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Institutions, innovation and growth: cross-country evidence

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Summary

This paper looks at the link between the quality of economic institutions and innovation, and innovation and growth. We construct a measure of the innovation content of individual manufacturing industries and show that countries with stronger economic institutions specialise in more innovation-intensive industries. Our results also provide evidence that industries involving higher levels of innovation grow relatively faster in countries with better economic institutions. The results suggest that innovation is an important channel through which higher-quality economic institutions contribute to better growth performance in the long run.

Keywords: innovation, technology adoption, exports, trade, economic growth, institutions

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1. Introduction

Economic institutions – understood, alongside political institutions, as the rules of the game in a society (North, 1990) – are among key determinants of long-term economic growth (see, for instance, Mauro (1995), Hall and Jones (1999), Robinson et al. (2005)). In broad terms, in countries with stronger economic institutions – more secure property rights, better business environment and effective rule of law – incentives to make long-term, risky investments are stronger (see, for instance, Olson (2000)). As a result, physical and human capital can be employed more effectively.

This broad relationship between institutions and growth manifests itself through various channels. To name a few, poor institutions and corruption reduce foreign direct investment (Javocik and Wei, 2009) and undermine incentives for domestic firms to reinvest their earnings (Cull and Xu, 2005), with negative implications for growth. A difficult business environment impedes the entry of new firms to the market (Bruno et al., 2011), which is in turn an important driver of overall productivity growth. In countries with stronger contract enforcement, industries that rely on customised inputs and relation-specific investments grow faster (Nunn, 2007) as better contract enforcement facilitates the necessary investment. Countries with better economic institutions also specialise in more complex production processes in terms of number of various inputs required (Levchenko, 2007). More sophisticated exports can in turn be linked to better growth performance over the long run (Hausmann et al. (2007)).

One potential important channel that has received relatively less attention in the literature is the impact of the quality of economic institutions on innovation. Innovation is an important driver of improvements in productivity and growth performance. In turn, poor economic institutions – red tape, corruption, weak property rights – significantly increase uncertainty about financial returns on innovation while at the same time increasing the cost of investment needed to develop new products and services. In other words, poor economic institutions are likely to discourage innovation, and less innovation in turn would lead to lower economic growth.

This paper offers an empirical test of this channel. Few studies have focused on the link between economic institutions and innovativeness of economies. Cross-sectional analysis generally finds a positive link (see, for instance, Tebaldi and Elmslie (2013)) – but is subject to potential biases as many factors may simultaneously affect innovation outcomes at the country level. To overcome this problem our analysis focuses on the performance of individual industries within countries. It seeks to explain differences between the average rates of growth of exports and output in industries that rely on innovation to a greater extent and those where innovation tends to be less prominent, depending on a country's quality of economic institutions. Industries that are more innovation-intensive are shown to grow relatively faster in countries with better economic institutions.

The measure of innovation intensity of individual industries is unrelated to individual countries' circumstances (and thus should not be affected by industry performance in individual countries, the left-hand-side variable). This measure is constructed using industry-specific patent grants and employment data for the United States, an economy with a developed innovation ecosystem and a large consumer market, where various industries are expected to realise their innovation potential most fully and where businesses face strong incentives to patent their innovations. Alternative measures of innovation intensity of industries are also considered, for instance, one based on industry-specific research and development (R&D) expenditures per employee in Japan.

We also find that the relationship holds at the country-level: countries with higher quality institutions tend to have a more innovation-intensive export structure – that is, they tend to export more in innovation-intensive industries.

Overall, the findings suggest that innovation is an important channel through which good-quality economic institutions can boost long-term economic growth. In particular, when quality economic institutions needed for effective innovation are in place, industries with a higher innovation component can grow faster and so become the locomotives of economic growth.

The paper is organised as follows. Section 2 examines the relationship between innovation and growth and discusses a measure of innovativeness of industries and economies. Section 3 presents the econometric specification and estimation strategy. Section 4 describes the data. Section 5 reports the estimation results and robustness checks. Section 6 concludes.

2. Innovation, institutions and growth

2.1 Innovation and growth

Economic growth can be driven by a growth in production inputs (namely labour and capital), by a higher efficiency in their allocation across sectors of the economy, or by improvements in productivity. Improvements in productivity are in turn largely underpinned by innovation. The introduction of new products or processes helps to improve the efficiency with which various factors of production are combined and thus raise total factor productivity – the unexplained residual in the neoclassical growth theory framework. Various endogenous growth models illustrate ways in which innovation process may be endogenous and influenced by institutions, structural and policy variables (Aghion and Howitt, 1998).

Empirical studies of the impact of innovation on economic growth (whether it is at the industry or economy level) have focused notably on testing the effect of a proxy of innovation on the total factor productivity (TFP) growth. In these studies, innovation is usually proxied by inputs in the innovation process (in particular R&D spending) or by measures of creation of knowledge (such as patenting of new technologies).

For instance, using the ratio of R&D investment to GDP, Scherer (1982), Griliches and Lichtenberg (1984), Aghion and Howitt (1998) and Zachariadis (2004) provide strong evidence that in the US economy, R&D investment and TFP growth are positively related. A similar relationship has been documented for a number of other advanced economies (for instance in Lichtenberg (1992) and Patel and Soete (1988)) and for a sample of 20 OECD and 10 non-OECD countries (Ulku, 2007).

At the same time, innovation arguably has the highest impact on economic growth at the point when many firms adopt a new technology – in other words, when technological advances are matched with labour and capital resources in the economy. While in advanced markets development and adoption of new technologies may be aligned to a higher extent, many emerging markets tend to mainly adopt technologies developed elsewhere. The importance of international spillovers of ideas and innovation, especially from industrialised to developing countries, is well documented. Such spillovers can be channelled through trade (Coe and Helpman, 1995; Eaton and Kortum, 1997), a combination of trade and foreign direct investment (Lichtenberg and Van Pottelsbergh de la Potterie, 1998), licensing of foreign patents (Nadiri, 1993; Mohnen, 1996), or other transmission mechanisms such as licensing agreements, joint ventures or international migration of highly skilled labour such as scientists and engineers (Bernstein and Mohnen, 1998; Görg and Strobl, 2005).

