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FORECASTING PRODUCTIVITY AND GROWTH WITH INTERNATIONAL FUTURES (IFs) PART 2: DRIVING THE DRIVERS AND INDICES

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Forecasting Productivity and Growth in International Futures (IFs)

Part 2: Driving the Drivers and Indices

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Abstract

The forecasting of economic growth is central to the forecasting of global futures. It is impossible to explore the future of human development, changes in the international system, the quality of the environment, or much of anything else without looking to patterns of economic growth.

In the forecasting of economic growth, understanding the likely development of capital and labor stocks is important. But understanding productivity gains is the real key. We know that there are many drivers of productivity in contemporary knowledge-based societies.

This manuscript is one of two that together map an approach to representing that growth in International Futures (IFs). The first of the two (Part 1) reviews the literature around some of the key potential drivers of productivity growth, draws lessons from that literature, and describes the formulation developed within IFs to forecast productivity and growth. It also discusses the use and control of that formulation via the user interface of IFs. The second manuscript (Part 2) focuses on the drivers of productivity and, in turn, on their representation. In essence it explores what drives the drivers. That second manuscript directs special attention to a number of indices that have been developed in other literature that have proven relevant in the effort to represent productivity change within IFs.

This report is Part 2. It gives special attention to indices and variables around governance, the knowledge society, infrastructure, and globalization, but its general purpose is to explore the forecasting of economic growth. It is a companion piece to the more general report on the modeling of multifactor productivity.

1. The Objectives and Context[1]

International Futures (IFs) is a large-scale integrated global modeling system. The broad purpose of the International Futures (IFs) modeling system is to serve as a thinking tool for the analysis of near through long-term country-specific, regional, and global futures across multiple, interacting issue areas. The issue areas include demographics, economics, education, energy, agriculture, the environment, and socio-political systems.

Yet economic growth drives much of what changes in the other systems, including the ability to satisfy human needs, loads upon the environment, and the position of states in the global system. The economic model of IFs is general equilibrium, representing supply, demand, and exchange in six sectors (agriculture, energy, other primary goods, manufactures, services, and ICT). Although the demand side of the model is important, in the long-term the supply-side and, in particular, the production function is critical. The two papers in this set focus on that key aspect of IFs and document ongoing efforts to improve its representation and to increasingly endogenize changes in multifactor productivity.[2] The companion paper to this one, Part 1 of the set, documents the formulation of the production function in IFs and the drivers of it.

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[1] Thanks to Anwar Hossain for assistance in finding many of the indices, data, and pieces of literature that supported this project and in contributing his thoughts and advice to the work.

[2] The Strategic Assessments Group (SAG) has used the IFs system for a variety of analyses including an examination of the changing power positions of major countries. It supported this project to enhance IFs by more fully representing the drivers of change in the economic size and strength of countries. In addition, Frederick S. Pardee is providing sustaining support for the International Futures (IFs) project, and that support has helped integrate the extensions desired by SAG into a more comprehensive framework of revision in the production function of IFs.

More specifically, Part 1 of this pair of papers presented and described a typology of potential drivers of growth:

- Human Capital
  - Education and Training (quantity and quality)
  - Health
- Social Capital and Governance
  - Trust/Community Strength
  - **Governance Quality**
  - **Governance Policies/Orientation (especially openness/liberalization)**
- Physical Capital
  - **Infrastructure (traditional and modern)**
  - Robustness of Systems (e.g. energy diversity)
  - Natural Capital (forests, land quality, etc.)
- Knowledge Base
  - **Creation**
  - **Adaptation/Diffusion**

This paper will not discuss all of these drivers. Some of them are embedded deeply in various models and submodels of IFs. For instance, formal education is represented within IFs in a separate submodel of primary, secondary, and tertiary education.[3] Similarly, the representations of energy and natural/environmental systems are found in other submodels. This paper will focus on those in bold above.

More specifically, this paper, Part 2 of the set, has the objective of reviewing the incorporation within IFs of several new indices that represent contemporary drivers of productivity. They can be thought of as components of economic strength in and of themselves and can help capture a static picture of the relative performance of countries. They can, however, also be clearly seen as contributors to the dynamics of systemic change because they are among the most critical components of economic productivity.

The four indices identified for special examination were governance quality, modern infrastructure, positioning for technological dynamism (which can also be seen as creating and adapting knowledge), and globalization level.[4] In addition, this project required further development of the education submodel of IFs, with special attention to the tertiary sector and the quality of human capital.[5]

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[3] Mohammod T. Irfan has developed this submodel as part of his Ph.D. dissertation work and is documenting it separately. A basic introduction to it can be found in the Help system of IFs and in Hughes with Hossain and Irfan (2004).

[4] Thanks to Paul Herman of the Strategic Assessments Group for leadership in building this list.

[5] Mohammod T. Irfan has developed the education model of Ifs as part of his PhD dissertation work at the Graduate School of International Studies (GSIS), University of Denver.

The intent of the project has been to integrate these four critical areas within IFs as fully as possible.[6] That has meant giving attention both to their drivers (backward linkages) and to the variables they will affect (forward linkages).

In exploring and implementing such indices, two key questions or criteria consistently shape the work:

1. Can an index be useful in helping to forecast key model variables? In particular, can an index help forecast economic growth potential? Although each of the indices are of interest in and of themselves, the deeper reason for attention to them is because they are commonly seen as contributing to the economic and more general vitality and success of societies. Thus in formulation of the indices for the model, we want to be attentive to the strength of such forward linkage. In addition to economic impact, another forward linkage of interest is to political stability and/or violence.

2. Can the index itself be forecast within the model? That is, are the drivers of the index (backward linkages) in place within the model or can they be added? Regardless of the strength of forward linkages (the inherent utility of a variable or index), its utility will be reduced significantly if the model does not have the capability of forecasting the index itself. Nonetheless, an index can be useful without backward linkages, or if such linkages are not fully developed, because exogenous assumptions about the future of the index can be introduced and the impact of those assumptions can be explored.

[6] Thanks to José Roberto Solorzano for his key role in implementing the new production function within IFs and for more general contributions to the IFs project.

2. Social Capital: Governance Quality

It is clear from the review of productivity and growth literature that governance quality does affect productivity and must be included in the production function. The purpose of this chapter is to discuss approaches to conceptualizing and measuring the concept and to present an approach to incorporating the concept into IFs.

2.1 Existing Measures/Indices

Some of the best-known measures of governance are those associated with the World Bank Governance and Anti-Corruption Resource Center[7]and with the work of Daniel Kaufmann and a variety of collaborators (see Kaufmann, Kraay and Zoido-Lobatón 1999; Kaufmann, Kraay, and Mastruzzi, 2003; Kaufmann 2004a and 2004b).[8]

The project presented data on six indices clustered roughly around three aspects of governance:

> (1) the process by which governments are selected, monitored and replaced, (2) the capacity of the government to effectively formulate and implement sound policies, and (3) the respect of citizens and the state for the institutions that govern economic and social interactions among them (Kaufmann, Kraay and Mastruzzi 2003: 2).

On the first aspect of governance, they presented measures of Voice and Accountability and of Political Stability and the Absence of Violence. On the second aspect, their measures were Government Effectiveness and Regulatory Quality.[9] On the third aspect, they provided Rule of Law (including, importantly, the enforceability of contracts) and Control of Corruption.

The division of governance measures by this project into the three categories is quite useful, especially with respect to considering which of them might be given special attention within International Futures. The first dimension is already tapped to some considerable degree within IFs by the measures of democracy and autocracy from the Polity project and the measure of freedom from Freedom House, as well as the measures of state failure from the State Failure Project. The third dimension is tapped to some

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[7] See http://www.worldbank.org/wbi/governance/

[8] See many downloadable papers at http://www.worldbank.org/wbi/governance/wp-governance.html. Another useful project related to governance at the World Bank is the database of political institutions, which contains a wealth of political information on 177 countries over the 1975-1995 period (Beck, Clarke, Groff, Keefer, and Walsh (2001). It is available at http://www.worldbank.org/research/bios/pkeefer.htm.

[9] This dimension is also addressed by the World Bank's project on Doing Business, which tracks the time and financial costs involved in setting up businesses.

degree already by including within IFs the corruption perception index of Transparency International (TI).[10] Specifically, the corruption perception index (see Lambsdorff 2003) draws on many other sources and measures including the World Bank, all of which focus on the perception of corruption (measurement of actual corruption is, of course, nearly impossible). TI creates an aggregate measure from the other sources.

Given this overlap with the broader measures within IFs, it made sense in this enhancement of IFs to focus on adding information about the capacity of government, as captured by the Bank's Government Effectiveness and/or Regulatory Quality measures (as well as on bringing the three dimensions of governance into forward linkages to productivity).

Are there sources other than the World Bank, Freedom House and TI to look to for indices or input concerning the capacity of government?

- The International Country Risk Guide (ICRG) covers 140 countries and data for many of them go back to 1984, with updates monthly. Because it has been so widely used in studies of the impact of governance on growth, it is a candidate for use in IFs also. The disadvantage, however, is that the service is commercial; downloading a single month of values (the composite index only) cost $45 in early 2005. For the purposes of the IFs project, there is much to be said for looking primarily to the World Bank measures, not least of which is their logical clustering in three governance areas.

- The World Economic Forum publishes an annual Global Competitiveness Report.[11] Their growth competitiveness index[12] has three components: a technology index (weighted ½), a public institutions index (weighted ¼) and a macroeconomic environment index (weighted 1/4). The public institutions index is essentially another measure of governance and is built on two subindices: contracts and law; corruption. We have added recent values of the index (both rank and score values) to the IFs database, but the measures are not as useful as those of the World Bank.

Consideration of the measures of governance that are available and of the ones that are already in IFs suggests that special attention should be given to the World Bank's Governance Effectiveness and Regulatory Quality measures and possibly to the Bank's Rule of Law measure and/or the CGI's Contracts and Law measure. One important way

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[10] See http://www.transparency.org/surveys/index.html

[11] See http://www2.weforum.org/site/homepublic.nsf/Content/Global+Competitiveness+Programme/Global+Competitiveness+Report/Global+Competitiveness+Report+2003-2004.html for access to several recent ones.

[12] Jeffrey D. Sachs, now of Columbia University, and John W. McArthur of the Earth Institute originally developed the global competitiveness index for the 2001-2002 report.

of identifying the dimensions that might be useful to add to IFs involves looking at the relationships among these measures.

The table below shows such correlations for the six World Bank measures, the Transparency International Corruption Perception measure, and the World Economic Forum/Global Competitiveness Public Institutions index. Interestingly, the first two measures of the World Bank clearly do seem to tap a different dimension that do the other four. The R-squared calculations seldom exceed 0.6. Interesting, however, the two measures themselves do not correlate highly, suggesting the value within IFs of separating type of government (e.g. level of democracy) from political and social stability (e.g. the state failure measures). In contrast the last four measures of the World Bank all correlate at levels of 0.75 or better suggesting that the two dimensions are quite closely linked. Moreover, the high correlation of Effectiveness with Regulatory Quality (0.869) and of the Rule of Law with Corruption (0.920) to suggest that the four measures are appropriately grouped on their two sub-dimensions. Note that the Transparency International and World Bank measures of corruption are nearly identical with an R-squared of 0.935. Moreover the World Economic Forum's measure correlates most highly with the two corruption indicators, suggesting that it is also basically a perception of corruption measure.

	Voice & Acc	Stability	Effective-ness	Reg Qual	Rule of Law	Corrup-tion	TI Corrup-tion
Voice & Acc							
Stability	.568						
Effectiveness	.675	.610					
Reg Quality	.808	.574	.869				
Rule of Law	.699	.663	.931	.871			
Corruption	.608	.587	.909	.799	.920		
TI Corruption	.563	.568	.886	.748	.869	.935	
WEF Pub Inst	.48	.540	.783	.728	.826	.834	.887

Table 1. Adjusted R-squared correlations across measures of governance. Computed in IFs using most recent data for all countries available.

What conclusions about representation within IFs can we draw from the above table? It reinforces the predisposition to add the capacity of government measure rather than those focusing on governance types/inputs, stability, or corruption and rule of law. Thus as we move forward into investigation of forward linkages, we want to pay special attention to the World Bank's Governance Effectiveness and Regulatory Quality measures.

2.2 Forward Linkages: Does Governance Affect Growth?

As indicated before, we want to focus especially on linkages of governance quality to economic productivity and growth. There is a huge literature on this topic, and a separate paper in the IFs project, a companion to this paper, has reviewed some of the literature linking governance to economic growth.

The purpose of this section is to undertake a very quick independent analysis of that linkage using some of the data already in the IFs database, and thereby also to set the stage for discussing the implementation of the relationship in IFs.

In looking at linkages between governance quality and economic performance, it is critical to understand that the relationship is close, and that it is probably long-term and bi-directional (see Kaufmann and Kraay 2003). The figure below shows an R-squared of 0.74 between GDP per capita and GDP per capita at purchasing power parity. A similar relationship characterizes all other measures of governance quality.

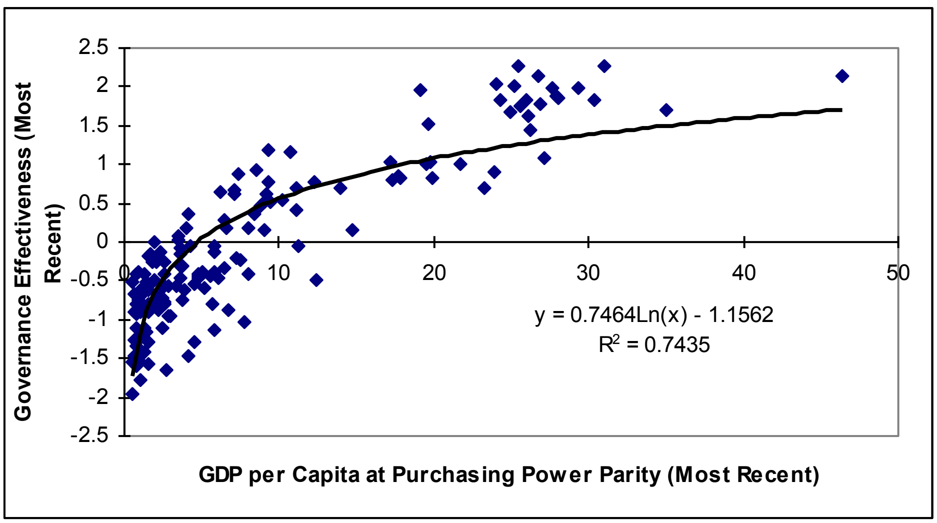


Figure 1. Governance Effectiveness as a Function of GDP per Capita.

Clearly, better governed countries are, on the whole, richer and/or richer countries are better governed. Of more interest in forecasting, however, is whether an improvement of governance is likely to lead to a rise in economic growth rates, all else being equal. The figure below suggests that perhaps it does, but that the relationship, if any, is very weak. Some good news about the above relationship is that it holds up also if we control for GDP per capita; in fact, the impact of effectiveness rises somewhat if we do so.

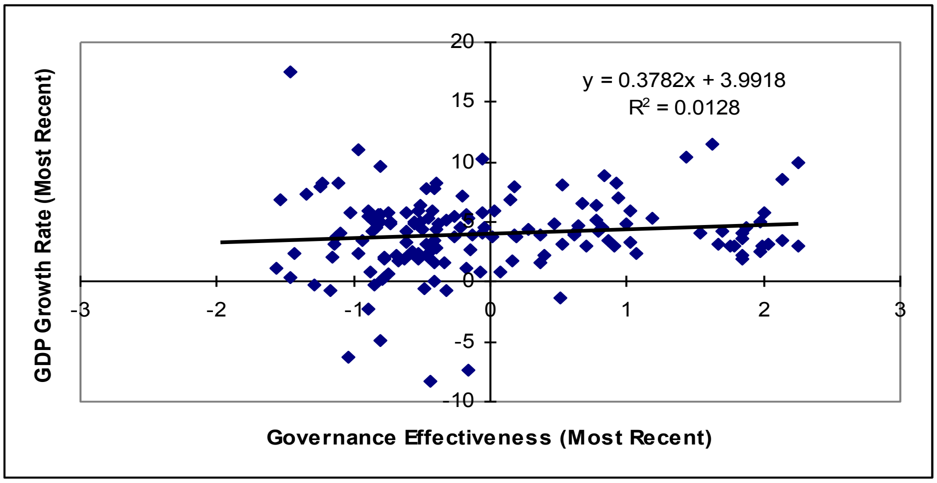


Figure 2. GDP Growth as a Function of Governance Effectiveness.

Growth rates are highly volatile, however, so it makes sense to look at a longer time period, such as the 1990-2000 period. Additionally, it is possible to focus on per capita growth, so as to control for the differential growth rates of population with its own contributions to growth – doing so will also control for the fact that less developed countries tend to have higher GDP growth (but not necessarily higher per capita growth) and that they tend to have less effective governments, thereby reducing the relationship inappropriately. The figure below does that. It suggests that GDP per capita in countries with the least effective governments shrunk by about 17% during the decade of the 1990s while in the countries with most effective government it grew by about 37%. The difference of 54% is equivalent to an annual growth differential of 4.4%, quite an astounding potential impact of effectiveness. If GDP per capita at PPP is added as a second independent variable (so as to control for the effect of absolute economic level, the adjusted R-squared in the relationship below rises to just above 0.2.

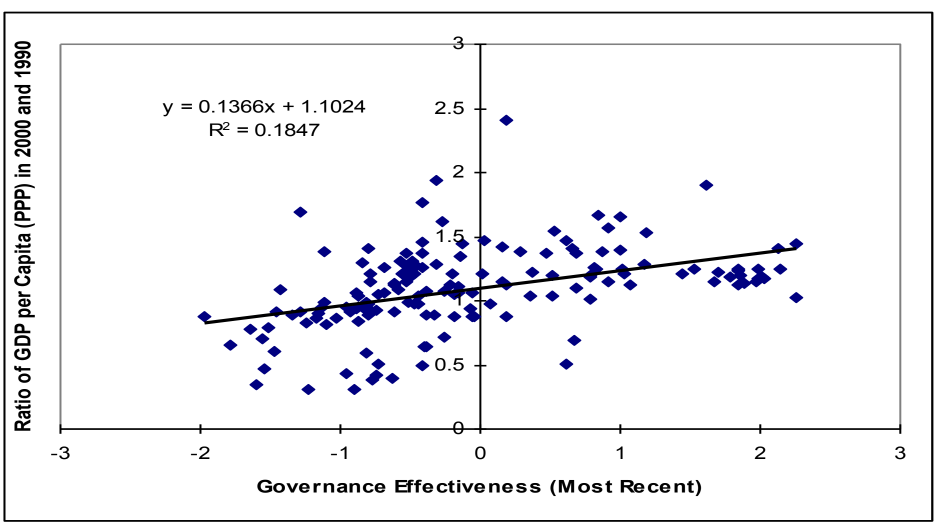


Figure 3. Decade-long GDP per Capita Growth as a Function of Governance Effectiveness.

The impact is, however, only potential. It is still unclear which direction the difference goes. Concern that it might go the other direction is increased by the fact that the above figure uses governance effectiveness data that is mostly from 2002, after the decade of growth. Yet governance effectiveness does not tend to change very rapidly according to the World Bank Data. The figure below shows that phenomenon over the rather short time of its data set, namely 1996 through 2002. Although governance effectiveness rises very slightly in the European Union of the 15 and falls very slightly in South America, it is mostly unchanged.

