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The role of creative innovation in economic growth: Some international comparisons☆

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ABSTRACT

For many countries, export-driven policies have thus far produced dramatic increases in real per capita income. At the same time, sustainable growth requires that technological innovation proceed at comparable rates if mutual gains from globalization are to be realized. In this paper, we derive a measure of innovation and test the extent to which institutional policy choices enhance or delay its diffusion. To do so we use a panel regression model, with data on a sample of 103 countries in different geographic regions for the 1980–2005 period. Our findings provide empirical evidence of the positive role of creative innovation in economic growth, and from which we derive several basic policy conclusions.

1. Introduction

For many countries in East Asia, export-driven policies have led to significant increases in per capita income over the past several years. This "Asian" model of growth is based in several key elements. It depends in the first instance on favorable rates of exchange, access to primary and intermediate inputs, and finally on relative access to the major industrialized economies where these exports have gone. Over the longer term, however, as differences in per capita incomes diminish, sustainable economic growth will depend not just on the above factors, but also on the ability to innovate. In this paper, we develop a model of creative innovation to explain relative differences in growth, test for its determinants, and then calibrate how changes in institutional variables produce significant variations in per capita income. To do so, we rely on a global sample of 103 countries that covers the 1980–2005 period. We develop a nested panel model that is applied to the global sample as well as to six geographic sub-samples. Our findings point to several policy conclusions.

The focus of this paper is on the role of institutions in economic growth. What motivates this perspective is the growing recognition that standard models of economic growth capture only a portion of the underlying dynamics that drive saving and investment in general, and risk management and creative innovation in particular. To do so, we proceed in several steps. First we examine the relationship between creative innovation and economic growth in which we underline the importance of creative innovation and how institutions shape the underlying level of risk that accompanies innovations.

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We follow the conceptual issues in this section with a review of relevant literature on growth, technological innovation, risk, and institutional governance. This is followed by a general formulation of growth and innovation as used in standard treatments, from which we then define our model of innovation based on a hierarchical set of institutional determinants. We then apply our model first to a global sample of countries, followed by regional estimates to gain some measure of differences in innovation and institutional governance by region. From the global and regional estimates, we then examine the economic value of institutional change in expanding the rate of creative innovation, from which we drive some basic conclusions that may be helpful in formulating policy guidance.

2. The role of creative innovation in economic growth

Economic growth depends on a variety of factors. Among them are a country's rate of saving, increases in the stock of productive inputs, and technical change. Innovation bears most directly on technical change, and thus is a major determinant of economic growth. In a globalizing world in which rising population places growing pressure on the stock of natural resources, sustainable growth depends more than ever on how innovation can be nurtured. Innovation is what may be considered as knowledge capital, and it stands in distinction to traditional measures of capital, notably physical stocks. While there is some concern about this distinction, because innovation is treated separately from other forms of capital, we use it in this sense in our analysis put forth here.

Given the importance of innovation to economic growth, it is useful to define the context through which it occurs and how economic studies explain its role. In the first instance, we can think of innovation as applied knowledge. Invention may be a necessary pre-requisite to innovation, but not all inventions become innovations. Nor, for that matter, do all innovations succeed. Taking invention to the market requires agents who are capable and prepared to take on the associated risks over the time frame through which an innovation moves forward. Such agents typically do not operate in isolation—they reflect institutions that provide much of the necessary financial commitment and to distribute the associated risks in ways that make continued innovation possible. Thus, if we seek to understand the role of creative innovation in economic growth, it is important to include consideration of institutions and risk.

What do we mean by institutions? Institutions refer to the level and depth of financial intermediaries as well as to firms that implement an innovation. All countries have some intermediaries and firms, but the quality of institutions can vary significantly, depending on how countries craft policies to promote economic efficiency. In turn, the quality of governance has a direct bearing on the level of risk that innovaters confront. It thus is important to examine factors that determine the quality of governance among institutions, as well as how governance bears on the level of risk.

What about risk? Economists tend to think of risks in essentially financial terms, and look at how markets derive relative prices that reflect the degree of financial risk. However, financial measures represent only one dimension of risk. Other aspects include political, economic, and environmental risk. Together they constitute the overall context through which institutions must make decisions on launching new innovations.

In some countries, there are proxy measures for various categories of risk. Where markets are more complete, these risks can be incorporated to some extent into the pricing of resources. For example, political risk might be reflected in the risk premium on sovereign debt instruments. In turn, economic risk might be translated in terms of the premium returns that investors require in markets where fluctuations are significant. As to environmental risk, whether negative externalities have been addressed in public policy will affect the pricing of resources as well.

The problem with many of these dimensions of risk is that in many countries adequate measures do not exist. Some countries do not have well-developed sovereign debt markets and must rely on proxies such as IMF conditionality, or some alternative measure of financing sustainability. In turn, if equity markets are not well developed or absent, such incomplete markets make it difficult to measure risk. We take up this question in this paper and suggest an approach to incorporating a proxy measure of risk that can be linked to innovation and economic growth.

3. Studies on growth and innovation

Studies on economic growth (Barro & Sala-I-Martin, 1995; Chenery & Syrquin, 1975; Denison, 1962; Jorgenson, Gollop, & Fraumeni, 1987; Porter, 1990) affirm the central roles of saving and the stock of inputs, but point to several underlying factors that may be crucial. Among them are: technology, aid and financial innovation, foreign direct investment, research and development, and the governance of economic institutions.

Technological change offsets the classical economic problem of diminishing returns. We know how technology affects economic growth (David, 1975; Grossman & Helpman, 1991; Jorgenson, 1995; Rosenberg, 1976; Schmookler, 1966; von Hippel, 1988). As Arrow (1962) pointed out, innovation derives from experimentation, and it is a key element in achieving cost efficiencies in production (Leibenstein, 1966). What is less obvious is how to achieve technical change (Burns & Stalker, 1966). Does it, for example, depend essentially on markets, as suggested by Rostow (1960), or by Schumpeter's entrepreneur (1982, 1934, 1913), or does it require some measure of public intervention, as suggested by Aghion and Howitt (1996), Aghion and Tirole (1994), and by Arrow and Kurz (1970).

To the extent that markets alone do not provide a satisfactory rate of technical change can only be determined with reference to some underlying criteria. A benchmark could be sustainable growth, growth of one economy in comparison to some previous historical experience, or comparison to another economy with a higher rate of growth (Berthélemy & Varoudakis, 1996; Bordo, Taylor, & Williamson, 2003; Olson, 1982).