These spillovers can have significant positive effects on TFP growth of developing countries (for instance, Griffith, Redding and Reewen, 2004). Coe, Helpman and Hoffmaister (1997) use the R&D stocks in the OECD nations weighted by trade flows between OECD countries and a given developing country as a measure of spillovers to that developing country. This variable, which captures the joint effect of technology and trade, has a significant positive effect on developing countries' growth. Savvides and Zachariadis (2005) show that both domestic R&D and FDI increase domestic productivity and value added growth.

Focusing on patent output or R&D spending in emerging market and developing economies would not allow the link between innovation and economic performance to be captured properly. Indeed, studies of innovation and growth focus largely on advanced economies. To address this issue, this paper constructs a measure of innovation that is based on industry outcomes in the United States and is then applied internationally.

2.2. Economic institutions and innovation

It is generally acknowledged that innovation relies on strong economic institutions. High incidence of corruption, weak rule of law or burdensome red tape can drive up the costs of introducing new products and make returns to innovation much more uncertain. Hence risk-adjusted returns to innovation are likely to look less attractive in countries with weak economic institutions. A number of empirical studies (for example, Habiyaremye and Raymond (2013) and Mahagaonkar, 2008) document a negative relationship between corruption and innovation; Tebaldi and Elmslie (2013) report a positive link between the quality of economic institutions and innovation. However, the results of cross-sectional studies are highly tentative as many factors may simultaneously affect innovation outcomes at the country level and bias the estimates.

Several studies looked at the link between specific economic institutions and the patterns of country specialisation/sophistication of country exports. Nunn (2007) used an industry-specific measure of contract intensity based on the proportion of intermediate inputs that require relation-specific investments and a country-level measure of the quality of contract enforcement to show that exports of contract-intensive industries grow faster than those of non-contract-intensive industries in countries with better contract enforcement. Levchenko (2007) interacted a country measure of institutional quality with an industry-level measure of institutional dependence defined as the Herfindahl index of intermediate input use in the United States and showed countries with better institutions specialise in goods which have more complex production processes, as measured by the variety of inputs used.

This paper applies a difference-in-difference approach and shows that the quality of economic institutions has a differential impact on more innovation-intensive industries compared with less innovation-intensive industries in the same countries. It thus provides more rigorous evidence of the importance of innovation as a channel through which institutions can affect long-term growth and quantifies this impact.

2.3. Innovation-intensity of industries

To identify the differential impact of economic institutions on industry performance we define a measure of innovation intensity of different industries. In particular, the innovation intensity of a given industry is proxied by the number of patent grants per 1,000 workers in the United States (a measure of an industry's patent intensity). As discussed above, using a US-based measure for all countries ensures that technology adoption in emerging markets is better captured and that characterisation of industries on the right-hand side is not influenced by country-specific industry performance, the key variable that we seek to explain.

It should be acknowledged that patent intensities do not perfectly reflect the amount of innovation in various industries. Not all inventions are patented. Those which are patented do not necessarily lead to commercialisation of new products. Moreover, value of patents differs from patent to patent, but also across time and geography. Patents are more likely to be used in large consumer markets and when they are effective and in jurisdictions where they can be effectively enforced. Patents may also play a different role and vary in importance across industries.

Nevertheless, patent counts have been extensively used in economic analyses – principally microeconomic analyses – as the best available proxy for innovation,[1] with some extensions aimed to make these measures more robust.[2] There is also strong empirical evidence of the relationship between R&D intensity and patents in developed economies (Griliches, 1984). The link between R&D and patenting, and the link between patenting and commercialisation are also more likely to be strong for recognised frontier innovators, which have the right environment, right support and right incentives — such as the United States or Japan. Moreover, on average, firms in industries that patent more tend to introduce new products more frequently, and the life span of these products tends to be shorter, prompting firms to continuously innovate.[3]

Thus on balance patent intensities provide a reasonable approximation of the role of innovation across different sectors in the United States. For other countries, the measure could be seen as a measure of innovation potential of different industries (not necessarily realised yet) as well as a measure of likely technological spillovers. Lower patent intensities in the same industries in other jurisdictions mainly reflect a combination of lower incentives to file patent applications and a less supportive innovation environment.

In some instances, production in innovation-intensive industries (such as computing equipment) in emerging markets may originally be limited to final product assembly with little value added creation or transfer of knowledge. Over time, however, by participating in global value chains, firms tend to develop skills and expertise that enable them to move up the value added chain and produce original innovations (Hwang, 2007). Overall, potential for direct or indirect knowledge transfer tends to be higher in the case of companies operating in more innovation-intensive industries.

[1] See contributions by Schmookler and Brownlee (1962); Griliches and Schmookler (1963); Pakes (1985); Hall, Griliches and Hausman (1986); Jaffe (1986, 1989); Griliches (1990); Hall, Jaffe and Trajtenberg (2000, 2001).

[2] For instance, by considering patent citations and citation-weighted patent counts (see Jaffe and Trajtenberg (2002)), and implementing truncation corrections (see Hall, Jaffe and Trajtenberg, 2001).

[3] Evidence from firm-level surveys is consistent with this (see for instance EBRD (2014)).

Innovation intensities of 26 manufacturing industries are presented in Table 1 (data and methodology are further discussed in section 4). The most innovation-intensive industries include computing equipment, communication equipment, chemical and pharmaceuticals, while textiles, food and beverages, and wood products are among the least innovation intensive.

Table 1: Innovation intensity of industries

Industry	US Patent Intensity
Computer and Peripheral Equipment	277.5
Communications Equipment	264.8
Semiconductors and Other Electronic Components	111.6
Other Computer and Electronic Products	108.5
Navigational, Measuring, Electromedical, and Control Instruments	96.1
Basic Chemicals	80.2
Electrical Equipment, Appliances, and Components	54.3
Pharmaceutical and Medicines	46.8
Other Miscellaneous	37.5
Other Chemical Product and Preparation	32.4
Medical Equipment and Supplies	32
Machinery	31.6
Resin, Synthetic Rubber, and Artificial and Synthetic Fibers and Filaments	26
Plastics and Rubber Products	10.7
Motor Vehicles, Trailers and Parts	8.1
Nonmetallic Mineral Products	7.3
Other Transportation Equipment	7.1
Aerospace Product and Parts	5.8
Textiles, Apparel and Leather	4.1
Fabricated Metal Products	3.6
Primary Metal	2.2
Furniture and Related Products	2
Paper, Printing and support activities	1.2
Beverage and Tobacco Products	1.1
Wood Products	0.8
Food	0.5
Other (incl. commodities)	0

Source: Authors' calculations using data from the USPTO (US patent grants) and the US Bureau of Labor Statistics (employment).
Note: The patent intensity is calculated as the total number of patents granted in a given industry over the period 2004-08 over the average number of workers in that industry over the same period. It is expressed in number of patents per 1,000 workers.