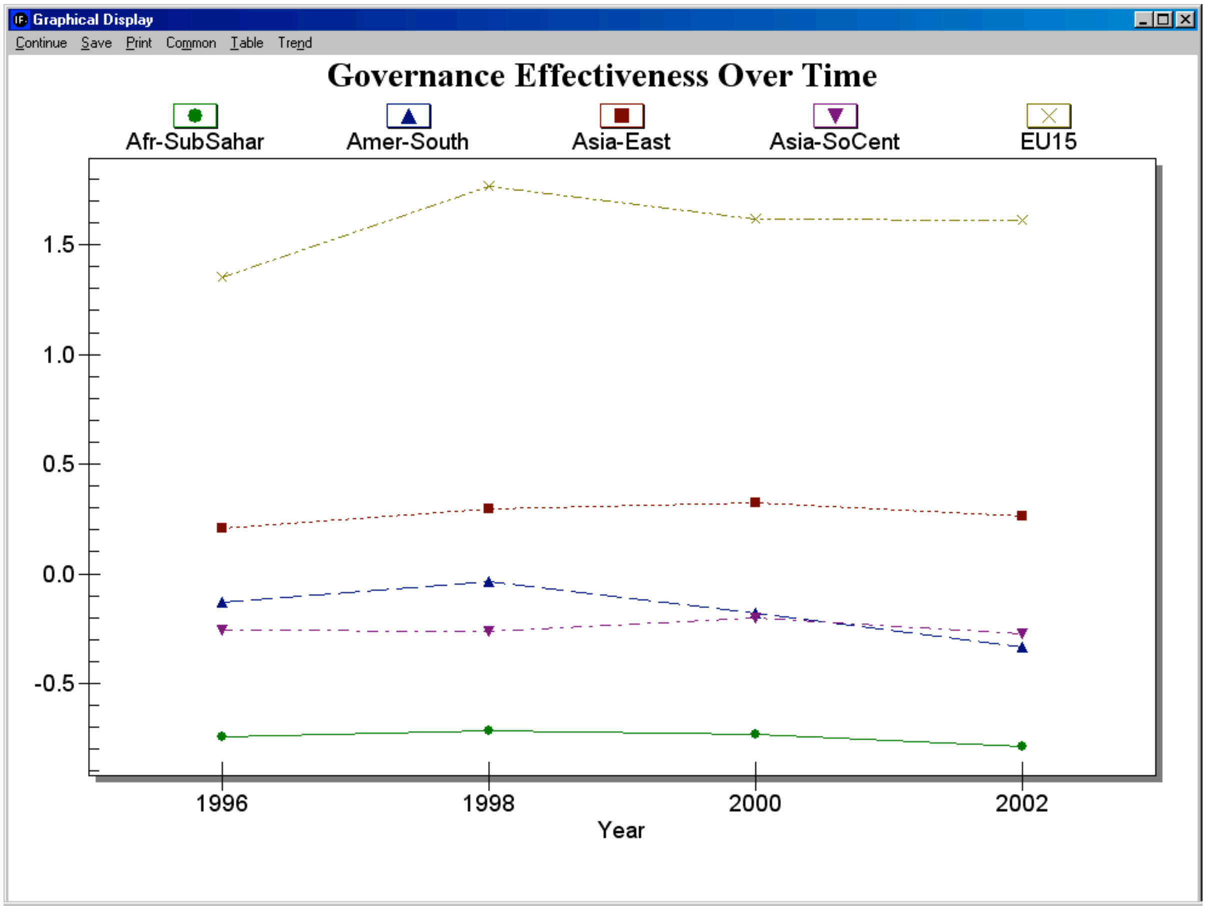


Figure 4. A Look at Governance Effectiveness Over Time in Major Regions

That relatively stable character of governance over time might even give us a little more confidence that the direction of impact could be from effectiveness to growth. The figure below adds to such confidence by shifting the data for governance effectiveness from mostly 2002 to mostly 1996 in the relationship with decade-long growth. The relationship stays pretty much the same as that in Figure 3, but the slope of the curve actually rises slightly.

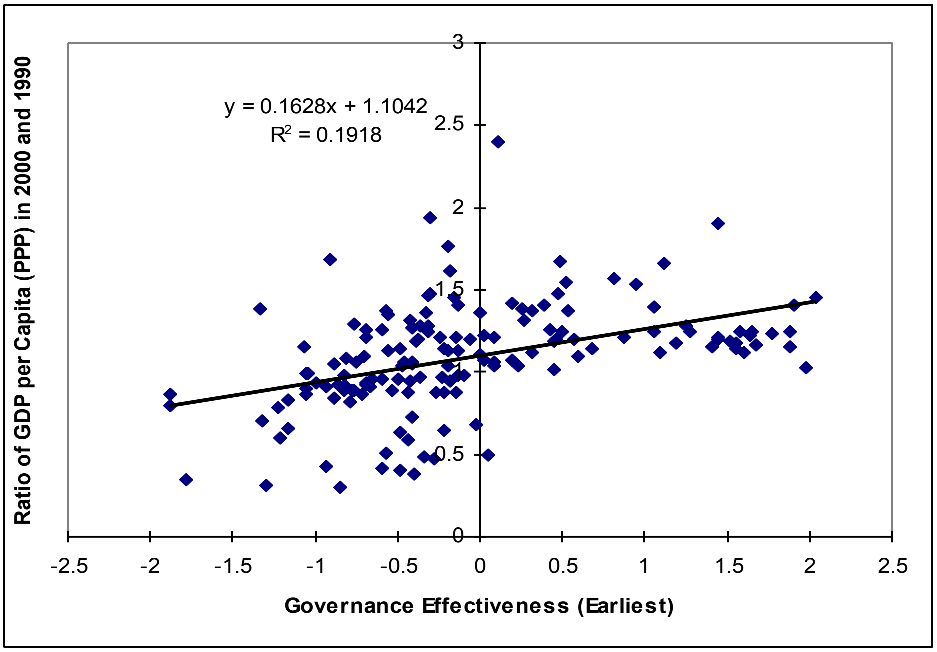


Figure 5. Decade-long GDP per Capita Growth as a Function of Governance Effectiveness (Earliest Data).

Lest we become too confident, the figure below looks at governance effectiveness near 1996 and growth from 1996 to 2000. The slope would be expected to be lower and therefore the correlation to be less strong, but it is obviously not a strong relationship at all. Still, that should not be too discouraging, because shorter-term growth rates are highly variable and dependent on many shorter-term effects.

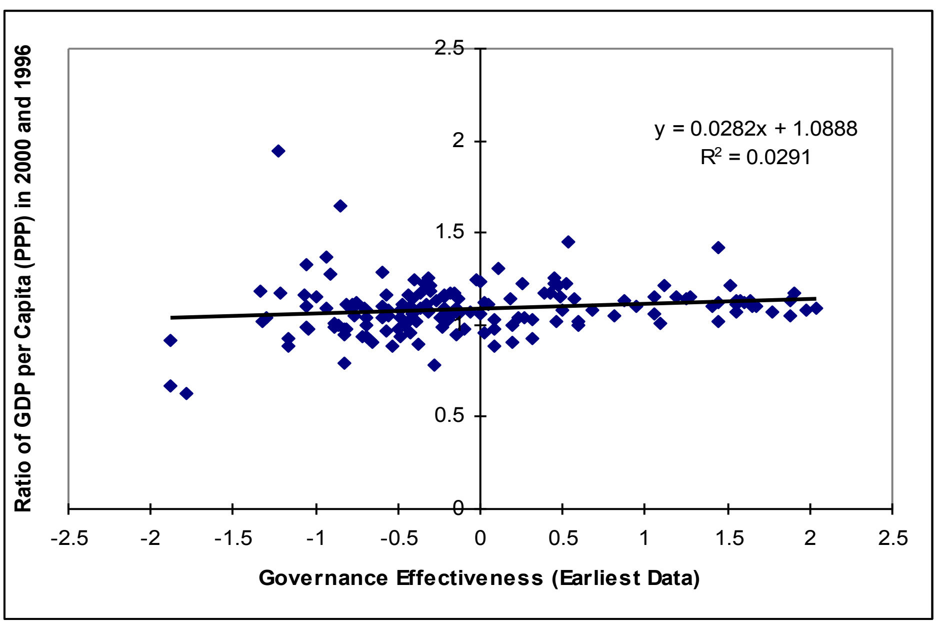


Figure 6. Half decade-long GDP per Capita Growth as a Function of Governance Effectiveness (Earliest Data).

Although it difficult, if not impossible, to prove that higher levels of governance effectiveness result in faster growth, the evidence is strong. Kaufmann and Kraay (2003) undertake a more extensive and sophisticated analysis and conclude that the relationship running from income levels to governance is perhaps even negative, while the relationship from governance to income is strongly positive.

In this discussion we have not looked at other measures of governance. There have been two reasons for that. First, as indicated before, it is the governance capability dimension that would most clearly augment formulations in IFs existing prior to this project. Second, in the analysis underpinning the above figures other measures were, in fact, also examined, but governance effectiveness almost invariably generated the highest correlations with growth. For instance, in looking at the relationship in Figure 3 between effectiveness and decade-long growth rate, it was noted that when a control for GDP per capita was added the relationship climbed just above an R-squared of 0.2. The comparable numbers for regulatory quality and rule of law were 0.17, for voice and accountability was 0.12, for corruption was .09, and for political stability was 0.08. As we move forward with this discussion we will therefore continue to give special attention to governance effectiveness.

2.3 Backward Linkages (Drivers): How Forecast Governance Effectiveness?

Although Kaufmann and Kraay (2003) argue that changes in income levels do not positively affect governance quality and that the relationship runs in the other direction, it is pretty obvious from Figure 1 that levels of GDP per capita are strongly associated with better governance. We would expect over the longer term, that as countries rise in income, they will rise in governance quality. What else might drive changes? How might we formulate forecasts of governance effectiveness?

One possibility is education level. We would expect and/or hope that higher levels of education would result in improved governance. The figure below shows a strong correlation.

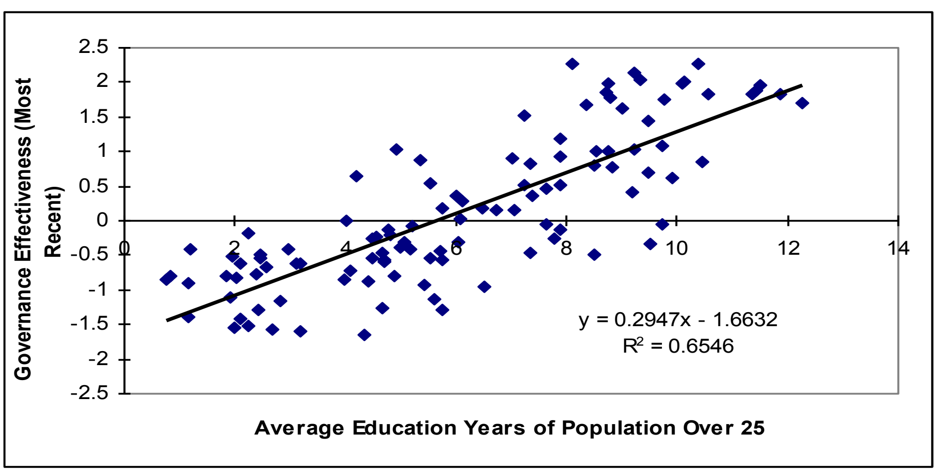


Figure 7. Governance Effectiveness as a Function of Years of Education.

The above relationship clearly interacts with growth levels of GDP per capita. When GDP per capita is added as an independent variable (logged) the adjusted R-squared grows to 0.78. That is, unfortunately, not much above the 0.74 of GDP per capita alone (see again Figure 1), but both variables remain significant and the beta of education remains clearly positive.

Another factor that is often argued to be negatively associated with quality of governance (especially corruption) is dependence on raw materials exports, which offer a honey-pot for potentially corrupt officials. Paul Collier has often argued this in his analysis (see Collier, Elliot, Hegre, Hoeffler, Reynal-Querol, Sambanis 2003). His work focuses also on the relationship between raw-material dependence and domestic conflict, which helps explain the detrimental impact of such dependence on growth.

The figure below relates governance effectiveness to energy exports relative to GDP and finds a relationship in the expected direction, but not a very strong one. If the corruption perceptions index is substituted for governance effectiveness the R-squared actually drops slightly. Further, if reliance on agricultural and other raw materials exports as a portion of total merchandise exports are substituted for energy export ratios, the function is largely unchanged. And if either education years or GDP per capita (or both) are added to energy export dependence, the total adjusted R-squared is reduced relative to those variables alone. It might be that a more sophisticated, comprehensive measure of raw material dependence (we should look to Collier's analysis for this) might allow its use as a predictor of governance quality, but it does not appear useful with energy alone.

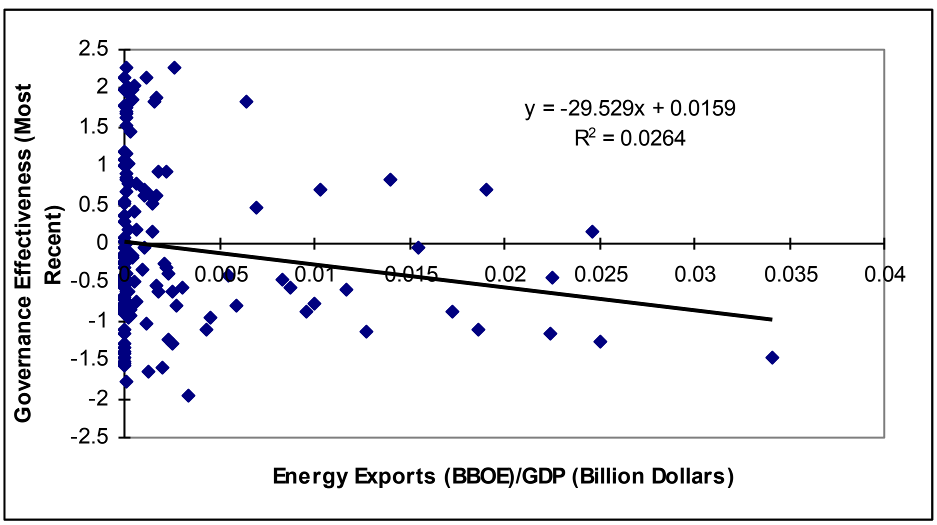


Figure 8. Governance Effectiveness as a Function of Energy Export Dependence.

Some observers might expect a cultural explanation for governance quality. The map below could reinforce that image, perhaps drawing special attention to a number of Islamic societies. Yet more study of the map suggests that economic development probably remains a much better predictor.

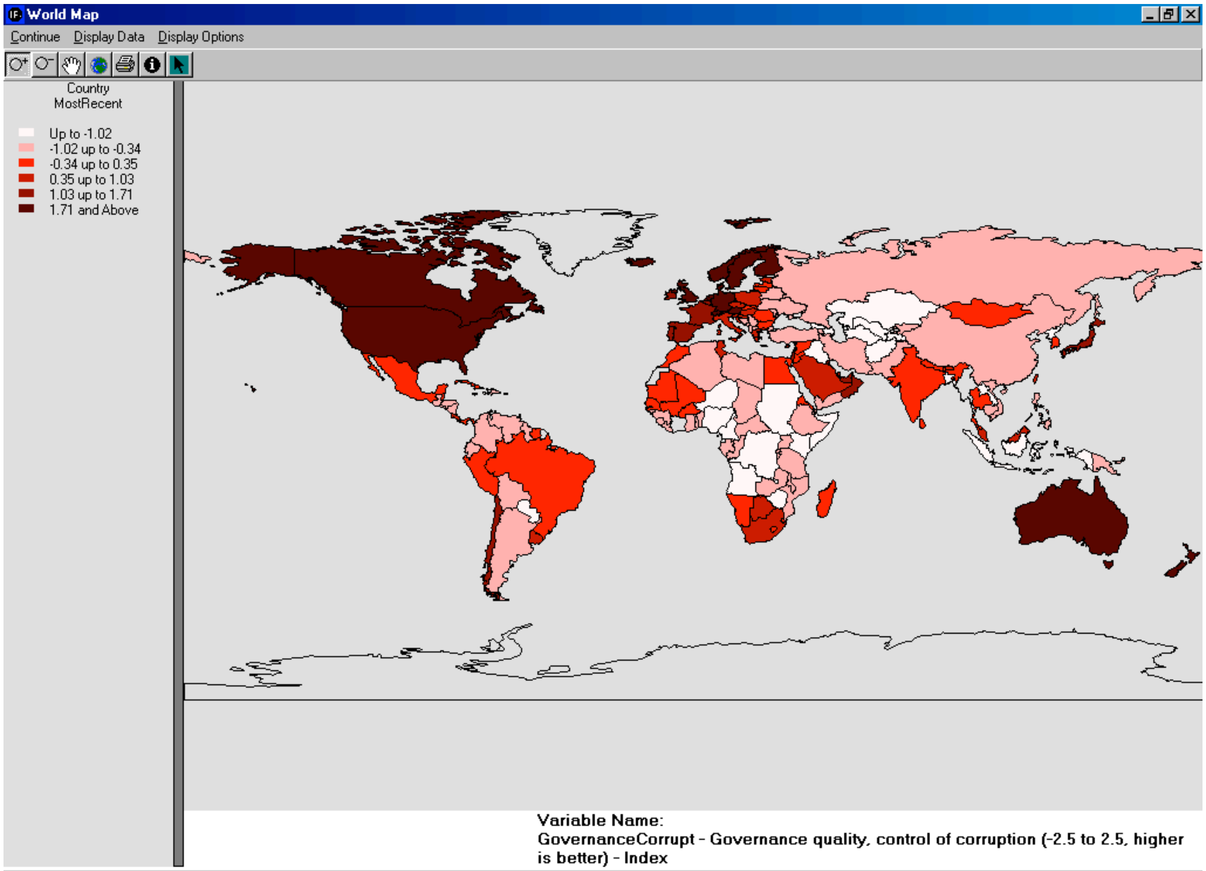


Figure 8. Political Map of the World Bank's Governance Corruption Measure.

In fact, if a dummy variable for Islamic cultural dominance is correlated with either the World Bank's corruption or governance effectiveness measures, the R-squared is below 0.03. If the Islamic-culture dummy variable is added to GDP per capita (logged) and correlated with governance effectiveness, the adjusted R-squared rises to 0.76, somewhat above that of GDP per capita alone. Both variables remain significant. If education years are added, the R-squared rises further to 0.78 and the significance level for culture is slightly higher than that for education. But the total variance explained by GDP per capita, education, and Islamic culture is no better than that with GDP per capita and education alone. Parsimony, if not concerns about cultural bias, would argue for remaining with GDP per capita and education as drivers of governmental effectiveness.

2.4 Specifics of Implementation in IFs: Backward Linkages

During the course of this project, both backward and forward linkages for governance were added to IFs. A separate document ("Forecasting Productivity and Growth") elaborates the entire formulation of productivity within IFs and the interested reader should turn to that for information on forward linkages. Here we focus only on the representation of the drivers of governance quality.

As indicated above, it was decided that the World Bank's focus on three dimensions of governance would be useful for IFs. Those three again are

> (1) the process by which governments are selected, monitored and replaced, (2) the capacity of the government to effectively formulate and implement sound policies, and (3) the respect of citizens and the state for the institutions that govern economic and social interactions among them (Kaufmann, Kraay and Mastruzzi 2003: 2).

With respect to the first dimension, IFs already includes two different measures of democratization, one linked to the Freedom House's approach and summing the two measures of Freedom House into a single measure (FREEDOM) and one linked to the Polity Project's approach (DEMOCPOLITY). Discussions of the formulations for FREEDOM and DEMOCPOLITY can be found in the Help system of the model.

With respect to the second dimension, it was decided to add a variable to IFs on government effectiveness (GOVEFFECT) and empirically to ground that in the World Bank data series of the same name.

With respect to the third dimension, we have seen that the Transparency International index of corruption perceptions correlates highly with the Rule of Law and Control of Corruption measures with which Kaufmann and colleagues elaborate that dimension. Because it is so well known and regularly measured, it was decided to add a variable based on it called GOVCORRUPT to IFs.

Within IFs there are three general ways in which variables can be represented (backward linkages) so that they can be shown in forecasts. These overlap somewhat and are not pure types:

1. As functions of deep driver variables in the model. In particular, large numbers of variables of interest, including governance quality measures, correlate very highly with GDP per capita, especially at purchasing power parity. Such deep drivers are useful, but they are not fully satisfactory. Specifically, they risk creating a kind of circularity in formulation, wherein GDP per capita drives a variable and that variable is of interest to us because it affects GDP growth. If the level of the variable is of interest to us in and of itself (as quality of governance and many other such variables, such as democracy level, are), that problem is less significant. Also, if the formulation involves two or more deep drivers, and years

of education is another variable often found to be of relevance, the problem is reduced.

2. As functions of policy levers. For instance, the model represents the direction of government spending towards education, health, the military, and R&D. The user can manipulate the balance. Such linkage to policy levers allows us to create a base forecast in which historical or "typical" patterns of allocation prevail, but also to intervene with alternative scenarios. This is not likely relevant with respect to governance quality (but could be with both infrastructure and knowledge development/transfer).
3. As functions of exogenous specification/manipulation. IFs often allows a variable to be directly altered by a multiplier or additive parameter. This form of representation tells us nothing, of course, about possible or probable levels of the variable, but does allow us to look at the impact of exogenous changes in level on other variables (forward linkages).

Implementations in IFs often involve a combination of these three elements. With respect to governance quality, the balance is heavily weighted towards the first and third.

We began by adding the governance effectiveness (GOVEFFECT) variable name to IFs. We also added data for all six indices of the World Bank's Governance Matters III project to the IFs database (for the years 1996, 1998, 2000, and 2002). We then used the data on governance effectiveness to initialize values of GOVEFFECT on a country-by-country basis for all of those countries covered by the Bank. We used a cross-sectionally estimated function against GDP per capita (PPP) to fill the limited number of holes in this initialization process.

For future years, we developed a formulation that has three components. The first is a term that computes governance effectiveness as an analytic function of GDP per capita (PPP) and education years of the population (EDYRSAG25), as discussed above. This is, for the most part, a "deep driver" formulation. The addition of education years does, however, allow some policy/scenario manipulation by the users who can vary the attention given to education.

$$GOVEFFECT_r = \left(ANALFUNC(GDPPCP_r, EDYRSAG25_r) + ConvergTerm\right) * \mathbf{goveffectm}_r$$

The above formulation has two other important elements around that base. The first is a convergence term (ConvergTerm) that over a very long period of time brings the specification of governance effectiveness towards the cross-sectionally estimated value. This is a common approach within IFs, recognizing that differences between initial conditions and typical levels of variables for countries at given development levels often erode. The second additional term above is an exogenous multiplier (goveffectm), allowing scenario manipulation for the purpose of forward analysis.

