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GROWTH, INSTITUTIONS AND PRODUCTIVITY:

An empirical analysis using the Bayesian approach

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Tiivistelmä: Tämän tutkimuksen tarkoituksena on selvittää, miten instituutioiden tarjoama kasvuympäristö vaikuttaa taloudelliseen kasvuun. Parametriestimaattien luotettavuutta on kontrolloitu ehdollisen konvergenssi-ilmiön vaikutuksien osalta käyttäen hyväksi mennyttä tuotantoa. Tämän lisäksi on käytetty tuotantofunktioteoriaa ottaaksemme huomioon tuotannon tekijöiden kasvuvaikutukset estimoitavassa mallissa. Tutkimuksessa on myös tarkasteltu estimaattien sensitiivisyyden ja heikkolaatuisen aineiston vaikutuksia saatuihin tuloksiin, käyttämällä 22 teollisuusmaan osaotosta 86 maata sisältävän kokonaisotoksen lisäksi. Bayesilaiseen päättelyyn perustuva analyysimme vahvistaa, että instituutioiden laadulla on tärkeä merkitys taloudellisen kasvuun vaikuttavana tekijänä. Merkitys ei kuitenkaan ole niin voimakas kuin aikaisemmissa tutkimuksissa on esitetty.

Asiasanat: taloudellinen kasvu, instituutiot, tuottavuus, Bayesialainen analyysi

Abstract: In this paper we explore how the environment offered by institutions influences long-run growth. In order for the estimation results to be trustworthy we control the reliability of the estimates in several ways. Firstly, we include the lagged level of output per worker in the model to control the effect of conditional convergence. Secondly, we use the production function theory to form an environment of other inputs which may affect the parameter value of institutions and handle the issue of endogeneity using convenient instruments for institutions and other inputs. Thirdly, we use institutional indicator which is built using 18 indicators which all reflect the ability of institutions to create an environment in which the citizens can manage their risks they encounter during their life time. Finally, we study the sensitivity of estimation and control the effect of outliers and bad quality of data using a subsample of 22 industrial countries in addition to the total sample of 86 non-oil countries. Our cross-country analysis – based on Bayesian inference – confirms that the production environment offered by institutions has a significant role on economic growth, but it does not seem as dramatical as some may have expected.

Key words: growth, institutions, productivity, Bayesian analysis

Contents

1 Introduction

The integration of the modern production process and its complexity has changed the attributes of productivity. For example, the increasing amount of interest groups has changed the role of institutions in society. There is a growing consensus among economists who think that differences in institutions, in particularly the enforcement of property rights, the rule of law, and constraints placed on politicians and elites, have a first order effect on long-run economic development (see, among others, North and Weingast, 1989, North, 1990, Olson, 1982). Recent empirical findings support this notion. It seems that there is strong correlation between institutions and economic and financial development (e.g., Knack and Keefer, 1995, Hall and Jones, 1999), especially when we look at the historically determined differences in institutions (e.g., Acemoglu, Johnson and Robinson, 2001, 2002).

The formation and alteration of institutions is a pure public good but the enforcement of institutions is a mixed public good like many joint projects of public and private actors. These formal rules, along with the informal rules of broader society, are the institutions that mediate the human behaviour. But the public sector is not merely a referee, making and enforcing the rules from the sidelines; it is also a player, indeed often a dominant player, in the economic game. Every day, state and communal authorities invest resources, direct credit, procure goods and services, and negotiate contracts. These actions have profound effects on transaction costs and on economic activity and economic outcomes.

For the economic research purposes the role of institutions is a part of more general questions on public regulation. The main issues may be divided into four themes: (i) market failures and the corrective measures that can be undertaken by direct legislation and public administrative control, i.e., the rationale for regulatory skill and knowledge to improve social welfare; (ii) the effects of regulatory measures, i.e., the economic performance of regulated markets; (iii) constitutional, fiscal and political causes of regulatory policies, i.e., the universalities[1] behind regulation; and (iv) the anatomy of the desegregated contractual and organisational framework of public and private governance.

In this paper the themes (i) and (ii) are the most relevant concerning institutions and their role in the long-run growth process. If it is possible to accelerate the formation of institutions in the different areas of society it is also possible to create better competitiveness and to increase economic growth related to the use of social infrastructure. The preliminary experience for the role of institutions seems to promote these goals, but there is also suspicion of the regulative results gained. According to Hall and Jones: *"Regulations and laws may protect against diversion, but they all too often constitute the chief vehicle of diversion in an economy"*.

There is a numerous body of econometric research where the researchers are examining how the political and constitutional institutions and economic policies influence long-run growth[2]. In these papers the results seem more or less convincing, which implies that both political institutions and government policies do have direct effect on the long-run growth of output per capita. However, the literature is burdened by a range of problems with the methodology, identification, data and determination of institutional determinants (Aron (2000)). In our cross-country analysis, we establish the significance of institutional structure to economic growth by controlling the reliability of the parameter estimates in several ways. Firstly, we include the lagged level of output per worker in the model to control the effect of conditional convergence. Secondly, we use production function theory to form an environment of other inputs which may affect the parame-

[1] One important universality in this context is asymmetric information.

[2] See for example: Barro (1997), Easterly, Levine (1997), Hall and Jones (1999), Acemoglu, Johnson and Robinson (2001, 2002), Acemoglu, Johnson, Robinson and Thaicharoen (2003), Alcala and Ciccone(2002), Rodrik, Subrama-

ter value of institutions. We state that when the standard Cobb-Douglas production function is used, the log differences of human and physical capital are determined simultaneously with the log difference of output. Therefore, the OLS estimates of input share may suffer from the endogeneity bias. We handle the issue using convenient instruments for institutions and other inputs. Finally, in addition to our 86 non-oil producer country sample we study the sensitivity of estimation and control the effect of the outliers and bad quality of data using a subsample of 22 industrial countries.

Moreover, several recent papers have mainly concentrated on investigating economic policy and political and constitutional (or closely connected to political and constitutional) institutions. On the macroeconomic level, the group of the institutions which are important for growth is broader than the one used in these studies. For example, educational and health care institutions are clearly major factors of economic development. It is a political and constitutional choice to create an environment where such institutions can develop, but it is the institutions themselves, not only the political or constitutional system, which matters for growth. In our paper we explore how the quality of institutions influences long-run growth under the "broad" context of institutions. Our institutional indicator is built using 18 indicators which all reflect some aspects of the quality of institutions. We assume that these indicators reflect the quality of institutions by creating the environment to manage risk which citizens encounter during their life time.

We have divided these indicators into 5 groups: 1) governance and regulative institutions, 2) health and social services institutions, 3) urban policy institutions, 4) basic educational institutions and 5) economic institutions.

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nian and Trebbi (2002), World Economic Outlook (2003), and Dollar and Kraay (2003) and finally, the surveys of Aron (2000) and Hjerppe (2003).

Finally, to obtain efficient estimators for the parameters we build a Bayesian two stage model with heteroskedasticity correction. We choose a prior distribution which gives weight to solutions which are informative about the parameters of interest. Using the Bayesian approach, we can make precise inference about the parameters even in the cases of small sample sizes and obtain credible intervals for them easily.

The rest of the paper is organized as follows. In the next section, we use a modified version of the model used by Hall and Jones (1999), for distinguishing the effect of institutions on the growth of capitals and output over the period 1970-2000. We also describe the structure of our institutional indicator and introduce a Bayesian Two Stage Model with Heteroskedasticity correction (B2SH). Finally, we document the empirical results. In Section 4 we build one possible model for the evolution of productivity, estimate the Cobb-Douglas production function using this model and document the empirical results of Cobb-Douglas model. Our conclusions are given in Section 5.

2 Institutions and Growth

2.1 Empirical Analysis of Institutions in Economy

The development of institutions is strongly tied to the historical process in creating economic welfare. Output and wealth are connected to the attributes of institutions. These attributes define the capacity of institutions to contribute to economic growth. From the economic point of view, market institutions are the most important ones when we are modelling the behaviour of actors in the market. We think that these attributes of institutions are also factors of production as the latest research seems to conclude (e.g. Hall and Jones). National overhead capital in the broad sense also includes the institutions.

We assume that the quality of institutions is determined by interactions between individuals (human capital in our model) and the structure of institutions. The structure of institutions mainly consists of the following elements: cultural inertia, social capital and contractual environment. Different kinds of historical shocks determine the evolution of these characteristics. The structural model of institutions, human capital and wealth institutions in country *i* at time period *t* can therefore be written as

$$Q_{it} = a_0 + a_1 \ln y_{i,t-k} + a_2 \ln h_{it} + \sum_{d=0}^{D} \theta'_d \mathbf{x}_{i,t-d} + \eta_i + u_{it}, \quad (1)$$

$$\ln h_{it} - \ln h_{i,t-k} = a_0 + a_1 \ln h_{i,t-k} + a_2 Q_{it} + u_{it}, \quad (2)$$

where η_i is an unobservable country specific effect which is assumed to influence inputs and outputs through institutions, u_{it} an error term, h_{it} the human capital per worker, Q_{it} the indicator for the quality of institutions, $y_{i,t-k}$ the past output per worker and x_{it} a vector of exogenous variables from regional and global sources.