3. Econometric specification

3.1 General approach

To test the impact of the quality of economic institutions on innovation, we look at the determinants of exports of various industries in various countries by estimating the following model:

$$[1] \qquad X_{i,j,t} = \alpha . X_{90_{i,j}} + \beta . y_i . F_j + \gamma_1 . h_i . H_{j,t} + \gamma_2 . k_i . K_{j,t} + \delta_i + \lambda_{j,t} + \varepsilon_{i,j,t}$$

where $X_{i,j,t}$ denotes the natural logarithm of total exports in industry i from country j in year t; $X_{90_{i,j}}$ denotes the natural logarithm of total exports in industry i from country j at the start of the period (in 1990); y_i is a measure of the innovation intensity of industry i; F_j is a measure of the quality of economic institutions in country j; h_i and k_i are, respectively, measures of the skill and capital intensities of production in industry i; $H_{j,t}$ and $K_{j,t}$ are measures of the endowments of skilled labour and capital of country j in year t; δ_i are industry fixed effects; $\lambda_{j,t}$ are country-year fixed effects and $\varepsilon_{i,j,t}$ is an error term.

A positive coefficient on the interaction term between the innovation intensity of industries and quality of country economic institutions would indicate that in countries with better institutions innovation-intensive industries enjoy relatively higher exports compared with less innovation-intensive industries. Control variables include the initial value of exports (to account for saturation, or convergence, effects) and interactions between factor endowments and the corresponding factor intensities of industries (to account for the fact that countries abundant, say, in labour may have higher exports in labour-intensive industries – see Romalis (2004) for evidence on importance of factor endowments for exports of individual industries).

Looking at exports rather than the total output of an industry restricts the analysis to tradeable goods. At the same time, focus on exports has the advantage of picking up goods that are competitive in international markets and that are thus more likely to be based on advanced technologies, with innovation content closer to the technological frontier.

Overall, the model broadly follows the approach of Rajan and Zingales (1998) first used to show that industries which are relatively more dependent on external financing grow relatively faster in countries with more developed financial systems (Beck (2003) and Manova (2008) provide further evidence that better private credit availability positively affects exports of industries that rely heavily on external financing). It was also used in Nunn (2007), Levchenko (2007) and a number of other studies of industry-specific export performance.

3.2. Other specifications

In equation [1], we consider the level of exports. To further test the relationship between institutions, innovation and growth we also estimate a cross-country model with the following structure:

[2] $$G_{i,j} = \alpha . X_{90_{i,j}} + \beta . y_i . F_j + \gamma_1 . h_i . H_j + \gamma_2 . k_i . K_j + \delta_i + u_j + \varepsilon_{i,j}$$

where $G_{i,j}$ is the annual compounded growth rate of exports of industry i in country j over the period 1990-2010; u_j are country fixed effects and the other variables are the same as in specification [1]. Factor intensities are estimated for the initial year (1990).

Finally, we estimate a dynamic panel data model to fully exploit the time dimension of the data and at the same time account for persistence of exports of various industries. The specification is as follows:

[3] $$X_{i,j,t} = \alpha . X_{i,j,t-1} + \beta . y_i . F_j + \gamma_1 . h_i . H_{j,t} + \gamma_2 . k_i . K_{j,t} + \delta_i + \lambda_{j,t} + \varepsilon_{i,j,t}$$

where $X_{i,j,t}$ is the logarithm of the level of exports. As the specification includes the lag of the dependent variable, it effectively assesses the determinants of growth of exports of various industries across countries (it can also be expressed as equation [4]):

[4] $$X_{i,j,t} - X_{i,j,t-1} = (\alpha - 1) . X_{i,j,t-1} + \beta . y_i . F_j + \gamma_1 . h_i . H_{j,t} + \gamma_2 . k_i . K_{j,t} + \delta_i + \lambda_{j,t} + \varepsilon_{i,j,t}$$

where the difference in log-exports is approximately equal to the rate of growth of exports in year t.

3.3. Estimation

Model [1] is estimated using fixed effects estimator with industry fixed effects and country-year fixed effects (which account for country-year specific factors such as population size or GDP in a given year). Model [2] is a cross-section model which includes country and industry fixed effects (dummy variables).

Fixed effects estimation of a dynamic panel model (model [3]) produces biased results, with the bias inversely proportional to the time dimension of the panel (Nickel, 1981). Moreover, the variable of interest (interaction between y and F) is time invariant. Therefore, generalised method of moments (GMM) estimation methods making use of first differencing (see Arellano and Bond (1991), Blundell and Bond (1998)) cannot be directly used to estimate the coefficient of interest. Following Kripfganz and Schwarz (2013), we use a two-stage estimation procedure. In the first stage, we estimate the coefficients of time varying variables using GMM. In the second stage, we recover the coefficient for time invariant variables from the estimated residual.

Equation [3] can be written as:

[6] $$X_{i,j,t} = \alpha . X_{i,j,t-1} + \beta . M_{i,j} + \boldsymbol{N'}_{i,j,t} . \boldsymbol{\gamma} + e_{i,j,t}$$

where $X_{i,j,t}$ is the natural log of the export value, M is the observable time-invariant regressor and N' is a vector of observable time-varying regressors. $e_{i,j,t}$ is the error term which includes the individual unobserved fixed effect $u_{i,j}$ and the error $\varepsilon_{i,j,t}$ such that $e_{i,j,t} = u_{i,j} + \varepsilon_{i,j,t}$.

In the first stage of the estimation, we subsume the time-invariant variable $M_{i,j}$ under the unit-specific effects, $u^*_{i,j} = u_{i,j} + \beta. M_{i,j}$, and we consistently estimate the coefficients α and **γ** independent of the assumptions on the correlation structure between $M_{i,j}$ and $u_{i,j}$. The first-stage model can be expressed as:

$$\begin{cases} X_{i,j,t} = u^* + \alpha. X_{i,j,t-1} + \boldsymbol{N'}_{i,j,t} . \boldsymbol{\gamma} + e^*_{i,j,t} \\ e^*_{i,j,t} = u^*_{i,j} - u^* + \varepsilon_{i,j,t} \end{cases}$$

where $u^* = \beta. E[M_{i,j}]$.

