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Understanding multilevel interactions in economic development

Martin Srholec
CERGE-EI
Academy of Sciences of the Czech Republic
martin.srholec@cerge-ei.cz

Micheline Goedhuys
UNU-MERIT
Maastricht University
micheline.goedhuys@skynet.be

Abstract

National framework conditions not only directly affect firms? productivity but also mediate returns on their technological efforts. Although this has been recognized in literature for long, quantitative tests that explicitly consider this hypothesis remain rare. Using panel data methods on a World Bank dataset of about 16,000 manufacturing firms in 35 developing countries, we estimate the magnitude of the direct and indirect effects of the institutional framework on firm?s total factor productivity. Our results confirm the importance of the national factors for firms? productivity. Furthermore, the estimates reveal significant indirect influence of the national institutions on productivity of firms through mediating the returns on firms? technological efforts.

Jelcodes:O12,C33

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Abstract

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Keywords: Productivity, technology, institutions, microdata, multilevel mixed-effects model.

JEL codes: C39, D24, O12, O14, O31, O43

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1. Introduction

Economic development is a multilevel problem. Many factors at various levels of aggregation chip in. Firms invest in research and development (R&D), adopt new technologies and train their workers to use them productively. Governments design policies aimed to, at least in an ideal world, providing infrastructure, incentives and institutions that boost firms' productivity. Still other factors often out of reach for firms or even governments, such as deeply rooted cultural traits, play a role too. Because none of these factors is likely to be the dominant, or sufficient, driver of productivity alone, and because the factors operating at different levels intertwine with each other, their effects should be studied in an integrated multilevel framework. The main contribution of this paper is to illuminate these multilevel interactions in a more complete way than the empirical literature has been able to do so far.

Since Schumpeter (1934, 1939 and 1943), economists have been challenged to study how the "micro, mezzo and macro" spheres of the economy jointly evolve in the process of economic development. Endogenous growth models have gone a long way to elaborate the thesis of increasing returns driven by knowledge spillovers between firms and other organizations (Romer, 1986; Grossman and Helpman, 1990; Aghion and Howitt, 1992). Even broader framework conditions have been emphasized in the literature on technological catching up (Abramovitz, 1986; Fagerberg, 1987; Verspagen, 1991). Neo-Schumpeterian perspectives on long waves drew attention to the (mis)match between the techno-economic system and socio-institutional characteristics in diffusion of new technologies (Perez, 1983). Nevertheless, these contributions and the vast empirical research that has recently followed from them are distinctly macroeconomic, with implicit micro foundations, but focusing on the national patterns.

Explicitly micro-founded is the thesis about survival of firms propelled by innovation, but determined by the environment, which is at the core of growth modeling in evolutionary economics (Nelson and Winter, 1982). Here the focus is on dynamic interactions between heterogeneity of firms given by their technology, selection environment given by markets and innovation. But in this approach the interaction goes one-way, predominantly bottom-up in the sense that the macro patterns become derived as aggregations of micro outcomes, hence distinctly macro phenomena are lacking. As Castellacci (2007) rightly laments, understanding of how behavior of firms is shaped by specific characteristics of the macro environment, even though repeatedly called for (Dosi, 1997; Dosi and Nelson, 2010), remains limited in this tradition.

Multilevel thinking about economic development, at least at the conceptual level, has become emblematic for systemic approaches to innovation (Lundvall, 1992; Nelson, 1993; Edquist 1997). Innovation and therefore development is portrayed as a collective problem, which cannot be fully understood by focusing at a single level of analysis. At the core of this perspective is a firm, which performance is affected by the national institutions, but which in turn shapes the aggregate development, so forming the essential link between micro and macro patterns. Synergies, feedbacks and interactions between private and public actors within complex macrostructures naturally become the main focus of these studies. But formal modeling of relations like these proves to be difficult, especially in a dynamic framework, which prevented the systemic perspective to be formalized into mathematical models so far (Fagerberg et al. 2004; Lundvall et al., 2009).

Studies of technological upgrading in developing countries have long argued for a need to recognize not only technological capabilities at the firm level, but also the role of the national framework conditions (Kim, 1980; Dahlman et al., 1987; Lall, 1992). Lessons from industrialization in South-East Asia, the most favorite subject of these studies, offer a particularly strong practical support for the multilevel perspective. Upgrading efforts of firms on the one hand and governments on the other hand have been purposefully coordinated in Japan, later the Asian Tigers or more recently China, which generated some of the most spectacular development spurts our times, whereas dusty infrastructure, poorly educated workforce and generally weak institutions bulldozed upgrading efforts of firms elsewhere. Similarly to the systemic perspective, as Figueiredo (2006) points out, however, this literature has been seldom forged into formalized models and therefore econometric testing of the underlying hypotheses remains extremely rare.

Econometric estimates based on micro data to investigate the relationship between R&D, innovation and productivity have become increasingly synchronized using the same model on datasets from different countries, so that the results can be directly compared between them (Lööf et al., 2003; Griffith et al., 2006; Raffo et al., 2008; OECD 2009). Some researchers have even been even able to pool micro data from different countries (Janz et al., 2004; Mohnen et al., 2006; Goedhuys et al., 2008a), which allowed them to include dummies to capture the national contextual effects. By using dummy variables, however, we are able to detect whether the national differences matter, which is often the case, but we can only speculate what exactly drives them. Moreover, the effect of firm's technological efforts on their productivity is likely to differ by country too, but we have learnt very little from these studies about the mechanisms how the micro and macro effects interact with each other. All too many questions remain unanswered, because an integrated framework to analyze the multilevel interactions has been lacking.

The aim of the paper is to fill in this gap. To handle problems identified at different levels like these, we need micro data from many countries and macro indicators that capture the salient aspects of the nation framework conditions. For this purpose, we pool micro data from 35 countries, derived from the Productivity and Investment Climate Survey (PICS) organized by the World Bank (2003), which provides harmonized information on about 16,000 manufacturing firms. And we collect from various sources macro indicators, which directly measure the quality of research infrastructure, general education, financial system and governance. Using panel data methods, including multilevel hierarchical models, we test the explanatory power of the national conditions with regards to firms' productivity. More specifically, the index of firms' total factor productivity is estimated as a function of firm-level characteristics, national framework conditions and interactions thereof; while accounting for the unobserved heterogeneity between countries and treating the potential endogeneity of the explanatory variables with regards to the latent country effect.

