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Explaining Differences in Economic Growth among OECD Countries*

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Abstract. This paper re-examines the determinants of growth of GDP per capita using panel data for OECD countries for the period 1970–1999 with data averaged over five-year periods from new perspectives. First, we introduce indicators of innovation input and technological specialization simultaneously into the empirical growth equation. Second, we employ the system-GMM (Generalized-Method-of-Moments) panel estimator that controls for (a) the possible specification bias when variables are highly persistent over time and (b) the possible simultaneity bias. We find a large and statistically significant impact of business enterprise R&D (BERD) intensity on GDP per capita with an elasticity of 0.22. The share of high-technology exports is also significantly positively related to GDP per capita, but the magnitude suggests that BERD is more important than technological specialization in explaining the level of GDP per capita. Furthermore, we find that the budget deficit and government consumption (both measured as percentages of GDP) and the volatility of growth are significantly negatively related to GDP per capita.

Key words: Economic growth, R&D, technological change, fiscal policy, government expenditures, panel data regressions

JEL codes: E62, H20, H50, O23, O40

I. Introduction

The OECD countries in the 1990s are characterized by widening disparities of growth rates of GDP per capita (see Aiginger and Landesmann, 2002;

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OECD, 2003a). In the empirical literature, there is widespread agreement on the importance of innovation activities, human capital, product market and labor market reforms for economic growth (OECD, 2003a). The number of scholars using dynamic panel data methods to investigate the sources of differences in growth rates among industrialized countries is growing. Caselli, Esquivel and Lefort (1996) introduced the panel approach into the empirical growth literature. Similar techniques have been applied in growth research by Bond et al. (2001) and, among others, Beck et al. (2000). Most studies use five-year averages of the variables in order to eliminate short-run fluctuations.

The aim of this paper is to provide some new insights on the determinants of economic growth in OECD countries. Particularly, we investigate the impact of specialization in R&D industries, innovation activity and government size in a growth equation controlling for human capital, investment ratio, time and country fixed effects. In addition, the growth contribution of the volatility of growth is examined. We estimate the growth equation using a dynamic Generalized-Method-of-Moments (GMM) panel estimator. The dynamic GMM panel estimator has a number of advantages compared to cross-sectional estimators: it accounts for country fixed effects and allows us to control for endogeneity of all explanatory variables. Following Bond et al. (2001), we use the system GMM estimator rather than the more usual first-differenced GMM estimator. Bond et al. (2001) and Blundell and Bond (1998) show that first-differenced GMM estimator performs poorly in finite samples and produces biased coefficients if the sample size is small or if the time series is highly persistent, as is the case with R&D intensity and technological specialization. We use data for 21 OECD countries with data averaged over each of the five-year periods between 1970 and 1999.

Previous empirical research suggests that innovation activity measured as the change in R&D intensity is one of the most significant factors affecting differences in GDP and productivity growth (Coe and Helpman, 1995; Bassanini et al., 2001; Guellec and Van Pottelsberghe, 2004). Using panel data for 16 OECD countries, Guellec and van Pottelsberghe (2004) find that the long-run elasticities of total factor productivity with respect to public sector R&D and business sector R&D capital are on average 0.17 and 0.13, respectively. Related literature suggests that human capital has a significant impact on economic growth in OECD countries. Using annual data for 21 OECD countries from 1971 to 1998, Bassanini and Scarpetta (2002) find that the social return on one additional year of schooling is a six percent increase in steady-state output.

However, R&D intensity could be regarded as an indicator of innovation input rather than of innovation output. Improvements in the efficiency of the innovation process (i.e. higher GDP with stable R&D expenditures) can be mistakenly interpreted as a reduction of the innovative effort. Therefore, we also examine innovation output indicators such as the export share of high-technology industries and patent activity. It is well known that some smaller OECD countries such as Finland and Ireland have increased the share of R&D intensive exports and patents per capita far more rapidly than any other OECD country over the last 20 years. Both countries are also characterized by above-average growth rates of GDP per capita. Figure 1 in the Appendix shows that the change of export share of high-technology industries and the growth of GDP per capita are significantly positively correlated. Using data for 21 OECD countries over the period 1981–2001, we find a correlation of 0.56 with a *p*-value of 0.00.

The literature also confirms the positive growth effects of specialization in high-technology industries. Using panel data on 28 OECD countries for the period 1990–1998, Peneder (2003) investigates the impact of industry structure on economic growth. The set of regressors includes demography, employment rates, capital investment, average years of education, as well as relative shares in the exports and imports of technology-driven and high-skill industries. The author finds that the export share of technology-driven and high-skill-intensive industries (expressed as relative share to the OECD average) has a positive and significant impact on the level and growth of GDP per capita. Using panel data for OECD and non-OECD countries, Wörz (2003) finds that the share of medium-high-skill-intensive exports is positively associated with GDP growth, while the share of low-skill-intensive exports shows the expected negative effect.

