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Institutions and Innovations as Sources of Productivity Growth
Cross-Country Evidence

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Institutions and Innovations as Sources of Productivity Growth Cross-Country Evidence*

Abstract

The investigation of the determinants of economic growth plays an important role for our understanding of the sources of cross-country income differences. This paper analyzes the effects of institutions and innovations on country productivity growth. The empirical evidence shows that institutions and innovations matter, in particular for human capital efficiency. Without controlling for endogeneity the effect of innovations turns significant only when aggregate institutions indexes or human capital efficiency are included. When controlling for endogeneity innovations become insignificant, but more institutional variables become relevant. Under robustness checks innovations indeed have a direct effect on country productivity growth moderated by a country's human capital efficiency. Allowing for three alternative institutional variables does not change the effects of the institutional variables of interest.

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Keywords: Productivity growth, institutions, information and communication technology, research and development, panel regressions.

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1. Introduction

The investigation of the determinants of economic growth plays an important role for our understanding of the sources of today's cross-country income differences. It helps us to examine why some countries have grown much more rapidly over the past decades while others have not. This becomes even more significant with regard to the divergence in growth rates between European countries and the US before the current financial crisis.

Part of the subsequent analysis will be on the contributions of physical capital, labor, and technological change to growth in the production possibility frontier of countries. Because of various studies technological progress has gained importance in our understanding of cross-country and over-time differences in economic performance (Barro, 1991; Nelson and Phelps, 1966; Hall and Jones, 1999; Caselli and Coleman, 2001, 2006). Over the last decades, major innovations and the employment of new technologies facilitated shifts in the production possibility frontier of nations leading them to higher living standards. It is the combination of increased efficiency in the production process, the development of new products, the availability of skilled workers to employ new technologies, and the expected gains derived from profitable investments that encourage firms to invest in innovations, and that ultimately boost productivity growth and long-term living standards.

Regarding the tremendous productivity increases of the US economy post 1995, particularly generated in high-tech sectors, sectoral productivity gains are expected to emanate from innovation activities. During the emergence of the New Economy in the mid–1990s, the employment of new IT equipment, especially in the ICT-producing industries (semiconductors, computers, and telecommunications) spurred US economic growth dramatically. But also higher ICT investments in other sectors that intensively used these new technologies enabled the generation of higher productivity gains. The utilization of both ICT and research and development (R&D) apparently provides a symbiotic relationship catalyzing productivity growth, branding ICT a general purpose technology (GPT). Such GPT triggers complementary innovations and R&D expenditures in other sectors (Bresnahan and Trajtenberg, 1995; Helpman and Trajtenberg, 1998a, b).

Modeling the interaction effect of ICT and innovations rests upon economic mechanisms postulated by models of endogenous rather than neoclassical growth, since standard neoclassical growth models abstain from assigning an explicit role to innovations. While neoclassical models are primarily based on the work of Solow (1956, 1957), the branch of endogenous growth models has originated by Romer (1986, 1990), and followed by Arrow (1962), Coe and Helpman (1995), Grossmann and Helpman (1991), and Aghion and Howitt (1992, 1998). Those endogenous growth models became of increasing importance as they no longer assume technological progress to be exogenously given, but rather endogenously determined through entrepreneurs' profit maximization behavior subject to their investment decision.

However, the endogenous growth literature also establishes that reward structures faced by firms and individuals play a central role in shaping whether individuals undertake the investments in new technology and in human capital necessary for economic growth. These reward structures are determined by policies and institutions, and provide the fundamentals to the understanding of the growth process over time as well as across countries. However, political institutions themselves are not exogenously given *per se*, but change along the equilibrium path as a result of their own dynamics and *stimuli* stemming from changes in technology, trading opportunities, and factor endowments.

Since this study seeks to investigate the fundamental causes of cross-country productivity differentials, I additionally – besides standard neo-classical and New Growth theory – consider the *institutional hypothesis* (Acemoglu, 2009) suggesting that it is the rules, regulations, laws, contracts, and policies that affect economic incentives and thus the incentives to invest in technology, physical and human capital (Acemoglu, Johnson, and Robinson, 2001, 2002, 2005a, b):

> "...the factors we have listed (innovation, economies of scale, education, capital accumulation etc.) are not causes of growth; they are growth." (North and Thomas, 1973, p. 2)

As outlined by Acemoglu (2009), contrary to potential growth determinants such as geography and culture, a society collectively can decide to change its institutions so as to achieve better economic outcomes, rendering institutions highly endogenous. It is the direct control that the members of the society exert that shapes institutions and that demarcates institutional from cultural effects.

The policy relevance of studying institutions is in understanding their effects on growth and in determining which specific types of institutions matter. One therefore may expect nations endowed with economic institutions, that facilitate and encourage factor accumulation, innovation, and the efficient allocation of resources to prosper compared to nations that do not dispose of such institutions.

In this paper I analyze the effects of institutions and innovations on country productivity. In my first attempt without controlling for endogeneity I find that aggregate institutions matter, in particular, basic institutional quality and human capital efficiency. The effect of innovations turns statistically significant only when aggregate institutions or basic institutional quality and human capital efficiency are accounted for. ICT and Non-ICT capital deepening matters throughout all specifications. When controlling for endogeneity the results are that ICT capital deepening loses significance, except when human capital efficiency is included. Also, innovations become insignificant throughout all specifications, but more institutional variables are estimated as statistically significant.

Controlling for correlation between institutional covariates leaves a parsimonious benchmark model including three institutional variables: human capital efficiency, labor markets, and capital markets. Empirical evidence further shows that innovations have a direct effect on country productivity growth and that this effect is moderated by a country's human capital efficiency. Allowing for three alternative institutional variables does not change the effects of the institutional variables of interest. Ultimately, ICT capital deepening becomes significant in the parsimonious benchmark model as well as in the other robustness check specifications.

The paper proceeds as follows. Section 2 explains the data employed to construct output, input, innovation, and institutional variables. For the latter, the sub-components of the employed *DICE Institutions Climate Index* (Eicher and Roehn, 2007) are explained in detail. Section 3 presents the estimation strategy of determining the effects of standard neoclassical factors, innovations, and institutions on country productivity growth. In addition, I present a robustness analysis applying correlation and sensitivity tests to the basic results, while section 4 provides concluding remarks.

2. Data

2.1 Output, Input, and R&D Stocks

The analysis focuses on the effects of innovations and institutions on labor productivity growth of 10 selected OECD countries covering the period 1992–2005.[1] I commence by employing a standard neoclassical production function with output and input factors motivated by the Solow (1956) growth model. The input factors are capital and labor, where capital is

[1] The countries in the panel are Denmark, Finland, France, Germany, Italy, Netherlands, Spain, Sweden, United Kingdom, and the United States.

measured as capital services and labor as total hours worked by persons engaged; output is value-added. Output and input factors for Germany are provided by the *Ifo Industry Growth Accounting Database* (henceforth IIGAD)[2], while international data on output and inputs are obtained from the *EUKLEMS Growth and Productivity Accounts* (henceforth EUKLEMS).[3] Since our period of analysis coincides with the launching phase of the New Economy during the second half of the 1990s, the data accounts for productivity effects stemming from information and communication technology (ICT) by allowing capital services to differ in ICT and Non-ICT.

Due to the sectoral nature of the data disaggregation into 13 goods-producing industries (for a detailed industry list see Table A1, Appendix) and accounting for industry-specific trends in new technologies underlying the employed investments become available. This is illustrative for the US and other industrialized countries, particularly for high-tech sectors as e.g. Office Machinery & Computers, as most countries' productivity growth accelerated post 1995. Jorgenson (2005), for example, argues that the magnitude of the US growth resurgence outpaced all but the most optimistic expectations. After advances in the productivity measurement allowed for effective accounting of information technology in national statistics (Schreyer, 2001), it became clear that the recent productivity increases originated mainly with ICT investments.