As far as we know, this is the first time the impact of the macro factors on productivity of firms is analyzed in an integrated multilevel framework. So far this econometric approach has been applied in education studies, health science, human geography and biology, but rarely in the field of economics, innovation or development studies; with the exception of the recent papers by Srholec (2010, 2011), which used this methodology to study regional and national effects on the innovativeness of firms, but not their productivity. Clearly, the enormous requirement on scale and scope of data to estimate this kind of models has been a major reason for a lack of such evidence. But as new sources of data emerge from national statistical offices and international organizations, multilevel modeling becomes a viable method to econometrically study the more complex relationships that have been hypothesized in the theoretical literature.

2. Data

The analysis is based on micro data from the Productivity and Investment Climate Survey (PICS) organized by the World Bank. Firms were asked about various aspects of their business activity, including information on financial variables and a set of questions providing direct evidence on their technological activities, in a questionnaire harmonized across many developing countries. For more details on methodology of the survey see World Bank (2003).

To obtain total factor productivity, we need a measure of output, capital and labor. Y refers to the value added, measured by the difference between sales (turnover) and the sum of material and energy costs. The capital stock, denoted by K, is measured by the sum of the net book value - the value of assets after depreciation - of machinery and equipment (including vehicles) and land and buildings at the end of the fiscal year. Labor input, denoted by L, is measured as the sum of full-time permanent and seasonal (temporary) employees. In addition, as further explained below, we also need input factor costs, which for labour, denoted by W, refers to the wage bill of the firm, i.e. the total annual cost of labor (including wages, salaries, bonuses, social payments) and for capital, denoted by D, is estimated using the assumption of 20 percent annual depreciation of the net capital stock. All of the financial variables are expressed in 2000 constant USD according to Purchasing Power Parity (PPP) derived from World Bank (2007).

Besides the traditional production function variables, the dataset provides information on industry, age, foreign ownership and technological variables. The industry was difficult to identify because somewhat different classifications had been used in the various national datasets. For this reason we can distinguish only between five broad manufacturing sectors as follows: 1) Food and beverages; 2) Apparel, garments, leather and textiles; 3) Chemicals; 4) Wood, paper, non-metal materials and furniture; and 5) Metallurgy, machinery, electronics and transport equipment. AGE is the log of years since the firm has started operating in the country, which accounts for accumulated resources that are the function of time, including learning by doing effects. FOR refers to share of foreign ownership, which controls for benefits from access to technologies developed by the parent company abroad.

Equally essential to take into account are resources of firms directly devoted to search, absorption and generation of new technology. Research and development (R&D) is the traditional, and for a long time the only, seriously considered indicator. $R\&D_{ij}$ is defined as a dummy with value 1 if the firm devotes expenditure on this activity. But technological upgrading in developing countries is arguably about more than just R&D spending. Hence, it is fortunate that the dataset further provides information on adherence to ISO norms and formal training of employees. ISO is a dummy with value 1 if the firm has received ISO (e.g. 9000, 9002 or 14,000) certification and thus reflects the ability of the firm to conform to international standards. TRN is a dummy with value 1 if the firm provides formal (beyond “on the job”) training to its permanent employees. It is interesting to note that these broader technological characteristics of firms have been emphasized as particularly relevant but under-measured in the context of developing countries in the third edition of the Oslo Manual (OECD, 2005, pp. 141-144). Along these lines the PICS data provide much richer evidence as compared to what can be derived from most of the innovation surveys that have been conducted in developing countries so far.

A basic overview of the micro data is given in Table 1. After omitting observations with missing records, the sample comprises of about 16,000 manufacturing firms.[1] A quick look at the composition of the sample reveals widely different firms in terms of age, ownership and technological efforts. A typical age of the firm is 13 years, around a tenth of them did not operate for more than 5 years, and about a quarter of them were older than 25 years. A quick look at composition of the sample by ownership reveals that on average foreigners own about 7.7% of the equity and that about 4.5% of the sample consists of affiliates with 100% of foreign ownership. Averages of the technological variables are self-explanatory, and will be examined in more detail in the econometric framework below.

Table 1: Overview of the micro sample

Variable	Obs.	Mean	Std. Dev.	Min	Max
Ln(Y)	16,310	13.56	2.16	3.74	24.12
Ln(K)	16,310	13.25	2.28	3.28	22.24
Ln(L)	16,310	4.02	1.51	0	10.31
W/(W+D)	16,310	0.63	0.26	0	1
D/(W+D)	16,310	0.37	0.26	0	1
AGE	16,310	2.61	0.84	0	6.43
FOR	16,310	0.08	..	0	1
R&D	16,310	0.33	..	0	1
ISO	16,310	0.24	..	0	1
TRN	16,310	0.44	..	0	1

Since we use a multilevel model, we need data for specific country-level variables that capture the salient features of the national framework conditions. To reduce the influence of shocks and measurement errors occurring in specific years, we use these indicators in the form of three-year averages over a period prior to the year when the survey was conducted, if not specified

[1] It should be mentioned that 31 observations have been already excluded at this point, because they have been identified as major multivariate outliers at 1% significance level on the base of Mahalanobis distance computed for sales per employee, input costs per employee, labour costs per employee and the net capital stock per employee.

otherwise below.[2] This also limits the extent of missing data, which is crucial in a sample containing many developing countries. Still missing information had to be estimated for some countries, which is explained for the particular indicators below.