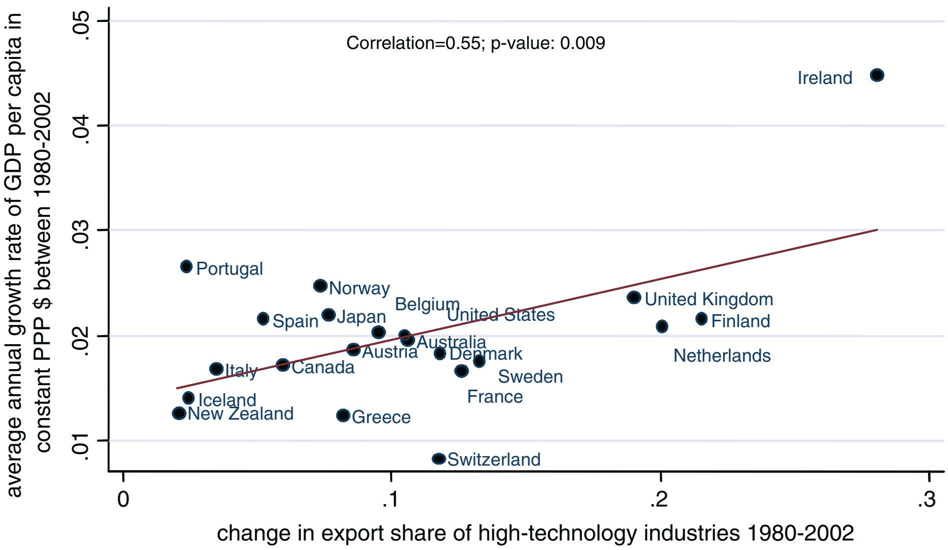

Figure 1. Correlation between the change in export share of high-technology industries and growth of GDP per capita.

The relationship between fiscal policy and economic growth also attracts considerable interest from both policymakers and academics (for a recent overview see Zagler and Dürnecker (2003)). Many studies regress an indicator of overall economic performance (like the growth rate or the unemployment level) on different measures of government size (such as indirect taxes, social security contributions, budget deficit, subsidies and government consumption). However, the empirical results are not always consistent (see among others Mendoza et al. (1997), Padovano and Galli (2001), Sachverständigenrat (2002/2003)). Fölster and Henrekson (2001) examine the growth effects of government spending and taxation in rich countries. Using cross-country panel data for the period 1970–1995, the authors find a robust negative relationship between government expenditures and economic growth. In addition, the authors conclude that a 10% increase in government expenditure as a percentage of GDP is associated with a decrease in the economic growth rate by 0.8% points (Fölster and Henrekson, 2001). Similarly, Kneller et al. (1999) provide evidence that financial policies can affect long-run growth rates in OECD countries. The authors find that productive expenditures such as educational and health expenditures increase growth while unproductive expenditures such as social security and welfare have no effect. More recently, Mueller and Stratmann (2003) have found a negative effect of government size on economic growth for a sample of industrialized countries.

This paper is an extension of the previous literature in a number of ways. Firstly, innovation input and innovation output are introduced simultaneously into the empirical growth equation. Most previous studies cited above utilize either innovation input or specialization in high technology. Furthermore, we use a broad set of determinants of GDP of capita (e.g., patents per capita, patent structure, taxation, different categories of government expenditures, strike activity, etc.). Finally, we employ the system-GMM panel estimator that controls for (a) the possible specification bias when variables are highly persistent over time and (b) the possible simultaneity bias.

The paper is structured as follows: Section II discusses the empirical specification, while Section III discusses the dataset and descriptive statistics. Section IV presents the main results and some robustness checks, and Section V concludes.

II. Empirical Model and Hypothesis

We empirically implement the model by imposing a steady-state restriction, implying that countries are on a steady-state long-run growth path for the period examined. Under this assumption, growth rates (the dependent variable) can be expressed without reference to the stocks of physical or human capital, but as functions of the investment rate, a human capital variable and other factors such as knowledge (proxied by the R&D ratio or patents per capita), population or labor force growth and an initial level.

Using panel data, we can write the steady state GDP per capita equation as:

$$\ln(y_{i,t}) = \beta \ln(y_{i,t-1}) + \ln(x_{i,t})\delta + \eta_i + \lambda_t + \varepsilon_{i,t},$$

where $y_{i,t}$ is per capita GDP expressed in 1995 purchasing power parities in country i in period t, $x_{i,t}$ is a row vector of determinants of GDP per capita, η_i is a country-specific effect, λ_t is a period-specific effect and $\varepsilon_{i,t}$ is an error term. The explanatory variables $x_{i,t}$ and the country effect η_i are proxies for the long-run level to which the country converges. If $\beta = 1$, there is no convergence effect. The choice of the variables $x_{i,t}$ depends on the particular variant of the neoclassical growth model one wishes to examine. Often, the empirical growth equation is based on the augmented Solow model discussed in Mankiw et al. (1992) with human capital or Barro and Sala-i-Martin (1995) with human capital and R&D. Policy variables interact with accumulation variables and could have a potential impact on long-run steady-state levels of growth. The country-specific effects capture the existence of time-invariant determinants of a country's steady state that are not already controlled for by $x_{i,t}$. The obvious candidates are differences in the technology level (Islam, 1995).

We can derive the regression equation by taking first differences to remove unobserved time-invariant country-specific effects:

$$\ln(y_{i,t}) - \ln(y_{i,t-1}) = \tilde{\beta}(\ln(y_{i,t-1}) - \ln(y_{i,t-2})) + (\ln(x_{i,t}) - \ln(x_{i,t-1}))\tilde{\delta} \\ + \lambda_t + (\varepsilon_{i,t} - \varepsilon_{i,t-1}).$$

Then we have to instrument the explanatory variables in the first-differenced equations using lagged levels under the assumption that the time-varying disturbances in the original levels equations are not serially correlated. The conventional dynamic panel model approach developed by Arellano and Bond (1991) has a major drawback if the regressors display persistence over time. In this case, their lagged levels may be very poor instruments for their differences. Blundell and Bond (1998) show that the first-differenced GMM panel estimator performs poorly when the time series are persistent and the number of time series is small, which is typically the case in empirical growth models. To reduce the potential bias and imprecision associated with the difference-estimator, an alternative system-GMM estimator is suggested by Arellano and Bover (1995) and implemented by Blundell and Bond (1998). The system GMM estimator combines the regression equation in first differences – instrumented with lagged levels of the regressors – with the regression equation in levels, instrumented with lagged differences of the regressors. The latter become valid instruments if we add stationarity assumptions. Blundell and Bond (1998) show that the system-GMM estimator produces large increases in both consistency and efficiency. In order to check whether the right-hand variables are characterized by a near unit root process we run simple AR(1) regressions using the system-GMM estimator. Unreported results show that business enterprise R&D (BERD) intensity, GDP per capita and some indicators of government size are characterized by high AR(1) coefficients of about 0.90 and higher.

