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Potential Output Growth in Several Industrialised Countries: a Comparison*

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Abstract

In this paper, we present international comparisons of potential output growth among several economies —Canada, the euro area, France, Germany, Italy, Japan, the Netherlands, the United Kingdom, and the United States— for the period 1991-2004, for which we construct consistent and homogenous capital stock series. The main estimates rely on a structural approach where output of the whole economy is described by a Cobb-Douglas function and Total Factor Productivity (TFP) is estimated allowing for possible breaks in the deterministic trend. The results confirm that over the considered period the potential GDP growth has been faster in the United States than in other studied countries, reflecting a combination of higher labour contribution and faster TFP growth. Overall, this paper might help to shed some light on cross-country differences in economic performance over the recent period.

Keywords: potential growth, production function, total factor productivity, age of equipments.
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1 Introduction

For a central banker, potential growth estimates are of major interest for several reasons. First, they provide a quantitative assessment of inflationary pressures on product and labour markets at the agregate level. Measurements of the output gap, defined as the difference between actual and potential output, may be used for such an assessment. Second, for monitoring purposes, quarterly measurements of output gap can be drawn upon as a composite and simple indicator of the economy's position in the business cycle. Finally, potential growth estimates may also be used for macroeconomic forecasts. For all these reasons, several research projects have been carried out in central banks on potential growth estimates.[1] Recent developments in Europe have also stimulated fresh interest in potential output growth measures, particularly those based on structural approaches. In fact, international comparisons suggest that potential growth in Europe remained below other areas or countries over the past two decades, especially as compared to the United States. From this point of view, the breakdown of potential growth between labour and capital contributions is a simple but accurate way to ascertain cross-country differences in growth performance.

In this paper, we present estimates of potential growth for several economies, namely: Canada, the euro area, France, Germany, Italy, Japan, the Netherlands, the United Kingdom, and the United States. Our main findings rely on a structural approach. Following Baghli, Cahn, and Villetelle (2006), we use Solow's neoclassical model and the so-called production function framework. In the Solow's model, economic growth is a function of standard factors of production (labour and capital stock) and an unobserved technological change. More precisely, this approach consists in choosing a technical relationship supposed to represent the productive capacity of the economy, calibrating key parameters on the basis of the relevant data, determining the level of potential output by means of this calibrated function and modelling the resulting Solow residual in order to explain its developments using econometric techniques. Among them, we systematically tested the existence of trend breaks in the technological change, using an econometric package implemented by Le Bihan (2004) based on the work of Bai and Perron (1998, 2003).[2] Regarding the collection of the data, contrary to Baghli et al. (2006) where only the business sector is modelled, we consider the productive capacity of the economy as a whole. This is well adapted to cross-country comparisons given that the definition of business sector is often different between countries. Moreover, this enabled us to compute harmonized capital stock data based on the permanent inventory technique using National Accounts data as an input.

In this paper, we consider medium-term developments where the contributors to potential growth are the standard inputs of the production function (capital stock and labour), as well as the determinants of total factor productivity. The main results of our research are as follows: there is a clear distinction between European countries and Japan on the one hand and the United States on the other hand with

[1] See, for instance, Banque de France (2002) and de Bandt, Hermann, and Parigi (2006).

[2] We consider this package as convenient in order to identify possible breaks in the trend component. Going further, one would investigate all the variables supposed to be directly affected by TFP breaks in order to test the robustness of the occurring dates. Nevertheless, we did not consider these econometric extensions as they were beyond the scope of this paper and we postponed them for further research.

regard to the sources of economic growth over the last fifteen years. First, our findings suggest that differences in the growth of labour input, rather than capital input, have played a crucial role in terms of explaining the shortfall in growth in Europe (except for the Netherlands) and Japan as compared with the United States and Canada. As for the Netherlands, the labour contribution appears to be higher than other European economies, owing to a significant increase in the participation rate between 1991 and 2000. As for Canada and the United States, more favourable demographic developments account primarily for the higher labour contribution. Second, divergence in potential output growth between the United States and European countries are also partly explained by total factor productivity (TFP) developments, as its contribution in the US largely exceeds those in Europe -except for the United Kingdom. This seems to coincide with more important R&D efforts in the US. As far as the US economy is concerned, our results suggest that total factor productivity growth accelerated in the mid-1990s. This specific feature explains the other side of the US higher economic achievements over the period. Jorgenson (2005) insists on the crucial role of IT investment in the resurgence of economic growth in the United States during the 1990s. Our paper suggests that this development is mainly reflected by the acceleration in TFP growth, more than capital deepening.