As far as the indicators for national framework conditions are concerned, a natural starting point is to consider the quality of the national science, research and educational systems (Nelson, 1993). Availability of research infrastructure, like universities, R&D labs and a pool of researchers in the labor force, reduce costs and uncertainties associated with firm's innovative activities, and are likely to generate positive externalities in the economy. As measures of the quality of national research institutions, we use three indicators that has been readily employed for this purpose in the existing literature on this topic (Furman, et al., 2002; Archibugi and Coco, 2004; Fagerberg and Srholec 2008): i) the number of scientific articles published in journals covered by Science Citation Index (SCI) and Social Sciences Citation Index (SSCI) derived from NSF (2010); ii) the number of international PCT (Patent Cooperation Treaty) patent applications recorded by WIPO (2010); and iii) gross domestic expenditure on R&D obtained from UNESCO (2010) that covers the sectors of private businesses, government, higher education institutes and other public organizations. For these indicators only the R&D data in Bangladesh had to be estimated. [3]

Education, which is at the heart of what Abramovitz (1986) would refer to as "social capabilities", and which Baumol, et al. (1989), Verspagen (1991) and many others have shown to be a crucial variable for explaining successful technological catching up, is a must to take into account. This aspect of the national institutional framework is represented by the following

[2] Since the surveys were conducted in different years, we computed averages over the three-year periods prior to the reference period of the particular survey.

[3] Since R&D data is not available in Bangladesh, we imputed the missing information by the average of 0.23% of other least developed countries (10 observations) over the relevant period in UNESCO (2010). This is consistent with the educated estimated by Gaillard (2010, pg. 96) about R&D levels in Sub-Saharan Africa where most of the other least developed countries are located that "The R&D budgets of Sub-Saharan African countries is around or less than 0.3 per cent of GDP, with the exception of South Africa" (pg. 96). More detailed R&D data by the source of funding does not exist for 13 countries and by the sector of performance does not exist for 11 countries, i.e. this information cannot be used because the data is missing data for about a third of the sample.

variables: i) the literacy rate in adult population (% of people ages 15 and above) derived from UNESCO (2010), because there is a relatively low frequency of this indicator, we use data from the latest year available; ii) public expenditure on education derived from World Bank (2010); and iii) average years of schooling (people ages 25 and above) in 2000 obtained from the updated version of Barro and Lee (2010) dataset.

Another feature of the institutional framework that has been traditionally emphasized by the existing research on cross-country differences in economic development, see for example King and Levine (1993), Levine (1997) and Levine and Zervos (1998), is the development and quality of financial institutions, for which we use the following two indicators: i) the amount of domestic credit to private sector that represents the size of the financial sector and therefore general availability of credit in the economy; and ii) bank nonperforming loans (% of total gross loans) that proxy the quality of the national financial institutions. Both of these indicators have been derived from World Bank (2010).

Yet one must not neglect broader aspects of formal institutions affecting how business is conducted in the country, for which data on the quality of governance generated in the "Governance Matters" project by Kaufmann, et a. (2009) in the World Bank comes handy. Using data from multiple sources, this dataset is an ensemble of indicators measuring various formal institutions and policies that are deemed to be relevant for productivity and growth, which are used by the authors to forge a set of six variables representing the quality of governance in the country as follows: i) Voice and Accountability; ii) Political Stability & Absence of Violence/Terrorism; iii) Government Effectiveness; iv) Regulatory Quality; v) Rule of Law; and vi) Control of Corruption. Higher scores indicate better governance and vice-a-versa.

Although there is a straightforward conceptual distinction between these aspects of the national institutional framework, another matter is to be able to distinguish between them empirically. As it comes out, these indicators tend to be highly correlated to each other, which makes it problematic to use them simultaneously in a regression due to concerns about multicollinearity.

Since it is empirically difficult to disentangle between their independent effects, we follow Fagerberg, et al. (2007) and Fagerberg and Srholec (2008) and use factor analysis to construct an overall measure that can represent their joint impact. Table 2 shows the results. All of the variables, except only of the Governance Matters indexes, are used in logs, partly because of assuming non-linearity in their effects as commonly assumed in the literature, but also to limit the possible impact of outliers. And whenever appropriate the variables are used relatively to the size of the country, i.e. on per capita basis. Only one factor score with eigenvalue higher than one was detected, explaining 60.9% of the total variance. So-called factor loadings, which are the correlation coefficients between the indicators (rows) and the principal factor (column), are reported in the table. Since all the indicators come out with high loadings, we use the variable derived from the factor analysis, denoted by INSTI in the following, as representing the overall quality of institutions in the country. Note that this variable comes out standardized from the factor analysis, i.e. mean of zero and standard deviation of one, with higher scores indicating better institutions.

Table 2: Results of the factor analysis

	INSTI
Log of science and engineering journal articles (per mil. people)	0.85
Log of PCT patent filings (per mil. people)	0.76
Log of gross expenditure on R&D (PPP, constant 2005 USD per capita)	0.86
Log of adult literacy rate (% of people ages 15 and above)	0.59
Log of public expenditure on education (PPP, constant 2005 USD per capita)	0.79
Log of average years of schooling (people ages 25 and above)	0.71
Log of domestic credit to private sector (PPP, constant 2005 USD per capita)	0.76
Log of bank nonperforming loans (% of total gross loans)	-0.56
Voice and Accountability (index)	0.71
Political Stability & Absence of Violence/Terrorism (index)	0.65
Government Effectiveness (index)	0.94
Regulatory Quality (index)	0.92
Rule of Law (index)	0.84
Control of Corruption (index)	0.87

Note: The number of observations is 35; one factor with an eigenvalue greater than 1 was detected, which explains 60.9% of the total variance; the extraction method was iterated principal factors.

Table 3 provides overview of the data by country. Surveys conducted in 35 developing countries are included. There is a lot of variety in the sample, ranging from the least developed countries with relatively adverse institutional frameworks (Ethiopia, Bangladesh and Madagascar) to emerging economies in Central and Eastern Europe (Hungary, Poland and Romania). Also both small and large countries, including most of the largest developing economies such as Argentina, Brazil, China and India, are covered by the data. A particularly thorny issue is whether the data are representative. Since we fully acknowledge this concern, we have included into the sample only national datasets with a reasonable number of observations given size and structure of the country. In addition, one should keep in mind that the micro data cover the manufacturing sector only, which remains relatively limited in many developing countries.[4]

[4] Even these could be seen as a relatively low number by some observers; in particular by those in developed countries who have the fortune to analyze large datasets. Nevertheless, micro data from developing countries (particularly on technological variables) are extremely scarce, so that we should not judge this dataset by standards of the most advanced countries. In fact, one can find plethora of papers in the literature based on samples of a few hundreds of firms, which at least implicitly claim to be representative to the context in question. Much more extensive micro data in a reasonably large number of developing countries is not likely to emerge anytime in the near future. Some developing countries have conducted surveys based on the CIS methodology (UNU-INTECH 2004), but access to micro data from these surveys remains limited, which prevents pooling them together for the purpose of multilevel analysis.

