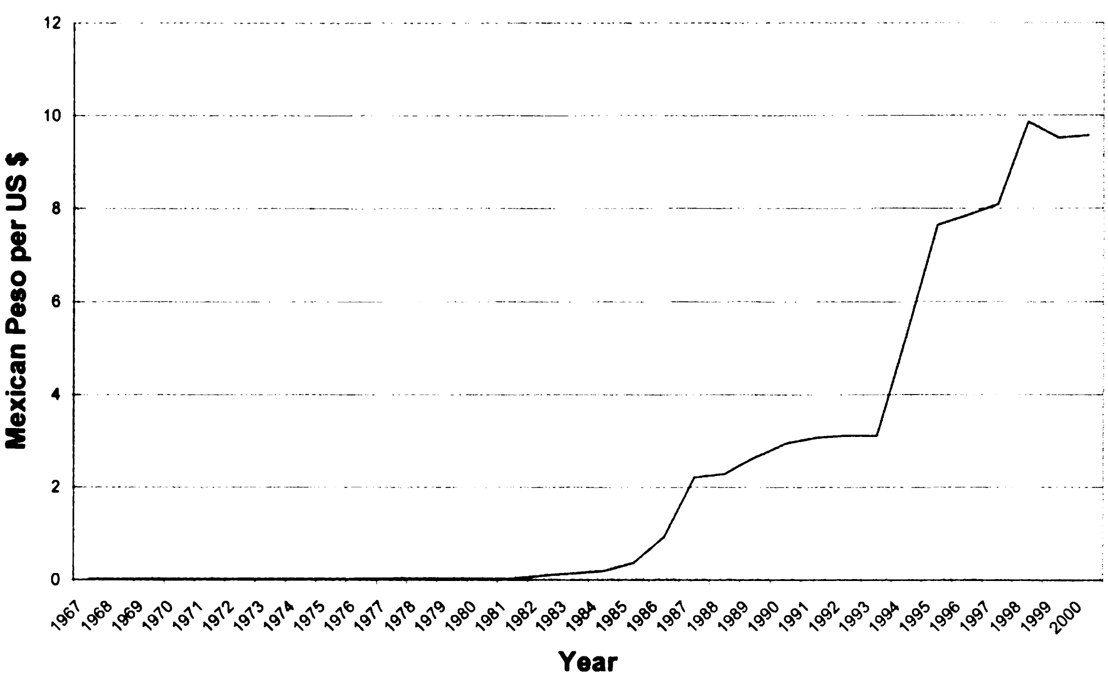


Figure 3.11 - The Exchange Rate in Nicaragua

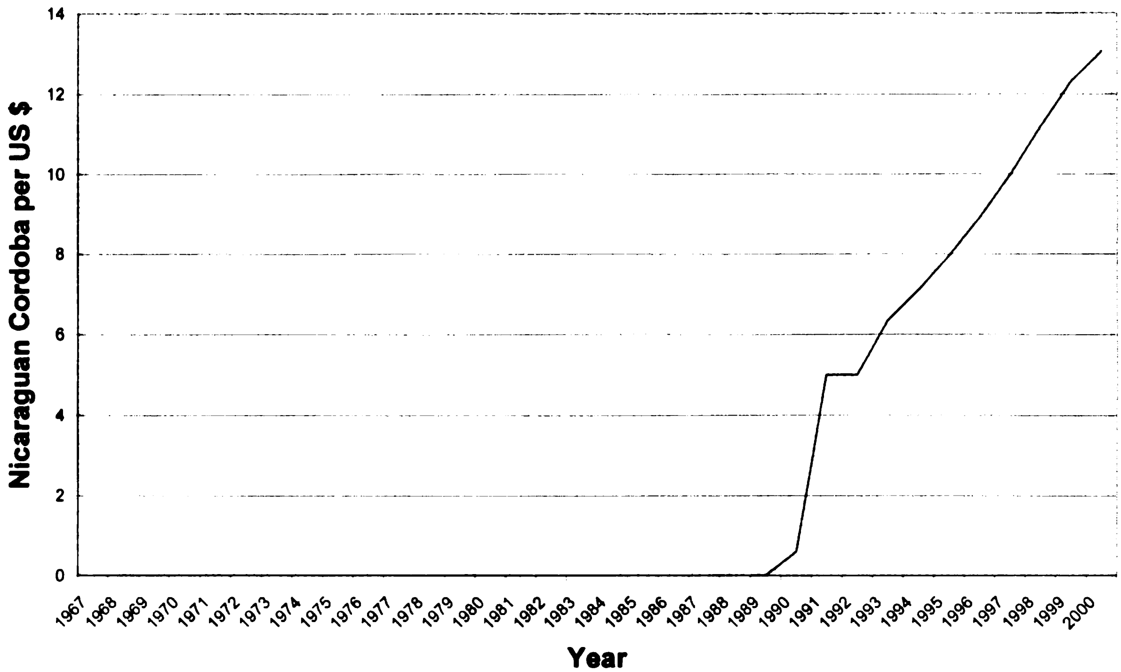


Figure 3.12 - The Exchange Rate in Peru

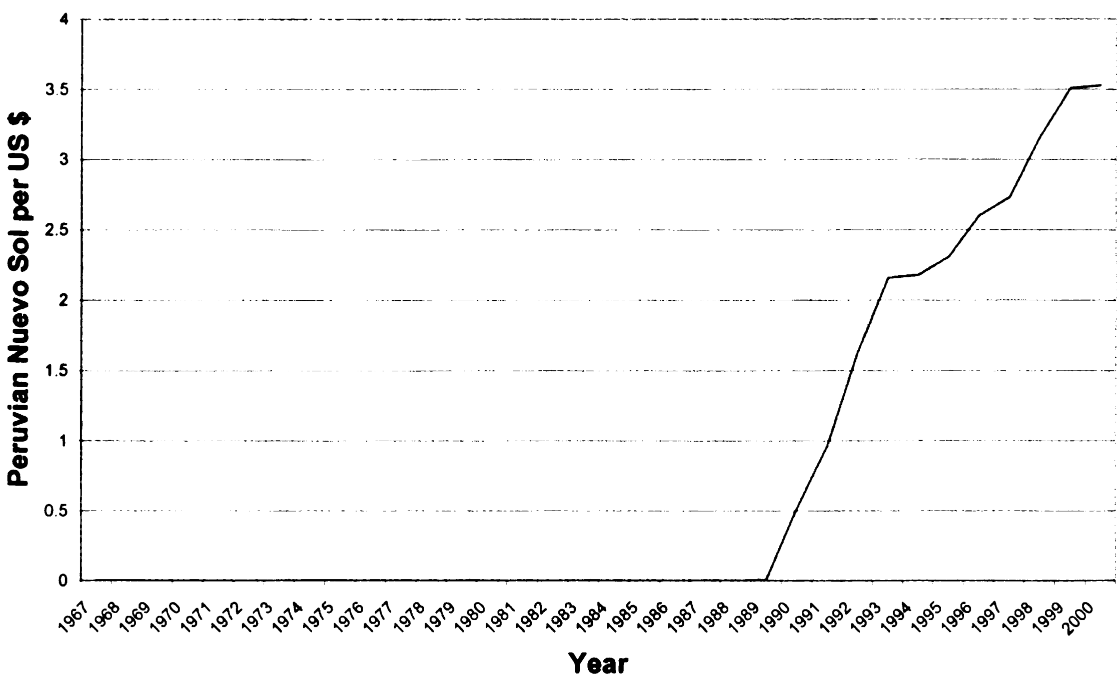


Figure 3.13 - The Exchange Rate in Trinidad and Tobago

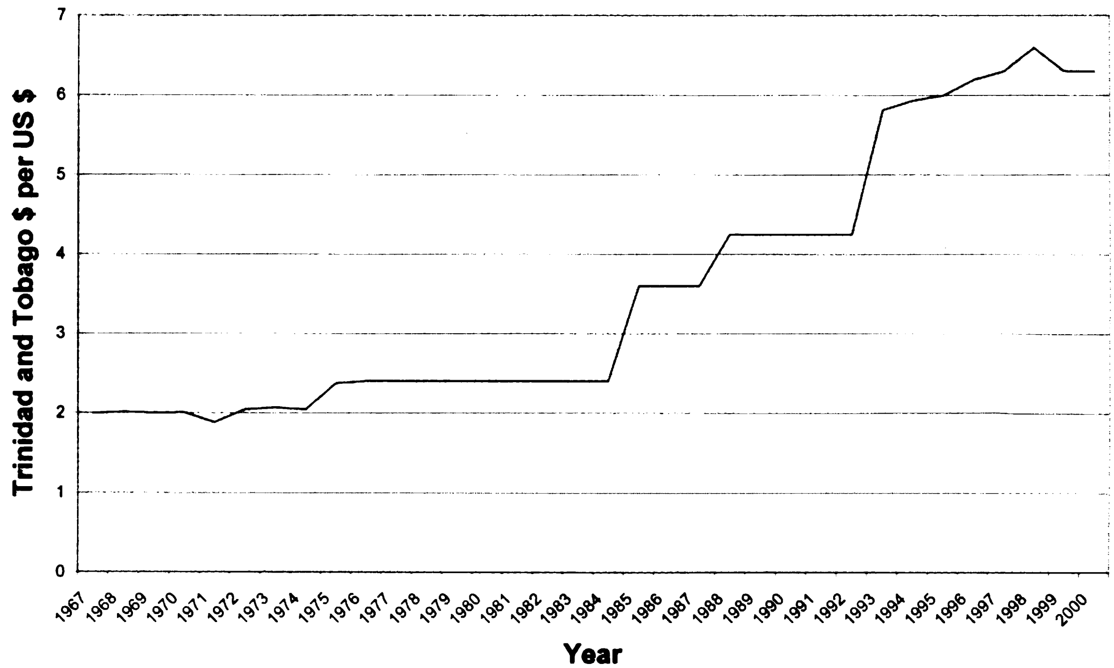


Figure 3.14 - The Exchange Rate in Uruguay