Going beyond the standard neoclassical assumptions of factor accumulation as the main source of country growth differentials, I turn to the "The New Growth Theory" (Romer, 1990; Aghion and Howitt, 1992; Grossman and Helpman, 1991) that highlights the forces generating technological change within the economy to produce sustained long-term growth. The key insight is that sustained growth requires ever more efficient use of available resources, and that this increase in efficiency is ultimately driven by industry R&D. Hence, the New Growth Theory outlines exactly how technological progress is driven by innovations undertaken by firms seeking to maintain their competitive market position. Firm R&D efforts prevent a decline of the marginal product of capital, as new technologies are embodied in capital services.

Incorporating the implications of New Growth Theory, I try to capture innovation effects on country productivity growth by deriving an appropriate proxy for technological change, replacing the total factor productivity residual usually organically derived from

[2] For a detailed description of the data, see Roehn et al. (2007).
[3] For a detailed description of the data, see Timmer et al. (2007a, b).

growth accounting exercises. Thereby I seek to account for the scale-effects critique by Jones (1995) and construct industry-level R&D stocks by country, using the OECD methodology outlined in Guellec and Pottelsberghe (2001). The employed R&D data is provided by the *OECD STAN R&D Database* (henceforth OECD).[4]

Since my main interest is on labor productivity growth, all output and input variables, as well as the R&D stocks are given in growth rates. For detailed descriptive statistics of these variables, see Table 1.

2.2 Institutional Indexes

Inspired by the emergence of endogenous growth theories, many empirical cross-country studies have extended the framework of Mankiw, Romer and Weil (1992) by adding regressors determined outside of Solow's (1956) neoclassical growth model. Besides innovations, I further account for institutional variables. Introducing institutions in the analysis seeks to determine how far institutions matter for country productivity growth and doing so tries to mitigate potential omitted variables biases on the country level. Instead of introducing country fixed effects, I will model the country effects explicitly by their underlying institutional settings.

Following Mancur Olson in his book *The Rise and Decline of Nations* (Olson, 1982), the "sources of economic growth" haven been expressively demonstrated by Denison's and Jorgenson's sophisticated measurement approaches of the contributions of capital accumulation and technology progress; but those estimations do not reveal the deeper underlying causes of growth. In particular, Olson argues that past research on the real causes of growth were lacking since they did not answer the fundamental question as to the primary establishment of growth prospects; rather:

> "they trace the water in the river to the streams and lakes from which it comes, but they do not explain the rain" (Olson, 1982, p. 4).

The institutional variables employed in this study are derived from the *DICE Institutions Climate Index* developed by Eicher and Roehn (2007). The central purpose of the DICE index is to assess the extent to which individual OECD countries dispose of the institutional quality to achieve economic growth. Therefore the authors seek to identify a set of institutional variables that can be robustly related to economic performance in OECD economies by

[4] For a detailed description of the construction of R&D stocks, see Guellec and Pottelsberghe (2001).

summarizing a country's overall institutional performance in several distinct growth-relevant dimensions. The total index as well as its sub-components measure institutional quality with respect to the best-practice country, i.e. as the indexes ranges from 0 to 1 (assigning higher values to those institutions that are better for economic growth) the closer a country's value is to 1, the better its institutional quality compared to the OECD leader. A key feature of the index is that all components of the indexes are selected and weighted based on their predictive power. Each of the sub-components will be described in detail in the following.[5]

Optimal Taxation

With 21.2 percent, *Optimal Taxation* carries the largest weight, due to its large statistical and economic contribution to the overall index. This sub-index assigns low values to countries with either insufficiently low or excessively high tax rates. The intuition is that taxes have a nonlinear effect on growth. A certain quantity of tax revenues is necessary for growth to provide, for example, productivity enhancing infrastructure investments. However, excessive tax rates deter private investment. This idea was first formalized in an endogenous growth framework by Barro (1990, 1991) and is incorporated in the index by including a tax wedge measure and a squared tax component. The index also comprises a top marginal tax rate, which assigns higher ratings to countries with lower marginal tax rates accounting for the effect at higher income thresholds (Fraser Institute, 2006).

Basic Institutional Quality

Another important sub-index is the *Basic Institutional Quality* with a weight of 21 percent. *Basic Institutional Quality* resembles the original index of government anti-diversion policies employed in Hall and Jones (1999). It measures the extent to which the government protects individuals from diverting resources into unproductive uses through, e.g. protection of property rights, law and order enforcement, impartial courts or bureaucratic quality, or how the government themselves acts as a diverter, for example, through corruption.

The *Basic Institutional Quality* sub-index comprises 7 components. The first component measures how political stability influences the climate of foreign investors. Another component captures the institutional strength that minimizes revisions of policy when governments change (bureaucratic quality). Therefore, high points are given to countries where the bureaucracy has the strength and expertise to govern without drastic changes in policy or

[5] For more details on the *DICE Institutions Climate Index*, its construction and sub-components, see Eicher and Roehn (2007).

interruptions in government services (ICRG, 2006). The component law and order assesses the strength and impartiality of the legal system and the observance of the law. Countries that enjoy a high law-and-order rating exhibit sound judicial systems and legal enforcement with effective sanctions (ICRG, 2006). The component property rights and legal structure contains valuations of judicial independence, impartial courts, protection of intellectual property, military interference in rule of law and the political process, and the integrity of the legal system (Fraser Institute, 2006). A further component is the assessment of a country's level of corruption. Finally, the last two components are survey questions of Ifo's World Economic Survey (WES) about a country's confidence in economic policy as well as about the extent to which the climate of foreign investors is influenced by a country's legal/administrative restrictions for foreign firms to invest and/or to repatriate profits.

Fiscal Burden

The *Fiscal Burden* component contributes to the overall index with 16.7 percent. It measures the extent to which the government diverts resources away from private and possibly more productive use. A country's fiscal burden is proxied by the *total tax revenue* as percentage of a country's GDP. The component is a good measure of the extent of a country's tax system. Direct taxes might be low, but the government might alternatively generate revenues from indirect taxes as well as from a host of alternative fees and hidden taxes. The revenue section is thus perhaps the best measure of the negative impact of the size of the government that has been highlighted by Barro (1990).

Human Capital Efficiency

The importance of human capital as a driver of economic growth has been acknowledged in economics at least since the influential papers of Lucas (1988) and Romer (1990). Human capital can either act as a factor of production in the technology sector (Romer, 1990) or it can facilitate the adoption of technology diffusion (Nelson and Phelps, 1966; Benhabib and Spiegel, 1994). The measure of *Human Capital Efficiency* receives a weight of 14.9 percent in the overall index. This sub-index is composed of the subsequent four components: tertiary gross enrolment ratio, average years of schooling, secondary gross enrolment ratio, and total public educational expenditure. Tertiary gross enrolment ratio is the number of pupils enrolled in tertiary education, regardless of age, expressed as a percentage of the population of the five-year age group following on from the secondary school leaving age. Average years of schooling of adults is the years of formal schooling received, on average, by adults over age 15. Secondary gross enrolment ratio is the number of pupils enrolled in secondary, regardless of age, expressed as a percentage of the population in the theoretical age group for secondary education. Finally, total public educational expenditure is measured as the current and capital expenditures on education by local, regional and national governments, including municipalities, expressed as a percentage of GDP.

Trade Openness

The positive impact of a country's openness towards other countries on growth was empirically shown by Sachs and Warner (1995). Trade promoting policies do not only yield benefits from specialization and facilitate the adoption of technology from other countries, but as Hall and Jones (1999, p. 98) point out, provide "lucrative opportunities for private diversion". Thus, Hall and Jones include a measure of openness in their index of institutional quality. The measure of the degree of *Trade Openness* employed here contains the following components: tariffs, trade size, and black market premium. Tariffs contains information about the revenues from taxes on international trade as a percentage of exports plus imports, the mean tariff rate as well as the standard deviation of tariff rates (Fraser Institute, 2006). The component trade size measures the actual size of the trade sector compared to expected size. It then allocates higher ratings to countries with large trade sectors compared to what would be expected, given their population, geographic size, and location. On the other hand, countries with small trade sectors relative to the expected size receive lower ratings (Fraser Institute, 2006). The component black market premium assesses the difference between official exchange rate and black market rate. This component allocates the highest rating to countries without a black-market exchange rate, i.e. those with a domestic currency that is fully convertible without restrictions. When exchange rate controls are present and a black market exists, the ratings will decline toward zero as the black market premium increases toward 50 percent. The lowest rating is given when the black market premium is equal to, or greater than, 50 percent (Fraser Institute, 2006).