Table 3: Overview of the sample by country

Country	Year	Number of observations	INSTI
Algeria	2006	90	-0.39
Argentina	2005	342	0.16
Bangladesh	2006	1,172	-1.56
Bolivia	2005	162	-0.31
Brazil	2002	1,432	0.61
Chile	2005	317	2.36
China	2002	954	0.01
Colombia	2005	195	0.07
Costa Rica	2004	191	1.24
Ecuador	2005	219	-0.88
Egypt	2003	714	-0.32
El Salvador	2005	289	-0.20
Ethiopia	2005	207	-1.58
Guatemala	2005	262	-0.83
Honduras	2005	188	-0.73
Hungary	2004	195	2.32
India	2004	1,489	-0.32
Indonesia	2002	305	-0.98
Madagascar	2004	90	-0.68
Mexico	2005	705	0.85
Morocco	2002	650	-0.01
Nicaragua	2005	205	-0.81
Pakistan	2001	810	-1.22
Paraguay	2005	84	-0.97
Peru	2005	230	-0.09
Philippines	2002	450	-0.11
Poland	2004	316	1.59
Romania	2004	129	0.55
Saudi Arabia	2004	509	0.44
South Africa	2002	402	1.38
Thailand	2002	1,084	0.50
Turkey	2004	439	0.54
Uruguay	2005	141	1.14
Vietnam	2004	1,056	-0.67
Zambia	2006	287	-1.10

Finally, there is a long list of indicator for exogenous national conditions have been suggested as relevant instruments of difference in governance, institutions and policies across countries in the recent growth literature. Examples include factors such as differences in geography, nature, religion, ethnic divisions and colonial legacy (Acemoglu et al., 2002; Alesina et al., 2003; Bloom at al., 2003; Gallup et al., 1999; Masters and McMillan, 2001; Sachs et al., 2004). After screening of the recent literature on this subject the following five variables were selected: i) TROP refers to the proportion of land in tropical ecozone derived from Gallup et al. (1999); ii) MAL is the index of the stability of Malaria transmission developed by Kiszewski et al. (2004); iii) DIS is given by log of the number of persons killed (confirmed as dead, missing and presumed dead) in disasters of natural origin (droughts, earthquakes, extreme temperatures, floods, slides, waves, wind storms, etc.) per million people over 1975-2004 derived from UNEP (2005); iv) INDEP is to the log of years since national independence (Fearon, 2003); and v) MUSL refer to religions adherence of the population given by the proportion of Muslims in 1900 obtained from (McCleary and Barro, 2006).

3. Estimation and results

Total factor productivity of a firm is calculated following the methodology developed by Caves et al. (1982) which accounts for endogeneity of factor inputs. The methodology consists of constructing an index of productivity, where each firm's output, inputs and input cost shares are compared to those of a hypothetical firm, the reference point, given by the mean values of the industry. Hence, for each firm we obtain a non-parametrically calculated TFP index, which represents the productivity of the firm relatively to the industry, as follows:

(1) $$TFP_i = \left(lnY_i - \overline{lnY}\right) - \left(\sum_m \frac{1}{2}(\alpha_{im} + \overline{\alpha_m})\left(lnX_{im} - \overline{lnX_m}\right)\right)$$

where i is the firm, Y is the output, X is the input m, α is the cost share of the respective input factor, $\overline{Y}$, $\overline{X}$ and $\overline{\alpha}$ are the mean values for the industry in which the firm i is active and thus represent the reference point. More specifically, Y refers to the value added, m=[1,2] for the two inputs considered in the analysis, i.e. K for capital and L for labour, and therefore α is the ratio of the respective capital and labour costs to the sum of these costs.

A standard panel data regression model explaining the total labour productivity of the firm is as follows:

$$(2) \qquad \mathrm{TFP_{ij}} = \beta \mathrm{X_{ij}} + \gamma \mathrm{Z_j} + \mathrm{u_j} + \mathrm{e_{ij}}$$

where i is a firm, j is a country, β and γ are g and h vectors of coefficients associated with firm-level and country-level observable variables, the firm-level error term e_{ij} is assumed uncorrelated with the columns of (X_{ij}, Z_j, u_j) and has zero mean and constant variance σ_e conditional on X_{ij} and Z_j, and the latent country effect u_j is assumed to be a country-level random variable, distributed independently across countries, with variance σ_u.

Table 4 gives the results of traditional panel data estimators. First, there are the results of within fixed effects and generalized least squares (GLS) random effects estimators in the first and second columns, respectively. All of the firm-level predictors are statistically significant at conventional levels and with expected signs, except only of AGE_{ij}. Our main interest is in the estimated coefficient of the country-level $INSTI_j$ variable for the quality of national institutional framework, which as the panel-invariant variable is eliminated from the within estimator due to the underlying data transformation, but which is reported by the GLS estimator, because the latter exploits both the within- and between-country variation. Since $INSTI_j$ comes out with a positive and highly statistically significant coefficient, the GLS estimator strongly supports the thesis that institutions directly affect the productivity of firms: one standard deviation increase of $INSTI_j$ is estimated to boosts firms' TPF_{ij} by 22.3%. Arguably, this is a healthy contribution to firm's productivity.

GLS is more efficient than the within estimator, because of taking not only the within but also the between variation of X_{ij} into account, but requires additional orthogonality assumptions. In particular, the GLS estimator assumes that the explanatory variables are uncorrelated to u_j, i.e. $E(u_j \mid X_{ij}, Z_j) = 0$, which is likely to be violated in this model, whereas the within estimator does not require this assumption in order to be consistent. Note that the correlation coefficient across countries denoted by ρ almost halved from 0.124 to 0.076 after $INSTI_j$ have been taken into account in the GLS estimator, indicating that the remaining latent country effect is relatively small. Yet the unobserved heterogeneity across countries turns out to be consequential in econometric terms.