Estimates of α and **γ** (noted thereafter as $\hat{\alpha}$ and $\hat{\boldsymbol{\gamma}}$) are derived using the GMM estimator, making use of the difference equation and of the corresponding level equation, and taking into account that the error term of the first-stage model is $e^*_{i,j,t}$ instead of $e_{i,j,t}$. Differences serve as instruments for the level equation and further lags are used as instruments in the difference equation.

From the first stage, an estimate of the residual (noted $\hat{r}_{i,j,t}$) can be obtained and contains observed and unobserved time-invariant effects as well as the normally distributed regression error $\varepsilon_{i,j,t}$. In the second stage, we estimate the coefficient β of the time-invariant variable based on the following level equation:

$$\hat{r}_{i,j,t} = \beta. M_{i,j} + v_{i,j}$$

Where

$$\begin{cases} \hat{r}_{i,j,t} = X_{i,j,t} - \hat{\alpha}. X_{i,j,t-1} - \boldsymbol{N}'_{i,j,t}. \hat{\boldsymbol{\gamma}} \\ v_{i,j} = u_{i,j} - (\hat{\alpha} - \alpha). X_{i,j,t-1} - \boldsymbol{N}'_{i,j,t}. (\hat{\boldsymbol{\gamma}} - \boldsymbol{\gamma}) \end{cases}$$

This can be estimated either by two-stage-least-square, where time-invariant regressors from the first-stage estimate serve as instruments, or in order to maintain all time periods, using the fixed effects estimator with industry and country-year fixed effects.

4. Data

4.1. Exports and production data

Data on industry-level merchandise exports are from Feenstra et al. (2005) and from the UN Comtrade database. We convert the original data which are classified by 4-digit SITC (Standard International Trade Classification) codes (Rev. 2 for the former and Rev. 3 for the latter) to NAICS (North American Industry Classification System) codes. The final data are classified into 26 industry categories corresponding to NAICS patent classification used by the United States Patent and Trademark Office (USPTO).[4]

Exports values are expressed in base year prices using United States export deflators from the US Bureau of Labour Statistics.[5] This adjustment is needed to account for price movements in particular industries and global technological developments (prices of goods of constant quality tend to fall in innovation-intensive industries relative to less innovation-intensive ones as innovation boosts productivity and reduces production costs).

Although we are primarily interested in export performance, as discussed above, we also perform the analysis based on total output of industries and report the results in section 4.3. Data on industry-level merchandise production is from UNIDO Industrial Statistics Database INDSTAT4 (2014 edition).[6] The original data, classified by 4-digit ISIC (Rev. 3) is also converted to NAICS codes, aggregated into 26 industry categories.

4.2. Innovation intensity and institutions

Our primary measure of the innovation intensity of industries is based on patent intensity in the United States. Patent intensity is a measure of the total number of patents granted in each industry over the period 2004-08 divided by the number of workers in this industry[7] (expressed in thousands).

For robustness checks we construct another measure of innovation intensity of each industry using data for Japan, one of the world's top innovators. This measure relies on data from the Japanese Statistics Bureau and reflects the total amount of R&D spending by businesses in a given fiscal year in a given industry divided by the total number of employees of enterprises performing R&D at the end of this fiscal year in that industry. It is expressed in billion yens per 1,000 employees and is averaged over the 2004-08 period.

Our measure of the quality of economic institutions is the average of four Worldwide Governance Indicators: control of corruption, regulatory quality, government effectiveness

[4] See Table 1 for the complete list of industries.

[5] Country-specific deflators are not available. US deflators are used as approximation since exporters face similar trends in prices.

[6] Data and documentation available at: www.unido.org/en/resources/statistics/statistical-databases.html.

[7] Our primary measure uses the period 2004-08 as reference. Other reference years have been used to compute alternative measures of innovation intensity and the results using these are reported as robustness checks in section 5.3.

and rule of law.[8] The indicator varies from -2.5 to 2.5 with higher values corresponding to stronger underlying economic institutions.[9]

4.3. Control variables

Time series of countries' stocks of human capital and physical capital are constructed as in Antweiler and Trefler (2002). For human capital endowment, we use data from the latest Barro-Lee educational attainment dataset (version 2.0).[10] Human capital stock is measured by the natural logarithm of the share of the population that has completed secondary education.[11] Physical capital endowment is computed as the natural logarithm of the average capital stock per worker using data from Penn World Table 8.0.[12]

Skill and capital intensities of production are derived from the NBER-CES Manufacturing Industries Database, which is based largely on the US Annual Surveys of Manufacturing (Becker, Gray and Marvakov, 2013).[13] Capital intensity of production is computed as the total real capital stock per industry over the total real value added in this industry. Skill intensity measures the ratio of non-production worker wages to total wages in the industry.[14] Skills and capital intensities of production are averaged to derive a value for each of the 26 industries.

The level of financial development is captured by the ratio of private sector credit by deposit money banks and other financial institutions to GDP[15] and is obtained from the World Bank Global Financial Development Database.[16] It primarily reflects the level of development of banking services. Descriptive statistics for various variables are presented in Table 2.

[8] See Kaufmann et al. (2009) for a discussion.

[9] In the estimation, this indicator is rescaled by adding a constant (to range from 0 to 5).

[10] See Barro and Lee (2013). Dataset available at http://barrolee.com/. As data is only available at a five-year interval, we interpolate for other years.

[11] Using the share which has completed tertiary education instead of secondary education does not significantly change the results.

[12] See Feenstra et al. (2013).

[13] NBER-CES data and documentation are available at www.nber.org/nberces.

[14] It is computed as: (1-production worker wages/total payroll).

[15] Using the ratio of domestic credit to private sector to GDP does not change the results.

[16] Data available at: http://data.worldbank.org/data-catalog/global-financial-development.