The formulation below for government corruption is completely analogous.

$$GOVCORRUPT_r = \left(ANALFUNC(GDPPCP_r) + ConvergTerm\right) * \mathbf{govcorruptm}_r$$

2.5 Comments on Other Aspects of Social Capital

Taxonomies of social capital contributions to productivity (see the companion piece to this document) often contain elements that move beyond governance quality, including at least two additional elements. The first is trust/community strength. Although IFs does represent the two dimensions of the World Value Survey, neither of these is a truly good proxy for that measure. Given the difficulty of developing drivers, we will not add it. The survey results of the World Value Survey's question on trust are in the database

The second is governance policies/orientation (especially openness/liberalization). IFs already contains a general measure of governance policies/orientation in the form of a variable of economic freedom (ECONFREE). There are two primary sources of data/indices on economic freedom. One is the project of The Heritage Foundation and the Wall Street Journal, which is produced in an annual report called *Index of Economic Freedom* (Miles, Feulner, O'Grady 2004). The other report and index is *Economic Freedom of the World* (Gwartney and Lawson 2004). The IFs project has included the latter in its dataset and updated the data values for this project. The ECONFREE variable in the model is calculated in much the same way that the GOVEFFECT variable was constructed.

3. Physical Capital: Modern (or Information-Age) Infrastructure

Talk of digital divides and public attention to availability of modern or ICT infrastructure became intense in the 1990s and countries around the world feared being left behind in the race to be at the leading edge. Many organizations and political leaders have embraced the goal of creating modern information-age economies and societies, and explicitly recognized the infrastructure foundation of that goal.

For instance, the Global Information Infrastructure Commission (GIIC; see http://www.giic.org/) has been promoting it at the World Summit on the Informationa Society (WSIS) and elsewhere. They state their mission as:

> The GIIC is a confederation of chief executive officers of firms that develop and deploy, operate, rely upon, and finance information and communications technology infrastructure facilities. Together as GIIC commissioners, these executives are dedicated to speeding the spread of information infrastructure throughout the world. The GIIC was established during a 1995 meeting in Brussels at which the political heads of the world's leading national economies formally and for the first time acknowledged the transforming forces of computer and telecommunications technologies and the emergence of an "information society." In doing so, the heads of state challenged business leaders to unite in the promotion of public policies and information technology applications likely to spur needed investment in communications infrastructure facilities. Thus was born the GIIC. Commissioners of the GIIC come from firms based in developed nations, as well as in developing and emerging market nations.

Not surprisingly, ICT infrastructure was a major topic of conversation at the World Summit on the Information Society (WSIS) in Geneva during 2003, with the follow-on in Tunis scheduled for November, 2005. From the statement of principles in Geneva comes this

> 21. Connectivity is a central enabling agent in building the Information Society. Universal, ubiquitous, equitable and affordable access to ICT infrastructure and services, constitutes one of the challenges of the Information Society and should be an objective of all stakeholders involved in building it. Connectivity also involves access to energy and postal services, which should be assured in conformity with the domestic legislation of each country.[13]

The plan of action says that

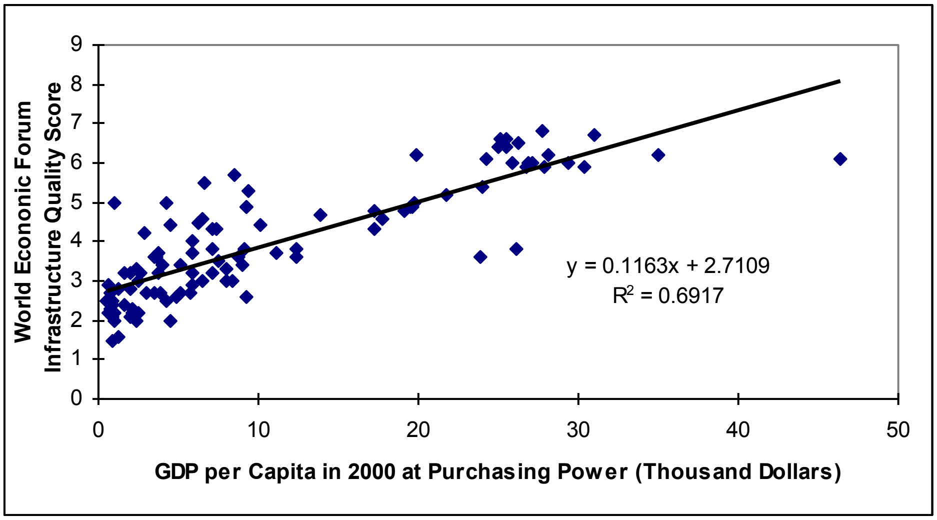
> 9. Infrastructure is central in achieving the goal of digital inclusion, enabling universal, sustainable, ubiquitous and affordable access to ICTs by all, taking into

[13] See http://www.itu.int/wsis/docs/geneva/official/dop.html

account relevant solutions already in place in developing countries and countries with economies in transition, to provide sustainable connectivity and access to remote and marginalized areas at national and regional levels.[14]

3.1 Existing Infrastructure Indices: Is There a Quick and Easy Approach?

It would be ideal if there were an existing index of infrastructure quality that could be initialized, driven, and used within IFs. Such an index was not found in the course of this project. For instance, the project considered the Infrastructure Quality measure of the World Economic Forum's *Global Competitiveness Report* (Porter, Schwab, Sala-i-Martin, and Lopez-Claros 2004: 512), and we included some of its measures in the IFs database. The figure below plots values on that index against GDP per capita at PPP.



The Infrastructure Quality measure,[15] like many of the other indices in the competitiveness report, come from the Executive Opinion Survey (EOS) of the World Economic Forum for more than 100 countries. The same source contains data on railroad infrastructure development, port infrastructure quality, air transport infrastructure quality, quality of electricity supply, telephone/fax infrastructure quality, postal efficiency,

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[14] See http://www.itu.int/wsis/docs/geneva/official/poa.html

[15] Kaufmann (2004a: 5) shows results on the quality of infrastructure from Executive Opinion Surveys. These surveys come from the *Global Competitiveness Report* of the World Economic Forum, see http://www2.weforum.org/site/homepublic.nsf/Content/Global+Competitiveness+Programme/Executive+Opinion+Survey+of+the+Global+Competitiveness+Report.html The data are available in the CD of results from the surveys 2003 for 300 Swiss Francs, see http://www2.weforum.org/site/homepublic.nsf/Content/Global+Competitiveness+Programme/Purchasing+and+Contact+Information.html and http://www2.weforum.org/site/homepublic.nsf/Content/Global+Competitiveness+and+Technology+Reports+CD-ROMs.html

quality of public schools, and quality of healthcare. In addition there are data from other, objective sources on paved roads (as percent of total in 1999) and other related indicators.

The respondents that helped the WEF formulate their 7-point subjective scales are "business executives in these countries" (p. xi) and the number of respondents per country is not obvious. Unfortunately, the outliers do not give one great confidence in the measure and make one wonder whether a few respondents with regime connections or grudges can greatly shift results. The two countries well below the line between $20-30 thousand dollars are Italy and Ireland; their infrastructure may not be great, but the extent of deviation from the cross-sectional pattern seems extreme. The country at about 5 on the index but with very low GDP per capita is North Korea—the survey claims of exceptional infrastructure seem dubious, as do those of Jordan and Namibia, also shown well above the cross-sectional relationship. In contrast, Malaysia almost certainly deserves its position well above the line.

Even if IFs were to initialize an infrastructure index with such data, it is not clear how it could forecast change in the index. We therefore need to consider an approach based more in hard data and in building up an index from understandable components.

3.2 Background: Conceptual, Data and Measurement Issues

Before turning primarily to modern or information-society infrastructure, it is important to note that, in terms of a broad taxonomy of forces that drive dynamism and growth, traditional infrastructure is potentially as important as modern or information-age infrastructure. The working papers of the task forces for the Millennium Project (striving to develop a strategy for pursuit of the Millennium Development Goals) made this point quite clearly. It is often electricity, roads, railroads, and ports that hold back development, not ICT systems.

For a more integrated perspective it is useful to refer back to the *World Development Report 1994: Infrastructure for Development* (World Bank 1994).[16] They (1994: 2) defined infrastructure services as

- Public utilities—power, telecommunications, piped water supply, sanitation and sewerage, solid waste collection and disposal, and piped gas.
- Public works—roads and major dam and canal works for irrigation and drainage.
- Other transport systems—urban and interurban railways, urban transport, ports and waterways, and airports.

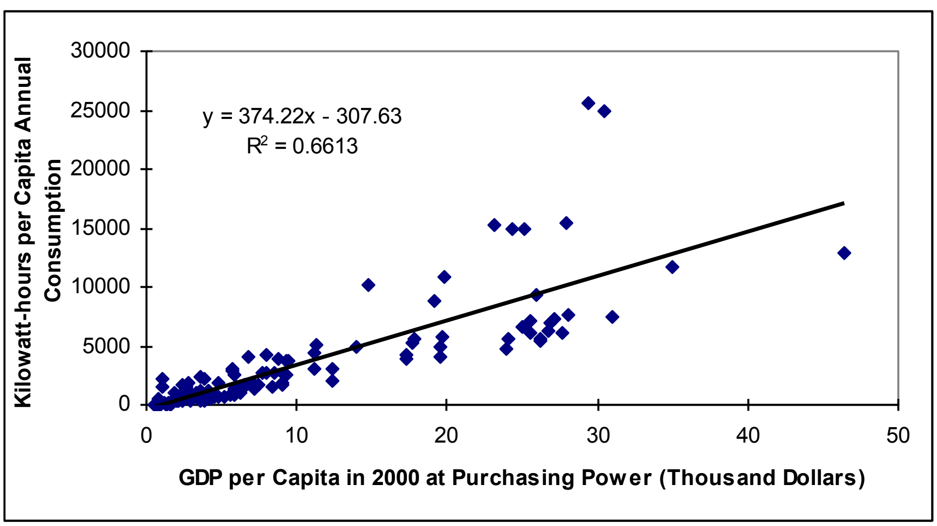
Data are skimpy and difficult to normalize by country size/characteristics on many elements of the World Bank infrastructure definition, including sanitation and sewerage, waste collection, and transport. In contrast, data on electricity and telephone lines are

[16] There is also a World Bank project on traditional infrastructure called the Living Standards Measurement Study. For information on surveys from 15 countries see http://ideas.repec.org/p/wbk/wbrwps/2551.html

quite widely available, as are data on telecommunications and computer usage. We have added significant amounts of such data to IFs. Unfortunately, we have been less successful in discovering data on the spread of bandwidth, an important element of the ICT infrastructure.

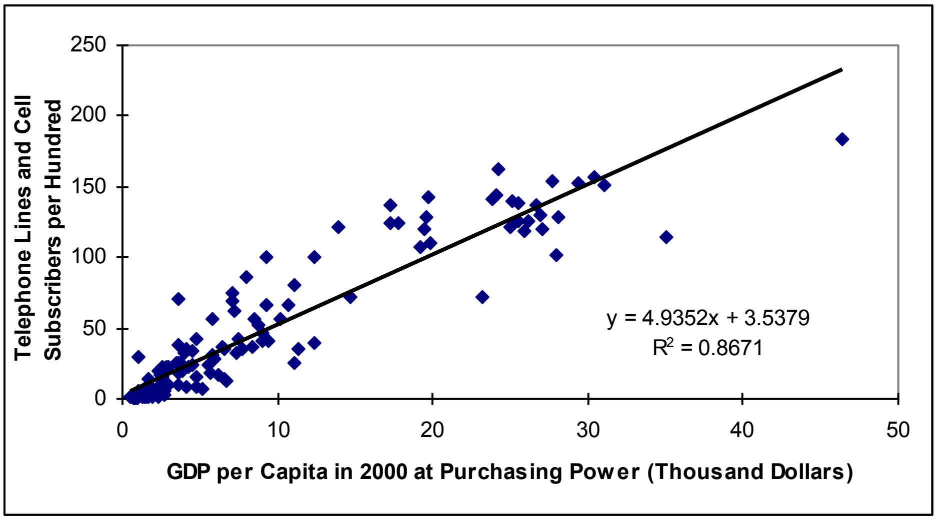
It is interesting to note that telecommunications is the key element in the World Bank listing of infrastructure types that would by many be considered modern or information-age infrastructure. Work by Fay and Yepes (2003: 2) at the World Bank (1994:4) suggests that the cost-based share of that component of infrastructure stocks increases with development level, but is still only about 7% of total infrastructure by value at high income levels. In contrast, electric power systems increase their share of the total sharply with development, reaching about 40% at the high income levels (just under roads which account for 45% of stocks by value). The importance of power systems to modern infrastructure suggests that it be considered for inclusion in an index of modern infrastructure, or at least be represented as a foundation. One could even argue that, given the enthusiastic adoption of most ICT technology by individual, business, and government users (there are very long delays, for instance, in getting telephones installed in most developing countries), the provision of basic electricity is the key infrastructure bottleneck of the knowledge society. Telephone access might be the next level of bottleneck (opening up use of PCs), followed possibly by access to higher bandwidth, but the expenditure requirements in these areas appear not to be so relatively great.

It is useful to explore the notion of an infrastructure ladder prior to specifying a formulation for forecasting of infrastructure in IFs. The graph below shows the quite close relationship between GDP per capita and electricity consumption.



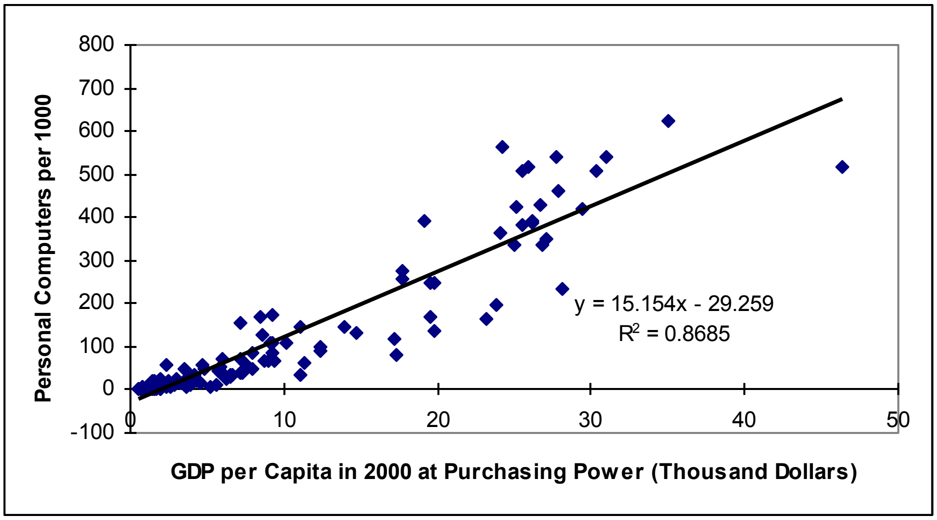
Countries well above the line include Canada, Norway (at over 24,000 kilowatt-hours of annual consumption), Iceland (nearly 25,000), and Finland at (15,000). Although climate is a logical explanation, it is interesting that these electrically-connected societies tend also to rank high on many technology indices. Logically, electricity lays a necessary but not sufficient foundation for electronic networking more generally, although both may result in part from general communitarian impulses in a society, creating a spurious relationship. Countries in hot climates, such as the Arabian Gulf emirates and Singapore, also tend to have unusually high electricity consumption rates; the latter shares high ICT technology with the Scandinavians, but the former do not. This suggests that, indeed, extensive electrification may be a necessary, but not sufficient foundation for ICT.

Moving one step up the potential modern-infrastructure ladder, the graph below shows the sum of telephone land lines and cell subscribers as a function of GDP per capita. Interestingly, although there is a hint of saturation effect at upper levels, the linear fit is quite a bit better than the logarithmic (which yields an adjusted R-squared of only 0.78).



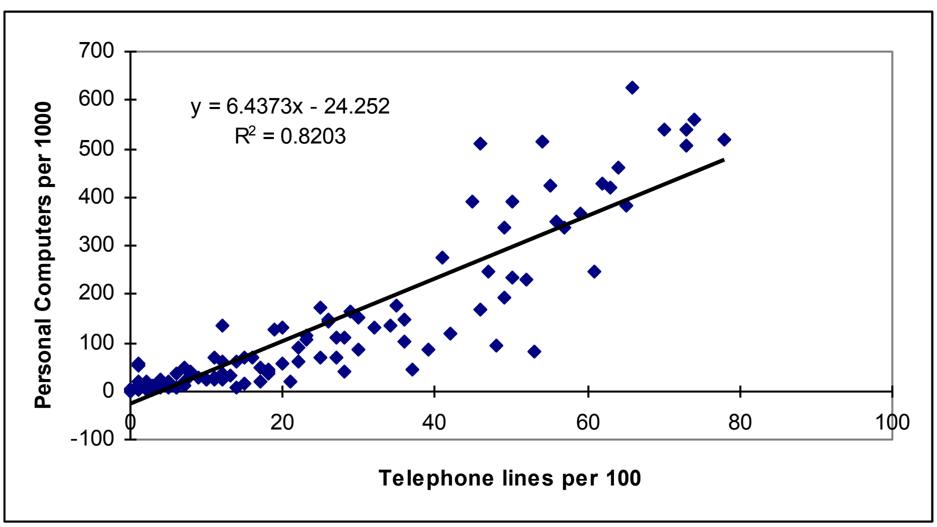
Adding electricity consumption per capita to the formulation reduces adjusted R-squared to 0.85 (or to 0.86 if electricity consumption is added logarithmically). Electricity consumption by itself has an R-squared of only 0.55 with telephone usage (entered logarithmically, that becomes 0.64). This begins to suggest that the hypothesis of a foundation for telephones in electricity use is questionable–both electricity and telephone usage are best explained by GDP per capita alone.

Moving up the posited ladder to personal computers, the graph below shows computers per thousand as a function of GDP per capita, once again with a very high adjusted R-squared.

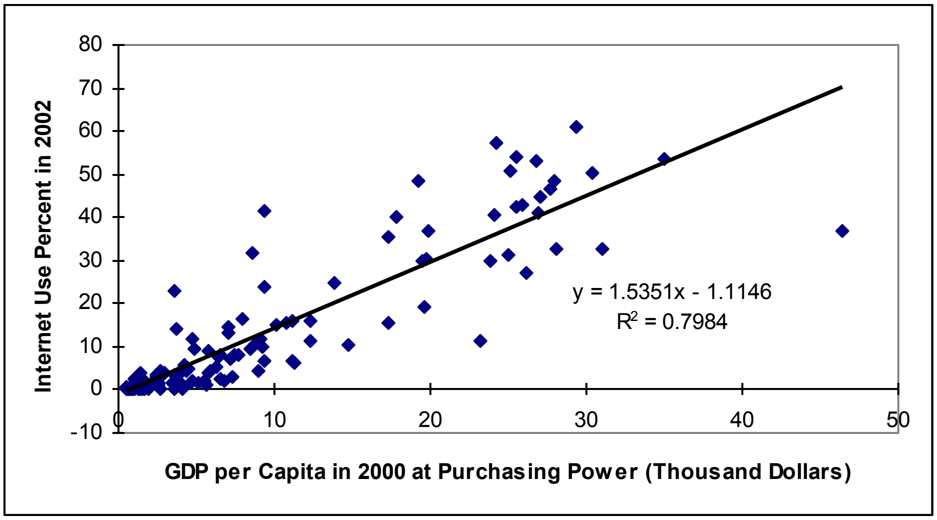


Again there is little hint of saturation in the above curve. There is also a slight hint of an s-curve with a rise around 20,000 and using a power curve with slight upward rise does raise the R-squared to 0.88; but that added complexity adds little real power to the formulation.

Adding telephone lines plus cell subscribers per thousand as a driver of personal computer usage rates raises adjusted R-squared only to 0.87. And looking at personal computer usage as a function of telephone lines alone (without cells) yields 0.82. See the graph below, which again has a hint of upward s-shaped behavior with a marked rise (or a threshold phenomenon) around 40 lines per 100 citizens. Still again, however, GDP per capita does about as well alone as any more complex formulation.

