Exchange Rate Misalignment and Growth: Old and New Econometric Evidence

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Abstract

Several studies have tried to identify the relationship between growth and misaligned or overvalued currencies. Many works (Easterly (2001) and Fajnzylber et alii (2002)), find negative correlations between exchange rate misalignment and growth for a long list of developing countries since the seventies; the more overvalued the currency, the smaller the *per capita* growth rates. Even after controlling the regressions for several types of variables, the studies cannot reject the statistical significance of overvalued exchange rates in explaining growth. This paper presents new econometric evidence for the exchange rate levels and growth relation based on a panel data study for 58 developing countries from 1960 until 1999 using PPP deviation measures. Our main contribution here is to estimate growth regressions with a real exchange rate index that deals with changes in real GDP *per capita* levels. We use a new overvaluation index that takes into account variations in real *per capita* incomes, adjusting, thus, our exchange rate estimates for the so-called Balassa-Samuelson effect. By correcting traditional real exchange rate annual estimates for GDP *per capita* increases, we intend to control our whole series for appreciations due to productivity increases as many authors do for some specific years.

Keywords: Exchange Rate Levels, Overvaluations, Growth

JEL Classification: O11, F31, F4

Resumo

Existe hoje uma importante literatura empírica que procura relacionar taxas de crescimento econômico com níveis de taxa de câmbio real. Em trabalhos sobre o tema, vários autores encontram uma relação negativa entre desalinhamento cambial e crescimento econômico para uma longa série de países nos últimos 30 anos; quanto maior a sobrevalorização da taxa de câmbio, menores as taxas de crescimento. Mesmo controlando regressões por uma série de varáveis, não conseguem descartar o efeito do nível do câmbio real em taxas de crescimento *per capita*. Com o objetivo de contribuir para essa discussão, este trabalho apresenta novos resultados empíricos para essa relação. Nossa principal inovação aqui é estimar a relação entre crescimento econômico e sobrevalorização a partir de um índice de câmbio real que leva em consideração variações na renda *per capita* de diversos países. Ajustamos, portanto, nossa série de câmbio real tomando em conta o efeito Balassa-Samuelson, o que significa que nossos resultados estão controlados por variações de produtividade. Em linha com outros trabalhos da literatura que usam metodologias distintas também encontramos resultados de sobrevalorizações associadas a baixo crescimento.

Palavras-Chave: Crescimento, Nível da Taxa de Câmbio, Sobrevalorizações
Classificação JEL: O11, F31, F4

1. Introduction

The impacts of exchange rate misalignment on growth have become an important econometric research topic in the last 10 or 20 years. Following several works by the World Bank on the virtues of outward orientation and competitive currencies for growth (Dollar (1992) and Cavallo et alii (1990)), many econometric studies have measured, among other variables, the effects of exchange overvaluation on *per capita* growth rates (Easterly (2001) and Fajnzylber et alii (2002)). There is also today a growing policy-oriented literature discussing the role of exchange rate policies in the successful Asian development strategy. Competitive currencies are boosting regional income and investment according to these studies (Bresser-Pereira (2004), Dooley et alii (2005)), whereas overvaluations are amongst the main causes of crises and stagnation in Latin America in the last 20 years (Frenkel 2004).

Currency misalignment measures are far from consensual. Two methods of dealing with the problem are the most popular: purchasing power estimates and "fundamental" exchange rate equilibriums. The first one is based on PPP comparisons, usually adjusted for the Balassa-Samuelson effect, and considers high international price levels as a proxy for overvaluations for a given real GDP *per capita* level. The second method takes into account internal and external conditions (capacity utilization and balance of payment financing conditions for a given state of variables) when measuring "fundamental" exchange rate equilibriums and considers low growth levels or unsustainable current account trajectories as possible signs of misalignment (see Montiel e Hinkle (1999) for a detailed discussion).

In misalignments measured as PPP deviations with Balassa-Samuelson adjustments, a currency is regarded to be in a "wrong" position if prices in international comparisons are too high as compared to what they should be if *per capita* income levels are taken into account (Dollar 1992). *Per capita* income levels can be taken as proxies for productivity levels and, thus, as good measures for non-tradeables remuneration, especially labor, as compared to tradeables. A

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"correct" exchange rate in terms of PPP deviations would align real wages with productivity levels. Overvalued currencies would be associated with excessively high real wages and foreign indebtedness problems or high trade protectionism. An equilibrium real exchange rate would, thus, be associated with adequate real wage levels according to *per capita* income. For the second method, an equilibrium exchange rate would be associated with reasonable growth and sustainable external debt, in other terms, to full employment (internal balance) and proper current account financing (external balance). This "equilibrium" usually depends on several other macro variables, such as:

(i) terms of trade;
(ii) domestic and international interest rates;
(iii) tariffs;
(iv) international transfers and aid;
(v) capital controls;
(vi) government spending and
(vii) productivity shifts.

An increase in international interest rates, worsening terms of trade and lower tariffs or transfers and aid tend to depreciate the currency. An opening of capital accounts, an increase in government spending in non-tradeables and productivity increases tend to appreciate the currency (for a discussion, see Cavallo et alii (1990) and Edwards (1989)).

Several studies have tried to identify the relationship between growth and misaligned or overvalued currencies. Many works find negative correlations between exchange rate misalignment and growth for a long list of developing countries since the seventies; the more overvalued the currency, the smaller the *per capita* growth rates. Even after controlling the regressions for all sorts of variables, the studies cannot reject the statistical significance of overvalued exchange rates in explaining growth (Razin e Collins (1997), Benaroya e Janci (1999), Acemoglu et alii (2002) and Fajnzylber et alii (2002)). Other studies have found positive correlations between growth and undervalued currencies measured as accumulation of reserves (Polterovich e Popov 2002), a result that seems to suggest an important relationship between growth and real exchange rate levels.

Following the discussion, this work presents new econometric evidence for the relation between exchange rate levels and growth rates. Our main contribution here is to estimate growth regressions with a real exchange rate index that deals with changes in real GDP *per capita* levels. We use a new overvaluation index that takes into account variations in real *per capita* incomes, adjusting, thus, our exchange rate estimates for the so-called Balassa-Samuelson effect. By correcting traditional real exchange rate annual estimates for GDP *per capita* increases, we intend to control our whole series for appreciations due to productivity increases (as Dollar (1992), Benaroya e Janci (1999) and Ong (1997) do for some specific years). In line with these works, our results show a negative relationship between growth and overvaluations. In what follows, the paper discusses studies that have dealt with the problem of estimating equilibrium exchange rates and its relation to growth and presents new evidence from a panel data study for 58 developing countries from 1960 until 1999 using PPP deviation measures. The paper is divided in four sections, besides the Introduction. The next section discusses old econometric evidence based on three measurement methods: PPP deviations, internal and external equilibrium and reserves' levels. Section 3 deals with the real exchange rate (RER) measurement methodology that will be used in our econometric estimation, with special attention to our methodology for RER productivity corrections. Section 4 presents the data, the regressions and the results. Section 5 brings some brief conclusions.