Another problem facing cross-country regressions is the possible endogeneity of the growth determinants. The endogeneity problem can arise because of reverse causality. Several of the factors that may explain the GDP per capita can also be explained by the GDP per capita. We use lagged values of the suspected endogenous variables as instruments. Finally, there is a problem with respect to the potential covariation between business cycles and the explanatory variables, e.g. investment rate and R&D intensity. It is well known that investment rate and R&D intensity are pro-cyclical. A relatively accepted remedy in the literature is to use data averaged over 5 years rather than annual data.

The set of variables explaining GDP per capita includes a group of baseline variables (those derived from the basic theory): The initial GDP per capita, physical and human capital and the ratio of business enterprise R&D expenditures to GDP. We introduce the investment rate as a proxy for physical capital as well as average years of education among the working age population (from 25 to 64 years of age) as a proxy for human capital.

The variables of the baseline growth equation are as follows:

Total investment, % GDP is one of the main factors determining the level of real per capita output.

R&D expenditures, % GDP: R&D plays an important role in increasing productivity and growth. The strength between R&D and growth is of particular policy relevance. Governments are actively engaged in the promotion of R&D though direct funding of private R&D, tax incentives for private R&D and public sector R&D. Innovation activity will be primarily measured by business enterprise R&D (BERD) intensity and total R&D (GERD) intensity. We expect R&D intensity to have a positive impact on GDP per capita with output elasticities exceeding the GDP share devoted to R&D expenditures.

Human capital: The proxy measure used here is average years of education among the working age population (from 25 to 64 years of age) (see De la Fuente and Doménech, 2001). This indicator has also been employed by

Bassani and Scarpetta (2001). It is well known that this variable is a weak indicator of human capital because it cannot account for differences in the quality of one year of education (see Wößmann, 2003). We expect the impact of average years of schooling to be positive, yet not always significant.

The extended growth equation includes the following explanatory variables:

EPO (European Patent Office) patent applications per capita are an indicator of the output of the innovations process. Here, we also use the patent structure measured as the share of biotechnology patents and information and communication technology (ICT) patents (both as a share of total patents). ICT patents may reflect the differences in ICT diffusion in continental Europe as compared to the United States and the Nordic countries. The expected effects of patents per capita and patent specialization are positive.

Specialization in R&D intensive industries: R&D intensity is at best an indicator of innovation input rather than innovation output. For this reason, we use the share of high-technology exports in total manufacturing exports as an additional explanatory variable. High-technology exports are characterized by a high intensity of R&D and measure the technology intensity of a country's exports. The share of high-technology exports also reflects the degree of specialization in high-tech activities. They include high-technology products such as in aerospace, computers, pharmaceuticals, scientific instruments and electrical machinery (see OECD, 2003b). The narrow definition excludes scientific instruments.

Size of the government: In theory, the relationship between government expenditures and economic growth is ambiguous. New growth models conclude that fiscal policy can increase the steady-state economic growth rate if policies aim at influencing the quantity and/or quality of the capital stock (see Barro, 1990). A priori, high public expenditures could be associated with a well-functioning government and high quality of public goods and services. Therefore, a larger size of government expenditures does not necessarily indicate inefficient or bad government. In general, growth effects of fiscal policy can be divided into productive and non-productive expenditures and distortionary and non-distortionary taxes (Kneller et al., 1999). Productive expenditures and non-distortionary taxes stimulate growth due to crowding-in effects, whereas non-productive expenditures and distortionary taxes reduce growth due to crowding-out effects. It is generally assumed that public investment in infrastructure, education and health fall under the category of productive government expenditures (Kneller et al., 1999). Examples of non-productive government expenditures are subsidies to state-owned enterprises.

Taxation: Similarly, it is not clear whether high taxation is bad in any case. Depending on who pays for the tax and who bears it, this transfer of purchasing power from the private to the public sector not only means redistribution of incomes, but also carries deadweight losses and may thus have important implications for the behavior of private agents and overall economic growth.

Ratio of direct to indirect taxes: Theoretically, the mix of direct and indirect taxes may also have an impact on economic growth (Engen and Skinner, 1996). Mendoza et al. (1997) found in their empirical research that the tax structure has no significant effect on the rate of growth but does significantly affect the rate of private investment.

Government consumption, % GDP: The impact is expected to be negative. As government consumption increases as a percentage of GDP, investors modify their investment plans because of an anticipated increase in tax rates to cover the increased government consumption spending.

Government budget deficits and debts: In general, budget deficits could have a negative impact on economic growth. Higher debts or deficits increase real interest rates and, thus, crowd out private investment expenditure and adversely affect economic growth and employment. Borrowing will also lead to higher future taxes. This may further discourage private investment. Moreover, higher budget deficits may increase risk premiums on interest rates, in particular raising the inflation risk and the default risk premium. Higher interest rate risk premiums may discourage private investment (Alesina and Perotti, 1997).

Subsidies as a percentage of GDP belong to the ''unproductive'' government activities. We expect the impact of subsidies to be negative.

Social Security contribution, % GDP: It is commonly argued that increases in social security contributions lead to higher labor costs. Such a rise in wages will depress the profitability of private investment (Alesina et al., 1999). In addition, there are negative effects due to their distortionary effects on labor market participation.

