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THE POLICY AND INSTITUTIONAL DRIVERS OF ECONOMIC GROWTH: NEW EVIDENCE FROM GROWTH REGRESSIONS

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ABSTRACT/RÉSUMÉ

The policy and institutional drivers of economic growth across OECD and non-OECD economies: new evidence from growth regressions

This paper analyses the policy and institutional determinants of long-run economic growth for a sample of OECD and non-OECD countries, with two objectives. First, it assesses the extent to which the main findings from growth regressions covering industrial countries are robust to a larger sample covering lower-income OECD and non-OECD countries. Confirmation is found from pooled mean group estimates for the larger sample of countries that long-run GDP per capita levels are increased *inter alia* by education policies, trade openness, R&D expenditures and policy frameworks that are conducive to low inflation, although the estimated effect of education is implausibly large. Second, the paper proposes a new growth regression framework that explicitly models technology diffusion and allows exploring the growth effects of a wider set of policies and institutions, while alleviating some of the constraints of the pooled mean group estimator. Under this approach, the estimated return to education is more in line with available evidence from microeconomic studies. Regulatory barriers to entrepreneurship, explicit barriers to trade and – especially – patent rights protection appear to be fairly robust determinants of long-run cross-country differences in technology. Some other policies and institutions such as trade liberalisation are found to speed up technology convergence. There is limited evidence here that the effects of policies and institutions vary depending on countries' level of development. These findings are subject to the usual limitations of growth regression analysis.

JEL classification codes: N10; O40; O47.
Keywords: Economic Growth; Policy and Institutions; Panel Data.

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Les déterminants politiques et institutionnels de la croissance économique au sein des économies OCDE et non OCDE : nouveaux résultats à partir d'équations de croissance

Cet article analyse les déterminants politiques et institutionnels de la croissance économique de long terme pour un échantillon de pays membres et non membres de l'OCDE avec deux objectifs. Premièrement, il évalue dans quelle mesure les principaux résultats de régressions couvrant des pays industrialisés sont robustes à un échantillon plus large couvrant les pays de l'OCDE à bas revenus et des pays non membres. Les résultats d'estimations en *pooled mean group* sur l'échantillon élargi de pays confirment que la croissance de long terme du PIB par tête augmente notamment avec les politiques d'éducation, l'ouverture aux échanges commerciaux, les dépenses en R-D et les structures politiques associées à un faible niveau d'inflation, bien que l'estimation élevée de l'effet de l'éducation soit peu plausible. Deuxièmement, le papier propose un nouveau cadre de régressions de croissance qui modélise de façon explicite la diffusion technologique et permet d'explorer les effets sur la croissance d'un ensemble plus vaste de politiques et d'institutions, tout en allégeant certaines des contraintes de l'estimateur *pooled mean group*. Sous cette approche, le rendement estimé de l'éducation est davantage en accord avec les estimations provenant d'études microéconomiques. Les barrières réglementaires à l'entreprenariat, les barrières explicites aux échanges commerciaux et surtout, la protection des droits sur les brevets apparaissent comme des déterminants assez robustes des différences technologiques de long terme entre pays. D'autres politiques et institutions, telles que la libéralisation des échanges commerciaux, accélèrent la convergence technologique. Il existe une évidence limitée en faveur d'effets différents des politiques et des institutions suivant le niveau de développement des pays. Ces résultats sont soumis aux limites habituelles de l'analyse en régressions de croissance.

Codes JEL : N10 ; O40 ; O47.
Mots clé : Croissance économique ; Politiques et institutions ; Données de panel.

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THE POLICY AND INSTITUTIONAL DRIVERS OF ECONOMIC GROWTH: NEW EVIDENCE FROM GROWTH REGRESSIONS

By Romain Bouis, Romain Duval, and Fabrice Murtin[1]

1. Introduction and executive summary

1. Over the past years, academic literature has contributed to a better understanding of the determinants of long-run economic growth by identifying a set of growth-enhancing policies and institutions on top of the traditional influences of physical capital accumulation (Solow, 1957) and human capital in the form of education or health (Mankiw *et al.*, 1992; Benhabib and Spiegel, 1994; Cohen and Soto, 2007; Lorentzen *et al.*, 2007; Aghion *et al.*, 2011). A number of studies stress the importance for economic growth of trade openness (Frankel and Romer, 1999; Wacziarg and Welch, 2008), of the level and the structure of taxation and government expenditures (Barro, 1990; Easterly and Rebelo, 1993; Lee and Gordon, 2005), of research and development activity (Nelson and Phelps, 1966; Vandenbussche *et al.*, 2006), of well-developed financial markets (King and Levine, 1993; Levine, 2005), of economically-friendly institutions or cultural traits (Hall and Jones, 1999; Tavares and Wacziarg, 2001; Djankov *et al.*, 2003; Acemoglu *et al.*, 2005; Aghion *et al.*, 2010). On methodological grounds, several empirical approaches have been considered. Some studies rely on panel data growth regressions, allowing to examine convergence issues among countries (Islam, 1995; Bassanini *et al.,* 2001 among others). Other papers directly estimate the long-run relationship of the augmented Solow model in static form by using cross-country regressions (Mankiw *et al.*, 1992), with more recent contributions of this strand conducting sensitivity analysis with the so-called Bayesian Averaging of Classical Estimates (BACE) approach (Sala-I-Martin *et al.*, 2004) or Monte-Carlo simulations (Hauck and Wacziarg, 2009). Finally, some efforts have been taken to address the endogeneity of policies and institutions through the use of various instrumental approaches.

2. This paper follows previous OECD literature in taking a panel approach to identify the growth effects of policies and institutions (see *inter alia* Bassanini *et al.,* 2001; OECD, 2003; Arnold, 2008; Boulhol *et al.,* 2008). All earlier OECD papers primarily rely on a so-called conditional convergence framework, under which investment in various forms of capital as well as policies and institutions are assumed to have a permanent impact on cross-country differences in GDP per capita levels but only

1. The authors are members of the Economics Department of the OECD. Without implication, the authors would like to thank several OECD colleagues, in particular Jens Arnold, Orsetta Causa, Alain de Serres, Sean Dougherty, Jørgen Elmeskov, Guiseppe Nicoletti, Oliver Rohen, Jean-Luc Schneider, Anita Woelfl, for their valuable comments and Martine Levasseur for technical assistance as well as Celia Rutkoski and Olivier Besson for editorial support. The paper has also benefited from comments by members of the Working Party No. 1 of the OECD Economic Policy Committee and from comments in an internal OECD Economics Department seminar. The usual disclaimer applies.

temporary effects on growth rates.[2] On the technical side, the common econometric approach has been to use the so-called pooled mean group (PMG) estimator.The purpose of the present paper is two-fold:

- Assess whether the main findings from these various growth regressions are robust to a larger sample of countries including all OECD member states, accession and large non-member countries. To this end, growth regressions are run using the PMG estimator for a sample of 40 countries, rather than the typical 20-22 countries covered in earlier OECD work.[3]

- Propose a new, alternative growth regression framework that alleviates some of the limitations of the PMG approach – which increase the sensitivity of results to small changes in specification when regressions are run for a larger number of institutions and a more unbalanced cross-country time-series panel dataset – and allows exploring a wider set of policies and institutions. The approach developed here builds on Bloom *et al.* (2002) and Bloom and Canning (2005). It explicitly models the technology diffusion process across countries and over time, which appears warranted in a context where *analysis* covers a more heterogeneous set of countries – in terms of levels of total factor productivity (TFP) – than in the past. Policies and institutions are then assumed to be potential influences on cross-country differences in both the speed of diffusion of technology and long-run TFP levels.

3. The main findings from the PMG estimates are:

- Most of the key results obtained in previous OECD papers appear to be robust to considering a larger sample of countries. In particular, the coefficient on the physical investment rate is of a similar order of magnitude, and there is confirmation that policies and institutions such as trade openness, research and development (R&D) expenditures and policy frameworks that are conducive to low inflation have a significant positive impact on long-run GDP per capita levels. One exception is inflation volatility, which is not found to be detrimental for long-run income levels when accession and large non-member countries are included in the sample, at odds with the significant negative impact found on a sample covering only OECD countries in both this paper and previous OECD analysis. Finally, some of the earlier analyses could not be replicated over the enlarged sample for lack of data. In particular, the growth effects of taxes could not be fully tested for as detailed information on tax variables is not available for non-OECD countries. Even so, the growth effects of the overall tax burden, the tax structure and government consumption obtained for an extended sample of OECD countries are found to be qualitatively similar to those previously obtained for the restricted sample of 21 OECD countries. In particular, a high overall tax burden and lower reliance on consumption and property taxes in taxation appear to reduce long-run GDP per capita levels.

- The importance of education for long-run material living standards is confirmed, although the estimated effect is implausibly large. To some extent, a larger coefficient on human capital in regressions featuring a greater proportion of emerging countries is consistent with available evidence on decreasing marginal returns to education. Still, the values obtained for the full

2. However, the estimated equation is general enough to encompass other types of growth models, such as an endogenous growth model *à la* Lucas (1988). See Arnold *et al.* (2007) for details.

3. The 40 countries are Australia, Austria, Belgium, Brazil, Canada, Chile, China, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, India, Indonesia, Ireland, Israel, Italy, Japan, South Korea, Luxembourg, Mexico, the Netherlands, New Zealand, Norway, Poland, Portugal, Russia, Slovakia, Slovenia, South Africa, Spain, Sweden, Switzerland, Turkey, the United Kingdom, and the United States.

sample can be twice as large as the already fairly high coefficients obtained for the restricted sample of 21 OECD countries or in most of the existing empirical literature.

4. Empirical analysis based on the alternative growth regression framework presented in this paper yields the following results:

- The coefficient obtained on human capital implies an average return to one additional year of education of about 10%, which is more consistent than PMG estimates with the returns derived from microeconomic studies. However, this estimate is not robust across all of the specifications estimated in this paper.