2. Old Evidence

In a well known paper from 1992, David Dollar argues that outward oriented developing countries tend to grow more when compared to inward oriented economies. He analyses 95 developing countries in the period 1976-1985 and, based on an "outward orientation" index constructed with PPP comparisons, concludes that the more outward oriented the country, the higher its *per capita* growth rates (Dollar 1992, p. 541). Classifying the countries in three groups, Latin America, Africa and Asia, he demonstrates that the latter, well known for their successful development strategy, are more outward oriented than African or Latin American countries. Based on measures of volatility and international price comparisons, Dollar (1992) shows that more stable and depreciated currencies are associated with higher *per capita* growth rates.

According to his calculations, based on regression analysis, if Latin American and African countries were to change to Asian exchange rate patterns their growth rates could have been, respectively, 1.5% and 2.1% higher on average from 1976 until 1985 (Dollar 1992, p. 535). The author concentrates his work in carrying out the empirical analysis, dedicating little space for a theoretical discussion. Among the few arguments presented, the author points out to the tradeables' sector dynamism and to the importance for economic growth of positive externalities brought about by exports. Benaroya e Janci (1999) also work with PPP deviations as measures of real exchange rate levels and find results in accordance with Dollar's (1992) work. They build an extended version of the Balassa-Samuelson model (Balassa 1964) and relaxing some of the traditional hypothesis used by the authors they find significant correlations between exchange rate levels and growth rates. Countries that show relative undervaluation as compared to an extended Balassa-Samuelson rule (the higher the *per capita* income, the more appreciated the currency), tend to have higher exports and *per capita* growth rates (Benaroya and Janci 1999, p. 234).

Easterly (2001) analyzes growth in developing countries from 1980 until 1998. He shows that despite the reforms of the 80s and 90s, observed growth rates were less than expected and lower than in the 60s and 70s. Lower growth in OECD countries, higher interest rate levels and debt burden would be important candidates to explain this general growth slow down. In the regression analyses, several of the traditional variables of the literature are used, such as: initial GDP *per capita*, schooling, infra-structure and price stability among others. The results tend to confirm the basic findings of the literature where better education and infra-structure contributes to growth whereas higher inflation rates tend to be an obstacle to growth. One important innovation of this work is the calculation of a long series of real exchange rates for developed and developing countries using averages calculated by Dollar (1992), as we will discuss further on. Easterly's (2001) results also point out to a negative correlation between exchange rate overvaluation and *per capita* growth rates. A possible shortcoming of his work is that it doesn't extend Dollar's methodology to take into account changes in *per capita* income levels as we do in this paper.

Fajnzylber et alii (2002) report similar results when comparing growth in Latin American economies and other countries during the period 1960-99. They work with the real exchange rate overvaluation index constructed by Easterly (2001). After controlling the regressions for the traditional variables in the literature, they also come to the conclusion that exchange rate overvaluations have an important negative impact on growth. About possible theoretical explanations for the empirical findings, they point out to the increasing probability of balance of payment crises associated with exchange rate overvaluations. Acemoglu et alii (2002) present similar evidences in the relation between real exchange rate levels and *per capita* growth rates when working with Easterly's (2001) index. In a work on macroeconomic institutions and growth with 96 countries from 1970 until 1997, they do not discard the effects of real exchange rate levels in variations of *per capita* growth rates through time. Although one of the main conclusions of the study highlights the importance of institutions instead of macro variables as a cause of economic development, real exchange rates still appear with relevance. Bad macroeconomic administration would be a symptom of the presence of "weak institutions". The authors find strong correlations between institutions and macroeconomic volatility, crises and growth. When taking into account the effects of institutions on product volatility, the traditional macroeconomic variables lose relevance, with the possible exception of the real exchange rate (Acemoglu et alii 2002). Both works of Acemoglu et alii (2002) and Fajnzylber et alii (2002) suffer from the problem of not adjusting the real exchange rate for productivity increases because they are all based on Easterly's (2001) overvaluation index.

Ironically, one of the important empirical works that tries to measure the impacts of exchange rate misalignment on growth based on the notion of internal and external equilibrium was Cavallo et alii (1990). The authors build an index of exchange rate disequilibrium for developing countries in the period 1960-1983. They correlate *per capita* income growth rates with this index that represents exchange rate deviations in relation to a supposed equilibrium position to reach the typical result of this literature: exchange rate overvaluations associated with lower *per capita* growth rates in developing countries (Cavallo *et alii* 1990, p. 75). They also find the result of higher exchange rate volatility associated to lower rates of *per capita* growth. The index constructed by the authors takes into account some measures to try to identify real exchange equilibrium positions: excessive currency and credit creation by the government, excessive capital inflows or external indebtedness and protectionist policies. They argue that the absence of these factors implies in a real exchange rate closer to equilibrium. According to Cavallo et alii (1990), those measures would identify exchange rate misalignments induced by domestic policies and, therefore, not dependent on external shocks.

When discussing the results, the authors do not present a long theoretical discussion on the subject, following the majority of the works in the literature. They limit themselves to present arguments in relation to the negative consequences of overvaluations, such as reductions of profitability in the tradeables sector. When pointing out to the importance of the technological dynamism observed in the non traditional tradeables sector, they have in mind the problem of the Dutch Disease and its potential negative effects in terms of productivity increases in domestic industries (Cavallo *et alii* 1990, p. 62). Regarding real exchange rate volatility, they point out to the negative consequences of uncertainty on production and investment decisions. It is important to notice that Cavallo et alii (1990) also highlight the possibility of exchange rate appreciation as a consequence of economic development. In this case, appreciations as a consequence of productivity increases in the domestic industries would mean a natural movement towards equilibrium, not a misalignment problem, as we shall discuss below.

Razin e Collins (1997) also explore the relation between exchange rate misalignment and *per capita* growth rates. They build a measure of misalignment for 93 countries from 1975 until 1993 based on the concepts of internal and external equilibrium that resembles Cavallo's et al (1990) index. According to their methodology, the long run equilibrium exchange rate would be one capable of generating sustainable current account dynamics at full employment levels, in Williamson's (1995) definition, an "equilibrium real exchange rate". Misalignments would be represented by deviations of the real exchange rate in relation to this supposedly neutral level. Based on this misalignment index, Razin e Collins (1997) make regression analyses in order to estimate the relation between *per capita* growth rates and real exchange rate levels. They find that strongly appreciated currencies are associated to lower *per capita* growth rates whereas moderately devaluated currencies are associated to higher rates (Razin e Collins 1997, p. 20). Their work concentrates on misalignment measures, not worrying about the theoretical explanations for the empirical findings.

