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Institutions and Total Factor Productivity Convergence

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Abstract

The paper examines the effect that institutions have on Total Factor Productivity (TFP) growth. This is done by creating a TFP gap between the leader and each of the following countries. The global leaders used are the USA and an average of OECD members. The coefficient on the gap measures each country's ability to learn or absorb new technology from the more advanced leader. The results show that institutions do not seem to have as significant a role in TFP growth as other literature has suggested. The most influential variables are country-specific factors: this would indicate that a one size fits all model will not help developing nations to catchup. When institution variables were added to the model they manage to only explain 31 per cent of TFP difference. This implies that there is still a large portion of TFP growth that is random and not explicable using current economic models.

1 Introduction

Much of the recent literature on economic growth has discussed the impact that institutions can have on economic efficiency. For instance, Hall and Jones (1999) and Acemoglu, Johnson and Robinson (2001) have emphasised institutional differences as perhaps the key factors explaining why some countries are rich while others are poor. The existing literature, however, contains very little evidence on the exact form of the linkages between institutions and improvements in efficiency. This paper addresses this issue by examining the relationships between growth in Total Factor Productivity (TFP) and various measures of institutions in a large cross-country panel dataset.

One channel through which institutions are likely to affect TFP growth is through their influence on a country's ability to absorb or adapt superior technologies in use elsewhere. That the ability to adapt technologies may play a key role in determining a country's position in the world income distribution has been emphasised in various theoretical analysis based on learning models such as Bernard and Jones (1996) and Acemoglu (2008). This paper provides a first empirical assessment of the role that institutions play in affecting economic growth through this learning channel. It also examines the extent to which institutions influence those components of TFP growth that are unrelated to learning.

The key findings in the paper are that there is some evidence that TFP in poorer countries tends to catchup with TFP in the leading countries, i.e. there is some evidence for unconditional catching up. In addition, we find evidence that institutions have an effect on TFP growth, both through their effects on the speed of learning and also through direct effects. That said, the empirical fits produced by these models are relatively poor. In addition, we find that country-specific intercept terms—random unexplained differences in growth across countries—explain far more of the variation in TFP growth than do institutional variables. This finding of a limited role for institutions may be a function of the weakness of the institutional proxies used here. However, the paper uses a far wider and more comprehensive set of institutional variables than previous studies, building on recent work in studies such as Glaeser and Shleifer (2002) and Djankov et al (2002).

The contents of this paper are as follows. Section 2 outlines the model used in the analysis. Section 3 describes the methodology and data. Section 4 presents the results. Finally section 5 is the conclusion and summary.

2 Model

2.1 Model Assumptions

The model used in this paper is a standard model of technology transfer. There are a number of variations of this type of model. Nelson and Phelps's (1966) model looks at the effect that educated people have on innovation, and how education can speed the process of technology diffusion. Bernard and Jones's (1996) version of model is based on technology diffusion in the manufacturing sector of the USA. The model we use in this paper is a slightly different version of the model presented in Acemoglu (2008).

This version of the model examines the gap in technology growth levels in countries across the world. It is assumed that there is a lead country and all other countries follow the leader. The leader has technology level, A, which grows at rate g. All other countries have technology levels B_{it}, where $B_{it} < A_t$. The model assumes that the lead country's technology growth rate is exogenous while the following countries' technology growth is endogenous. In continuous time these technology levels grow at a rate of:

$$\dot{B}_i(t) = \lambda_i \left(A(t) - B_i(t)\right) \tag{1}$$

where $(A(t) - B_i(t))$ is the technology or productivity gap between the lead country and the follower. The parameter λ_i measures the fraction of the gap that can be closed due to country $i's$ convergence speed through absorbing knowledge and new technology from the advanced country. The larger the gap the more the following country has to learn and therefore the more convergence needed.

2.2 Steady State Solution

In the steady state solution of this model, technology in all countries grows at the same rate. So the growth rate of $B_i(t)$ is given by:

$$\frac{\dot{B}_i(t)}{B_i(t)} = \lambda_i \left(\frac{A(t) - B_i(t)}{B_i(t)}\right) \tag{2}$$

In the steady state, the growth rate of the follower must equal the growth rate in the lead country, g.

$$\lambda_i \left(\frac{A(t) - B_i(t)}{B_i(t)}\right) = g \tag{3}$$

So,

$$A(t) - B_i(t) = \frac{g}{\lambda_i} B_i(t) \tag{4}$$

which can be rearranged to:

$$B_i(t) = \frac{A(t)}{1 + \frac{g}{\lambda_i}} \tag{5}$$

or, alternatively;

$$B_i(t) = \frac{\lambda_i}{g + \lambda_i} A(t) \tag{6}$$

The fundamental part of this model is that following countries can never actually catch-up because:

$$\frac{\lambda_i}{g + \lambda_i} < 1 \tag{7}$$

The following country always has technology levels less then the leader and can only experience growth in technology if there is a gap between their level of technology and the leaders. That is, as long as the lead country grows at rate g, the followers can acquire new technologies from them. Therefore in the steady state they must have lower technology levels than the leader.

2.3 Convergence to the Steady State Path

By solving equation (1) it can be shown that the steady state equilibrium is relevant if convergence occurs. It is expressed below with all $B_i(t)$ terms on the left hand side

$$\dot{B}_i(t) + \lambda_i B_i(t) = \lambda_i A(t) \tag{8}$$

Given that $\frac{\dot{A}(t)}{A(t)} = g$, its particular solution is $A(t) = A(0)e^{gt}$ therefore the differential equation can be re-written in the form

$$\dot{B}_i(t) + \lambda_i B_i(t) = \lambda_i A(0)e^{gt} \tag{9}$$

One possible solution for a $B_i(t)$ process that will satisfy this equation which is in the form $D_1 e^{gt}$ where D_1 is some unknown coefficient. It must satisfy the following equation

$$gD_1 e^{gt} + \lambda_i D_1 e^{gt} = \lambda_i A(0)e^{gt} \tag{10}$$

Canceling the e^{gt} terms, gives

$$gD_1 + \lambda_i D_1 = \lambda_i A(0) \tag{11}$$

so that

$$D_1 = \frac{\lambda_i}{g + \lambda_i} A(0) \tag{12}$$

so this is solution corresponds exactly to the steady-state path in which all countries have income levels that are a constant fraction of the leader's level:

$$B_i(t) = \frac{\lambda_i}{g + \lambda_i} A(t) \tag{13}$$

We will label this solution as

$$B_i^1(t) = \frac{\lambda_i}{g + \lambda_i} A(t)$$

Now note that we a solution of the form

$$B_i(t) = B_i^1(t) + B_i^2(t)$$

has the property that

$$\dot{B}_i(t) = \dot{B}_i^1(t) + \dot{B}_i^2(t) \tag{14}$$

So, a combined solution of this form will still satisfy equation (8) as long as

$$\dot{B}_i^2(t) + \lambda_i \dot{B}_i^2(t) = 0 \tag{15}$$

Which solves as

$$B_i^2(t) = D_2 e^{-\lambda t} \tag{16}$$

The General solution is the combination of the two solutions above

$$B_i(t) = \frac{\lambda_i}{g + \lambda_i} A_0 e^{gt} + D_2 e^{-\lambda t} \tag{17}$$

or, alternatively:

$$B_i(t) = \frac{\lambda_i}{g + \lambda_i} A_t + D_2 e^{-\lambda t} \tag{18}$$

Given that $e^{-\lambda_i t}$ tends toward zero as time goes on, the solution converges to the first term, which is growing at rate g, as required in the steady state.