If innovation may depend in part on public sector intervention, it also may depend on financial innovation, international aid, and governance institutions. Mauro, Sussman, and Yafeh (2006) examine the role of financial innovation in historical perspective, and note the positive relationship between financial innovation and growth. This supports the findings of Levine (1997) and Berthélemy and Varoudakis (1996). However, financial innovation alone may not explain major differences in per capita income, which suggests that other factors such as foreign direct investment (Aghion & Howitt, 1996; DeMello, 1999; Granstrand, 1999) also are at work.

One factor is the role of international aid. Although Burnside and Dollar (2004) found a positive relationship between aid and growth, this runs contrary to most findings, as summarized in Rajan and Subramanian (2006). The Burnside and Dollar findings point, however, to the quality of institutional governance, which has been examined in a number of related studies, notably Kaufmann, Kraay, and Mastruzzi (2003), Perotti (1996), and Saint-Paul and Verdier (1993). Because the quality of governance matters, institutions matter, and this forms the focus of the analysis we put forth in this paper. To do so, we first derive the analytic framework of basic growth models, from which we then apply our institutional variables as they apply to creative innovation.

4. Modeling economic growth and innovation

Empirical growth models build on the traditional neoclassical approach set forth in Solow (1956, 1957). In this approach, aggregate production function model in which factor accumulation establishes conditions for steady-state growth. An important conclusion from this work is that in order to sustain growth, there must be a continuous process of technological change to offset diminishing marginal returns to capital stock accumulation.

In general, we can portray economic growth through a standard neoclassical function:

$$Y = f(L, K; T), \tag{1}$$

where Y is the output, which empirically can be measured in terms of PPP real per capita GDP, L the labor input, K the capital input and T is the level of technology.

In empirical studies, this relationship often has taken the form of

$$Y = A(K, L), \tag{2}$$

where A is the level of technology.

One variant of Eq. (2) is the Harrod–Domar model, in which labor inputs expand in proportion to increases in capital stocks. Under this balanced factor proportions approach, the warranted rate of growth reduces to the ratio of the national savings ratio to the incremental capital–output ratio. More formally, the warranted rate of growth can be expressed as

$$r = \frac{s}{k}, \tag{3}$$

where r is the warranted, or steady-state rate of growth in output, as indicated in (1), s the rate of savings, which in empirical estimations can be determined as a percentage of GDP, and k is the incremental capital–output ratio, or investment in time t divided by the change in GDP from t to $t + 1$.

In a closed economy, growth can thus be portrayed as a function of the rate of savings, which encapsulates the allocation of capital and labor inputs. When we include the role of trade, the economy's rate of growth thus can be portrayed as

$$Y = f(S, \mathrm{Tr}), \tag{4}$$

where S is the national saving rate, expressed as a percentage of GDP and TR is the degree of trade dependence, expressed as a weighted share of imports and exports as a percentage of GDP.

Empirical problems abound in these formulations, notably in measuring the level of technology and determining its impact on per capita income. In Solow's early models (1956, 1957), technology was treated in the residual of regression equations. This approach led to international empirical studies by Denison (1962) as well as work that inspired many of the original lending policies of the World Bank in developing countries (Chenery & Syrquin, 1975). In most of these studies, technology once again was considered to be exogenous to the growth process, taking second place to factor accumulation and required levels of international aid to achieve target levels of growth in real per capita income.

An alternative approach to growth accounting has come to be known as endogenous growth theory (Aghion & Howitt, 1992). Inspired originally by work undertaken by Romer (1990), this approach builds on insights put forth in Schumpeter's *Theory of Economic Development* (1934, 1911), and in his *Capitalism, Socialism, and Democracy* (1942). For Schumpeter, growth depends first and foremost on the entrepreneur, as elaborated in his *Theory*. In his latter work, innovation serves to explain persistent differences in rates of return across industries, and may, as in Adam Smith's steady state, cease to occur once levels of wealth have reached a level that no longer stimulates its production. That very success, Schumpeter suggested, is how capitalism would then be transformed into a socialist economy, in contrast to Marx's prediction of imminent collapse from a rising rate of exploitation. This latter, and now quaint, interpretation seems distant at best, given the collapse of the

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Soviet Union and the expansion of market-driven globalization. As emphasized by Romer, nurturing innovation works best not by subsidizing physical capital accumulation, but by increasing the incentives for research.

Recent research that draws on Schumpeterian innovation theory utilizes several interrelated measures of growth. Key among them are research and development expenditures, patent and trademark applications, scientific citations, and net flows of copyright and trademark revenues. In an ideal setting, one could frame the optimal level of research and development as that which generates a maximum level of innovation. Thus

$$U = \int_0^\infty e^{-r\tau} y(\tau)\,dt = \int_0^\infty e^{-r\tau} \left(\sum_{t=0}^{\infty} \Pi(t,\tau) A_t x^\alpha \right) d\tau, \tag{5}$$

where U is the level of social welfare, e.g. a welfare adjusted level of per capita income, t the number of innovations, τ the time, and A is the level of technology.

If innovations arrive according to some Poisson style process, we can then portray their rate as

$$\prod(t,\tau) = \frac{(\lambda n \tau)^t}{t!} e^{-\lambda n \tau}. \tag{6}$$

Expected welfare can then be defined as

$$U(n) = \frac{A_0 (L-n)^a}{r - \lambda n(\gamma - 1)}. \tag{7}$$

The socially optimal level of research and development expenditures would be where the first derivative of 7 is set to zero, in which case we then derive the reduced expression:

$$1 = \frac{\lambda(\gamma-1)(1/\alpha)(L-n^*)}{r - \lambda n^*(\gamma-1)}, \tag{8}$$

where L is the quantity of labor input and γ is the factor increase in output from each innovation.

Under these conditions, the level of research would lead to an average rate of growth in welfare adjusted per capita income of

$$g^* = \lambda n^* \ln \gamma. \tag{9}$$

Although this framework provides a useful starting point for empirical estimates, there are several limitations that should be noted. One is that an aggregate formulation does not capture the transitional phases of growth in many developing countries, in particular, the shift of resources from agriculture into industry and services. Another is that knowledge itself cannot be readily captured in an empirical form. A third is that the implementation of successful innovation requires that one take into consideration the role of institutions and transactions costs. Thus, while the theoretical framework specified in Eqs. (1)–(9), we find it useful and necessary to reformulate the framework when we take up the role of institutions. We take up these issues in the following section.