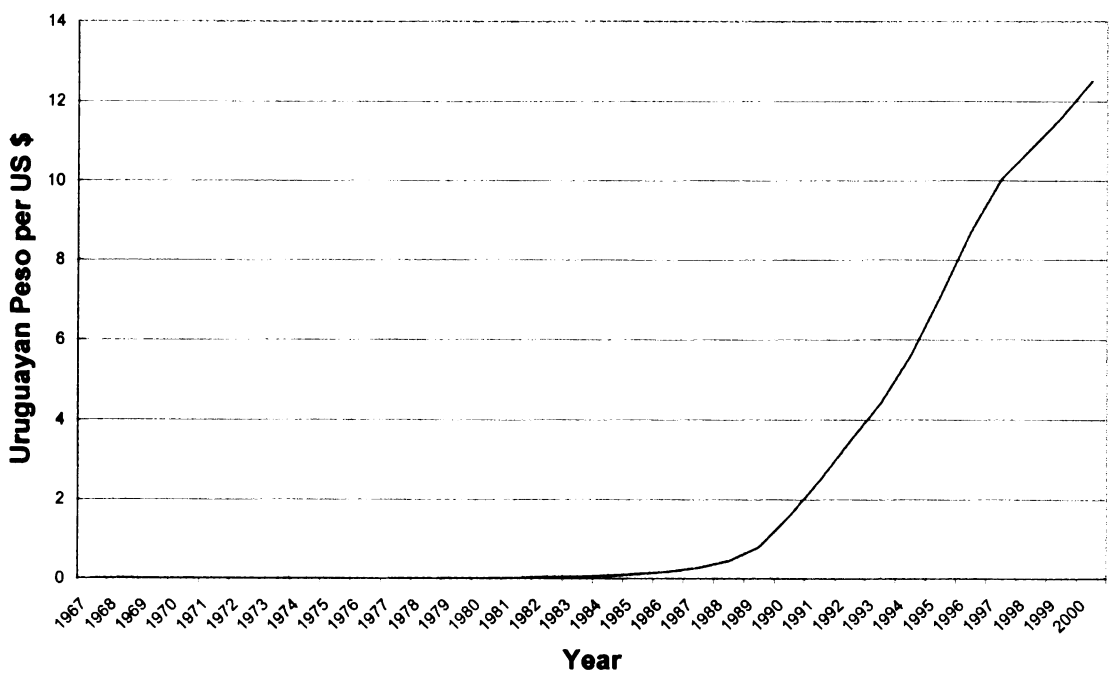


Figure 3.15 - The Exchange Rate in Venezuela

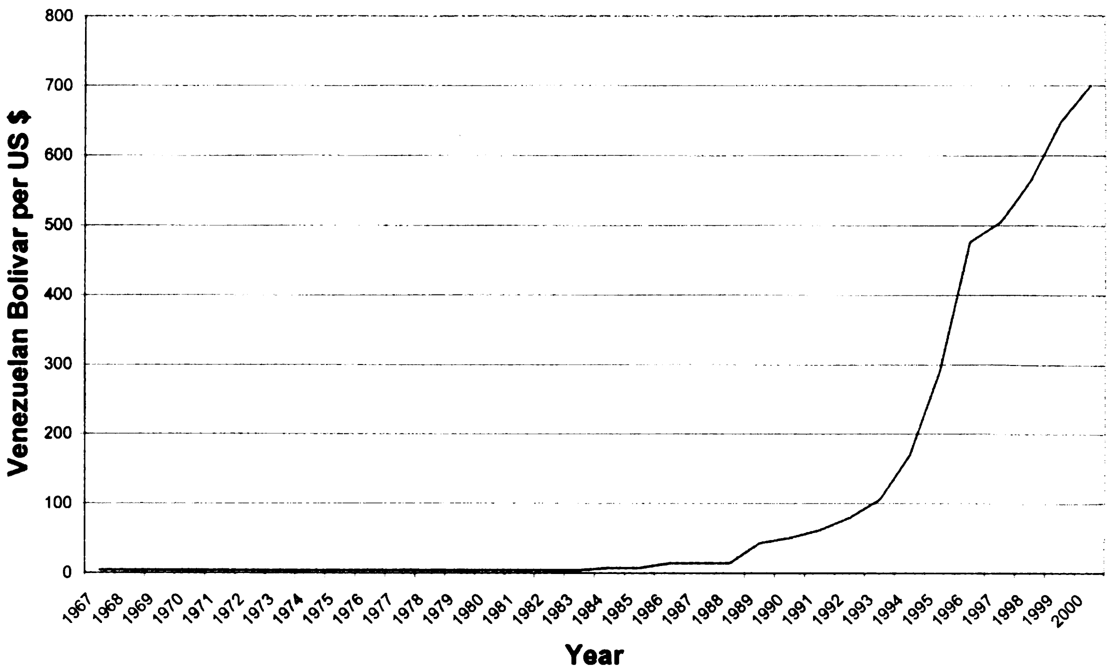


Table 3.1 – Coefficient of Variation of Exchange Rates Over Different Time Periods

Country	1967-1980	1981-2000	1967-2000
Argentina	0.015	1.665	0.716
Bolivia	0.0007	58.869	1.558
Brazil	0.0012	0.921	0.434
Chile	88.79	0.0203	1.48
Columbia	0.014	0.034	0.112
Costa Rica	0.0043	0.024	0.162
Ecuador	0.002	0.098	0.204
Guyana	0.018	0.24	0.605
Jamaica	2952.23	0.202	1.068
Mexico	0.0047	9.98	3.801
Nicaragua	0.00004	2.488	0.727
Peru	0.0024	1.91	0.654
Trin. & Tob.	0.015	0.062	0.143
Uruguay	0.051	436420.4	1.977
Venezuela	0.0001	0.22	0.408