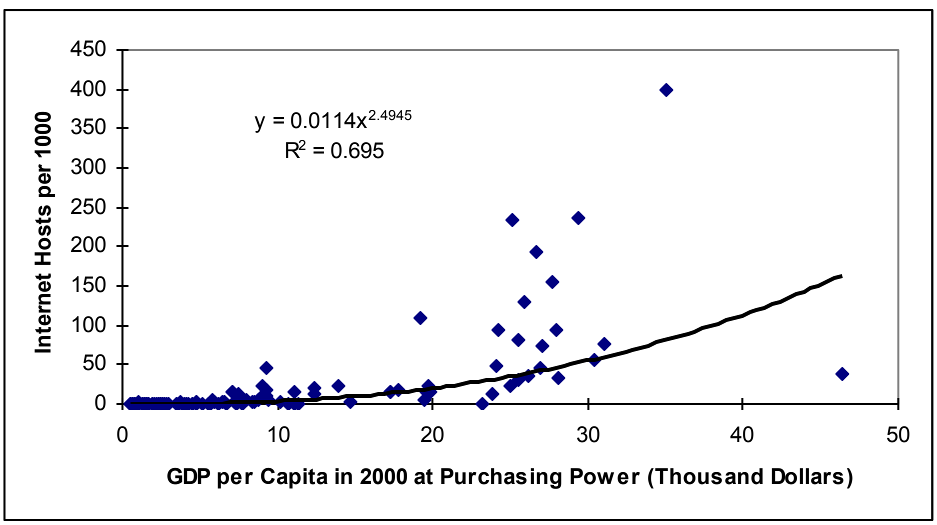


Moving up our rapidly disintegrating ladder to internet use, the graph below shows internet usage as function of GDP per capita alone, with a strong R-squared yet again.

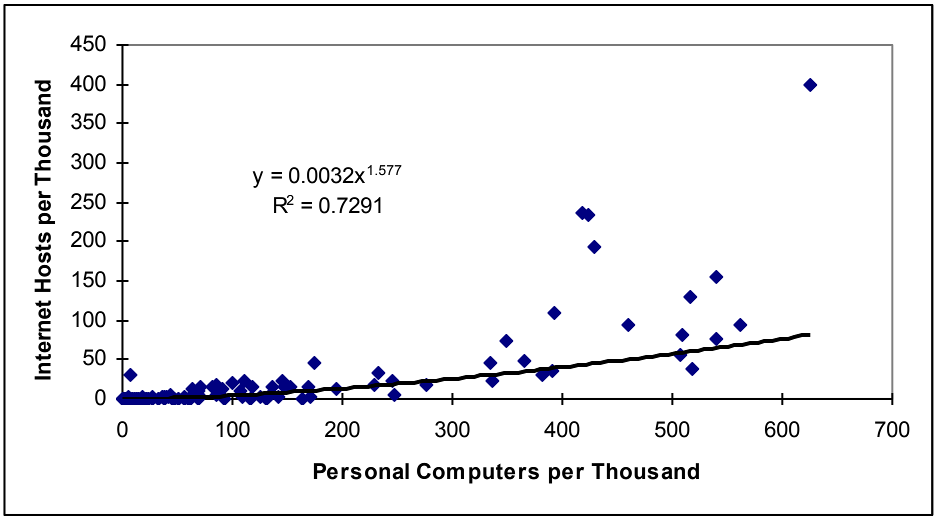


If personal computer usage per thousand is added, the R-squared climbs above 0.86 and both independent variables are significant. Or if telephone lines are added instead, the R-squared climbs to 0.84. This is the first real confirmation that there may be some kind of infrastructure ladder-like phenomenon and it certainly makes sense that internet usage would require telephones and computers.

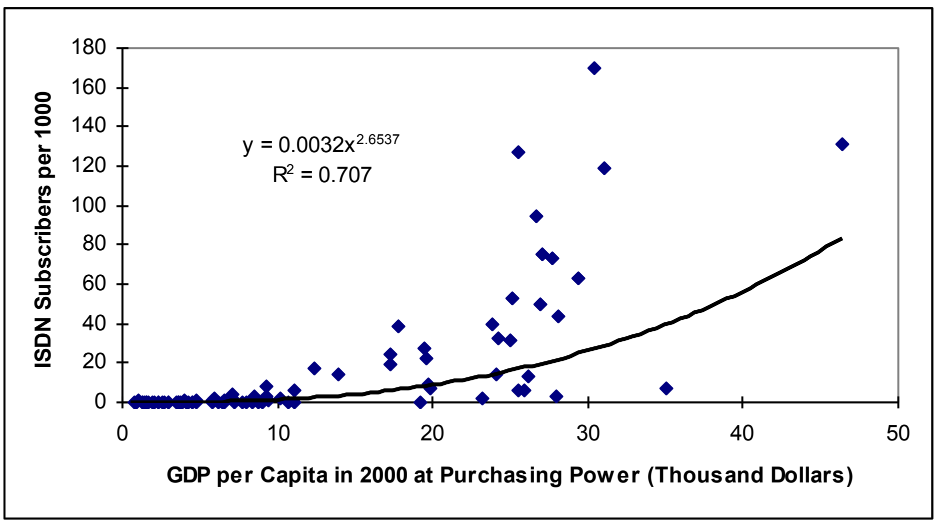
Moving up the ladder once again to internet hosts, the graph below with GDP per capita suggests for the first time a very clear threshold phenomenon (at perhaps $7,000 per capita at PPP). It appears that the curve should rise even more steeply than the function that was fit below.



Again in this instance, the availability of personal computers is actually a slightly stronger predictor of internet hosts than is GDP per capita, giving some weak support to the ladder theory. Yet the R-squared in the figure below is little better than that for GDP per capita.



ISDN subscribers are a somewhat weak measure of the spread of bandwidth, but the best that we found. The curve below again suggests that GDP per capita remains a very strong basis for forecasts. The R-squared rises only to 0.74 if we use personal computer usage instead of GDP per capita (and it falls to 0.67 if we substitute internet usage rates).



Some overall conclusions are possible from the above analysis, and they have clear implications for model enhancement:

> There are close correlations across modern infrastructure elements. It may be reasonable to use single a indicator of modern infrastructure, initialized by reference to data on telephone lines and cell phones, personal computers, and/or internet usage (electricity consumption may be a prerequisite, but local climate appears to be a big factor for that usage, so correlations with it are not that great).
>
> There are high correlations of GDP per capita with all elements of modern infrastructure; we can use GDP per capita as a key driver of modern infrastructure.

There may not much point in trying to represent separate elements with a ladder of development steps–doing so seems to add relatively little beyond use of GDP per capita alone. We can only see significant correlations, suggesting possible step-by-step development between (1) telephone lines and personal computers and (2) personal computers and internet hosts. Because the lower elements of the ladder would, in any case, be driven by GDP per capita, attempting to substitute lower rungs as drivers for higher ones would be more artificial than real.

Given the variation in the relationships of all types of infrastructure with GDP per capita, there clearly is room for the impact of policy decisions; we can represent such intervention by adding exogenous multipliers.

Possibly we should use a formulation or some mechanism to represent saturation in modern infrastructure–it has to happen in almost all of these areas, even though it is only really becoming clear in telephones. Yet saturation in modern infrastructure could be quite a distance away, because new levels of technological capability keep appearing, such as broadband usage and internet host numbers. In fact, there could well be additional layers of infrastructure to add that are not even foreseen yet. Therefore perhaps it is better to build saturation into measures focused on discrete technologies (like internet useage rate), but not into an overall index of modern infrastructure.

3.3 Infrastructure in IFs

There are perhaps two basic approaches for IFs to represent infrastructure, with an emphasis on modern infrastructure. The first was taken some time ago in the context of the TERRA project and involves focusing only on the growth of electronic networking. The IFs project developed a measure of the number of networked persons (NUMNWP) that was based on data collected from the ITU series on internet use as a percent of population. This variable is driven by a formulation that relies on a growth rate calculated from the same source and that builds in a dampening of that growth rate as the portion of a population networked begins to reach an exogenously specified saturation limit. That approach was useful as a first cut, but it is especially weak for developing countries where other infrastructure, such as electricity network coverage, may remain inadequate.

The second and probably preferable approach is to build indices of infrastructure that explicitly recognize the two largest components of infrastructure stocks, namely electricity and roads, and then explicitly to add telecom for modern infrastructure, and finally to add networking (internet use is close to the WSIS concept noted earlier). It may even prove possible to go back later and add water and sanitation and rail, the major missing components in the Fay and Yepes (2003) infrastructure stock accounting system.

In elaborating the second approach, it would be ideal to be able to link physical representations (e.g. road density per person and telecom lines per person) with monetary representations. The latter would give us the basis for connecting government and private spending on infrastructure with values of stocks and to introduce financial trade-offs in the model between spending on infrastructure and other spending (such as on education or the military). Unfortunately, we have been able to find extremely limited data on government infrastructure spending.[17] Thus as a first step on this second approach, we have introduced the physical representations only.

We have created five infrastructure variables for IFs. The first four are specific to major categories: roads (INFRAROAD) in thousands of kilometers of road per million hectares of land, electricity (INFRAELEC) in kilowatt-hours per year per capita, telcommunications (INFRATELE) in main and cell lines per capita, and electronic networking (INFRANET) in percentage of population with internet connections. In each of the first three cases the default driver is GDP per capita at PPP. In the fourth case the driver is the existing forecast in IFs of the number of networked people (NUMNWP), the fifth and pre-existing variable. As indicated above, that is driven by a growth rate over recent years and a saturation formulation as the portion of the population networked approaches a specified limit (numnwplim). These four indices say a great deal about infrastructure levels, both across countries and across time.

$$INFRAROAD_r = \left(\frac{ANALFUNC(GDPPCP_r, \frac{POP_r}{LANDAREA_r})}{ANALFUNC(GDPPCP_r^{t-1}, \frac{POP_r^{t-1}}{LANDAREA_r^{t-1}})} * INFRAROAD_r^{t-1} \right) * \mathbf{infraroadm}_r$$

$$INFRATELE_r = \left(\frac{ANALFUNC(GDPPCP_r)}{ANALFUNC(GDPPCP_r^{t-1})} * INFRATELE_r^{t-1} \right) * \mathbf{infratelem}_r$$

$$INFRAELEC_r = \left(\frac{ANALFUNC(GDPPCP_r)}{ANALFUNC(GDPPCP_r^{t-1})} * INFRAELEC_r^{t-1} \right) * \mathbf{infraelecm}_r$$

$$INFRANET_r = \left(\frac{NUMNWP_r}{POP_r} * 100 \right) * \mathbf{infranetm}_r$$

The fifth variable (INFRAIMOD) is an aggregate measure of the three "modern" infrastructure forms: electricity, telecommunications, and networking. It currently is a simple average of the three, each of which is controlled in the computation of the average by the "expected" level given the basic underlying formulation. Thus if the relative level of infrastructure development in the telecommunications category for a country is 30% above the cross-sectional relationship between GDP per capita and telecommunications infrastructure levels and remains at 30% above the relationship as GDP per capita rises, the contribution of telecommunications to the infrastructure index remains essentially constant.

[17] We have e-mailed Fay and Yepes with a request for help.

$$INFRAIMOD_r = \frac{TeleRatio + ElecRatio + NetRatio}{3} * 100$$

where

$$TeleRatio = \frac{INFRATELE_r}{ANALFUNC(GDPPCP_r)}$$

$$ElecRatio = \frac{INFRAELEC_r}{ANALFUNC(GDPPCP_r)}$$

$$NetRatio = \frac{INFRANET_r}{\text{PredictionNet}}$$

The rationale for such a formulation of the overall index is that it indicates infrastructure strength relative to that expected at different levels of development, not absolute levels that would vary greatly across levels of development. The index is scaled the first year from 0 to 100 for easy comparison across countries and time. Such an index would theoretically be ready for inclusion as a driver in the productivity representation of IFs. It was decided, however, that although the index has intrinsic interest, it makes sense to add the individual measures of infrastructure, rather than the aggregate one, to the productivity formulation; it seems unnecessary to throw away information from the individual ones.

Until there are linkages to the infrastructure indices from government and/or private expenditures on infrastructure (and government will be the first to be developed) the only real way to move the modern infrastructure index levels and thus to move productivity is to change the values of multipliers on some subset of the four basic infrastructure indicator values (infraroadm, infraelecm, infratelem, and infranetm). The next step for development around infrastructure is thus quite obvious: Link government spending to infrastructure development, thereby also adding automatic trade-offs across attention to infrastructure and other government spending and transfers[18]

[18] The Fay and Yepes (2003) work make provide a foundation for that representation of infrastructure in government spending. Briceño-Garmendia, Estache, and Shafif (2004) cite them as pegging world's infrastructure stock, excluding housing, at $15 trillion, 60% in high-income countries, 28% middle-income, and 13% low income; electricity and road about 80% of total. Briceño-Garmendia, Estache, and Shafif (2004) also cite calculations indicating that govt or public utilities financed 70% of total spending in 1990s, ODA financed 5-10%. In total, private sector financed 20-25% (pp 16-17). "Currently, in developing countries, the public sector … is spending roughly between around 2% (in high middle income countries) to around 4% (in low income countries) of GDP on infrastructure." (p. 17)

4. Positioning for Technological Dynamism: Knowledge Creation

Positioning of a society for technological dynamism needs definitional clarification. On its surface, foundations of technological dynamism could easily be interpreted to encompass strength of educational institutions, strong technological infrastructure, an open society, substantial spending on infrastructure, and even high governance quality. This section will review some existing indices that are, in fact, rather broad and encompassing.

For the purposes of the IFs project, and especially for the purpose of forward linkages, however, it makes more sense to maintain sharper conceptual differentiation. Thus separately tracking years of education, types of technological infrastructure, and dimensions of governance makes sense for IFs (they have been addressed elsewhere in this and other project reports). In addition to such elements, the most specific components of positioning for dynamism that appear most in need of incremental representation in this paper are probably knowledge creation and knowledge adaptation/diffusion. Thus after the review of existing broader indices we will turn to consideration of representation of those components in more detail.

4.1 Review of Existing Indices on Technological Capability

There are at least three existing indices of technological capability/sophistication to consider when determining how best to represent knowledge creation and adaptation within IFs: the Networked Readiness Index of the World Economic Forum, the Technology Achievement Index of the United Nations Development Program, and the Digital Access Index of the International Telecommunication Union.[19]

The World Economic Forum publishes a well-known annual Global Competitiveness Report.[20] Their growth competitiveness index (CGI) has three components (2003: 21-21): a technology index (weighted ½), a public institutions index (weighted ¼) and a macroeconomic environment index (weighted ¼). The technology index is built on three sub-indices: innovation, technology transfer and ICT (which could be considered an infrastructure component). Interestingly, the weighting of innovation and transfer is different across countries, higher for what are called the "core innovators" – what in international political economy might be called the system technology leaders. The

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[19] There is also an Information Society Index prepared by the IDC Continuous Intelligence Service. Their web site says the index tracks 52 countries using 15 variables: " IT spending as a percent of GDP, software spending, IT services spending, PC penetration, Internet users, home Internet users, mobile Internet users, ecommerce spending, broadband households, wireless subscribers, handset shipments, secondary education levels, tertiary education levels, civil liberties, and government corruption. " They apparently have compiled the index for 2004 and forecast all variables for 2005-2009. The service is proprietary so data and forecasts are not readily available.

[20] See http://www2.weforum.org/site/homepublic.nsf/Content/Global+Competitiveness+Programme/Global+Competitiveness+Report/Global+Competitiveness+Report+2003-2004.html for access to several recent ones.

public institutions index is built on two sub-indices: contracts and law and corruption. The macroeconomic environment index is built on three sub-indices: macroeconomic stability, country credit rating, and government expenditure.

Thus the index is an effort to capture a substantial range of the variables that drive economic competitiveness and productivity, ranging well beyond technological competiveness. For instance, the governance measures discussed in an earlier section of this paper are included. It is the technological index that would particularly interest us here.

The World Economic Forum also produces, however, a less-well known annual Global Information Technology Report.[21] That report includes a Networked Readiness Index (NRI) that goes back at least to the Kirkman, Osorio, and Sachs (2002) version for the 2001-2002 report and has been prepared in recent years in collaboration with the World Bank and INSEAD.[22] In 2003-2004 the index had three component indices, on environment (including market environment, political and regulatory environment and infrastructure environment), readiness (individual, business, and government), and usage (individual, business, and government). The environmental component cuts across the governance and infrastructure domains of this project, but the readiness and usage components more closely focus on the ICT environment and its usage. As with the GCI, this index appears to draw on a substantial number of survey responses, as well as some objective indicators.[23] The IFs project has incorporated the index for 2003 in its database under the variable name ICTNetworkReadinessIndex.

The United Nations Development Program (2001) introduced the Technology Achievement Index (TAI) in its *Human Development Report 2001*. The index has four components: creation of technology (patents, fees from abroad); diffusion of recent innovations (internet hosts per capita and technology exports); diffusion of old innovations (telephones and electricity consumption per capita); and human skills (mean years of schooling, tertiary enrollment in science, mathematics and engineering). The data appendices of the HDR 2001 show computation of the measure for only 72 countries, presumably because of unavailability in the underlying input measures (one reason that the World Economic Forum's measures, dependent on survey data created by the organization, has more extensive coverage).

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[21] See, for example, World Economic Forum, *Global Information Technology Report, 2003-2004*. http://www2.weforum.org/site/homepublic.nsf/Content/Global+Competitiveness+Programme/Purchasing+and+Contact+Information.html and CD Rom information at http://www2.weforum.org/site/homepublic.nsf/Content/Global+Competitiveness+and+Technology+Reports+CD-ROMs.html

[22] See a more recent description by Dutta and Jain (2004) for the 2003-2004 report; the same co-authors also described the 2002-2003 version.

[23] One unique feature of the GCI is its very heavy use of data from surveys for many components; the downside of that is that the basic data for representing components such as innovation or technology transfer in the model is correspondingly limited.

Interestingly, the 2003 and 2004 volumes of the *Human Development Report* do not show the index again, but rather provides a table with a variety of variables tapping technology creation and diffusion. The variables show roughly correspond to the index components named above, but there are significant differences. For instance, R&D spending and scientists engaged in it are added, while technology exports and electricity consumption are dropped. It appears perhaps that, as the UNDP has turned heavily to a focus on the Millennium Development Goals, it has reduced its attention to technology and its support of the TAI. This is unfortunate because, except for the components in its measure that seem to tap infrastructure (like internet hosts and users), the measures in its table seem fairly sharply to focus on knowledge creation and adaptation. The IFs project has incorporated the index for 2001 (perhaps the only year it was ever compiled) in its database under the variable name ICTTechnologyAchievementIndex.

The International Telecommunications Union (ITU) has created a Digital Access Index (DAI). The ITU collapses 8 indicators into five components for the index: infrastructure, affordability, knowledge, quality, and usage.[24] The IFs project has incorporated the index for 2002 in its database under the variable name ICTDigitalAccessIndex.

Some general observations about these indices might be useful. First, their content tends to cut across a wide range of growth/dynamism factors, not just technological positioning. There is tapping of some combination of human capital, infrastructure, governance, and knowledge/technology level components, the mixture of which varies across the indices. Second, most of the measures are oriented towards description of the current situation, not forecasting. Perhaps the Networked Readiness Index of the World Economic Forum is the most clearly future-oriented, and the authors note that there appear to be important threshold effects with respect to the benefits of networking and ICT developments (Dutta and Jain 2003: 16). Third, in part because of the conflation of various elements, but also because of the large number of factors involved in most of these indices, it is not easy to see a path towards representation of them in the model. That is the topic of the next section.

The three indices discussed above are rather different in their components, but the table below shows that they are nonetheless highly correlated.

	Digital Access	Technology Achievement
Network Readiness	.817	.832
Technology Achievement	.900	

Adjusted R-squared Correlations among Three Modern Technological Indices

[24] See the ITU Digital Access Index at http://www.itu.int/newsroom/press_releases/2003/30.html.

4.2 Conceptualizing Knowledge Creation and Adaptation/Diffusion for IFs

None of the technology-oriented measures discussed above is really a measure focused on the ability of a society to create knowledge or to adapt it from elsewhere. They all tap multiple dimensions that this analysis and the IFs model are attempting to track with more care separately. Moreover, each broader index is subject to a variety of additional limitations for the purposes of IFs, especially the availability of underlying data series over a significant period of time.

It is important to remember that we have already covered governance and infrastructure dimensions in previous chapters and that we intend to turn to globalization in the next chapter. What is of interest in this chapter and the next is knowledge creation and adaptation/diffusion. That narrower focus is, to some considerable degree, the same as that of the *1998/99 World Development Report: Knowledge for Development,* under the team leadership of Carl Dahlman (World Bank 1999).

Based on that issue of the WDR and from the above discussion of indicators, especially the UNDP's Technology Achievement Index, it appears useful to consider the following components and drivers of knowledge creation and diffusion, recognizing that all components in the creation category can be very helpful also with respect to adaptation:

> Knowledge creation. Research and Development expenditures; patents granted to residents; numbers of scientists and engineers (or size of tertiary education more generally); receipts of royalties and license fees.
>
> Knowledge adaptation/diffusion. Manufactured imports as a portion of total imports or the GDP; inflows of foreign direct investment (FDI) as a portion of total investment or the GDP; payments of royalties and license fees.

Looking at this list it becomes clear that we should defer consideration of knowledge adaptation/diffusion to the next chapter and the discussion of globalization. The A. T. Kearney/*Foreign Policy* globalization index (GI), to be discussed in that chapter, is heavily linked to variables such as trade and FDI. In fact, within that index is a sub-dimension called economic integration that we have replicated in IFs as an approach to capturing those key drivers of knowledge adaptation/diffusion.