5. A model of creative innovation

If economic growth depends partly on factor accumulation and for an open economy, partly on international trade, we can enrich our growth model through incorporation of two additional factors, namely, risk and innovation. In previous work, we have examined the role of aggregate country risk on economic growth and find that it presents a transactions cost that can lower per capita income (LeBel, 2005). Management of risk requires that one take stock of institutional variables, namely, property rights and judicial independence. Increased levels of property rights and judicial independence tend to lower aggregate country risk, and in so doing, raise real per capita incomes. By including aggregate country risk and its determinants in our growth accounting, we thus respond to one of the critiques of endogenous growth theory.

We now turn to creative innovation. Although research and development expenditures provide one measure of innovation, data are infrequent and sparse in many instances, thus making it difficult to derive meaningful international comparisons of its impact on economic growth. However, there are other indicators that may serve as proxies for creative innovation. From them, we derive an index of creative innovation, which we define below.

We propose an index of creative innovation that contains two key elements: per capita scientific citations and the ratio of per capita royalty fees to per capita royalty fee payments. Countries that engage in creative innovation do so in part through the frequency of scientific citations. In turn, when we consider both scientific and artistic innovation, these changes will have an effect on a country's royalty revenues and royalty payments. For countries with low levels of scientific and artistic innovation, royalty payments will exceed royalty revenues. As creative innovation expands the ratio of royalty revenues to royalty fees will increase. We thus use the per capita net royalty ratio as the second component of our creativity innovation index.

Formally, we now define an index of creative innovation as

$$\text{INNOVINDEX} = \frac{\text{per capita scientific citations} + \text{per capita net royalty ratio}}{2}. \tag{10}$$

It is reasonable to ask why the choice of the innovation index given in (10). In some studies, spending on research and development, along with the number of patents, are used to measure innovation. Indeed, R&D and patents are linked and they do reflect innovation activity. However, in many cases, expenditures on R&D are poorly tracked, particularly in developing economies, and the same applies to patents. Moreover, an index based on patent applications or patents granted, while appealing, presents several problems in empirical modeling.

First is that even where adequate information on patent applications or patent grants is available, the economic impact may well be lagged and quite heterogeneous in any specific context. For example, analog television technology was demonstrated at the U.S. 1939 World's Fair but did not have much commercial impact until the late 1940s after the Second World War. Similarly, fax machine technology existed as far back as the late 1930s, but did not acquire more ubiquitous use until miniaturization changes were implemented in the 1970s and 1980s. As a third example, Philips electronics marketed laser disk technology as early as the 1980s, well before the VHS and Betamax contest, and only when compression technology enabled DVD's to carry full-length films did videotapes begin their long exit from the market.

In some cases, firms may use patents as a barrier to entry by prospective competitors, thus vitiating the expected positive relationship between patents, innovation, and economic growth. Finally, patent documentation is weak in many countries that we wish to examine, reflecting the weak status of property rights in some countries. If we restricted our sample only to those countries that have strong patent laws, the range of the institutional factors we wish to examine would probably not be possible.

Given the above observations and because we wish to test for innovation over a broad range of countries, we use scientific citations as a proxy for research and development, while net royalties provide a measure of the impact of patents. In so doing, we recognize that if property rights are weakly enforced, even royalty payments may not capture the full range of innovation. While we do not claim that this index can capture all of the relevant dimensions of creative innovation, it does enable us to examine how innovation affects the level of per capita income, and in turn, how institutional factors influence its level.

We now turn to the measurement of risk. As noted above, risk is prevalent in many dimensions and market prices in the presence of incomplete contracts make it difficult to rely on relative prices to reflect varying risk premia. For this reason, we decided to use a composite index of aggregate country risk. Our index is based on the ICRG measure reported by the World Bank for individual countries. It ranges from 0 for the highest level of risk to 100 for the lowest level. As this is counter-intuitive to the expected inverse relationship between risk and income, we have derived the complement of the index, which we have labeled RCCRISK in our model.

As will be applied in our model, we also develop determinants of risk, in particular, the level of property rights and the degree of judicial independence, which then can be used to tie risk to the level of innovation. The intuition behind this approach is straightforward: measures to reduce the level of risk produce positive effects on the level of innovation, which in turn, have a positive effect on the level of per capita income. Because markets are incomplete in many of the countries we examine, we look to our aggregate country risk composite as a way of demonstrating the linkages between institutions, innovation, and economic growth.

We now specify the structure of our model of growth through creative innovation. Instead of an aggregate production function approach as indicated in Eqs. (1) and (2), we use the framework of Eq. (4), namely, the rate of saving and the level of international trade dependence. In turn, we add the role of aggregate country risk, which provides a proxy for the level of efficiency in institutional governance. We then add to this our index of creative innovation, which we treat as exogenous to per capita income in this analysis. Our first order specification of economic growth thus is

$$\text{PPPRPCGDP} = f(\text{GNSGDP}, \text{TRDEP}, \text{RCCRISK}, \text{INNOVATION}), \tag{11}$$

where PPPRPCGDP is the purchasing power parity real per capita GDP, GNSGDP the rate of national saving as a percentage of GDP, TRDEP the level of trade dependence as a percentage of GDP, RCCRISK an index of aggregate country risk and INNOVINDEX is the index of creative innovation as defined in (10).

We first derive panel regression estimates of Eq. (11), allowing for sequential incorporation of risk and innovation. Results of preliminary estimates for our global sample of 103 countries over the 1980–2005 time period are show in Table 1. We find that while savings and trade dependency are important determinants of real per capita income, aggregate country risk has a larger negative effect than either one alone. Measures to reduce aggregate country risk through institutional reform carry important effects for economic growth. When we factor in foreign direct investment, it has a positive, but statistically insignificant effect on growth. This suggests that the choice of institutional regime may have much to do with the positive effects of foreign direct investment.

Turning to innovation, we look first at the individual effect of scientific citations on growth and find that it is statistically and economically significant. In fact, scientific citations carry a larger economic effect than either savings or trade dependency alone, and they offset the negative effect of aggregate country risk. When we then examine the effect of our innovation index on economic growth, it outweighs all other variables by a rough factor of 3–1. In short, innovation is a major determinant of per capita income, and measures to expand its level carry important consequences for globalization policies.