(Note that the coefficients a_0, a_1 and a_2 and the error u_{it} are not the same in equations (1)-(4).) Each entry of the vector θ_d could be negative, positive or zero, depending on the effect of the variable on output with lag d. However, we will not estimate model (1), since in practice it would be difficult to specify the variables in x_{it} and obtain data for them.

Dollar and Kraay (2003) show that in several recent papers in which the influence of the quality of institutions and trade on the long-run growth process has been studied the results have been unreliable because of the use of weak instruments. On the other hand, the authors themselves focus on a relatively short period (10 years). Hence, to explore the potential influence of institutions on output per worker we will return to the formulation of Hall and Jones (1999) with past output per worker:

$$\ln y_{it} - \ln y_{i,t-k} = a_0 + a_1 \ln y_{i,t-k} + a_2 Q_{it} + u_{it}. \qquad (3)$$

Allthough in the recent growth accounting literature the analysis of growth has more and more to do with the short-run variations we focus on a considerably longer analysis (k=30 years). Institutional change is a relatively slow process and its effects may be missed when the focus is on a shorter time interval.

Equation (3) implies that the quality of institutions determines the environment in which the transition dynamics and the growth process are related. We found several reasons why the convergence is conditional on institutions, not for example on human capital or different kinds of macroeconomic structures or policies[3] (Acemoglu, Aghion and Zilibotti (2002)):

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[3] Over the past fifteen years many governments have responded to internal and external pressure by launching far-reaching reforms to improve their performance. Typically, changes in macroeconomic policy – dealing with exchange rates, fiscal policy, and trade policy – have come fastest. These reforms have political implications but do not require the overhaul of institutions. But other state reforms, dealing with the regulation of social services, finance, infrastructure, and public works, cannot be accomplished so rapidly because they involve changing established things for different purposes, to fit different rules of the game. Comprehensive reform along these lines will take a great deal

a) The amount of human capital is heavily dependent on educational institutions and social networks.
b) The quality of institutions, constitutional framework, property rights, entrepreneurial skill etc. determine the level where individuals are capable to accumulate physical and human capital, engage in enterprise and develop technology (imitation and innovation).
c) Institutions determine the abilities and incentives to evolve the financial system and commit macroeconomic policies.
d) Countries' abilities to handle global and local crises, economic slowdowns and global developments are directly related to their institutional structure, see, for example, Acemoglu, Johnson, Robinson and Thaicharoen (2002).

One primary objective of our models above is to explore the institutional and organisational responses to the variations of specific contracting attributes that may impede mutually beneficial productivity measures. Oliver Williamson, for example, emphasises contractual attributes such as the frequency of transaction, the uncertainty of outcome, the open-endedness of contract, the investment in specialisation and non-redeployable assets, etc.

At the heart of the analysis is the paradigm holding the real world contracts to be incomplete and consented upon by actors who are boundedly rational, and, if it pays off, with the potential to act opportunistically. Bounded rationality, opportunism, lack of information, contractual incompleteness, and unanticipated contingencies have been argued to set the stage for performance problems.

Transaction costs emerge as costs to coordinate parties, draft liabilities, consent on the division of gains, monitor performance, adapt to contingencies, and en-

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of the time and effort, and the agenda varies considerably from region to region (World Development Report (1997), The World Bank).

force obligations. One assumed driving force affecting the choice among alternative institutional arrangements is the joint desire among contracting parties to economise on transaction costs and to promote transactions.

Rational response to contracting dilemmas is important in relation to market institutions and regulatory characteristics. The issue at stake is to what degree there is a transaction cost rationale embedded in institutional response to a failing market. Institutional theory does not thereby neglect the fact that pressure groups and political entrepreneurs are organised and act strategically to capitalise on institutional changes as much as possible. In the words of Douglas North, "*institutions everywhere are a mixed bag composed of those that lower costs and those that raise them*".

To explore how institutions influence the incentives of an individual to accumulate wealth (different kinds of assets) we model the growth of physical capital as

$$\ln k_{it} - \ln k_{i,t-k} = a_0 + a_1 \ln k_{i,t-k} + a_2 Q_{it} + u_{it}, \tag{4}$$

where k_{it} is physical capital per worker. We use a cross-country sample[4] of 86 countries and estimate equations (2)-(4) with Bayesian IV regression and control these results using the subsample of 22 industrial countries. Moreover, we control the effect of interpolated and extrapolated series estimating these regressions using a subsample of 76 countries. We affirm that in models (2)-(4) the past dependent variables and recent institutions may be endogenous variables. This

[4] The stock of physical capital is estimated using each country's investment rates from Penn World Tables 6.1 and perpetual inventory methods. The capital stock in 1960 is estimated using $K_i = I_i/(g_i+d+n_i)$ where I denotes the investments, g the growth rate of GDP per worker, d the depreciation rate and n the growth rate of population, calculated as the average growth rate from 1961 to 1970. The depreciation rate d is assumed to be 0.07. In the case of human capital we follow Bils and Klenow (2000) who approximate the human capital per person using the years of schooling per person and the experience of each age group. We set ψ at 0.28. The years of schooling series is from Cohen and Soto (2001). Population data are from the International Data Base of the U.S. Census Bureau (Population Division of the International Programs Center (IPC)) and the United Nations population data (1995). Labour stock in each country is obtained from World Development Indicators (2002). Output series have been taken from Penn World Tables 6.1. Moreover, we have interpolated or extrapolated the missing GDP and investment values in the cases of 10 countries (3 of them are extrapolated). Finally, the list of countries is given Table 13 in Appendix 2.

causes the simple OLS estimators to be inconsistent. A commonly used way to deal with the issue of endogeneity is to instrument for endogenous regressors with variables that are correlated with them but exogenous to them and the regressed variable. We therefore instrument for the past human capital per worker and recent institutions using the initial[5] years of schooling, the fraction of country's land area subject to malaria in 1994 ("Malaria", Gallup, Sachs and Mellinger (1998)), initial life expectancy at birth ("Life", World Development Indicators (2002)) and the initial political variable named Regime Durability ("Durable", Marshall and Jaggers 2000). Furthermore, we instrument for the past physical capital and recent institutions with the variables Malaria, Life and Durable and with the initial level of physical capital, and for the past output per worker and recent institutions using the geographical variable Dist and the initial values of the following variables: Age, Life, and output per worker[6].

When analysing the subsample of industrial countries we instrument for the past human capital per worker and recent quality of institutions with the distance from equator ("Dist", Easterly and Sewadeh (2003)), the proportion of the country's land area within the geographical tropics ("Tropics", Gallup and Sachs (1999)) and the initial levels of years of schooling per capita and age dependency ratio ("Age", World Development Indicators (2002)). We instrument for the past physical capital per worker and recent quality of institutions with Dist, Tropics and the initial levels of physical capital per worker and Age. Finally, we instrument for the past level of output per worker and the recent quality of institutions using Dist, Tropics and the initial levels of output per worker years of schooling and Age.

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[5] We refer to the values of 1960 as initial values of the variables.

[6] In the case of 76 countries and model (2) and (3) we use the same instruments as in the total sample case. In the case of model (4) we again use the same instruments as in the total sample case but replace the initial life series by the initial years of schooling series.

We checked the robustness of the results in the total sample using several sets of political and geographical variables as ancillary variables. In general, we found that the estimation results were not sensitive to using these variables. In our final analysis we used African and Latin American country dummies. The estimates of the institutional indicator are somewhat higher without these dummies.

The consistency of the IV estimators in all models of this paper is checked using two specification tests. Hansen's test for over-identification restrictions in the case of heteroskedastic errors is used to see whether the model specification is correct and the instruments are uncorrelated with the error process. In the cases of homoskedasticity, Sargan's test is used. We accepted the null hypothesis in all cases of this paper with level 5%. The second test is for weak instruments. We follow Stock and Yogo (2002) who propose quantitative definitions of weak instruments based on the maximum IV estimator bias or the maximum Wald test size distortion. We rejected the null of weak instruments in all cases of this paper with level 5%.

2.2 The Indicator of Institutions

Several recent papers have focus only on the political and some of them also on the economic and social institutions. We have chosen our indicators so that we can analyse most characteristics of institutions on the macroeconomical level. The most prominent motivation to use data for the characteristics of institutions and make indicators for them is the apparent easiness to relate them with social networks and cooperation. The concept of networks could be used locally or in a more general way in the whole society. If we consider cooperation and the cohesion of groups it is important to go on like Fukuyama and divide the cooperation to more analytical characteristics such as *linking, bonding and bridging*. Linking refers to vertical relations between groups and individuals, in which networking is mostly hierarchical (based more on the command and control behaviour). Bonding means that the behaviour of individuals is tightly connected to the rules inside groups and the solidarity between the groups is weak. The concept of bridging is related to "generalised trust" which helps to communicate between the groups in society. Also trust in more unfamiliar cultural characteristics of other institutions is easier if the ability of bridging is on a high level. Therefore, our data set of indicators includes 18 variables which all reflect some aspects of the quality of institutions and are scaled from zero to one, so that the best practice institutional environment obtains one. For the purpose of analysis we have classified these indicators to five groups:

(i) *governance and regulative institutions;* Voice and Accountability, Political Stability, Governmental Effectiveness, Regulatory Quality, Rule of Law and Control of Corruption.