Table 2: Descriptive statistics

	Obs	Mean	Std. Dev.	Min	Max
Industry variables					
Industry Innovation Intensity	26	48.2	74.1	0.50	277.5
Skill Intensity	520	0.45	0.14	0.23	0.81
Capital Intensity	520	0.96	0.44	0.38	2.77
Country variables					
WGI	112	2.53	0.92	0.83	4.40
Human Capital (log)	2177	-1.99	0.94	-5.62	-0.31
Physical Capital	2177	-3.33	1.45	-6.77	-0.82
Country*Industry variables					
Industry's share in total exports in 1990	2309	2.60	7.21	0.00	100
Industry Innovation Intensity * WGI	2309	118.9	202.5	0.4	1221.1
Skill Intensity * Human Capital	42685	-0.76	0.41	-4.28	-0.08
Capital Intensity * Physical Capital	42685	-2.87	1.92	-18.58	-0.41

Source: Authors' calculations.

5. Results

5.1. Cross-country evidence

Before estimating the models introduced in section 2, we look at the relationship between innovation, exports and the quality of institutions in a cross-country perspective. To do so, the concept of innovation intensity for individual industries can be extended to countries by using countries' export mixes.[17]

Innovation intensity of a country's exports can be defined as the average innovation intensity of the goods it exports, calculated as $\bar{Y}_j = \sum_i z_{i,j}.y_i$ where $z_{i,j}$ is the share of industry i in country j's total exports, and y_i is the innovation intensity of industry i.

Table 3 shows that there is a strong correlation between the quality of economic institutions and the average innovation intensity of exports in a large sample of countries (see Annex 1 for a list of these countries).[18] Column (1) reports the estimated relationship between the quality of institutions and the average innovation intensity of exports; column (3) reports the relationship with the average innovation intensity of output; and columns (2) and (4) report the results using a Japan-referenced measure of innovation instead of the baseline US-referenced measure (based on simple regressions).

Table 3: Quality of institutions and average innovation intensity of exports and production

	Exports		Production	
Variable	(1) $\overline{Y_{exp}}^{ref\ US}$	(2) $\overline{Y_{exp}}^{ref\ JPN}$	(3) $\overline{Y_{prod}}^{ref\ US}$	(4) $\overline{Y_{prod}}^{ref\ JPN}$
Quality of institutions	8.76***	0.509***	5.88***	0.374***
	(0.326)	(0.014)	(0.268)	(0.014)
Number of observations	3306	3306	3385	3385
R^2	0.18	0.31	0.19	0.19

Source: Authors' calculations.

Notes: The dependent variables are respectively the average innovation intensity of exports and of production, using either the US-based measure of patent intensity (columns (1) and (3)) or the Japanese-based measure of R&D intensity (columns (2) and (4)). Robust standard errors are reported in parentheses. *** indicates significance at the 1 per cent level.

[17] See, for instance, Hausmann and Klinger (2007) for an example of a measure of economic sophistication based on the export mix.

[18] In a separate paper (Gelebo, Plekhanov and Silve, 2015) we discuss further the measure of innovation intensity of exports and its correlation with the quality of economic institutions. We show in particular that the link with institutional quality is especially strong in low-quality institutional environments. Besides the quality of economic institutions, we also show that innovation intensity of exports is strongly correlated with the size and openness of the economy (positive correlation) and the presence of natural resources rents (negative correlation).

This suggests a strong positive relationship between quality of economic institution and innovation intensity, which is investigated further using data on industry-country exports.

5.2. Results

Table 4 reports fixed-effects estimation results for equation [1]. The first column reports estimates for the basic specification, which controls for the initial share of the industry's exports in total exports of the country, industry and country-year fixed effects. The coefficient on the interaction term between industry innovation intensity and country economic institutions is positive and statistically significant, suggesting that countries with stronger economic institutions enjoy higher exports in more innovation-intensive industries.

In the second column we report estimates when the coefficient of interest is allowed to vary between advanced economies and emerging markets in order to investigate whether the impact of institutions is stronger in one of these two groups. The estimates indicate that the quality of institutions matters for both advanced economies and emerging markets (the difference between the estimated marginal effects is not statistically significant).

Next, we control for human and capital factor endowments, which are likely to be significant determinants of comparative advantage (column (3)). The coefficient on the interaction term remains positive and statistically significant. Column (4) reports estimates with the interaction with the *Advanced* and *Emerging* dummies. The magnitude of the coefficients decreases somewhat but they remain positive and statistically significant at the 10 per cent level of significance.

To test the link between innovation and growth, we now turn to the estimation of equation [2] in which the dependent variable is the annual compounded growth rate of exports for a given country and a given industry over the period 1990-2010 (Table 5). In all specifications, we control for the initial share of exports in 1990 and we include country and industry fixed effects. As in Table 4, column (1) reports estimates with only the interaction term between industry innovation intensity and country quality of institutions, while column (2) provides separate estimates for advanced and emerging market economies, and columns (3) and (4) report estimates of the specification including skill and capital factor endowment interactions.

The estimated coefficient for the interaction term between institution and innovation intensity is positive and statistically significant in most specifications. This result suggests that exports of innovation-intensive industries do grow relatively faster in countries with stronger economic institutions, and this effect is statistically significant. The estimates further indicate that the quality of institutions matters more for the relative growth of innovation-intensive exports in emerging markets and developing economies compared with advanced economies (the difference between the respective coefficients is statistically significant at the 5 per cent level).

In order to understand the magnitude of this effect, we can look at one industry which is in the first quartile in terms of innovation intensity (for instance, pharmaceuticals) and another which is around the 75th percentile of the distribution (such as primary metals). A one standard deviation improvement in the quality of economic institutions (say, from the level of

Albania to that of Poland) will boost the average growth rate of the exports of the more innovation-intensive industry, pharmaceuticals, by an extra 0.4 percentage point a year relative to the growth rate of base metals. In the case of emerging markets, the extra growth premium for the more innovation-intensive industry is estimated to be around one percentage point a year. This is a sizeable difference, given that the median rate of growth across all industries and countries in the sample is around 8 per cent.