Table 1
Global sample basic growth estimates

	A. Fixed	B. None	C. Fixed	D. None	E. Fixed	F. None	G. Fixed	H. None
C	6061.29	318.27	3536.08	83.87	3536.08	83.87	4461.10	7616.09
GNSGDP (*t*)	8.61	235.88	11.15	110.57	11.15	110.57	3.45	56.98
	(4.207)	(33.915)	(8.035)	(30.717)	(8.035)	(30.717)	(2.073)	(16.182)
TRDEP (*t*)	28.21	33.76	16.71	28.00	16.71	28.00	14.44	14.15
	(26.551)	(16.557)	(21.613)	(19.803)	(21.613)	(19.803)	(17.344)	(9.973)
RCCRISK (*t*)							−17.02	−139.44
							(14.706)	(38.512)
PCSCITES (*t*)			27.22	29.52				
			(54.943)	(99.535)				
INNOVINDEX (*t*)					54.44	59.05	54.17	49.23
					(54.943)	(99.535)	(55.021)	(81.988)
Adjusted *R*-squared	0.9598	0.6655	0.9873	0.8535	0.9873	0.8535	0.9781	0.8993
F-statistic	615.45	2664.04	1978.23	5198.41	1978.23	5198.41	1129.94	5976.71
Number of cross-sections	103	103	103	103	103	103	103	103
Number of observations	2678	2678	2678	2678	2678	2678	2678	2678
Method	PLS	PLS	PLS	PLS	PLS	PLS	PLS	PLS
Effects								
Cross-section	Fixed	None	Fixed	None	Fixed	None	Fixed	None
Period	None	None	None	None	None	None	None	None
GLS weights	CS	CS	CS	CS	CS	CSW	CS	CS
Granger null values								
GNSGDP (pr.)	4.76	4.60	4.76	4.60	4.76	4.60	4.76	4.60
	(0.009)	(0.009)	(0.009)	(0.009)	(0.009)	(0.009)	(0.009)	(0.009)
TRDEP (pr.)	40.23	40.23	40.23	40.23	40.23	40.23	40.23	40.23
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
RCCRISK (pr.)							5.30	5.30
							(0.005)	(0.005)
PCSCITES (pr.)			16.30	16.30				
			(0.000)	(0.000)				
INNOVINDEX (pr.)					16.30	16.30	16.30	16.30
					(0.000)	(0.000)	(0.000)	(0.000)

Dependent variable: PPPRPCGDP.

In Table 1, we report panel estimates using fixed and pooled samples using cross-section weights. Fixed effects estimates allow us to take into consideration some of the inter-country characteristics, notably the extent to which the regression coefficients do not vary across individual countries or across time. However, for our purposes, ordinary panel regression estimates are consistent not just in our global sample, but also when applied to the sub-sample regions we examine.

Of the estimates in Table 1, version H reflects the structure of the basic model we develop below. Version H also suggests that while a country's rate of saving and its trade dependency are significant determinants to the level of income, risk and innovation may be more important. We thus need to examine the determinants of both risk and innovation, as these determinants may clarify the role of institutions and governance in achieving a given level of income.

5.1. Determinants of innovation

Although raw values for our index of risk and our index of innovation are significant determinants of the level of per capita income, because we are interested in their determinants, we now proceed to elaborate a nested hierarchy, as is shown in Fig. 1. Instead of raw values for our index of risk and for our index of innovation in our model of growth, we apply estimated values of these indices using various institutional determinants.

Fig. 1 indicates the directional causality relationships used in our model of creative innovation. To derive the model in Fig. 1, we apply Granger causality tests to a set of institutional variables. In each case, we use Granger causality *F*-null tests to

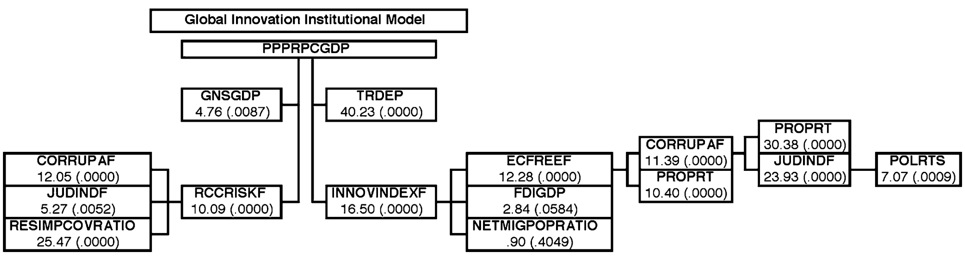

Fig. 1. Expanded model of institutional innovation.

Table 2
Global sample expanded model regression estimates

	A. Fixed	B. None	C. Fixed	D. None	E. Fixed	F. None
C	6991.92	27395.21	−516.68	−98.46	739.39	15021.03
GNSGDP (*t*)	7.44	6.03	7.93	100.57	6.88	16.79
	(3.633)	(1.297)	(3.836)	(28.043)	(3.291)	(5.821)
TRDEP (*t*)	27.37	10.70	26.59	32.38	26.22	4.04
	(25.644)	(8.007)	(24.644)	(22.825)	(24.238)	(3.513)
RCCRISKF (*t*)	−23.54	−524.07			−15.39	−282.78
	(4.977)	(94.525)			(3.090)	(54.758)
INNOVINDEXF (*t*)			112.04	60.39	101.10	37.70
			(7.691)	(83.282)	(6.757)	(50.008)
Adjusted *R*-squared	0.9700	0.8054	0.9700	0.8168	0.9703	0.8709
F-statistic	826.91	3695.15	826.47	3979.46	827.29	4517.32
Number of cross-sections	103	103	103	103	103	103
Number of observations	2678	2678	2678	2678	2678	2678
Method	PLS	PLS	PLS	PLS	PLS	PLS
Effects						
Cross-section	Fixed	None	Fixed	None	Fixed	None
Period	None	None	None	None	None	None
GLS weights	CS	CS	CS	CS	CS	CS
Granger null values						
GNSGDP (pr.)	4.76	4.60	4.76	4.60	4.76	4.60
	(0.009)	(0.009)	(0.009)	(0.009)	(0.009)	(0.009)
TRDEP (pr.)	40.23	40.23	40.23	40.23	40.23	40.23
	(0.000)	(0.000)	(0000)	(0.000)	(0.000)	(0.000)
RCCRISKF (pr.)	10.10	10.10	10.10	10.10	5.30	5.30
	(0.000)	(0.000)	(0.000)	(0.000)	(0.005)	(0.005)
INNOVINDEXF (pr.)	16.50	16.50	16.50	16.50	16.30	16.30
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)

Dependent variable: PPPRPCGDP.

establish a hierarchy for the variables in the model, and in which we can reject possible reverse causality, running from growth to institutions. Below each determinant is the value of the Granger null causality test, followed by the corresponding probability of the null hypothesis in parentheses. Through nested panel regression estimates, we establish estimates for each determinant. We then use estimated values to re-estimate our growth equation based on the global sample defined in Eq. (11). Results from our revised model are summarized in Table 2.