All in all, these findings might help to define possible directions for structural reforms in Europe. They are also consistent with the views expressed in the Lisbon "strategy for growth and jobs" on the need for specific economic policies in Europe, especially with respect to immigration, natality or innovation.[3]

The remainder of this paper is organized as follows. In the next section, we describe the theoretical specifications underlying our study. Data are briefly described in section 3. Section 4 presents results and estimates of potential growth, which are discussed and compared in Section 5. Section 6 outlines our conclusions.

2 Theoretical framework

In this section, we present the main features of our production function approach. We first set up the underlying specification and functional form of the technology and inputs of production. Then we derive the expression for medium-term potential growth.

We consider that economy-wide production technology can be represented by a Cobb-Douglas-like production function with a constant return to scale on labour and capital. Analytically, we assume that the production function can be expressed as $Y_t = \sigma e^{\gamma t} \tilde{K}_t^{1-\alpha} (N_t H_t)^{\alpha}, \;\; 0 < \alpha < 1$, where Y_t is the actual economy's output taken as the gross domestic product (GDP), $\tilde{K}_t$ is the stock of available productive capital, N_t is total employment, and H_t stands for per capita hours worked. Parameters α, γ, and σ represent, respectively, the wage share, the growth rate of a purely exogenous deterministic technical change, and a scale factor.

The stock of available productive capital is derived primarily from the accumulation of investment

[3]See European Commission (2006) for instance.

flows. Moreover, we assume that, thanks to capital embodied technological progress, one unit of investment shows at each period a productivity gain amounting to $1+\epsilon$, with $\epsilon \geq 0$. The case where $\epsilon = 0$ would correspond to the situation where quality improvements of investment are fully reflected in the price index.[4] Finally, the capacity utilisation rate CUR_t determines the availability of productive capital stock for the economy. As a result, available productive capital is tied up with measured capital stock K_t and age of capital equipment τ_t according to:[5]

$$\tilde{K}_t = CUR_t e^{\epsilon(t-\tau_t)} K_t. \tag{1}$$

Let us denote g_t the log of Total Factor Productivity (TFP).[6] The two-step approach we adopt consists in, first, setting the wage share at its average level over the sample to define the TFP as the Solow residual of the neoclassical model:[7]

$$g_t = y_t - (1-\alpha)k_t - \alpha(n_t + h_t). \tag{2}$$

From the above mentioned definitions, we derive the following theoretical definition of the TFP:

$$g_t = \ln(\sigma) + \gamma t + (1-\alpha)(cur_t + \epsilon(t-\tau_t)). \tag{3}$$

Finally, we derive from this theoretical framework the empirical reduced form for TFP that will serve four our estimations. The impacts of the determinants of TFP, around a time trend, are estimated by using the following specification:[8]

$$g_t = \gamma_0 + \gamma_1 g_{t-1} + \gamma_2(cur_t - \overline{cur}) + \gamma_3(\tau_t - \overline{\tau}) + \gamma_4 t + \gamma_5 t_1 + \gamma_6 t_2 + \varepsilon_t, \tag{4}$$

where $cur_t - \overline{cur}$ is the gap between the capacity utilisation rate in logs and its long-term average, $\tau_t - \overline{\tau}$ is the gap between the age of the stock of capital equipment goods in absolute terms and its long-term average, ε_t is an error term.[9] Compared to the theoretical form, we introduce an autoregressive term to better capture inertia in the changes in TFP. The deterministic trend t is considered by assuming that the technical change is exogenous so that TFP grows at a piecewise constant rate in the long run. Both of the terms t_1 and t_2 ($t_i = \mathbb{I}(t > T_i)(t - T_i)$) are introduced in order to capture possible country-specific breaks in the rate of change at dates T_1 and/or T_2.[10] γ_2 measures the cyclical component of TFP. We expect TFP to grow as domestic production capacities are used more intensively than usual, so the parameter γ_2 should be positive. Moreover, an ageing stock of capital as compared to its average age, could impact negatively on TFP in such a way that the parameter γ_3 should be negative.