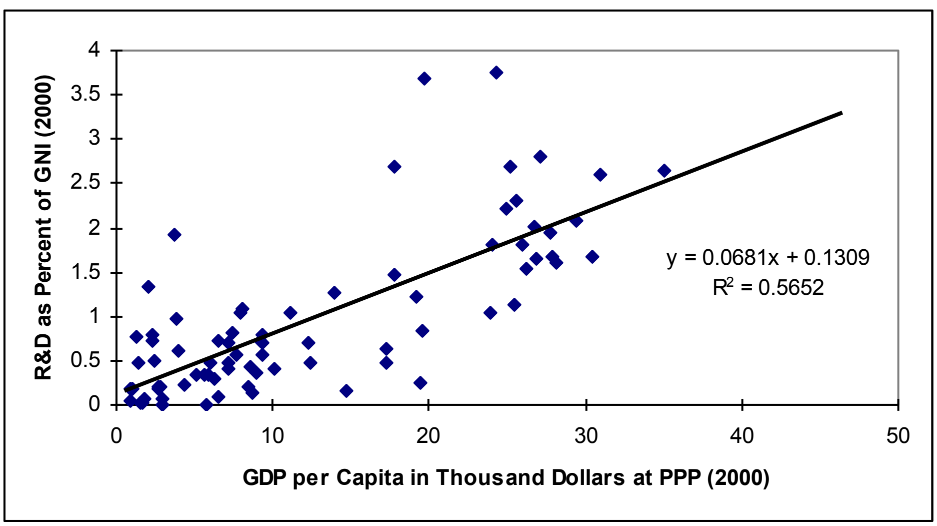
This chapter restricts focus to knowledge creation. Can the IFs model reasonably forecast the elements identified above as important to knowledge creation? IFs includes a calculation of research and development expenditures, already driven by deep drivers, open to policy manipulation of government spending, and accessible via an exogenous multiplier. It also includes the number of individuals (or the percent of population) that have tertiary education. It does not include any variables on patents, scientists or engineers as separate from other tertiary degree holders, or receipts of royalties or license fees (although the database has series on each). For the purposes of long-term forecasting, R&D expenditures and tertiary graduates very probably are the best driver variables for knowledge creation in any case, and the rest of this chapter will explore them, concluding with the specification of a knowledge society index for IFs that is based upon them.

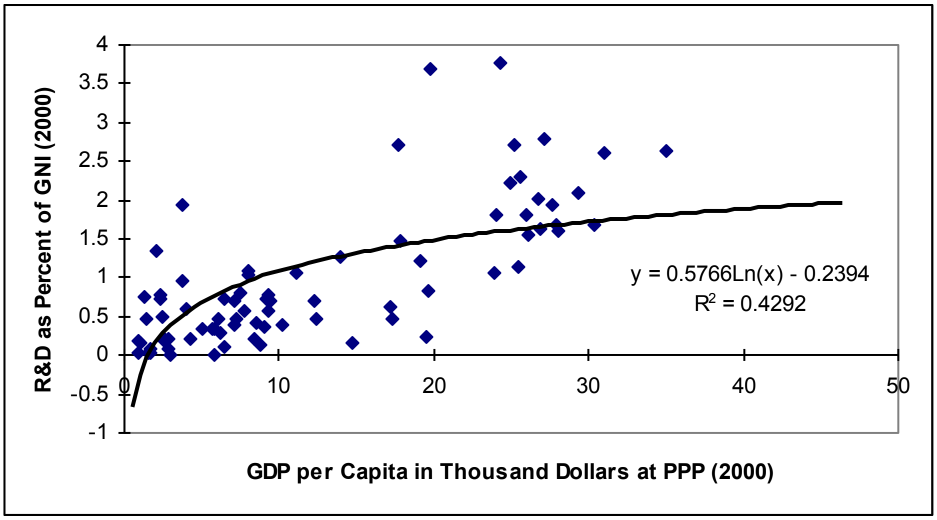
4.3 Exploring Knowledge Creation: R&D

The discussion of R&D in this paper is a supplement to that of the companion paper (Part 1), which explores the productivity literature for insights about the impact of R&D spending on economic growth and describes the implementation of a productivity formulation in IFs that drives multifactor productivity with a variety of variables including R&D spending. This section supplements the discussion of the companion paper by exploring the relationships between GDP per capita and R&D on the one hand (backward linkages for R&D) and between R&D and economic growth on the other hand (forward linkages for R&D) using the database of IFs itself.

The data on R&D spending in IFs come overwhelmingly from two sources, the World Bank's World Development Indicators (WDI) and the Organization for Economic Cooperation and Development (OECD). The advantage of WDI data is extensive country coverage, but the cost is a lack of disaggregation of R&D types. The OECD offers such disaggregation, including public and private expenditures, but provides very limited country coverage.

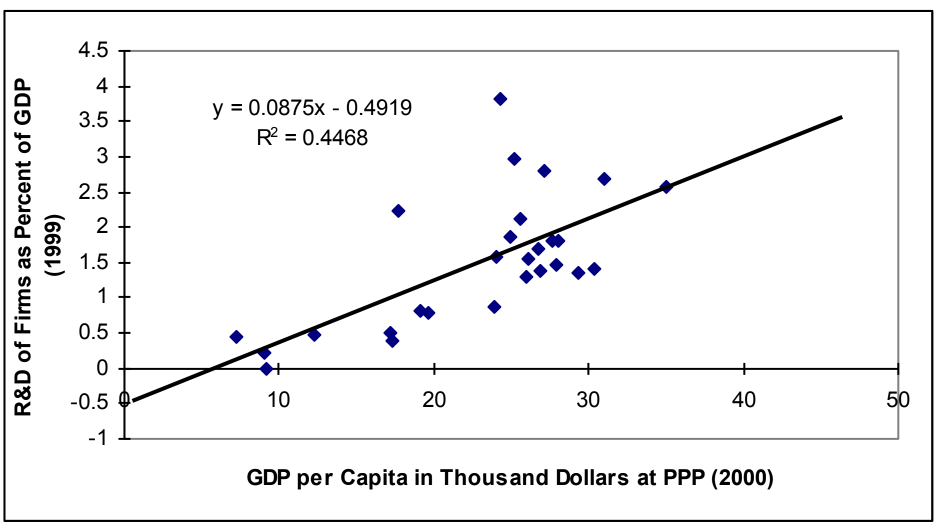
The two graphs below use the country-extensive WDI data to explore the relationship between GDP per capita at purchasing power and the portion of Gross National Income (GNI) spent on R&D by public and private sectors.

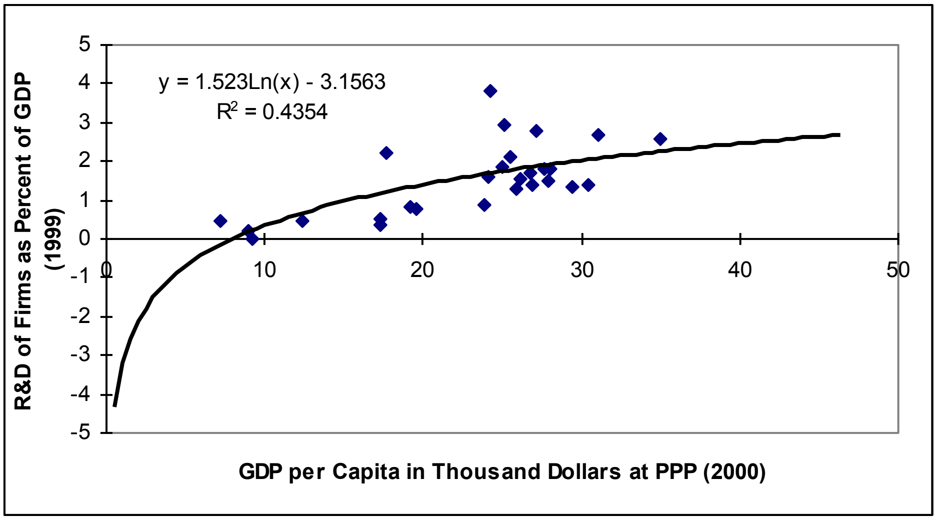


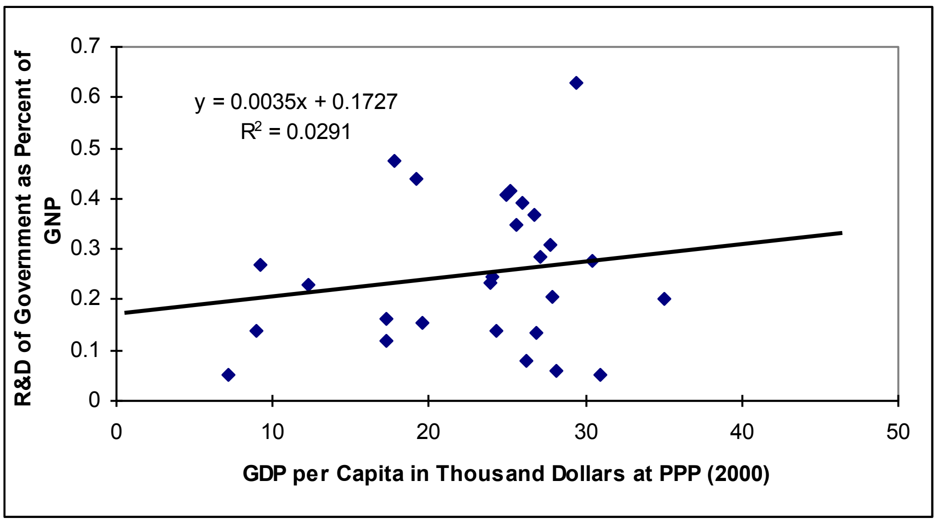


In the above two graphs, the linear relationship looks stronger and that is the one used within IFs to represent the backward linkage of R&D to GDP per capita. Among the outliers near the top of the graphs are Israel at $19,700 and 3.7% spending on R&D and Sweden at $24,300 and 3.76%. A sample outlier at the bottom of the graph is Cyprus at $19,500 and 0.25%.

But it will be important for both backward and forward linkages to distinguish private and public R&D. The three graphs below use OECD data for a much more limited set of countries to show the relationships between R&D of firms and governments separately with GDP per capita.

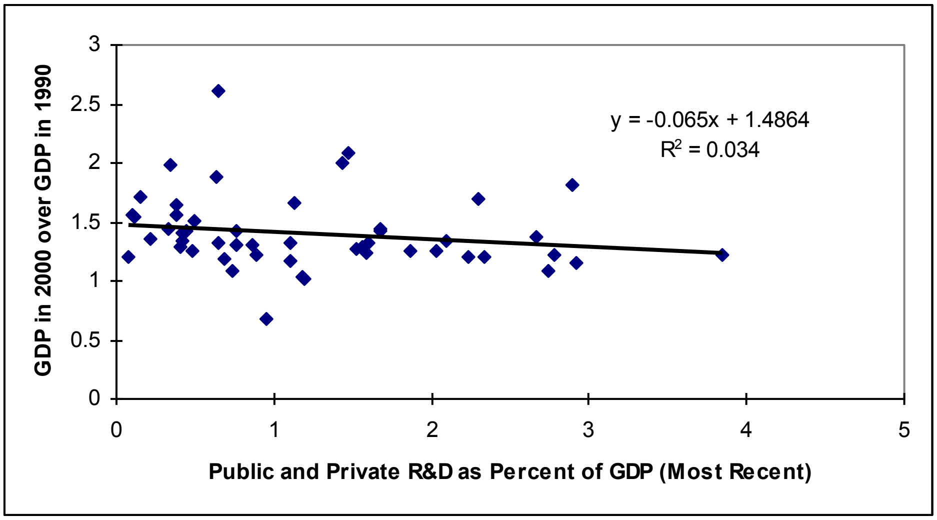




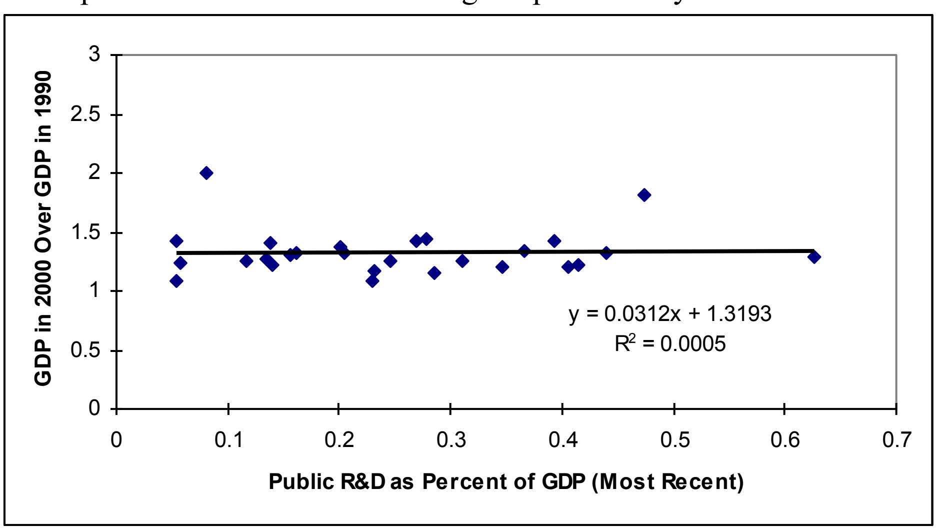


Several conclusions can be drawn from the above graphs. First, private R&D is nearly an order of magnitude larger than public R&D. Second, the slope of private R&D is quite a bit higher, suggesting that within OECD countries with lower incomes are relatively more reliant on government spending than those with the highest incomes. Driving R&D forecasts within IFs is rather complicated as a result of the different patterns and the importance of the private and public distinction. In large part because of the two data sources and their distinctive coverage, it was decided to represent separately within IFs total R&D spending as a portion of GDP (RANDDEXP) and government spending on R&D (GDS, RandD).

Turning to forward linkages, the next two graphs show the relationship between total R&D (public and private) and GDP growth between 1990 and 2000 and then between public R&D only and the same growth. Unfortunately it was not possible to use R&D spending at the beginning of the period (1990) as desired to capture possible causal direction with lags, because there were not enough data points.



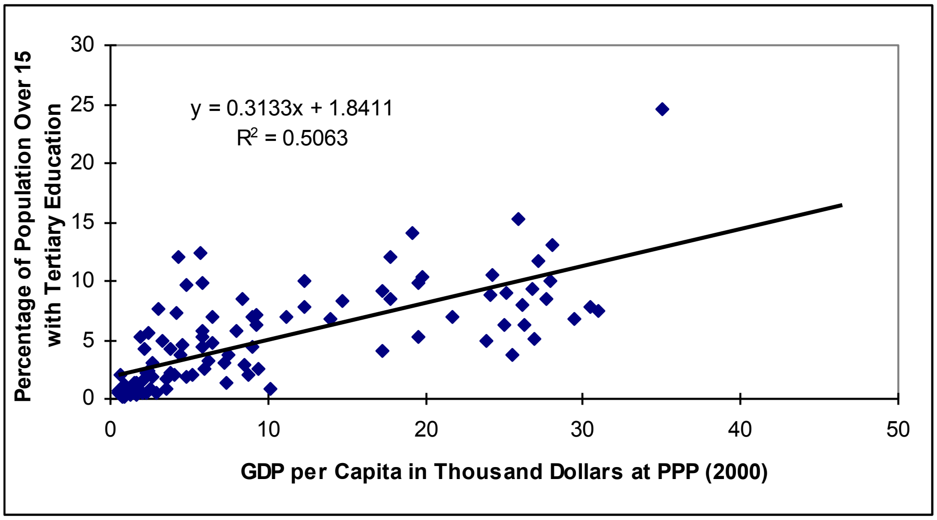
Surprisingly, the graph above suggests an inverse, not a positive impact of R&D spending levels on growth. The one below, focusing on government R&D spending, shows a very slightly positive one. But both graphs have correlations that are too low to be significant. In general, these results contradict the findings of the productivity literature reported in the companion paper to this one. Because the studies in that literature go so much more deeply into the relationship, however, the IFs formulation for the impact of R&D on productivity comes from it. The two graphs are slightly disconcerting, but only slightly for three reasons: (1) the time sequences wrong in them, (2) GDP growth is quite different from productivity growth, (3) the data set used here is extremely limited. The main purpose of showing the two graphs is to indicate the complications of exploring the relationship and thereby to reinforce the utility of using more specialized literature in creating the productivity formulations of IFs.

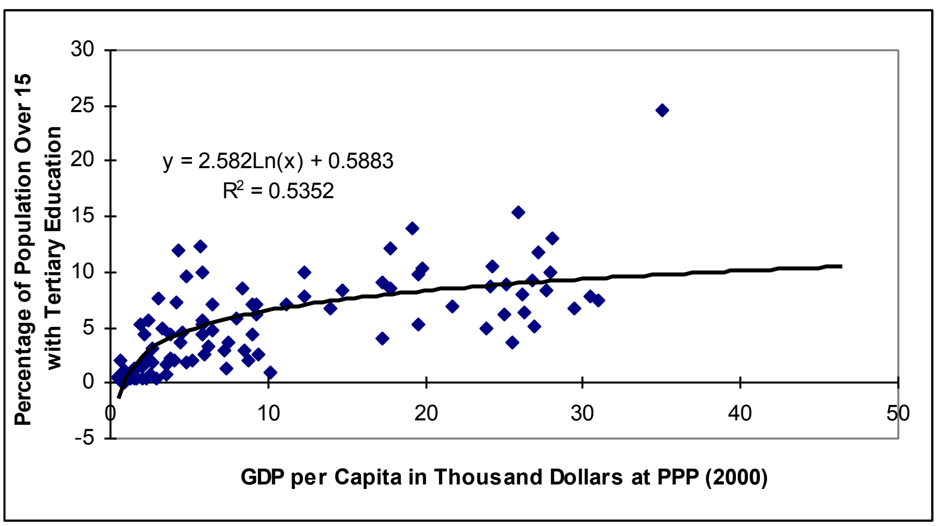


4.4 Exploring Knowledge Creation: Tertiary Education

In parallel to the last section, this one explores the linkages between GDP per capita and levels of tertiary education and between tertiary education and economic growth. The former is quite unnecessary with respect to model specification, because IFs includes a full formal education model across primary, secondary and tertiary levels (developed by Mohammod T. Irfan as part of his Ph.D. dissertation work). Nonetheless, it is useful to see the relationships.

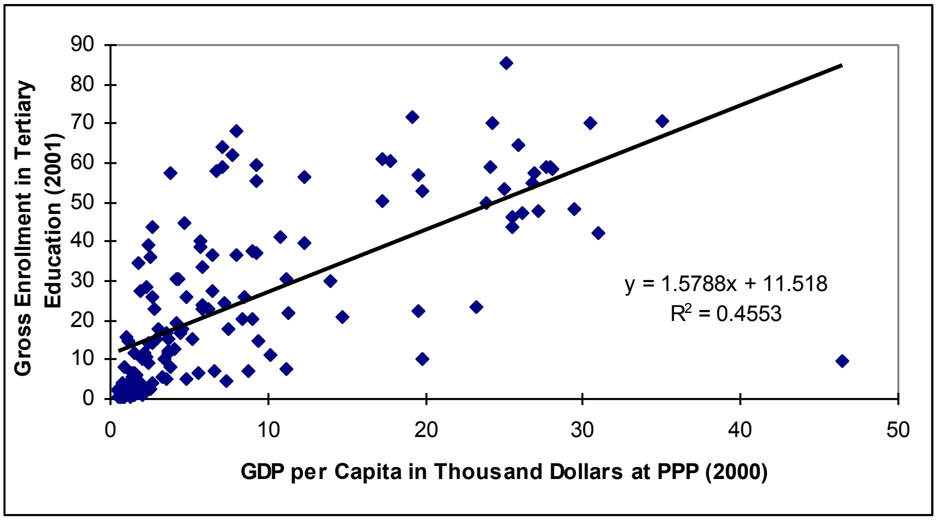
The two graphs below show the quite strong relationships between GDP per capita and the number of those over 15 years of age with tertiary education (the IFs database also includes information on those over 25).

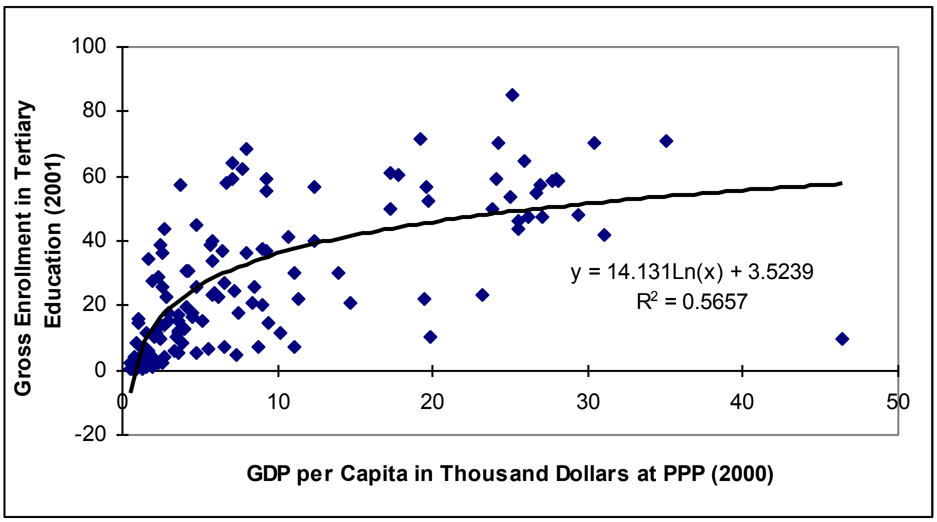




In the above graphs, the outlier at the 24.9% level of tertiary education is the United States; the outlier at $10,150 and 0.9% is Mauritius.