The expanded model estimates point to several findings. First, while predicted savings rates and trade dependency continue to exert a positive effect on growth, once risk and innovation are taken into account, their role is reduced. And while predicted aggregate country risk has the largest single influence on per capita income, our second most important determinant is the predicted index of creative innovation. Obviously, measures to reduce aggregate country risk as well as to increase the level of innovation are keys to raising real per capita income. As such, they complement measures to increase the rate of savings and the degree of trade dependency.

5.2. Extensions of the expanded model

We now conduct extensions to our expanded model. First we test for the significance of risk and creative innovation using geographic sub-samples of the global model. Second, we undertake estimates of the impact of single and multiple measures to reduce aggregate country risk and expand creative innovation on the predicted level of per capita income. Results of our geographic regional estimates are shown in Table 3.

Our regional sub-model estimates validate our global model findings, namely, that risk and innovation work in opposite directions in terms of their effects on per capita income. However, while risk and innovation are important determinants of per capita income, strategies to manage them will vary according to underlying conditions in a given economic region. For example, innovation has the strongest effect on per capita income among Asian countries, followed by those in East Europe. This may reflect the relative starting positions of these regions in applied innovations, but it also may reflect the establishment of a more innovative environment in these regions based on recent economic reforms.

To better gauge the relative importance of creative innovation and risk, we now conduct simulations in a two-step process, using comparisons based on 2005 mean values for the respective variables and changes. First, we derive the impact on per capita income from a one-time change in an institutional parameter. Second, we then use the prevailing discount rate to derive present values of the change in per capita income from the one-time changes in institutional parameters. Finally, we derive the ratio of one-time and present-value changes in parameters to per capita income.

Results of changing institutional variables are shown in Table 4. Strengthened political rights increase judicial independence, which then increases real per capita by the effect on reductions in aggregate country risk and in expansions in

Table 3
Expanded model regional regression estimates

	A. Global	B. Africa	C. Asia	D. CACarib	E. WEurope	F. EEurope	G. MENAf
C	15021.03	1523.83	13400.41	4261.67	20408.98	7067.88	3684.88
GNSGDP (*t*)	16.79	27.62	13.37	6.18	214.33	31.82	32.85
	(5.821)	(11.822)	(3.209)	(9.221)	(65.437)	(11.804)	(I7.765)
TRDEP (*t*)	4.04	6.25	28.23	6.02	48.74	4.22	25.21
	(3.513)	(8.126)	(22.468)	(14.864)	(116.200)	(3.617)	(45.170)
RCCRISKF (*t*)	−282.78	−23.49	−458.38	−32.19	−384.99	−170.11	−63.61
	(54.758)	(6.826)	(31.465)	(24.909)	(140.401)	(18.868)	(12.924)
INNOVINDEXF (*t*)	37.70	268.00	6283.58	426.29	61.85	2994.27	618.46
	(50.008)	(74.808)	(22.700)	(94.326)	(22.002)	(17.254)	(46.885)
Adjusted *R*-squared	0.8709	0.9193	0.9949	0.9952	0.9926	0.8858	0.946404
F-statistic	4517.32	2220.25	826.47	4232.33	14861.17	551.45	1267.981
Number of cross-sections	103	30	13	17	17	11	12
Number of observations	2678	750	338	408	442	285	288
Method	PLS	PLS	PLS	PLS	PLS	PLS	PLS
Effects							
Cross-section	None	None	Fixed	None	None	None	None
Period	None	None	None	None	None	None	None
GLS weights	CS	CS	CS SUR	CS SUR	CS SUR	CS SUR	CS SUR
Granger null values							
GNSGDP (pr.)	4.76	4.60	9.52	4.60	3.52	4.60	0.078
	(0.009)	(0.009)	(0.000)	(0.009)	(0.030)	(0.009)	(0.925)
TRDEP (pr.)	40.23	40.23	4.62	40.23	18.40	40.23	4.65459
	(0.000)	(0.000)	(0.011)	(0.000)	(0.000)	(0.000)	(0.0103)
RCCRISKF (pr.)	10.10	10.10	10.06	10.10	0.15	5.30	0.84406
	(0.000)	(0.000)	(0.000)	(0.000)	(0.857)	(0.005)	(0.4311)
INNOVINDEXF (pr.)	16.50	16.50	9.07	16.50	16.41	16.30	0.55696
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.5736)

Dependent variable: PPPRPCGDP.

the level of creative innovation. Strengthened property rights reduces corruption, which in turn reduces aggregate country risk, while expanding economic freedom, thus increasing the level of creative innovation. Increases in a country's reserve to import ratio, a standard measure often advocated in economic reform programs, has the primary effect of reducing aggregate country risk, and thus expanding the level of real per capita income. This also is true of increases in the level of foreign direct investment relative to GDP. There may be, in fact, additional positive effects on the level of FDIP through changes in institutional variables and their attendant effects on risk, even though we have not made such estimates here.

We also estimate the effects of an increase in a region's national saving rate and its level of trade dependence on real per capita GDP. Although increases in these variables do produce positive effects on the level of real per capita GDP, they are outweighed in most instances by reductions in aggregate country risk and in increases in creative innovation.

We now turn to the derivation of the relative impact of one-unit one-time changes in independent variables on real per capita income. Table 5 reports the results of these ratios. Our results indicate that in general, for all regions, the relative positive effect of greater innovation is higher than for reductions in risk in all regions.