Table 3.2 – Results of Individual OLS Estimation of the Monetary Model Using Panel 1

Country	$m_t - m_t^*$ (b_1)	$y_t - y_t^*$ (b_2)	Root of Residuals
Argentina	0.95 (0.014) [0.014]	-5.47 (1.15) [1.04]	0.40
Bolivia	0.95 (0.02) [0.02]	-4.43 (0.96) [0.99]	0.18
Brazil	1.02 (0.009) [0.012]	-0.204 (0.35) (0.45]	0.73
Chile	0.96 (0.02) [0.03]	-2.15 (0.62) [0.62]	0.14
Colombia	0.17 (0.15) [0.16]	10.733 (2.26) [2.499]	0.87
Costa Rica	1.06 (0.04) [0.04]	-3.25 (0.62) [0.696]	0.47
Ecuador	-4.39 (0.503) [0.66]	8.63 (1.06) [1.34]	0.97
Guyana	1.17 (0.07) [0.09]	-0.296 (0.47) [0.59]	0.78
Jamaica	0.91 (0.08) [0.10]	-1.04 (0.53) [0.66]	0.70
Mexico	0.997 (0.02) [0.03]	-1.25 (0.68) [0.798]	0.80
Nicaragua	1.24 (0.05) [0.07]	4.36 (1.34) [1.64]	0.41
Peru	0.94 (0.01) [0.02]	-4.504 (0.67) [0.697]	0.53
Trinidad & Tobago	0.46 (0.04) [0.04]	-2.15 (0.22) [0.23]	0.28
Uruguay	0.96 (0.01) [0.02]	-3.54 (0.35) [0.398]	0.38
Venezuela	1.25 (0.14) [0.16]	1.08 (1.47) [1.79]	0.86

Notes: The explained variable is the log exchange rate
Heretoskedasticity Robust standard errors are in parentheses
Newey-West standard errors are in square brackets

Table 3.3 – Individual Unit Root Test Results for Exchange Rates

Country	Root	Statistic	Critical Value	Outcome
Argentina	0.99	-0.829	-2.980	I(1)
Bolivia	0.97	-0.863	-2.980	I(1)
Brazil	0.99 (0.81)	-0.808 (-1.728)	-2.980 (-2.980)	I(2)
Chile	0.93	-2.775	-2.978	I(1)
Colombia	1.01	0.495	-2.980	I(1)
Costa Rica	0.999	-0.027	-2.978	I(1)
Ecuador	1.03	1.506	-2.980	I(1)
Guyana	1.01	0.427	-2.978	I(1)
Jamaica	1.01	0.288	-2.978	I(1)
Mexico	0.99	-0.410	-2.980	I(1)
Nicaragua	0.99	-0.433	-2.980	I(1)
Peru	0.99	-0.477	-2.980	I(1)
Trin. & Tob.	0.99	-0.159	-2.978	I(1)
Uruguay	0.99	-0.687	-2.978	I(1)
Venezuela	1.04	1.746	-2.978	I(1)

Notes: DF and ADF tests conducted
Critical values differ based on the number of lags
Unit root test results on the first difference of the variable are in parentheses

Table 3.4 – Individual Unit Root Test Results for Relative Money Supply

Country	Root	Statistic	Critical Value	Outcome
Argentina	0.87	-2.185	-3.572	I(1)
Bolivia	0.86 (0.58)	-2.211 (-2.831)	-3.572 (-2.98)	I(2)
Brazil	0.93 (0.76)	-2.275 (-1.992)	-3.572 (-2.980)	I(2)
Chile	0.898	-2.786	-2.980	I(1)
Colombia	-0.034	-5.659	-3.568	I(0)
Costa Rica	0.673	-2.422	-3.568	I(1)
Ecuador	0.90	-1.559	-3.568	I(1)
Guyana	0.87	-2.074	-3.572	I(1)
Jamaica	0.899	-1.341	-3.568	I(1)
Mexico	0.88	-2.148	-3.572	I(1)
Nicaragua	0.91 (0.76)	-2.542 (-2.036)	-3.572 (-2.980)	I(2)
Peru	0.89 (0.62)	-2.196 (-2.644)	-3.572 (-2.980)	I(2)
Trin. & Tob.	0.93	-1.767	-2.980	I(1)
Uruguay	0.99 (0.56)	-1.064 (-2.683)	-2.980 (-2.980)	I(2)
Venezuela	1.05	1.859	-2.978	I(1)

Notes: DF and ADF tests conducted
Critical values differ based on the presence or absence of time trends and the number of lags
Unit root test results on the first difference of the variable are in parentheses