(ii) *health and social services institutions;* Age dependency ratio (dependants to working-age population), Life expectancy at birth, (total years), Health expenditure, (total % of GDP),

(iii) *urban policy institutions;* Urban population (% of total), Improved water source (% of population with access), Improved sanitation facilities (% of population with access),

(iv) *basic educational institutions;* Illiteracy rate, adult total (% of people aged 15 and above), Illiteracy rate, youth total (% of people ages 15-24) and the years of schooling in average, 15 years older in total population.

(v) *economic institutions;* indicator of Trade Openness[7], Import duties (% of imports) and Indicator of income distribution[8].

We use a large variety of indicators to describe the quality of institutions, which is determined by their ability to reduce the overall risk in society. Institutions determine the level at which the citizens encounter their individual risks. They

[7] The values of (import + export)/GDP which are greater than 150% are set at 150%, since we assume that such values are outliers.

[8] This indicator is constructed using the income share held by the lowest and highest 10% and 20%, so that the most uniform income distribution obtains the largest indicator value. The data is from the World Development Indicators.

also help the society manage risks and accelerate economic growth if their quality is good enough. Risks are connected in many ways to the economic growth process. One mechanism comes from incentives, to which institutions affect. The first group of indicators is related to the formation of institutions and the control of their quality. The others are more direct contributions to the risk level.

The source of the first six variables is the report of Kaufmann, Kraay and Zoido-Lobaton (2000) where the authors who construct aggregate governance indicators. Detailed description of these variables is to be found in the report. The remaining 12 variables are from World Development Indicators (2002) and the data base of Summers, Heston and Aten (2002), named Penn World Table 6.1.

Let Q_{it} be an unobserved indicator for the quality of institutions in country *i* (i=1,…,N) at time period *t* and x_{ikt} the observed score of the *k*th indicator. One can model the observations using the simple linear model

$$x_{ikt}=Q_{it}+u_{ikt}$$

where the error terms ε_{ikt} are independent with zero mean and σ^2_{ikt} variance. Some of our indicators are fragmentary and we have interpolated the missing values. We have assumed that the variance of the existing indicator values is constant σ^2_{it} in the *i*th country at time *t*, while the interpolated indicator value has a large variance. Consequently, we have used a weighted mean in order to obtain efficient estimates for Q_{it}. The weight for the existing indicators is 1 and for interpolated indicators p_{ikt} (<1), where p_{ikt} is our personal opinion about the ratio $\sigma^2_{it}/\sigma^2_{ikt.}$ The correlations between the indicator of institutions, the averages of its component groups, output per worker and its growth rate are presented in Table 12 of Appendix 2.

2.3 Econometric Method

A random variable is said to be heteroskedastic if its variance is not the same for all observations. Under heteroskedasticity of error terms, conventional IV estimators are inefficient and their standard errors inconsistent, which prevents valid inference. In order to estimate the economic models of this paper under heteroskedasticity, we build a limited information simultaneous equation model

$$y_1 = Y_2\beta + Z\gamma + \varepsilon_1,$$

$$Y_2 = X\Pi + Z\Gamma + V_2,$$

where $Y = (y_1\ Y_2)$ is an $N \times m$ matrix of endogenous variables, Z an $N \times k_1$ matrix of included exogenous variables, X an $N \times k_2$ matrix of excluded exogenous variables, that is, instruments, and ε_1 an $N \times 1$ vector and V_2 an $N \times (m\text{-}1)$ matrix of errors. Vectors β and γ contain the structural parameters of interest. The matrices Z and X are assumed to be of full column rank, uncorrelated with ε_1 and V_2, and weakly exogenous for the structural parameter β. The elements ε_{1i} of ε and the rows V_{2i} of V_2 are assumed to be normally distributed with zero mean and $m \times m$ covariance matrix

$$\Sigma_i = \text{var}\,(\varepsilon_{1i}\ V'_{2i})' = \lambda_i \begin{pmatrix} \sigma_{11} & \Sigma_{12} \\ \Sigma_{21} & \Sigma_{22} \end{pmatrix},$$

where heteroskedasticity is captured by the coefficient λ_i. The structural equations above can be reparametrized as

$$y_1 = W\delta + v_1,$$

$$Y_2 = UB + V_2,$$

where $W = (UB\ Z)$, $\delta = (\beta'\ \gamma')'$, $U = (X\ Z)$, $B = (\Pi'\ \Gamma')'$ and $v_1 = \varepsilon_1 + V_2\beta$. Denoting

$$\Omega_n = \text{var}\ (v_{1n}\ V'_{2n})' = \lambda_n \begin{pmatrix} \omega_{11} & \Omega_{12} \\ \Omega_{21} & \Omega_{22} \end{pmatrix},\ \omega_{11.2} = \omega_{11} - \Omega_{12}\Omega^{-1}_{22}\Omega_{21} \text{ and}$$

$$\phi = \Omega^{-1}_{22}\Omega_{21}$$

we obtain that $e_1 = v_1 - V_2\phi$ is uncorrelated with V_2 and $\text{var}(e_{1n}) = \lambda_n\omega_{11.2}$. The likelihood function for the Bayesian Two Stage model[9] with Heteroskedasticity correction (B2SH) is given by

$$L=P(Y|\ X, Z, \theta) = P(Y_2|\ X, Z, \theta)P(y_1|\ Y_2, X, Z, \theta),$$

where θ denotes the vector of all parameters and

$$P(Y_2|\ X, Z, \theta) \propto |\ \Omega_{22}|^{-0.5N}|\ \Lambda^{-0.5(m-1)}\exp\{-0.5\ \text{tr}\ \Omega^{-1}_{22}(Y_2\text{-}UB)'\Lambda^{-1}(Y_2\text{-}UB)\},$$

$$P(y_1|\ Y_2, X, Z, \theta) \propto \omega_{11.2}{}^{-0.5N}\Lambda^{-0.5}\exp\{-0.5\ \omega_{11.2}{}^{-1}(y_1\text{-}W\delta\text{-}V_2\phi)'\Lambda^{-1}(y_1\text{-}W\delta\text{-}V_2\phi)\},$$

and $\Lambda = \text{diag}(\lambda_i)$, $\lambda_i = \exp\{\xi\ z_i\}$, $i = 1,\ldots,N$ and z_i is a variable (or a row of variables) possibly identical to some other variables in the model. In the Bayesian analysis we have used Jeffrey's non-informative prior distributions. However, in deducing the prior of B we have only used the marginal density function of Y_2, not the whole density. The prior and posterior distributions of parameters are given in Appendix 3.

[9] A Bayesian two-stage approach was presented by Kleibergen and Zivot (1998).

2.4 Estimation Results

Table 1 of Appendix 1 presents the B2SH estimation results[10] for our three specifications (2)-(4) in the framework of basic growth models. A general result concerning all these models and the total sample is that the heteroskedasticity parameter[11] (ξ) is significantly negative. This means that the larger the level of output per worker in 1970, the smaller is the variance of residual terms. Since we are modelling the "β convergence" out, this finding may reflect that in less developed countries there occur more unexplained growth possibilities. However, these possibilities seem to disappear when the countries' starting points are close to each other. Table 3 presents the results estimated using the B2S model and Table 7 presents the results concerning the subsample of 76 countries. We report the B2S results in the cases when there is no heteroskedasticity.

Looking at the results of the first column in Table 1, one can find that the estimates of the convergence parameters are -0.25 and -0.34 (B2S) in the total and industrial samples, respectively. This reflects that when we eliminate the effect of institutions[12] on education and experience, it becomes more difficult to boost the growth of human capital if the present level is already large. The coefficients 0.29 and 0.80 for the influence of institutions on the cumulative growth of human capital over the period 1970-2000 are unsignificant in the level of 5% in both samples. This result does not necessarily indicate that institutional environment has no influence on the growth of human capital, but more likely there is limited ability to grade the value of schooling in the production process in different countries. For example, compared to the situation in many African countries, the comprehensive schooling system in Scandinavian countries creates a totally different kind of basis to individual learning process and ability to practice opera-

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[10] The Bayesian estimation results of this paper are based on 20000-80000 simulation rounds, depending on the rates of convergence to the stationary distributions.

[11] Heteroskedasticity is modeled by $Cov(Y_i | X_i, Z_i, \theta) = \exp(\xi z_i)\Sigma$, where $z_i = \ln y_i(1970)$.

[12] We think that institutions create an environment for the accumulation of human capital

tions required in production activities. Therefore, the comparison of human capital stocks between the countries is problematic.

The convergence coefficient of physical capital is estimated as -0.52 in the total sample and as -0.45 (B2S) in the industrial subsample (see Tables 1 and 3). These relatively large convergence coefficients support the general conception that institutions of high quality help technological diffusion between countries. The effects of institutions on the cumulative growth of physical capital per worker are 3.28 and 6.51 (B2S) in the samples, which means that 0.01 increase in the quality of institutions is associated with 7 % and 10 % faster annual growth rates of physical capital per worker in the total and industrial samples, respectively. These results imply that the quality of institutions determines the incentives of production processes and the national innovation systems. This structural environment strongly affects the growth of investments and the efficiency to use physical capital.