Using mean regional rates of interest, we now derive present values for the effects of the respective independent variables on real per capita GDP. These values provide a basis on which to determine the extent to which, on a per capita basis, one should consider investing in improvements in institutional governance variables. As long as the costs of improvements in institutional governance variables are less than the values reported in Table 6, the underlying implicit rate of return will be

Table 4
Absolute effect of a one-time one-unit change in independent variables on real per capita GDP

	Global	Africa	Asia	CACARIB	WEurope	EEurope	MENAf
Absolute change in model variable							
POLRTS1	187$	14$	379$	194$	3,052$	144$	95$
PROPRT1	308$	103$	319$	227$	509$	1286$	257$
RESIMPCOVRATIO1	283$	125$	231$	81$	427$	279$	394$
FDIGDP1	14$	106$	243$	22$	409$	283$	93$
GNSGDP1	75$	30$	15$	27$	622$	41$	33$
TRDEP1	0$	6$	30$	29$	456$	4$	25$
1 unit increase in MIGPOPGRATIO	60$	100$	59$	24$	419$	36$	14$
1 unit decrease in RRCRISKF	283$	126$	425$	81$	679$	297$	64$
1 unit increase in INNOVINDEXFA	38$	267$	6209$	223$	469$	2368$	618$
Global mean predicted base PPPRPCGDF	8128$	1944$	8025$	5408$	23,427$	7157$	5096$

Table 5
Relative effects of a one-time one-unit change in independent variables on real per capita GDP

	Global	Africa	Asia	CACARIB	WEurope	EEurope	MENAf
Relative change (%)							
POLRTS1	2.30	0.71	4.72	3.58	13.03	2.01	1.87
PROPRT1	3.79	5.29	3.97	4.20	2.17	17.97	5.04
RESIMPCOVRATIO1	3.49	6.45	2.87	1.50	1.82	3.90	7.73
FDIGDP1	0.18	5.45	3.03	0.40	1.74	3.96	1.82
GNSGDP1	0.92	1.52	0.19	0.51	2.65	0.57	0.64
TRDEP1	0.01	0.32	0.37	0.53	1.95	0.06	0.49
1 unit increase in MIGPOPGRATIO	0.74	5.13	0.74	0.44	1.79	0.51	0.27
1 unit decrease in RRCRISKF	3.49	6.48	5.30	1.49	2.90	4.15	1.25
1 unit increase in INNOVINDEXFA	0.46	13.75	77.36	4.13	2.00	33.08	12.14

Table 6
Present-value effects of one-time one-unit changes in independent variables on real per capita GDP

Relative change	Global	Africa	Asia	CACARIB	WEurope	EEurope	MENAf
POLRTS1	2.30%	0.71%	4.72%	3.58%	13.03%	2.01%	1.87%
PROPRT1	3.79%	5.29%	3.97%	4.20%	2.17%	17.97%	5.04%
RESIMPCOVRATIO1	3.49%	6.45%	2.87%	1.50%	1.82%	3.90%	7.73%
FDIGDP1	0.18%	5.45%	3.03%	0.40%	1.74%	3.96%	1.82%
GNSGDP1	0.92%	1.52%	0.19%	0.51%	2.65%	0.57%	0.64%
TRDEP1	0.01%	0.32%	0.37%	0.53%	1.95%	0.06%	0.49%
1 unit increase in MIGPOPGRATIO	0.74%	5.13%	0.74%	0.44%	1.79%	0.51%	0.27%
1 unit decrease in RRCRISKF	3.49%	6.48%	5.30%	1.49%	2.90%	4.15%	1.25%
1 unit increase in INNOVINDEXFA	0.46%	13.75%	77.36%	4.13%	2.00%	33.08%	12.14%

competitive with existing rates of interest in a given geographic region.

It is reasonable to ask why should we examine one-time, relative, and present-value effects of our institutional variables. Most models of economic growth rely on traded and observable values. However, in our institutional analysis, we find it useful to separate out how these institutional variables bear on the level of per capita income. An analogy would be if all of the countries in our sample had sovereign debt ratings and well-developed capital markets, prices of assets would provide an efficient measure of the risk premia that agents confront in making allocation decisions. However, in their absence, the question of governance becomes more crucial, and we emphasize that there is a significant economic value in strengthening such determinants as property and political rights. This acquires particular significance in the context of international efforts to promote greater transparency in governance, but for which there often is little economic value assigned in doing so.

6. Tests on variables and model equations

To examine the robustness of our estimates, we undertake several tests on variables used in the model. First we examine stationarity using unit root tests using the Augmented Dickey Fuller Test and the Phillips Perron Test. Then we look at cointegrating relations used in the model indicated in Fig. 1. Results of these tests are given in Table 7.

With the exception of Eastern Europe, we cannot reject a unit root for PPPRPCGDP, but can do so for the other variables in the expanded model. However, our Pedroni Engle–Granger and Johansen Fisher tests provide support for cointegration in the various geographic samples, which may offset the problem of stationarity within individual variables. For this reason, we keep our revised model estimates, noting that stationarity cannot be ruled out entirely. In so doing, it is reasonable to ask why we have organized the panels using only geographic samples rather than around some alternative criterion such as high and low income, weak or strong property rights, or some other combination. In our present analysis, we made this choice simply to illustrate variations across regions, and not to suggest that regions provide ready alternatives for policy choices.

7. Policy implications and conclusions

Institutions matter in achieving economic growth. Although economic models traditionally have ignored the economic impact of governance on growth, it is increasingly clear that a failure to do so can produce weak or counterproductive effects. This applies not just to a country's rate of saving or trade dependence. It also extends to such areas as foreign direct investment. Where it becomes critical is in terms of the impact of institutional governance on aggregate country risk and in a country's rate of creative innovation. Measures to reduce aggregate country risk and expand creative innovation may have significant payoffs. We note briefly some of the kinds of policy measures that derive from our model.