[4] This might be the case for the US where price index are corrected for quality bias.
[5] See Appendix A for further details.
[6] In the following, small case letters denote logarithms.
[7] See Section 3 for the calibrated values.
[8] For forecasting purposes, one would prefer to use a stochastic instead of a determinstic trend process in the TFP equation; in the former case, measurement errors could be less systematic than in the latter case. Nevertheless, after testing model TS versus model DS, we decided to choose TS specification that better fits the data.
[9] This specification differs from Baghli, Cahn, and Villetelle (2006) as regards the age of capital stock, namely in absolute terms rather than in log, as we take into account capital embodied technical change —see the definition of available productive capital stock in equation (1).
[10] The indicator function $\mathbb{I}(\cdot)$ is defined as $\mathbb{I}(A) = 1$ if A is true and $\mathbb{I}(A) = 0$ otherwise.

Ascertaining the medium-term trend in TFP requires two assumptions. First, medium-term TFP is assumed to fluctuate around a time trend and we assume that these fluctuations are negligible at the first order.[11] Second, the capacity utilisation rate is assumed to stand at its average level so that $cur_t = \overline{cur}$. Accordingly, we obtain the following equation which defines medium-term TFP:

$$\begin{aligned} \tilde{g}_t \quad = \quad & \tfrac{\gamma_0 - \rho + \gamma_4 + \gamma_5 (1-T_1)\mathbb{I}(t>T_1-1) + \gamma_6 (1-T_2)\mathbb{I}(t>T_2-1)}{1-\gamma_1} \\ & + \tfrac{\gamma_3}{1-\gamma_1}(\tau_{t+1} - \overline{\tau}) + \left(\tfrac{\gamma_4 + \gamma_5 \mathbb{I}(t>T_1-1) + \gamma_6 \mathbb{I}(t>T_2-1)}{1-\gamma_1} \right) t. \end{aligned} \tag{5}$$

In the medium run, TFP fluctuates around a trend that can be divided into a measure of capital embodied technical progress which includes ageing effects, given by the first term of the second line of equation (5), and the exogenous deterministic component, represented by the last term of this equation. We assume that inflexions due to capital stock ageing or replacement sluggishly disappear at a slower pace than those caused by changes in the CUR. These inflexions impact on TFP and last over the medium term. However, the effect of capital ageing is assumed to vanish in the long run.[12]

After computing medium-term TFP, we have to estimate potential labour input. As we consider labour input in hours, we first smooth per capita hours worked, h_t. The potential employment, N_t^*, in the economy is defined by:

$$N_t^* = \Omega_t^* r_t^* (1 - u_t^*), \tag{6}$$

where Ω_t^*, r_t^*, and u_t^* represent respectively the filtered working age population, the filtered medium-term participation rate and the non-accelerating inflation rate of unemployment (NAIRU).[13] As regards levels, medium term potential GDP is given by:

$$Y_t^* = K_t^{1-\alpha} (N_t^* h_t^*)^{\alpha} e^{\tilde{g}_t}. \tag{7}$$

3 Data

This section provides a brief overview of the data used for this study.[14] Labour market series are mostly taken from OECD (2005), except for hours worked by employee which are taken from the University of Groningen (2005) database. Finally, shares of labour input are taken from the study of Lequiller and Sylvain (2006) as an approximation of the constant parameter α. Table 1 presents the calibrated values chosen in this paper.

[11] See Appendix A for detailed calculations.