Table 3.5 – Individual Unit Root Test Results for Relative GDP

Country	Root	Statistic	Critical Value	Outcome
Argentina	0.94	-0.972	-2.978	I(1)
Bolivia	0.86	-2.426	-3.572	I(1)
Brazil	0.84	-4.206	-2.978	I(0)
Chile	0.98	-0.370	-2.978	I(1)
Colombia	0.81	-1.822	-3.572	I(1)
Costa Rica	0.79	-2.836	-2.980	I(1)
Ecuador	0.97	-0.568	-3.568	I(1)
Guyana	0.75	-2.137	-3.572	I(1)
Jamaica	0.75	-2.245	-3.568	I(1)
Mexico	0.85	-2.400	-2.980	I(1)
Nicaragua	0.75	-2.435	-3.568	I(1)
Peru	0.95	-0.726	-2.983	I(1)
Trin. & Tob.	0.86	-1.474	-2.978	I(1)
Uruguay	0.898	-1.622	-2.983	I(1)
Venezuela	0.566	-2.979	-3.572	I(1)

Notes: DF and ADF tests conducted
Critical values differ based on the presence or absence of time trends and the number of lags

Table 3.6 – Fixed Effects Estimation of the Panel Version of the Monetary Model

Sample	$m_t - m_t^*$ (b_1)	$y_t - y_t^*$ (b_2)
Panel 1	***1.01 (0.009)	***-1.32 (0.28)
Panel 2	***0.95 (0.015)	***-4.57 (0.49)
Panel 3	***1.02 (0.01)	*-0.44 (0.246)

Notes: The explained variable is the log exchange rate
Standard errors are in parentheses
*, **, and *** denote significance at the 10, 5, and 1% level respectively

Table 3.7 – Panel Engle and Granger Results

Sample	T-Statistic	Root
Panel 1	-8.82	0.71
Panel 2	-10.21	0.48
Panel 3	-1.05	0.976

Notes: The Engle and Granger procedure is applied to the residuals from the fixed effects regression of equation (9) (the panel version of the monetary model)

Table 3.8 – Individual Cointegration Test Results

Country	Panel 1	Panel 2	Panel 3
Argentina	*-3.655	***-5.451	
Bolivia	***-5.18	***-4.706	
Brazil	-2.209	-2.865	-2.604
Chile	***-4.929	**-3.783	
Colombia	-1.211[a]	-1.309[a]	-2.460
Costa Rica	-3.279	-1.508	**-3.970
Ecuador	-0.407	-1.317	-0.170
Guyana	-2.127	*-3.474	
Jamaica	-2.433	-2.840	
Mexico	-2.462	***-6.577	
Nicaragua	**-3.701	**-3.676	-3.139
Peru	-2.974	-3.094	-3.175
Trinidad & Tobago	**-4.238	***-4.874	
Uruguay	***-4.189	***-4.234	
Venezuela	-1.652	-1.479	-1.593

Notes: The critical values are from Engle and Yoo (1987) and are 4.32, 3.67, and 3.28 at the 1,5, and 10% levels respectively
The critical values for [a] are from Engle and Granger (1987) and are 4.07, 3.37, and 3.03 at the 1,5, and 10% levels respectively (3.73, 3.17, and 2.91 with lags)
*, **, and *** denote rejection at the 10, 5, and 1% levels respectively

Table 3.9 – Panel Cointegration Test Results

Sample	Levin et al		Pedroni	
	test statistic	critical value	test statistic	critical value
Panel 1	***-3.95	-1.65	***-19.08	-1.65
Panel 2	***-4.62	-1.65	***-40.94	-1.65
Panel 3	**-1.92	-1.65	***-13.71	-1.65

Notes: The tests are applied to the residuals from the fixed effects regression equation (9) (the panel version of the monetary model)
*, **, and *** denote rejection at the 10, 5, and 1% levels respectively
5 % critical values are displayed in the table

Table 3.10 – Error Correction Coefficient Estimates for Panel 1 Countries

Country	k_s	k_m	k_y
Argentina	-0.11 (0.59)	0.22 (0.29)	**-0.05 (0.02)
Bolivia	***-2.38 (0.75)	**-1.19 (0.54)	0.02 (0.02)
Chile	-0.19 (0.18)	**0.66 (0.28)	0.02 (0.02)
Nicaragua	-0.92 (0.57)	-0.41 (0.27)	***0.05 (0.01)
Trinidad & Tobago	-0.02 (0.17)	-0.02 (0.21)	***-0.37 (0.11)
Uruguay	-0.52 (0.35)	0.04 (0.13)	-0.02 (0.04)

Notes: Heteroskedasticity Robust standard errors are in parentheses
*, **, and *** denote significance at the 10, 5, and 1% levels respectively
Coefficients are the speed of adjustment parameters for exchange rates, relative money supply, and relative income (based on equations 23-25)

Table 3.11 – Error Correction Coefficient Estimates

Sample	k_s	k_m	k_y
Panel 1	-0.075 (0.083)	0.135 (0.091)	-0.0006 (0.003)
Panel 2	-0.151 (0.13)	**0.285 (0.146)	-0.001 (0.005)
Panel 3	-0.055 (0.074)	-0.035 (0.034)	0.0005 (0.003)

Notes: Heteroskedasticity Robust standard errors are in parentheses
*, **, and *** denote significance at the 10, 5, and 1% levels respectively
Coefficients are the speed of adjustment parameters for exchange rates, relative money supply, and relative income (based on equations 23-25)

APPENDIX

Table A1.1 – Unbalanced Panel – Causality from Trade to Growth

Statistic	K = 3	K = 2	Critical Value
Z^{FHNC}	5.199	7.993	1.650
Z^{HNC}	6.803	6.974	1.650