Hausman specification test considers the null hypothesis that the coefficients estimated by the within and GLS procedures are the same (Hausman, 1978). If there is no systematic difference between them, both of the estimators are consistent. But a rejection casts a doubt on whether the GLS results are unbiased, because some of the explanatory variables can be correlated to the latent u_j. Even though at the first glance the estimated coefficients seem reasonably similar, the test rejects the null at 5 percent significance level; the covariance matrices are based on the estimated disturbance variance from the consistent estimator. In other words, there seems to be a misspecification in the random effects model, as anticipated above.

Another way to look at this result is that the between and within effects of X_{ij} significantly differ from each other. The estimated between effects of X_{ij} may differ from the estimated within effects of X_{ij} due to omitted country-specific explanatory variables that simultaneously affect country-mean X_{ij} and the country-specific residual u_j and hence the country-mean TFP_{ij}, given the included explanatory variables. For instance, countries where firms tend to engage in R&D more frequently may also have more favourable unmeasured (or unmeasurable) characteristics, such as informal institutions, social traits and cultural context, including social capital, attitudes to technology, etc. In other words, this is the source of a potential country-level omitted variable bias, i.e. a potential endogeneity bias.

From this follows, however, that we can easily relax the assumption that the between and within effects of X_{ij} are the same, i.e. account for the potential endogeneity of X_{ij} with regards to u_j, by including the country-mean X_{ij} into the GLS estimate (Rabe-Hesketh and Skrondal 2008, pg. 115), because in this specification X_{ij} serve as instrumental variables of themselves.[5] In this

[5] An equivalent solution, which leads to the same results, is to exclude the original X_{ij} variables and instead control

specification of the GLS model, the estimated coefficients of the country-means X_{ij} represent the difference in between and within effects. If the between and within coefficients are equal, this model collapses to the previous GLS model. Hence, in the next step we fit the model with the country means of X_{ij}, denoted by $\overline{X}_{ij}$ in the table, as covariates.

Besides accounting for the potential country-level omitted variable bias, this allows us to identify whether the important sources of variation of X_{ij} are in firms' variation around the country means or in those means themselves. Note that in this specification the estimated coefficients of X_{ij} refer to the within effects, i.e. they are equivalent to the results of these variables in the within estimate, whereas the sum of the estimated coefficients of X_{ij} and country mean X_{ij} denote to their between effects. For instance, the results indicate that for the $R\&D_{ij}$ variable the estimated within-country effect is only 0.174, whereas the between-country effect is 0.174 + 1.082 = 1.256, i.e. the effects of firms' R&D capabilities concentrate at the country-level; perhaps because of economy-wide benefits driven by knowledge spillovers from firms' R&D to other firms operating in the same country. Similarly, the penetration of foreign ownership represented by FOR_{ij} explains noticeably more differences in firms' total factor productivity between countries than within them; perhaps because of strong country-level efficiency gains from the inflow of foreign direct investment. Also the differences of the within and between effects for these two variables appear to be non-random, i.e. statistically significant at 10% level, which indicates that these two are the endogenous troublemakers driving the rejection of the null hypothesis in the Hausman's specification test above. In contrast, the opposite result has been detected for the ISO_{ij} and TRN_{ij} capability variables, which seems to matter predominantly for productivity differences within the country. Arguably, these differences are quite potent findings in themselves. And we are going to pick up on them in more detail below. Furthermore, the possible inconsistency in estimating the corresponding X_{ij} coefficients could have been transmitted to results of the $INSTI_j$ variable of our prime interest too. However, this does not seem to be the case, because the magnitude of the $INSTI_j$ coefficient somewhat decreased after

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for deviation of X_{ij} from the country-mean and the country-mean X_{ij}, because this only affects the interpretation of the X_{ij} explanatory variables.

the country means of X_{ij} are accounted for but the coefficient remains highly statistically significant. Hence, this does not undermine the key finding of the analysis so far, namely that national institutions directly affect productivity of firms.

Adding the country means of X_{ij} solves the potential source of inconsistency due to correlation of the firm-level covariates and u_j, however this specification does not handle the potential endogeneity problem of the country-level covariate, i.e. correlation between $INSTI_j$ and u_j. Hence, in the next step we address this source of inconsistency in the framework of the instrumental variables estimate - G2SLS random-effects regression - treating $INSTI_j$ as endogenous. Exogenous variables given by geography, nature and history of the country are used as the excluded instruments: $TROP_j$ (-0.16), MAL_j (-0.37), DIS_j (-0.54), $INDEP_j$ (0.57) and $MUSL_j$ (-0.36); correlation to the $INSTI_j$ variable in brackets. The estimated $INSTI_j$ coefficient increased by about a third as compared to the last GLS estimate, while remaining highly statistically significant, hence these results indicate that there seems to be only a relatively weak endogeneity bias. Sargan's and Hansen's tests of overidentifying restrictions consider the null hypothesis that the excluded instruments are valid instruments, where a rejection casts doubt on whether the instruments are correctly excluded from the estimated equation. Neither of them rejects the null at any reasonable size test, so the instruments are confirmed to be empirically sound. Hence, the instrumental variables estimate provides consistent results with regards to the potential country-level endogeneity.[6]

[6] Note that if the country means of X_{ij} are not included in the G2SLS random-effects regression, Sargan's and Hansen's tests of overidentifying restrictions come out even less statistically significant.