The estimate of the convergence parameter for the output per worker in the total sample, -0.48, is relatively high, reflecting strong conditional convergence between the 86 countries of our sample. The slope –1 (B2S) implies complete conditional convergence between the industrial countries over the period 1970-2000. This means that for every per cent a country's per capita income was below average in 1970, its cumulative growth rate was 1 per cent higher than average over the next 30 years, given the level of the quality of institutions (Obstfeld and Rogoff, 1996).

An increase in the components of the institutional indicator which is sufficient to produce 0.01 increase in the indicator is associated with 7.3 % and 5.7 % faster average annual growth rates in the total and industrial samples, respectively. These results correspond to 2.48 % and 3.24 % (B2S) increases in the final year output per worker and describe the importance of institutional environment in the growth process. Moreover, the estimation results of the equation (3) are consistent with the results of e.g. Hall and Jones. The high difference in the coefficient of institutional influence (2.48) compared[13] to that of Hall and Jones (5.1) firstly arises from controlling the effect of past output per worker and secondly from the fact that our indicator for quality of institutions is more realistic than the corresponding index used by Hall and Jones, since it covers a wider sphere of institutional phenomena.

Table 9 of Appendix 2 presents the OLS and B2SH results for model (3) when the component groups of institutions, defined in Chapter 2.2, are used instead of the composite indicator. The effect of the urban policy institutions is the strongest among the component indicators, although the effect of the health and social service institutions is not far from it.

We compared our estimates with the corresponding heteroskedasticity corrected ML estimates (See Tables 1 and 5). In general, the absolute values of the ML estimates were larger in the case of the industrial sample. The differences are due to the prior distribution, which gives more weight to matrices B such that their columns are far from being linearly dependent. This improves the identifiability of β. Moreover, it seems that the prior distribution compensates the use of information from $\mathbf{y}_1$ in the estimation of B and makes the results closer to those obtained by the 2SLS.

Finally, the multiple correlation coefficient of the error terms ε and $\mathbf{v}_2$ tells the proportion of the variance of ε explained by $\mathbf{v}_2$ and thus the degree of endogeneity. It is fairly small (<0.2) for the input and output models in the total sample, while in the industrial subsample it is considerably larger for output and physical capital.

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[13] Clearly, we can write model (2) in the form $\ln y_t = 0.52 \ln y_{t-k} + 2.48\ Q_t + u_t$

Furthermore, we study the role of institutions in the context of the traditional production function theory. We have several incentives for doing this: a) We want to check the robustness and reliability of our results using a structural model for growth and b) explore the magnitude of institutional parameters when the role of human and physical capital is taken into account. We are also interested c) to know how the traditional growth accounting framework behaves if the institutions are included and d) to take a closer look at the transitional process.

3 Institutions, Productivity and Growth

3.1 Simple Structural Model

In accordance with Mankiw, Romer and Weil (1992), Barro and Sala-I-Martin (1995), Bils and Klenow (2000) and many others we start our structural analysis modelling economy's production technology. We assume that nations' income is related to human capital and physical capital as

$$Y_{it} = (A_{it}H_{it})^{1-\alpha}K_{it}^{\alpha}, \qquad (5)$$

where Y_{it} is the flow of output, A_{it} the productivity, i.e. Solow's residual, H_{it} the aggregate human capital and K_{it} the aggregate physical capital. In empirical investigation we prefer the use of Cobb-Douglas production function - as a heart of our structural analysis - instead of general equilibrium models because:

a) In order to apply general equilibrium models we also have to specify the endogenous institutions on the macroeconomical level. That kind of model has not yet been formulated in a satisfactory manner and it goes beyond this study.
b) The comparability of the empirical results of general equilibrium models is quite restricted because of different kinds of assumptions related to these models.
c) Referring to the Kaldor Facts[14] it seemed that the Cobb-Douglas production function approximates the process of growth very well. In addition, it is easy to apply.

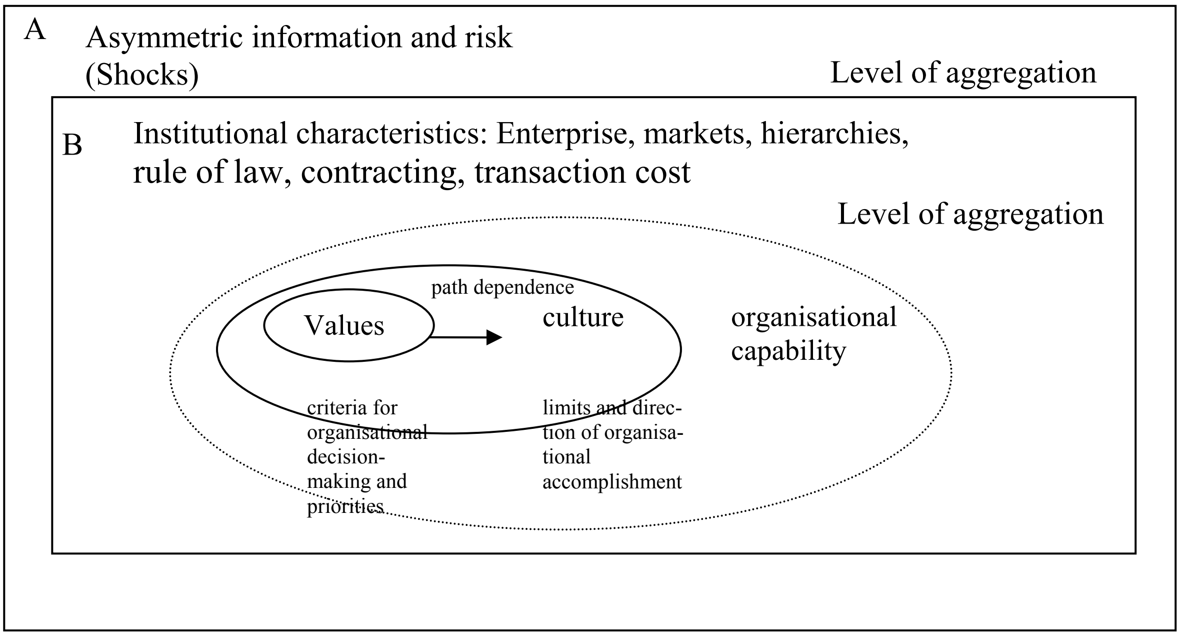
[14] 1) Per capita output grows at roughly constant rate. 2) The capital-output ratio is roughly constant. 3) The real rate of return to capital is roughly constant. 4) The shares of labour and capital in national income are roughly constant.

Taking log differences of the production function (5), we obtain for long-run growth the formula

$$\Delta_k \ln Y_{it} = (1-\alpha)\, [\Delta_k \ln A_{it} + \Delta_k \ln H_{it}] + \alpha\, \Delta_k \ln K_{it}. \qquad (5)'$$

where Δ_k denotes k-step difference. Unlike Romer (1990), Benhabib and Spiegel (1994), Bils and Klenow (2000) and many others, we assume that in the growh process of productivity (technology in their cases[15]) it is not human capital but institutions which determine the environment where the productivity (TFP) can evolve. The influence of institutions on productivity is illustrated in Figure (1).

Figure 1. Source of productivity by institutions: Benefit and cost[16]



The interactions of market and regulative institutions have a strong influence on the development of the dynamic capability of the production unit. The shared goals of those institutions define in the long-run the preconditions as to how the

[15] We think that, in the context of institutions, the exploration of total factor productivity (TFP) instead of just technology gives us more perspective to understand the process of growth. We state that technology adoption and technology itself are elements of TFP.

[16] Modified from Kirsimarja Blomqvist, Partnering in the Dynamic Environment; The role of Trust in Asymmetric Technology Partnership Formation, Acta Universitas Lappeenrantaensis, 122, p. 46, 71, 2002

production unit can resolve the strategic vision of its capabilities. Some aspects of these institutional characteristics could be put as follows:

- to promote the usages of resources, which are not production unit specific
- to promote the development of production unit specific resources by organisational capabilities (core capabilities included)
- to promote characteristics, which enable different kinds of joint activities of actors
- to help define risks and liabilities as specific resources for the production unit.

Business organisations and networks of individuals develop specific cultures that can affect their performance. The nature of a specific culture originates from different sources such as social capital, institutions, management systems and the background of individuals. Business successes and failures have been attributed to corporate cultures. The analysis done with institutions has several interesting implications. First, in good institutional environments agents have stronger incentives to undertake cultural specific investments (to decrease diversion in terms of Hall and Jones, 1999).

Second, the institutional problems are connected to path dependence. Human capital such as skill and experience has limited transferability and this induces imperfect mobility of workers between different vintages. Workers accumulate skills by learning by doing when employed, thus increasing their productivity in the current job during the employment spell. However, these skills are to some degree specific to the capital and cultural vintages of the current match. Therefore, it could be predicted that incentive problems will tend to manifest themselves in culturally diverse environments. This conclusion holds only if the cultural structure is exogenous, but that is not the case. However, it will be particularly important for culturally diverse institutional environments to spend more effort and resources dealing with incentive problems.