Table A1.2 – Unbalanced Panel – Causality from Growth to Trade

Statistic	K = 3	K = 2	Critical Value
Z^{FHNC}	4.108	7.230	1.650
Z^{HNC}	5.549	6.369	1.650

Table A1.3 – Balanced Panel – Three Lags

Sample Split	Trade to Growth	Growth to Trade	Critical Value
All Countries	5.086	4.119	1.650
Low Income	*1.199	*0.800	4.615
Lower Middle	5.642	*4.454	4.538
Upper Middle	*1.882	*-0.666	4.950
Middle Income	5.693	*3.252	4.356
High Income	*0.873	*3.038	4.815

Note * denotes non-rejection at the 5% level

Table A1.4 – Balanced Panel – Two Lags

Sample Split	Trade to Growth	Growth to Trade	Critical Value
All Countries	2.310	3.493	1.650
Low Income	*0.803	*1.321	3.106
Lower Middle	*1.186	*1.648	3.049
Upper Middle	*1.223	*0.793	3.356
Middle Income	*1.821	*1.960	2.913
High Income	*1.518	3.311	3.256

Note * denotes non-rejection at the 5% level

Robust Results

Table A1.5 – Unbalanced Panel – Causality From Trade to Growth

Statistic	K = 3	K = 2	K = 1	Critical Value
Z^{FHNC}	8.734	9.341	6.325	1.650
Z^{HNC}	10.861	8.043	7.373	1.650

Table A1.6 – Unbalanced Panel – Causality From Growth to Trade

Statistic	K = 3	K = 2	K = 1	Critical Value
Z^{FHNC}	7.628	10.662	4.842	1.650
Z^{HNC}	9.591	9.091	5.743	1.650

Table A1.7 – Balanced Panel – Three Lags

Sample Split	Trade to Growth	Growth to Trade	Critical Value
All Countries	17.006	14.756	1.650
Low Income	*3.381	*4.279	4.615
Lower Middle	18.332	11.694	4.538
Upper Middle	6.505	*3.121	4.950
Middle Income	18.724	11.350	4.356
High Income	*4.156	9.681	4.815

Note * denotes non-rejection at the 5% level

Table A1.8 – Balanced Panel – Two Lags

Sample Split	Trade to Growth	Growth to Trade	Critical Value
All Countries	8.091	11.916	1.650
Low Income	4.535	7.323	3.106
Lower Middle	5.262	7.170	3.049
Upper Middle	*2.381	*2.883	3.356
Middle Income	6.165	8.173	2.913
High Income	3.575	5.806	3.256

Note * denotes non-rejection at the 5% level

Table A1.9 – Balanced Panel – one lag - Causality from Openness to Growth

Measure of Openness	All Countries	Low Income	Lower Middle	Upper Middle	Middle Income	High Income
Trade Percentage	7.812	2.821	8.008	*0.958	7.092	2.769
Gravity – Differentiated Goods	5.003	2.240	5.548	*0.883	5.040	*0.478
Gravity – Homogeneous Goods	5.039	2.324	5.174	*0.954	4.776	*0.872

Note * denotes non-rejection at the 5% level

Table A1.10 – Balanced Panel – one lag - Causality from Growth to Openness

Measure of Openness	All Countries	Low Income	Lower Middle	Upper Middle	Middle Income	High Income
Trade Percentage	8.559	10.218	2.086	*0.986	2.272	3.187
Gravity – Differentiated Goods	9.551	9.598	3.080	2.361	3.878	3.596
Gravity – Homogeneous Goods	9.888	12.236	3.449	1.898	3.912	*1.153

Note * denotes non-rejection at the 5% level

Table A2.1 – Estimation Results with Initial Values and using instruments for *y* only

Regressor	Cross-Sectional	POLS	FE-IV	FD-IV
Grav_Open1[a]	-0.00283 (0.00230)	0.00091 (0.00171)	***0.03135 (0.00792)	***0.03424 (0.00712)
Log (Income)	0.001681 (0.00192)	-0.00151 (0.00224)	-0.04268 (0.06928)	***-0.14389 (0.0311)
Log (Population)	***0.00469 (0.00150)	***0.00301 (0.00114)	0.01660 (0.07274)	**-0.09921 (0.04687)
Log (Area)	***-0.00490 (0.00099)	***-0.00393 (0.00084)		
Investment	***0.05873 (0.02267)	***0.14472 (0.03965)	**0.09357 (0.0458)	***0.13425 (0.02999)
Government	0.00019 (0.01536)	-0.00014 (0.01373)	-0.03199 (0.03292)	-0.05438 (0.02404)

Notes: [a]Grav_Open1 represents the difference between trade predicted by the gravity model and actual trade assuming that trade is in differentiated products.
the Huber/White/Sandwich standard error estimates are in parentheses
*denotes significance at the 10% level
** denotes significance at the 5% level
***denotes significance at the 1% level

Table A2.2 – Estimation Results with Initial Values and using instruments for *y* only