Table 4
Dependent variable: TFP_{ij}

	(1) Within		(2) GLS		(3) GLS		(4) G2SLS		(5) HT	
$Intercept_{ij}$	-1.035***	0.031	-0.992***	0.065	-2.281***	0.878	-1.973**	0.997	-0.985***	0.200
$INSTI_j$	..		0.223***	0.058	0.187***	0.066	0.248***	0.096	0.535***	0.200
AGE_{ij}	0.014	0.011	0.015	0.011	0.014	0.011	0.014	0.011	0.015	0.011
FOR_{ij}	0.434***	0.039	0.437***	0.039	0.434***	0.039	0.434***	0.039	0.435***	0.039
$R\&D_{ij}$	0.174***	0.021	0.177***	0.021	0.174***	0.021	0.174***	0.021	0.174***	0.021
ISO_{ij}	0.202***	0.024	0.201***	0.024	0.202***	0.024	0.202***	0.024	0.202***	0.024
TRN_{ij}	0.123***	0.022	0.124***	0.022	0.123***	0.022	0.123***	0.022	0.123***	0.022
mn_AGE_j	..		..		0.291	0.338	0.186	0.380	..	
mn_FOR_j	..		..		1.596*	0.848	1.596*	0.909	..	
$mn\_R\&D_j$	..		..		1.082*	0.556	1.188*	0.607	..	
mn_ISO_i	..		..		-0.076	0.692	-0.272	0.771	..	
mn_TRN_j	..		..		0.053	0.413	0.010	0.445	..	
σ_u	0.432		0.329		0.329		0.354		0.495	
σ_e	1.148		1.148		1.148		1.149		1.148	
ρ	0.124		0.076		0.076		0.087		0.157	
R^2 within	0.029		0.029		0.029		0.029		..	
R^2 between	0.362		0.376		0.575		0.565		..	
R^2 overall	0.051		0.102		0.123		0.126		..	
F	97.97***		..		..		..		..	
Wald χ^2	..		514.56***		528.30***		522.95***		684.89***	
Hausman's statistic	..		χ^2_5=13.48**		χ^2_5=0		χ^2_5=0		χ^2_5=0.77	
Sargan's statistic	..		..		..		χ^2_4=5.53		χ^2_2=0.81	
Hansen's statistic	..		..		..		χ^2_4=5.88		χ^2_2=0.80	
							Endogenous: $INST_j$ Excl. instruments: $TROP_j$, MAL_j, DIS_j, $INDEP_j$, $MUSL_j$		Endogenous: FOR_{ij}, $R\&D_{ij}$, $INST_j$	
Number of firms	16,310		16,310		16,310		16,310		16,310	
Number of countries	35		35		35		35		35	

Note: Estimated coefficients reported in the first column. Standard errors reported in the second column. *, **, *** denote significance at the 10, 5 and 1 percent levels.

Yet another way to tackle this source of endogeneity, i.e. correlation between $INSTI_j$ and u_j, is by the estimator suggested by Hausman and Taylor (1981), which exploits residuals from the within estimator for this purpose. But the identification of this estimator relies on the presence of exogenous within country varying variables. Because the between variation of FOR_{ij} and $R\&D_{ij}$ has been shown to be weakly correlated to the latent country effect, we treat them as if correlated to u_j as well, whereas AGE_{ij}, ISO_{ij} and TRN_{ij} are included as the exogenous explanatory variables that identify the estimation. Table 4 shows results of this exercise in the last column. Based on this estimator the magnitude of the $INSTI_j$ coefficient more than doubled compared to the earlier results; remaining highly statistically significant. Not much has changed for the firm-level coefficients. Again, Hausman's, Sargan's and Hansen's tests do not indicate a specification problem in this estimate.

To handle hypotheses identified at different levels like these, the method of multilevel modeling has been developed in the recent econometric literature (Goldstein, 2003). A multilevel model, sometimes also called a 'hierarchical', 'random coefficient' or 'mixed-effect' model is a statistical model that relates the dependent variable to predictor variables at more than one level. If a hierarchical structure of data exits, multilevel models allow us to properly estimate the extent to which differences between the higher-level units, such as countries, are accountable for performance at the micro level, in this case the productivity of firms. In addition, in a more complex model, we can examine whether the country conditions interact with the technological efforts the firms undertake individually to raise productivity, in other words to which extent the contextual effects influence the link between firms' technological capabilities and their productivity.

Hence, in the next step, we move to the more complex specification of the random effect model, where we not only consider the random intercept, but also allow the slope effects to be random. Raudenbush, et al. (2004) developed for this purpose the so-called Hierarchical Lineal Model

(HLM) estimator. There are two main differences as compared to the conventional GLS model. First, this estimator is based on the maximum likelihood procedure; more specifically in this paper we use the restricted maximum likelihood, which is more suitable for datasets with a relatively small number of panels. Second, in the GLS estimator we include $INSTI_j$ directly into the firm-level part of the model. However, as soon as $INSTI_j$ represents a genuinely country-level characteristic, as it truly is here, it is more appropriate to allow it to affect only the country-level variables, i.e. only the random effect of the country and the random slope effects. And this is precisely the main purpose of the following hierarchical system of equations:

(3) Firm-level model:

$$TFP_{ij} = \alpha_{0j} + \beta_{1j}\,AGE_{ij} + \beta_{2j}\,FOR_{ij} + \beta_{3j}\,R\&D_{ij} + \beta_{4j}\,ISO_{ij} + \beta_{5j}\,TRN_{ij} + e_{ij}$$

Country-level model:

$$\alpha_{0j} = \gamma_{00} + \gamma_{01}\,INSTI_j + u_{0j}$$

$$\beta_{1j} = \gamma_{10} + \gamma_{11}\,INSTI_j + u_{1j}$$

$$\beta_{2j} = \gamma_{20} + \gamma_{21}\,INSTI_j + u_{2j}$$

$$\beta_{3j} = \gamma_{30} + \gamma_{31}\,INSTI_j + u_{3j}$$

$$\beta_{4j} = \gamma_{40} + \gamma_{41}\,INSTI_j + u_{4j}$$

$$\beta_{5j} = \gamma_{50} + \gamma_{51}\,INSTI_j + u_{5j}$$

where i is a firm, j is a country, α_{0j} is the conditional productivity level of firms operating in country j, in other words the average total factor productivity (TFP_{ij}), which is indentified by the estimated grand intercept γ_{00} and the country-level effect γ_{01} on the total factor productivity. In a similar fashion, effects of the firm-level variables β_{1j}, β_{2j} ... β_{5j} are allowed to differ by country, because they are given not only by the estimated means of the slope coefficients γ_{10}, γ_{20} ... γ_{50} across countries, but also by the cross-level interactions between the firm- and country-level predictors γ_{11}, γ_{21} ... γ_{51}. Error terms u_{0j} for the intercept and u_{1j}, u_{2j} ... u_{5j} for the slope coefficients indicate that these effects vary not only as a function of the predictors but also as a function of unobserved country effects conventionally assumed to be sampled from a normal distribution with expected zero mean and variance = σ^2_u and independent from the firm-level error term e_{ij} and from each other. [7]