Table 4: Dependent variable – industry exports value (logarithm)

	(1)	(2)	(3)	(4)
Variable	Institutions measured as average of 4 World Governance Indicators (WGI) [avg. over 1996-2010]			
Industry's share in total exports in 1990	0.092*** (0.006)	0.092*** (0.006)	0.098*** (0.007)	0.098*** (0.007)
Industry Innovation Intensity * WGI	0.003*** (0.000)		0.003*** (0.000)	
Innovation Intensity * WGI * Advanced		0.003*** (0.000)		0.002*** (0.001)
Innovation Intensity * WGI * Emerging		0.002*** (0.001)		0.001* (0.001)
Skill Intensity * Human Capital			0.852*** (0.194)	0.902*** (0.194)
Capital Intensity * Physical Capital			0.071*** (0.022)	0.072*** (0.022)
Industry Fixed Effects	Yes	Yes	Yes	Yes
Country-Year Fixed Effects	Yes	Yes	Yes	Yes
Number of observations	45,637	45,637	42,685	42,685
Number of countries	144	144	112	112
R^2	0.84	0.84	0.84	0.84

Sources: Authors' calculations using data from UN Comtrade and Feenstra et al. (2005) (exports data), US Bureau of Labor Statistics (deflators, employment), USPTO (US patent grants), the World Bank's Worldwide Governance Indicators, the NBER-CES Manufacturing Industry Database (skill and capital intensities), Barro and Lee (2013) (human capital stock) and the Penn World Table 8.0 (physical capital stock).

Notes: The dependent variable is the natural logarithm of total exports in current US$ for a given industry in a given country. Export values have been deflated using industry-specific deflators calculated for US industries. As the United States is used to estimate the innovation intensity of industries, it is excluded from all regressions. All regressions include industry and country-year fixed effects (coefficient estimates not reported). Data on Worldwide Governance Indicators are averages for the period 1996-2010. Robust standard errors are indicated in parentheses. ***, ** and * denote statistical significance at the 1, 5 and 10 per cent levels, respectively.

Table 5: Dependent variable – annual compounded growth rate of industry exports, 1990-2010, in per cent

Variable	(1)	(2)	(3)	(4)
	Institutions measured as average of 4 World Governance Indicators (WGI) [avg. over 1996-2010]			
Industry's share in total exports in 1990	-0.176***	-0.175***	-0.265***	-0.216***
	(0.020)	(0.020)	(0.041)	(0.040)
Industry Innovation Intensity * WGI	0.0084***		0.001	
	(0.003)		(0.003)	
Innovation Intensity * WGI * Advanced		0.013***		0.008*
		(0.004)		(0.005)
Innovation Intensity * WGI * Emerging		0.022***		0.018**
		(0.006)		(0.007)
Skill Intensity * Human Capital			5.65***	5.16***
			(1.870)	(1.869)
Capital Intensity * Physical Capital			-0.900**	-0.960**
			(0.378)	(0.377)
Industry Fixed Effects	Yes	Yes	Yes	Yes
Country Fixed Effects	Yes	Yes	Yes	Yes
Number of observations	3069	3069	2573	2573
Number of countries	144	144	118	118
R^2	0.50	0.50	0.54	0.54

Sources: Authors' calculations using data from UN Comtrade and Feenstra et al. (2005) (exports data), US Bureau of Labor Statistics (deflators, employment), USPTO (US patent grants), the World Bank's Worldwide Governance Indicators, the NBER-CES Manufacturing Industry Database (skill and capital intensities), Barro and Lee (2013) (human capital stock) and the Penn World Table 8.0 (physical capital stock).

Notes: The dependent variable is the average annual growth in exports for a given industry in a given country between 1990 and 2010. Export values have been deflated using industry-specific deflators calculated for US industries. As the United States is used to estimate the innovation intensity of industries, it is excluded from all regressions. All regressions include industry and country fixed effects (coefficient estimates not reported). Data on Worldwide Governance Indicators are averages for the period 1996-2010. The annual compounded growth rate of exports is calculated using as initial export value the average over [1990-1992] and as final export value the average over [1998-2000]. Robust standard errors are indicated in parentheses. ***, ** and * denote statistical significance at the 1, 5 and 10 per cent levels, respectively.

Table 6 reports the results of the dynamic panel model estimation looking at the annual rates of export growth. The estimated coefficient for the institution/innovation intensity interaction term remains positive and statistically significant. The long-run effect of institutions on differences between export growth rates of various industries can be estimated by dividing the estimated coefficient β by the convergence factor $(1-\alpha)$, where α is the coefficient on the lag of the dependent variable. Based on this calculation, the long-run growth premium (corresponding to a one standard deviation improvement in institutions) for an industry at the 25th percentile of innovation intensity compared with an industry at the 75th percentile is estimated at around 9 percentage points.

Results suggest that industries involving higher levels of innovation are able to grow faster, thereby driving economic growth – provided that the quality of economic institutions is appropriate. The estimates also imply that the quality of economic institutions is particularly important for the development of innovation-intensive industries.

Table 6: Dependent variable – exports (log)

	(1)
1-year lag of industry export value	0.667*** (0.019)
Skill Intensity * Human Capital	0.718*** (0.103)
Capital Intensity * Physical Capital	0.087*** (0.009)
Industry Innovation Intensity * WGI	0.0006*** (0.0001)
Number of observations	48,365
Number of countries	130
R^2	0.52

Sources: Authors' calculations using data from UN Comtrade and Feenstra et al. (2005) (exports data), US Bureau of Labor Statistics (deflators, employment), USPTO (US patent grants), the World Bank's Worldwide Governance Indicators, the NBER-CES Manufacturing Industry Database (skill and capital intensities), Barro and Lee (2013) (human capital stock) and the Penn World Table 8.0 (physical capital stock).

Notes: The dependent variable is the natural logarithm of total exports in current US$ for a given industry in a given country. Export values have been deflated using industry-specific deflators calculated for US industries. As the United States is used to estimate the innovation intensity of industries, it is excluded from the regression. Data on Worldwide Governance Indicators are averages for the period 1996-2010. Coefficients are estimated by two-stage GMM. Robust standard errors are indicated in parentheses. ***, ** and * denote statistical significance at the 1, 5 and 10 per cent levels, respectively.

5.3. Robustness checks

Total output

We conduct a number of robustness checks. First, we test the impact of the quality of institutions on the level and growth of industry output rather than exports. The results, reported in Table 7, are similar to those obtained with exports, with coefficients on the interaction term of similar magnitude and similar significance. The long-run growth premium corresponding to a one standard deviation improvement in the quality of institutions for an industry at the 25th percentile of innovation intensity compared with an industry at the 75th percentile is estimated at around 8 percentage points (column 5). We note, however, that total output exhibits greater path dependence (with an estimated coefficient on the first lag $\hat{\alpha} = 0.879$) and that factor endowments appear to be less important for total outputs than for exports. This is consistent with the view that exports rather than industrial production give a more accurate picture of industry output that is internationally competitive.