- Many policy and institutional variables are found to correlate significantly and with the expected sign with long-run TFP levels. Because some of these policies and institutions are strongly correlated – with richer countries typically benefiting from more favourable policy settings in multiple areas, it is hard to discriminate between them, however. Only the negative impact of regulatory barriers to entrepreneurship, explicit barriers to trade and low patent rights protection appears to be robust to controlling for other potential policy drivers of long-run TFP levels. When controlling more broadly for all unobserved country-specific (policy and non-policy) drivers of long-run TFP levels by means of country fixed effects, patent rights protection still remains significant – although the impact of some other, time-invariant policy indicators can no longer be tested for in such a setting.

- Some other policies and institutions, in particular trade liberalisation, are found to be associated with higher speed of convergence of TFP to its steady state, and through this channel with higher long-run GDP per capita levels.

- There is limited evidence here that the effects of policies and institutions vary depending on countries' level of development.

5. Over and above the caveats mentioned above, the main findings from this paper are subject to the usual limitations of growth regression analysis, including *inter alia* the potential endogeneity of policies and institutions and the difficulty of identifying long-run drivers of income over relatively short periods. Another issue is that several countries – especially former transition economies – featured in the sample experienced large macroeconomic shocks over the estimation period that can hardly be fully controlled for.

6. The remainder of the paper is organised as follows. Section 2 provides a brief reminder of the PMG approach and presents new estimates for various samples including the full sample of OECD, accession, and enhanced engagement countries. Section 3 presents a new framework for exploring the role of policies and institutions on growth, and presents estimation results. Section 4 concludes. Data construction methodology and sources are described in Appendix 1, with greater details on human capital data in Appendix 2.

2. The pooled mean group approach

Methodology

7. The underlying framework of the empirical approach is the human capital augmented neoclassical growth model (Mankiw *et al.*, 1992) with the Cobb-Douglas production function:[4]

4. A detailed description of this approach can be found in Bassanini *et al.* (2001) and in Boulhol *et al.* (2008).

$$Y(t) = K(t)^{a} H(t)^{b} \left(A(t)L(t)\right)^{1-a-b}, \qquad [1]$$

where *Y*, *K*, *H* and *L* are respectively output, physical capital, human capital, and labour, a and b are the elasticities of output with respect to physical and human capital, and $A(t)$ is the level of technological and economic efficiency. Following amongst others Cellini (1997), $A(t)$ can be decomposed into two elements: An economic efficiency part $I(t)$, that depends on a set *X* of institutions and public policies, and an exogenous technological progress component $\Omega(t)$ assumed to grow at the rate $g(t)$.

8. From the dynamics of physical and human capital, one obtains the following expression for the steady-state output

$$\ln y^{*}(t) = \ln A(t) + \frac{a}{1-a}\ln s_K(t) + \frac{b}{1-a}\ln h^{*}(t) - \frac{a}{1-a}\ln(g(t)+n(t)+d), \qquad [2]$$

where s_K is the investment rate in physical capital, $n(t)$ is the population growth rate and *d* the depreciation rate. This expression is however not very useful as observed growth rates of output include out-of-steady state dynamics. Considering the transitional dynamics of *y* and adding the short-run dynamics around the transition path (see Mankiw *et al.*, 1992) yields the following error correction equation

$$\Delta \ln y(t) = -\lambda\left(\ln y(t-1) - \frac{a}{1-a}\ln s_K(t) - \frac{b}{1-a}\ln h(t) + \frac{a}{1-a}\ln\left(g(t)+n(t)+d\right) - \sum_j z_j \ln X_t^{\,j} + gt\right) \qquad [3]$$
$$+ a_0 + a_1 \Delta \ln s_K(t) + a_2 \Delta \ln h(t) + a_3 \Delta \ln\left(g(t)+n(t)+d\right) + \sum_j b_j \Delta \ln X_t^{\,j} + \varepsilon_t .$$

where, as noted earlier, the X^js denote policies and institutions that influence long-run TFP levels.

9. At this stage, three options are available for the estimation of the equation. First, it can be assumed that coefficients on short-run dynamics (a_1, a_2, a_3, and b_j) and the convergence parameter λ are the same for all countries (pooling assumption), and that all cross-country heterogeneity is captured by the constant coefficients $a_{0,i}$ (country-fixed effects approach). Imposing identical dynamics in each economy is however quite implausible, due for instance to the well documented differences in the degrees of resilience to macroeconomic shocks across OECD countries (see *e.g.* Duval *et al.*, 2007). At the other extreme, one can impose heterogeneity on all coefficients by estimating separate equations for each country and calculate the simple mean of these estimates across countries to obtain the mean group estimator (MG). However, this approach entails a significant loss of efficiency, and rests on the questionable assumption that integrated economies with access to common technologies have nevertheless different long-run production function parameters. Finally, an intermediate option, which is followed here, is to assume that countries share the same long-run production function but have specific convergence speed, short-run dynamic coefficients and error variances. Under this approach, implemented with the so-called pooled mean group (PMG) estimator developed by Pesaran *et al.* (1999), the error correction equation is written as follows:

$$\Delta \ln y_{i,t} = -\lambda_i\left(\ln y_{i,t-1} - \frac{a}{1-a}\ln s_{Ki,t} - \frac{b}{1-a}\ln h_{i,t} + \frac{a}{1-a}\ln\left(g+n_{i,t}+d\right) - \sum_j z_j \ln X_{i,t}^{\,j} + gt\right) \qquad [4]$$
$$+ a_{0,i} + a_{1,i}\Delta \ln s_{Ki,t} + a_{2,i}\Delta \ln h_{i,t} + a_{3,i}\Delta \ln\left(g+n_{i,t}+d\right) + \sum_j b_{j,i}\Delta \ln X_{i,t}^{\,j} + \varepsilon_{i,t} .$$

10. The main assumption of the PMG approach – the homogeneity of long-run coefficients – can be tested using Hausman test. The MG estimator is indeed always consistent but less efficient than the PMG estimator, while the latter may be inconsistent if the equation is wrongly specified. Under the null hypothesis of the test, the variance-covariance matrix of the two estimators is the same so that the more efficient estimator (*i.e.* the PMG one) must be used if the null is not rejected.

11. Following Arnold *et al.* (2007), regressions include country-specific time controls to account for non-constant country idiosyncrasies. Non-linear time controls such as five-year period dummies are *a priori* more appropriate than a linear time trend given the observed variations in trend productivity growth in many countries over the past decades.

Variable and data description

12. Growth equations are estimated on an unbalanced annual panel of 40 countries over the period 1971-2007.[5] Data sources and variables construction are detailed in Appendix 1. The baseline variables are:

- *Dependent variable* ($\Delta \ln y_t$): growth in real GDP per capita of population aged 15-64 years expressed in 2005 constant purchasing power parities (PPP);
- *Convergence variable* ($\ln y_{t-1}$): lagged real GDP per capita of population aged 15-64 years in 2005 PPPs;
- *Physical capital accumulation* ($\ln S_K$): ratio of real gross fixed capital formation to real GDP;
- *Stock of human capital* ($\ln h_t$): average number of years of schooling of the population aged 25-64 years. The education database is an enhanced version of the Cohen-Soto (2007) database borrowed from Morrisson-Murtin (2010). Importantly, it corrects for differential mortality rates across educational groups (see Appendix 2 for details);
- *Population growth* (n_t): growth of the working age population (15-64 years).

13. The policy/institutional variables are (for a more detailed discussion of their expected effects on growth, see *e.g.* OECD, 2003):

- *Indicators of government size and financing:* ratio of taxes over GDP, share of consumption and property taxes in total taxes, and ratio of government nominal final consumption expenditure to nominal GDP (in log). Both the size of the public sector and the structure of taxation and public spending can influence overall economic efficiency and growth.
- *Measures of inflation:* growth rate of the private final consumption deflator and the standard deviation of this rate over three years. Lower and more stable inflation is expected to be beneficial for growth by reducing uncertainty in the economy and enhancing the efficiency of the price mechanism.
- *Measures of R&D intensity:* gross domestic expenditure on R&D as a percentage of GDP. R&D expenditures can translate into new technologies, faster absorption of existing ones, and more

5. Former West Germany is technically considered as a country over 1971-89, and reunified Germany as another one from 1991. Countries formerly in transition such as Hungary, Poland, Russia, or the Slovak Republic enter the sample in 1990 or 1995.

efficient ways of using available resources of physical and human capital. If successful in these respects, higher R&D spending might permanently raise economic growth.

- *Financial development:* IMF financial liberalisation index, as described in Abiad *et al.* (2010). Well-developed financial systems are likely to channel resources more efficiently throughout the economy. In order to mitigate endogeneity concerns, a policy index is used here instead of the usual financial development measures such as stock market capitalisation or overall credit to GDP ratios.

- *Trade openness:* ratio of exports plus imports to GDP, adjusted for country size by taking the residual from a regression of the crude trade exposure variable on population size. Trade openness can stimulate growth through a variety of channels including greater exploitation of comparative advantage, economies of scale, diffusion of knowledge and the exit of least productive firms and expansion of most productive ones.

All these policy/institutional variables are introduced with a one-year lag to better identify their impact on output. For several non-OECD countries, many of these variables are not available or only for a few years, making the sample even more unbalanced in richer specifications.