Popov e Polterovich (2002) follow a distinct path in the literature. The authors are worried about the possible positive effects of exchange rate undervaluation on long run growth rather than the problems of overvaluation. They investigate in cross country analyses the effects of competitive currencies on growth. The authors work with a sample of 100 developed and developing countries in the period 1960-1999 and introduce a new real exchange rate measure associated to foreign exchange reserves accumulation. Reserve accumulation would serve as a proxy for situations of relative real exchange rate undervaluation and many governments of developing countries would practice that kind of deliberate policy as a development strategy. Such an option expresses itself in the constant acquisition of reserves by governments that would end up keeping their currencies very competitive for long periods of time. China, Hong Kong, Taiwan, Singapore, Malaysia and Thailand with about 1/5 of today's world reserves are good examples.

When analyzing the period 1960-1999, they find wide variation in the levels of foreign exchange reserves of different countries. Some economies have already reached more than 40% of the GDP in reserves for different periods of time, such as: Hong Kong 40%, Singapore 60%, Botswana 100%, while other countries present quite reduced levels, varying between 5 and 10% of the GDP. When correlating levels of reserves with *per capita* growth rates, they find a positive relation for developing countries. After controlling the cross country regressions for the initial level of *per capita* income, investment rates over GDP and population growth, they find the result that the accumulation of foreign exchange reserves as a deliberate policy of monetary authorities is a relevant factor in explaining *per capita* growth rates (Polterovich and Popov 2002, p. 13). The authors also find strong positive correlations between foreign exchange reserves accumulation and: investment rates over GDP, trade volume over GDP, levels of foreign direct investment (FDI) and undervaluation measured as PPP deviations.

3. Misalignments Measured as PPP Deviations and Balassa-Samuelson Adjustments

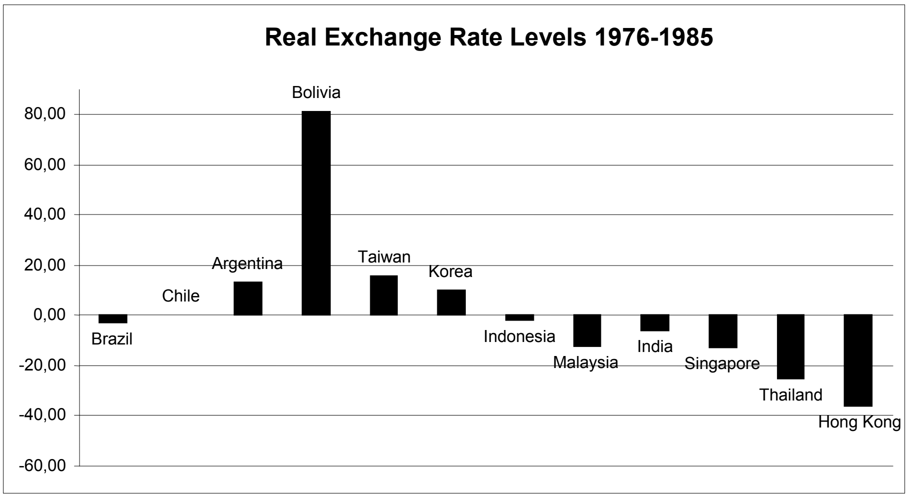
Most works on PPP deviations and growth reviewed above are based on Dollar's (1992) methodology for estimating real exchange rate disequilibrium (Benaroya e Janci (1999), Easterly (2001), Fajnzylber et alii (2002), Acemoglu et alii (2002)). Dollar (1992) uses Heston and Summers' PPP estimations to calculate relative international price levels RPL_i for 95 developing countries from 1976 until 1985. The author compares local prices measured in dollars using current nominal exchange rates with prices in dollars in the United States. If prices are the same, the exchange rate is said to be in a neutral position. If prices are higher (lower) there might be some overvaluation (undervaluation). As Dollar (1992) argues, those estimates have to take into account the fact that prices of non tradeables in poorer countries tend to be lower because of lower wages. Thus, overvaluation or undervaluation has to be analyzed in terms of relative *per capita* income levels.

A good way to evaluate those differences of prices in non tradeables is to think about countries' factors endowments. If there is scarcity of a non tradeable in country A (labor for example), its price will probably be higher when compared with country B, where the same factor is abundant. Since labor is one of the main components of non tradeable goods, it is reasonable to expect that countries with labor abundance will have relatively lower prices of non-tradeables as compared to countries where labor is scarce. As developed countries have lower endowments of labor than developing countries, it seems reasonable to assume that the prices of non-tradeables will be relatively higher in the former.

A positive relation between *per capita* income and relative price levels RPL_i should be expected according to this argument. By raising the production cost of goods in wage terms, higher prices of non tradeables in developed countries make relative international price levels between countries RPL_i higher in developed countries. This line of reasoning approaches the Balassa-Samuelson argument. According to Balassa, developed countries are more productive than developing countries in tradeables and have the same productivity in non tradeables. Assuming that prices of tradeables equalizes between countries (law of one price) and that the domestic labor markets are not segmented, lower productivity of labor in tradeables will mean lower wages in developing countries in both sectors, tradeables and non tradeables, resulting in lower relative prices of non tradeables in these economies (Balassa 1964, p. 586).

Dollar (1992) tries to capture this relative price RPL_i differences based on an analysis of endowments in different countries. As a direct measure of endowments would be practically impossible, the author opts for using the real GDP *per capita* (measured in PPP) as a proxy for measuring relative factor endowments. GDP *per capita* represents the availability of factors of production, especially capital, for each individual of a determined country in a given moment of time. The lower is the GDP *per capita*, the higher is the abundance of labor and the scarcer is the capital stock. When regressing relative price levels on real GDP *per capita* growth (measured in PPP), the author finds "adequate" price levels for each country, given its *per capita* income level. The higher the real GDP, the higher its relative price level or exchange rate appreciation should be. A comparison between regressions predicted and observed price levels results in a distortion measure as compared to the American benchmark. According to author, excessively high price levels in international comparisons would mean, everything else being constant, protectionism or overvaluation.

Figure 1 shows the results found by Dollar (1992) for a series of 12 countries. The indexes are an average of the period 1976-85 that, according to author, would be able to cancel out short run variations, therefore approaching a long run equilibrium position. The values above 0 represent overvaluation in relation to the PPP price of the considered basket and below 0, undervaluation. The results adjust reasonably, according to author, to the known studies for these countries.