Volatility of growth: Theoretically, the effect of the volatility could be positive or negative. On the one hand, the relationship could be negative, as volatility could deter the accumulation of physical and human capital. On the other hand, the relationship could be positive, as volatility could be a manifestation of the adoption of a new purpose technology (Imbs, 2002). Empirically, the sign of the relationship between growth and volatility remains inconclusive. For example, there are a number of studies based on cross-country or cross-regional comparisons in which the correlation between the average growth of output and the variability of output growth is found to be sometimes positive (Imbs, 2002) and sometimes negative (e.g., Ramey and Ramey, 1995; Martin and Rogers, 2000).

Openness: Trade openness (measured as exports plus imports in current prices as a proportion of nominal GDP) may increase GDP per capita by allowing a country to exploit comparative advantages or, additionally, by exploiting economies of scale and being exposed to competition.

Terms of trade: An improvement in a country's terms of trade – measured as the ratio of export to import prices – leads to higher levels of investment and hence long-run economic growth.

Corruption perception index: This index indicates the degree of corruption as perceived by business people, academics, and risk analysts (10 (highly clean) to 0 (highly corrupt)).

Indicators for labor market rigidity may also have an impact on GDP per capita. We use union coverage and the net union density rate (less retired), the labor force participation ratio, the non-accelerating wage rate of unemployment (NAWRU) as well as indicators on strikes (workers involved in strikes per employee and working days lost due to strikes per employee).

III. Data and Descriptive Statistics

The main data source is the OECD economic outlook database for the period 1960–2002 and is available for download at www.sourceoecd.org. Aggregate R&D intensity is defined as the ratio of GERD or BERD expenditures to GDP and is drawn form the OECD MSTI database. The share of high-tech exports is calculated using the OECD STAN database and is only available for the period 1981–2001. Patents data are drawn from the OECD patent database. Average years of schooling data are drawn from the educational attainment database developed by De la Fuente and Doménech (2001) and are available every five years (i.e., 1965, 1970, 1975, 1980, 1985, 1990 and 1995). The corruption perception index is provided by Transparency International for the period 1980–2002. Union density and the coverage ratio are taken from the Golden et al. (2002) dataset. Data on strikes are taken from the ILO database.

Table I contains the means of the variables averaged over each of the eight five-year periods and one three-year period: 1960–1964, 1965–1969, 1970–1974, 1975–1979, 1980–1984, 1985–1989, 1990–1994, 1995–1999 and 2000–2002. The mean investment ratio increased until the first half of the 1970s and decreased afterwards. The average ratio of BERD to GDP reached 1.4% for the period 2000/2002 compared to 0.8% in the first half of the 1980s. Similarly, we observe a steady increase in the share of high-technology-intensive exports now accounting for 22% of total manufacturing exports. Patents per capita also increased considerably during the sample period. Turning to indicators on the size of government, we observe that the tax ratio, social security contributions and government consumption (both as a percentage of GDP) increased until the first half of the 1990s and decreased afterwards. Table A1 (in the Appendix A) reports means, standard deviations, minima and maxima for the sample periods.

Table I. Descriptive statistic for OECD countries, five-year averages, 1960–2002

	1960–1964	1965–1969	1970–1974	1975–1979	1980–1984	1985–1989	1990–1994	1995–1999	2000–2002
GDP per working age population in 1995 US-$ ppp(in 1000s)	14.5	17.4	20.9	23.0	24.4	26.9	28.9	32.0	35.4
Total investment, % GDP	24.6	25.1	26.0	24.9	23.3	22.6	21.0	20.7	21.0
Private investment, % GDP	23.7	23.5	23.9	22.3	20.2	19.8	17.8	17.4	17.2
Business enterprise R&D (BERD), % GDP			0.8	0.8	0.8	1.0	1.0	1.2	1.4
Gross expenditures on R&D (GERD), % GDP	1.5	1.2	1.2	1.3	1.4	1.7	1.7	1.8	2.1
Average years of schooling	8.4	8.7	9.0	9.4	9.9	10.3	10.5	11.0	11.4
High-tech export share (narrowly defined)	n.a.	n.a.	n.a.	n.a.	8.4	10.5	12.2	15.2	18.2
High-tech export share (wider definition)	n.a.	n.a.	n.a.	n.a.	11.1	13.4	15.3	18.5	21.9
EPO biotechnology patent applications, % total EPO patents	n.a.	n.a.	n.a.	1.4	2.2	3.8	4.9	5.6	5.0
EPO ICT patent applications, % total EPO patents	n.a.	n.a.	n.a.	14.6	15.7	17.7	21.0	25.3	30.0

EPO patent applications per population	n.a.	n.a.	n.a.	15.8	41.1	61.0	63.9	98.5	102.5
Government Consumption, % GDP	14.5	15.9	17.5	19.5	20.6	20.1	20.8	20.0	20.0
Government Consumption, excl. wages, % GDP	5.3	5.9	6.3	7.0	7.7	7.7	7.9	8.2	8.6
Government Consumption, wages, % GDP	8.6	9.7	10.9	12.2	12.7	12.2	12.6	11.6	11.2
Total taxes , % GDP	20.0	21.1	23.9	24.3	25.8	27.4	27.8	28.3	28.7
Indirect taxes, % GDP	11.4	11.7	12.2	11.8	12.3	13.0	13.1	13.3	13.3
Direct taxes, % GDP	8.6	9.6	11.9	12.5	13.3	14.4	14.7	15.0	15.4
Ratio of direct to indirect taxes	0.79	0.87	0.98	1.07	1.10	1.14	1.14	1.14	1.17
Social security contributions, % GDP	6.9	8.5	9.2	10.6	11.1	11.0	11.1	11.5	11.3
Taxes and social security contributions, % GDP	26.9	29.5	33.1	34.9	36.9	38.4	38.9	39.8	40.1
Employment, government, % of total employment	11.1	12.5	14.5	16.6	18.0	18.4	19.0	18.3	17.8

Table I. (Continued)