Empirical results

Baseline equations

14. Table 1 presents estimates of the baseline growth regression for different sample sizes using the PMG estimator.[6] All specifications include five-year period dummies, as several information criteria suggest that this specification is more appropriate than a linear or quadratic time trend. For comparison purposes, column (1) shows long-run coefficient estimates for the sample of 21 OECD countries used in previous OECD work.[7] The sizes of the coefficients are broadly similar to those reported in Arnold *et al.* (2007).[8] The coefficient of the physical investment rate is equal to 0.26, which implies an elasticity of output to capital of about 0.2, while the unit coefficient of human capital implies an elasticity of output to mean years of schooling of about 0.9.[9] However, when the sample is extended to all pre-enlargement (30) OECD countries (column (2)) or all 40 countries (column (3)), the coefficient of human capital becomes implausibly large, increasing from around 1 to 2.3. To some extent, a larger coefficient on human capital in

6. The assumption of slope homogeneity for the long run parameters (the null hypothesis of the Hausman test) is never rejected, indicating that the pooled mean group estimator must be preferred over the mean group approach.

7. These countries are Australia, Austria, Belgium, Canada, Denmark, Finland, France, Greece, Ireland, Italy, Japan, the Netherlands, Norway, New Zealand, Portugal, Spain, Sweden, Switzerland, the United Kingdom, the United States and West Germany (until 1989). One major difference in this paper is that the reunified Germany is also considered from 1991. Results are however qualitatively unchanged when excluding this country.

8. One exception concerns the coefficient on population growth. The reason is that in order to be consistent with the theoretical model (see equation [4]), the growth rate of the population is augmented here by a constant term of 0.05 that captures the depreciation rate of capital and the exogenous rate of technological progress, as in Boulhol *et al.* (2008).

9. From equation [4], the implied elasticities of output to physical and to human capital are respectively given by $\hat{\alpha} = \frac{\hat{b}_{inv}}{1+\hat{b}_{inv}}$ and $\hat{\beta} = \frac{\hat{b}_{hc}}{1+\hat{b}_{hc}}$, where $\hat{b}_{inv}$ and $\hat{b}_{hc}$ are the estimated coefficients for the physical investment rate and the mean years of schooling, respectively.

regressions featuring a greater proportion of less advanced countries is consistent with available microeconomic evidence on decreasing marginal returns to education (see *e.g.* Psacharopoulos and Patrinos, 2004). However, these microeconomic studies still typically imply returns to schooling about half as large as those obtained here (see *e.g.* Psacharopoulos and Patrinos, 2004, or Heckman *et al.*, 2008).[10] Therefore the extension of the baseline growth regressions to a larger sample of countries seems to exacerbate the overestimation problem of the effect of human capital on growth.

Table 1. Pooled mean group results, baseline equations

	Dependent variable: Log GDP per capita		
	(1)	(2)	(3)
Long-run parameters			
Physical investment rate	0.256*** (0.04)	0.246*** (0.02)	0.255*** (0.02)
Human capital	1.078*** (0.06)	2.316*** (0.08)	2.241*** (0.08)
Population growth	-0.258*** (0.04)	-0.143*** (0.03)	-0.143*** (0.03)
Short-run parameters			
Convergence parameter	-0.293*** (0.06)	-0.374*** (0.04)	-0.339*** (0.03)
5-year dummies	Yes	Yes	Yes
Number of countries	21	30	40
Number of observations	788	1046	1352

Variables are in logarithm. Short-run coefficients are not reported, except for the convergence parameter. Estimations include country-specific five-year dummies. Standard errors are in parentheses. ***, **, * indicate a significance of the coefficients at the 1%, 5%, and 10% level, respectively.

The impact of policies and institutions on growth

15. The effects of policy and institutional variables are reported in Table 2. Columns (1) and (2) show the estimated impacts of trade openness, inflation and inflation volatility for the sample of pre-enlargement OECD countries and the full sample,[11] respectively. In both cases, as well as in all specifications in Table 2, the effect of trade exposure is statistically significant and of the same order of magnitude as that reported in previous studies for the restricted sample of 21 OECD countries.[12] Among OECD countries, both the level and the volatility of inflation have a negative effect on output per capita, but only the coefficient of inflation volatility is statistically significant at conventional levels. The opposite is found in regressions on the restricted sample of 21 OECD countries, as the coefficient for the level of inflation is significant but not the one for volatility (results not reported), suggesting that estimates are sensitive to sample composition. Such sensitivity is confirmed when estimating the equation for the whole sample (column (2)), which again yields a significant negative impact of the level of inflation but not of its volatility.[13]

10. As an example, consider a country where mean years of schooling would increase from 10 to 11 years. With a 2.3 coefficient estimate for human capital, this increase would translate into a $2.3 \times \log(11/10) = 22\%$ increase in GDP per capita. This is more than twice the expected value which typically falls between 4 and 12%.

11. The full sample in these specifications excludes Estonia and Russia, for which the time series are too short.

12. This robustness could also partly reflect business-cycle effects, however.

13. The effect of inflation volatility is even significantly positive at the 10% confidence level. However, this surprising result fully depends on the presence of Brazil and Slovenia in the sample, and may reflect the difficulty to properly control for catching-up or transition effects in these countries characterized by high inflation volatility as Slovenia or Brazil in the first half of the 1990's (dropping these two countries from

16. Turning to indicators of government size and financing, it appears that a high overall tax burden reduces long-run GDP per capita levels (column (3)), in line with previous results from Bassanini *et al.* (2001). Controlling for the overall tax burden, government consumption is found to have a positive effect on output per capita (column (3)). Column (4) shows the estimates for both the overall tax burden ratio and the share of consumption and property taxes in total tax revenues. As found in Arnold (2008), a higher reliance on consumption and property taxes (as opposed to income taxes) is positively related to long-run GDP per capita levels, consistent with the view that the former entail smaller economic distortions.

Table 2. Pooled mean group results with institutional and policy variables

	Dependent variable: Log GDP per capita					
	(1)	(2)	(3)	(4)	(5)	(6)
Long-run parameters						
Physical investment rate	0.188*** (0.01)	0.205*** (0.01)	0.243*** (0.02)	0.266*** (0.02)	0.068*** (0.02)	0.148*** (0.01)
Human capital	1.432*** (0.07)	1.461*** (0.06)	1.546*** (0.08)	1.923*** (0.09)	1.032*** (0.10)	1.372*** (0.07)
Population growth	-0.186*** (0.02)	-0.198*** (0.03)	-0.172*** (0.02)	0.016 (0.03)	-0.036 (0.04)	-0.102*** (0.02)
Trade openness	0.281*** (0.02)	0.296*** (0.01)	0.283*** (0.01)	0.350*** (0.02)	0.439*** (0.02)	0.295*** (0.01)
Inflation	-0.026 (0.04)	-0.005** (0.002)				
Inflation volatility	-0.209** (0.10)	0.011* (0.01)				
Government consumption			0.183*** (0.04)			
Overall Tax Burden			-0.399*** (0.10)	-0.484*** (0.12)		
Consumption & Property taxes				0.541*** (0.11)		
Research & Development					0.061*** (0.02)	
Financial liberalisation						0.021 (0.02)
Short-run parameters						
Convergence parameter	-0.369*** (0.07)	-0.307*** (0.07)	-0.365*** (0.07)	-0.295*** (0.05)	-0.227*** (0.07)	-0.367*** (0.07)
5-year dummies	Yes	Yes	Yes	Yes	Yes	Yes
Number of countries	30	38	29	29	31	34
Number of OECD countries	30	30	29	29	26	27
Number of observations	1001	1210	958	956	669	1078

Variables are in logarithm except the level and the volatility of inflation, the tax variables, and the financial liberalisation index. Short-run coefficients are not reported, except for the convergence parameter. Estimations include country-specific five-year dummies. Standard errors are in parentheses. ***, **, * indicate a significance of the coefficients at the 1%, 5%, and 10% level, respectively.

the sample dramatically changes the estimates). It also emphasizes the fragility of the results obtained with the PMG approach.

17. Expenditures on research and development have a positive effect on output per capita (column (5)), as previously suggested by studies based on a smaller sample of countries.[14] However, the estimated coefficient is significantly lower than in Bassanini *et al.* (2001) or Arnold (2008), who report elasticities of output per capita to the share of R&D expenditures in GDP of about 0.15 instead of 0.06 here. Finally, the financial liberalisation index has the expected positive sign but it is not statistically significant, unlike in recent IMF work which however controlled less extensively for other growth determinants (Christiansen *et al.*, 2009).

Limitations of the PMG approach

18. The PMG approach has one serious limitation, namely the large number of parameters to be estimated. This has the following consequences:

- Maximisation algorithms such as maximum likelihood can have difficulties to converge. The larger the set of explanatory variables, the larger the number of country-specific parameters to be estimated. Consequently, the number of covariates must remain limited to ensure numerical convergence. In practice, considering simultaneously more than three policy and institutional variables often proves to be difficult.
- Estimated coefficients are very sensitive to the inclusion of any new variable. In particular, the coefficient of human capital is dramatically reduced in specifications that also feature certain policies and institutions (see Table 2).
- PMG estimations are here performed by including country-specific five-year period dummies, which are found to better control for time influences than do *e.g.* country-specific linear time trends. Applying the PMG estimator on annual data with five-year period dummies however amounts to identifying the coefficients on the basis of annual variations within five-year periods. This is somewhat at odds with the objective of estimating a long-run growth model. Since the long-term relationship includes five-year dummies with country-specific coefficients, it is also identified on the basis of annual variations within five-year periods. This magnifies the risk of measurement error, as the within variance of many explanatory variables is only a small share of their total variance (see Hauck and Wacziarg, 2009).

These limitations of the PMG estimator, as well as the need to consider a broad set of potential policy and institutional drivers of growth that do not always have the time-series required for PMG estimation, point to the usefulness of considering an alternative approach. The alternative approach chosen, detailed below, turns out to dramatically reduce the number of parameters to be estimated, and thereby to achieve a higher degree of robustness.