This shows that even if there is TFP growth in poor countries and they close some of the gap with rich countries they will never actually catch-up because $\frac{\lambda_i}{g+\lambda_i}$ is less then one. The leader will always be growing at rate g, this implies that the follower will always have technology levels below that of the leader. The model also shows that it is not the countries' ability to invent new capital goods that is the key to growth but instead their ability to absorb and learn technology from advanced countries. Therefore, the higher the absorption speed of the follower countries, the faster they will converge on the leader.

2.4 Determinants of λ

The model also makes predictions about the relationship between the rates of technological convergence, λ_i, and the country's places in the long-run world income distribution. The faster the speed of learning the higher the country's long run level of income. If a country can increase its λ_i via education or science related policies its position in the steady state distribution of income may move upwards with the economy then going through a phase of rapid growth.

The next issue to address is what causes differences in TFP across countries? And what drives the pace of technological convergence in poorer countries? Hall and Jones (1999), Acemoglu, Johnson and Robinson (2001) and Glaeser, La Porta, Lopez-de-Silanes and Shleifer (2004) are among many that address these issues. They all seem to agree that institutional and social infrastructure are the keys to explaining productivity and growth differences across countries.

3 Methodology and Data

3.1 Total Factor Productivity (TFP)

Using the absorption and convergence models discussed above this paper examines the convergence speeds of technology growth. The TFP gap is the difference between the leader's TFP growth and the follower's, rather then the steady state difference above. It is determined by calculating TFP for each country over time using Hall and Jones decomposition of output per worker. This is done using the Cobb-Douglas production function:

$$Y_i = K_i^{\alpha}(A_i H_i)^{1-\alpha} \tag{19}$$

where α is a production function parameter, which is equal to the share of capital income in national output. H_i is human capital, which is used rather then labour. It is derived as

$$H_i = e^{\phi E_i} L_i \tag{20}$$

Hall and Jones assume that L_i is homogeneous within a country and that each unit of labour has been trained with E_i years of schooling. This paper uses the Barro-Lee tables of average years of schooling for this variable E in the estimations. In this specification the function of ϕE reflects the efficiency of a unit of labour with E years of schooling relative to one with no schooling.

This production function can be written in term of output per worker

$$y_i = k_i^{\frac{\alpha}{1-\alpha}} h_i A_i \tag{21}$$

where $k_i \equiv K/Y$ is the capital-output ratio, $y \equiv Y/L$ is output per worker and $h \equiv H/L$ is human capital per worker. This can be re-written to give the TFP or A_i value:

$$TFP_i = \frac{y_i}{k_i^{\frac{\alpha}{1-\alpha}} h_i} \tag{22}$$

Figure 1 shows the effect of accounting for human capital on TFP. The broken lines show that the TFP or the residual is lower when h_i is used instead of L_i given that more of the output per worker has been explained.

In these calculations the standard value of $\alpha = 1/3$ is used, as done in Hall and Jones (1999) and McQuinn and Whelan (2007). However the results where similar when alternative values, such as $\alpha = 0.4$ were used, as done in Easterly and Levine (2001).

Table 1 shows the output per worker ratios to the leader, for a selection of countries. The leader is the USA and it covers the entire sample. It is split into high, middle and low income countries and shows that output per worker has been catching up in some countries e.g. Ireland, Hong Kong and China. It also shows that some countries such as Italy, Mexico, Argentina, Japan and Kenya started to converge in the 1970s and 1980s but then diverged again in the 1990s. These countries are compared to the USA values in the same year, therefore USA growth needs to be considered. Over the sample the US experienced output per worker growth of 1.4 percent per year. This implies that when a country converged with the US during this period, output per worker needed to be growing in excess of 1.4 percent.

Tables 2 and 3 show the break-down of the productivity calculations for 2000 as ratios to the USA. The 58 countries are divided up into regional groupings: Europe, Austral-Asia, the Americas and Africa and the Middle East. It can be seen that in the more developed countries, TFP contributes more to their output per worker growth-rates then in less developed countries. This would imply that developed countries invest sufficiently in labour and capital, and that their growth comes from how productively and efficiently this investment is used.

Hall and Jones concluded that differences in productivity (A or TFP) play a key role in the generation of output per worker differences across countries. They find that their measure of productivity is highly correlated with human capital accumulation and moderately correlated with the capital-output ratio. It is from this perspective that we examine what really affects productivity and explore what merit there is in learning-type models explaining the differences across countries.

3.2 Creation of K, I and δ

The main source of data for this paper is the Penn World Tables, from which we draw 58 countries over 41 years (1960-2000). The country selection was based on availability of the institutions data and the Barro-Lee tables. Analysis is restricted to 2000 because average years of school is a vital part of the model and the Barro-Lee tables are only available between 1960-2000. The first variable that had to be calculated was capital as it is not a primary data source in the Penn World Tables. Before it could be generated assumptions needed to be made regarding depreciation and initial conditions. The depreciation assumptions (δ) follow those of McQuinn and Whelan (2007b). They claim that depreciation is around six per cent per annum. They come to this conclusion by assuming that there are different rates of capital depreciation for each type of capital input.

$$Y_t = S_t^{\gamma} E_t^{\alpha-\gamma} \left(A_t L_t\right)^{1-\alpha} \tag{23}$$

where S_t is physical structures and E_t is equipment. They show that this equation can only be obtained in this case if the weights used to calculate the "aggregate depreciation rate" reflect the contribution of each asset to production. That would be $\frac{\gamma}{\alpha}$ and $\frac{\alpha-\gamma}{\alpha}$ in this example. Empirical calculations from Whelan (2003) report Cobb-Douglas exponents of 0.145 for equipment and 0.165 for physical structures, where value weights points to physical structures being more important. An equally weighted average of a two percent structures depreciation rate and a ten percent equipment depreciation rate points to an overall depreciation rate of six percent.

Given the assumed depreciation rate the time series for capital stock (K) can be created using the perpetual inventory method below.

$$K_t = K_{t-1} \left(1 - \delta\right) + I_{t-1} \tag{24}$$

The problem is that initial capital, K_{t-1}, cannot be observed. To deal with this issue we follow the calculation from McQuinn and Whelan (2007b). They estimate the initial capital stock by making an "informed guess" based on the ratio of investment to capital, which is given by:

$$\frac{I_t}{K_{t-1}} = \frac{\Delta K_t}{K_{t-1}} + \delta \tag{25}$$

and thus,

$$K_{t-1} = \frac{I_t}{\frac{\Delta K_t}{K_{t-1}} + \delta} \tag{26}$$

where $\frac{\Delta K_t}{K_{t-1}}$ is the average growth rate of investment over a ten year period. It is used as a proxy for the growth rate of capital. When they tested this method they found that their estimated capital stock for 2000 had a correlation of 0.99 with later series that were almost completely based on data rather then the initial assumptions. In this paper the first available ten years are used. Once this initial value has been generated it was entered into equation 25, which then determined the entire series of capital stock. See Appendix 1A-1D for a full list of the variables and countries used in this paper.