Labor Markets

Rigid labor markets or tight regulations might prevent an economy from reacting to technological changes and allocate labor to the most productive use and, hence, distort growth. Furthermore, other institutional arrangements that affect the labor market such as the pension system, retirement age or family policy or child care can lead to the exclusion of whole groups of the population from the labor market and thereby from production. The components of the *Labor Markets* variable are discussed as follows. An early retirement index is constructed as 1 minus the male labor force participation rate of age 55–64. A country receives a higher value the lower the early retirement index. Another index of labor market regulations combines information about the impact of minimum wage, hiring and firing practices, the share of the labor force whose wages are set by centralized collective bargaining, unemployment benefits and the use of conscripts to obtain military personnel (Fraser Institute, 2006). Finally, the female labor participation rate is also included. This component proxies for the obstacles existing within a country that prevents women from actively participating in the labor market.

Government Expenditures

Next, it is assumed that output diverted to government expenditures captures the cost of government in a society. When a government expends money, it acquires resources, diverting them away from potentially more productive private choices of resource allocations (Fraser Institute, 2006). The variable *Government Expenditures* is measured as general government consumption spending as a percentage of total consumption as well as government enterprises and investment as a percentage of total investment.

Capital Markets

The beneficial effect of capital markets or financial intermediation on economic performance was found, e.g. in the seminal contribution of Levine, Loayza and Beck (2000). Financial intermediation is seen to help a) production of ex ante information about possible investments, b) monitoring of investments and implementation of corporate governance, c) trading, diversification, and management of risk, d) mobilization and pooling of savings, and e) exchange of goods and services.

Aghion, Howitt and Mayer-Foulkes (2005) additionally stress the importance of financial intermediation for the rate of technology diffusion. The preferred proxy for financial intermediation is usually the ratio of private credit to GDP (see Levine, Loayza and Beck, 2000; Aghion, Howitt and Mayer-Foulkes, 2005; Levine 2005). The here employed measure of *Capital Markets* or financial intermediation is comprised of private sector domestic credit as a percentage of GDP and capital market controls. Private sector domestic credit refers to financial resources provided to the private sector, such as through loans, purchases of non-equity securities, and trade credits and other accounts receivable that establish a claim for repayment (WDI, 2006). Capital market controls assesses the access of citizens to foreign capital markets and foreign access to domestic capital markets as well as restrictions on the freedom of citizens to engage in capital market exchange with foreigners (Fraser Institute, 2006).

Since many institutional variables do not show strong variability over time, I will incorporate institutions in terms of levels in the growth regressions. The introduction of the initial levels of institutions is sought to capture the effect of conditional convergence in country productivity growth rates. For detailed descriptive statistics of the institutional variables, see Table 1.

3. Econometric Estimation

3.1 Estimation Strategy

Beginning the econometric strategy I implement a benchmark cross-country panel regression according to

$$\Delta \ln y_{i,j,t} = \alpha + \beta_1 \Delta \ln k^{ICT}_{i,j,t} + \beta_2 \Delta \ln k^{NICT}_{i,j,t} + \beta_3 \Delta \ln R_{i,j,t} + \Delta \ln \varepsilon_{i,j,t} \qquad (1)$$

with $y_{i,j,t}$ representing labor productivity (measured as value-added per hour worked) of industry i in country j at time t, $k_{i,j,t}$ is capital deepening (measured as capital services per hour worked) separated for ICT and Non-ICT, and the stock of R&D, $R_{i,j,t}$. For the error term, $\varepsilon_{i,j,t}$, I assume time-variant industry and country effects, $a_{i,t}$ and $b_{j,t}$, and a stochastic component, $e_{i,j,t}$, being i.i.d:

$$\Delta \ln \varepsilon_{i,j,t} = \Delta \ln a_{i,t} + \Delta \ln b_{j,t} + \Delta \ln e_{i,j,t}\,. \qquad (2)$$

Since labor productivity is in growth rates, all time-invariant effects are already purged from the regression.

To directly examine the impact of institutions on productivity growth I specify the country effects of equation (2) to be determined by institutional variables $X_{m,j,t}$ (institutions m = 1, …, M as listed in Table 1). Those institutions are invariant for all industries within countries, but may vary across countries and time. This renders the country effects to

$$\Delta \ln b_{j,t} = \gamma + \sum_{m=1}^{M} \delta_m X_{m,j,t} + \Delta \ln \nu_{j,t} \qquad (3)$$

with $\nu_{j,t}$ being i.i.d. As country productivity growth rates are assumed to be significantly determined by input factors and innovations conditioned on established institutions, the DICE indexes enter growth regressions in levels.

To estimate the institutional effects in a one-step approach I insert equation (2) and (3) into equation (1):

$$\Delta \ln y_{i,j,t} = \beta_1 \Delta \ln k^{ICT}_{i,j,t} + \beta_2 \Delta \ln k^{NICT}_{i,j,t} + \beta_3 \Delta \ln R_{i,j,t} + \Delta \ln a_{i,t} + \sum_{m=1}^{M} \delta_m X_{m,j,t} + \Delta \ln \xi_{i,j,t} \,, \quad (4)$$

with $\xi_{i,j,t}$ being i.i.d.

As the specter of endogeneity looms large in this short panel and the i.i.d. assumption of $\xi_{i,j,t}$ is unlikely to hold, particularly as changes along the transition path are expected to feedback into capital services, R&D and alterations in institutional settings, an implementation of GMM techniques (Roodman, 2005) for consistency of coefficient estimates becomes necessary. Since appropriate external instruments are not easily to obtain, I revert to lagged values of regressors as internal instruments. Due to higher efficiency in short panels the system GMM constituted by Arellano and Bover (1995) and Blundell and Bond (1998) is chosen over the first-difference GMM (Arellano and Bond, 1991). As the regressors are to some extent in growth rates I implement lags t-4 and deeper as valid instruments. Furthermore, to test how specific institutions prepare the ground for innovations and long-term productivity, growth interactions between $R_{i,j,t}$ and $X_{m,j,t}$ are included, as well as alternative institutional covariates for robustness checks.

3.2 Time Series Analysis

As a next step, I conduct panel time series analyses to check for panel stationarity and to ensure that problems of spurious correlations do not apply to the data. For panel unit-root tests the approaches of Levin, Lin and Chu (2002) and Im, Pesaran and Shin (2003), henceforth LLC and IPS, in case of balanced variables, and Fisher-type tests for augmented Dickey-Fuller (1979) and Phillips-Perron (1988), henceforth ADF and PP, for unbalanced variables are employed.

The panel unit-root tests (Table A4, Appendix) reject the assumption of panel non-stationarity for output and input variables in growth rates; hence, their employment is unproblematic.[6] Supported by the tests no sectoral growth trends underlie the data generating process (DGP) signaling that no further differencing of variables is required. Regarding the institutional variables in levels one may expect them to exhibit strong unit roots, which is why I conduct panel unit-root tests on the residuals of the least-square dummy variable regressions

[6] The panel unit-root tests implement specifications without and with one lag included. For all variables and lag specifications the hypothesis of non-stationarity in the panel can be rejected on the highest level of significance throughout all test approaches.

in Table 2. A rejection of the hypothesis of non-stationarity in the residuals will indicate that the models are well specified. The results of the panel unit-root test on the residuals will be discussed in the following section.