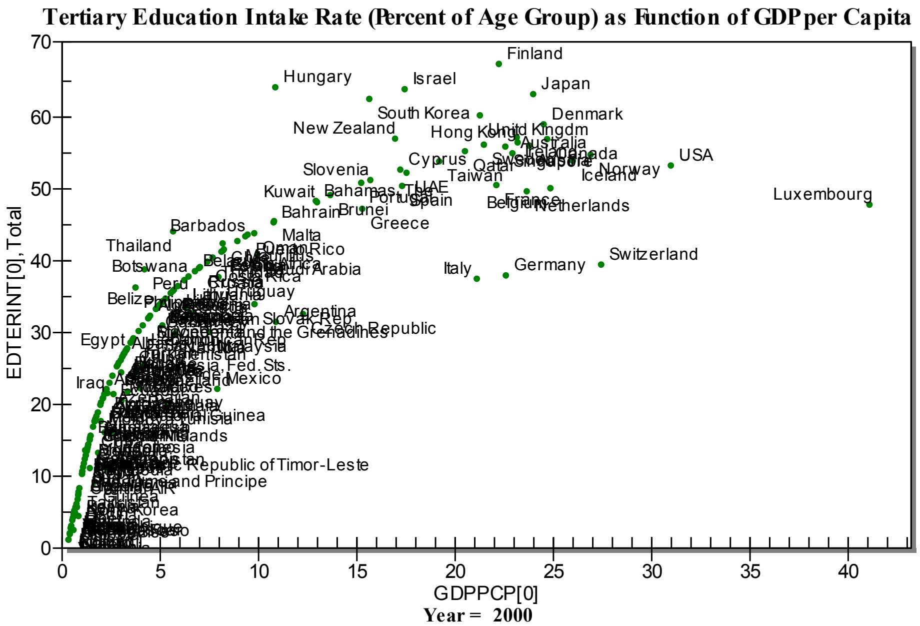
The two graphs below show the relationship of GPD per capita with gross tertiary enrolment rather than levels within the adult population.





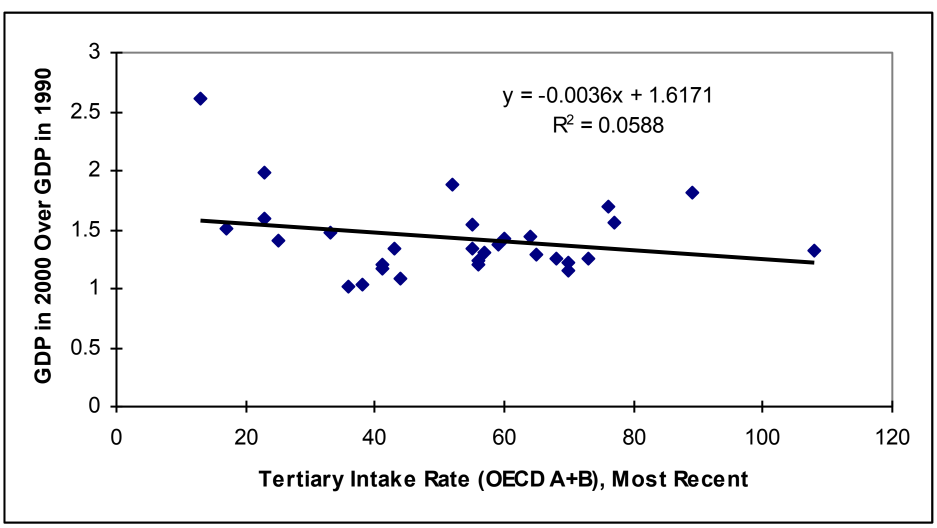
In the above graphs the outlier in lower right-hand corner is Luxembourg; the outlier at $25,100 and over 80% gross tertiary enrollment is Finland.

In the formal education model of IFs, the tertiary intake rate is available. The figure below shows the relationship of GDP per capita with tertiary intake levels in the IFs model itself. Unfortunately, the large number of points on the logarithmic curve do not indicate a surprisingly strong relationship; instead they are illustrative of the large amount of missing data for tertiary education (it also is largely available for OECD countries); the points on the line are estimated from the function computed with the smaller set of data that is available.

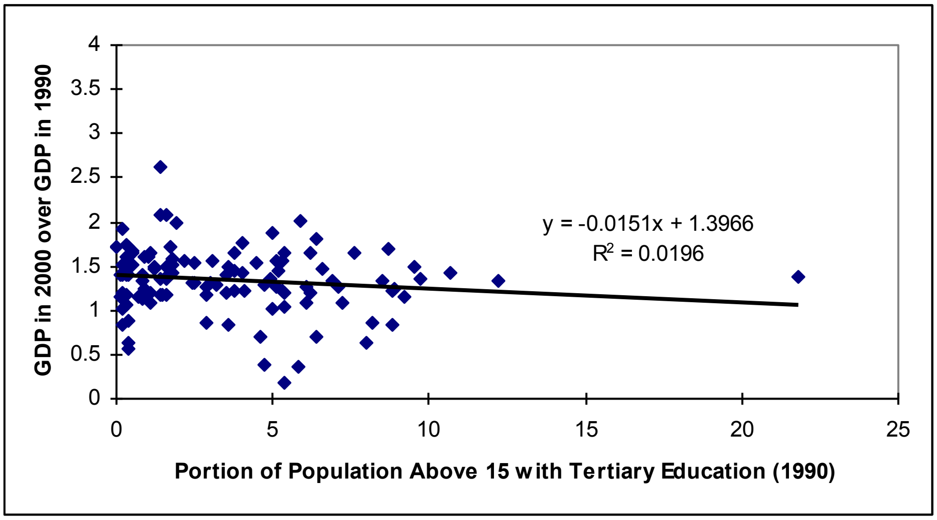


In spite of the relatively small number of real data points in the figure above, there is some useful information there. The outliers are, for the most part, not surprising in the figure. We would expect intake rates to be exceptionally high in Israel, Finland, and South Korea. And we would expect somewhat lower ones in Italy and Germany. A significant surprise is that intakes have risen so sharply in many countries that large numbers are now well above the US rate. The implication of this is that the US will steadily lose the sharp advantage that was shown in an earlier figure with respect to stocks of those within the adult population with tertiary education rates.

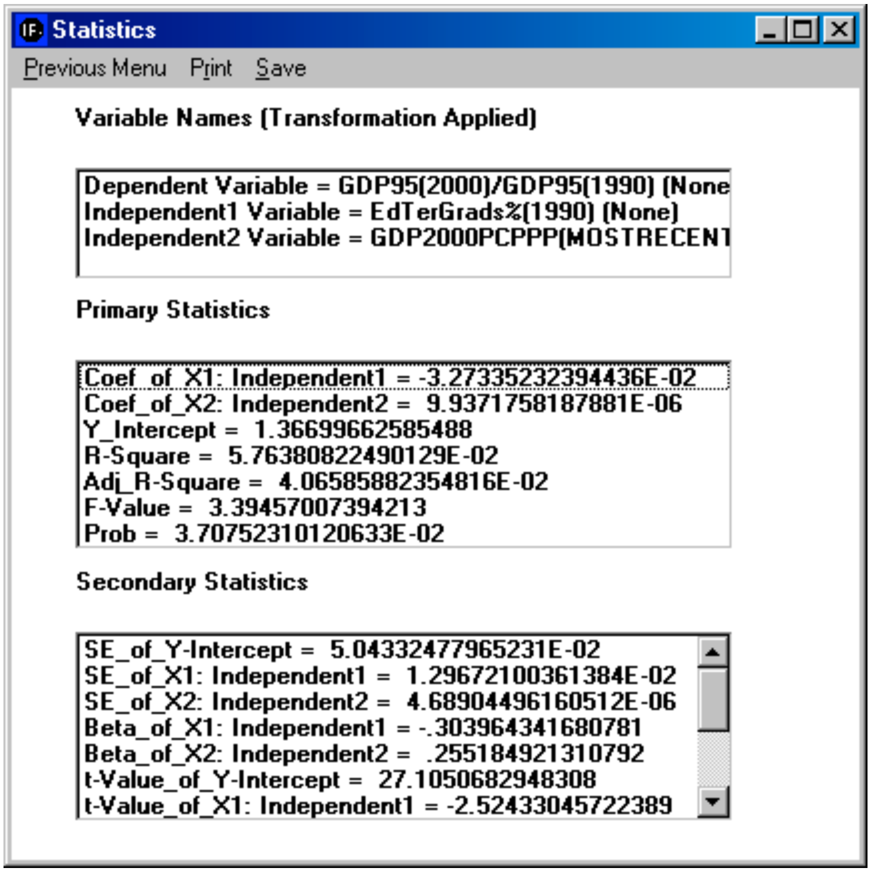
Turning to forward linkages between tertiary education and economic growth, the import of the figure below is again greatly limited by the small number of countries represented in it. As with R&D, however, we once again see an inverse relationship rather than the expected positive one.



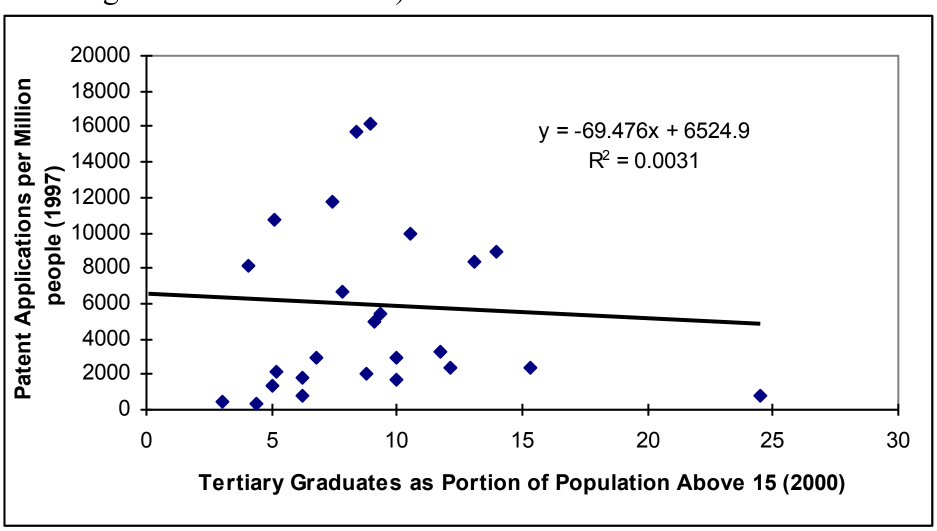
Turning in the figure below to population with tertiary education instead of intake rates, and moving to education data in 1990 and therefore in advance of the period of growth examined, the figure below again surprises somewhat with an inverse relationship between tertiary education and growth.



The unexpectedly inverse relationship in the figures above is not statistically significant. Does the level of GDP per capita influence the relationship? Could it be that richer countries with higher education levels could have grown less rapidly in the 1990s than poorer countries? If we add GDP per capita at PPP to the analysis, we find in the table below that the negative relationship between tertiary education and economic growth in the 1990s actually intensifies and has a high t-value. This result is especially surprising since the 1990s were supposed to have been a decade influenced by an emergent knowledge society.



We would at least expect that higher portions of tertiary graduates would result in higher rates of patents per capita. Surprisingly, the figure below shows again a small negative relationship. (Iceland was removed because it had nearly 100,000 applications per million people – that may reflect the big push in Iceland on energy and biotechnologies, but it might also be a data error).



Overall, the above analysis does not give us a great deal of confidence in any relationship between tertiary education levels and economic growth rates. In contrast to the analysis of R&D, there is not a productivity literature to fall back on that provides us contrary information and a basis for including tertiary education in the IFs production function in spite of our own analysis. Thus we will not include it (see the companion paper, Part 1, for a discussion of the linkages between knowledge variables and productivity).

4.5 Implementation of Knowledge Creation Index in IFs

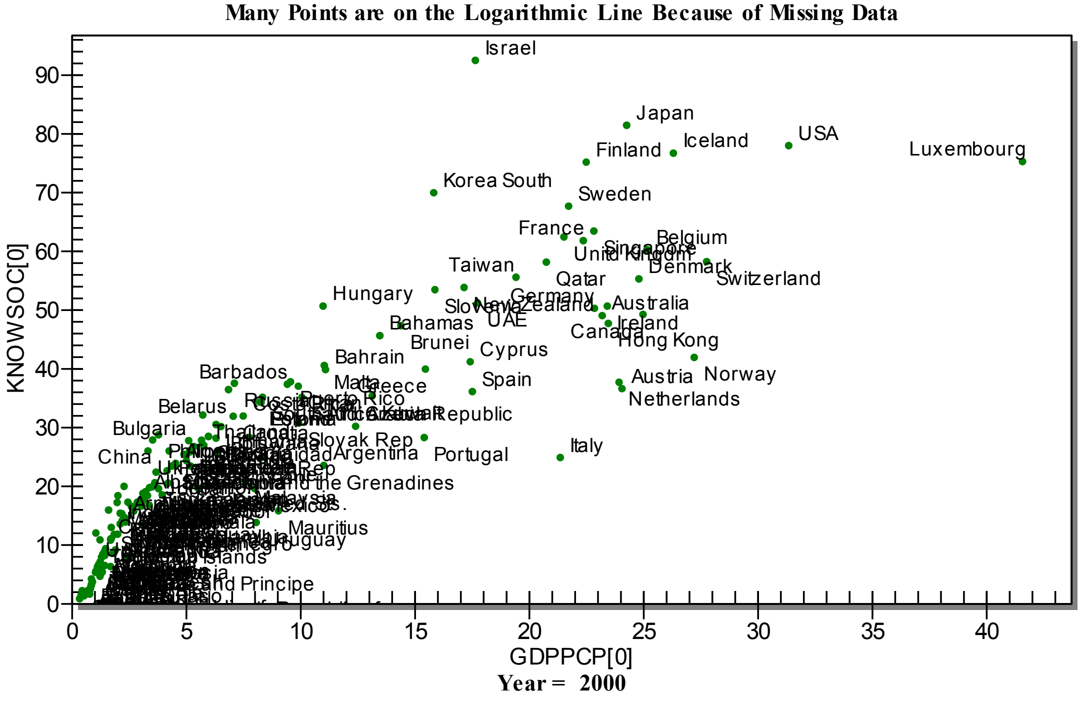
In spite of the decision not to include tertiary education among the drivers of productivity, it is useful to have a measure of knowledge creation tied to R&D spending and tertiary education. Therefore a variable called knowledge society (KNOWSOC) was created based on R&D spending as a portion of GDP and on the tertiary graduation rage as a percentage of population. The two components are weighted equally.

$$KNOWSOC_r = \frac{RANDEXP_r + EDTERGRATE_{r,Total}}{2}$$

The figure below shows how the knowledge society index may provide some useful insights. That figure looks at the index as a function of GDP per capita (at PPP).

Knowledge Society Index Displayed Across GDP per Capita (PPP) Levels

Many Points are on the Logarithmic Line Because of Missing Data



There are some potential surprises in the figure above. Finland, Israel, Iceland, Japan, and South Korea, all sit comfortably above the curve. A fair number of European countries, however, including Italy, Portugal, Spain, Austria, and Norway are positioned below it. So, too, is Ireland (the "Celtic Tiger"). Although it is impossible to see in the cluttered graphic above, the position of the four BRICS (Brazil, Russia, India and China) is also significant. On public R&D alone, all four are well above values expected at their levels of GDP per capita, indicating a strong governmental effort to move forward on the knowledge society dimension. But when total R&D and tertiarty graduation rates are added to the picture and into the index above, with the partial exception of China none particularly stands out from the crowd.

This chapter has focused on knowledge creation and the knowledge society index of IFs. The next turns to knowledge diffusion/adaptation, a key element of globalization.

5. Globalization

This chapter shifts focus to globalization. When the topic turns to possible indices of globalization only one leaps out: the A.T. Kearney/*Foreign Policy* Globalization Index (GI). *Foreign Policy* released the fifth annual results in their May/June 2005 issue.[25] There is no truly competitive index of globalization. See articles by Kurdle (2004) and Lockwood (2004) for some evaluations of the GI.

Although the index has changed a little over time, its structure has remained relatively stable. It consists of four sub-indices: (1) political engagement (international organization memberships, UN peacekeeping, treaties ratified, and government transfers or aid); (2) technological connectivity (internet users, internet hosts, secure servers); (3) personal contact (travel and tourism, international telephone traffic, remittances and personal transfers); and (4) economic integration (trade and foreign direct investment; in past years this also included portfolio flows and income payments).

This chapter will explore two issues around the Globalization Index (GI). The first is the degree to which IFs can replicate the GI or something approximating it. This project has added a variable called GLOBALIZ to the model for that purpose. Many components of the index exist within IFs. On the political engagement dimension, IFs represents official developmental assistance or foreign aid. It makes no attempt to capture elements such as international organization (IO) memberships or treaty ratification, because these variables are highly subject to political decisions. On the technological connectivity dimension, the INFRANET index described in Chapter 3 of this report taps internet users; internet hosts and servers are closely related and, in long term forecasting, would add relatively little. Therefore this chapter will focus on the personal contact dimension (describing a new measure in IFs called PERSCON) and the economic integration dimension (describing a new measure called ECONINTEG). The GLOBALIZ index of IFs brings these four dimensions together in parallel to the GI.

The second issue is what to do with the index. Beyond its intrinsic interest, are there any forward linkages of importance? The last chapter discussed the most obvious one, namely the linkage of globalization to knowledge diffusion across the global system. The last section of this chapter will return to this issue.

5.1 The Personal Contact Dimension

Chapter 3 described the addition to IFs of a measure on telephone infrastructure (INFRATELE), a key foundational element for both domestic and international telephone contact. Although the GI uses actual minutes of international communication, that is a better short-term descriptive measure than a forecasting measure. IFs uses INFRATELE as the backbone of such traffic volume for its PERSCON measure.

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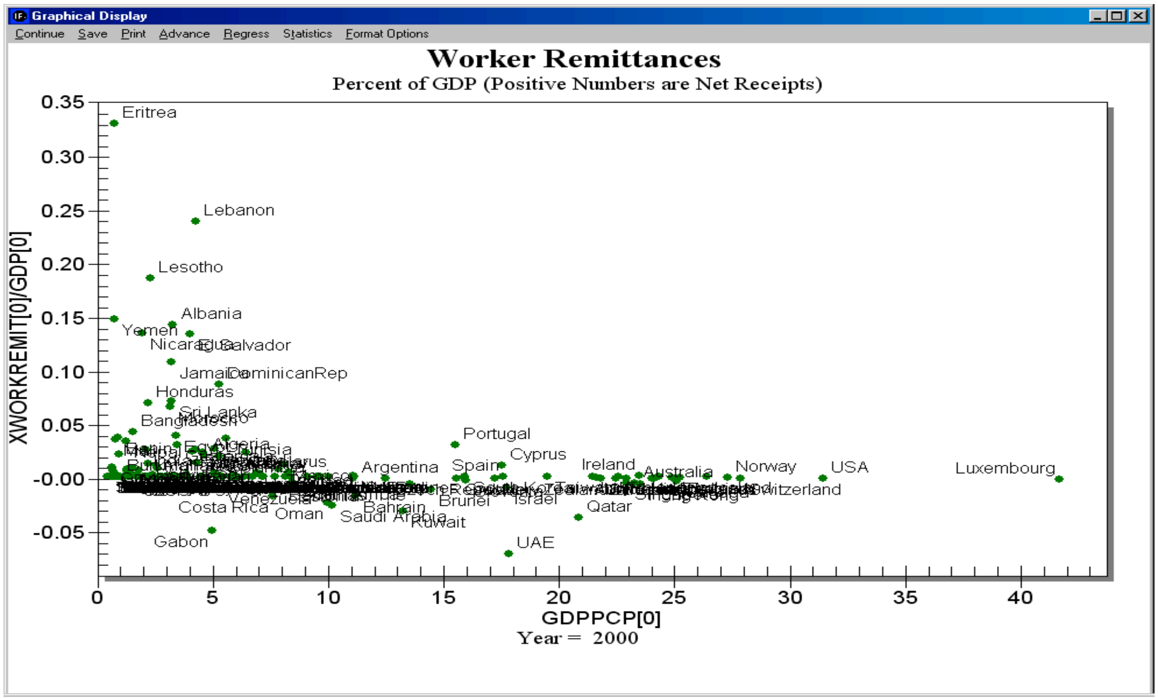
[25] The timing of annual release has become somewhat later over time. The two previous years were released in Jan/Feb 2003 and March/April 2004.