3.3 Institution Variables

This section describes the various institutions indicators used in the analysis. The data was obtained from Andrei Shleifer's web site. It was downloaded as cross sections, combined and then made into a panel. Some of the variables do not change over time, and the ones that do are not year on year changes but 5 and 10 year averages. However, this is not necessarily a problem given that institutional change can take a long time to implement and even longer before effects are seen. Also when these variables are interacted with the gap which do change over time they then become time varying indicators.

As the construction of TFP is based on average years of schooling the data set was restricted to countries that were available in the Barro-Lee tables. This variable also restricts the years of the data set to 1960-2000.

The data set is then sub-divided into groupings that give general indications of the influence of institutions in any given country. The six groupings are indicators of the country's commitment to development and change. These are Political Government Variables, Citizens Rights, Health Benefits, Social Security Benefits and Labour Regulations. Most of these indicators are inter-related and correlated. This is to be expected as a country with good government policy will tend to have good social, health and education standards also.

The *Social Benefits* variables are all taken from Botero, Djankov, La Porta, Lopez-De-Silanes and Shleifer (2004). This paper examines the effects of social security, industrial and labour laws on labour force participation rates. The measures we use are: labour union power, collective disputes, the availability of alternative employment, social security provided by the state, employer requirements, unemployment, old age and maternity benefits. The purpose of this group is to determine the effects of unions and social policies of the state.

The *Health Benefits* are a combination of health indicators taken from Boterov, Djankov, La Porta, Lopez-De-Silanes and Shleifer (2004), Djankov, La Porta, Lopez-De-Silanes and Shleifer (2002) and Glaeser, La Porta, Lopez-De-Silanes and Shleifer (2004). These combine the responsiveness of the health services, sick benefits from the state, risk of malaria and the ISO environmental and quality standards.

Labour Regulations are made up of the cost of overtime, firing costs, labour force participation, minimum wage and age requirements, and legal requirements placed on the employers. These are all taken from Botero, Djankov, La Porta, Lopez-De-Silanes and Shleifer (2004) and are essentially the labour laws that are used in their paper.

The *Citizen Rights* group is a more general grouping of the basic right of citizens. These are taken from Boterov, Djankov, La Porta, Lopez-De-Silanes and Shleifer (2004), Djankov, La Porta, Lopez-De-Silanes and Shleifer (2002) and Glaeser, La Porta, Lopez-De-Silanes and Shleifer (2004). It is composed of expropriation risk, civil rights, corruption levels in the government, court formalisation and property rights.

Political Government measures are taken from Boterov, Djankov, La Porta, Lopez-De-Silanes and Shleifer (2004) and Glaeser, La Porta, Lopez-De-Silanes and Shleifer (2004). It measures the quality of the country's government, and consists of the division of the government, legislature process competition, government effectiveness, executive constraints and levels of democracy.

School enrollment measures secondary level school participation. It is taken from the World Bank Indicators as a proxy for the role of education in a country. The skills gained from this education has already been accounted for in the human capital ratio derived above. A more complete description of the institutions variables is given in appendix 1B-1D.

3.4 Creating the Rankings

The variables within each of the institutional groups are highly correlated with each other. This multicollinearity problem implies that the coefficient of the variables will not be very reliable as they will be prone to changes as other variables are added or withdrawn from the regression. In order to over come this problem a Borda ranking system was used. The Borda Count was first developed by Jean-Charles Chevalier de Borda in 1770. It is an electoral scheme that provides a method to rank-order scoring. This type of ranking system has been used by economists such as Amartya Sen (1977) and Partha Dasgupta (1993) to analyse social choice and well-being respectively.

The Borda rank was created by ranking each country's score for a particular variable within the institutional groupings relative to the other countries in the study. In other words the best performing country in a particular category will obtain a score of 1 and the worst performing country gets a score of 58. This process is repeated for every variable in each group.

Once all the variable rankings are obtained, it is then necessary to sum the ranks for each institutional grouping. This provides us with one number for each of the institutional groups, it indicates their effectiveness in a particular country relative to the other countries in the study. The sum of the ranks contains the essential information given by the original variables without imposing any serial correlation problems for our modeling.

3.5 Regression Specifications

There are six different specifications of the model tested in this section. They all represent variations of the learning model and the effect of institutions on TFP growth. The sample leaders used are the USA and an average of OECD members, i.e. all countries in the sample learn from these two leaders. While the USA does not always have the highest absolute TFP levels, it is still used as the global leader because it has managed to maintain consistent output per worker growth for much longer periods then any other country.

Given that unconditional convergence is low and not all countries will converge on the USA or even on the OECD average the sample is broken into regions which have their own local leaders. The regions are Austral-Asia, Europe, The Americas and the rest of world which is made up of Africa and the Middle East(see Appendix 1A for details). In the regions there is no one leader for the entire sample in any of the regions, the leaders change sporadically depending on who has the highest TFP levels in any given year. This incorporates the random disturbance term, $\epsilon_i(t)$, which allows the leader to change. The entire sample is then estimated allowing each country to learn from its regional leader, without causing sampling errors but running each of the regions separately.

The regression specifications will be discussed in discrete time as that is the format of the data. The first regression tests the pure learning effect on TFP growth as described in equation (1). This is done by using the technology gap between each country and the leader:

$$\Delta \log T\hat{F}P_{it} = \lambda_i \left(G\hat{A}P_{it} \right) + \epsilon_{it} \tag{27}$$

where the gap is defined as the difference between each country's estimated TFP and the leader's TFP:

$$G\hat{A}P \equiv \left(\log TFP_{t-1}^{usa} - \log TFP_{i,t-1} \right) \tag{28}$$

The fraction of the gap that is closed each year is measured by the parameter λ_i. Each country's convergence speed is due to their ability to absorb and implement new technology and knowledge from the lead country. The error term is ϵ_{it}. The gap can be lagged because the following country can only acquire technology from the previous periods. This is to incorporate R&D patents in the advanced country.

The rest of the regressions include institutions; the purpose of this is to determine the direct and indirect effects that institutions have on TFP growth. For example, if a following country were to implement a new health system, that was learned about from the leader, there would be two different channels of influence. The direct effect is the benefit of the new system itself, while the indirect effect measures how much the gap is reduced and how much convergence occurred through learning and implanting this new system.

The second regression tests the indirect effect of institutions on TFP growth through the gap. The effect on the gap is measured by creating interaction variables, i.e. multiplying institutions by the gap. This test measures whether or not the institutions matter for learning speeds and convergence.

$$\Delta \log T\hat{F}P_{it} = \beta_1 \left(G\hat{A}P_{it} \right) + \beta_2 \left(INST_{it} * G\hat{A}P_{it} \right) + \epsilon_{it} \tag{29}$$

where INST is a combination of institution indicators that measure government, citizens rights, trade, health, social and labour behaviour in a country. In this case λ_i becomes a function of the gap and the interaction variables.

$$\lambda_i = (\beta_1 + \beta_2 * INST_{it}) \tag{30}$$

The lower the λ_i the more slowly the country converges toward the leader of a given gap. This implies that the indirect effect of institutions should be negative, because if they are reducing the gap they are creating convergence; where λ_i determines the speed of that convergence.