3.3 Estimation Results

3.3.1 Basic Model Estimations

Starting the empirical strategy I estimate equation (4) via a least-square dummy-variable (LSDV) approach. As shown in Table 2 the specifications include country-specific institutional variables of the *DICE Institutions Climate Index* separately and jointly.

The standard neoclassical input factors, ICT and Non-ICT capital deepening, are estimated as highly statistically significant in the specifications without country institutions (column I, II). Non-ICT shows a stronger positive impact than ICT, while R&D is estimated as statistically insignificant (column II). Introducing the composite *DICE Institutions Climate Index* (column III) does not change the estimates for ICT and Non-ICT considerably, but turns the positive R&D effect significant. The composite DICE index is also significant, suggesting that the institutions positively influence growth, thereby supporting the *institutional hypothesis* as a fundamental cause for economic growth.

Dwelling deeper on the single institutional characteristics, I split the composite DICE index into its sub-components including each of them into the regressions separately (column IV–XI). As a result, most of the institutions appear to be insignificant, except *Basic Institutional Quality* and *Human Capital Efficiency*. Both sub-components are estimated as highly statistically significant with a positive marginal effect on country labor productivity growth. Moreover, the inclusion of both institutions renders R&D significant. The last column, which includes all institutional sub-components jointly, reveals that several of the insignificant institutions in the separate specifications are now estimated as statistically significant. Those are *Optimal Taxation*, *Total Tax Revenue*, *Labor Markets*, and *Government Expenditures* that all reduce growth the closer regulation quality moves towards the OECD best-practice country.

These unexpected latter results may be due to problems of collinearity, as institutions are usually correlated among each other. Under such circumstances the estimated coefficients may change erratically in response to small changes in the model. However, collinearity does not reduce the reliability of the model as a whole, but mainly affects calculations regarding individual predictors, i.e. the correlated variables indicate how well the entire bundle of covariates predict country labor productivity growth, but they may not provide valid estimates about individual coefficients or about the redundancy of single institutions with others. To control for collinearity issues I conduct a robustness check in the subsequent section.

Examining the idiosyncratic industry effects of the LSDV regression in more detail discloses many industries with significantly estimated average labor productivity growth rates across countries (see Table A2 in the Appendix). Industries with high average labor productivity growth rates are Chemicals (including others), Machinery, Office & Electronic Equipment, Automobiles & Other Transport, and Electricity, Gas & Water Supply. Construction exhibits significantly negative growth rates on average throughout all specifications. In particular, Office & Electronic Equipment shows very strong average labor productivity growth across countries with about 5% as those sectors managed to reap enormous productivity gains from increased ICT investments during the New Economy post 1995.

The panel unit-root tests for the residuals of the LSDV regressions reject the hypothesis of non-stationarity on the highest level of significance for both unit-root tests, all model and lag specifications (III–XII) (Table A5, Appendix). These test results affirm not having underlying trends in the DGP of the panel missed by the deterministic part of the regression models that may violate necessary conditions of the error terms and thus deny reliability of statistical inference.

Rerunning the specifications of Table 2 this time controlling for endogeneity discloses significant changes in the estimation results. In Table 3 the system GMM regressions show that there is a persistent t-4 lag structure in the dependent variables across all specifications including institutions. The table further reveals that ICT capital deepening now turns statistically insignificant, while Non-ICT is still significant. Only in case of including human capital (column VII) is the effect of ICT estimated as weakly significant. These results conjecture that productivity gains accrue to those countries that manage to combine increased sectoral investments in new technologies with a high human capital endowment. This relationship will be analyzed more formally in the following section. However, accounting for endogeneity still keeps the overall DICE index significant (column III), while R&D turns insignificant throughout.

Disaggregation into single DICE sub-components now reveals that many more institutions matter compared to the results of Table 2. Those are *Optimal Taxation*, which negatively impacts a country's labor productivity growth the closer the taxation institutions move toward the OECD best-practice country.[7] *Trade Openness* and *Capital Markets* exhibit statistically significant productivity growth enhancing effects the closer intuitions change towards those of the OECD leader. *Basic Institutional Quality* and *Human Capital Efficiency* are still estimated as significant with a positive impact on growth. The joint inclusion of all institutional variables (column XII) shows the same mixed picture as in specification XII of Table 2: Labor productivity improvements go along with *Basic Institutional Quality*, while *Optimal Taxation*, *Labor Markets*, and *Government Expenditures* show negative growth effects.

3.3.2 Robustness Checks

In the next step I implement robustness checks for the joint specification (column XII in Table 2 and 3) by controlling for correlation between covariates and conducting sensitivity analyses of results. For testing coefficient estimates without collinearity among the covariates a reduced set of variables is employed. This variables set is selected from correlation analysis as depicted in Table A3 (Appendix).

According to Table A3 it becomes obvious that there is a marked correlation between *Optimal Taxation* and various different institutions: strong correlation of more than 70 percent is given for this variable and *Total Tax Revenue* and *Labor Markets*, while weaker correlation (around 50 percent) can be found in case of *Government Expenditures* and *Capital Markets*. But also *Human Capital Efficiency* and *Basic Institutional Quality* show strong correlation of above 70 percent. Weaker correlations of around 50 percent can also be stated for *Government Expenditures* and *Total Tax Revenue* as well as *Capital Markets* and *Labor Markets*. These correlations may be responsible for some of the non-significances of single institutional covariates in the joint specifications, which is why I decide to drop some of them.

As *Optimal Taxation* is correlated with many variables, I started to excluded it from the regressions first. Among the highly correlated variables *Basic Institutional Quality* and *Human Capital Efficiency*, *Basic Institutional Quality* is dropped since it captures more of an overall effect of institutions like the total DICE index. Since *Government Expenditures* is correlated with *Total Tax Revenue* and both are being estimated as statistically insignificant in the separated specifications, I drop these two covariates as well. Since *Trade Openness* has

[7] Outlined in Eicher and Roehn (2007) the *Optimal Taxation* sub-component captures linear and non-linear effects. This makes it hard to meaningfully separate the sub-component's single factors, which is why a discussion of this sub-component should be provided only as a whole. Whether the non-linearity of the tax effect is adequately captured for all countries as well as modeled in the regressions is not yet clear. That is why the effects of this coefficient should be interpreted with caution.

been estimated statistically insignificant in LSDV and only weakly significant at the 10 percent level in system GMM, I also excluded this variable, ending up with a parsimonious benchmark specification of three institutional variables: *Human Capital Efficiency*, *Labor Markets*, and *Capital Markets*.

Column I in Table 4 shows the last column of Table 3 for comparison purposes. For the parsimonious benchmark specification (column II) it can be stated that the lag structure of the dependent variable is still significant on the third and fourth lag. But ICT capital deepening now turns weakly significant, while Non-ICT keeps its high statistically significance. All of the three institutional variables of interest are estimated as significant and will be discussed in greater detail in the following.

Human Capital Efficiency shows a positive effect on labor productivity growth as institutions approach the institutional level of the best-practice OECD country. Put differently, the more countries reform their human capital institutions towards those of the best-practice country the stronger their labor productivity growth will be. For *Labor Markets*, on the contrary, getting closer to the best-practice OECD country coincides with negative labor productivity growth. This may be due to improvements in labor market regulations in France, Spain, and the Netherlands (with low GDP per capita growth) moving toward the OECD best-practice country in recent years, but that have not yet transformed into better productivity growth. Also, Scandinavian countries like Sweden and Finland are far from the liberal labor market regulations in Anglo-Saxon countries like the UK and the US, which are usually associated with better economic growth. The *Capital Markets* institutions show productivity growth enhancing effects from improving institutions of private sector domestic credit and capital markets control towards those of the OECD leader.

In the following specification III I control for interaction effects between the three institutional covariates and the R&D stock component to formally test whether productivity growth through innovations is supported by specific institutional settings. The estimates disclose that R&D positively interacts only with human capital efficiency. This finding supports the view of human capital as an important driver for growth (Lucas 1988; Romer, 1990), particularly, as it facilitates the adoption of technology diffusion (Nelson and Phelps, 1966; Benhabib and Spiegel, 1994). In the case of *Capital* and *Labor Markets* the R&D interaction terms show no significant growth effect.