Regressor	Cross-Sectional	POLS	FE-IV	FD-IV
Grav_Open2[a]	-0.00239 (0.00309)	*0.00421 (0.00248)	***0.02581 (0.00804)	***0.03463 (0.00661)
Log (Income)	0.00259 (0.00166)	-0.00213 (0.00223)	-0.04975 (0.07092)	***-0.14826 (0.02993)
Log (Population)	***0.00519 (0.00161)	**0.00236 (0.00116)	0.00491 (0.07119)	**-0.10580 (0.04456)
Log (Area)	***-0.00512 (0.00097)	***-0.00395 (0.00083)		
Investment	**0.05799 (0.02334)	***0.14000 (0.0396)	***0.10431 (0.03949)	***0.13231 (0.02923)
Government	0.00065 (0.01596)	-0.00024 (0.01372)	-0.03021 (0.03241)	**-0.05498 (0.02403)

Notes: [a]Grav_Open2 represents the difference between trade predicted by the gravity model and actual trade assuming that trade is in differentiated products.
the Huber/White/Sandwich standard error estimates are in parentheses
*denotes significance at the 10% level
** denotes significance at the 5% level
***denotes significance at the 1% level

Estimation Results Using Alternative Measure of Openness With Interaction Term

Table A2.3 – Estimation of equation 1 using alternative measure of openness

Regressor	Cross-Sectional	POLS	Fixed Effects	First-Difference
Grav_Open1[a]	**-0.03882 (0.01598)	-0.00241 (0.01571)	**0.08161 (0.03503)	0.04589 (0.07390)
Log (Initial Income)	**0.02980 (0.01373)	-0.00128 (0.01341)	***-0.12439 (0.03456)	***-0.12507 (0.01080)
Openness*log (Income)	**0.00473 (0.00188)	0.00058 (0.00178)	-0.00668 (0.00438)	-0.00130 (0.00893)
Population Growth	***-0.93838 (0.21634)	*-0.53111 (0.29091)	0.30573 (0.23913)	0.37994 (0.24439)
Log (Area)	-0.00113 (0.00073)	***-0.00185 (0.00052)		
Investment	***0.11794 (0.02801)	***0.1818 (0.03577)	***0.19745 (0.02917)	***0.2103 (0.04937)
Government	-0.00013 (0.0147)	-0.00575 (0.01355)	-0.0373 (0.02559)	-0.05058 (0.03344)

Notes: [a]Grav_Open1 represents the difference between trade predicted by the gravity model and actual trade assuming that trade is in differentiated products.

the Huber/White/Sandwich standard error estimates are in parentheses

*denotes significance at the 10% level

** denotes significance at the 5% level

***denotes significance at the 1% level

Table A2.4 – Estimation of equation 1 using alternative measure of openness

Regressor	Cross-Sectional	POLS	Fixed Effects	First-Difference
Grav_Open2	-0.00518 (0.02269)	*0.03756 (0.01951)	***0.08912 (0.03419)	0.03933 (0.07703)
Log (Initial Income)	-0.00261 (0.00822)	**-0.01821 (0.00754)	***-0.09927 (0.01443)	-0.12950 (0.01099)
Openness*log (Income)	0.00101 (0.00267)	-0.00369 (0.00228)	*-0.00743 (0.00420)	-0.00045 (0.00924)
Population Growth	***-0.89836 (0.22062)	*-0.51082 (0.27049)	0.33377 (0.23832)	*0.39722 (0.24144)
Log (Area)	**-0.00154 (0.00073)	***-0.00251 (0.00054)		
Investment	***0.11635 (0.03102)	***0.17548 (0.03661)	***0.19765 (0.02901)	***0.21144 (0.04946)
Government	0.00246 (0.01576)	-0.00674 (0.01359)	-0.04076 (0.02559)	-0.05228 (0.0336)

Notes: [a]Grav_Open2 represents the difference between trade predicted by the gravity model and actual trade assuming that trade is in homogeneous products.
the Huber/White/Sandwich standard error estimates are in parentheses
*denotes significance at the 10% level
** denotes significance at the 5% level
***denotes significance at the 1% level

Table A2.5 – Results using Alternative Openness Measures and instruments for *y* only

Regressor	FE-IV1[a]	FE-IV2[b]	FD-IV1	FD-IV2
Initial Openness	*0.10799 (0.06084)	**0.13959 (0.05679)	0.04653 (0.05153)	0.04876 (0.04965)
Log (Initial Income)	-0.10445 (0.08829)	-0.05895 (0.05591)	**-0.12016 (0.06075)	***-0.11788 (0.03109)
Openness*log (Income)	-0.01068 (0.00741)	**-0.01530 (0.00714)	-0.00139 (0.00651)	-0.00178 (0.00623)
Population Growth	0.34926 (0.31027)	0.40895 (0.31941)	0.34638 (0.22525)	0.36106 (0.22450)
Investment	***0.20482 (0.05375)	***0.21692 (0.05723)	***0.21684 (0.03777)	***0.22085 (0.03811)
Government	-0.04272 (0.04836)	-0.05016 (0.04918)	*-0.05198 (0.03142)	*-0.05325 (0.0314)

Notes: [a]1 represents trade in differentiated products.
[b]2 represents trade in homogeneous products
standard errors are in parentheses
*denotes significance at the 10% level
** denotes significance at the 5% level
***denotes significance at the 1% level

Table A2.6 – Results using Alternative Openness Measures and instruments for y, I & G