Other interactions

To check the robustness of our results, we also test whether other country characteristics rather than the quality of institutions could explain why countries specialise in the export of innovation-intensive goods. To do so, considering our second specification, we interact the innovation intensity of industry with country characteristics such as the level of financial development, human capital endowment and physical capital endowment. Results are reported in Table 8. All coefficients for added interaction terms are positive and statistically significant which may reflect the strong correlation of alternative country characteristics with the quality of institutions. Yet, the estimated coefficient for the interaction between innovation intensity and the quality of institutions remains positive, statistically significant and preserves its magnitude. Column (5) reports the results when adding an interaction term between the innovation intensity and the number of letters in a country's name as a "placebo test". The estimated coefficient for this interaction term is not statistically different from 0 confirming that the positive results for the quality of institutions are not spurious effects arising by construction.

Japan-referenced measures of innovation intensity

We now consider the robustness of our results to the use of an alternative measure of innovation intensity based on industry-specific spending on R&D in Japan (described in section 3.1). Results for all three specifications are reported in Table 9. The impact of the quality of institutions remains positive and statistically significant at the 1 and 5 per cent levels even when controlling for factor endowment. The results are also robust to the addition of additional interaction terms between other country characteristics and the quality of institutions (see Table 10).

Table 7: Determinants of industry output

Dependent variable	Industry output value (Panel)				Industry output value (Dynamic Panel)
	(1)	(2)	(3)	(4)	(5)
1-year lag of industry output value					0.879*** (0.015)
Industry's share in total output in 1995	0.119*** (0.016)	0.119*** (0.016)	0.123*** (0.017)	0.123*** (0.017)	
Industry Innovation Intensity * WGI	0.003*** (0.001)		0.002*** (0.001)		0.0002** (0.0001)
Innovation Intensity * WGI * Advanced		0.003*** (0.001)		0.003*** (0.001)	
Innovation Intensity * WGI * Emerging		0.003*** (0.001)		0.003** (0.001)	
Skill Intensity * Human Capital			0.358 (0.374)	0.348 (0.395)	0.0370 (0.075)
Capital Intensity * Physical Capital			-0.033 (0.047)	-0.033 (0.047)	0.073** (0.010)
Industry Fixed Effects	Yes	Yes	Yes	Yes	
Country Fixed Effects					
Country-Year Fixed Effects	Yes	Yes	Yes	Yes	
Number of observations	14691	14691	13856	13856	21568
Number of countries	55	55	48	48	97
R^2	0.88	0.88	0.88	0.88	0.36

Sources: Authors' calculations using data from UN Comtrade and Feenstra et al. (2005) (exports data), US Bureau of Labor Statistics (deflators, employment), USPTO (US patent grants), the World Bank's Worldwide Governance Indicators, the NBER-CES Manufacturing Industry Database (skill and capital intensities), Barro and Lee (2013) (human capital stock) and the Penn World Table 8.0 (physical capital stock).

Notes: The dependent variable is the natural logarithm of total output in current US$ for a given industry in a given country. As the United States is used to estimate the innovation intensity of industries, it is excluded from all regressions. All regressions include industry and country-year fixed effects (coefficient estimates not reported). Data on Worldwide Governance Indicators are averages for the period 1996-2010. Robust standard errors are indicated in parentheses. ***, ** and * denote statistical significance at the 1, 5 and 10 per cent levels, respectively.

Table 8: Additional robustness checks

	(1)	(2)	(3)	(4)	(5)
Industry's share in total exports in 1990	0.065*** (0.024)	0.065*** (0.025)	0.099*** (0.007)	0.092*** (0.006)	0.065*** (0.002)
Innovation Intensity * WGI	0.0033*** (0.0004)	0.0012*** (0.0006)	0.0027*** (0.0005)	0.0022*** (0.0006)	0.0033*** (0.0004)
Innovation Intensity * Private Credit		0.00008*** (0.0001)			
Innovation Intensity * Human Capital Endowment			0.0016*** (0.00055)		
Innovation Intensity * Physical Capital Endowment				0.0012*** (0.0004)	
Innovation Intensity * Length of Country Name					0.0001 (0.00008)
Industry Fixed Effects	Yes	Yes	Yes	Yes	Yes
Country-Year Fixed Effects	Yes	Yes	Yes	Yes	Yes
Number of observations	53253	51911	42714	45227	53253
Number of countries	143	137	113	127	143
R^2	0.81	0.81	0.82	0.81	0.81

Sources: Authors' calculations using data from UN Comtrade and Feenstra et al. (2005) (exports data), US Bureau of Labor Statistics (deflators, employment), USPTO (US patent grants), the World Bank's Worldwide Governance Indicators, the World Bank Global Financial Development Database (ratio of private-sector credit to GDP), the NBER-CES Manufacturing Industry Database (skill and capital intensities), Barro and Lee (2013) (human capital stock) and the Penn World Table 8.0 (physical capital stock).

Notes: The dependent variable is the natural logarithm of total exports in current US$ for a given industry in a given country. Export values have been deflated using industry-specific deflators calculated for US industries. As the United States is used to estimate the innovation intensity of industries, it is excluded from all regressions. All regressions include industry and country-year fixed effects (coefficient estimates not reported). Data on Worldwide Governance Indicators are averages for the period 1996-2010. Robust standard errors are indicated in parentheses. ***, ** and * denote statistical significance at the 1, 5 and 10 per cent levels, respectively.

Table 9: Determinants of industry export and export growth with the innovation intensity derived from the Japanese R&D intensity

Dependent variable	Compounded annual growth rate of exports between 1990 and 2010 (%) (Cross-section)		Total exports of the industry (USD) (Panel)		Total exports of the industry (USD) (Dynamic Panel)
	(1)	(2)	(3)	(4)	(5)
1-year lag of industry export value					0.656*** (0.020)
Industry's share in total exports in 1990	-0.254*** (0.040)	-0.249*** (0.040)	0.094*** (0.006)	0.093*** (0.006)	
Industry Innovation Intensity * WGI	0.332** (0.133)		0.158*** (0.013)		0.0402*** (0.0050)
Innovation Intensity * WGI * Advanced		0.569*** (0.169)		0.136*** (0.017)	
Innovation Intensity * WGI * Emerging		0.961*** (0.262)		0.105*** (0.027)	
Skill Intensity * Human Capital	4.594** (2.013)	4.118** (2.011)	0.560*** (0.126)	0.582*** (0.125)	0.829*** (0.113)
Capital Intensity * Physical Capital	-1.118*** (0.399)	-1.197*** (0.397)	0.082*** (0.020)	0.084*** (0.020)	0.088*** (0.009)
Industry Fixed Effects	Yes	Yes	Yes	Yes	
Country Fixed Effects	Yes	Yes			
Country-Year Fixed Effects	n.a.	n.a.	Yes	Yes	
Number of observations	2193	2193	36308	36308	41142
Number of countries	118	118	112	112	130
R^2	0.54	0.55	0.84	0.84	0.53