The subsequent specifications further test for robustness of coefficients by introducing three other institutional variables, which are *ICT Patents* (in 1000), *Internal Conflict* and *Civil Liberties*. The inclusion of alternative covariates serves as a sensitivity analysis of our previous results. The first additional covariate is a proxy for a country's innovation or technology potential measured by technology patents as provided by the OECD.[8] Its aim is to include a differently measured technology indicator unlike ICT capital services and R&D stocks.

The second institutional variable intends to account for a country's conflicts provided by the International Country Risk Guide (ICRG), which provides ratings comprising 22 variables in three sub-categories of risk: political, financial, and economic. From the sub-categories I use *Internal Conflict* for the robustness check as other ICRG variables are already implemented in the construction of the *DICE Institutions Climate Index*. This variable ranges from 0 to 12 with lower (higher) values indicating higher (lower) risk and assesses a country's political violence and its actual or potential impact on governance. Highest ratings are given to those countries where the government does not indulge in arbitrary violence, direct or indirect, against its own people. Lowest ratings are given to those countries involved in civil wars.[9]

The last robustness variable is *Civil Liberties* provided by Freedom House, which publishes annual reports on the degree of perceived democratic freedoms in each country. The *Civil Liberties* variable ranges from 1 to 7 indicating most (1) to least liberties (7). Countries that receive highest ratings come closest to ensuring most possible civil liberties as freedom of expression, assembly, association, education, and religion. Countries with lower but still high ratings (as e.g. rating of 2) have deficiencies in a few aspects of civil liberties and slightly weaker civil liberties than those countries with a rating of 1. Reasons for this may be limits on media independence, restrictions on trade union activities, and discrimination against minority groups and women.[10]

As depicted in column IV–VI of Table 4 the additional covariates are all estimated statistically significant and their inclusion does not impact the effects of the institutional vari-

[8] Further details on *ICT Patents* can be obtained from the *OECD Main Science and Technology Indicators* available on the internet: http://www.oecd.org/document/26/0,3343,en_2649_34451_1901082_1_1_1_1,00.html [accessed February 9, 2010].
[9] Further details on the *Internal Conflict* methodology are available on the internet: http://www.prsgroup.com/ICRG_Methodology.aspx [accessed February 9, 2010].
[10] Further details on the *Civil Liberties* methodology are available on the internet: http://www.freedomhouse.org/ template.cfm?page=351&ana_page=354&year=2009 [accessed February 9, 2010].

ables of interest. Increasing the number of *ICT Patents* generates higher labor productivity growth, but substitutes the effect of ICT capital deepening. Higher index values of *Internal Conflict* reduce labor productivity growth and turn ICT capital deepening statistically significant. This negative effect may be explained by high-productivity countries like the US and UK but also Sweden, which exhibit declining trends in the ICRG institutions variable post 2000, whereas low-productivity countries like Italy and Spain managed to improve their internal conflict ratings in most recent years. Regarding the last robustness variable, higher index values of *Civil Liberties* impact labor productivity growth positively, suggesting countries with lower but still high civil liberties to perform better in terms productivity growth. This may be due to similar reasons as in the case of *Internal Conflict*, since many countries (e.g. Italy, Spain, UK, and France) have improved their civil liberties from rating 2 to 1 in recent years, although these specific countries are characterized by low productivity growth. Other high-productivity countries (like the US and Finland) exhibit a rating of 1 throughout the entire period.

Including all alternative institutional variables jointly into the regression (column VII) leaves the statistical inferences as well as the magnitudes of the institutional variables of interest unaltered. This is also the case for the robustness variables. Moreover, ICT capital deepening is estimated as significant in this last specification, supporting the view that new technologies embedded in employed investments contribute to country labor productivity growth.

4. Conclusion

This paper analyzes the effects of institutions and innovations on country productivity growth. In my first attempt without controlling for endogeneity, I find that aggregate institutions matter, in particular, basic institutional quality and human capital efficiency. The effect of innovations turns significant only when aggregate institutions or basic institutional quality and human capital efficiency are included. ICT and Non-ICT capital deepening matters throughout all those specifications. On the contrary, when controlling for endogeneity the empirical evidence shows that ICT capital deepening loses significance, except when human capital efficiency is included. Also, innovations become insignificant throughout all the specifications, but more institutional variables turn statistically significant. Besides the two institutions basic institutional quality and human capital efficiency, optimal taxation, trade openness, and capital markets become important institutions for productivity growth.

Controlling for correlation between institutional covariates ends up in a parsimonious benchmark model including three institutions: human capital efficiency, labor markets, and capital markets, which are all determined to exhibit a significant impact on productivity growth. I further find that innovations have a direct effect on country productivity growth and that this effect is moderated by a country's human capital efficiency. Interactions between industry innovations and human capital endowment stimulate productivity growth. Allowing for three alternative institutional variables does not change the effects of the institutional variables of interest. Ultimately, ICT capital deepening becomes significant in the parsimonious benchmark model as well as in the other robustness check specifications.

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Table 1
Descriptive Statistics of Input and Institutional Variables

	Variable	Status	Mean	Std. Dev.	Min.	Max.	Obs.
	Labor Productivity	Growth Rates	0.0289	0.0582	-0.2040	0.3155	1677
	ICT Capital Deepening	Growth Rates	0.1001	0.0818	-0.2170	0.5341	1632
	Non-ICT Capital Deepening	Growth Rates	0.0284	0.0432	-0.3851	0.4103	1632
	R&D Stock	Growth Rates	0.0580	0.1262	-0.1541	1.1963	1546
DICE Index	Total Composite Index	Level	0.5974	0.0513	0.4924	0.6965	1800
	Optimal Taxation	Level	0.7111	0.1123	0.3550	0.7874	1800
	Basic Institutional Quality	Level	0.8033	0.1380	0.4609	0.9952	1800
	Total Tax Revenue	Level	0.3028	0.1852	0.0024	0.6827	1800
	Human Capital Efficiency	Level	0.5658	0.1160	0.3588	0.8291	1800
	Trade Openness	Level	0.7132	0.0722	0.4487	0.8541	1800
	Labor Markets	Level	0.4350	0.1987	0.0539	0.7943	1800
	Government Expenditures	Level	0.4679	0.1783	0.1583	0.9752	1800
	Capital Markets	Level	0.5681	0.1372	0.2016	0.8243	1800
Robust-ness	ICT Patents (in 1000)	Level	1.7216	2.5425	0.0281	12.0099	1800
	Internal Conflict	Level	10.9632	1.1149	7.3167	12.0000	1800
	Civil Liberties	Level	1.3933	0.4393	1.0000	2.2000	1800

Note: Outliers excluded. *Sources:* EUKLEMS (2008), OECD (2006) and IIGAD (2008).