Based on the discussion above and the promising results of model (3) we shall attempt to model the evolution of productivity as

$$\ln A_{it} - \ln A_{i,t-k} = \alpha_0 + \mu \ln A_{t-k}^*/A_{i,t-k} + \lambda Q_{it} + u_{it} \quad (6)$$

where λ is a parameter describing the influence of institutions, μ a convergence parameter and $A_{i,t-k}$ the past level of total factor productivity (TFP). Output per worker is used as a proxy for the TFP. A^*_{t-k} is the past level of TFP in the most productive country and the productivity gap $\ln A_{t-k}^*/A_{i,t-k}$ therefore describes the distance of the *i*th country from the best practice country.

According to model (6), the growth of productivity is dependent on the structure of institutions. It can be seen as an environment for the growth process of productivity as well as for the transition process. The term μ describes the transition dynamics of the economy around the long-run growth path of productivity. The transition process is a consequence of technological diffusion and diminishing returns to inputs.

To explore how the structures of institutions influence the long-run growth, we use model (6) to rewrite the production function (5)' in the form

$$\Delta_k \ln Y_{it} = \pi \ln A_{t-k}^*/A_{i,t-k} + \rho Q_{it} + (1-\alpha) \Delta_k \ln H_{it} + \alpha \Delta_k \ln K_{it} + u_{it}, \quad (7)$$

where $\pi = (1-\alpha)\mu$ and $\rho = (1-\alpha)\lambda$. The corresponding equation in per worker terms is

$$\Delta_k \ln y_{it} = \pi \ln A_{t-k}^*/A_{i,t-k} + \rho\, Q_{it} + (1-\alpha)\, \Delta_k \ln h_{it} + \alpha\, \Delta_k \ln k_{it} + u_{it}. \qquad (8)$$

In order to make the parameters of model (7) identifiable we follow the example of Benhabib and Spiegel (1994), Papageorgiou (2001) and many others and assume that the log differences of physical and human capital are uncorrelated with unexpected country specific growth opportunities. That is, we assume that the log differences of physical and human capital are independent of the error term u_{it}. We are sceptical about this assumption and we shall ignore it later. For the moment, we assume that the past productivity gap and recent institutions are endogenous variables. To deal with the issue of endogeneity we assume that Dist and the initial values of Life, Age, executive constraint (Marshall and Jaggers 2000) and output per worker are uncorrelated with unexpected future growth shocks. Consequently, we instrument for the past technological gap and recent institutions using the above series as instruments. In the instrumental variables regression we use Latin American and African regional dummies.

In the case of the industrial sample we have chosen as instruments the variables Tropical and Dist and a couple of initial variables: Age and output per worker. We also tested the sensitivity of results using a set of political and geographical variables as ancillary variables and found that the results reported in the following are non-sensitive to the use of these variables.

3.2 Estimation Results for the Structural Models

The first column in Table 2 presents the estimation results for the model (7) using the B2SH. The heteroskedasticity parameter in the model (7) is negative and significant in the total sample and in the subsample of industrial countries. We find that the input shares of human capital are significant with estimates 0.45 and 0.34 in the total and industrial samples, respectively. The corresponding estimates for the input shares of physical capital, 0.44 and 0.52, are also significant. The effects of convergence on cumulative growth over the period 1970-2000 are

0.28 and 0.72. Finally, an increase of 0.01 in the quality of institutions is associated with 1.73% and 2.69% increases in the final year output. This corresponds to 1.7% and 2.9% accelerating effects on the average yearly growth of output.

The above results deserve some careful comments. Firstly, as typical in empirical growth literature, our estimates for the input share of physical capital are too high and the estimates for the input share of human capital are too low compared to corresponding micro evidence. We are convinced that this result is due to uncontrolled endogeneity which leads to biased estimates of the input shares. Secondly, the results affirm that under the influence of institutions and other inputs of production, it is the conditional convergence not divergence which is the story over the period 1970-2000. Anyhow, from our point of view, we should condition the convergence on institutional quality, not on human capital[17]. The estimate of the transition parameter in the industrial sample is more than twice the value in the total sample. Thus, it seems that countries with a closer starting point acquire more benefit from the catch-up process. Thirdly, the coefficient of institutions is higher in the industrial subsample than in the total sample.

We suggest that model (7) is not specified correctly, since in practice the assumptions about endogeneity of past output gap and exogeniety of log differences of physical and human capital are likely false. Therefore, we treat the 1970 output gap as an included exogenous variable and recent institutions and the growth rates of physical and human capital as endogenous variables and instrument them using the geographical variable Dist and the initial values of the following variables: Age, Life, output per worker and physical capital per worker. Moreover, in the regression we used African and Latin American country dummies. In the case of the industrial sample we instrument for recent institutions and the log differences of human and physical capital with the variables Tropical and Dist and

[17] When replacing the institutional indicator for the past level of human capital per worker we found that the value of convergence parameter almots halved.

with the initial values of output per worker, physical capital per worker and years of schooling per capita.

The estimates for model (7) with endogenous inputs are given in the second column of Table 2. The corresponding results for the B2S model with no heteroskedasticity correction are shown in Table 4 and the results concerning the subsample of 76 countries are given in Table 8. The results are something we have expected. Using our data samples all parameters are statistically significant. An increase of 0.01 in the quality of institutions speeds the average yearly growth of output 2.1% and 2.3% in the total and industrial samples, respectively. The corresponding effects on the final year output are 2.07% and 2.12%. Thus, the difference between the two samples in the previous model specification is now absent.

The estimated input shares for human capital are 0.69 and 0.36 in the total and industrial samples, respectively. We see that in the case of the total sample the human capital share in the production process is close to 2/3 as it should be under the constant return to scale production function. The estimates of physical capital share are 0.28 and 0.36 which both are quite close to the theoretical value of α (1/3). The transition parameter μ obtains the estimates 0.34 and 0.55, which supports our earlier findings about the nature of the catch-up process.

When estimating equation (8) in which the variables are in per worker terms we found that the effect of the growth of human capital was clearly insignificant[18]. Because of the shortcomings in grading human capital (cf. our discussion about the estimation results of model (2)) we write equation (8) in the form

[18] When the log difference of human capital per worker was modelled without control variables and the institutional indicator, the estimate of the input share was statistically significant and near to (2/3). When some control variables were added, the estimates became nonsignificant. The model in the aggregate level gives a significant result, since labor input contributes the basic explanation of human behavior in the production process.

$$\Delta_k \ln y_{it} = \pi \ln A_{t-k}^*/A_{i,t-k} + \rho\, Q_{it} + \alpha\, \Delta_k \ln k_{it} + u_{it}, \tag{9}$$

where we assume that the institutional indicator and the log difference of physical capital per worker are endogenously determined. Therefore, we instrument for them using the initial values of Age, Life, physical capital per worker and output per worker. When regressing Equation (9) we used African and Latin American country dummies. The corresponding instruments in the industrial sample are Tropical, Dist and the initial values of output per worker and physical capital per worker.

The results of model (9) reported in the third column of Table 2 show that an increase of 0.01 in the quality of institutions corresponds to 2.10 % and 2.56% increases in the final year output per worker. The corresponding average yearly effects of institutions on speeding up the growth are 6.2 % and 4.5 % in the total and industrial samples, respectively. The influences of transition dynamics on economic growth, 0.34 and 0.46, support our earlier results that transition is more powerful when countries have closer starting points. The estimates of α are 0.34 and 0.67 in the total and industrial samples, respectively. Finally, if our explanation for the negative heteroskedasticity parameter (ξ) is correct, poor countries have more variability in growth possibilities.

The OLS and B2SH results for models (7) and (9) when using the institutional indicator or the averages of its component groups are shown in Tables 10 and 11 of Appendix 2. Urban policy institutions and the health and social service institutions are the most influencal as they are in the case of model (3).

When comparing the estimation results with the corresponding ML results we find that the ML estimates for the effects of output gap and institutions are larger in the small subsample of industrial countries. This supports our earlier discussion about the role of the prior distribution.

Finally, we find that the multiple correlation coefficient, $R^2_{\varepsilon,\mathbf{v}_2}$, is approximately four times as large in the model of endogenous inputs as in the model of exogenous inputs. This confirms our concept that log differences of inputs are endogenous. For the industrial sample the estimate of $R^2_{\varepsilon,\mathbf{v}_2}$ is very large in all cases.

4 Summary and Remarks

The complexity and integration of production processes has changed the linkages of productivity and growth. The sources of productivity in private and public activities are more and more based on formal and informal rules produced by different kinds of institutions in society on national and global levels. This trend has created powerful interest groups in many areas of economic activities, which means that the problem of insiders and outsiders has become more acute than before and it has made the asymmetric information problem more serious. In physical production networking and specific production processes this means that productivity profits arise more from how large and complex networks are managed.

Our cross-country analysis confirms that the growth environment offered by institutions has a significant and important role in economic growth. The role of institutions is important not only when the range of institutional quality is large but also among countries of high institutional quality. In fact, when the statistical model is specified correctly, the estimate for the effect of institutions in the industrial subsample is similar to that in the total sample.

However, the effect of institutional quality does not seem as dramatically high as some previous studies have indicated. For example, our estimate for the effect of institutions (2.10) is less than half of the corresponding figure (5.14) given in Hall and Jones (1999). We believe that the differences are due to the following two reasons: Firstly, our indicator of institutions covers a wider sphere of institutions than just the political and economic. Secondly, we have controlled the effect of convergence and the inputs in the production process, although the effect of including the inputs is surprisingly small.