The third regression includes country specific factors as well as the indirect institution effect. This is to determine how much TFP growth should be assigned to country specific factors that can not be measured. The purpose of this regression is to determine if the difference in global TFP growth is based on domestic differences or if they explained by learning alone.

$$\Delta \log T\hat{F}P_{it} = \beta_1 \left(G\hat{A}P_{it}\right) + \beta_2 \left(INST_{it} * G\hat{A}P_{it}\right) + \beta_3 \left(DUMMY_i\right) + \epsilon_{it} \quad (31)$$

It is important to return to the direct effect that institutions have on TFP growth as new policies and systems can have a significant influence on society. The fourth regression tests this direct effect, independently of the gap:

$$\Delta \log T\hat{F}P_{it} = \beta_1 \left(G\hat{A}P_{it}\right) + \beta_2 \left(INST_{it}\right) + \epsilon_{it} \quad (32)$$

The fifth regression examines the combined direct and indirect effects of institutions on TFP growth. If they are not correlated the effect should be the sum of the direct and indirect effect. This will not be the case as there is correlation between the variables and this makes it difficult to attribute definite effects.

$$\Delta \log T\hat{F}P_{it} = \beta_1 \left(G\hat{A}P_{it}\right) + \beta_2 \left(INST_{it} * G\hat{A}P_{it}\right) + \beta_3 \left(INST_{it}\right) + \epsilon_{it} \quad (33)$$

To compensate for this correlation, joint significance tests are run to determine if all of the variables are significant as a group rather then just looking at the individual institution's effects.

Given that both the direct and indirect effects are potentially affected by county specific factors it is important to test for this effect independently of other factors. The final regression therefore tests for the county specific effect on its own:

$$\Delta \log T\hat{F}P_{it} = \beta_1 \left(G\hat{A}P_{it}\right) + \beta_2 \left(DUMMY_i\right) + \epsilon_{it} \quad (34)$$

This will given an indication of how much TFP growth is due to internal factors in each country. These are things that would be difficult to replicate. While this paper does not analyse any country specifically we can use Ireland as an example to explain the intuition behind this regression.

It is unlikely that other countries will be able to have the same growth rates for as long as Ireland because there were so many things that created its TFP growth. There were demographic changes, returns on previous investment in education, joining the European Unions and attracting large quantities of FDI etc. All of these factors could be replicated but the chances of them all coming together at the same time and having the same effect in another country is very slim. So how much of the Celtic Tiger was due to luck, domestic circumstance or implementation of better institutions? This paper will attempt to determine these answers at a global rather then country level.

4 Results

4.1 Summary Statistics

This section examines the relationship between the institution variables and the gap in TFP compared to the leader. The two global leaders used in this paper are the USA and an average of OECD member's TFP. Regional leaders changed over the course of the sample so there is no specific leader for any given region. This allows the leader in each respective region to change with all local countries learning from that years local leader. The coefficient of the TFP gap is λ, it measure the fraction of the gap that is closed each year due to learning. It is therefore also the convergence speed for the following country over the entire sample.

Figure 2 shows a selection of TFP gaps with the USA and how they have changed over time. The Developed countries used are Canada, Finland, Ireland and the UK. Since the 1980's, Canada and Finland seem to have become less productive in relation to the USA. Ireland became more productive in the 1990's, while the UK has been performing constantly better than the USA since the early 1970's. The speed at which these countries closed this gap, λ, was approximately 0.04 over the course of the sample.

The absolute gap between the Latin American countries and the USA has also been small but there is some evidence of divergence since the early 1980's. This panel indicates that Argentina and Mexico were both more productive then the USA until the mid 1980's. That is, they were more efficient in their use of resources. However, after 1980 they began to lose this relative efficiency. In other words, Latin America was not able to increase its productivity levels as rapidly as the USA. Argentina and Brazil convergence speeds are 0.11 and 0.10 respectively, with Chile and Mexico at 0.06 and 0.03. However, these learning speeds do not appear to have had the expected theoretical effects of catch-up.

The size of the absolute gaps in Asia and Africa are quite similar and much larger then Latin America and the developed countries. In Asia a large portion of that gap has been closed in recent years. China for example has halved its gap with the USA, with the rest of Asia increasing their productivity levels by about 0.5. India, China and Korea had convergence speeds of 0.01, with Japan's converging at a rate of 0.10.

Africa's TFP levels have been relatively consistent with the USA over time. This does not mean that there has been no TFP growth in Africa, but that whatever growth they have had has been over shadowed by growth in the USA TFP. The convergence speeds in these four African countries have also been very low, all are less then 0.006.

4.2 Regression Results

Table 5 shows results from equation 27 in the model. It measures the pure effect of learning on TFP growth over five year intervals. The five year time scale is an industry standard and it is used to minimise disturbances in the data, that is it focuses on longer term trends ignoring short term fluctuations such as the business cycle. Given that TFP is a residual the R^2 tends to be quite low.

In the global economy analysis, the TFP gap between the USA and all the other countries has a coefficient of 5.4 per cent on TFP growth. As we have used the industry standard of a five-year TFP growth rate, this implies that every five-years global learning speeds are about 5.4 per cent. This implies that all countries in the sample are learning at this speed. However, this pure learning effect is weaker for OECD averages and local leaders.

The next regression tests equation 29 and the results are displayed in Table 6. It tests whether institutions matter for the speed of learning. The coefficient of the gap (λ) measures the speed of convergence through learning. By interacting the institution variables with the gap the indirect effect of these institutions on TFP can be seen, as they works through learning that is the λ defined in equation 30. The R^2 shows that adding the institution variables to the regression only increases the fit of the model by 2 per cent.

Given that Table 5 claims that each country is learning at 5.4 per cent it is interesting to see how vastly different the learning speeds are once institutions are added. For example Australia, Austria, Denmark, Belguim, Sweden and Canada all have learning rates greater then 13 per cent. This imples that they are learning at least twice as much as expected without institutions. On the other hand Mali, Senegal, Zambia and Mozambique all have learning speeds less then 1 per cent. This indicates that there is a huge variation across countries in the quality of institutions and their effect on that country's ability to learn.

It can also be seen that the interacted institutions do not have significant coefficients, this is most likely due to the correlation between them. This is not surprising given the probability of a country only having one good institution indicator is very slim. Therefore exclusion tests were run on the interacted variables and these tests showed that the variables are jointly significant at the 1 per cent level. These tests shows that institutions clearly affect the speed of learning which facilitates the catch-up shown in Table 5.

The next step was to determine how much of this convergence is due to the direct effect of institutions on TFP growth and how much due to the gap. Table 7 shows the results from equation 32 which indicate that there is a significant direct effect on TFP growth by institutions that is not related to the country's ability to learn. The R^2 are slightly better: in the case of the USA it increases to 11 per cent, while the OECD and Local Leader regressions only increase to 9 per cent. However, these figures may be misleading because Table 6 and 7 only examine one aspect of the effects of institutions at a time, that is either the direct or indirect effects.