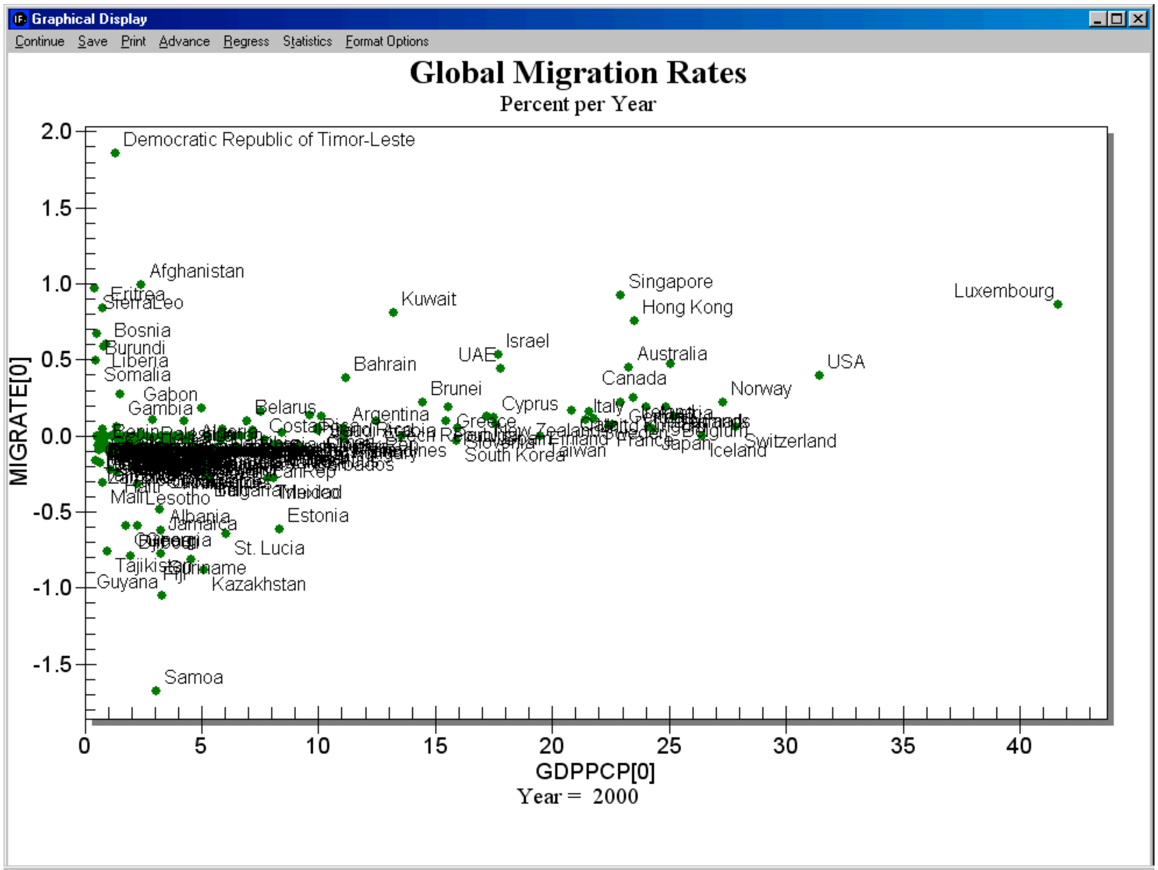
With respect to remittances and personal transfers, the GI measure builds on a data series called Compensation to Employees[26] Although this is useful, IFs looks to the broader World Bank data series on worker remittances. In the GI series, which is keyed heavily to corporate payments, the value for Mexico in 2000 was about $1 billion and that for the United States was about $3 billion. In the series on worker remittances series the values were closer to $4 and $18 billion. IFs uses the broader series because these numbers are integrated into the model's current account calculations and are important to it; they are also important to globalization and would perhaps be used in the GI measure if they were produced fast enough to meet the annual publication cycle. As a general rule, the IFs formulation tries to look to the underlying and large-scale elements of the globalization process, not just to the latest descriptive series.

The figure below shows worker remittances as a portion of GDP. What strikes one immediately is that many of the countries most "globalized" by such flows are not even among the 62 countries on which the GI focuses (those 62 include the largest and richest countries of the world) and are certainly not among the stars of the GI ranking. For instance, Eritrea, Lebanon, Lesotho, and Albania appear highly globalized in the figure. It could be argued that remittance receipts might indicate the extent of a diaspora or even vulnerability to globalization processes, but not so much globalization in the positive sense of using the process that A. T. Kearney/*Foreign Policy* normally taps. Yet flows of Mexican immigrants into and out of the U.S. and their remittances home have been a very powerful force for globalization of both countries. In adding this measure to PERSCON, the values were capped at two times the global average to limit the weighting of extreme cases.

[26] See http://www.atkearney.com/main.taf?p=5,4,1,117 for data behind the 2005 index.



It would also be possible to focus in constructing a measure of personal contact on migration rates as a portion of population. The figure below shows those rates at the turn of the century. In some cases, especially for inward flows, they clearly do represent an attractiveness to other countries that could be considered part of globalization. Yet for many of the developing countries, higher values clearly can indicate living in a bad neighborhood and receiving refugee flows (note Bosnia and Burundi) or can indicate a repatriation of earlier outward flows (e.g. Afghanistan, Eritrea, and Timor-Leste). Again the figure suggests the complexity of extending many measures beyond the richest countries. Although Singapore, Hong Kong and Israel always rank highly on the GI index, Afghanistan and Timor-Leste do not. The PERSCON measure of IFs does not include these migration rates – the purpose of this discussion has been to show the complications involved in choosing variables for it.

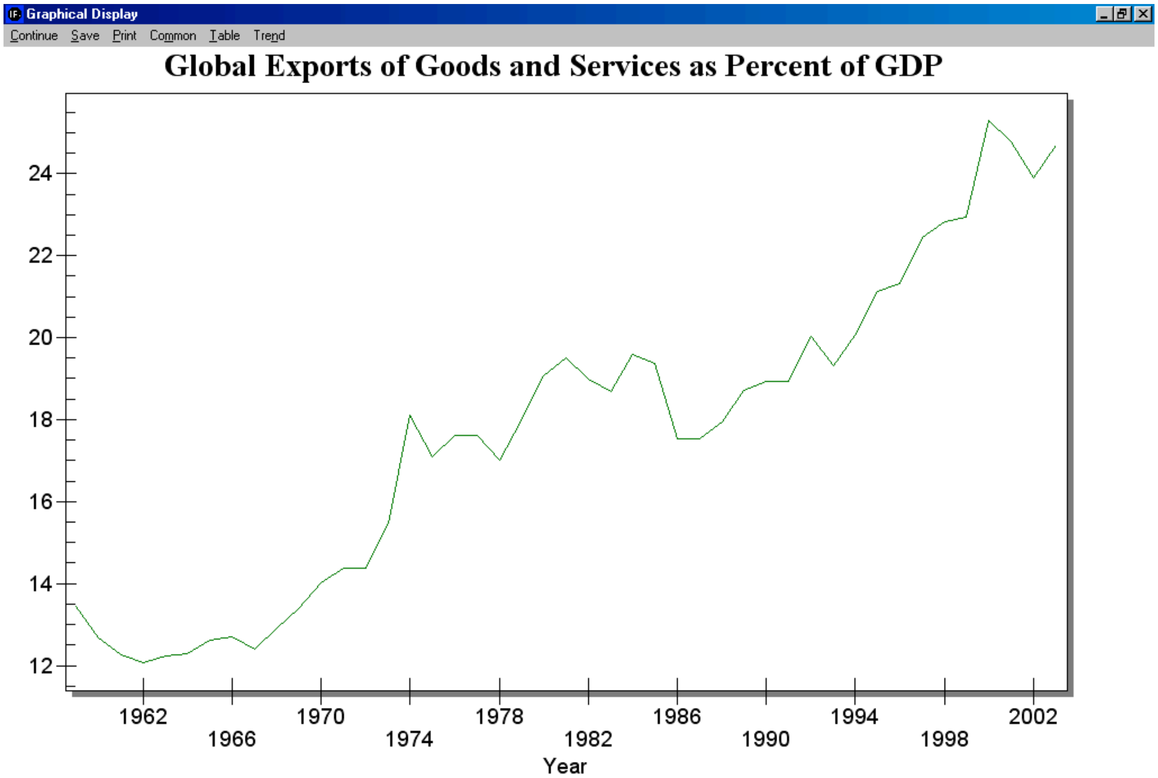


5.2 The Economic Integration Dimension

Turning to economic integration, the measure of ECONINTEG in IFs focuses, as does the GI measure, on trade and foreign direct investment. More specifically, the GI measure apparently uses exports as the indicator of trade and inflows as the measure of FDI (looking at the data shown on the A.T. Kearney web site). Obviously, it is important to look at these relative to GDP, not in absolute terms. There is significant reason to believe that the both trade and FDI are closely tied to knowledge diffusion and thus to productivity, an issue that to which a later section returns.

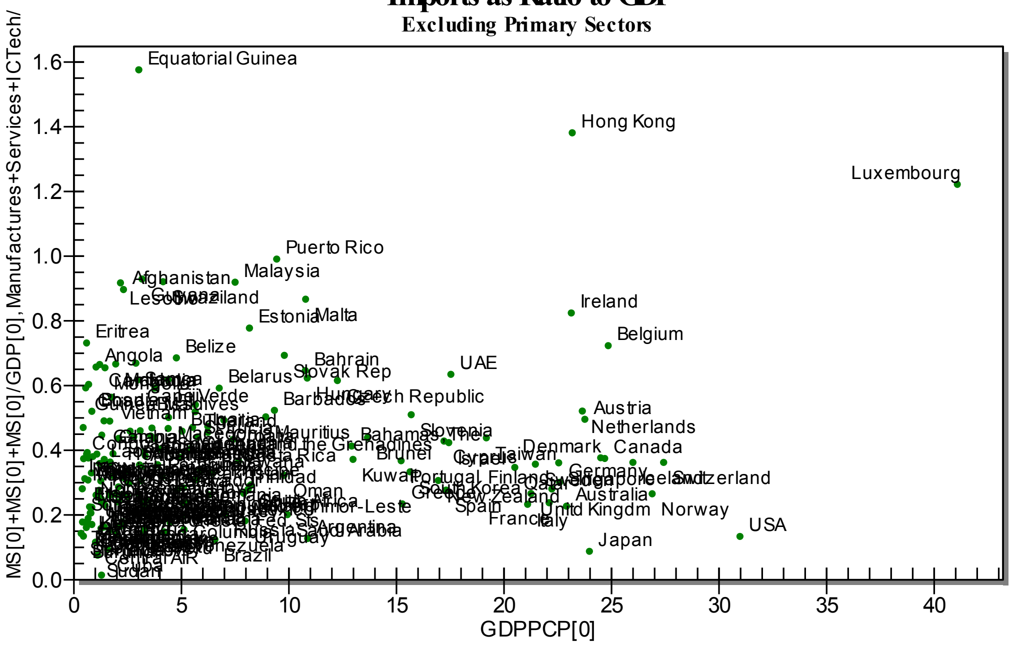
Exploring Knowledge Diffusion: Trade

The figure below shows how trade has grown as a portion of GDP since the 1960s. This growth and that of financial flows can easily be considered the backbone of the globalization process.



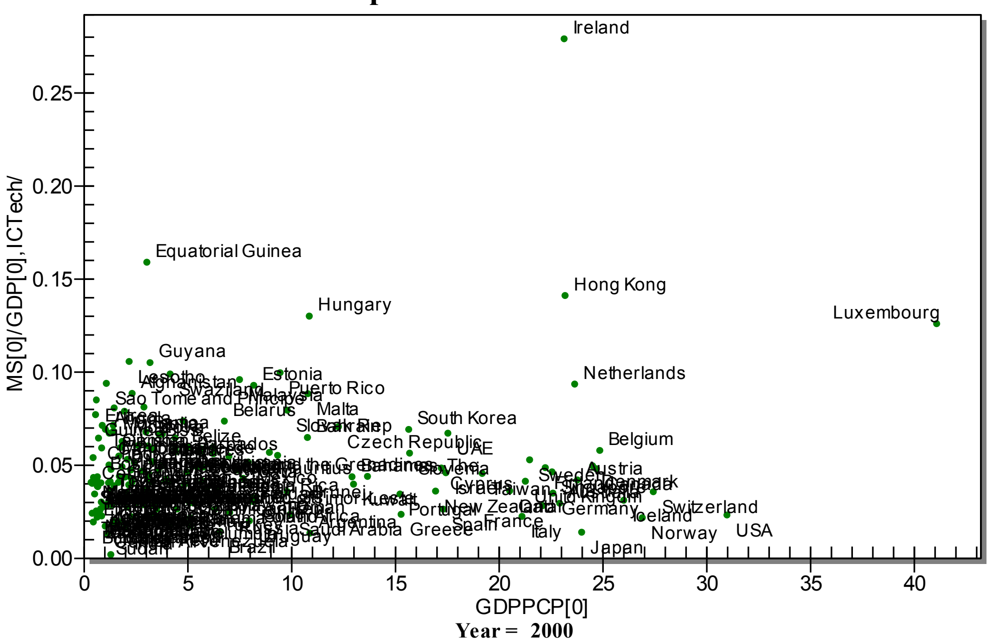
Is there any kind of obvious relationship between economic development level and trade? The figure below suggests that there is not. That figure excludes primary sectors to focus on those aspects of trade that might be most likely to carry knowledge with them (manufactures, services, and ICT trade). Some high rates of trade appear associated with entrepôt economies (e.g. Hong Kong and Luxembourg). Some appear associated with what might be called "dependent" economies, e.g. Eritrea, Belize, and Afghanistan. Others are "rentier" economies, e.g. UAE and Bahrain. Those economies who might be most benefiting from technology transfers embedded in trade, like Malaysia, Ireland and Belgium, are somewhat swamped by countries manifesting these other categories of trade connection. One could argue that this weighs against the inclusion of trade in the globalization measure. At the same time, however, it is clear that countries like Aghanistan, Belize, and the UAE are, in fact, heavily globalized in many respects–just not, perhaps, as the GI measure is normally interpreted.

Imports as Ratio to GDP
Excluding Primary Sectors



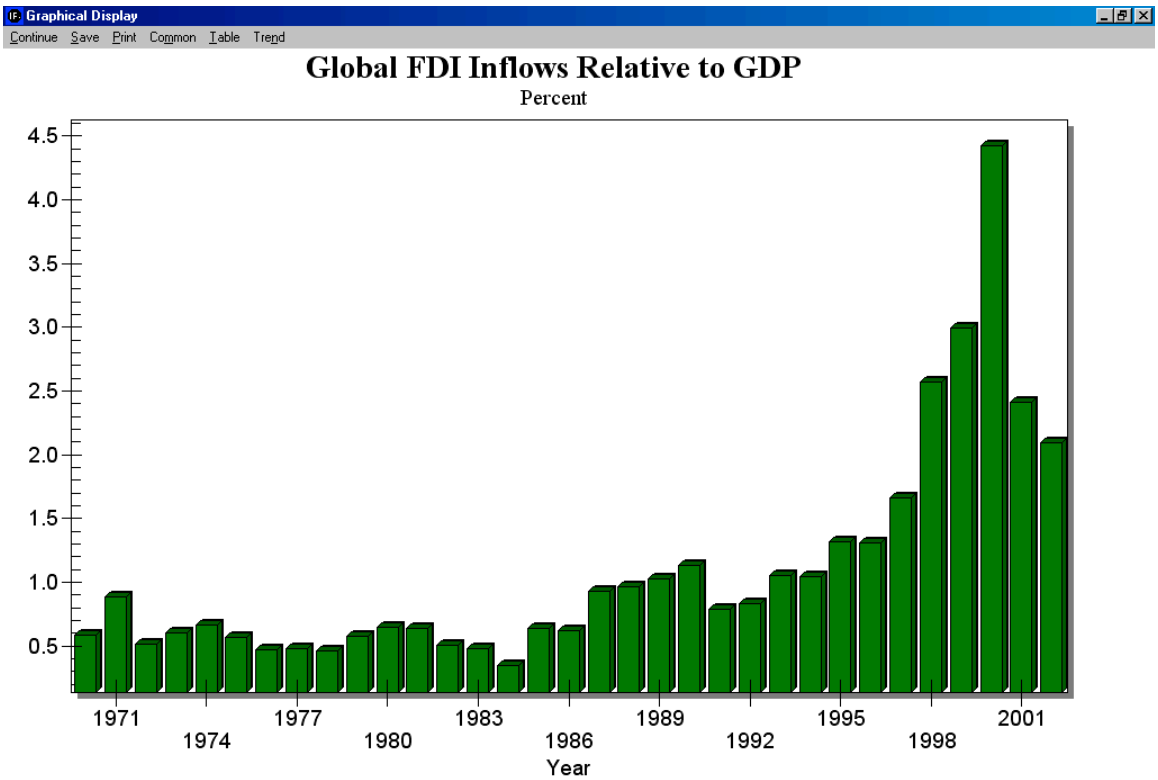
Manufactures very much dominate above the graph. Looking only at ICT imports (below) changes the perspective and highlights somewhat more the countries in the developed world that tend to rank highly on the GI. But the data quality is low in this sector and there is still a strong entrepôt -economy effect.

Imports of ICT as Ratio to GDP



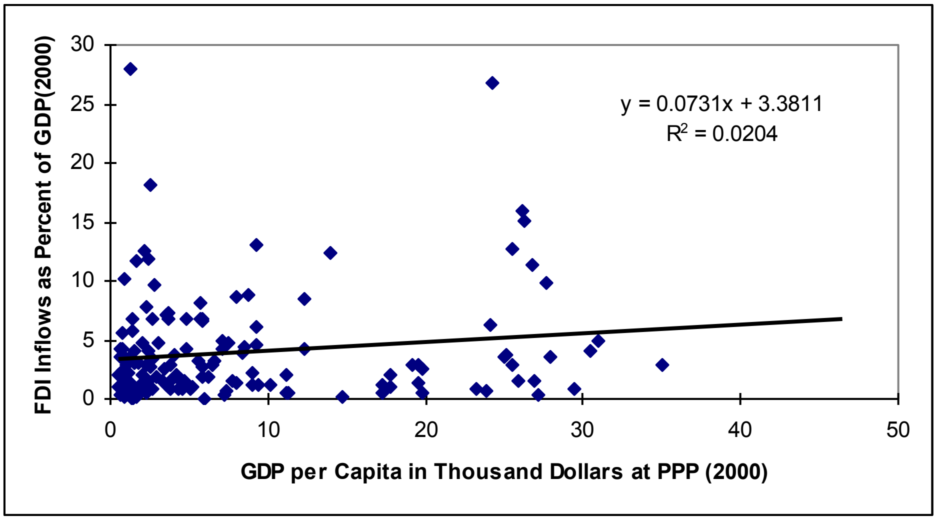
Exploring Knowledge Diffusion: FDI

Turning to FDI, the figure below, like that for trade, shows the rapid growth of this foundation of globalization since the 1960s and especially since the 1980s. It also shows a surge and collapse in the 1990s and thereafter, indicating a strong cyclical element around FDI flows to which we will return.

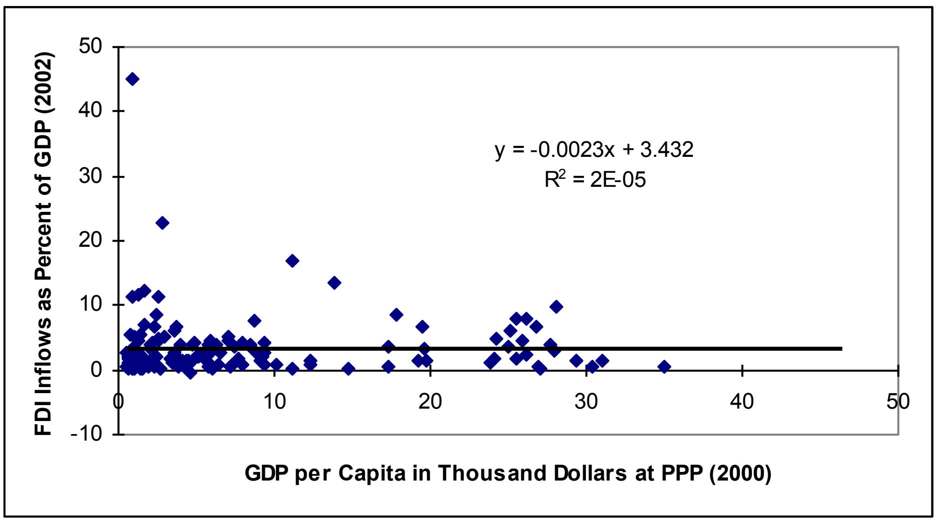


Among the important questions for the representation of FDI in IFs and within the economic integration measure are whether to use flows or stocks of FDI and how to drive the forecast of FDI. The rest of this section will focus on these issues.