Regressor	FE-IV1[a]	FE-IV2[b]	FD-IV1	FD-IV2
Initial Openness	0.20502 (0.15283)	0.02128 (0.24598)	-0.16214 (0.47810)	-0.23611 (0.46613)
Log (Initial Income)	-0.17200 (0.17212)	-0.05457 (0.11950)	0.11742 (0.48134)	0.03213 (0.23328)
Openness*log (Income)	-0.02021 (0.01592)	0.00413 (0.02814)	0.01639 (0.03981)	0.030010 (0.04757)
Population Growth	0.18026 (0.47593)	0.37677 (0.48897)	-0.43278 (0.77140)	-0.19664 (0.56746)
Investment	0.04189 (0.37703)	-0.13063 (0.33366)	1.24093 (2.05612)	0.75354 (1.11497)
Government	-0.35308 (0.22412)	-0.2292 (0.19996)	-0.25952 (0.81786)	-0.27744 (0.59057)

Notes: [a]1 represents trade in differentiated products.
[b]2 represents trade in homogeneous products
standard errors are in parentheses
*denotes significance at the 10% level
** denotes significance at the 5% level
***denotes significance at the 1% level

Table A2.7 – Estimation Results – using different reduced forms for each time period

Regressor	FE-IV1[a]	FE-IV2[b]	FD-IV1	FD-IV2
Initial Openness	***0.35358 (0.12512)	***0.24401 (0.07306)	***0.44016 (0.16583)	***0.26607 (0.09867)
Log (Initial Income)	***-0.44949 (0.15000)	***-0.22658 (0.05784)	***-0.60517 (0.20653)	***-0.31842 (0.08634)
Openness*log (Income)	***0.35358 (0.12512)	***-0.02575 (0.00878)	**-0.05017 (0.02070)	**-0.02710 (0.01208)
Population Growth	*0.53480 (0.31477)	*0.59124 (0.30577)	**0.61483 (0.30455)	**0.64029 (0.29923)
Investment	0.09501 (0.06047)	*0.10454 (0.05515)	0.10449 (0.06665)	*0.11095 (0.06376)
Government	0.01648 (0.04606)	0.01232 (0.04356)	0.01893 (0.05799)	0.01385 (0.05401)

Notes: [a]1 represents trade in differentiated products.
[b]2 represents trade in homogeneous products
standard errors are in parentheses
*denotes significance at the 10% level
** denotes significance at the 5% level
***denotes significance at the 1% level

Table A2.8 – Estimation Results with Initial Values and using instruments for *y* only

Regressor	Cross-Sectional	POLS	FE-IV	FD-IV
Grav_Open1[a]	**-0.04278 (0.01693)	-0.00205 (0.01588)	***0.15867 (0.05414)	0.06391 (0.05167)
Log (Initial Income)	**0.03506 (0.01422)	-0.00065 (0.01356)	***-0.17729 (0.06583)	**-0.14790 (0.05952)
Openness*log (Income)	***0.00515 (0.00199)	0.00050 (0.00181)	**-0.01616 (0.00675)	-0.00327 (0.00657)
Population Growth	***-1.12059 (0.26149)	**-0.59562 (0.29682)	0.46637 (0.29143)	*0.43529 (0.22621)
Log (Area)	-0.00097 (0.00084)			
Investment	0.03968 (0.02457)	***0.14277 (0.03868)	***0.08876 (0.03338)	***0.12018 (0.02949)
Government	0.00076 (0.01275)	-0.00658 (0.01346)	-0.03278 (0.03007)	*-0.04609 (0.02455)

Notes: [a]Grav_Open1 represents the difference between trade predicted by the gravity model and actual trade assuming that trade is in differentiated products.
the Huber/White/Sandwich standard error estimates are in parentheses
*denotes significance at the 10% level
** denotes significance at the 5% level
***denotes significance at the 1% level

Table A2.9 – Estimation Results with Initial Values and using instruments for *y* only

Regressor	Cross-Sectional	POLS	FE-IV	FD-IV
Grav_Open2[a]	-0.01774 (0.02328)	*0.03339 (0.01962)	***0.18034 (0.05540)	0.06155 (0.05074)
Log (Initial Income)	0.00437 (0.00827)	**-0.01532 (0.00748)	***-0.10195 (0.03974)	***-0.13549 (0.03011)
Openness*log (Income)	0.00257 (0.00269)	-0.00317 (0.00231)	***-0.01928 (0.00696)	-0.00307 (0.00638)
Population Growth	***-1.10859 (0.26629)	**-0.59167 (0.27733)	*0.54416 (0.29987)	**0.45365 (0.22599)
Log (Area)	*-0.00146 (0.00084)	***-0.00246 (0.00055)		
Investment	0.03208 (0.02391)	***0.13477 (0.03969)	***0.09009 (0.03333)	***0.12129 (0.02946)
Government	-0.00144 (0.01371)	-0.00691 (0.01358)	-0.03936 (0.03151)	*-0.04658 (0.02461)

Notes: [a]Grav_Open2 represents the difference between trade predicted by the gravity model and actual trade assuming that trade is in homogeneous products.
the Huber/White/Sandwich standard error estimates are in parentheses
*denotes significance at the 10% level
** denotes significance at the 5% level
***denotes significance at the 1% level

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