Finally, opposite to many earlier cross-country studies we found that when the effect of institutions and the endogeneity of the growth of physical and human capital are controlled, the estimates for the input shares of the capitals are close to their theoretical values 1/3 and 2/3, respectively.

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Appendix 1

Table 1: The B2SH results for the institutional process

a) Total sample (N=86)

Variables	Δ_{30} ln h_{00}, (2)	Δ_{30} ln k_{00}, (4)	Δ_{30} ln y_{00}, (3)
ln h_{70}, ln k_{70}, ln y_{70}	-0.25 (-0.37, -0.12)	-0.52 (-0.70, -0.35)	-0.48 (-0.67, -0.29)
Q_{00}	0.29 (-0.04, 0.62)	3.28 (1.57, 4.99)	2.48 (1.25, 3.74)
ξ (heteroskedasticity)	-0.39 (-0.60, -0.18)	-0.33 (-0.54, -0.13)	-0.37 (-0.58, -0.16)
R^2_{ε,v_2}	0.18 (0.05, 0.34)	0.13 (0.02, 0.32)	0.11 (0.01, 0.30)

b) Industrial sample (N=22)

Variables	Δ_{30} ln h_{00}, (2)	Δ_{30} ln k_{00}, (4)	Δ_{30} ln y_{00}, (3)
ln h_{70}, ln k_{70}, ln y_{70}	-0.31 (-0.45, -0.18)	-0.42 (-0.78, -0.08)	-1.05 (-1.23, -0.86)
Q_{00}	0.92 (0.03, 1.80)	6.13 (1.72, 10.68)	3.51 (2.04, 4.83)
ξ (heteroskedasticity)	1.08 (-0.49, 2.46)	-0.42 (-1.71, 1.33)	1.37 (-0.13, 2.95)
R^2_{ε,v_2}	0.23 (0.01, 0.58)	0.70 (0.42, 0.88)	0.59 (0.25, 0.83)

Table 2: The B2SH results for the Cobb-Douglas case

a) Total sample (N=86)

Variables	Δ_{30} ln Y_{00}, (7)	Δ_{30} ln Y_{00} (7) Endogenous inputs	Δ_{30} ln y_{00}, (9)
Ln y_{70}^*/y_{70}	0.28 (0.12, 0.43)	*0.34* (0.22, 0.47)	*0.34* (0.21, 0.49)
Q_{00}	1.73 (0.74, 2.72)	2.07 (1.23, 2.96)	2.10 (1.27, 3.01)
Δ_{30} ln H_{00}	*0.45* (0.23, 0.68)	0.69 (0.45, 0.94)	-
Δ_{30} ln K_{00}, Δ_{30} ln k_{00}	*0.44* (0.32, 0.56)	0.28 (0.14, 0.43)	0.34 (0.19, 0.49)
ξ (heteroskedasticity)	-0.65 (-0.89, -0.42)	-0.52 (-0.70, -0.34)	-0.68 (-0.90, -0.48)
R^2_{ε,v_2}	0.10 (0.00, 0.27)	0.37 (0.17, 0.57)	0.30 (0.10, 0.51)

b) Industrial sample (N=22)

Variables	Δ_{30} ln Y_{00}, (7)	Δ_{30} ln Y_{00} (7) Endogenous inputs	Δ_{30} ln y_{00}, (9)
Ln y_{70}^*/y_{70}	0.72 (0.33, 1.20)	*0.47* (0.21, 0.76)	*0.46* (0.18, 0.80)
Q_{00}	2.69 (0.49, 5.35)	1.90 (0.21, 3.73)	2.56 (0.69, 5.21)
Δ_{30} ln H_{00}	*0.34* (-0.04, 0.67)	0.40 (0.00, 0.81)	-
Δ_{30} ln K_{00}, Δ_{30} ln k_{00}	*0.52* (0.29, 0.73)	0.46 (0.21, 0.69)	0.67 (0.44, 0.89)
ξ (heteroskedasticity)	-3.00 (-4.37, -1.65)	0.65 (-2.11, 0.93)	-2.66 (-4.34, -1.13)
R^2_{ε,v_2}	0.62 (0.11, 0.92)	0.28 (0.03, 0.66)	0.60 (0.15, 0.89)

Table 3: The B2S results for the institutional process

a) Total sample (N=86)

Variables	Δ_{30} ln h_{00}, (2)	Δ_{30} ln k_{00}, (4)	Δ_{30} ln y_{00}, (3)
ln h_{70}, ln k_{70}, ln y_{70}	-0.20 (-0.34, -0.06)	-054 (-0.71, -0.38)	-0.43 (-0.60, -0.25)
Q_{00}	0.28 (-0.07, 0.63)	3.45 (1.80, 5.09)	2.04 (0.92, 3.16)
R^2_{ε,v_2}	0.21 (0.07, 0.38)	0.13 (0.01, 0.32)	0.06 (0.00, 0.20)

b) Industrial sample (N=22)

Variables	Δ_{30} ln h_{00}, (2)	Δ_{30} ln k_{00}, (4)	Δ_{30} ln y_{00}, (3)
ln h_{70}, ln k_{70}, ln y_{70}	-0.34 (-0.47, -0.21)	-0.45 (-0.74, -0.17)	-1.03 (-1.22, -0.85)
Q_{00}	0.80 (-0.09, 1.69)	6.51 (2.86, 10.19)	3.24 (1.66, 4.81)
R^2_{ε,v_2}	0.28 (0.02, 0.62)	0.56 (0.24, 0.80)	0.54 (0.21, 0.80)

Table 4: The B2S results for the Cobb-Douglas case

a) Total sample (N=86)

Variables	Δ_{30} ln Y_{00}, (7)	Δ_{30} ln Y_{00} (7) Endogenous inputs	Δ_{30} ln y_{00}, (9)
ln y_{70}^*/y_{70}	0.28 (0.14, 0.48)	*0.36* (0.25, 0.48)	*0.35* (0.23, 0.46)
Q_{00}	1.56 (0.65, 2.47)	1.94 (1.08, 2.81)	1.82 (1.10, 2.56)
Δ_{30} ln H_{00}	*0.47* (0.27, 0.68)	0.64 (0.43, 0.85)	-
Δ_{30} ln K_{00}, Δ_{30} ln k_{00}	*0.37* (0.25, 0.48)	0.15 (-0.02, 0.32)	0.18 (0.02, 0.35)
R^2_{ε,v_2}	0.05 (0.00, 0.18)	0.39 (0.19, 0.59)	0.33 (0.13, 0.53)

b) Industrial sample (N=22)

Variables	Δ_{30} ln Y_{00}, (7)	Δ_{30} ln Y_{00} (7) Endogenous inputs	Δ_{30} ln y_{00}, (9)
ln y_{70}^*/y_{70}	0.75 (0.49, 1.02)	*0.55* (0.30, 0.80)	*0.68* (0.44, 0.90)
Q_{00}	3.21 (1.66, 4.82)	2.12 (0.43, 3.79)	2.31 (0.73, 3.87)
Δ_{30} ln H_{00}	*0.28* (0.01, 0.55)	0.36 (0.01, 0.72)	-
Δ_{30} ln K_{00}, Δ_{30} ln k_{00}	*0.35* (0.18, 0.53)	0.41 (0.21, 0.62)	0.36 (0.16, 0.56)
R^2_{ε,v_2}	0.53 (0.15, 0.81)	0.24 (0.03, 0.57)	0.35 (0.04, 0.69)

Table 5: The ML results for the institutional process

a) Total sample (N=86)

Variables	Δ_{30} ln h_{00}, (2)	Δ_{30} ln k_{00}, (4)	Δ_{30} ln y_{00}, (3)
ln h_{70}, ln k_{70}, ln y_{70}	-0.24 (-0.37, -0.07)	-0.54 (-0.72, -0.36)	-0.48 (-0.68, -0.29)
Q_{00}	0.26 (-0.12, 0.63)	3.35 (1.65, 5.05)	2.42 (1.23, 3.62)
ξ (heteroskedasticity)	-0.38 (-0.60, -0.16)	-0.34 (-0.56, -0.13)	-0.40 (-0.64, -0.15)
R^2_{ε,v_2}	0.18	0.11	0.08

b) Industrial sample (N=22)

Variables	Δ_{30} ln h_{00}, (2)	Δ_{30} ln k_{00}, (4)	Δ_{30} ln y_{00}, (3)
ln h_{70}, ln k_{70}, ln y_{70}	-0.31 (-0.42, -0.19)	-0.52 (-1.00, -0.05)	-1.02 (-1.21, -0.82)
Q_{00}	1.20 (0.48, 1.92)	7.41 (1.24, 13.57)	4.01 (2.31, 5.71)
ξ (heteroskedasticity)	2.28 (2.16, 2.40)	-0.57 (-2.82, 1.68)	1.96 (1.81, 2.09)
R^2_{ε,v_2}	0.31	0.74	0.56

Table 6: The ML results for the Cobb-Douglas case

a) Total sample (N=86)