Source: Dollar (1992)

Fig. 1. RER levels

Dollar's methodology inspired several other works. In our own estimations bellow, we followed his methodology trying to generalize it for all years and all countries in our panel analysis. Easterly (2001), for example, uses Dollar's index but doesn't take into account variations in real GDP *per capita*. Based on Dollar's work (1992), Easterly (2001) constructs a series of real exchange rates from 1960 until 1999 for developed and developing countries. He applies, initially, the traditional methodology for calculations of real exchange rates: "(Domestic CPI)/(Exchange Rate Domestic Currency to per Dollar"*US CPI)". To make the series of different countries fairly comparable, he centers his results in index numbers using the values found by Dollar (1992). For each country, the author benchmarks the series of index numbers in order to make the averages for the period 1976-1985 equal to Dollar's work (Easterly 2001, p. 9). A real exchange rate of 100 in Easterly's (2001) series means a position equivalent to a PPP exchange rate adjusted for the *per capita* income of the country between the years 1976-1985 using Dollar's methodology, in other words, a "neutral" exchange rate. An index higher than 100 means a relative appreciation and lower than 100 a relative undervaluation. Easterly's work does not include the calculation of a real exchange rate series for Brazil in the period 1960-1980. From Abreu (1990) nominal exchange rate data and from Brazilian and American CPIs, we also calculate a series for Brazil in the period 1965-1985 based on Easterly's (2001) methodology.

Easterly's (2001) methodology for the construction of the real exchange rate series does not take into account variations in *per capita* incomes in relation to the US during the analyzed period. Dollar's (1992) calculation considers this variation when constructing exchange rate indexes measured as PPP deviations with *per capita* income adjustments. When adopting only inflation and nominal exchange rate variations, Easterly (2001) ignores variations of *per capita* income. A country that went through considerable increases of *per capita* income as compared to the US should present real appreciation according to the Balassa-Samuelson argument. Thinking again in terms of relative scarcity of factors, a more productive country in tradeables in relation to non tradeables and, therefore, with a higher *per capita* income, should present higher real wages that would be reflected in higher prices of non tradeables. Countries with higher *per capita* incomes should present more appreciated real exchange rates.

The evolution of the real exchange rates presented by Easterly (2001) would only be adequate if during the analyzed period *per capita* income levels of those countries remained constant as compared to the American levels, which does not seem to be the case. Countries whose ratio of *per capita* income compared to the US increased throughout this period should be going through productivity increases and real exchange rate appreciation. Some countries such as Brazil and Chile present small variations in terms of real relative *per capita* income (measured in PPP terms) in relation to the US, meaning therefore small relative productivity changes. For countries with few *per capita* income variations, the series constructed by Easterly (2001) does not present many problems. For countries such as Taiwan and South Korea, with considerable increases in real *per capita* income and, thus, productivity in the period, Easterly's index (2001) can be somewhat distorted. South Korea and Taiwan, for example, have multiplied their relative real *per capita* incomes as compared to the US by 4.7 and 5.32 respectively.

From data on the variation of relative *per capita* incomes for different countries it is possible to construct a new series of exchange rate distortions in line with Dollar's (1992) work. As mentioned above, real *per capita* income increases can be taken as proxies for productivity increases. Countries with higher productivity and *per capita* income would have higher labor scarcity and, thus, higher wages, driving prices of non-tradeables up (real exchange rate appreciation). To measure this effect, we can calculate potential appreciations (depreciations) based on *per capita* income increases (reductions). For example, if Taiwanese productivity increased 107.9% in relation to its relative position to the US in 1976-85 between the average period 76-85 and 1999, its real exchange rate should have appreciated in some magnitude reflecting the relative wage increases occurred in Taiwan. In other words, the Taiwanese dollar should have appreciated as a consequence of productivity increases. In the Brazilian case, the exchange rate should have been depreciated in 20% in 1999 in relation to its 1976-1985 average level in order to make up for the loss of productivity of the Brazilian economy as compared to the US (if we assume a conversion factor of 100% of variation of relative *per capita* income in relation to the US to variations in the real exchange rate).

Following this reasoning, we can build a series of exchange rate distortions measured as the variation of the observed real exchange rate divided by the variation of *per capita* income relative to the US. For example, in 1999 the Brazilian index of real exchange rate should be 80.0 if adjusted for the relative productivity increases/decreases of the Brazilian economy as compared to the US. The number found by Easterly (2001) was of 83.77. The index was 16.23% points below this "neutral" exchange rate and its variation in relation to the average 76-85 was (83.77/97)*100 = 86.3. Comparing this level with the variations of the Brazilian *per capita* income we get the result (86.3/80) = 1.079, in other words, a distortion of 7.9% above the average 1976-1985. Since, according to Dollar (1992), this average was 3% below the equilibrium, we should apply another correction to find the final distortion of the exchange rate in 1999 in terms of a "neutral" exchange rate, (1.0795*97) = 104.70.

In the Taiwanese case, the data of *per capita* income variations points to a real exchange rate adjusted for productivity variations 107.9% more appreciated in 1999 than in the 1976-1985 average. Easterly (2001) finds a real exchange rate calculated just taking into consideration variations of prices and nominal exchange rate of 117.96, in other words, an appreciation of 17.96% in relation to the "neutral" exchange rate year and 1.68% in relation to the 1976-1985 average which was 116.0. Comparing Easterly's number (101.68) with the Taiwanese variation of relative *per capita* income to the US of 207.9 we get the result (101.68/207.9) = 0.489. Since the average of Dollar (1992) for this period pointed out to a small overvaluation (16%) of the Taiwanese dollar, we can multiply it by 0.489 to find the Taiwanese exchange rate distortion, (0.489*116) = 56.73. In other words, the exchange rate would be depreciated in relation to its equilibrium position calculated by Dollar (1992) in the difference (100 − 56.73) = 43.27%.

In the Chilean case, in 1979, the index of variation of relative *per capita* income points out to a 104.8 exchange rate, that is 4.8% above the average 1976-85 and the rate calculated by Easterly (2001) points out to a value of 105.27. Making the same calculations we can find the distortion of the Chilean exchange rate in relation to its 76-85 average, (105.27/104.8) = 1.004. In this year, the Chilean currency would be, thus, practically in the position equivalent to the average of the period 76-85. Since the Chilean average for 76-85 of 100 is equivalent to its equilibrium in Dollar's methodology (1992), the rate in 1979 seems to be in a non distorted level.