In terms of aggregate country risk, efforts to strengthen property rights and judicial independence have significant positive effects. While greater political rights increase judicial independence, expanded property rights reduce the level of

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Table 7
Tests for unit roots and cointegration

	A. Global	B. Africa	C. Asia	D. CACarib	E. WEurope	F. EEurope	G. MENAf
(A) Panel unit root tests							
PPPRPCGDP							
ADF–Fisher chi-square (pr.)	119.96	70.89	3.66	16.84	3.41	37.97	7.99
	(1.000)	(0.159)	(1.000)	(0.994)	(1.000)	(0.018)	(0.999)
Phillips Perron–Fisher chi-square (pr.)	100.53	62.64	3.81	16.80	2.77	22.81	9.68
	(1.000)	(0.383)	(1.000)	(0.994)	(1.000)	(0.412)	(0.996)
GNSGDP							
ADF–Fisher chi-square (pr.)	353.63	127.97	52.91	53.36	47.37	38.82	40.95
	(0.000)	(0.000)	(0.001)	(0.019)	(0.064)	(0.025)	(0.017)
Phillips Perron–Fisher chi-square (pr.)	329.76	119.60	40.22	56.78	39.51	25.00	47.73
	(0.000)	(0.000)	(0.037)	(0.009)	(0.237)	(0.297)	(0.003)
TREDP							
ADF–Fisher chi-square (pr.)	256.80	87.88	16.97	49.54	31.01	48.72	34.02
	(0.009)	(0.011)	(0.910)	(0.041)	(0.615)	(0.001)	(0.084)
Philips Perron–Fisher chi-square (pr.)	235.79	76.84	15.14	48.18	22.96	43.49	32.96
	(0.076)	(0.070)	(0.955)	(0.054)	(0.925)	(0.004)	(0.105)
RCCRISKF							
ADF–Fisher chi-square (pr.)	308.87	52.98	47.66	76.71	67.57	20.41	24.39
	(0.000)	(0.728)	(0.006)	(0.000)	(0.001)	(0.557)	(0.439)
Phillips Perron–Fisher chi-square (pr.)	295.79	48.00	38.39	88.80	117.13	20.57	24.62
	(0.000)	(0.868)	(0.056)	(0.000)	(0.000)	(0.548)	(0.427)
INNOVINDEXF							
ADF–Fisher chi-square (pr.)	254.10	35.48	31.60	72.28	46.76	28.34	35.99
	(0.013)	(1.000)	(0.226)	(0.000)	(0.071)	(0.165)	(0.056)
Phillips Perron–Fisher chi-square (pr.)	416.80	92.62	27.29	55.75	31.57	32.15	42.41
	(0.000)	(0.004)	(0.394)	(0.011)	(0.587)	(0.075)	(0.012)
(B) Panel cointegration tests (unrestricted version: PPPRPCGDP, GNSGDP, TRDEF, RCCRISKF, INNOVINDEXF)							
Pedroni Engle–Granger test							
Panel ADF-Stat (pr.)	5.44	4.49	1.00	0.67	2.84	1.83	1.17
	(0.000)	(0.000)	(0.241)	(0.320)	(0.007)	(0.075)	(0.202)
Panel PP-Stat (pr.)	1.13	3.02	1.22	1.94	1.09	0.92	1.72
	(0.212)	(0.004)	(0.189)	(0.061)	(0.220)	(0.262)	(0.091)
Johansen Fisher test							
None (pr.)	1567.00	348.00	263.90	356.60	380.00	225.10	256.50
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
At most 1 (pr.)	708.60	173.10	137.90	182.20	173.20	112.20	118.00
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)

corruption, expand economic freedom, and thus a country's level of creative innovation. In turn, reductions in corruption that are accompanied by expansions in judicial independence also reduce the level of aggregate country risk.

In terms of creative innovation, since our innovation index builds on scientific citations and the ratio of net royalties to per capita GDP, measures to increase their level produce positive effects on per capita income. Scientific innovations reflect a country's education and research capacity. Investments in education and research produce obvious effects in scientific citations. In turn, many scientific achievements are complemented by the level of creativity in other domains, as in music and the arts. How a country nurtures the environment in which these innovations take place is critical, particularly in that they translate into greater royalty producing income relative to royalty payments for a given country. Strengthened property rights are a necessary mechanism for this to take place, while a nurturing and open environment also has a role to play.

In conclusion, aggregate country risk and creative innovation typically carry greater economic consequences on a country's level of per capita income than such traditional variables as the rate of national saving and trade dependence. Devising suitable policies built around credible models is an important step in raising per capita income. The results of this analysis lend support to such efforts.

Appendix A. Data sources and model specification

Preliminary to our analysis, we have gathered time-series and cross-section data from a variety of sources, including the World Bank Development Indicators, the Heritage Foundation Index of Economic Freedom, and Freedom House political variables. Table A.1 lists the definitions, scales, and sources of variables used in the present analysis.

See Tables A.2–A.4.

Table A.1
Variable definitions and sources

Variable	Variable symbol	Definition	Scale		
			Lowest	Highest	
Political rights	POLRTS	A supportive measure of democratic institutions	1.00	7.00	Freedom House, Freedom in the World
Property rights	PROPRT	A measure of the strength of economic freedom	1.00	5.00	The Heritage Foundation, The Index of Economic Freedom
Judicial independence	JUDIND	A measure of the strength of economic freedom	1.00	10.00	The Heritage Foundation, The Index of Economic Freedom
Economic freedom	ECFREE	The aggregate index of economic freedom	1.00	5.00	The Heritage Foundation, The Index of Economic Freedom
Reserve import coverage ratio	RESIMPCOVRATIO	Ratio of Reserves to imports	0.00	1.00	The World Bank, World Development Indicators
Foreign direct investment to GDP ratio	FDIGDP	Ratio of FDI to GDP	0.00	1.00	The World Bank, World Development Indicators
Net migration to population ratio	NETMIGPOPRATIO	Net official migration to population	Negative	Positive	The World Bank, World Development Indicators
Revised country composite risk	RCCRISK	An index of political, economic, financial, and environmental country risk	0.00	100.00	ICRG, as reported by the World Bank, and re-scaled
National saving rate	GNSGDP	Ratio of national saving to GDP	Negative	Positive	The World Bank, World Development Indicators
Trade dependency ratio	TRDEP	Ratio of exports and imports to GDP	0.00	Positive	The World Bank, World Development Indicators
Per capita scientific citations	PCSCITES	Per capita scientific citations	0.00	Positive	The World Bank, World Development Indicators
Innovation index	INNOVINDEX	Average of per capita scientific citations and net royalty ratio	0.00	Positive	The World Bank, World Development Indicators
PPP per capita real GDP	PPPRPCGDP	Real per capita GDP at purchasing power parity rates	Positive	Positive	The World Bank, World Development Indicators
Real interest rate	REALINRATE	Real discount rate of central bank in a country	Negative	Positive	The World Bank, World Development Indicators
Corruption index	CORRUPA	Corruption perceptions index, inverted scale	0.00	10.00	Corruption Perceptions Index, Inc.