3. An alternative framework based on technological diffusion

Theoretical formulation

19. Bloom and Canning (2005) propose a growth model that allows for both cross-country differences in steady-state levels of TFP and slow diffusion of technology. The latter feature seems especially realistic when dealing with a sample of widely heterogeneous countries. Indeed one major "new stylised fact of growth", which contradicts basic neo-classical growth theory (such as *e.g.* Mankiw *et al.,* 1992), is that wide and persistent cross-country differences in TFP levels account for the bulk of GDP per capita gaps (Easterly and Levine, 2001; Hall and Jones, 1999; Duval and de la Maisonneuve, 2010).

14. In this regression, the number of countries is twice as large as in Bassanini *et al.* (2001) and includes OECD countries (except Czech Republic, Luxembourg, Mexico, and Slovak Republic) as well as China, Israel, Russia, Slovenia, and South Africa.

Therefore the present paper extends the Bloom-Canning framework by allowing policies and institutions to influence both (country-specific) TFP levels but also potentially the speed of convergence towards these steady states. Incidentally, this extension also has the practical advantage of allowing some analysis of policies and institutions which (for lack of data) do not have the time-series dimension that would be required to identify their effect based on their within variance.

20. The model is as follows. The production function is a Cobb-Douglas function with constant returns to scale

$$Y_{it} = A_{it} K_{it}^{\alpha} \left(L_{it} e^{\phi s_{it}} \right)^{1-\alpha}, \quad [5]$$

where K is the stock of physical capital, L the labour force, s the average number of years of schooling, α the partial elasticity of output with respect to physical capital, ϕ the return to schooling, and A_{it} the country-specific level of TFP. Following Bills and Klenow (2000) and Hall and Jones (1999) among many others, education enters the production function in an exponential manner. In other words, human capital is defined as proposed by Mincer (1974), which has the advantage of providing robust micro-foundations. Indeed, as evidenced by plenty of microeconomic studies, this assumption is more realistic than the linear form used in equation [1] of the previous model. Taking logs and expressing equation [5] in intensive form (output per worker) yields:

$$\ln\left(\frac{Y}{L}\right)_{i,t} = a_{i,t} + \alpha \ln\left(\frac{K}{L}\right)_{i,t} + \beta s_{i,t}, \quad [6]$$

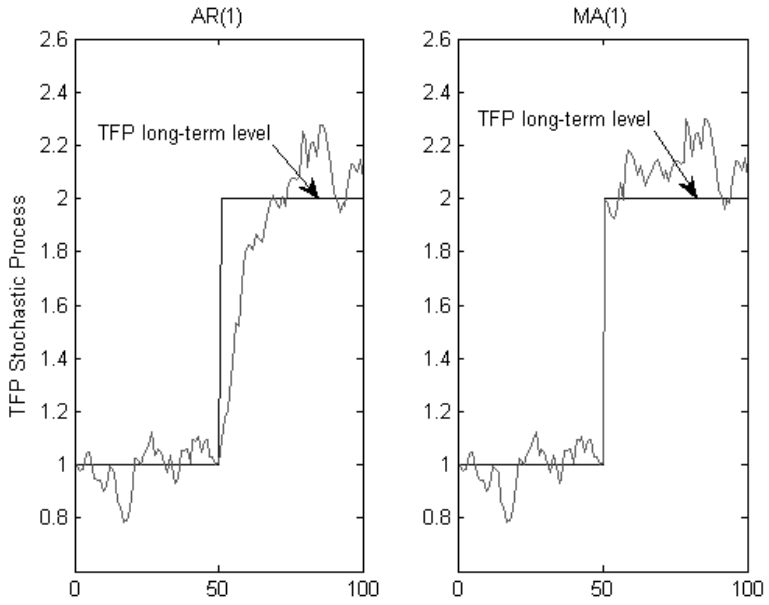
where $\beta = (1-\alpha)\phi.$ [7]

21. TFP in each country is assumed to converge towards a specific steady state according to the following auto-regressive (AR) process of order 1:

$$a_{i,t} = (1-\rho) a_{i,t-1} + \rho a_{i,t}^{*} + \varepsilon_{i,t} \Leftrightarrow \Delta a_{i,t} = \rho\left(a_{i,t}^{*} - a_{i,t-1}\right) + \varepsilon_{i,t}, \quad [8]$$

implying convergence to the specific steady-state TFP level $a_{i,t}^{*}$ at rate ρ. This AR formulation allows for a sluggish adjustment of TFP levels to shocks to the productivity frontier. It is consistent with the type of productivity models estimated in various recent empirical analyses of productivity growth (see *e.g.* Scarpetta and Tressel, 2002; Nicoletti and Scarpetta, 2003; Griffith *et al.,* 2004; Conway *et al.,* 2006). It is also more realistic than *e.g.* a moving average specification, which would impose an instantaneous adjustment of TFP levels (Figure 1).

Figure 1. The adjustment of TFP towards its steady-state level for two different diffusion processes



The steady-state level of TFP differs from the worldwide technology frontier, which is captured by time dummies d_t, depending on a set of country-specific features $x_{i,t}$ that includes policies and institutions:

$$a^*_{i,t} = \delta x_{i,t-1} + d_t . \qquad [9]$$

22. Differencing the production function [6] and using the expressions [8] and [9] for $\Delta a_{i,t}$ and $a^*_{i,t}$ yields the empirical specification:

$$\begin{aligned} \Delta \ln\left(\frac{Y}{L}\right)_{i,t} &= \alpha \Delta \ln\left(\frac{K}{L}\right)_{i,t} + \beta \Delta s_{i,t} \\ &+ \rho\left(d_t + \delta x_{i,t-1} + \alpha \ln\left(\frac{K}{L}\right)_{i,t-1} + \beta s_{i,t-1} - \ln\left(\frac{Y}{L}\right)_{i,t-1} \right) + \varepsilon_{i,t} . \end{aligned} \qquad [10]$$

23. Equation [10] is estimated by imposing equality constraints on the short- and long-run coefficients – *i.e.* on the first differences and levels – of the human and physical capital variables, and as a consequence with non-linear least squares.[15] As outlined by Bloom *et al.* (2002), estimating equation [10] is prone to an endogeneity problem as the contemporaneous growth rates of the factor inputs may respond positively to contemporaneous TFP shocks $\varepsilon_{i,t}$. In order to address this problem, the current input growth rates are instrumented with their one-period lagged values.

15. Equality constraints are tested by estimating the unrestricted model and by allowing the coefficients on the growth and level terms to differ. These constraints can never be rejected whatever the specifications.

Variables and data

24. The sample covers the 40 countries already considered above, and observations are five-year averages over 1970-2005.[16] Compared with the PMG approach, the use of five-year averages drastically reduces the risk that coefficient estimates may partly capture business cycle effects. The dependent variable is the growth rate of the ratio of real GDP (expressed in USD 2005 PPPs) to total employment. The physical stock of capital series are constructed using the perpetual inventory method. This method requires the use of long annual time series for investment, which are taken from the Penn World Tables (see Appendix 1 for details). The human capital series is the same as used in the PMG approach.

Institutional and policy variables

25. Unlike the PMG approach, the technological diffusion approach presented above allows to consider *both* time-varying and time-invariant policy and institutional variables as determinants of cross-country differences in steady-state TFP levels. Five time-varying and five time-invariant policy and institutional indicators that appear to be potential candidates for explaining long-run TFP are considered (see Appendix 1 for details). The time-invariant indicators are:

- The quality of education index developed by Hanushek and Woessmann (2009). The number of years of schooling is a rather crude measure of the human capital stock that does not account for the quality of education. As a result, in the framework adopted here cross-country differences in the quality of education are likely to show up in TFP levels.
- The OECD's product market regulation (PMR) index value for 2008, its three components (State control, Barriers to entrepreneurship, and Barriers to trade and investment), and seven subcomponents. Overly stringent anti-competitive product market regulations can harm steady-state productivity *inter alia* by reducing the efficiency of resource allocation across firms and sectors and also within firms (so-called X-inefficiency). Such regulations can also slow down the adoption of new technologies (Conway *et al.*, 2006).
- The OECD's employment protection legislation (EPL) index value for 2008. Overly strict EPL may harm steady-state TFP and/or the speed of adoption of new technologies *e.g.* by preventing staff adjustment in otherwise high-turnover industries (Bassanini *et al.,* 2009).
- A summary indicator of the quality of governance, which is computed through principal component analysis as the first component of the seven World Bank indicators of governance featured in Kaufmann *et al.* (2009). Although causal links can be hard to identify as growth itself may bring about the emergence of better institutions, good governance, such as *e.g.* effective contract enforcement, would be expected to be associated with higher TFP levels.
- An index of the strength of physical property rights (including rights on financial assets) compiled under the supervision of de Soto (*Property Rights Alliance*, 2009). While establishing causality is again an issue, secure property rights protect firms and individuals against expropriation and promote investment, financial sector development and risk-taking behaviour (Acemoglu *et al.,* 2005). Some of these benefits should show up in higher TFP levels.

The time-varying policy and institutional variables are:

- The OECD's index of product market regulation in energy, transport and communications (ETCR), which however has narrower scope and coverage – it is available only for OECD countries – than the time-invariant PMR indicator.

16. Former transition countries are included in the sample only from 1990.

- The OECD's EPL index, only available for OECD countries.
- The IMF's financial liberalisation index. As already noted, well-developed financial systems are likely to enhance overall economic efficiency by channelling resources more efficiently throughout the economy.
- A trade liberalisation index based on average actual tariff rates.
- An index of the strength of patent rights protection from Park and Lippoldt (2008). Intellectual property rights (IPRs) protection increase patent holders' perceived demand for their technology and therefore their incentives to license (see *e.g.* Arora *et al.,* 2001). This should speed up the adoption of technology and also raise steady-state TFP, *ceteris paribus*. However, overly strong IPRs protection may induce inventors to raise prices, thereby discouraging transfers (see *e.g.* Correa, 2005).