To address this issue Table 8 shows both the direct and indirect effect of institutions on TFP growth. It finds that they both are important though it is difficult to determine which one is the most influential. This is because the correlation between the variables change some of the signs and significances when direct and indirect effects are combined. However, after conditioning on the direct effect, there seems to be less evidence that institutions matter for learning speeds.

Equations 31 and 34 add country specific dummy effects to the regression which have a significant effect on the R^2 as shown by the joint significant test displayed in Table 9. Country-specific factors alone account for an R^2 ranging from 21 to 28 across regional and global levels. This indicates that there are systematic country differences in TFP that do not seem to have anything to do with institutions. However, once interacted institutions are added to the dummy variables, as in equation 31, the value of R^2 increase, to range from 24 to 31.

4.3 Implication of Results

There are a number of reasons for these weak results. First TFP is a residual and by its very nature is difficult to explain. Second, the institutions data are not time varying in their own right, although this is not a major issue given that implementing new institutions take time to have a significant effect. Third, the regions used are very broad and while there may be learning at a micro level it does not appear to be transfered to this regional level. That is a country may be more inclined to learn from a close neighbour or their dominant trading partner rather then the regional or global TFP leaders.

Also given the strength of the country-specific factors in explaining TFP growth, it should be noted that institutions are very difficult to measure and that Acemoglu, Johnson and Robinson (2001) and Glaeser, La Porta, Lopez-De-Silanes and Shleifer (2004), stated this in their respective research.

For robustness these regressions were run using Gross National Product (GNP) rather then GDP as discussed above and also using hour worked rather then labour in the human capital estimations. The purpose of using GNP is to test what effect Foreign Direct Investment (FDI) has on TFP growth. There was practically no difference at a global level as would be expected given that global GDP equals global GNP. However there was only a very small difference in the regional markets too which would suggest that GNP only really makes a difference at a country level. However the impact of FDI is beyond the scope of this paper.

Substituting hours worked into the regressions could only be done for the 17 European countries in the dataset. The data was taken from the Groningen Growth and Development Center but there was not enough coverage of the other regions to analyse them. The overall growth rates were left relatively unchanged although one or two countries changed position in their global ordering.

5 Conclusion

The purpose of this paper is to examine the direct and indirect effects of institutions on Total Factor Productivity (TFP) growth. It uses a basic absorption model which measures a following country's ability to absorb knowledge and technology from the lead country.

In this paper there are two global leaders, the USA and an average of OECD member countries. There are also four regions analysed: Austral-Asia, Europe, The Americas and the ROW (which includes the Middle-East and Africa). There are no outright leaders in the regions so the leaders are allowed to vary over time. Indicating that it is possible for followers to over take leaders depending on which country is more productive at any particular point in time. The regional leader regression is run over the entire sample with each country learning form its local leader, this prevents sampling errors.

The gap between the respective leaders and followers is generated using TFP levels. The larger the gap the further behind the follower is and the more convergence need to catch-up. The coefficient on the gap, λ_i measure the fraction of the gap that is closed given its absorption ability.

The results show that despite the absence of unconditional convergence in the overall sample data, there appears to be some evidence that there is a tendency for poorer countries to catch-up with wealthier ones. The rate of this catch-up can be influenced by the quality of the country's institutions. There is both a direct and indirect effect from institutions. The direct effect on TFP growth comes from the policies set by these institutions, while the indirect effect is administered through the gap between the leader and the follower. However these effect are still relatively small.

The most interesting finding of this research is that country-specific factors, that are not picked up by the institution variables used, have the highest explanatory power of all. This demonstrates that there is still a large random element in cross country TFP growth rates and convergence rates.