Table 2
Cross-Country Labor Productivity Growth Regressions, 1992–2005

	LSDV	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
	ICT Capital Deepening	**0.0503****	**0.0498****	**0.0394***	**0.0419***	**0.0427****	**0.0566****	**0.0431****	**0.0497****	**0.0458****	**0.0580*****	**0.0483****	**0.0556****
		[0.0208]	[0.0215]	[0.0216]	[0.0223]	[0.0212]	[0.0220]	[0.0215]	[0.0215]	[0.0224]	[0.0221]	[0.0219]	[0.0223]
	Non-ICT Capital Deepening	**0.2880*****	**0.2782*****	**0.2851*****	**0.2848*****	**0.2792*****	**0.2705*****	**0.2814*****	**0.2783*****	**0.2795*****	**0.2711*****	**0.2781*****	**0.2687*****
		[0.0495]	[0.0507]	[0.0515]	[0.0518]	[0.0514]	[0.0508]	[0.0531]	[0.0506]	[0.0511]	[0.0495]	[0.0507]	[0.0515]
	R&D Stock		0.0199	**0.0251***	0.0221	**0.0304****	0.0199	**0.0272***	0.0200	0.0215	0.0195	0.0212	**0.0331****
			[0.0143]	[0.0149]	[0.0145]	[0.0146]	[0.0139]	[0.0138]	[0.0149]	[0.0148]	[0.0139]	[0.0154]	[0.0142]
Institutional Variables	Capital Markets											0.0080	0.0203
												[0.0147]	[0.0221]
	Government Expenditures										-0.0136		**-0.0362*****
											[0.0115]		[0.0110]
	Labor Markets									0.0094			**-0.0457*****
										[0.0099]			[0.0138]
	Trade Openness								0.0018				-0.0332
									[0.0224]				[0.0210]
	Human Capital Efficiency							**0.0702*****					0.0102
								[0.0165]					[0.0281]
	Total Tax Revenue						-0.0156						**-0.0431****
							[0.0125]						[0.0198]
	Basic Institutional Quality					**0.0514*****							**0.0350***
						[0.0117]							[0.0200]
	Optimal Taxation				-0.0251								**-0.1429*****
					[0.0188]								[0.0369]
	Total Composite Index			**0.0791****									
				[0.0352]									
	Observations	1629	1497	1497	1497	1497	1497	1497	1497	1497	1497	1497	1497
	R^2	0.31	0.31	0.32	0.31	0.32	0.31	0.33	0.31	0.31	0.31	0.31	0.34
	Adj. R^2	0.31	0.31	0.31	0.31	0.32	0.31	0.32	0.31	0.31	0.31	0.31	0.33

Notes: Outliers excluded. Robust standard errors in brackets allowing for intra-industry correlation. Significance levels *, **, ***: significant at 10, 5, and 1 percent. *Sources:* EUKLEMS (2008), OECD (2006) and IIGAD (2008).

Table 3 Cross-Country Labor Productivity Growth Regressions, 1992–2005

	SYSTEM GMM	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
	ALP_{t-1}	-0.0623	-0.0045	0.0055	0.0060	-0.0011	0.0539	0.0287	0.0219	0.0721	0.0266	0.0169	-0.0472
		[0.0701]	[0.0694]	[0.0667]	[0.0722]	[0.0684]	[0.0663]	[0.0660]	[0.0626]	[0.0641]	[0.0648]	[0.0699]	[0.0652]
	ALP_{t-2}	0.0753	0.0148	0.0108	-0.0178	0.0114	0.0750	0.0234	0.0151	0.0330	-0.0104	0.0308	-0.0058
		[0.0719]	[0.0691]	[0.0539]	[0.0606]	[0.0556]	[0.0578]	[0.0539]	[0.0615]	[0.0551]	[0.0613]	[0.0551]	[0.0614]
	ALP_{t-3}	**0.2127*****	0.1142	**0.1612****	**0.1840*****	**0.1485****	**0.1716*****	**0.1595*****	**0.1664*****	**0.1947*****	**0.1592****	**0.1933*****	**0.1469****
		[0.0758]	[0.0703]	[0.0625]	[0.0622]	[0.0602]	[0.0596]	[0.0585]	[0.0625]	[0.0605]	[0.0729]	[0.0577]	[0.0575]
	ALP_{t-4}	0.0485	0.0704	**0.0971***	**0.1207*****	**0.0987****	**0.1048****	**0.1088****	**0.0922***	**0.1336*****	**0.1029****	**0.1311****	**0.0982****
		[0.0554]	[0.0529]	[0.0492]	[0.0455]	[0.0458]	[0.0494]	[0.0518]	[0.0502]	[0.0510]	[0.0517]	[0.0535]	[0.0440]
	ICT Capital Deepening	-0.0061	0.0008	0.0156	0.0107	0.0212	0.0381	**0.0535***	0.0480	0.0396	0.0179	0.0427	0.0434
		[0.0312]	[0.0330]	[0.0279]	[0.0309]	[0.0292]	[0.0308]	[0.0286]	[0.0320]	[0.0266]	[0.0322]	[0.0312]	[0.0337]
	Non-ICT Capital Deepening	**0.1962****	**0.2385****	**0.2496*****	**0.2581*****	**0.2231*****	**0.2644*****	**0.1638****	**0.1913****	**0.2690*****	**0.2807*****	**0.2251*****	**0.2608*****
		[0.0990]	[0.1025]	[0.0845]	[0.0890]	[0.0788]	[0.0894]	[0.0733]	[0.0791]	[0.0894]	[0.0922]	[0.0802]	[0.0874]
	R&D Stock		-0.0517	-0.0053	-0.0277	0.0223	-0.0299	-0.0271	-0.0529	-0.0077	-0.0259	-0.0137	0.0096
			[0.0346]	[0.0287]	[0.0277]	[0.0293]	[0.0287]	[0.0303]	[0.0324]	[0.0232]	[0.0320]	[0.0293]	[0.0278]
Institutional Variables	Capital Markets											**0.0430****	0.0592
												[0.0209]	[0.0359]
	Government Expenditures										0.0112		**-0.0276***
											[0.0139]		[0.0155]
	Labor Markets									0.0129			**-0.0689*****
										[0.0101]			[0.0200]
	Trade Openness								**0.0587***				-0.0189
									[0.0324]				[0.0310]
	Human Capital Efficiency							**0.0527*****					0.0247
								[0.0153]					[0.0346]
	Total Tax Revenue						0.0011						-0.0189
							[0.0118]						[0.0242]
	Basic Institutional Quality					**0.0533*****							**0.0382***
						[0.0135]							[0.0228]
	Optimal Taxation				**-0.0449****								**-0.1347*****
					[0.0206]								[0.0500]
	Total Composite Index			**0.1441*****									
				[0.0409]									
	Constant	**0.0141****	**0.0165*****	**-0.0765*****	**0.0429****	**-0.0337*****	0.0046	**-0.0219****	-0.0332	-0.0026	0.0048	**-0.0197***	0.0861
		[0.0057]	[0.0057]	[0.0243]	[0.0170]	[0.0114]	[0.0056]	[0.0100]	[0.0252]	[0.0056]	[0.0068]	[0.0114]	[0.0537]
	Observations	1195	1076	1076	1076	1076	1076	1076	1076	1076	1076	1076	1076
	Nr. of countries x sectors	120	120	120	120	120	120	120	120	120	120	120	120
	AR1 Test	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	AR2 Test	0.4419	0.9998	0.7103	0.3439	0.7795	0.8866	0.5847	0.6466	0.4396	0.4480	0.6916	0.9366
	Nr. of Instruments	129	160	212	212	213	213	213	190	213	190	213	250
	Over-Identification	0.5774	0.9919	1.0000	1.0000	1.0000	1.0000	1.0000	0.9999	1.0000	1.0000	1.0000	1.0000

Notes: Outliers excluded. Robust standard errors in brackets allowing for intra-industry correlation. Significance levels *, **, ***: significant at 10, 5, and 1 percent. *Sources:* EUKLEMS (2008), OECD (2006) and IIGAD (2008).