26. The latter three variables are new proxies for financial development, trade openness and innovation. They have three main advantages compared with the type of variables used in much of the existing growth regression literature, including in previous OECD work (*e.g.* Bassanini *et al.*, 2001). First, the positive effect on output per capita of more usual indicators of financial development (*e.g.* bank credit or stock market capitalisation to GDP ratios), trade openness (*e.g.* share of imports and exports in GDP) and innovation (*e.g.* R&D spending as a share of GDP) found in the literature may to some extent capture business cycle co-movements between GDP and financial activity, trade and innovation. Instead, the three indexes used here should be less prone to this particular type of endogeneity problem.[17] Second, credit or stock market capitalisation, trade intensity and R&D expenditure represent performance indicators rather than policy variables,[18] unlike the three aforementioned indexes which directly capture policy stances in their respective fields. Finally, the IMF's financial liberalisation index and the Park index of patent rights protection are available for more countries and over longer periods than series of banking credit provided to the private sector or R&D expenditure, which are available from the early 1980s only for 22 countries. All specifications include three dummy variables to control for the effects of financial crises on growth. Each of these dummies take value one when a country experienced respectively a banking crisis, a currency crisis or a sovereign debt crisis over the five years of interest, and zero otherwise (see Laeven and Valencia, 2008).

Results

Baseline specification

27. Baseline specification results are presented in Table 3. The coefficients of physical and human capital are respectively equal to 0.285 and 0.074 (column (1)), implying from relation [7] a return on education of around 10%, which is fully consistent with estimates from microeconomic studies (Bils and Klenow, 2000 or Psacharopoulos and Patrinos, 2004). In comparison, the PMG approach yields an elasticity of output per capita to mean years of schooling at least twice as high, which would imply implausibly large externalities from education.[19] No clear evidence is found for non-linearities in the effect

17. The GMM estimator, which is the standard approach used to treat endogeneity issues, cannot be employed here as the estimated model is non-linear. A GMM analysis of the effects of policies and institutions on growth will nevertheless be explored in a revised version of this paper due to be published as an ECO working paper.

18. As regards R&D, this is only true for private expenditures since public R&D expenditures can be considered as a policy variable.

19. Note that the estimated coefficient of human capital in Table 3 is a semi-elasticity of output to education, while the PMG approach provides an elasticity estimate. Therefore the two coefficients cannot be directly

of human capital. An interaction between education and a dummy variable for lower-income countries (which here include Brazil, Chile, China, India, Indonesia, Russia, and South Africa)[20] is not statistically significant at conventional levels (column (2)), and there is no evidence for non-linear effects of human capital when adding a square term to the baseline specification (column (3)). Interestingly, the effect of human capital becomes somewhat larger and even more significant when adjusted for the quality of education (column (4)).

Table 3. Baseline results of the technological diffusion approach

	Dependent variable: Log GDP per worker			
	(1)	(2)	(3)	(4)
Physical capital	0.285***	0.234***	0.286***	0.262***
	(0.06)	(0.06)	(0.06)	(0.06)
Human capital	0.074***	0.035*	0.064	
	(0.02)	(0.02)	(0.05)	
(Human capital) × (Lower-income country dummy)		0.078		
		(0.05)		
Lower-income country dummy		-0.164***		
		(0.06)		
(Human capital)²			0.0005	
			(0.002)	
Human capital, adjusted for quality				0.089***
				(0.02)
Convergence speed ρ	0.055***	0.104***	0.056***	0.059***
	(0.01)	(0.02)	(0.01)	(0.01)
Time fixed-effects	Yes	Yes	Yes	Yes
Country fixed-effects	No	No	No	No
Number of countries	40	40	40	40
Observations	271	271	271	271

Robust standard errors are in parentheses. ***, **, * indicate a significance of the coefficients at the 1%, 5%, and 10% level, respectively.

Testing for the effect of policies and institutions

28. In Table 4a, the policy and institutional variables are considered one by one as determinants of cross-country differences in long-run TFP (columns (1) to (14)), except for the sub-components of the PMR which are included simultaneously in the regressions. Most variables are significant with the expected sign. The quality of education, trade liberalisation, stronger patent rights protection, and financial liberalisation are all associated with higher long-run TFP levels (columns (1), (10), (11), and (12)). More stringent PMR (in particular as regards barriers to entrepreneurship and barriers to trade and investment) and stricter EPL in OECD countries have a negative impact on the steady-state levels of TFP. However, all these results should be considered with great care given the high degree of collinearity between the different institutions and policies, which makes it hard to discriminate between them. Including all these variables simultaneously and subsequently dropping insignificant ones yields specification (15), which features only competition barriers to entrepreneurship and patent rights protection as significant influences on long-run TFP levels.

compared. However, at the sample average (corresponding to about ten years of education), a 10% increase in the level of education amounts to an extra one year of schooling.

20. The aforementioned lower-income countries are selected on the basis of country fixed-effects estimated from a regression similar to equation (1) of Table 3. Incidentally, this approach yields rankings that roughly correspond to a simple ranking of average GDP per capita levels over the sample period.

29. Only little evidence is found here that institutions and policy variables have different growth effects depending on the level of development of the countries considered (Table 4b).[21] Stringent EPL seems more detrimental to long-run TFP for lower-income countries (column (6)), but this result should be qualified given the lack of time dimension of the EPL indicator used here. Barriers to entrepreneurship seem to reduce long-run TFP (at the 10% confidence level, see column (4)), but neither this variable nor the other dimensions of product market regulation are found to entail significant "distance-to-frontier" effects. This is somewhat in contrast with some recent literature based on different theoretical frameworks, econometric approaches and estimation samples. Based on cross-section and panel data analysis of output per capita growth across 44 countries over one decade (1998-2007), Wölfl *et al.* (2010) find some support for larger negative growth effects of PMR in more advanced economies. Likewise, Aghion *et al.* (2009) provide tentative evidence for a sample of 17 OECD countries that a combination of strict product and labour market regulations is detrimental to TFP growth in countries that are close to the technological frontier, but beneficial in other countries. Finally, Bourlès *et al.* (2010) also find some distance-to-frontier effects of PMR on sectoral productivity growth for a sample of 15 OECD countries.

21. This also holds when using a dummy variable equal to one for countries that are close to the frontier (defined here as the US GDP per capita level) instead of the low-income country dummy considered in Table 4b.

Table 4a. Effect of institutional and policy variables on long-run TFP levels

	Time-varying?	Dependent variable: Log GDP per worker																	
		(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)
Physical capital	Yes	0.233*** (0.06)	0.278*** (0.06)	0.286*** (0.06)	0.248*** (0.06)	0.283*** (0.06)	0.245*** (0.06)	0.278*** (0.06)	0.298*** (0.06)	0.164** (0.08)	0.269*** (0.06)	0.236*** (0.07)	0.290*** (0.06)	0.289*** (0.06)	0.296*** (0.06)	0.259*** (0.06)	0.172*** (0.06)	0.101 (0.06)	0.161*** (0.06)
Human capital	Yes	0.041* (0.02)	0.059*** (0.02)	0.071*** (0.02)	0.047** (0.02)	0.063*** (0.02)	0.051** (0.02)	0.077*** (0.02)	0.004 (0.02)	-0.030 (0.03)	0.059*** (0.02)	0.078*** (0.02)	0.049** (0.02)	0.071*** (0.02)	0.059*** (0.02)	0.051*** (0.02)	0.049** (0.02)	0.021 (0.02)	0.019 (0.02)
Convergence speed ρ		0.058*** (0.01)	0.075*** (0.02)	0.060*** (0.02)	0.075*** (0.01)	0.076*** (0.02)	0.077*** (0.02)	0.055*** (0.01)	0.115*** (0.04)	0.099*** (0.02)	0.071*** (0.02)	0.079*** (0.02)	0.081*** (0.02)	0.058*** (0.01)	0.082*** (0.02)	0.086*** (0.02)	0.327*** (0.07)	0.280*** (0.07)	0.338*** (0.06)
Variables in long-run TFP																			
Educational quality	No	0.914*** (0.30)																	
PMR 2008	No		-0.349** (0.15)																
State Control 2008	No			-0.073 (0.13)															
Barriers to Entrepreneurship 2008	No				-0.590*** (0.17)														
Barriers to Trade and Investment 2008	No					-0.336** (0.13)													
State Public Ownership	No						0.052 (0.09)												
State Public Involvement	No						0.049 (0.10)												
Adm. Burden barriers to entrepreneurship	No						-0.132 (0.14)												
Opacity barriers to entrepreneurship	No						-0.062 (0.10)												
Competition barriers to entrepreneurship	No						-0.360** (0.15)									-0.327** (0.13)			
Explicit barriers to trade	No						-0.320 (0.21)												
Other barriers to trade	No						0.121 (0.15)												
EPL 2008	No							0.113 (0.13)											
ETCR (OECD countries only)	Yes								0.014 (0.05)										
Time-varying EPL (OECD countries only)	Yes									-0.090* (0.05)									
Trade Liberalisation	Yes										0.919** (0.44)						-0.009 (0.14)		
Financial Liberalisation	Yes											0.758** (0.37)						0.080 (0.22)	
Patent rights	Yes												0.226** (0.10)			0.202** (0.08)			0.081* (0.05)
Physical Property Rights	No													0.079 (0.09)					
Governance indicators (first component)	No														0.113*** (0.04)				
Time fixed-effects		Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country fixed-effects in steady-state TFP		No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	Yes	Yes	Yes
Number of countries		40	40	40	40	40	40	40	29	28	40	36	38	40	40	38	40	36	38
Observations		271	271	271	271	271	271	271	165	97	245	218	256	271	271	256	245	218	256

Note: Robust standard errors are in parentheses. ***, **, * indicate a significance of the coefficients at the 1%, 5%, and 10% level, respectively.