Table 5 gives results of the HLM estimates. Fixed effects are reported in the upper part, while random effects are in the lower part of the table. First, we consider the basic HLM model, where the country-level $INSTI_j$ predictor is included only for the intercept, but both the estimated intercept and slope coefficients are allowed to vary across countries by including the respective random effects. Second, we examine the full HLM model, which adds the country-level predictor $INSTI_j$ not only for the intercept but also for the slopes. Next, as above, we control for the country means of X_{ij} and perform the instrumental variables estimate, which treats $INSTI_j$ as endogenous by using the same set of exogenous variables given by geography, nature and history of the country as the excluded instruments.

Results of the basic model are presented in the first column in Table 5. Overall, the slope random coefficients reveal that there is a considerable variability in the effects of X_{ij} by country highlighting their sensitivity to the national framework conditions. [8] More specifically, the random effects indicate to which extent the effects of X_{ij} are distributed around the estimated mean. A useful characteristic of the standard deviation is that with normally distributed observations, about 68% of the observations lie less than one standard deviation from the mean, and about 95% of the observations lie between two standard deviations below and above the mean. Hence, one can easily calculate how much the firm-level effects are expected to vary across countries.

$R\&D_{ij}$ boosts the outcome by 0.157, confirming that this aspect of technological capabilities is relevant in the context of most developing countries. However, a closer look at the distribution of

[7] Note that the GLS model could be seen as the reduced version of the HLM model, where the country-level equations are substituted for $\alpha_{0j} + \beta_j$ into the firm-level model.

[8] Since the HLM (version 6.04) package assumes that the variances may not be normally distributed, a chi-square test of the residuals is performed (Raudenbush, et al. 2004). Nevertheless, this should be interpreted with caution because the variances are bounded at zero by definition, while we generally expect the residuals to be non-zero, so that the meaning of their statistical significance is not the same as for an ordinary variable.

this coefficient reveals that for 68% of the countries the effect of R&D is estimated to lie in the fairly broad range of [-0.031, 0.345], which indicates that for firms in countries with the least favorable conditions the positive effect of R&D on productivity does not hold, while in countries with the most enabling environment R&D is a strong productivity enhancing activity. And in a small number of countries the effect of R&D is estimated to stretch even to the negative territory. Normally, this is difficult to envisage, but in extremely adverse conditions, for instance during a steep slump of aggregate demand, the negative relationship may actually start to kick in.

FOR_{ij} comes out with the largest firm-level coefficient, which confirms the prevailing productivity gap between foreign- and domestic-owned firms, because the foreign affiliates benefit from access to technology developed by the parent company. The mean effect is a rise of TFP_{ij} by 0.430, but within a large range of [0.062, 0.798] in 95% of the countries; in other words from a fairly dual economy that is typical for most developing countries to roughly equal productivity in both groups of firms that is commonplace in advanced economies, from where most of the leading multinational companies originate.

Similarly the other firm-level effects are quite widely distributed around the mean. For 68% of the countries, the coefficient is estimated in the range of [-0.100, 0.162] for AGE_{ij}, even though the corresponding fixed effect remains statistically insignificant at the conventional levels, and in the range of [0.056, 0.286] for ISO_{ij} and [-0.016, 0.250] for TRN_{ij}. It is clear that the national differences clearly matter for the impact of firm-level characteristics, including their technological capabilities, on the performance of firms. Indeed, this is an encouraging finding for the more detailed analysis, in which we attempt to pin down the specific national framework conditions with which these effects vary.

Hence, in the next step, we investigate whether the estimated slopes of the firm-level predictors vary along the quality of the institutional framework represented by the $INSTI_j$ variable, which is the estimate reported in the second column of Table 5. In other words, the "slopes-as-outcomes" model examines not only whether $INSTI_j$ directly affects the intercept, but also whether this national factor has an indirect impact by mediating the respective firm-level relationships. Given the large random differences across countries detected above, the idea is to test whether the firm-level effects vary with the national institutions.

The main result is, first, a positive and weakly statistically significant interaction between the $INSTI_j$ and $R\&D_{ij}$ variables, which signals that the effect of internal R&D activity of firms increases with the quality of institutions in the country. Hence, firms benefit more from their R&D activity if located in an advanced environment with superior quality of the science base, research infrastructure, education system, governance and other complementary assets to their own innovative efforts. In other words, there seems to be credible evidence in the data that the beneficial effects of these national institutions tend to be reinforced for firms with their own R&D capabilities. From the policy perspective, this result suggests that resources devoted to improving institutions, including the research infrastructure, yields tangibly positive effects on a broad stratum of firms, though these resources become much more productive if the local firms come forward with nurturing appropriate absorptive capacity by themselves. Governments certainly need to improve the institutions, but firms have their job to do too.

Second, somewhat more statistically significant cross-level interactions have been detected between $INSTI_j$ of the country on one hand and the adherence to ISO_{ij} standards and the commitment to training given by the TRN_{ij} dummy at the firm-level. The negative sign of these interaction terms indicates that, in contrast to the previous case, these aspects of firm's capabilities contribute relatively more to productivity of firms in less institutionally advanced countries. A quality certificate signals to other contracting parties that the firm is a high-performer on quality management issues (Terlaak and King, 2006; Swann et al., 1996), which is especially beneficial when information asymmetries are large and when firms fear opportunistic behavior of their partners (King et al., 2005). To the extent that the $INSTI_j$ variable can be understood as a broad proxy for institutions, including the lack of trust in the society, firms with their credentials backed by the quality certificate come out more competitive. Hence, the ability to adhere to international quality standards naturally makes more difference in an environment, where the national “rules of the game” (and the adherence to them) are rather weak. Likewise, resources devoted to training of employees appear more important for firms operating in countries with lower quality of education. In other words, to achieve desired productivity levels, firms tend to leverage deficiencies of national education systems by establishing their own training programs. Arguably, this highlights a systemic failure of governments in developing countries to furnish incumbent firms with educated people they demand to produce effectively. General education must be clearly a priority for every government serious about economic development.