Table 4
Cross-Country Labor Productivity Growth Regressions, 1992–2005

	SYSTEM GMM	I[a)]	II	III	IV	V	VI	VII
	ALP_{t-1}	-0.0472	0.0030	0.0304	0.0145	0.0251	0.0210	0.0045
		[0.0652]	[0.0612]	[0.0497]	[0.0500]	[0.0496]	[0.0499]	[0.0503]
	ALP_{t-2}	-0.0058	0.0300	0.0395	0.0221	0.0454	0.0364	0.0256
		[0.0614]	[0.0540]	[0.0495]	[0.0530]	[0.0498]	[0.0502]	[0.0538]
	ALP_{t-3}	**0.1469****	**0.1539*****	**0.1167****	**0.1133****	**0.1202****	**0.1153****	**0.1112****
		[0.0575]	[0.0563]	[0.0545]	[0.0555]	[0.0541]	[0.0548]	[0.0560]
	ALP_{t-4}	**0.0982****	**0.0978****	**0.1154*****	**0.1156*****	**0.1209*****	**0.1231*****	**0.1218*****
		[0.0440]	[0.0464]	[0.0400]	[0.0399]	[0.0398]	[0.0400]	[0.0399]
	ICT Capital Deepening	0.0434	**0.0517***	**0.0453***	0.0451	**0.0591****	0.0421	**0.0531***
		[0.0337]	[0.0298]	[0.0271]	[0.0274]	[0.0290]	[0.0277]	[0.0303]
	Non-ICT Capital Deepening	**0.2608*****	**0.2367*****	**0.3018*****	**0.3024*****	**0.3024*****	**0.2974*****	**0.3066*****
		[0.0874]	[0.0750]	[0.0750]	[0.0792]	[0.0774]	[0.0798]	[0.0828]
	R&D Stock	0.0096	-0.0068	-0.0831	-0.1334	-0.1165	-0.1067	-0.2000
		[0.0278]	[0.0252]	[0.1408]	[0.1410]	[0.1400]	[0.1390]	[0.1411]
Institutional Variables	Capital Markets	0.0592	**0.0616*****	**0.0661*****	**0.0435***	**0.0692*****	**0.0667*****	**0.0455****
		[0.0359]	[0.0203]	[0.0190]	[0.0222]	[0.0177]	[0.0181]	[0.0210]
	Government Expenditures	**-0.0276***						
		[0.0155]						
	Labor Markets	**-0.0689*****	**-0.0254***	**-0.0245***	**-0.0293****	**-0.0360****	**-0.0295****	**-0.0451*****
		[0.0200]	[0.0132]	[0.0127]	[0.0127]	[0.0138]	[0.0129]	[0.0143]
	Trade Openness	-0.0189						
		[0.0310]						
	Human Capital Efficiency	0.0247	**0.0713*****	**0.0526*****	**0.0481****	**0.0726*****	**0.1005*****	**0.1065*****
		[0.0346]	[0.0183]	[0.0176]	[0.0186]	[0.0187]	[0.0255]	[0.0268]
	Total Tax Revenue	-0.0189						
		[0.0242]						
	Basic Institutional Quality	**0.0382***						
		[0.0228]						
	Optimal Taxation	**-0.1347*****						
		[0.0500]						
R&D Interactions	Capital Markets			-0.1520	-0.0652	-0.1974	-0.0894	-0.0229
				[0.2692]	[0.2661]	[0.2730]	[0.2690]	[0.2741]
	Labor Markets			-0.0232	-0.0534	-0.0260	-0.0367	-0.0695
				[0.1722]	[0.1776]	[0.1654]	[0.1708]	[0.1728]
	Human Capital Efficiency			**0.3364***	**0.3729***	**0.4212****	**0.3332***	**0.4492****
				[0.1985]	[0.2061]	[0.2018]	[0.1963]	[0.2128]
Robustness	ICT Patents (in 1000)				**0.0018***			**0.0019****
					[0.0010]			[0.0010]
	Internal Conflict					**-0.0038****		**-0.0036****
						[0.0016]		[0.0016]
	Civil Liberties						**0.0135****	**0.0112****
							[0.0054]	[0.0054]
	Constant	0.0861	**-0.0598*****	**-0.0546*****	**-0.0394****	-0.0223	**-0.0993*****	-0.0450
		[0.0537]	[0.0142]	[0.0130]	[0.0152]	[0.0192]	[0.0213]	[0.0285]
	Observations	1076	1076	1076	1076	1076	1076	1076
	Nr. of countries x sectors	120	120	120	120	120	120	120
	AR1 Test	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	AR2 Test	0.9366	0.9762	0.6802	0.7642	0.5561	0.6354	0.5855
	Nr. of Instruments	250	246	405	409	409	409	409
	Over-Identification	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000

Notes: a) Specification I resembles specification XII in Table 3. Outliers excluded. Robust standard errors in brackets allowing for intra-industry correlation. Significance levels *, **, ***: significant at 10, 5, and 1 percent. *Sources:* EUKLEMS (2008), OECD (2006) and IIGAD (2008).

Appendix

Table A1
Industry Coverage by ISIC Classification

		ISIC Classification Revision 3.0
1	Food and Tobacco	D: 15 to 16
2	Textiles, Apparel, and Leather	D: 17 to 19
3	Wood Products	D: 20
4	Paper, Pulp, Publishing, Printing	D: 21 to 22
5	Coke, Petroleum, Nuclear Fuels	D: 23
6	Chemicals and others[a)]	D: 24 to 26
7	Basic and Fabricated Metals	D: 27 to 28
8	Machinery	D: 29
9	Office Machinery and Electronic Equipment	D: 30 to 33
10	Automobiles and Other Transport	D: 34 to 35
11	Manufacturing n.e.c.[b)]	D: 36 to 37
12	Electricity, Gas & Water Supply	E: 40 to 41
13	Construction	F: 45

Notes: a) others comprise the sectors Rubber and Plastic, and Non-Metallic Mineral Products. b) consists of the sectors Furniture, Recycling, and Manufacturing n.e.c.

Table A2
Cross-Country Labor Productivity Growth Regressions of Table 1, Industry Effects

Industry	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
Food and Tobacco	0.0059	0.0048	-0.0418*	0.0232	-0.0359***	0.0092	-0.0344***	0.0035	0.0011	0.0107	0.0004	0.1343***
	[0.0065]	[0.0067]	[0.0219]	[0.0147]	[0.0106]	[0.0076]	[0.0102]	[0.0180]	[0.0083]	[0.0083]	[0.0113]	[0.0423]
Textiles, Apparel & Leather	0.0138***	0.0118**	-0.0350	0.0302**	-0.0295***	0.0162***	-0.0278***	0.0106	0.0081	0.0176***	0.0074	0.1403***
	[0.0047]	[0.0049]	[0.0217]	[0.0146]	[0.0107]	[0.0059]	[0.0106]	[0.0171]	[0.0063]	[0.0064]	[0.0095]	[0.0422]
Wood Products	0.0143*	0.0133	-0.0336	0.0315*	-0.0280**	0.0177**	-0.0263**	0.0120	0.0095	0.0192**	0.0088	0.1422***
	[0.0072]	[0.0081]	[0.0231]	[0.0167]	[0.0129]	[0.0082]	[0.0122]	[0.0197]	[0.0095]	[0.0095]	[0.0126]	[0.0439]
Paper & Pulp, Publish & Print	0.0096**	0.0082	-0.0388*	0.0264*	-0.0335***	0.0125*	-0.0316***	0.0069	0.0044	0.0140*	0.0037	0.1363***
	[0.0044]	[0.0056]	[0.0221]	[0.0144]	[0.0109]	[0.0066]	[0.0105]	[0.0178]	[0.0075]	[0.0073]	[0.0109]	[0.0424]
Chemicals and others[a)]	0.0210***	0.0203***	-0.0264	0.0386***	-0.0206**	0.0247***	-0.0190*	0.0190	0.0166***	0.0262***	0.0159*	0.1496***
	[0.0035]	[0.0037]	[0.0210]	[0.0142]	[0.0100]	[0.0053]	[0.0101]	[0.0161]	[0.0055]	[0.0059]	[0.0086]	[0.0419]
Basic & Fabricated Metals	0.0104**	0.0103**	-0.0363*	0.0287**	-0.0306***	0.0146**	-0.0290***	0.0090	0.0066	0.0161**	0.0059	0.1394***
	[0.0042]	[0.0045]	[0.0214]	[0.0144]	[0.0106]	[0.0058]	[0.0102]	[0.0174]	[0.0057]	[0.0068]	[0.0097]	[0.0421]
Machinery	0.0199***	0.0183***	-0.0286	0.0366**	-0.0231**	0.0227***	-0.0213**	0.0171	0.0146**	0.0242***	0.0138	0.1468***
	[0.0046]	[0.0043]	[0.0220]	[0.0141]	[0.0107]	[0.0055]	[0.0106]	[0.0167]	[0.0059]	[0.0063]	[0.0095]	[0.0424]
Office & Electronic Equipment	0.0595***	0.0591***	0.0122	0.0773***	0.0178	0.0636***	0.0198	0.0579***	0.0554***	0.0651***	0.0547***	0.1880***
	[0.0167]	[0.0157]	[0.0255]	[0.0214]	[0.0169]	[0.0162]	[0.0144]	[0.0193]	[0.0154]	[0.0169]	[0.0163]	[0.0446]
Automobiles & Other Transport	0.0187***	0.0184***	-0.0283	0.0367**	-0.0223**	0.0229***	-0.0208*	0.0171	0.0147*	0.0244***	0.0140	0.1481***
	[0.0066]	[0.0065]	[0.0220]	[0.0142]	[0.0105]	[0.0079]	[0.0106]	[0.0164]	[0.0078]	[0.0085]	[0.0102]	[0.0420]
Manufacturing n.e.c.[b)]	0.0078	0.0051	-0.0420*	0.0233	-0.0369***	0.0093	-0.0350***	0.0038	0.0013	0.0108	0.0005	0.1327***
	[0.0061]	[0.0065]	[0.0220]	[0.0150]	[0.0116]	[0.0072]	[0.0111]	[0.0172]	[0.0072]	[0.0080]	[0.0098]	[0.0426]
Electricity, Gas & Water Supply	0.0250***	0.0264***	-0.0205	0.0446***	-0.0147	0.0309***	-0.0131	0.0251	0.0226***	0.0323***	0.0219**	0.1555***
	[0.0043]	[0.0045]	[0.0214]	[0.0143]	[0.0106]	[0.0062]	[0.0106]	[0.0164]	[0.0061]	[0.0068]	[0.0094]	[0.0414]
Construction	-0.0126***	-0.0147***	-0.0613***	0.0039	-0.0561***	-0.0107**	-0.0543***	-0.0160	-0.0183***	-0.0091	-0.0191**	0.1132***
	[0.0036]	[0.0041]	[0.0215]	[0.0148]	[0.0108]	[0.0049]	[0.0106]	[0.0170]	[0.0056]	[0.0057]	[0.0095]	[0.0424]