Table 4b. Effect of institutional and policy variables on long-run TFP levels with interaction effects

	Time-varying?	Dependent variable: Log GDP per worker														
		(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)
Physical capital	Yes	0.219*** (0.06)	0.244*** (0.06)	0.241*** (0.06)	0.222*** (0.06)	0.244*** (0.06)	0.245*** (0.06)	0.189*** (0.06)	0.175*** (0.06)	0.214*** (0.06)	0.239*** (0.06)	0.258*** (0.05)	0.161** (0.07)	0.166*** (0.06)	0.091 (0.07)	0.155*** (0.06)
Human capital	Yes	0.036 (0.02)	0.047** (0.02)	0.055*** (0.02)	0.035* (0.02)	0.052*** (0.02)	0.063*** (0.02)	0.040** (0.02)	0.054*** (0.02)	0.028 (0.02)	0.040** (0.02)	0.041** (0.02)	0.035 (0.02)	0.050** (0.02)	0.011 (0.02)	0.016 (0.02)
Convergence speed ρ	No	0.082*** (0.02)	0.104*** (0.02)	0.094*** (0.02)	0.104*** (0.02)	0.100*** (0.02)	0.134*** (0.03)	0.117*** (0.02)	0.130*** (0.02)	0.145*** (0.03)	0.108*** (0.02)	0.123*** (0.03)	0.353*** (0.08)	0.326*** (0.06)	0.271*** (0.07)	0.336*** (0.06)
Varaibles in long-run TFP																
Educational quality	No	0.559* (0.34)														
Educ. Quality × Lower-income dummy	No	-0.278 (0.46)														
Lower-income dummy	No	0.558 (1.85)	-0.423 (1.40)	-0.893 (1.33)	-0.153 (1.08)	-0.876 (0.72)	0.541 (0.53)	-1.244*** (0.39)	-1.043*** (0.33)	-1.206*** (0.39)	-0.330 (1.54)	-0.518 (0.36)	10.293*** (0.88)	240.775*** (0.72)	-3.6e+03*** (0.89)	64.123*** (0.83)
PMR 2008	No		-0.107 (0.13)													
PMR 2008 × Lower-income dummy	No		-0.154 (0.56)													
State Control	No			0.029 (0.08)												
State Control × Lower-income dummy	No			-0.012 (0.38)												
Barriers to Entrepreneurship	No				-0.280* (0.15)											
Barriers to Entrep. × Lower-income dummy	No				-0.296 (0.50)											
Barriers to Trade and Investment 2008	No					-0.172 (0.12)										
Barriers to Trade and Inv. × Lower-income dummy	No					0.091 (0.38)										
EPL 2008	No						0.062 (0.06)									
EPL 2008 × Lower-income dummy	No						-0.623*** (0.22)									
Trade Liberalisation	Yes							0.226 (0.35)					-0.110 (0.17)	-0.197 (0.14)		
Trade Lib. × Lower-income dummy	Yes							0.493 (0.58)					0.189 (0.44)	0.381 (0.26)		
Financial Liberalisation	Yes								0.359 (0.24)				-0.061 (0.14)		0.060 (0.22)	
Financial Lib. × Lower-income dummy	Yes								0.555 (0.57)				0.334 (0.67)		0.310 (0.34)	
Patent rights	Yes									0.168*** (0.06)			0.063 (0.05)			0.074 (0.05)
Patent rights × Lower-income dummy	Yes									0.179 (0.13)			0.019 (0.15)			0.065 (0.09)
Physical Property Rights	No										0.033 (0.05)					
Physical Property Rights × Lower-income dummy	No										-0.078 (0.24)					
Governance indicators (first component)	No											0.054* (0.03)				
Governance ind. × Lower-income dummy	No											0.077 (0.10)				
Time fixed-effects		Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country fixed-effects in steady-state TFP		No	No	No	No	No	No	No	No	No	No	No	Yes	Yes	Yes	Yes
Number of countries		40	40	40	40	40	40	40	36	38	40	40	34	40	36	38
Observations		271	271	271	271	271	271	245	218	256	271	271	203	245	218	256

Note: Robust standard errors are in parentheses. ***, **, * indicate a significance of the coefficients at the 1%, 5%, and 10% level, respectively.

Controlling for unobserved country-specific determinants of long-run TFP levels

30. One caveat with the previous regressions is that they follow Bloom and Canning (2005) in explaining cross-country heterogeneity in long-run TFP levels based on a limited set of policy and institutional variables. This may create an omitted variable bias, and the potential correlation between (at least some of) the institutions considered and other omitted determinants of long-run TFP may further increase the risk of incorrect statistical inference. One careful way to address this issue is to control for omitted factors by systematically including country dummies along with the institutional variables tested for. However, the price to be paid for this greater robustness is that the TFP impact of time-invariant institutional variables can no longer be explored.[22] When considering all the time-varying policy and institutional variables separately or jointly in a specification with country-fixed effects, only the index of patent rights protection remains a robust determinant of long-run TFP (Table 4a, columns (16) to (18)).[23] It is also worthwile noting that the speed of convergence now becomes much closer to the value found with the PMG approach, casting some doubts on the models excluding country-fixed effects which yield very slow speeds of convergence. It indicates that TFP levels converge at a rate of 6% a year, corresponding to a half-life of the productivity gap of about 10 years. Likewise, the aforementioned distance-to-frontier effects found for certain institutions are not robust to controlling for country fixed effects (Table 4b, columns (12) to (15)).

Testing for influences of policies and institutions on the speed of TFP convergence

31. Because the growth model underlying the estimates features slow technology diffusion, it allows some exploration of the potential influence of policies and institutions not only on long-run TFP levels but also on the speed of convergence towards these steady states. To this end, the productivity diffusion process is rewritten as follows:

$$\Delta a_{i,t} = \rho_{i,t}\left(a^*_{i,t} - a_{i,t-1}\right) + \varepsilon_{i,t} = \left(\rho_c + \gamma z_{i,t}\right)\left(a^*_{i,t} - a_{i,t-1}\right) + \varepsilon_{i,t}, \qquad [11]$$

where z denotes the set of policies and institutions that influence the speed of convergence to (country-specific) long-run TFP levels. The estimated equation then becomes:

$$\begin{aligned}\Delta \ln(Y/L)_{i,t} = {} & \alpha \Delta \ln(K/L)_{i,t-1} + \beta \Delta s_{i,t-1} \\ & + \left(\rho_c + \gamma z_{i,t-1}\right)\left(d_t + \delta x_{i,t-1} + \alpha \ln(K/L)_{i,t-1} + \beta s_{i,t-1} - \ln(Y/L)_{i,t-1}\right) + \varepsilon_{i,t}.\end{aligned} \qquad [12]$$

32. Based on the above results, steady-state TFP differences across countries are controlled for by country dummies and the time-varying patent rights protection index. Table 5a reports estimates of equation [12] where (time-varying and time-invariant) policies and institutions are considered one by one as explanatory variables of the speed of convergence. Most estimates are in line with priors, *i.e.* trade liberalisation and financial liberalisation appear to be associated with faster TFP convergence (columns (7)

22. Another issue with time-invariant variables is that available observations are typically observed values in recent years rather than sample averages over the period 1970-2005. This may create estimation bias insofar as such policies and institutions have in fact experienced changes of different magnitudes across countries over the sample period that may have led to changing cross-country rankings.

23. The time-varying index of product market regulation in energy, transport, and communications (ETCR) and the time-varying index of employment protection legislation (EPL) are excluded from the analysis as they are only available for OECD countries.

and (8)).[24] A few results seem counterintuitive and/or at odds with previous empirical literature. For example, the quality of education is associated with a slower convergence (column (1)). However, this result should be discounted as – unlike the estimated effects of trade and financial liberalisation – it is based on a time-invariant policy indicator and might thus be correlated with, and thereby capture the effect of omitted country-specific factors. Overall, the positive effects of the time-varying indicators of trade and financial liberalisation are the most robust to omitted influences on the speed of convergence. The equation featuring the trade liberalisation index in the convergence force is the only specification that features a significant effect of human capital on long-run GDP per capita, and it seems to provide a good description of the TFP process across countries (column (7)).

33. Finally, there is some tentative evidence that the effects of policies and institutions on the speed of convergence of TFP may depend on a country's level of development (Table 5b). In particular, trade and financial liberalisation are found to speed up TFP convergence essentially in lower-income countries (columns (7) and (8)), consistent with the view that such reforms might facilitate technology transfers. There is also some support for stringent PMR and EPL slowing down TFP convergence in developing countries (columns (2) to (6)), although these results should be seen as more tentative as they rely on the use of time-invariant policy indicators.

24. Patent rights are not considered as an explanatory variable of the convergence force due to collinearity issues (the variable already appears as a determinant of long-run TFP levels).