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Data Sources

http://www.ggdc.net/maddison/

http://www.economics.harvard.edu/faculty/shleifer/shleifer.html

http://datacentre2.chass.utoronto.ca/pwt/

http://publications.worldbank.org/WDI/

Figure 1: Human Capital's Effect on TFP Growth

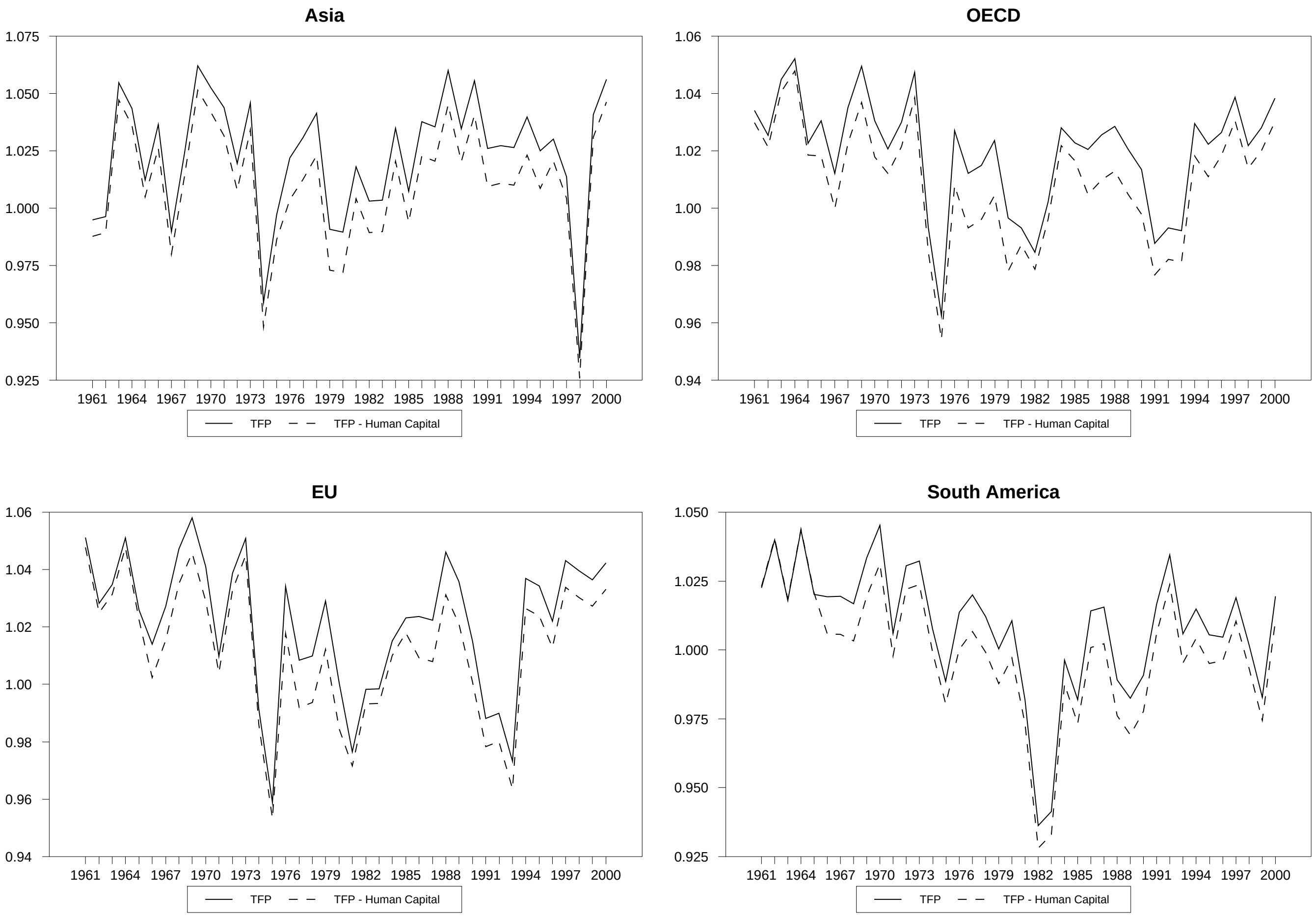

Table 1: Output per Worker: Ratios To U.S. Values

	1960	1970	1980	1990	2000
USA	1.000	1.000	1.000	1.000	1.000
Ireland	0.426	0.498	0.641	0.668	0.881
France	0.622	0.766	0.879	0.907	0.824
Italy	0.536	0.722	0.880	0.841	0.758
UK	0.700	0.681	0.723	0.742	0.734
Canada	0.886	0.848	0.844	0.763	0.743
Hong Kong	0.264	0.409	0.605	0.802	0.750
Japan	0.304	0.542	0.708	0.773	0.664
Argentina	0.624	0.610	0.635	0.407	0.417
Mexico	0.385	0.423	0.494	0.346	0.293
Brazil	0.243	0.274	0.380	0.286	0.231
Romania	0.070	0.107	0.256	0.228	0.163
China	0.026	0.024	0.031	0.053	0.100
India	0.060	0.064	0.069	0.083	0.090
Zimbabwe	0.146	0.153	0.162	0.141	0.109
Kenya	0.071	0.057	0.060	0.053	0.037

Table 2: Contribution to Output per Worker 2000: Ratios to USA

	YL	HL	$KY^{\frac{\alpha}{1-\alpha}}$	A
EUROPE				
Austria	0.871	1.013	0.630	1.365
Belgium	0.893	1.012	0.624	1.413
Switzerland	0.810	1.027	0.779	1.011
Denmark	0.752	1.009	0.749	0.995
Spain	0.661	1.008	0.512	1.283
Finland	0.674	1.018	0.754	0.878
France	0.824	1.010	0.595	1.372
U.K.	0.734	0.998	0.678	1.085
Greece	0.478	1.010	0.606	0.782
Ireland	0.881	0.989	0.649	1.374
Italy	0.758	1.012	0.495	1.514
Netherlands	0.845	1.009	0.668	1.254
Norway	0.953	1.012	0.949	0.991
Portugal	0.507	1.004	0.374	1.351
Sweden	0.694	1.009	0.888	0.775
Romania	0.163	1.010	0.693	0.232
Turkey	0.182	0.985	0.369	0.501
AUSTRAL-ASIA				
Australia	0.754	1.009	0.798	0.936
China	0.100	0.992	0.418	0.241
Hong Kong	0.750	1.005	0.689	1.083
India	0.090	0.961	0.367	0.255
Indonesia	0.116	0.988	0.364	0.323
Japan	0.664	1.028	0.712	0.907
Korea, Rep	0.456	1.018	0.787	0.570
Malaysia	0.401	0.996	0.557	0.722
New Zealand	0.611	1.008	0.907	0.669
Philippines	0.138	0.979	0.538	0.261
Sri Lanka	0.134	0.971	0.438	0.314
Thailand	0.162	1.020	0.439	0.362
U.S.A.	1.000	1.000	1.000	1.000

Table 3: Contribution to Output per Worker 2000: Ratios to USA

	YL	HL	$KY^{\frac{\alpha}{1-\alpha}}$	A
THE AMERICAS				
Argentina	0.417	0.994	0.604	0.695
Bolivia	0.107	0.970	0.407	0.272
Brazil	0.231	0.997	0.357	0.648
Canada	0.743	1.008	0.896	0.822
Chile	0.417	0.993	0.558	0.753
Colombia	0.210	0.978	0.379	0.565
Dominican Rep.	0.224	0.965	0.387	0.599
Ecuador	0.164	1.005	0.464	0.353
Jamacia	0.135	1.001	0.390	0.346
Mexico	0.293	0.993	0.477	0.617
Panama	0.280	0.991	0.558	0.506
Peru	0.166	1.000	0.517	0.320
Uruguray	0.356	0.986	0.512	0.705
Venezuela	0.267	0.996	0.411	0.653
AFRICA-MIDDLE EAST				
Egypt	0.178	0.941	0.381	0.496
Ghana	0.042	0.945	0.331	0.135
Israel	0.773	1.005	0.667	1.154
Jordan	0.182	0.985	0.520	0.356
Kenya	0.037	0.971	0.331	0.114
Mali	0.032	0.952	0.214	0.156
Mozambique	0.031	0.920	0.227	0.149
Malawi	0.026	0.949	0.274	0.100
Pakistan	0.100	0.971	0.269	0.384
Senegal	0.053	0.940	0.261	0.215
South Africa	0.295	0.962	0.556	0.551
Uganda	0.032	0.902	0.288	0.124
Zambia	0.031	1.006	0.401	0.076
Zimbabwe	0.109	0.984	0.372	0.297
U.S.A.	1.000	1.000	1.000	1.000