	1960–1964	1965–1969	1970–1974	1975–1979	1980–1984	1985–1989	1990–1994	1995–1999	2000–2002
Subsidies, % GDP	1.3	1.5	1.7	2.3	2.4	2.1	1.8	1.4	1.2
Gross government debt, % GDP	37.8	41.5	37.0	36.6	49.3	59.2	70.7	74.8	66.8
Primary balance, % GDP	0.8	0.2	0.9	−1.4	−1.8	0.5	−0.6	1.8	3.0
Investment government , % GDP	4.0	4.3	4.2	3.9	3.5	3.1	3.1	2.8	2.7
Corruption perception index	n.a.	n.a.	n.a.	n.a.	7.6	7.6	7.6	7.8	7.8
Structural unemployment rate, in %	3.7	2.9	3.8	4.4	5.3	6.5	7.3	6.9	6.2
Trade openness, in %	43.5	44.8	50.1	54.9	62.1	60.4	60.4	68.2	77.0
Terms of trade	1.04	1.06	1.06	0.97	0.92	0.96	0.98	1.00	1.00
Self-employed, % population 15-64	15.8	15.4	13.7	12.6	12.0	11.7	11.6	11.1	10.7
Labor force participation ratio in %	68.1	67.9	67.9	68.7	69.2	70.0	70.6	71.3	72.8

Working days lost due to strikes per employee	n.a.	0.41	0.31	0.31	0.22	0.15	0.08	0.06	0.04
Workers involved in strikes, % employment	n.a.	2.7	6.5	9.6	7.0	5.6	3.8	1.6	1.6
Net density rate in %	40.4	40.3	42.6	45.7	44.9	42.6	44.9	42.8	n.a
Adjusted coverage ratio, in %	n.a.	n.a.	n.a.	n.a.	70.8	72.6	67.4	67.3	n.a
Coefficient of variation of GDP growth per capita	0.5	0.6	0.9	1.7	7.8	0.7	7.2	0.4	0.9

Notes: The sample of OECD countries includes 21 member states: Australia, Austria, Belgium, Canada, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Japan, Netherlands, New Zealand, Norway, Portugal, Spain, Sweden, Switzerland, United Kingdom and United States.
Source: OECD economic outlook, OECD patent database, OECD MSTI, OECD STAN, ILO and Golden et al. 2002.

IV. Results

1. RESULTS FOR THE BASELINE GROWTH EQUATION

Table II presents the empirical results of the standard growth equation with human capital and R&D intensity. Table A2 in the Appendix A shows the empirical results of the standard growth equation with additional determinants of growth being included separately. All equations are estimated using GMM with *t*-values that are asymptotically robust to general heteroscedasticity. In all specifications, we capture time effects by including year dummies. Furthermore, we treat all explanatory variables as predetermined and instrument them using lagged values. However, allowing for endogeneity of innovation activities in the growth equation makes relatively little difference

Table II. Panel estimates of the growth equation (baseline)

	(1)		(2)	
	Coefficient	*t*-value	Coefficient	*t*-value
Lagged GDP per capita in ppp	0.82 **	17.58	0.80 **	22.23
Investment, % GDP	0.12 **	4.03	0.14 **	4.51
Average years of schooling	−0.03	−0.43	0.01	0.29
R&D (GERD), % GDP	0.038 **	3.21		
Business enterprise R&D (BERD), % GDP			0.040 **	5.73
Period dummy 1970–1974	0.03 **	2.11		
Period dummy 1975–1979	−0.03 *	−1.88	−0.03 **	−3.34
Period dummy 1980–1984	−0.05 **	−2.62	−0.05 **	−3.61
Period dummy 1985–1989	−0.01	−0.30	−0.01	−0.77
Period dummy 1990–1994	0.00	0.10	0.00	−0.01
Period dummy 1995–1999	0.04	1.45	0.03	1.64
Constant	−0.16	−0.41	−0.26	−1.06
R^2	0.967		0.971	
# of observations (# of countries)	144 (21)		113 (21)	
*m*1 (*p*-value)	0.044		0.027	
*m*2 (*p*-value)	0.771		0.929	
Sargan (*p*-value)	0.383		0.311	

Notes: *, ** statistically significant at the 10 and 5% level, respectively. All variables are measured in logarithms. The table renders the (one-step) system GMM estimator. *t*-values are robust to heteroscedasticity. The model uses data averaged over seven five-year periods: 1965–1969, 1970–1974, 1975–1979, 1980–1984, 1985–1989, 1990–1994 and 1995–1999. For the second specification, we use data for six five-year periods. For each period, we treat right-hand variables as endogenous in all regressions and instrument them using lags from $t-2$ to $t-3$ back in the first-differenced equation and using lags from t-1 in the level equation.

to the estimated coefficients. Since all variables are measured as first (=five-year) differences in natural logarithms, the coefficients can be interpreted as short-run elasticities. Long-run elasticities can be obtained when the coefficients are divided by 1 minus the coefficient of the lagged endogenous variable. Unreported results show that the results are robust to alternative linear specifications, for instance non-log specifications. We conduct two types of diagnostic tests for the empirical models. First, we report the *p*-value of the test proposed by Arellano and Bond (1991) to detect first – and second-order serial correlation in the residuals. We find that the statistics $m1$ and $m2$ of serial autocorrelation of the residuals do not reject the specification of the error term. Second, looking at the Sargan test, we see that the *p*-values do not indicate a decisive rejection of the model's overidentifying restrictions.