Table 5a. Effect of institutional and policy variables on the speed of convergence, controlling for long-run TFP differences

	Dependent variable: Log GDP per worker									
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Physical capital	0.136** (0.06)	0.164*** (0.06)	0.165*** (0.06)	0.160*** (0.06)	0.147** (0.06)	0.161*** (0.06)	0.155*** (0.06)	0.080 (0.06)	0.164*** (0.06)	0.145** (0.06)
Human capital	0.009 (0.02)	0.019 (0.02)	0.019 (0.02)	0.020 (0.02)	0.017 (0.02)	0.023 (0.02)	0.042** (0.02)	0.008 (0.03)	0.014 (0.02)	0.020 (0.02)
Convergence with institutions (lagged)										
Constant term	1.012*** (0.37)	0.286** (0.12)	0.215* (0.12)	0.378*** (0.11)	0.422*** (0.09)	0.431*** (0.15)	0.268*** (0.08)	0.167*** (0.04)	0.614** (0.24)	0.362*** (0.06)
Educational quality	-0.149** (0.07)									
PMR 2008		0.028 (0.08)								
State Control 2008			0.045 (0.06)							
Barriers to Entrepreneurship 2008				-0.028 (0.08)						
Barriers to Trade and Investment 2008					-0.068 (0.08)					
EPL 2008						-0.037 (0.05)				
Trade Liberalisation							0.221* (0.13)			
Financial Liberalisation								0.518*** (0.15)		
Physical Property Rights									-0.045 (0.03)	
Governance indicators (first component)										0.015 (0.02)
Variables in long-run TFP										
Patent rights	0.080* (0.05)	0.080* (0.05)	0.082 (0.05)	0.083* (0.05)	0.084* (0.04)	0.084* (0.05)	0.062* (0.04)	0.060* (0.03)	0.078 (0.05)	0.088* (0.05)
Time fixed-effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country-FE in steady-state TFP	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Number of countries	38	38	38	38	38	38	38	34	38	38
Observations	256	256	256	256	256	256	236	211	256	256

Note: Robust standard errors are in parentheses. ***, **, * indicate a significance of the coefficients at the 1%, 5%, and 10% level, respectively.

Table 5b. Effect of institutional and policy variables on the speed of convergence, controlling for long-run TFP differences

	Dependent variable: Log GDP per worker									
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Physical capital	0.121** (0.06)	0.090 (0.06)	0.111* (0.06)	0.090 (0.06)	0.133** (0.05)	0.048 (0.06)	0.117** (0.06)	0.101 (0.07)	0.164*** (0.06)	0.129** (0.05)
Human capital	0.017 (0.02)	0.018 (0.02)	0.015 (0.02)	0.019 (0.02)	0.016 (0.02)	0.010 (0.02)	0.034* (0.02)	0.009 (0.02)	0.016 (0.02)	0.019 (0.02)
Convergence with institutions (lagged)										
Constant term	0.203 (0.41)	0.174 (0.11)	0.132 (0.11)	0.316*** (0.11)	0.274*** (0.08)	0.075 (0.10)	0.350*** (0.09)	0.151*** (0.05)	0.519*** (0.18)	0.315*** (0.05)
Educational quality	0.013 (0.08)									
Educ. quality × Lower-income dummy	-0.724*** (0.18)									
Lower-income dummy	3.125*** (0.81)	2.131*** (0.51)	2.011*** (0.49)	2.322*** (0.56)	1.126*** (0.31)	2.734*** (0.52)	-0.137 (0.11)	0.016 (0.10)	-0.207 (0.88)	0.633*** (0.19)
PMR 2008		0.084 (0.07)								
PMR 2008 × Lower-income dummy		-0.896*** (0.21)								
State Control 2008			0.063 (0.05)							
State Control × Lower-income dummy			-0.564*** (0.14)							
Barriers to Entrepreneurship 2008				-0.010 (0.08)						
Barriers to Entrepreneurship × Lower-income dummy				-1.146*** (0.28)						
Barriers to Trade and Investment 2008					0.039 (0.07)					
Barriers to Trade and Investment × Lower-income dummy					-0.617*** (0.17)					
EPL 2008						0.067* (0.04)				
EPL 2008 × Lower-income dummy						-1.151*** (0.21)				
Trade Liberalisation							-0.077 (0.10)			
Trade Liberalisation × Lower-income dummy							0.932*** (0.26)			
Financial Liberalisation								0.010 (0.05)		
Financial Liberalisation × Lower-income dummy								1.132*** (0.38)		
Physical Property Rights									-0.039 (0.02)	
Physical Property Rights × Lower-income dummy									0.061 (0.14)	
Governance indicators (first component)										0.002 (0.01)
Governance indicators × Lower-income dummy										0.158*** (0.05)
Variables in long-run TFP										
Patent rights	0.119*** (0.04)	0.109** (0.05)	0.086* (0.05)	0.115*** (0.04)	0.107** (0.05)	0.176*** (0.05)	0.067 (0.05)	0.085 (0.06)	0.063 (0.06)	0.110** (0.05)
Time fixed-effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country FE in steady-state TFP	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Number of countries	38	38	38	38	37	37	38	34	38	36
Observations	256	256	256	256	254	254	236	211	256	252

Note: Robust standard errors are in parentheses. ***, **, * indicate a significance of the coefficients at the 1%, 5%, and 10% level, respectively.

4. Conclusion

34. This paper has re-estimated PMG growth regressions run in previous OECD work for a larger sample of 40 OECD, accession and large emerging (enhanced engagement) countries. Most of the earlier results regarding the growth effects of policies and institutions are found to remain valid. However, limited data availability (in the time-series dimension) for a number of countries and intrinsic limitations of the PMG approach impose significant practical constraints on the analysis. Therefore, an alternative, more flexible and robust approach is proposed that allows to explore a broader set of policies and institutions. On the theoretical side, this framework has the advantage of modelling explicitly the slow diffusion of technology, a feature that is consistent with stylised facts of economic growth. The results show a significant and reasonable impact of human capital on growth, although this effect is not significant across all specifications featuring policy and institutional variables. Also, a number of policies and institutions are found to bear a significant link with long-run TFP levels. However, it is hard to discriminate between them due both to multicollinearity and omitted variable bias issues. Addressing these issues requires controlling for fixed country effects on long-run TFP, and identifying the impact of policies and institutions on the basis of their within variance. Within the set of time-varying policy indicators that can be considered for this exercise, the strength of patent rights protection appears to be a robust determinant of long-run TFP levels once controlling for all other policy and institutional influences through country-fixed effects. As is typical with growth regressions, however, one caveat remains the possible endogeneity of changes in patent rights protection to growth performance. Looking at policy and institutional influences on the speed of convergence of TFP to its (country-specific) steady state, trade and financial liberalisation appear to be associated with faster TFP convergence. Finally, the paper lends limited support to the view that the growth effects of policies and institutions vary across different stages of economic development, so-called "distance-to-frontier" effects.

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APPENDIX 1. DATA SOURCES AND METHODOLOGY

Table A1.1. Basic Variables

	Definition	Source
Constant GDP in PPP[1]	Gross domestic product (GDP) in PPP	World Bank Development Indicators (WDI) for the current GDP value in 2005 and total population, International Comparison Program (ICP) for the 2005 level of PPP, and Penn World Tables (PWT) for the growth rates of real GDP (except for former West Germany for which data come from OECD)
Population	Total population aged between 15 and 64 years	WDI
Workers	Persons employed	Conference Board Total Economy Database
Investment rate	Gross fixed capital formation (% of GDP)	WDI and PWT, except for West Germany (OECD)
Capital stock	Stock of real capital, derived from the perpetual inventory method	PWT, WDI, and authors' calculations
Human capital	Mean years of schooling of population aged between 25 and 64 years	Authors' calculations based on Barro and Lee (2010), Cohen and Soto (2007), De la Fuente and Domenech (2006), and Lutz *et al.* (2007) database. See Appendix 2 for further details

1. Data adjustments: The 2005 value of GDP is adjusted for PPP in 2005 and extrapolated by using the growth rate of the real GDP in PPPs series from PWT.

Table A1.2. Policy and institutional variables

	Definition	Source
Product market regulation for the whole economy (PMR)	OECD summary indicator of regulatory impediments to product market competition in the broad economy.	Wölfl *et al.* (2010)
Product market regulation in non-manufacturing industries (ETCR)	OECD summary indicator of regulatory impediments to product market competition in seven non-manufacturing industries: gas, electricity, post, telecoms (mobile and fixed services), passenger air transport, railways (passenger and freight services) and road freight.	Conway *et al.* (2006)
Employment Protection Legislation (EPL)	OECD summary indicator of the stringency of Employment Protection Legislation.	OECD, Employment Outlook 2009
Overall tax burden	The ratio of general government current nominal tax revenues in nominal GDP.	OECD
Consumption and property taxes	The ratio of taxes on property (OECD category 4000), taxes on goods and services (category 5000), and other taxes (category 6000) in total tax revenues.	OECD
Inflation	The rate of growth of the private final consumption deflator.	OECD, WDI
Inflation volatility	The standard deviation of the rate of growth of the private final consumption deflator – estimated over three-year period.	OECD, WDI
Research & Development	Gross domestic expenditure on R&D as a percentage of GDP.	OECD
Trade openness	The ratio of exports plus imports over GDP, adjusted for country size. The adjustment is made by regressing the raw trade openness variable on the logarithm of the population size and taking the estimated residual from this regression.	WDI
World Bank indicators of governance	Aggregate indicators of six dimensions of governance: Voice & Accountability, Political Stability No Violence, Government Effectiveness, Regulatory Quality, Rule of Law, and Control of Corruption. The indicators are constructed using an unobserved components methodology described in Kaufmann *et al.* (2009). The six governance indicators are measured in units ranging from about –2.5 to 2.5, with higher values corresponding to better governance outcomes.	World Bank
Physical property rights index	De Soto physical property rights index.	Property Rights Alliance (2009)
IMF financial liberalisation index	Index of financial regulation across seven different dimensions: credit controls and reserve requirements, interest rate controls, entry barriers, state ownership, policies on securities markets, banking regulations, and restrictions on the capital account. Liberalization scores for each category are then combined in a graded index that is normalized between zero and one.	IMF
Trade liberalisation index based on average tariff rates	Average tariff rates, with missing values extrapolated using implicit weighted tariff rates. Index is normalized to be between zero and unity: zero means the tariff rates are 60% or higher, while unity means the tariff rates are zero.	Various sources, including IMF, World Bank, WTO, UN, and Clemens and Williamson (2004)
Index of patent rights	Intellectual property rights index.	Park and Lippoldt (2008)

APPENDIX 2. EDUCATIONAL DATA CONSTRUCTION

35. In this section we describe the modifications applied to the Cohen-Soto (2007) educational database. The latter has been corrected for differential mortality across educational groups along a procedure described below. These corrections can be viewed as an alternative to Morrisson-Murtin (2009) database.