[12] Drawing a parallel with the underlying structural parameters and functional specification, the following considerations apply. The coefficient related to embodied capital improvement would be $\epsilon \equiv 1/(1-\alpha).(-\gamma_3)/(1-\gamma_1)$, with $\gamma_3 < 0$. In the same way, the growth rate of the pure exogenous technical change is given by $\gamma \equiv (\gamma_4 + \gamma_5 \mathbb{I}(t > T_1 - 1) + \gamma_6 \mathbb{I}(t > T_2 - 1))/(1-\gamma_1) + \gamma_3/(1-\gamma_1)$. Nevertheless, since we take the age of material and equipment capital stock as proxy for τ_t , and since we use this variable to capture medium term cycle effect, identification problems concerning the breakdown of technical progress arise. Moreover, if no significant contribution of capital stock ageing is found through the estimation, as it is actually the case for UK and US economies, the same caveat applies. As a result, the distinction between the contribution of embodied capital improvement and the pure technical change is not clearly identified, as the deterministic trend in the TFP equation captures both terms.

[13] In order to derive smoothed components, the HP filter has been always used, with standard value for the smoothing parameter ($\lambda = 1600$, since we are dealing with quarterly data, except for the hours worked for which $\lambda = 20000$.) We choose a non-standard value for the smoothing parameter related to hours worked in order to eliminate any cyclical evolution of filtered data. As regards the NAIRU, we use as a proxy the series taken from the OECD (2005) database. These series are based on Kalman filter estimates of reduced-form Phillips curve equations, according to Richardson et al. (2000).

[14] A more detailed description is given in appendix B of the working paper version (Cahn and Saint-Guilhem, 2007).

Table 1: Calibrated value for the parameter α

Country	α
Canada	0.637
Euro area	0.645
France	0.654
Germany	0.649
Germany-WR	0.649
Italy	0.629
Japan	0.689
Netherlands	0.647
United Kingdom	0.655
United States	0.627

Source : Lequiller and Sylvain (2006), Whole economy excluding administrations, education, and health and social services; Self-employed compensations : average compensation of the related branch; FISIM taken as intermediate consumption.

Such an approximation is consistent with the assumption of a Cobb-Douglas like production function and constant returns to scale. To estimate potential growth, our starting point is mainly the datasets from the national accounts, as regards gross domestic product (GDP) and investment by product — "Machinery, Equipment, and Software" (MES) and "Structures including Housing" (SH)— for the whole economy. In order to get longer series on investment, we first backcasted all the national accounts series back to 1960 using the OECD (2005) database, except for the US for which BEA data are available back to 1950. Second, we used the long historical series on investment at an annual frequency constructed by Maddison (2003) for France, Germany, Japan, the Netherlands, United Kingdom, and the United States. We paid particular attention to the euro area and Germany data. As for the euro area, we chose to use the official data from Eurostat for the 1995–2004 period. We backcasted the series with OECD (2005) data back to 1963. As for the investment series, we used an aggregate made up by France, Germany, Italy, and the Netherlands, in order to give a breakdown by capital goods. With respect to Germany, we computed two different capital stock series based on two different assumptions regarding investment. In the former, we consider that Eastern and Western German investment grow at the same rate before 1991 —for the economy we call "Germany" in the remaining of this paper,— while in the other implies a discontinuity in 1991 since we assume that Eastern German investment is unusable —forming the so-called "Germany-WR" for West Retropolated. These two extreme cases might define the boundaries of the true path of investment for Germany as a whole.

For the whole panel of economies, we computed consistent data for real capital stocks and age of capital according to a methodology developed by Villetelle (2004), based on the permanent inventory method (PIM). Our methodology, which is quite easy to implement, requires data on gross fixed capital formation by product as the only input. Contrary to the PIM that requires long-time series, our method is meant to compute capital stock series from relatively short investment series. This was adapted to our study since we did not have at our disposal long investment series for the euro area, Canada and

Italy.[15] We used the same depreciation rates as for France for the whole panel, namely, 2.4 % and 0.4 % per quarter for MES and SH capital stock, respectively.