Table II shows that R&D intensity is positive and highly significant. This holds for both business enterprise R&D (BERD) intensity and the ratio of gross expenditures on R&D (GERD) to GDP. The long-run elasticity of business enterprise R&D intensity with respect to GDP per capita is about 0.22 ($=0.04/(1-0.80)$ based on the second specification. This implies that a 10% increase in business enterprise R&D intensity (an estimated 0.1% increase given the average BERD intensity of 1%) will increase GDP per capita by about 2.2% in the long run. The long-run effect of GERD as a percentage of GDP is of similar magnitude. Overall, the impact of R&D intensity on GDP per capita is larger than the impact found by Bassanini et al. (2001). Lagged GDP per capita is significant at the 1% level in all regressions. The corresponding estimated values of the adjustment coefficient range are 0.10 and 0.12, implying that between 10 and 12% of the adjustment take place within five years. The investment rate is also significant at the 1% level in all regressions. This is consistent with Sala-i-Martin (1997) who finds that the level of investment in equipment is one of the strongest correlates of economic growth. However, human capital is not significantly different from zero. This stands in contrast to Bassanini and Scarpetta (2002) using similar data.

Table A1 in the Appendix A shows the estimation results for the standard growth equation with additional explanatory variables being included separately. Again, we find that R&D intensity measured as BERD as a percentage of GDP, lagged GDP per capita and the investment rate enter positively and are significant in most of the cases when additional explanatory variables are added to the regression model. Furthermore, we find that some indicators of government size are significantly negative, indicating that government size is associated with a lower long-run GDP per capita. In particular, we find that government consumption as a percentage of GDP excluding wages, social security contributions as a percentage of GDP and primary deficit as a percentage of GDP are all significantly negative at the 1% significance level.

In contrast, we do not find a significant effect of taxation on GDP per capita. Looking at innovation activities, we find that EPO biotechnology patent applications as a percentage of total EPO patents are associated with higher GDP per capita. We do not find significant effects of total EPO patent applications per population and EPO and ICT patent applications as a percentage of total EPO patents. Furthermore, we find that the volatility of growth is significantly negatively associated with GDP per capita, indicating that a low volatility leads to higher GDP growth. Furthermore, openness is positively associated with GDP per capita, but the coefficient is not significantly different from zero. Unreported results show that terms of trade, strikes, corruption, union coverage, the net union density rate, the labor force participation ratio, the self-employed rate and the NAWRU are not significantly different from zero.

2. IMPACT OF TECHNOLOGICAL SPECIALIZATION AND PATENT STRUCTURE ON ECONOMIC GROWTH

The results of the standard growth equation with additional indicators on innovation activity such as patents per capita and the high-tech export share are presented in Table III. Column 1 in Table III presents the results of the growth equation augmented with the export share of high-technology industries but excluding business enterprise R&D intensity. In specification 2, we include both the export share of high-technology industries and business enterprise R&D intensity. Model 3 is essentially the same as model 2, except for the inclusion of the share of biotechnological patents.

Specification 1 shows that the export share of high-technology industries enters the growth equation with a positive sign and is significant at the 1% level. When both R&D (BERD) intensity and the high-tech export share are included, the coefficient on the high-tech export share drops from 0.035 to 0.015. In contrast, the R&D coefficient drops only slightly to 0.03 and remains significant at the 1% level. Thus, the effect on the point estimate of technological specialization is much bigger than the effect on the point estimate of BERD intensity. This indicates that BERD intensity is more important than technological specialization in explaining economic growth. Furthermore, the standard error of both coefficients is increased such that technological specialization is no longer significantly different from zero. However, an *F*-test indicates that both technology variables are jointly significant at the 1% level. The loss of precision of the impact of technological specialization is clearly due to the complementary relation between both variables and the resulting collinearity. Indeed, a simple static fixed effect regression relating the export share of high-technology industries yields a coefficient of about 1.05. Specification 3 shows that the share of

Table III. Impact of innovation input and output indicators on growth

	(1)		(2)		(3)	
	Coefficient	*t*-value	Coefficient	*t*-value	Coefficient	*t*-value
Lagged GDP per capita in ppp	0.82 **	15.42	0.74 **	13.26	0.83 **	17.90
Investment, % GDP	0.14 **	3.72	0.15 **	3.26	0.13 **	3.95
Average years of schooling	0.08 *	1.77	0.07	1.55	0.00	–0.08
R&D (BERD) % GDP			0.030 **	2.75	0.024 **	2.75
High-tech export share	0.035 **	3.53	0.015	1.19	0.017 *	1.67
EPO Biotechnology patents, % total patents					0.020 **	2.08
Period dummy 1985–1989	0.04 **	5.24	0.04 **	5.61	0.02 **	2.97
Period dummy 1990–1994	0.04 **	3.12	0.05 **	3.84	0.03 *	1.83
Period dummy 1995–1999	0.07 **	4.98	0.09 **	5.77	0.05 **	4.42
Constant	−0.51 *	−1.68	−0.66 **	−2.07	−0.13	−0.52
R^2	0.965		0.966		0.967	
# of observations (# of countries)	83 (21)		83 (21)		83 (21)	
*m*1 (*p*-value)	0.023		0.049		0.005	
*m*2 (*p*-value)	0.587		0.556		0.839	
Sargan (*p*-value)	0.257		0.609		0.334	
F-Test R&D (BERD) %					$F(2, 20) = 9.92$;	
GDP = high-tech export share = 0					*p*-value: 0.00	

Notes: * ,** statistically significant at the 10 and 5% level, respectively. All variables are measured in logarithms. The model uses data averaged over four five-year periods: 1980–1984, 1985–1989, 1990–1994 and 1995–1999. See Table II for additional notes.