Variables	Δ_{30} ln Y_{00}, (7)	Δ_{30} ln Y_{00} (7) Endogenous inputs	Δ_{30} ln y_{00}, (9)
ln y_{70}^*/y_{70}	0.28 (0.13, 0.43)	*0.35* (0.20, 0.50)	*0.34* (0.19, 0.49)
Q_{00}	1.70 (0.77, 2.63)	2.04 (1.02, 3.06)	1.96 (1.08, 2.84)
Δ_{30} ln H_{00}	*0.44* (0.24, 0.65)	0.67 (0.42, 0.94)	-
Δ_{30} ln K_{00}, Δ_{30} ln k_{00}	*0.43* (0.31, 0.55)	0.23 (0.02, 0.43)	0.30 (0.10, 0.49)
ξ (heteroskedasticity)	-0.55 (-0.80, -0.30)	-0.51 (-0.71, -0.32)	-0.65 (-0.87, -0.42)
R^2_{ε,v_2}	0.05	0.39	0.32

b) Industrial sample (N=22)

Variables	Δ_{30} ln Y_{00}, (7)	Δ_{30} ln Y_{00} (7) Endogenous inputs	Δ_{30} ln y_{00}, (9)
ln y_{70}^*/y_{70}	1.14 (0.71, 1.56)	*0.78* (0.53, 1.03)	*0.47* (0.12, 0.82)
Q_{00}	5.58 (2.61, 8.55)	3.68 (1.79, 5.57)	3.30 (-0.05, 6.64)
Δ_{30} ln H_{00}	*0.32* (-0.16, 0.80)	0.38 (-0.05, 0.82)	-
Δ_{30} ln K_{00}, Δ_{30} ln k_{00}	*0.17* (-0.13, 0.48)	0.29 (0.04, 0.54)	0.74 (0.32, 1.17)
ξ (heteroskedasticity)	1.75 (1.64, 1.87)	1.40 (1.30, 1.52)	-2.63 (-3.76, -1.50)
R^2_{ε,v_2}	0.88	0.48	0.72

Table 7: The B2SH results for the institutional process

Sample of (N=76) countries

Variables	Δ_{30} ln h_{00}, (2)	Δ_{30} ln k_{00}, (4)	Δ_{30} ln y_{00}, (3)
ln h_{70}, ln k_{70}, ln y_{70}	-0.23 (-0.38, -0.08)	-0.46 (-0.69, -0.23)	-0.41 (-0.63, -0.18)
Q_{00}	0.25 (-0.18, 0.68)	2.59 (0.34, 4.90)	2.07 (0.70, 3.49)
ξ (heteroskedasticity)	-0.44 (-0.66, -0.21)	-0.31 (-0.53, -0.10)	-0.28 (-0.50, -0.07)
$R^2_{\varepsilon,\mathbf{v}_2}$	0.20 (0.06, 0.38)	0.12 (0.01, 0.30)	0.10 (0.00, 0.29)

Table 8: The B2SH results for the Cobb-Douglas case

Sample of (N=76) countries

Variables	Δ_{30} ln Y_{00}, (7)	Δ_{30} ln Y_{00} (7) Endogenous inputs	Δ_{30} ln y_{00}, (9)
ln y_{70}^*/y_{70}	0.23 (0.05, 0.41)	*0.30* (0.16, 0.45)	*0.25* (0.10, 0.41)
Q_{00}	1.50 (0.35, 2.69)	2.00 (0.97, 3.12)	1.53 (0.57, 2.52)
Δ_{30} ln H_{00}	*0.43* (0.20, 0.66)	0.65 (0.41, 0.91)	-
Δ_{30} ln K_{00}, Δ_{30} ln k_{00}	*0.44* (0.31, 0.57)	0.26 (0.11, 0.42)	0.31 (0.15, 0.47)
ξ (heteroskedasticity)	-0.55 (-0.79, -0.32)	-0.53 (-0.72, -0.34)	-0.64 (-0.88, -0.41)
$R^2_{\varepsilon,\mathbf{v}_2}$	0.10 (0.00, 0.32)	0.43 (0.21, 0.63)	0.31 (0.09, 0.54)

Appendix 2

Table 9: Comparative results for the model (3)[19]

Model		R^2	ξ (heteroskedasticity)	institutional indicator	ln y_{70}
institutions	B2SH	0.11	-0.37	2.48	-0.48
		(0.01, 0.30)	(-0.58, -0.16)	(1.25, 3.74)	(-0.67, -0.29)
	OLS	0.50		1.68	-0.37
				(0.92, 2.48)	(-0.51, -0.23)
governance	B2SH	0.28	-0.13	2.16	-0.50
		(0.02, 0.58)	(-0.33,0.07)	(0.91, 3.41)	(-0.72,-0.28)
	OLS	0.46		0.91	-0.29
				(0.37, 1.45)	(-0.41, -0.17)
health	B2SH	0.21	-0.24	3.30	-0.53
		(0.02, 0.48)	(-0.44,-0.04)	(1.60, 5.04)	(-0.74, -0.31)
	OLS	0.47		1.69	-0.35
				(0.73, 2.64)	(-0.49, -0.20)
urban	B2SH	0.49	-0.54	3.79	-0.62
		(0.16, 0.75)	(-0.76,-0.33)	(2.10, 5.68)	(-0.85, -0.39)
	OLS	0.42		0.77	-0.25
				(0.15, 1.39)	(-0.38, -0.13)
educational	B2SH	0.17	-0.68	2.15	-0.45
		(0.02, 0.40)	(-0.90, -0.46)	(1.19, 3.15)	(-0.62, -0.28)
	OLS	0.47		0.93	-0.28
				(0.41, 1.45)	(-0.40, -0.16)
economic	B2SH	0.27	-0.16	1.39	-0.26
		(0.03, 0.56)	(-0.37, 0.05)	(0.41, 2.45)	(-0.38, -0.13)
	OLS	0.39		0.27	-0.17
				(-0.25, 0.74)	(-0.27, -0.07)

[19] We instrument for the past output and the recent governance indicator using Dist, Malaria, and the initial values of Life and output per worker. Furthermore, we instrument for a) the past ouput and the indicator of health and social service institutions, b) past output and the indicator of urban policy institutions and c) past output per worker and the indicator of basic educational institutions with Malaria and the initial values of Life, Age and output per worker. Finally, we instrument for the past output per worker and the indicator of economic institutions using the initial Life, Malaria, the past Illiteracy rate (youth) and the initial output per worker.

Table 10: Comparative results for the model (7)[20] (endogenous inputs)

Model		R^2	ξ (heteroskedasticity)	institutional indicator	ln y^*_{70}/y_{70}	$\Delta_{30}\ln H_{00}$	$\Delta_{30}\ln K_{00}$
institution	B2SH	0.37 (0.17, 0.57)	-0.52 (-0.70, -0.34)	2.07 (1.23, 2.96)	*0.34* (0.22, 0.47)	0.69 (0.45, 0.94)	0.28 (0.14, 0.43)
	OLS	0.69		1.32 (0.67, 1.96)	*0.25* (0.13, 0.36)	0.46 (0.24, 0.67)	0.37 (0.25, 49)
governance	B2SH	0.53 (0.30, 0.71)	-0.49 (-0.67, -0.31)	1.78 (1.08, 2.56)	0.40 (0.26, 0.55)	0.75 (0.52, 0.99)	0.24 (0.09, 0.40)
	OLS	0.69		0.87 (0.42, 1.33)	0.21 (0.10, 0.31)	0.52 (0.30, 0.75)	0.38 (0.26, 0.50)
health	B2SH	0.61 (0.41, 0.77)	-0.48 (-0.66, -0.31)	2.67 (1.41, 4.00)	0.44 (0.26, 0.63)	0.85 (0.59, 1.12)	0.08 (-0.09, 0.24)
	OLS	0.66		1.03 (0.22, 1.84)	0.20 (0.07, 0.33)	0.44 (0.21, 0.67)	0.37 (0.24, 0.50)
urban	B2SH	0.71 (0.49, 0.86)	-0.57 (-0.75, -0.40)	2.94 (1.77, 4.36)	0.43 (0.25,0.65)	0.77 (0.52, 1.04)	0.24 (0.09, 0.39)
	OLS	0.65		0.61 (0.09, 1.12)	0.16 (0.05, 0.27)	0.34 (0.12, 0.57)	0.40 (0.26, 0.52)
educational	B2SH	0.48 (0.27, 0.68)	-0.78 (-0.96, -0.60)	1.72 (0.94, 2.66)	0.29 (0.18, 0.42)	0.49 (0.29,0.71)	0.35 (0.19, 0.53)
	OLS	0.67		0.64 (0.22, 1.06)	0.17 (0.07, 0.27)	0.37 (0.15, 0.59)	0.39 (0.26, 0.51)
economic	B2SH	0.62 (0.43, 0.77)	-0.47 (-0.65,-0.29)	1.09 (0.52, 1.70)	0.18 (0.07, 0.29)	0.52 (0.33, 0.73)	0.20 (0.05, 0.34)
	OLS	0.63		0.09 (-0.33, 0.51)	0.08 (-0.01, 0.18)	0.36 (0.13, 0.59)	0.40 (0.27, 0.53)

[20] We instrument for a) the capitals and the indicators of governance and regulative institutions and b) the capitals and the indicator of health and social services institutions using country's land area (Gallup and Sachs, 1999), The proportion of a countrys's total land area within 100 km. Of the ocean coastline (Lt100km, Gallup and Sachs, 1999) and the initial values of the following variables: Age, Life and physical capital per worker. We also instrument for a) the capitals and the indicator of basic educational institutions and b) the capitals and the indicator of urban policy institutions using the air distance from the country's capital city to New York, Rotterdam or Tokyo (Adist, Gallup and Sachs, 1999) Dist and the above set of initial variables. Finally, we instrument for the capitals and economic institutions using Adist, the past Illiteracy rate (adult) and the above set of initial variables.