In formalized terms, the index can be expressed in the following way:

$$RER^* = [\text{real exchange rate variation / relative GDP variation}] \times \text{Dollar's index (1992)} \quad (1)$$

$$RER^* = [(S_{t+s}/S_t)/((GDP_i/GDP_{us})_{t+s}/(GDP_i/GDP_{us})_t)]S_t \qquad (2)$$

Simplifying the expression,

$$RER^* = S_{t+s}/[(GDP_i/GDP_{us})_{t+s}/(GDP_i/GDP_{us})_t] \qquad (3)$$

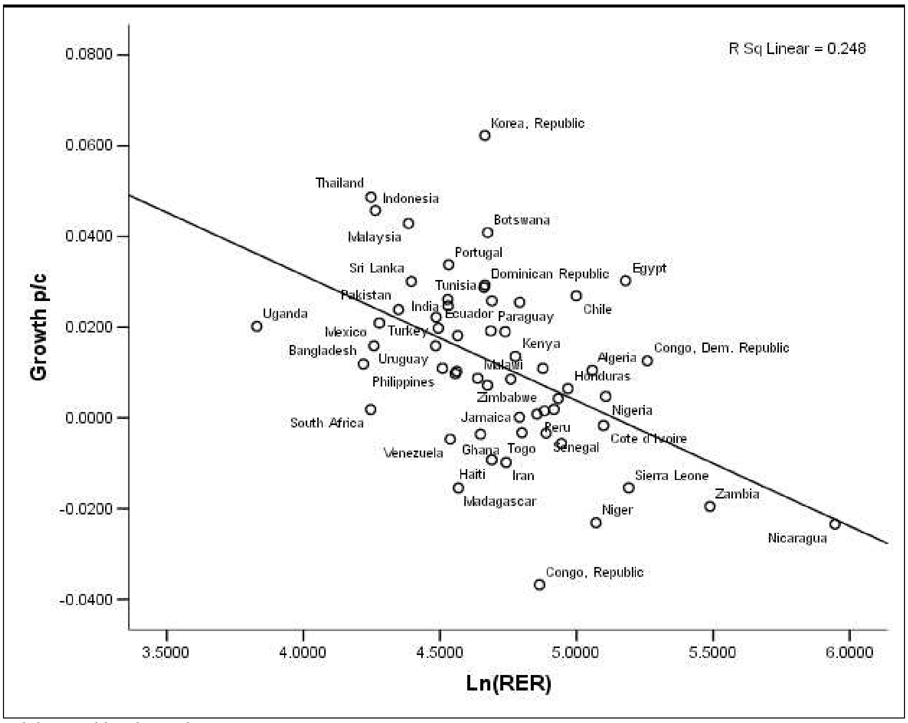
RER^*: Adjusted Real Exchange rate; S_t: real Exchange rate in year t [Dollar's average (1992)]; S_{t+s}:Real Exchange Rate in year s; GDP_i: *per capita* income in PPP of country i; GDP_{us}: *per capita* income in PPP of the US.

The corrected index is nothing more than the value found by Easterly (2001), deflated by a productivity differential (for indices with similar constructions for specific years see, Ong (1997) and Benaroya e Janci (1999)). However a qualification is important. In order to construct the index we assumed that 100% of variation of productivity relative to the United States is transmitted to the real exchange rate, making the index very sensible to real income variations. If a country had 20% of the American *per capita* income in t and goes to 40% in $t + s$, its real exchange rate should have appreciated in 100% in relation to the US dollar.

4. New Evidence

The prime data source for the panel data analysis that follows is the database compiled by Easterly (2005). Real exchange rate levels are measured by the computations of Easterly (2001), as explained above. GDP levels and growth rates are computed from the World Bank database. The sample contains 58 developing countries with an average *per capita* income between approximately 500 and 7.000 PPP US dollars in the period that goes from 1960 until 1999. If the lower bound for inclusion in the sample were below 500 dollars, many African countries which experienced significant exchange rate appreciation would be left outside the sample. If the bound was set above 7.000 PPP dollars, many countries that are now considered developed would be included. From a grand total of 58 countries, 23 are from Africa, 19 from Latin America and Caribbean, 13 from Asia and Middle East and 3 from Europe. Besides the selection based on *per capita* income levels, data availability was also taken into account.

The following figure shows – on a logarithmic scale – a scatter plot of GDP growth rates and exchange rate levels for the mentioned countries from 1960 until 1999. The averages were computed according to data availability. The data shows that for the period average, countries with relatively overvalued real exchange rates presented lower *per capita* income growth rates. The African countries tend to cluster on the right-hand side of the figure, presenting relative overvaluation and the Asian countries on the left-hand side, showing relative undervaluation.



Elaborated by the authors

Fig. 2. Growth and overvaluation

Control variables chosen for the econometric analysis can be classified into two groups: structural and macroeconomic. The first group represents the well known variables of the economic growth literature and includes *proxies* for human capital, physical and institutional infrastructures. The second group uses variables from a more recent literature which tries to correlate short-run variables with long-run economic results. On that group, we have selected inflation rates, capacity utilization – or output gap – exchange rate overvaluation and terms of trade shocks.

The first variable on the structural group is related to current investment on human capital, which is considered as a production factor, as well as having effects on total factor productivity. This is measured from data on the gross rate of secondary school enrolment, in accordance to Barro (1991), Mankiw et alii (1992) and Fajnzylber et alii (2002). The second structural variable to be used tries to measure public infrastructure availability. The results relating higher growth rates to better infrastructure are also well-known on the empirical literature. Given the difficulties on data collection on this area, we decided to use data on telecommunications infrastructure, measured as the number of *per capita* phone lines, as computed in Fajnzylber et alii (2002). It seems reasonable to use this variable as a proxy for physical infrastructure since the literature documents a high correlation between *per capita* phone lines and other infrastructure measures such as transport and energy. The third structural variable refers to the quality of institutional environment, which is to be directly connected to production and investment conditions. We used the index computed by the *Political Risk Services* (International Country Risk Guide – ICRG) which includes the following variables: rule of law, quality of bureaucracy, absence of corruption and the level of accountability of public servants.

Regarding macro-environment variables, the first one is related to price level stability. We take the yearly average inflation level as an indication of macroeconomic stability. The second one, which we denote "Initial GDP gap" gives an estimate of idle installed capacity or output gap and is measured as trend deviation. The lower the activity level, the greater the opportunities for increases in income and production are due to a greater use of already existing capital and labour stocks. The variable terms of trade shocks captures the positive – or negative – effects of international trade which can be translated into changes on GDP growth rates. Data on both the output gap and terms of trade are from Fajnzylber et alii (2002). Finally, the most important variable for the present paper measures the degree of overvaluation of the national currency. Following the reasoning presented on the previous sections, overvalued real exchange rates are related to lower GDP growth rates due to their negative short-run effects (balance of payments crises), as well as their long-run negative effects (lack of technological innovations as in Dutch Disease cases).