Notes: a) others comprise the sectors Rubber and Plastic, and Non-Metallic Mineral Products; b) consists of the sectors Furniture, Recycling, and Manufacturing n.e.c. Outliers excluded. Robust standard errors in brackets allowing for intra-industry correlation. Significance levels *, **, ***: significant at 10, 5, and 1 percent. *Sources:* EUKLEMS (2008), OECD (2006) and IIGAD (2008).

Table A3
Correlation Coefficients for Covariates (1992–2005)

	Labor Productivity *	ICT Capital Deepening*	Non-ICT Capital Deepening*	R&D Stock*	Optimal Taxation	Basic Institutional Quality	Total Tax Revenue	Human Capital Efficiency	Trade Openness	Labor Markets	Government Expenditures	Capital Markets
Labor Productivity*	**1.00**											
ICT Capital Deepening*	0.11	**1.00**										
Non-ICT Capital Deepening*	0.25	0.24	**1.00**									
R&D Stock*	0.04	0.05	0.01	**1.00**								
Optimal Taxation	-0.05	-0.20	0.04	0.09	**1.00**							
Basic Institutional Quality	0.12	0.07	0.01	-0.17	-0.20	**1.00**						
Total Tax Revenue	-0.05	0.16	-0.06	0.00	**-0.75**	-0.14	**1.00**					
Human Capital Efficiency	0.13	0.06	0.00	-0.10	-0.36	**0.73**	-0.18	**1.00**				
Trade Openness	-0.01	0.00	-0.03	-0.12	0.04	0.25	-0.17	0.14	**1.00**			
Labor Markets	0.04	0.16	0.01	-0.09	**-0.77**	0.26	0.46	0.44	-0.02	**1.00**		
Government Expenditures	-0.03	0.25	-0.06	-0.01	**-0.52**	0.15	**0.56**	0.00	0.11	0.16	**1.00**	
Capital Markets	0.03	0.12	0.03	-0.15	**-0.50**	0.37	0.43	0.17	0.43	**0.50**	0.39	**1.00**

Note: * indicates variables in growth rates, while others are in levels. Outliers excluded. *Sources:* EUKLEMS (2008), OECD (2006) and IIGAD (2008).

Table A4
Panel Unit-Root Tests of Output and Input Variables (1992–2005)

LLC			**IPS**			**ADF**			**PP**		
Labor Productivity											
Lag	(0)	0.0000	Lag	(0)	0.0000	Lag	(0)	0.0000	Lag	(0)	0.0000
Lag	(1)	0.0000	Lag	(1)	0.0000	Lag	(1)	0.0000	Lag	(1)	0.0000
ICT Capital Deepening											
Lag	(0)	---	Lag	(0)	---	Lag	(0)	0.0000	Lag	(0)	0.0000
Lag	(1)	---	Lag	(1)	---	Lag	(1)	0.0000	Lag	(1)	0.0000
Non-ICT Capital Deepening											
Lag	(0)	---	Lag	(0)	---	Lag	(0)	0.0000	Lag	(0)	0.0000
Lag	(1)	---	Lag	(1)	---	Lag	(1)	0.0000	Lag	(1)	0.0000
R&D Stocks											
Lag	(0)	---	Lag	(0)	---	Lag	(0)	0.0000	Lag	(0)	0.0000
Lag	(1)	---	Lag	(1)	---	Lag	(1)	0.0000	Lag	(1)	0.0000

Notes: All variables are in exponential growth rates. Unit-root tests are performed without trends including constants. LLC and IPS are only performed for balanced panels. An outlier industry as treated in the regressions excluded. *Sources:* EUKLEMS (2008), OECD (2006) and IIGAD (2008).

Table A5
Panel Unit-Root Tests of Regression Residuals of Table 2 (1992–2005)

ADF				PP			
Specification	**III**			**Specification**	**III**		
	Lag	(0)	0.0000		Lag	(0)	0.0000
	Lag	(1)	0.0000		Lag	(1)	0.0000
Specification	**IV**			**Specification**	**IV**		
	Lag	(0)	0.0000		Lag	(0)	0.0000
	Lag	(1)	0.0000		Lag	(1)	0.0000
Specification	**V**			**Specification**	**V**		
	Lag	(0)	0.0000		Lag	(0)	0.0000
	Lag	(1)	0.0000		Lag	(1)	0.0000
Specification	**VI**			**Specification**	**VI**		
	Lag	(0)	0.0000		Lag	(0)	0.0000
	Lag	(1)	0.0000		Lag	(1)	0.0000
Specification	**VII**			**Specification**	**VII**		
	Lag	(0)	0.0000		Lag	(0)	0.0000
	Lag	(1)	0.0000		Lag	(1)	0.0000
Specification	**VIII**			**Specification**	**VIII**		
	Lag	(0)	0.0000		Lag	(0)	0.0000
	Lag	(1)	0.0000		Lag	(1)	0.0000
Specification	**IX**			**Specification**	**IX**		
	Lag	(0)	0.0000		Lag	(0)	0.0000
	Lag	(1)	0.0000		Lag	(1)	0.0000
Specification	**X**			**Specification**	**X**		
	Lag	(0)	0.0000		Lag	(0)	0.0000
	Lag	(1)	0.0000		Lag	(1)	0.0000
Specification	**XI**			**Specification**	**XI**		
	Lag	(0)	0.0000		Lag	(0)	0.0000
	Lag	(1)	0.0000		Lag	(1)	0.0000
Specification	**XII**			**Specification**	**XII**		
	Lag	(0)	0.0000		Lag	(0)	0.0000
	Lag	(1)	0.0000		Lag	(1)	0.0000

Notes: Residuals are in exponential growth rates. Unit-root tests are performed without trends including constants.

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