Table 11: Comparative results for the model (9)[21]

Model		R^2	ξ (heteroskedasticity)	institutional indicator	$\ln y^*_{70}/y_{70}$	$\Delta_{30}\ln k_{00}$
institution	B2SH	0.30 (0.10, 0.51)	-0.68 (-0.90, -0.48)	2.10 (1.27, 3.01)	*0.34* (0.21, 0.49)	0.34 (0.19, 0.49)
	OLS	0.68		1.37 (0.74, 2.01)	*0.24* (0.12, 0.35)	0.40 (0.29, 0.52)
governance	B2SH	0.31 (0.11, 0.53)	-0.57 (-0.79,-0.35)	1.17 (0.46, 1.96)	*0.25* (0.11, 0.40)	0.36 (0.21, 0.52)
	OLS	0.66		0.80 (0.37, 1.22)	0.18 (0.08, 0.28)	0.42 (0.30, 0.54)
health	B2SH	0.68 (0.46, 0.83)	-0.59 (-0.80, -0.38)	4.10 (2.59 ,5.79)	0.64 (0.42, 0.87)	0.19 (0.03, 0.36)
	OLS	0.64		1.13 (0.33, 1.93)	0.19 (0.06, 0.32)	0.40 (0.27, 0.52)
urban	B2SH	0.63 (0.39, 0.83)	-0.84 (-1.06,-0.63)	2.90 (1.76, 4.44)	0.37 (0.22, 0.54)	0.32 (0.16, 0.49)
	OLS	0.63		0.57 (0.04, 1.09)	0.13 (0.02, 0.24)	0.42 (0.30, 0.54)
educational	B2SH	0.43 (0.20, 0.66)	-1.05 (-1.26, -0.84)	2.03 (1.24, 2.93)	0.31 (0.18, 0.45)	0.53 (0.35,0.70)
	OLS	0.66		0.72 (0.30, 1.15)	0.16 (0.06, 0.26)	0.41 (0.29, 0.53)
economic	B2SH	0.59 (0.38, 0.75)	-0.52 (-0.72,-0.32)	1.26 (0.72, 1.82)	0.18 (0.08,0.27)	0.27 (0.12, 0.41)
	OLS	0.61		0.15 (-0.28, 0.57)	0.06 (-0.03, 0.15)	0.43 (0.31, 0.56)

[21] In the case of the log difference of physical capital per worker and the indicators of governance and regulative institutions we use the initial values of Age, Life, institutions and physical capital as instruments. Moreover, in the cases of a) physical capital and the indicator of health and social services institutions and b) physical capital and the indicator of urban policy institutions we use the initial level of years of schooling and the above set of initial variables as instruments. We also instrument for the indicator of basic educational institutions using the above set of initial variables. Finally, we instrument for physical capital and the indicator of economic institutions using the past Illiteracy rate (adult) and the above set of initial variables.

Table 12: The correlations between the indicator of institutions, its components, per worker output and growth rate of output per worker

	The Bayesian mean of institutions	governance and regulative institutions	health and social services institutions	urban policy institutions	basic educational institutions	economic institutions	GDP per worker	growth rate of GDP per worker
The Bayesian mean of institutions	1							
governance and regulative institutions	0.93	1						
health and social services institutions	0.92	0.80	1					
urban policy institutions	0.88	0.75	0.81	1				
basic educational institutions	0.89	0.71	0.85	0.81	1			
economic instituti-ons	0.71	0.60	0.60	0.50	0.60	1		
GDP per worker	0.90	0.82	0.90	0.80	0.82	0.58	1	
growth rate of GDP per worker	0.41	0.37	0.41	0.29	0.38	0.33	0.49	1

Table 13: Sample of 86 countries

Algeria	Costa Rica	Haiti	Morocco	Spain
Angola	Cote dIvoire	Honduras	Mozambique	Sweden
Argentina	Cyprus	Hungary	Nepal	Switzerland
Australia	Denmark	India	Netherlands	Syria
Austria	Dominican Rep	Indonesia	New Zealand	Tanzania
Bangladesh	Ecuador	Ireland	Nicaragua	Thailand
Belgium	Egypt	Italy	Niger	Tunisia
Benin	El Salvador	Jamaica	Nigeria	Turkey
Bolivia	Ethiopia	Japan	Panama	Uganda
Brazil	Fiji	Jordan	Paraguay	United Kingdom
Burkina Faso	Finland	Kenya	Peru	United States
Burundi	France	Korea South	Philippines	Uruguay
Cameroon	Gabon	Madagascar	Portugal	Zambia
Canada	Germany	Malawi	Romania	Zimbabwe
Cen African Rep	Ghana	Malaysia	Senegal	
Chile	Greece	Mali	Sierra Leone	
China	Guatemala	Mauritius	Singapore	
Colombia	Guyana	Mexico	South Africa	

Appendix 3

The conditional and marginal prior distributions for the parameter are:

$$p(\xi) \propto \text{constant},$$

$$p(\Omega_{22}, \omega_{11.2}) \propto |\Omega_{22}|^{-0.5m}\omega_{11.2}^{-1},$$

$$p(B|\xi, \omega_{11.2}, \Omega_{22}) \propto |\Omega_{22}|^{-0.5k}|U'\Lambda^{-1}U|^{0.5(m-1)},$$

$$p(\phi| B, \xi, \omega_{11.2}, \Omega_{22}) \propto \omega_{11.2}^{-0.5(m-1)}|\Omega_{22}|^{0.5},$$

$$p(\delta| \phi, B, \xi, \omega_{11.2}, \Omega_{22}) \propto \omega_{11.2}^{-0.5(m+n-1)}|W'\Lambda^{-1}W|^{0.5}.$$

Given the joint prior, which is the product of the conditional and marginal priors

$$p(\delta, \phi, B, \xi, \omega_{11.2}, \Omega_{22}) \propto |\Omega_{22}|^{-0.5(m+k-1)}\omega_{11.2}^{-0.5(2m+k1)}|U'\Lambda^{-1}U|^{0.5(m-1)}|W'\Lambda^{-1}W|^{0.5},$$

and the likelihood function for the parameters ($\delta, \phi, B, \xi, \omega_{11,2}, \Omega_{22}$), the conditional and marginal posteriors is as follows:

$$q(\delta| \phi, B, \xi, \omega_{11.2}, \Omega_{22}, Y, X) \propto \omega_{11.2}^{-0.5(m+k1-1)}|W'\Lambda^{-1}W|^{0.5} \exp\{-0.5\omega_{11.2}^{-1}(\delta - \hat{\delta})'W'\Lambda^{-1}W(\delta - \hat{\delta})\},$$

$$q(\phi| B, \xi, \omega_{11.2}, \Omega_{22}, Y, X) \propto \omega_{11.2}^{-0.5(m-1)}|V_2'\Lambda^{-1}MV_2|^{0.5} \exp\{-0.5\omega_{11.2}^{-1}(\phi - \hat{\varphi})' V_2'\Lambda^{-1}MV_2 (\phi - \hat{\varphi})\},$$

$$q(\omega_{11.2}| B, \xi, \Omega_{22}, Y, X) \propto \omega_{11.2}^{-0.5(N+2)}[v'\Lambda^{-1}Mv]^{0.5T}\exp\{-0.5\omega^{-1}_{11,2}v'\Lambda^{-1}Mv\},$$

$$q(\Omega_{22}|\, B, \xi, Y, X) \propto |\, V_2'\Lambda^{-1}V_2|^{\,0.5(N+k-1)}|\, \Omega_{22}|^{\,-0.5(N+m+k-1)}\exp\{-0.5\mathrm{tr}\Omega^{-1}_{22}V_2'\Lambda^{-1}V_2\},$$

$$q(B, \xi|\, Y, X) \propto |\, U'\Lambda^{-1}U|^{\,0.5(m-1)}|\, \Lambda|^{\,-0.5m}|\, V_2'\Lambda^{-1}MV_2|^{\,-0.5}$$
$$[v'\Lambda^{-1}Mv]^{-0.5N}|\, V_2'\Lambda^{-1}V_2|^{\,-0.5(N+k-1)},$$

where $\hat{\boldsymbol{\delta}} = (W'\Lambda^{-1}W)^{-1}W'\Lambda^{-1}(y_1\text{-}V_2\phi)$, $\hat{\boldsymbol{\varphi}} = (V_2'\Lambda^{-1}MV_2)^{-1}V_2'\Lambda^{-1}My_1$, $M = I - W(W'\Lambda^{-1}W)^{-1}W'\Lambda^{-1}$, $v = y_1 - V_2\hat{\boldsymbol{\varphi}}$ and $V_2 = Y_2 - UB$. The joint marginal posterior for the parameters B and ξ is simulated using the M-H algorithm.

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