We also use the initial *per capita* income level as an additional regressor, following the conditional convergence hypothesis of the economic growth literature. Given the same macroeconomic and structural characteristics (such as human capital, inflation levels, etc.), countries with higher *per capita* PPP incomes are expected to grow less due to decreasing marginal returns on the capital stock. All variables on the estimations, except output gap, terms of trade shocks and *per capita* income growth rates, were subject to the logarithmic transformation. Despite our care in selecting countries regarding data availability, the final panel database was unbalanced since we could not find data for all countries in all years. [1]

In order to investigate the time series properties of the series, we carried out the procedure outlined by Maddala e Wu (1999), combining the *p*-values of the individual unit root tests. The advantage of this procedure is that it can be applied in an unbalanced panel, which is the case of our database. The results of the tests, with two lags to account for residual autocorrelation and an intercept, are presented on Table A.1 in the Appendix. The results seem to

[1] All estimators used herein are adjusted for unbalanced panels. As for the potential problem of sample selection induced by that, we are implicitly assuming the selection process is uncorrelated to the independent variables, as in Wooldridge (2002), pp. 577–578.

assure us of the stationarity conditions required for the following econometric analysis, such as those required in Bond, Hoeffler and Temple (2001, p. 8).

The econometric framework used follows the traditional literature of growth regressions (for some examples, see Acemoglu et alii (2002) and Fajnzylber et alii (2002)). GDP *per capita* growth rate is the dependent variable, which is expected to depend on a vector of variables representing growth determinants $X_{i,t}$, together with the initial GDP *per capita* levels $Y_{i,t}$ for each country i on a given time period t. The estimated model follows the traditional specification in which n is the number of periods included:

$$(\ln(Y_{i,t}) - \ln(Y_{i,t-1})) = \beta_0 + \beta_1 \ln(Y_{i,t-1}) + \beta_2 X_{i,t} + \epsilon_{i,t} \tag{4}$$

The models were initially estimated using cross-sectional averages for the whole period, and next using five year averages, computed according to the data availability for each country. For the model estimated using Ordinary Least squares and Heteroskedasticity and Autocorrelation Robust Standard Errors, the results are presented on the following table:

Table 1
Initial estimation results

Dependent variable: *per capita* growth rate	**O. L. S.**	**O. L. S. pool**
Initial GDP *per capita*	-0.0217***	-0.0072
	(-7.2353)	(-1.5157)
Schooling	0.0107**	0.0056
	(3.0099)	(1.8114)
Infrastructure	0.0080**	0.0031
	(3.3594)	(1.2795)
Institutions	0.0040	0.0043**
	(1.9352)	(2.8259)
Price Stability	-0.0049	-0.0188***
	(-1.3215)	(-5.3948)
Exchange Rate Overvaluation	-0.0168***	-0.0100**
	(-3.5846)	(-3.0760)
Constant	0.2730***	0.1783***
	(7.7994)	(5.0338)
Number of Obs.	58	341
R-sq	0.676	0.207
R-sq adj.	0.638	0.192
$^{*}p < 0.05$, $^{**}p < 0.01$, $^{***}p < 0.001$		

*Elaborated by the authors.

The coefficient associated with the real exchange rate overvaluation is equal to -0.0168, a highly significant value. Everything else being constant, a devaluation of the real exchange rate of 10% could contribute for an increase of 0.0168*10/100 = 0.00168, or 0.168 percentage points on average growth on *per capita* income. A devaluation of 40 percentage points would be associated to an increase on real *per capita* income growth rates of 0.0168*40/100 = 0.672 percentage points, over half a percentage point on average growth rates of real *per capita* income.

Since we have a panel data base, we took advantage of this structure and used techniques specifically designed for this kind of sample allowing us to include two other variables, output gap and terms of trade shocks, besides the productivity adjustment on exchange rates computed on the previous section and here denoted by RER^*. The main advantage of this technique is that it allows us to exploit both the cross-sectional and time series characteristics of the sample. However, some care must be taken regarding estimation problems on growth regressions. Among the possible pitfalls, we can single out the endogeneity problem posed by Bond et alii (2001). By using the initial level of *per capita* income on the right hand side of Equation (4) for convergence analyses, this model ends up using the dependent variable as one of the regressors, causing possible biases on the estimators. An additional problem lies on the fact that we used the *per capita* income level as a proxy for productivity differentials in order to adjust the level of real overvaluation. Thus, panel estimates, with either fixed or random effects for modelling the unobserved heterogeneity are expected to be biased.

Following Fajnzylber et alii (2002), we used the following specification expressed in first differences, in which the left-hand side of the equation represents *per capita* income growth rates for each period analyzed, μ captures time specific effects, η country specific effects, and $\epsilon_{i,t}$ represents the idiosyncratic errors. The time specific effects are intended to capture productivity changes that are common to all countries,[2] while the country specific effects aim to capture differences on the initial level of efficiency (Bond et alii 2001).

$$\ln(Y_{i,t}) - \ln(Y_{i,t-1}) = \beta_1 \ln(Y_{i,t-1}) + \beta_2 X_{i,t} + \mu_t + \eta_i + \epsilon_{i,t} \qquad (5)$$

We chose to use the Generalized Method of Moments (GMM) estimation technique, which is flexible enough to deal with the measurement errors and endogeneity problems, as in Bond et alii (2001).[3] Following Arellano and Arellano e Bover (1995) and Blundell e Bond (1998), we also used the GMM system estimators,[4] which are expected to outperform the GMM

[2] We did not try to choose the set of time specific effects to be included, because in addition to the more obvious productivity shocks such as the Oil Crisis, we might have some other ones, and the omission of these variables might bias our estimates.

[3] For this version of the GMM estimation, henceforth named "GMM-diff", the Equation (4) was rewritten, in which the left hand side of the expression comprises only $\ln(Y_{i,t})$ and the term $\ln(Y_{i,t-1})$ was absorbed on the right hand side. The resulting equation was differenced in order to remove time invariant country specific effects and the right hand side variables were instrumented using levels of the variables lagged two periods or more (Bond et alii 2001).

[4] For this version, we rewrote the Equation (4) presented above as in the previous footnote. However, when the time series used are persistent, the two period or more lagged variables are

difference estimator when the instruments present a high degree of persistence. When the instruments present a high degree of persistence through time, lagged differences are poor instruments, leading to unreliable estimates for the GMM difference estimators. All standard errors presented – for both the system and difference GMM estimates – are robust to heteroskedasticity and autocorrelation of arbitrary form. As for the choice of variables, we included the initial output gap for each five year period and terms of trade growth as exogenous, and the other ones are assumed to be endogenous, for which we used their own lags as instruments.

The estimates using the real exchange rate without productivity adjustments are in accordance to what we expected; the initial *per capita* income presents a significant negative sign on all estimated models, except in the GMM-sys, lending support to the hypothesis of conditional convergence. As for the structural variables, the coefficient associated with the schooling variable presents a positive sign, significant on the GMM-sys estimates. On the case of the macroeconomic variables, both inflation and the output gap present coefficients with the expected – and significant – signs on GMM system estimation. Terms of trade are positively related to *per capita* income growth rates, and exchange rate overvaluation is negatively related to *per capita* income growth; however, both relationships do not seem to be highly significant. The coefficients for the time dummies point to a decrease on the growth rates on the recent years. As for the estimations with real exchange rate productivity adjustments, the regressions show some differences (Table A.2 in the Appendix). Estimates using pool data show the same signs and some variables' significance increase. In the estimates using the GMM system methodology the coefficients associated with institutions, education and exchange rate overvaluation show increased significance and the expected signs. Dummies for the five year periods are also significant. Terms of trade, education, infra-structure and good institutions are positively correlated to *per capita* growth whereas inflation and overvaluation are negatively correlated.