Figure 2: TFP GAP with USA

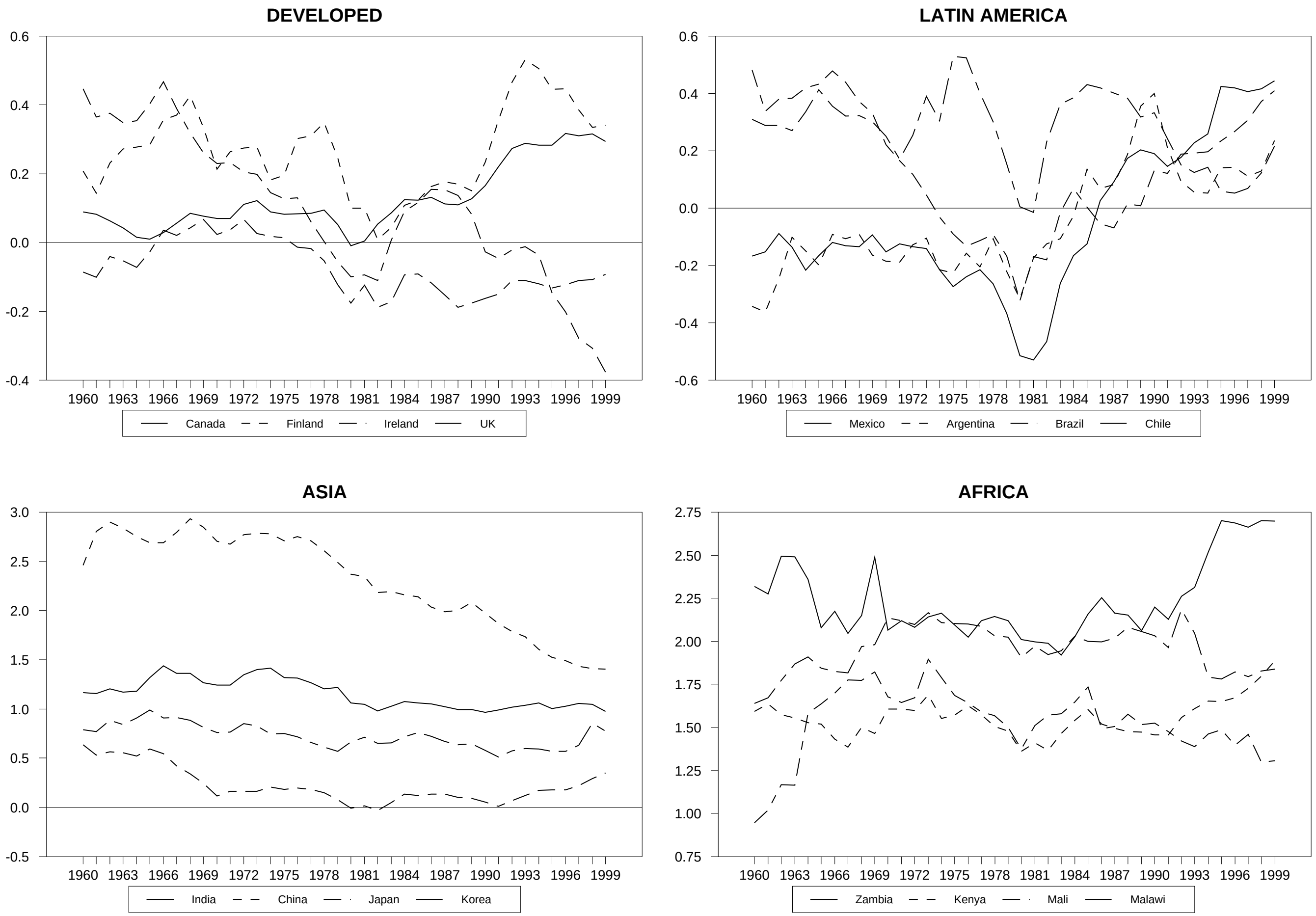

Table 4: Pure Learning Effect on TFP Growth

Dependent Variable: Five Year TFP Growth			
	USA	*OECD Average*	*Local Leader*
Five Yr GAP	0.054***	0.046***	0.034***
	(0.00)	(0.00)	(0.00)
Observations	2542	2542	2542
R^2	0.049	0.038	0.031

Notes:Linear robust regression (Equ. 27). Figures in brackets are standard errors.

Table 5: Interacted Institutions Effect on TFP Growth

Dependent Variable: Five Year TFP Growth			
	USA	*OECD Average*	*Local Leaders*
Five Yr GAP	-0.205	-0.254	-0.366
	(0.58)	(0.52)	(0.37)
Citizens Rights*GAP	0.034	0.053**	0.053**
	(0.02)	(0.02)	(0.02)
Health Benefits*GAP	-0.101***	-0.110***	-0.045
	(0.03)	(0.03)	(0.02)
Labour Regulation*GAP	0.173	0.187	0.201*
	(0.16)	(0.15)	(0.11)
Labour Regulation Sq*GAP	-0.165	-0.185	-0.236*
	(0.19)	(0.19)	(0.13)
Political Government*GAP	0.036**	0.030*	0.009
	(0.01)	(0.01)	(0.01)
School Enrollment*GAP	0.001***	0.000***	0.000***
	(0.00)	(0.00)	(0.00)
Social Benefits*GAP	0.046	0.048	0.019
	(0.03)	(0.03)	(0.02)
Observations	2542	2542	2542
R^2	0.07	0.06	0.06

Notes:Linear robust regression (Equ. 29). Figures in brackets are standard errors.

Table 6: Institutions Effect on TFP Growth

Dependent Variable: Five Year TFP Growth			
	USA	*OECD Average*	*Local Leaders*
Five Yr GAP	0.102***	0.093***	0.083***
	(0.00)	(0.00)	(0.01)
Citizens Rights	0.080***	0.078***	0.073***
	(0.01)	(0.01)	(0.01)
Health Benefits	-0.075***	-0.072***	-0.073***
	(0.01)	(0.01)	(0.01)
Labour Regulation	0.104	0.110	0.137
	(0.10)	(0.10)	(0.10)
Labour Regulation Sq	-0.102	-0.118	-0.168
	(0.11)	(0.11)	(0.11)
Political Government	0.009	0.009	0.015**
	(0.00)	(0.00)	(0.00)
School Enrollment	0.001***	0.001***	0.001***
	(0.00)	(0.00)	(0.00)
Social Benefits	-0.031**	-0.032**	-0.035**
	(0.01)	(0.01)	(0.01)
Observations	2542	2542	2542
R^2	0.11	0.09	0.09

Notes:Linear robust regression (Equ. 32). Figures in brackets are standard errors.

Table 7: Interaction and Institutional Effects on TFP Growth

Dependent Variable: Five Year TFP Growth			
	USA	*OECD Average*	*Local Leaders*
Five Yr GAP	-0.048	-0.212	-0.355
	(0.55)	(0.50)	(0.36)
Citizens Rights*GAP	-0.049	-0.037	-0.009
	(0.03)	(0.02)	(0.02)
Health Benefits*GAP	-0.038	-0.044	-0.011
	(0.04)	(0.04)	(0.04)
Labour Regulation*GAP	0.509***	0.616***	0.551**
	(0.17)	(0.18)	(0.17)
Labour Regulation Sq*GAP	-0.409**	-0.529**	-0.512**
	(0.20)	(0.21)	(0.20)
Political Government*GAP	0.034*	0.040**	0.002
	(0.01)	(0.01)	(0.02)
School Enrollment*GAP	-0.000	-0.000*	0.000
	(0.00)	(0.00)	(0.00)
Social Benefits*GAP	0.056	0.060*	0.052
	(0.03)	(0.03)	(0.03)
Citizens Rights	0.118***	0.118***	0.101***
	(0.01)	(0.01)	(0.02)
Health Benefits	-0.077***	-0.068**	-0.077***
	(0.01)	(0.01)	(0.02)
Labour Regulation	-0.191*	-0.252**	-0.327**
	(0.11)	(0.12)	(0.15)
Labour Regulation Sq	0.1473	0.185	0.272
	(0.12)	(0.13)	(0.16)
Political Government	0.006	0.003	0.013
	(0.00)	(0.00)	(0.01)
School Enrollment	0.001***	0.001***	0.001***
	(0.00)	(0.00)	(0.00)
Social Benefits	-0.056***	-0.061***	-0.045**
	(0.01)	(0.01)	(0.01)
Observations	2542	2542	2542
R^2	0.12	0.10	0.10

Notes: Linear robust regression (Equ. 33). Figures in brackets are standard errors.