Sources: Authors' calculations using data from UN Comtrade and Feenstra et al. (2005) (exports data), US Bureau of Labor Statistics (deflators), the Japanese Statistics Bureau (R&D expenditures and employment), the World Bank's Worldwide Governance Indicators, the NBER-CES Manufacturing Industry Database (skill and capital intensities), Barro and Lee (2013) (human capital stock) and the Penn World Table 8.0 (physical capital stock).

Notes: In specifications (1) and (2), the dependent variable is the average annual growth in exports for a given industry in a given country between 1990 and 2010. In specifications (3), (4) and (5) the dependent variable is the natural logarithm of total exports in current US$ for a given industry in a given country. Export values have been deflated using industry-specific deflators calculated for US industries. In this specification, the innovation intensity of industries has been derived from Japanese R&D intensities, and therefore Japan is excluded from all regressions. All regressions include industry and country-year fixed effects (coefficient estimates not reported). Data on Worldwide Governance Indicators are averages for the period 1996-2010. Robust standard errors are indicated in parentheses. ***, ** and * denote statistical significance at the 1, 5 and 10 per cent levels, respectively.

Table 10: Additional robustness checks with Japan-referenced data

	(1)	(2)	(3)	(4)	(5)
Industry's share in total exports in 1990	0.0085***	0.0086***	0.093***	0.087***	0.0085***
	(0.005)	(0.005)	(0.006)	(0.005)	(0.005)
Innovation Intensity * WGI	0.16***	0.12***	0.15***	0.13***	0.16***
	(0.012)	(0.020)	(0.015)	(0.019)	(0.012)
Innovation Intensity * Private Credit		0.0016***			
		(0.0005)			
Innovation Intensity * Human Capital Endowment			0.049***		
			(0.014)		
Innovation Intensity * Physical Capital Endowment				0.035***	
				(0.012)	
Innovation Intensity * Length of Country Name					-0.0019
					(0.003)
Industry Fixed Effects	Yes	Yes	Yes	Yes	Yes
Country-Year Fixed Effects	Yes	Yes	Yes	Yes	Yes
Number of observations	43062	41967	36333	38519	43062
Number of countries	143	137	113	127	143
R^2	0.82	0.83	0.84	0.83	0.82

Sources: Authors' calculations using data from UN Comtrade and Feenstra et al. (2005) (exports data), US Bureau of Labor Statistics (deflators), the Japanese Statistics Bureau (R&D expenditures and employment), the World Bank's Worldwide Governance Indicators, the World Bank Global Financial Development Database (ratio of private-sector credit to GDP), the NBER-CES Manufacturing Industry Database (skill and capital intensities), Barro and Lee (2013) (human capital stock) and the Penn World Table 8.0 (physical capital stock).

Notes: The dependent variable is the natural logarithm of total exports in current US$ for a given industry in a given country. Export values have been deflated using industry-specific deflators calculated for US industries. In this specification, the innovation intensity of industries has been derived from Japanese R&D intensities, and therefore Japan is excluded from all regressions. All regressions include industry and country-year fixed effects (coefficient estimates not reported). Data on Worldwide Governance Indicators are averages for the period 1996-2010. Robust standard errors are indicated in parentheses. ***, ** and * denote statistical significance at the 1, 5 and 10 per cent levels, respectively.

6. Conclusion

In this paper, we provide evidence that economic institutions are an important determinant of innovation in a large sample of advanced and emerging market economies. Innovation in turn translates into economic growth, and thus innovation appears to be an important channel through which better economic institutions can lead to higher growth in the long run.

In particular, the analysis showed that industries involving higher levels of innovation grow faster in countries with a higher quality of economic institutions. Countries with better economic institutions therefore tend to develop more innovation-intensive structures of exports as over time innovation-intensive industries increase their contribution to overall exports of these countries.

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Annex 1: Countries in the sample

Afghanistan
Albania
Angola
Argentina
Aruba
Australia
Austria
Bahamas
Bahrain
Bangladesh
Barbados
Belgium
Belize
Benin
Bermuda
Bolivia
Brazil
Bulgaria
Burkina Faso
Burundi
Cambodia
Cameroon
Canada
Central African Republic
Chad
Chile
China
Colombia
Congo
Costa Rica
Côte d'Ivoire
Cuba
Cyprus
Czech Republic
Denmark
Djibouti
Dominican Republic
Ecuador
Egypt
El Salvador
Equatorial Guinea
Ethiopia
Fiji
Greece
Guatemala
Guinea
Guinea-Bissau
Guyana
Haiti
Honduras
Hong Kong
Hungary
Iceland
India
Indonesia
Iran
Iraq
Ireland
Israel
Italy
Jamaica
Japan
Jordan
Kenya
Kiribati
Korea, Dem. Rep.
Korea, Republic of
Kuwait
Lao PDR
Lebanon
Liberia
Libya
Macao
Madagascar
Malawi
Malaysia
Mali
Malta
Mauritania
Mauritius
Mexico
Mongolia
Morocco
Mozambique
Myanmar
Nepal
Norway
Oman
Pakistan
Panama
Papua New Guinea
Paraguay
Peru
Philippines
Poland
Portugal
Qatar
Russia
Rwanda
Saint Kitts and Nevis
Samoa
Saudi Arabia
Senegal
Serbia
Seychelles
Sierra Leone
Singapore
Somalia
South Africa
Spain
Sri Lanka
Sudan
Suriname
Sweden
Switzerland
Syria
Tanzania
Thailand
Togo
Trinidad and Tobago
Tunisia
Turkey
Uganda
Ukraine
United Arab Emirates
United Kingdom
USA
Uruguay
Venezuela

Finland	Netherlands	Vietnam
France	Nicaragua	Yemen
Gabon	Niger	Zambia
Gambia	Nigeria	Zimbabwe
Germany		