As a check for the model's adequacy, we used the Sargan test for orthogonality of the instruments and error terms. The *p*-values of the tests indicate both models – system and difference GMM estimators – as adequate; however, the difference on the Sargan statistics point out to the superiority of the GMM system estimator as compared to the GMM difference estimator. We also tried to estimate the models without the heteroskedasticity and autocorrelation corrections, reaching much closer results to the ones presented by Fajnzylber et alii (2002) – shown in Table A.3 the Appendix.

poor instruments. Thus, the methodology uses, besides the differenced equations, for which the two period or more lagged variables are instruments, but also the levels equation. In this equation, the lagged first differences are instruments for the independent variables in levels (Bond et alii 2001)).

5. Conclusions

Our main concern in this paper was related to the impacts of overvaluations on growth. The estimates using PPP comparisons try to capture the influences of real exchange rate levels on *per capita* growth rates, especially when corrected for the Balassa-Samuelson effect. Our estimates using real exchange rate corrections for productivity differentials (proxied by *per capita* income differentials), show that both the absolute value and the significance of the coefficient associated with overvaluations are relevant. This indicates that productivity differentials may have an important role on the impact of real exchange levels on *per capita* real income growth rates. Our estimated coefficients for this variable are negative, ranging between 0.0080 and 0.0122 and highly significant. This implies that if the real exchange rate happens to be 10 percentage points more devalued, everything else being constant, real *per capita* income average growth rates could be 0,122% higher.

The corrected index for productivity differentials also shows that Asian countries seem to have been managing their currencies, trying to avoid appreciations; a result that has been recently referred as fear of floating (Calvo e Reinhart 2002). Because of space limitations we could not show the results of our correction index for all countries. The South Korean and Taiwanese cases in the eighties are certainly amongst the highest distortions in tems of undervaluation. Latin American countries seem to have distortions the other way round. Argentina and Brazil in the nineties are good examples here.

Our general findings point out to the relevance of exchange rate levels on real GDP *per capita* growth rates. The results are in line with the old econometric evidence that reports the shortcomings of overvaluations for long term growth. Our results also support several case studies that show the superiority of exchange rate management in East and Southeast Asia as compared to Latin American and African experiences in the last 30 years. Overvalued currencies in Mexico, Brazil and Argentina were an important cause of balance of payments crises in the eighties and nineties whereas competitive currencies are behind the successful export-led growth strategy of Asian countries since the seventies.

References

Abreu, M. P. (1990). *A Ordem do Progresso, Cem Anos de Política Econômica Republicana 1889-1989*. Ed. Campos, Rio de Janeiro.

Acemoglu, D., Johnson, S., Thaicharoen, Y., & Robinson, J. (2002). Institutional causes, macroeconomic symptons: Volatility, crisis and growth. NBER Working Paper 9124, Cambridge, MA., MIT.

Arellano, M. & Bover, O. (1995). Another look at the instrumental-variable estimation of error-componets models. *Journal of Econometrics*, 68(1):29–52.

Balassa, B. (1964). The purchasing power parity doctrine: A reappraisal. *Journal of Political Economy*, December:584–96.

Barro, R. J. (1991). Economic growth in a cross section of countries. *Quarterly Journal of Economics*, 56(2):407–43.

Benaroya, F. & Janci, D. (1999). Measuring exchange rates misalignment with purchasing power parity estimates. In Collignon, S., Pisani-Ferry, J., & Park, Y. C., editors, *Exchange Rate Policies in Emerging Asian Countries*. Routledge, New York.

Blundell, R. W. & Bond, S. R. (1998). Initial conditions and moment restrictions in dynamic panel data models. *Journal of Econometrics*, 87:115–143.

Bond, S., Hoeffler, A., & Temple, J. (2001). GMM estimation of empirical growth models. CEPR Discussion Paper 3048, London.

Bresser-Pereira, L. C. (2004). Brazil's *quasi*-stagnation and the growth *cum* foreign savings strategy. *International Journal of Political Economy*, 32(4):76–102.

Calvo, G. & Reinhart, C. M. (2002). Fear of floating. *Quarterly Journal of Economics*, 107(2):379–408.

Cavallo, D., Cottani, J. A., & Kahn, M. S. (1990). Real exchange rate behaviour and economic performance in LDCs. *Economic Development and Cultural Change*, 39:61–76.

Dollar, D. (1992). Outward-oriented developing economies really do grow more rapdidly: Evidence from 95 LDCs, 1976-1985. *Economic Development and Cultural change*, 40:523–44.

Dooley, M. P., Landau, D. F., & Garber, P. (2005). Interest rates, exchange rates and international adjustments. NBER Working Paper 11771, November.

Easterly, W. (2001). *The Lost Decades: Developing Countries' Stagnation in Spite of Policy Reform 1980-1998*. World Bank.

Easterly, W. (2005). Macro time series. http://www.nyu.edu/fas/institute/dri/Easterly.

Edwards, S. (1989). Exchange rate misalignment in developing countries. *The World Bank Research Observer*, 4(1).

Fajnzylber, P., Loayza, N., & Calderón, C. (2002). *Economic Growth in Latin America and the Caribbean*. The World Bank, Washington, DC.

Frenkel, R. (2004). Real exchange rate and employment in Argentina, Brazil, Chile and Mexico. Cedes, Buenos Aires, paper presented to the G24.

Maddala, G. S. & Wu, S. (1999). A comparative study of unit root tests with panel data and a new simple test. *Oxford Bulletin of Economics and Statistics*, 61:631–652.

Mankiw, G., Romer, P., & Weil, D. (1992). A contribution to the empirics of economic growth. *Quarterly Journal of Economics*, May:407–43.

Montiel, P. & Hinkle, L. (1999). *Exchange Rate Misalignment, Concepts and Measurement for Developing Countries*. World Bank Research Publication, Oxford University Press, Oxford.

Ong, L. L. (1997). Burgernomics: The economics of the Big Mac standard. *Journal of International Money and Finance*, 16:865–78.

Polterovich, V. & Popov, V. (2002). Acumulation of foreign exchange reserves and long term growth. New Economic School, Moscow, Russia, mimeo.

Popov, V. & Polterovich, V. (2002). Accumulation of foreign exchange reserves and long term growth. New Economic School, Moscow, Russia, unpublished paper.