Table 8: Joint Significance test on Institution Variables Global Leaders

Dependent Variable: Five Year TFP Growth			
USA			
	R^2	Chi-Squared	Significance Level
Interaction Institutions (Equ. 29)	0.07	42.97	0.000
Interaction Institutions with Dummies (Equ. 31)	0.31	62.87	0.000
Institutional Levels (Equ. 32)	0.11	156.38	0.000
Levels and Interaction Institutions (Equ. 33)	0.12	198.56	0.000
Country-specific Dummies (Equ. 34)	0.28	793.92	0.000
OECD Average			
	R^2	Chi-Squared	Significance Level
Interaction Institutions (Equ. 29)	0.06	42.65	0.000
Interaction Institutions with Dummies (Equ. 31)	0.25	39.62	0.000
Institutional Levels (Equ. 32)	0.09	136.76	0.000
Levels and Interaction Institutions (Equ. 33)	0.11	181.51	0.000
Country-specific Dummies (Equ. 34)	0.23	675.10	0.000
Local Leader			
	R^2	Chi-Squared	Significance Level
Interaction Institutions (Equ. 29)	0.06	51.09	0.000
Interaction Institutions with Dummies (Equ. 31)	0.24	54.00	0.000
Institutional Levels (Equ. 32)	0.09	131.42	0.000
Levels and Interaction Institutions (Equ. 33)	0.10	163.39	0.000
Country-specific Dummies (Equ. 34)	0.21	561.82	0.000

APPENDIX 1A: COUNTRIES AND REGIONS

EUROPE		AUSTRAL-ASIA	
Austria	AUT	Australia	AUS
Belgium	BEL	China	CHN
Switzerland	CHE	Hong Kong	HKG
Denmark	DNK	India	IND
Spain	ESP	Indonesia	IDN
Finland	FIN	Japan	JPN
France	FRA	Korea, Rep	KOR
U.K.	GBR	Malaysia	MYS
Greece	GRC	New Zealand	NZ
Ireland	IRL	Philippines	PHL
Italy	ITA	Sri Lanka	LKA
Netherlands	NLD	Thailand	THA
Norway	NOR		
Portugal	PRT		
Sweden	SWE		
Romania	ROM		
Turkey	TUR		
AMERICAS		**AFRICA & MIDDLE**	**EAST**
Argentina	ARG	Egypt	EGY
Bolivia	BOL	Ghana	GHA
Brazil	BRA	Israel	ISR
Canada	CAN	Jordan	JOR
Chile	CHE	Kenya	KEN
Colombia	COL	Mali	MLI
Dominican Rep.	DOM	Mozambique	MOZ
Ecuador	ECU	Malawi	MWI
Jamacia	JAM	Pakistan	PAK
Mexico	MEX	Senegal	SEN
Panama	PAN	South Africa	ZAF
Peru	PER	Uganda	UGA
Uruguray	URY	Zambia	ZMB
Venezuela	VEN	Zimbabwe	ZWE

APPENDIX 1B: PENN WORLD TABLES VARIBLES

Variable	Unit	Definition
POP	000'S	Population
XRAT	US=1	Exchange Rate
cgdp	$ current	Real Gross Domestic Product per capita (current prices)
cc	%	Consumption share of CGDP
ci	%	Investment share of CGDP
cg	%	Government share of CGDP
p	US=100	Price Level of GDP (current prices)
pc	ppp/xrate	Price Level of Consumption (current prices)
pg	ppp/xrate	Price Level of Government (current prices)
pi	ppp/xrate	Price Level of Investment (current prices)
openc	%	Openness (current prices)
cgnp	%	Ratio of GNP to GDP (current price)
csave	%	Current Savings
rgdpl	$ constant	Real GDP per capita (constant prices: Laspeyres)
rgdpch	$ chain	Real GDP per capita (constant prices: Chain series)
rgdpeqa	$ eq. Adult	Real GDP chain per equivalent adult
rgdpwok	$ worker	Real GDP chain per worker
rgdptt	$ terms of trade	Real Domestic Income (RGDPL adj. for Terms of Trade changes)
openk	%	Openness (constant prices)
kc	%	Consumption share of RGDPL
kg	%	Government share of RGDPL
ki	%	Investment share of RGDPL

APPENDIX 1C: NEW VARIBLES CREATED FROM PWT

Variable	Unit	Definition	Equation
Y	\$ chain	Total Domestic Output; RGDPCH by Population	$\frac{pop*1000*rgdpch}{1,000,000}$
trgdpl	\$ constant	Total Domestic Output; RGDPL by Population	$\frac{pop*1000*rgdpl}{1,000,000}$
L	000's	Labour Force	$\frac{trgdpl*1,000,000)/rgdpwok}{1000}$
INVST	\$ constant	Investment	$(\frac{ki}{100}) * trgdpl$
cgnp2	\$ current	Gross National Product (current Prices)	$\frac{cgdp*cgnp}{100}$
deflator	-	Deflator used in GDP chain linking base yr 2000	$\frac{cgdp}{rgdpch}$
rgnpch	\$ chain	Real Gross National Product (chain series)	$\frac{cgnp}{deflator}$
trgnpch	\$ chain	Total National Output; RGNPCH by population	$\frac{pop*1000*rgnpch}{1,000,000}$

APPENDIX 1D: SHLEIFER'S INSTITUTIONS VARIABLES

Variable	Definition and Source
Political Government	
Government effectiveness	This variable measures the quality of public service provision. Glaeser et.al.(2004)
Executive constraints	A measure of the extent of institutionalized constraints on the decision making powers of chief executives. Botero et.al.(2004)
Citizens Rights	
Expropriation risk	Risk of "outright confiscation and forced nationalization" of property. Glaeser et.al.(2004)
Corruption	Corruption perception index for 1999. Djankov et.al.(2002)
Civil Rights	Combination of two measurements Civil right index from Djankov et.al.(2002) and Botero et.al.(2004)
Property Rights	Property rights of citizens. Djankov et.al.(2002)
Court Index	Combination of two court formalism index - collection of bounced cheque and eviction non-paying tenants. Botero et.al(2004)
Labour Regulations	
Alternative contract Index	Measures the existence and cost of alternatives to the standard contract. Botero et.al.(2004)
Male(Female) Participation	Male(Female) participation rate as a percentage of the total male(female) population aged 15 to 64. Botero et.al (2004)
Minimum Age	Measures the age at which a child can be employed in an apprenticeship or in a full-time, non-farm, non-hazardous, non-night time job outside of the family business. Botero et.al.(2004)
Minimum Wage	Measure the minimum mandatory wage. Botero et.al.(2004)
Labour Index	Measures the protection of labor and employment laws as the average of:(1) Alternative employment contracts; (2) Cost of increasing hours worked; (3) Cost of firing workers; and (4) Dismissal procedures. Botero et.al (2004)
Health Benefits	
Response	Responsiveness of the health system. Djankov et.al (2002)
ISO ave	Combination of ISO environmental and quality standards. Djankov et.al (2002)
Sick index	Measures the level of sickness and health benefit. Botero et.al (2004)
Population at risk of malaria	Percentage of the population at risk of malaria transmission in 1994. Glaeser et.al.(2004)
% Population in temperate zone	Percentage of a country's population in Koeppen-Geiger temperate zone in 1995. Glaeser et.al. (2004)
Social Benefits	
Industrial Index	Measures the protection of collective relations laws as the average of: (1) Labor union power and (2) Collective disputes. Botero et.al (2004)
Social security index	Measures social security benefits as the average of: (1) Old age, disability and death benefits; (2) Sickness and health benefits; and (3) Unemployment benefits. Botero et.al.(2004)