Table IV. Panel estimates of the impact of government size

	(1)		(2)		(3)	
	Coefficient	*t*-value	Coefficient	*t*-value	Coefficient	*t*-value
Lagged GDP per capita in ppp	0.86**	15.92	0.89**	18.17	0.89**	17.92
Investment, % GDP	0.11**	2.62	0.12**	2.91	0.12**	3.05
Average years of schooling	−0.02	−0.58	−0.07	−1.56	−0.08*	−1.75
R&D (BERD) % GDP	0.03**	3.00	0.04**	3.33	0.04**	3.51
Primary balance, % GDP	0.56**	2.88	0.39**	2.15	0.41**	2.39
Total government consumption, % GDP	−0.04**	−2.14	−0.10**	−2.54	−0.09*	−1.95
Total taxes, % GDP			0.06*	1.99	0.06	1.40
Social security contributions, % GDP					0.00	−0.37
Period dummy 1975–1979	−0.04**	−2.68	−0.04**	−3.04	−0.04**	−3.04
Period dummy 1980–1984	−0.05**	−2.91	−0.06**	−3.36	−0.06**	−3.09
Period dummy 1985–1989	−0.03	−1.54	−0.03*	−1.90	−0.03*	−1.66
Period dummy 1990–1994	−0.02	−0.68	−0.02	−1.07	−0.02	−0.95
Period dummy 1995–1999	0.00	0.08	−0.01	−0.27	0.00	−0.16
Constant	−0.10	−0.30	0.16	0.54	0.18	0.62
R^2	0.972		0.973			0.973
# of observations (# of countries)	94 (18)		94 (18)		94 (18)	
*m*1 (*p*-value)	0.048		0.044		0.047	
*m*2 (*p*-value)	0.743		0.712		0.719	
Sargan (*p*-value)	0.835		0.931		0.968	

Notes: * ,** statistically significant at the 10 and 5% level, respectively. The model uses data averaged over six five-year periods: 1970–1974, 1975–1979, 1980–1984, 1985–1989, 1990–1994 and 1995–1999. See Table II for additional notes.

biotechnology patents in total patents enters the growth regression with a positive sign and is significant at the 5% level (see column 3).

3. IMPACT OF THE SIZE OF GOVERNMENT BY SOURCE OF REVENUES AND EXPENDITURES

Another purpose of this study is to address the impact of the composition of government expenditure and government revenues. The inclusion of both revenue and expenditure categories in the growth equation can be justified by the fact that the size of government expenditure is limited by the need to finance such spending through taxes. In fact, an increase in government spending is often financed by an increase in taxes. We can model such a policy as a simultaneous increase in government spending and taxes. Taking into account the possible interactions between government expenditures, deficits and taxes, we re-estimate the growth equation with indicators on government expenditures and revenues. Table IV shows that both budget deficit and government consumption are significantly negative in all three specifications, regardless of the inclusion of the tax ratio or social security contributions (see Table IV). The overall tax burden and the share of social security contributions do not affect GDP per capita.

V. Conclusions

This paper re-examined the impact of policy factors on economic growth in OECD countries from a number of new perspectives. First, the analysis is more detailed than in previous studies, as we use a broad set of potential determinants of economic growth. In particular, we estimate the impact of technological specialization and R&D intensity simultaneously, which has been overlooked in previous studies. We also investigate the impact of fiscal policy on GDP per capita. We estimate the growth equation using the system GMM panel estimator as proposed by Blundell and Bond (1998). The panel estimator controls for possible endogeneity of the regressors and for the possible bias in specifications with nearly integrated regressors, as is the case for GDP per capita and R&D intensity. To assess the long-run impact of the determinants of growth, we use panel data for 21 OECD countries averaged over the period 1970–1999.

We find a large and statistically significant impact of BERD intensity on GDP per capita. The long-run elasticity of business enterprise R&D intensity with respect to GDP per capita is about 0.22. Furthermore, we find a positive and significant impact of technological specialization (measured as the high-tech export share) on GDP per capita when entering the growth equation separately. However, the impact of technological specialization decreases considerably and is no longer significant when BERD intensity is

Appendix A

Table A1. Summary statistics (pooled data)

Variable	Mean	Standard Deviation	Min	Max	Observations
Total investment, % GDP	23.3	3.7	16.3	35.6	188 (21)
Private investment, % GDP	20.6	4.3	13.1	33.1	177 (20)
Business R&D (BERD), % GDP	1.0	0.6	0.0	3.3	131 (21)
Total R&D (GERD), % GDP	154.3	79.0	16.4	427.0	167 (21)
EPO biotechnology patent applications, % total EPO patents	3.8	2.7	0.0	12.5	125 (21)
EPO ICT patent applications, % total EPO patents	20.7	10.6	0.0	56.7	125 (21)
EPO patent applications per capita	64	67	0	325	125 (21)
High-tech export share (wider definition)	16.0	10.7	1.1	51.8	104 (21)
Average years of schooling	9.8	2.1	4.4	13.4	188 (21)
Indirect taxes, % GDP	12.5	2.9	6.5	18.1	165 (20)
Total taxes , % GDP	25.8	7.3	10.7	48.0	148 (19)
Direct taxes, % GDP	13.1	5.5	2.9	30.4	152 (19)
Ratio of direct to indirect taxes	1.2	0.7	0.5	4.0	148 (19)
Social security contributions, % GDP	10.4	4.9	1.3	20.6	148 (19)
Taxes and social security contributions, % GDP	36.2	8.2	16.2	52.8	148 (19)
Employment, government, % of total employment	16.4	6.7	4.7	33.4	171 (20)
Government consumption, % GDP	18.8	4.2	9.0	30.7	165 (19)
Government consumption, excluding wages, % GDP	7.2	2.3	2.4	13.2	171 (20)
Government consumption, wages, % GDP	11.4	2.8	5.5	19.7	171 (20)
Subsidies, % GDP	1.8	1.0	0.2	5.2	169 (20)
Gross government debt % GDP	56.6	27.8	10.3	140.6	134 (20)
Primary balance (deficit), % GDP	0.4	2.8	−6.8	10.9	147 (20)
Investment government , % GDP	3.5	1.0	1.2	5.8	159 (19)
Corruption perception index	7.7	1.4	4.2	9.9	104 (21)

Structural unemployment rate, in %	5.6	2.9	0.9	14.7	156 (21)
Openness, in %	58.0	29.4	9.1	177.9	187 (21)
Terms of trade	1.00	0.12	0.61	1. 42	187 (21)
Self-employed, % population 15–64	12.6	6.3	4.6	39.8	179 (21)
Labor Force, participation ratio in %	69.6	7.1	56.3	86.7	185 (21)
Working days lost due to strikes per employee	0.2	0.2	0.0	1.1	142 (20)
Workers involved in strikes, % employment	5.1	8.7	0.0	64.5	146 (21)
Net density rate in %	42.9	17.2	9.9	83.0	115 (16)
Coefficient of variation of GDP growth per capita	2.3	9.4	0.0	91.4	187 (21)
Adjusted coverage ratio, in %	69.1	25.7	16.0	99.0	53 (16)

Sources: See text.