Razin, O. & Collins, S. (1997). Real exchange rate misalignment and growth. In Razin,

A. & Sadka, E., editors, Forthcoming, *International Economic Integration: Public Economics Perspectives*. Cambridge University Press. Also at NBER Working Paper 6147.

Williamson, J. (1995). Estimates of FEERs. In Williamson, J., editor, *Estimating Equilibrium Exchange Rates*. Institute for International Economics, Washington, DC.

Appendix

Table A.1 – Maddala-Wu unit root test with drift

	P-Value	Test-stat	Lags
Growth	0.00460	61.9063	2
Initial GDP *per capita*	0.00280	63.983	2
Initial output gap	0.00000	81.9239	2
Education	0.46000	36.1863	2
Public infrastructure	0.01020	58.5268 2	
Governance	0.00050	70.7425	2
Lack of price stability	0.18920	49.8574 2	
Real exchange rate overvaluation	0.06620	49.5131	2
Terms of trade shocks	0.01530	56.7322	2

H0: All series are non-stationary.

Table A.2 – Estimations results (Robust)

Dependent variable: *per capita* growth rates	M.Q.O. pool	Fixed effects	GMM-DIFF	GMM-SYS
Initial GDP *per capita*	-0.0213***	-0.0753***	-0.0679***	-0.0427*
	(-4.6135)	(-8.4980)	(-3.6584)	(-2.4504)
Initial GDP gap	-0.1023*	-0.1102*	-0.1853***	-0.1736**
	(-2.1843)	(-2.4145)	(-3.6048)	(-2.8335)
Schooling	0.0125***	0.0028	0.0003	0.0216**
	(4.1783)	(0.4772)	(0.0230)	(2.9702)
Infra-structure	0.0083***	0.0214***	0.0275	0.0219*
	(3.4741)	(3.8201)	(1.6071)	(2.2767)
Institutions	0.0045***	0.0040	-0.0029	0.0041
	(3.4109)	(1.9437)	(-0.7306)	(1.1671)
Price stability	-0.0146***	-0.0118***	-0.0108*	-0.0165*
	(-4.8006)	(-3.6393)	(-2.0426)	(-2.0964)
Exchange rate overvaluation (adjusted)	-0.0128***	-0.0175***	-0.0095	-0.0122*
	(-4.7731)	(-4.2610)	(-1.1583)	(-2.3807)
Terms of trade	0.0460	0.0445	0.0454	0.0419
	(1.6265)	(1.7398)	(1.3755)	(1.4505)
Years 66-70	-0.0020	0.0062	0.0080	-0.0011
	(-0.2799)	(0.9631)	(1.1118)	(-0.2795)
Years 71-75	-0.0040	0.0060	0.0059	-0.0087
	(-0.5906)	(0.8490)	(0.4717)	(-1.4034)
Years 76-80	-0.0108	0.0075	0.0076	-0.0140
	(-1.5541)	(0.8824)	(0.4058)	(-1.4305)
Years 81-85	-0.0304***	-0.0093	-0.0085	-0.0352***
	(-4.5164)	(-0.9938)	(-0.3903)	(-4.5923)
Years 86-90	-0.0200**	-0.0039	-0.0036	-0.0308***
	(-2.9893)	(-0.3819)	(-0.1427)	(-4.1198)
Years 91-95	-0.0261***	-0.0114	-0.0087	-0.0426***
	(-3.7962)	(-0.9750)	(-0.2832)	(-4.3935)
Years 96-99	-0.0287***	-0.0145	-0.0150	-0.0499***
	(-4.0480)	(-1.0958)	(-0.4220)	(-4.7103)
Constant	0.2585***	0.6563***		0.3664**
	(7.1076)	(9.2941)		(2.9319)
N-Obs	341	341	281	341
R-sq	0.367	0.387		
Sargan *p*-val			0.191	0.994
P-val autocorr.1			0.000000	0.000000
P-val autocorr.2			0.485000	0.375000
$^{*}p < 0.05$, $^{**}p < 0.01$, $^{***}p < 0.001$				

Table A.3 – GMM Fixed and OLS results

Dependent variable: *per capita* growth rates	M.Q.O. pool	Fixed effects	GMM-DIFF	GMM-SYS
Initial GDP *per capita*	-0.0181***	-0.0587***	-0.0606**	-0.0252***
	(-3.9736)	(-7.2455)	(-3.0627)	(-3.8811)
Initial GDP gap	-0.0990*	-0.1477**	-0.2038***	-0.1851***
	(-2.0927)	(-3.1846)	(-4.0789)	(-8.3900)
Schooling	0.0121***	0.0016	-0.0069	0.0239***
	(3.9770)	(0.2611)	(-0.5537)	(5.6236)
Infra-structure	0.0075**	0.0210***	0.0226	0.0140**
	(3.1318)	(3.6069)	(1.3519)	(2.9993)
Institutions	0.0045***	0.0038	-0.0037	0.0042*
	(3.3575)	(1.7893)	(-1.1384)	(2.5292)
Price Stability	-0.0157***	-0.0143***	-0.0136*	-0.0198***
	(-5.1530)	(-4.3234)	(-2.1866)	(-6.6844)
Exchange rate overvaluation (adjusted)	-0.0125***	-0.0053	0.0049	-0.0080**
	(-3.9081)	(-1.2489)	(0.6260)	(-3.0559)
Terms of Trade	0.0486	0.0550*	0.0623*	0.0496***
	(1.6967)	(2.0892)	(2.1193)	(3.9076)
Years 66-70	-0.0018	0.0056	0.0114	-0.0023
	(-0.2466)	(0.8460)	(1.4098)	(-1.0574)
Years 71-75	-0.0035	0.0047	0.0124	-0.0101***
	(-0.5140)	(0.6459)	(1.0147)	(-3.8173)
Years 76-80	-0.0102	0.0045	0.0149	-0.0162***
	(-1.4415)	(0.5179)	(0.8785)	(-4.0367)
Years 81-85	-0.0297***	-0.0113	0.0033	-0.0356***
	(-4.3742)	(-1.1587)	(0.1553)	(-10.7591)
Years 86-90	-0.0204**	-0.0061	0.0107	-0.0303***
	(-3.0150)	(-0.5693)	(0.4313)	(-7.5604)
Years 91-95	-0.0266***	-0.0129	0.0093	-0.0396***
	(-3.8117)	(-1.0361)	(0.3076)	(-8.2420)
Years 96-99	-0.0291***	-0.0173	0.0048	-0.0448***
	(-4.0489)	(-1.2323)	(0.1361)	(-8.0622)
Constant	0.2409***	0.4925***		0.2426***
	(6.6264)	(8.1265)		(5.0004)
N-Obs	341	341	281	341
R-sq	0.353	0.349		
$^{*}p < 0.05$, $^{**}p < 0.01$, $^{***}p < 0.001$				