There are two primary sources of data on FDI for the IFs project, the World Bank's World Development Indicators (WDI) and UNCTAD's World Investment Report (WIR). The two figures below show the flow data from each as a function of GDP per capita at PPP. The first figure below looks at the pattern of flows in 2000 and the second looks at 2002. Whereas there appeared in 2000 to be an upward sloping curve linking GDP per capita and FDI flows, that disappeared in 2002. The reason is most likely that the downturn in FDI flows after 2000 was primarily for mergers and acquisitions (not green field investments) and M&As tend to be located disproportionately in more developed countries.



In the above graph the outlier with very high FDI inflows but low GDP per capita is Angola (oil investment). At high GDP per capita the outlier is Sweden (probably a surge of M&A in that data year). Such outliers also suggest the high variability of flows year by year.

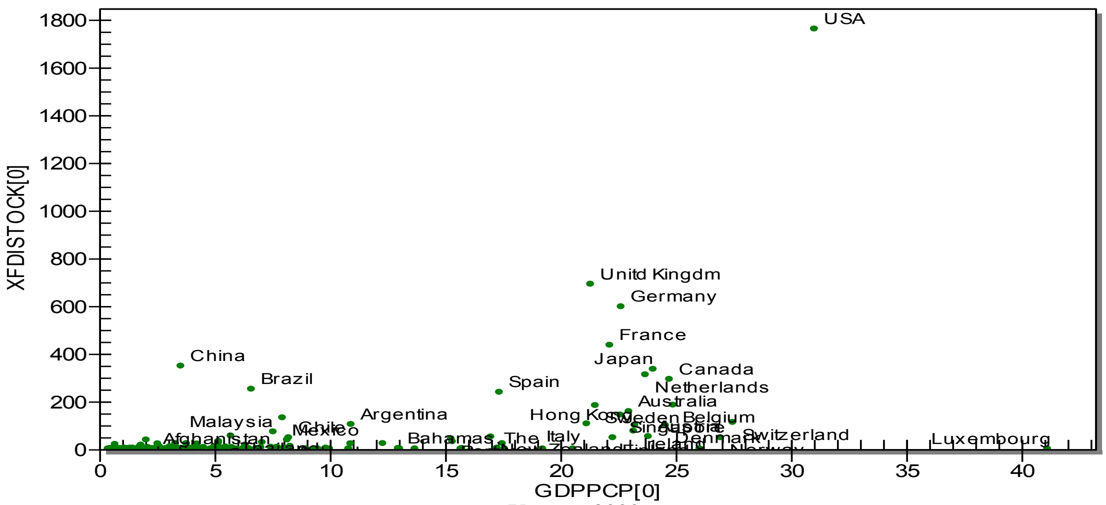


In the above graph, Luxembourg was removed because of its official value of 600% (representing transshipped FDI), as was Liberia with a value of negative 11% (representing the impact of a war). The outlier at the top of the graph is Chad, which gives us little confidence again in annual flow data as a measure of more fundamental globalization.

The two graphs above suggest that there is no obvious long-term relationship of FDI with development level, but perhaps an upward sloping one. More importantly, however, they suggest that annual flows are too volatile to be a good measure of globalization. It is surprising that the A.T. Kearney/*Foreign Policy* measure actually assigns them double weight, but that is a tribute to the obvious importance of FDI, not to the quality of FDI inflows as a specific measure of globalization.

The figures below turn to FDI stocks rather than flows. The data series was created by integrating the WDI flow series from 1970 – that is an imperfect measure of stocks, but the IFs project has not been able to find a better one across its large set of countries. The first figure below looks at absolute stocks. It is interesting because it shows the dominance of FDI by the US and other G-7 countries, along with a growing role of a few emerging countries, especially China and Brazil.

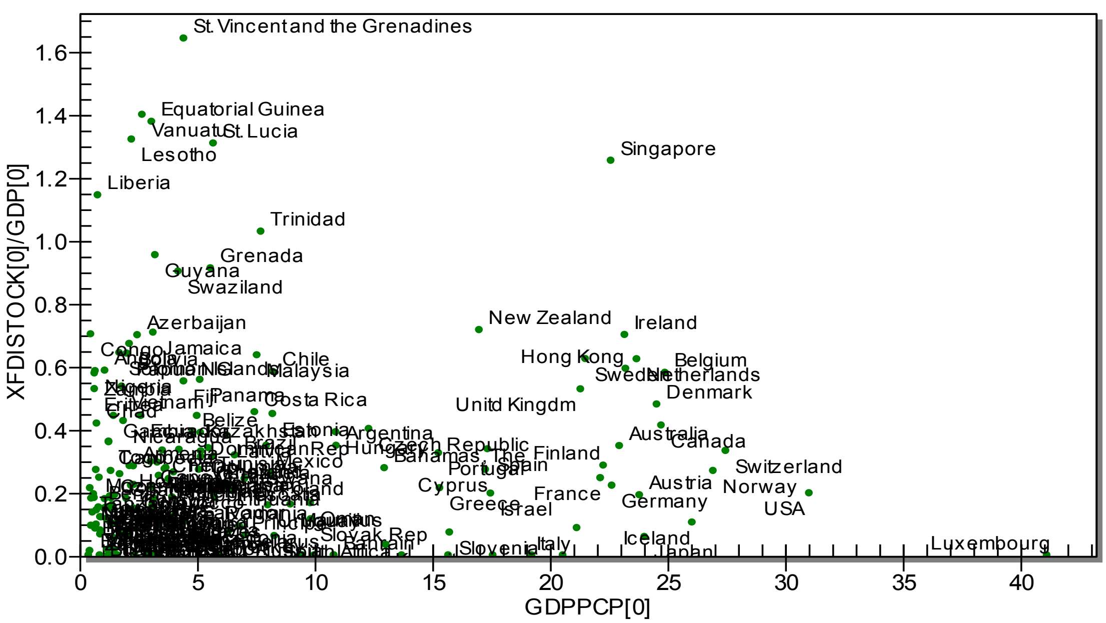
FDI Stocks from Abroad
Billion Dollars



Year = 2000

Yet it is obviously necessary to control for size of the economy to see the real impact of FDI on different countries and the figure below does that.

FDI Stocks from Abroad
Ratio to GDP



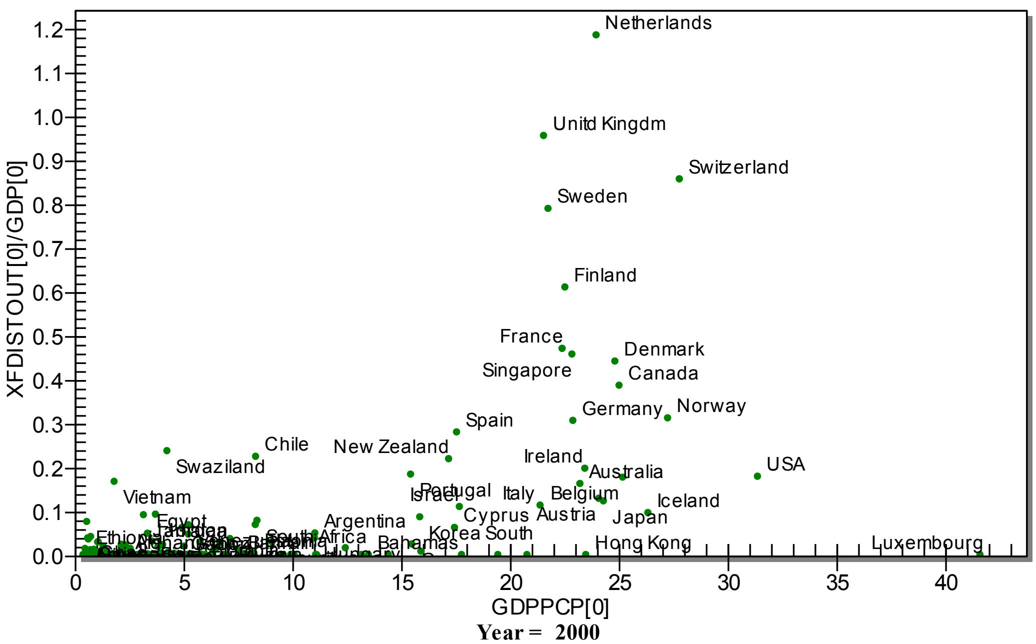
Year = 2000

In the figure above the average world ratio of FDI stocks to GDP is 0.224 (clearly this mixes a stock measure with a flow measure but is still of interest in terms of seeing the magnitude of FDI across countries). Around that average, specific values include China at 0.333, the US at 0.197, and India at 0.08. In looking at the above figure as a measure of globalization that might be bringing in access to technology, there is a clear problem associated with some LDCs that are receiving raw materials investment that is probably not bringing much technology for local use. For instance, consider the Congo at 0.702. Nonetheless, the above graph looks much more meaningful as a potential measure of the economic integration dimension of globalization.

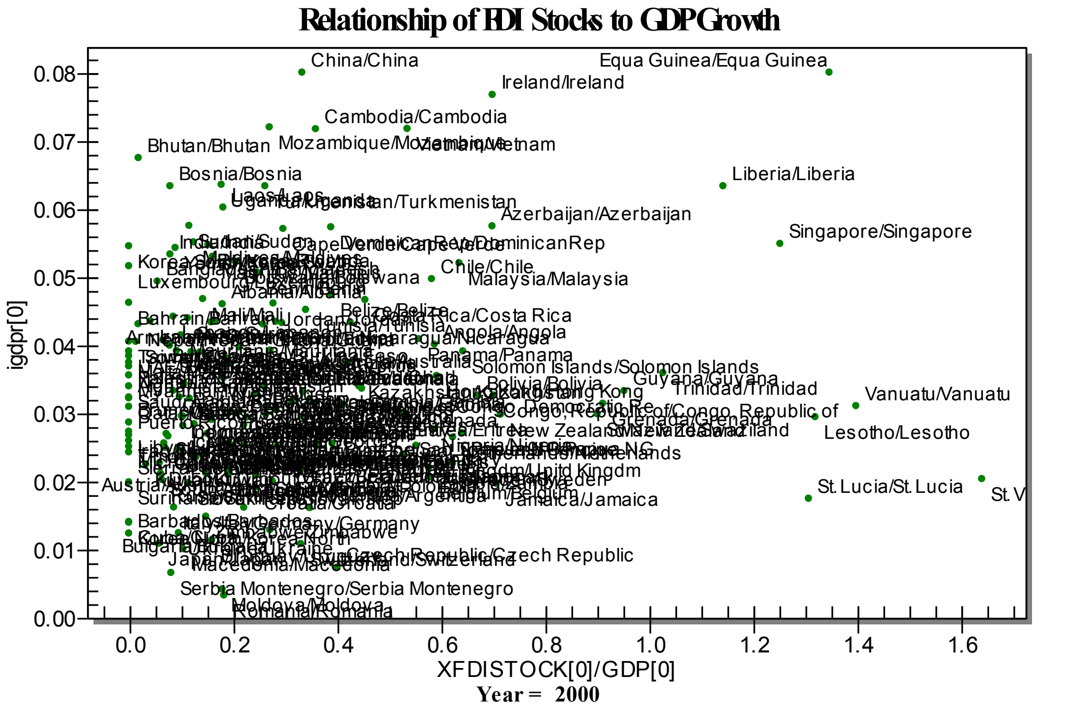
For completeness, the figure below looks at the holdings by countries of FDI stocks in other countries as a portion of GDP. This might be a very useful measure of national wealth as well as being a useful component measure of the economic integration dimension of globalization.

FDI Stocks in Other Countries

Ratio to GDP



Turning to forward linkages, the question is whether FDI inflows have a clear impact on productivity and economic growth. The figure below shows the relationship between accumulated stocks of FDI inflows in the last three decades as a percent of GDP and economic growth rates in the last decade of the 20th century. There is no obvious relationship. A graph of annual inflow rates and growth rate is equally uninformative.



5.3 Globalization in International Futures

The actual implementation of globalization (GLOBALIZ) in IFs follows from the above discussion. First, personal contact (PERSON) is computed as a simple average of two submeasures: a telephone infrastructure measure that is built as the ratio of telephone infrastructure in a country relative to what would be expected at that level of GDP and a worker remittance measure that compares the ratio of net remittances (sent or received) to GDP with the global average for such remittances.

$$PERSCON_r = \frac{TeleRatio_r + WorkRemit_r}{2}$$

where

$$TeleRatio_r = \frac{INFRATELE_r}{ANALFUNC(GDPPCP_r)}$$

and

$$WorkRemit_r = \frac{\dfrac{ABS(XWORKREMIT_r)}{GDP_r}}{\dfrac{\sum^{R} ABS(XWORKREMIT_r)}{\sum^{R} GDP_r}}$$

Second, economic integration (ECONINTEG) is computed as a weighted average (FDI given twice the weight of trade following the GI measure) of trade and FDI measures. The trade measure is the sum of exports and imports over GDP (the typical measure of trade openness) relative to the global level of trade openness. The FDI measure is the sum of stocks of investment into and out of a country over GDP relative to the global level of such FDI connectedness.

$$ECONINTEG_r = \frac{TradeComp_r + 2 * InvComp_r}{3}$$

where

$$TradeComp_r = \frac{\dfrac{XRPA_r + MRPA_r}{GDP_r}}{\dfrac{\sum^R (XRPA_r + MRPA_r)}{\sum^R GDP_r}}$$

and

$$InvComp_r = \frac{\dfrac{XFDISTOCK_r + XFDISTOUT_r}{GDP_r}}{\dfrac{\sum^R (XFDISTOCK_r + XFDISTOUT_r)}{\sum^R GDP_r}}$$

Third, a measure of political engagement (PolEngage) is calculated from the sum of foreign aid expenditures or receipts as a portion of GDP relative to the global average. Although the GI presumably focuses on expenditures, as with worker remittances and FDI it is reasonable to assume that receipts are a significant component of globalization.

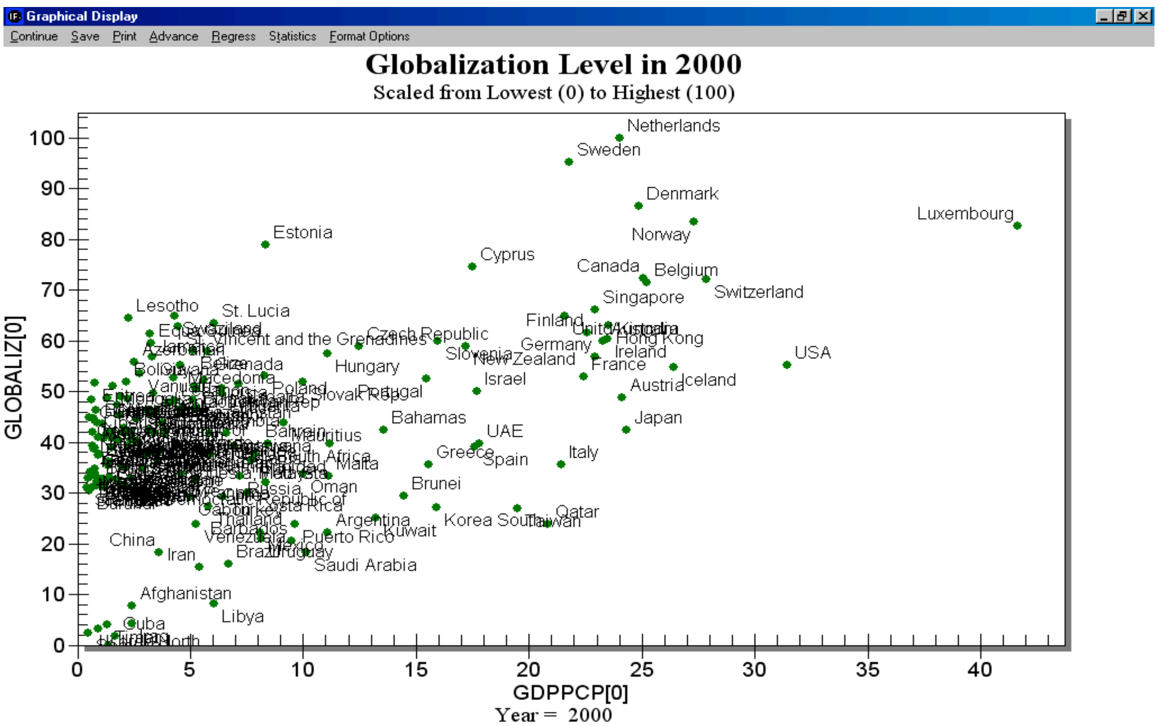
$$PolEngage_r = \frac{\dfrac{ABS(AID_r)}{GDP_r}}{\dfrac{\sum^R ABS(AID_r)}{\sum^R GDP_r}}$$

Fourth, the overall globalization measure is computed as a weighted average of political engagement (not shown in capital letters because it is not a displayable variable in IFs), the electronic network infrastructure measure (see Chapter 3 for the discussion of this), personal contact, and economic integration.

$$GLOBALIZ_r = \frac{PolEngage_r + INFRANET_r + PERSCON_r + ECONINTEG_r}{4}$$

Before the four components are averaged in the above calculation, they are scaled from 0-100, from the lowest to the highest values for countries in IFs. The GI uses rankings rather than scaled values. IFs uses the scaled values because it preserves underlying interval-level information. It does the same with the GLOBALIZ measure itself, which runs from lowest (0) to highest (100) values for all countries and country groupings in IFs.

Using this analog within IFs of the A.T. Kearney/*Foreign Policy* Globalization Index, the figure below shows the general pattern of globalization around the world as a function of GDP per capita.



There are some obvious similarities between the values in the above figure and the rankings of the GI. For instance, both place the Scandinavian countries and the Netherlands highly. But there are also some striking differences. For instance, the United States does not rank nearly as high in the figure above as it does in the annual GI tables. When one considers the component measures of the GLOBALIZ index that is not surprising. The PolEngage measure of IFs includes only official developmental assistance as a portion of GDP and the US scores low on this; in the GI political engagement carries other components, including treaty memberships (although were it scaled by size the US would not necessarily be high ranking on that either). The Economic Integration (ECONINTEG) dimension of both GLOBALIZ and GI scales countries by GDP; trade is a relatively small portion of the GDP of large countries like the United States and in both IFs and the GI measures it would probably make sense to control in some way for size. And although FDI stocks of the US abroad and of other countries in the US are huge, earlier figures have shown that when one controls for GDP, there are large numbers of countries at similar levels or higher. The same is true of personal connections when one controls for population size. It is quite possibly the use of ranking rather scaling, and the restriction of the GI to developed countries, that give the US much higher total scores on the GI measure than it achieves on the IFs GLOBALIZE measure. Because there is a strong argument for not throwing away the information that one has in interval measures in order to substitute ordinal ones, the use by IFs of scaling has good basis.

There are other surprises in the above figure. Although there is some tendency for richer countries to show up at higher levels of the GLOBALIZ index than do poorer countries, it is not a particularly strong relationship. In fact, a very large number of developing countries cluster just below the middle of the GLOBALIZ scale. Although richer countries may be absolutely more significant on the global stage, when GDP and population size are controlled, developing countries are clearly very much influenced by and involved in globalization processes. The 2005 release of the GI calculation reported only on 62 countries (A.T. Kearney 2005). Because those included cover 96 percent of the global GDP and 85 percent of the world's population, they are obviously the richest and largest of the 182 countries covered by IFs. The above figure shows that many of the other 130 countries are highly globalized, especially when the measures tap penetration by the outside world (aid and FDI receipt, remittances from workers abroad, etc) as well as penetration of the outside world. A striking case is China, which ranked 54 of 62 on the AT Kearney/*Foreign Policy* GI measure in 2005. As the above figure shows, when we control for GDP and population size, China appears below the vast majority of not just richer, but also of smaller, poorer countries on the GLOBALIZ measure.

5.4 The Use of Globalization in Forecasting Productivity

This chapter had two organizing issues. The first was to describe the IFs measure of globalization and its relationship to the GI. The second organizing issue of this chapter has been to determine the purposes to which IFs should put the globalization measure. In part, of course, it is interesting in and of itself; the GI measure attracts great attention every year when it is released. The IFs measure allows forecasting of something quite similar in spirit to it.

Beyond inherent interest, however, a key the purpose of this project (described by this paper and its companion piece) has been to enhance the ability of IFs to forecast productivity and growth. Those who have read the companion piece (Part 1 of this set) will know that IFs does not use the entire GLOBALIZ measure to drive knowledge diffusion/adaptation, but rather the economic integration (ECONINTEG) sub-dimension of it. There are two reasons for this. The first is that other dimensions of GLOBALIZ, such as network connectivity (INFRANET) and the telecommunications component of personal contacts already enter the IFs productivity formulation as part of the infrastructure representations in the physical capital dimension of the driver set. The second is that, in general, the literature on productivity focuses appropriately on analysis of narrower drivers of productivity, such as the trade and FDI elements of the ECONINTEG index, rather than on highly aggregate indices such as the GI or GLOBALIZ.   Thus IFs is on firmer ground looking to economic integration as a driver of productivity than to the aggregate globalization index.

The reader is, once again, invited to look to Part 1 of the paper set for further analysis of productivity.

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