Cohen-Soto database corrected for differential mortality across educational groups

36. We start from the data on educational attainment by age group that underlies Cohen-Soto (2007) database, which was kindly provided by the authors. Let $N_k^j(t)$ be the number of people belonging to the cohort of age *k* with *j* years of schooling at time *t*, and $p_k^j(t)$ the corresponding proportion among cohort of age *k*. Because surveys were scarce in the 1960s and in the 1970s, Cohen-Soto data rely mainly on surveys conducted later, generally in the 1980s or the 1990s. Let t_0 be the initial date and *t* the date of observation of one cohort, and $S_{k,t_0}^j(t-t_0)$ the survival probability after $t - t_0$ years of people initially aged *k* and endowed with *j* years of schooling. At date *t*, the remaining fraction of people from that group equals:

$$N_{k+t-t_0}^j(t) = N_k^j(t_0) S_{k,t_0}^j(t-t_0) . \quad [A1]$$

37. The bias in Cohen-Soto arises from the fact that they assume:

$$\forall i, j \; S_{k,t_0}^i(t-t_0) = S_{k,t_0}^j(t-t_0) . \quad [A2]$$

38. In contrast, we assume that differential mortality differs across educational groups. However, by lack of robust evidence on this issue, we do not assume that the educational gradient of mortality (*i.e.* differential mortality arising from differences in education) varies by age. More formally, let $\pi_{k,t_0}^j(t)$ the instantaneous mortality rate of group aged *k* at initial date t_0 with *j* years of schooling. As the first derivative of the log of the survival function is equal to the opposite of the mortality rate, one has:

$$S_{k,t_0}^j(t-t_0) = \exp(-\int_{t_0}^{t} \pi_{k,t_0}^j(u)du) . \quad [A3]$$

39. Then, one assumes that:

$$\pi_{k,t_0}^j(u) = \pi_{k,t_0}^0(u) - \gamma j , \quad [A4]$$

where $\pi_{k,t_0}^0(u)$ is the mortality rate of individuals with 0 years of schooling in cohort initially aged *k*, and γ is the educational gradient, namely the reduction in mortality rates arising from one additional year of schooling. Importantly, we assume that γ is constant with age and throughout time, and is common to all age cohorts. One retains $\gamma = 0.002$, which is a bit smaller than the values obtained by Lleras-Muney (2007, corrigendum) for the US in order to accommodate for starker differences in education among developing countries. Combining [A3] and [A4], one obtains

$$S_{k,t_0}^j(t-t_0) = S_{k,t_0}^i(t-t_0) \exp(\gamma(j-i)(t-t_0)) . \quad [A5]$$

40. Let us now denote $\hat{p}^{j}_{k,t_0}(t)$ the (inaccurate) proportion of individuals of age k at time t_0 displaying j years of schooling and observed at time t, as it is inferred by Cohen-Soto. Logically this proportion equals:

$$\hat{p}^{j}_{k,t_0}(t) = \frac{N^{j}_{k+t-t_0}(t)}{\sum_m N^{m}_{k+t-t_0}(t)}. \qquad [A6]$$

41. A corrected value of the later proportion can be obtained by using subsequently [1], [5] and [6]:

$$\begin{aligned} p^{j}_{k}(t_0) &= \frac{N^{j}_{k}(t_0)}{\sum_m N^{m}_{k}(t_0)} \\ &= \frac{N^{j}_{k+t-t_0}(t)/S^{j}_{k,t_0}(t-t_0)}{\sum_m N^{m}_{k+t-t_0}(t)/S^{m}_{k,t_0}(t-t_0)} \\ &= \frac{N^{j}_{k+t-t_0}(t)}{\sum_m N^{m}_{k+t-t_0}(t)\frac{S^{j}_{k,t_0}(t-t_0)}{S^{m}_{k,t_0}(t-t_0)}} \\ &= \frac{N^{j}_{k+t-t_0}(t)}{\sum_m N^{m}_{k+t-t_0}(t)\exp(\gamma(j-m)(t-t_0))} \\ &= \hat{p}^{j}_{k,t_0}(t)\frac{1}{\sum_m \hat{p}^{m}_{k,t_0}(t)\exp(\gamma(j-m)(t-t_0)}. \end{aligned} \qquad [A7]$$

42. Therefore, Cohen-Soto data (the $\hat{p}^{j}_{k,t_0}(t)$) can be corrected immediately with the help of the above equation. In practice, we consider the first date of surveys used by Cohen-Soto and correct all observations that have been extrapolated backward on the basis of this survey. We do not correct subsequent observations as the frequency of surveys is generally higher or the time span too short to entail large mortality differences. We apply this correction to each cohort of age 15-19, 20-24,..., 60-64, then we aggregate the corrected age-specific distributions of education across all ages in order to reconstitute the stock of education among the population aged 15-64 and 25-64.

43. Comparison with the original Cohen-Soto data is illustrated by Figure A2.1 using the population aged 25-64 (all years, excluding France, see below) as a reference. Corrections applied represent a modest fraction of observations, about 25%. However, corrections can be sometimes substantial, entailing more than one years of schooling in early years. Besides, corrections mostly concern OECD countries. It is worth noting that the bias contaminating levels also affects changes in education, which are directly relevant to our growth framework. As the variance of changes in education is substantially lower than the variance of the levels of education, this also means that the signal-noise ratio is lower with first-differenced variables. Figure A2.2 illustrates the larger relative deviation across Cohen-Soto and our corrected data among OECD countries.

Figure A2.1. Comparison of mean years of schooling in Cohen-Soto and constructed data sets

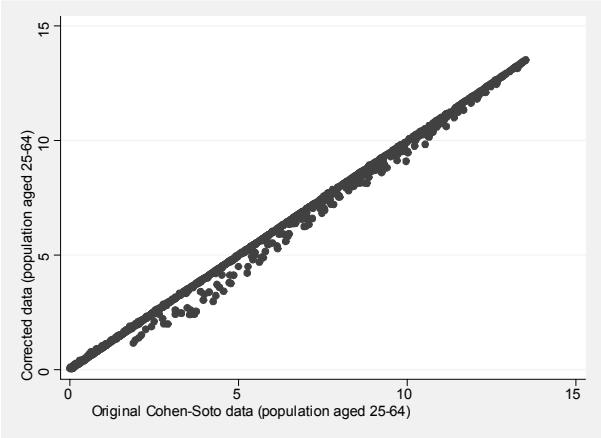
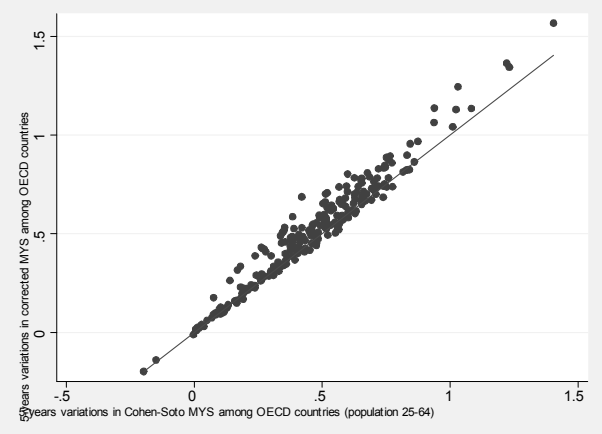


Figure A2.2. Comparison of the change in mean years of schooling in Cohen-Soto and constructed data sets



Construction of a higher frequency database

44. Cohen-Soto database uses a ten year time span between two observations. There is a case for maintaining a large time span in the estimation as it increases the signal-noise ratio. However, in a reduced sample of OECD countries, small sample size might also create problems so that increasing the time frequency by using a five year time span could be desirable.

45. The missing data in 1965, 1975, 1985, 1995 and 2005 cannot just be the simple average of preceding and subsequent observations. In practice, missing values depend on the evolution of the age pyramid as well as on the age-profile of enrolment rates. In a large extent, this information can be deduced from current observations. We have applied the following assumptions:

1. The size of cohorts aged k (k being larger than 20 and smaller than 60) is simply taken as the average of the cohort aged $k - 5$ at time $t - 5$ and of the cohort aged $k + 5$ at time $t + 5$. This is equivalent to assuming uniform mortality rates over a ten-year time period.

2. The same assumption is applied to the distribution of education by age. For instance, the proportion of individuals aged k who have completed primary schooling at time t is the average of the corresponding groups aged respectively $k - 5$ and $k + 5$ at time $t - 5$ and $t + 5$. In practice,

the two latter observations are often very close if not equal (they might differ for instance because of differential mortality.

3. The size of the cohorts aged 15-19 and 60-64 is the simple average of the corresponding sizes for the same cohorts of age at date *t - 5* and *t + 5*. This assumes a smooth evolution of the age pyramid between two decennial observations.

4. The distribution of education of the cohorts aged 15-19 and 60-64 is the simple average of the distributions of the same cohorts of age at date *t - 5* and *t + 5*. This assumes a smooth evolution of enrolment rates over time.

46. Educational attainment is then aggregated across cohorts, and consequently five year variations reflect genuine modifications of the age structure and of the educational age-profile.

Primary and Secondary definitions

47. We define primary as the first six years of schooling. Hence, if durations of primary are reported to last more than six years, years in excess are reported as secondary schooling. The division between secondary and tertiary schooling respects Cohen-Soto definition.

Outliers

48. Data for France has been corrected as there is a clear underestimation of average years of schooling all over the period, perhaps due to the fact that primary schooling was lasting seven years for a substantial portion of pupils before 1970. To build consistent series for France, we used the relative proportions drawn from corrected Cohen-Soto figures and applied them to Morrisson-Murtin (2009) series.

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