Table A2. Determinants of economic growth evaluated separately

	Add. right-hand var.	GDP per cap.	Investment ratio	BERD, % GDP	Av. yrs. schooling	Constant	*m*1, *p*-value	*m*2, *p*-value	Sargent, *p*- value	# of, obs.	# of countries
EPO patents	−0.01	0.83	0.11	0.05	0.03	−0.10	0.01	0.82	0.44	98	21
per population	−1.78	16.58	3.12	4.52	0.82	−3.2					
EPO ICT patents,	0.01	0.84	0.11	0.03	0.00	−1.8	0.01	0.71	0.33	97	21
% total patents	0.52	15.89	3.21	4.06	−1.3	−6.5					
EPO biotechnology	0.02	0.85	0.11	0.03	−0.3	0.04	0.01	0.77	0.42	94	21
pat., % tot. patents	2.02	15.68	3.54	4.63	−7.1	0.13					
High-tech export	0.01	0.74	0.16	0.03	0.08	−6.1	0.03	0.36	0.69	83	21
share (narrow def.)	0.91	12.41	3.20	2.52	1.74	−9.1					
Total taxes,	0.03	0.84	0.15	0.04	−0.4	0.07	0.03	0.68	0.65	99	19
% GDP	1.48	16.87	4.12	5.21	−9.6	0.22					
Indirect taxes,	0.01	0.86	0.16	0.04	−0.3	0.11	0.01	0.70	0.49	107	20
% GDP	0.79	23.88	4.68	6.43	−9.3	0.40					
Direct taxes,	0.02	0.85	0.15	0.03	−0.3	0.05	0.03	0.93	0.60	101	19
% GDP	1.54	16.75	4.02	4.63	−8.1	0.18					
Ratio direct taxes	0.01	0.84	0.14	0.03	−0.2	−0.5	0.02	0.67	0.60	99	19
to indirect taxes	0.75	16.46	3.54	4.20	−4.6	−1.8					
Social security	−0.2	0.86	0.16	0.05	−0.6	0.15	0.01	0.64	0.67	99	19
contribut. % GDP	−4.6	18.55	3.33	5.34	−7.1	0.52					
Taxes/social security	−0.1	0.84	0.14	0.04	−0.1	−0.7	0.01	0.68	0.63	99	19
contribut. % GDP	−4.5	17.11	3.30	4.39	−3.1	−2.4					
Employ. government,	0.01	0.86	0.16	0.03	−0.2	0.08	0.02	0.99	0.46	108	20
% employment	0.75	23.99	4.03	6.09	−7.7	0.30					
Government con-	−0.3	0.88	0.12	0.03	−0.2	−0.2	0.01	0.90	0.51	105	19
sumption, % GDP	−4.4	23.48	3.18	3.89	−5.0	−0.8					

Gov. consumption,	−0.3	0.87	0.14	0.04	−0.2	−0.1	0.01	0.92	0.50	109	20
excl. wages, % GDP	−9.0	26.56	3.67	7.02	−6.6	−0.6					
Government cons.,	0.00	0.86	0.15	0.04	−0.2	0.05	0.02	0.95	0.47	109	20
wages, % DP	0.25	24.45	4.25	5.73	−7.0	0.20					
Subsidies, % GDP	0.00	0.86	0.14	0.03	−0.2	0.04	0.01	0.93	0.46	109	20
	0.42	25.02	5.04	5.85	−6.5	0.16					
Gross government	0.00	0.84	0.14	0.04	0.00	−0.8	0.00	0.79	0.68	95	20
debt, % GDP	−1.8	13.46	3.42	4.29	0.03	−2.3					
Primary government	0.55	0.84	0.13	0.04	−0.3	−0.3	0.04	0.66	0.55	104	20
balance, % GDP	3.20	16.13	3.69	5.81	−0.2	−0.9					
Openness in %	0.01	0.85	0.15	0.03	−0.1	−0.2	0.01	0.95	0.42	113	21
	1.54	23.35	5.55	5.68	−4.3	−0.9					
Terms of trade	−0.3	0.84	0.13	0.03	−0.1	−1.1	0.02	0.85	3.99	113	21
	−5.8	23.17	4.87	5.58	−1.6	−4.4					
Volatility of growth	−0.2	0.86	0.12	0.03	−0.1	−0.7	0.03	0.43	0.47	113	21
	−8.7	32.24	5.05	4.18	−3.6	−4.3					

Source: MSTI and OECD STAN.

added. This indicates that business R&D is more important than technological specialization in explaining economic growth. Turning to patent applications, we find ambiguous results. The data do not suggest that higher EPO patents per capita increase GDP per capita. However, we find a positive and significant effect of the share of biotechnology patents on GDP per capita. Turning to the remaining explanatory variables, we find that budget deficit, government consumption and the volatility of growth are significantly negatively related to GDP per capita. We do not find a significant relation between taxation and the mix of taxes (i.e., ratio of direct to indirect taxes) and GDP per capita.

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