Table A.2
Expanded regional model: 2005 mean original and predicted values

	Global	Africa	Asia	CACARIB	WEurope	EEurope	MENAf
Panel number	103	30	13	17	17	11	12
Original values							
POLRTS	4.8641	3.7667	4.2308	5.7059	7.0000	1.4558	2.3333
PROPRT	2.9107	2.3933	2.7692	2.5294	4.5882	3.3000	2.1667
JUDIND	5.1332	4.6963	5.2170	4.7220	7.6163	4.5296	3.4200
ECFREE	2.0085	1.5532	1.8377	2.0065	2.9135	1.8995	1.5108
RESIMPCOVRATIO	4.6408	4.3266	6.9832	4.8464	1.8222	0.7988	7.3979
FDIGDP	3.1164	3.0106	1.9420	3.0580	4.6752	0.0009	1.9623
NETMIGPOPRATIO	0.0000566	−0.0015440	0.0056350	−0.0059000	0.0146620	0.0024150	−0.0016480
RCCRISK	29.12	38.69	27.94	31.10	15.94	33.46	27.83
GNSGDP	19.7955	12.9247	30.8755	18.2433	23.2020	26.9792	22.0137
TRDEP	77.5171	64.3841	89.8601	65.9278	93.0468	73.2015	70.4656
INNOVINDEX	71.3280	2.5644	1.0440	4.5358	7.8070	2.9488	2.0193
PPPRPCGDP	$10652.78	$2377.57	$9270.38	$6313.38	$30405.65	$6568.80	$6126.92
REALINRATE	6.3069	10.3003	4.8831	7.4590	3.1015	−11.7728	4.1405
Predicted values							
JUDINDF	5.0928	4.5202	5.0446	4.5043	7.8508	4.1275	3.4695
CORRUPAF	6.0196	7.2585	6.5947	6.9075	2.5777	6.4242	7.2696
ECFREEF	1.9193	1.4461	1.7626	1.9631	2.7434	1.9380	1.2750
RCCRISKF	34.9219	43.5928	32.9869	38.8303	17.0240	34.4199	38.8532
INNOVINDEXF	60.3168	2.5644	1.0640	4.4257	7.6219	1.6622	2.2360
PPPRPCGDPF	$8065.11	$1946.76	$8025.12	$5393.44	$23834.80	$7157.50	$5096.00

Table A.3
Estimating equations for revised expanded global model

Dependent variable	JUDIND	CORRUPA	ECFREE	RCCRISK	INNOVINDEX	PPPRPCGDP
C	4.84	9.79	4.50	55.02	48.75	15021.03
POLRTS	0.05 (8.941)					
PROPRT		−0.13 (5.178)	0.03 (2.018)			
JUDINDF		−0.67 (9.210)		−9.31 (3.717)		
CORRUPAF			−0.44 (6.144)	5.29 (2.003)		
RESIMPCOVRATIO				−0.98 (19.950)		
ECFREEF					5.25 (3.721)	
FDIGDP					0.48 (12.717)	
NETMIGPOPRATIO					11.85 (2.058)	
MIGPOPGRATIO						
RCCRISKF						−219.58 (22.199)
GNSGDP						24.34 (3.307)
TRDEP						10.91 (4.875)
INNOVINDEXF						47.65 (44.050)
INNOVINDEXF1						
Adjusted *R*-squared	0.9954	0.9935	0.9963	0.8843	0.9199	0.8545
F-statistic	5607.85	3923.36	6886.84	195.81	293.84	4053.53
Number of cross-sections	103.00	103.00	103.00	103.00	103.00	103.00
Number of observations	2678	2678	2678	2678	2678	2678
Method	PLS	PLS	PLS	PLS	PLS	TSPLS
Effects						
Cross-section	Fixed	Fixed	Fixed	Fixed	Fixed	None
Period	None	None	None	None	None	Fixed
GLS Weights	CS	CS	CS	CS	CS	CS
Granger *F*-null values						
POLRTS (pr.)	7.07 (0.001)					
PROPRT (pr.)		30.38 (0.000)	10.41 (0.000)			
JUDINDF (pr.)		23.93 (0.000)	6.79 (0.001)	5.27 (0.005)		
CORRUPAF (pr.)				12.05 (0.000)		
RESIMPCOVRATIO (pr.)				25.47 (0.000)		
ECFREEF (pr.)					12.28 (0.000)	
FDIGDP (pr.)					2.84 (0.058)	
NETMIGPOPRATIO (pr.)					0.90 (0.405)	
MIGPOPGRATIO (pr.)						
RCCRISKF (pr.)						10.10 (0.000)
GNSGDP (pr.)						7.91 (0.000)
TRDEPF (pr.)						27.51 (0.000)
INNOVINDEXF (pr.)						16.50 (0.000)

Table A.4
List of countries used in regional panel analysis

Global	Africa	Asia	South America and the Caribbean	West Europe	East Europe	Middle East and North Africa
Mexico	Benin	Bangladesh	Belize	Austria	Albania	Iran, Islamic Rep.
Canada	Botswana	China	Costa Rica	Belgium	Bulgaria	Lebanon
United States + all others	Burkina Faso	India	El Salvador	Denmark	Czech Republic	Oman
	C. Af. Republic	Indonesia	Guatemala	Finland	Estonia	Qatar
	Cameroon	Japan	Honduras	France	Hungary	Syrian Arab Republic
	Chad	Korea, Rep.	Nicaragua	Germany	Latvia	Turkey
	Congo, Dem. Rep.	Malaysia	Panama	Greece	Lithuania	Yemen, Rep.
	Congo, Rep.	Pakistan	Argentina	Ireland	Poland	Egypt, Arab Rep.
	Cote d'Ivoire	Philippines	Bolivia	Italy	Romania	Libya
	Ethiopia	Singapore	Brazil	Luxembourg	Slovak Republic	Tunisia
	Gabon	Sri Lanka	Chile	The Netherlands	Russian Federation	Algeria
	Ghana	Thailand	Colombia	Norway		Morocco
	Guinea	Vietnam	Ecuador	Portugal		
	Kenya		Paraguay	Spain		
	Madagascar		Peru	Sweden		
	Malawi		Uruguay	Switzerland		
	Mali		Venezuela, RB	United Kingdom		
	Mauritania					
	Mauritius					
	Mozambique					
	Niger					
	Nigeria					
	Senegal					
	South Africa					
	Sudan					
	Tanzania					
	Togo					
	Uganda					
	Zambia					
	Zimbabwe					
103	30	13	17	17	11	12

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