In the third column, as already anticipated, we test robustness of the results to the inclusion of the country means of X_{ij} to the model indicated by the set of δ_1, δ_2 … δ_5 coefficients. Again, the impact on the results is fairly limited, so the estimate is not sensitive to this. Finally, in the last column, we perform the instrumental variables estimate, treating $INSTI_j$ as endogenous, with the exogenous variables given by geography, nature and history of the country used as the excluded instruments. Here, the impact is more noticeable, especially on the statistically significance of the coefficients of interest, as the estimated standard errors increased, but qualitatively the main results remain the same.

Table 5: Dependent variable: TFP_{ij}

	(1) HLM		(2) HLM		(3) HLM		(4) H2SLM	
For Intercept$_{ij}$ (α_{0j})								
Intercept$_{ij}$ (γ_{00})	-1.011	(0.088)***	-1.010	(0.087)***	-2.617	(0.712)***	-2.404	(0.817)***
INSTI$_j$ (γ_{01})	0.233	(0.061)***	0.282	(0.075)***	0.234	(0.074)***	0.304	(0.121)**
For AGE$_{ij}$ slope (β_{1j})								
AGE$_{ij}$ (γ_{10})	0.031	(0.026)	0.031	(0.026)	0.029	(0.026)	0.029	(0.026)
INSTI$_j$ (γ_{11})	..		-0.013	(0.022)	-0.012	(0.021)	-0.024	(0.049)
For FOR$_{ij}$ slope (β_{2j})								
FOR$_{ij}$ (γ_{20})	0.430	(0.049)***	0.429	(0.050)***	0.430	(0.049)***	0.430	(0.050)***
INSTI$_j$ (γ_{21})	..		-0.043	(0.056)	-0.047	(0.057)	-0.043	(0.074)
For R&D$_{ij}$ slope (β_{3j})								
R&D$_{ij}$ (γ_{30})	0.157	(0.040)***	0.156	(0.039)***	0.153	(0.039)***	0.154	(0.040)***
INSTI$_j$ (γ_{31})	..		0.061	(0.032)*	0.059	(0.032)*	0.056	(0.036)
For ISO$_{ij}$ slope (β_{4j})								
ISO$_{ij}$ (γ_{40})	0.171	(0.028)***	0.173	(0.026)***	0.174	(0.026)***	0.172	(0.026)***
INSTI$_j$ (γ_{41})	..		-0.059	(0.024)**	-0.051	(0.024)**	-0.071	(0.027)**
For TRN$_{ij}$ slope (β_{5j})								
TRN$_{ij}$ (γ_{50})	0.117	(0.030)***	0.119	(0.028)***	0.116	(0.028)***	0.115	(0.030)***
INSTI$_j$ (γ_{51})	..		-0.066	(0.028)**	-0.066	(0.028)**	-0.059	(0.032)*
mn_AGE$_j$ (δ_1)	..		..		0.421	(0.277)	0.348	(0.315)
mn_FOR$_j$ (δ_2)	..		..		1.429	(1.001)	1.532	(1.070)
mn_R&D$_j$ (δ_3)	..		..		0.922	(0.526)*	0.949	(0.495)*
mn_ISO$_i$ (δ_4)	..		..		0.016	(0.569)	0.055	(0.593)
mn_TRN$_j$ (δ_5)	..		..		0.096	(0.381)	0.006	(0.361)
Intercept$_{ij}$ (u_{0j})	0.474 (233)***		0.474 (222)***		0.453 (151)***		0.448 (154)***	
AGE$_{ij}$ slope (u_{1j})	0.131 (195)***		0.133 (197)***		0.132 (197)***		0.130 (192)***	
FOR$_{ij\ j}$ slope (u_{2j})	0.184 (45)*		0.188 (44)		0.184 (44)		0.193 (45)*	
R&D$_{ij}$ slope (u_{3j})	0.188 (99)***		0.181 (96)***		0.184 (96)***		0.191 (98)***	
ISO$_{ij\ j}$ slope (u_{4j})	0.115 (47)*		0.097 (41)		0.092 (41)		0.098 (44)*	
TRN$_{ij}$ slope (u_{5j})	0.133 (62)***		0.115 (52)**		0.115 (52)**		0.124 (57)***	
e_{ij}	1.136		1.137		1.137		1.136	
Deviance	50,735		50,754		50,739		50,739	
Number of firms	16,310		16,310		16,310		16,310	
Number of countries	35		35		35		35	

Note: Linear unit-specific model; restricted maximum likelihood estimate; coefficients and robust standard errors in brackets reported for the fixed effects; standard deviation and Chi-square in brackets reported for the random effects; *, **, *** denote significance at the 10, 5 and 1 percent levels.

5. Conclusion

Using panel data methods, we estimated a model of total factor productivity of firms with effects of their technological capabilities nested in national framework conditions. Our results confirm the important role of the national institutional framework for explaining differences in the performance of firms. Furthermore, the results of the multilevel estimator reveal significant indirect influence of the national institutions on productivity of firms through interaction with the various proxies for firm's technological efforts. Indeed, while on average the firm-level technological variables are positively associated with their productivity, the magnitude of these effects differs markedly across countries. More specifically, we find that training of workers and adherence to international standards are important driving forces for productivity in less intuitionally developed countries, while R&D on the contrary is shifting productivity more in economies with more advanced institutional framework.

Multilevel modeling appears to be a promising item in the tool box of research on technological capabilities, which may allow us to formally test complex predictions of the contextual perspectives on economic development. Although we have constrained ourselves only to 2-level multilevel model in this paper, there is a variety of specifications of the model that in principle could be estimated. A straightforward extension would be to take into account a more complicated hierarchical structure. For example, we can specify 3-level models with firms in regions within countries or so-called cross-classified models with firms simultaneously nested in sectors and countries, which take into account the sectoral differences even more seriously than we have been able to do. All that matters is access to suitable data, which unfortunately remains scarce, especially for the least developed nations.

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