We particularly investigated our assessment of capital stock for the US economy. Indeed, we noticed that our data could be deemed to underestimate capital stock growth in the 1995-2000 period for the US economy compared to other studies.[16]

4 Results

4.1 Estimates for the TFP

We test the existence of trend breaks in the TFP model according to equation (4), following Le Bihan (2004) and Bai and Perron (1998, 2003). More precisely, the methodology consists in testing the stability of the coefficients on the deterministic trend in equation (4) following a two-step approach. First for any date T_1 of the sample of length T, we calculate the following usual Wald statistic :

$$F(T_1/T) = \frac{T - 2q - p}{T} \hat{\delta}' R' [R' \hat{V} R']^{-1} R \hat{\delta}$$

where $\hat{\delta}$ is the vector of estimated parameters, R the matrix of restrictions on the parameters such as $R\delta = 0$, $\hat{V}$ the covariance matrix, q is the number of restrictions, p the number of stable parameters. This F statistic follows the χ^2 distribution under usual assumptions. To calculate $\hat{V}$, we used a standard non-parametric correction for the residual autocorrelation and heteroscedasticity based on the studies of Newey and West (1987).[17]

In a second step, we choose the date that maximize the F statistics and we compute our final test statistic in the following way:

$$SupF = \max_{T_1 \in [T_{min}, T_{max}]} F(T_1/T),$$

where T_{min} and T_{max} define the range for candidate break dates excluding those too close to the start and end of the sample, *i.e.* by less than 16 quarters to avoid short term business cycle peak and trough effects.

Finally, we assess the statistical significance of the break using a non standard distribution table taken from Bai and Perron (1998). Critical values are higher than those required for the usual χ^2 distribution which leads to reject less often the assumption of stability as compared to the usual tables.

[15]See appendix A for further details on technical considerations.

[16]see Oliner and Sichel (2002) and Jorgenson and Vu (2005). We discuss this matter more deeply in the working paper version (see Cahn and Saint-Guilhem, 2007, Appendix B) and give a possible explanation for these differences in the magnitude of capital stock deepening in the 1995-2000 period. Different definitions of productive capital stock may explain this phenomenon. Indeed we consider the whole economy, including public sector and housing, as being the productive sector, contrary to conventional approaches that focus on business sector excluding housing. For the sake of comparison, we corrected our data of this sector effect and found that our capital stock growth appears to be higher than the BEA's figure, due to a composition effect on depreciation rates.

[17]As regards residual autocorrelations, we tested the presence of autocorrelation using Breush-Godfrey tests which are more appropriate than Durbin Watson statistics due to the presence of the lagged dependant variable in our estimates. Generally speaking, we found some autocorrelation at order greater than one, which was expected given that the model does not include lagged variables others that TFP with one lag. However we stick to our initial specification, since adding lags would compromise the ease of computing potential TFP.

We applied this procedure sequentially for one or two breaks. To do so we first test one break against zero. If the stability assumption is rejected, we then test two breaks against one, and finally select the most relevant specification.

One of our main concerns as regards the test method was to choose between two approaches. One possible approach would be to test the existence of breaks in a simple deterministic trend equation. But since the residuals of such a regression are considered to be stationary, there is no particular trade-off with our approach consisting in testing the existence of a trend break in the structural model. Yet it might be a problem to estimate a trend break in a model including an autoregressive component. Theoretically speaking, it is difficult to distinguish significantly the trend break from the potentially large effects of a persistent autoregressive process.[18] However, given the lack of any definitive and consensual view on this matter, we decided to perform tests in the structural model. Table 2 shows our results for break tests. We simultaneously tested the stability of the model by iterating on the initial estimation date, with the end date set in 2004q4. Consequently, we finally chose different starting estimation dates for each country, and selected the sample showing the best stability properties.

Table 2: Period of estimation and significant TFP break

Country	Start date	Break date	Test-stat. SupF
Canada	1982q4	1989q4(+)	25.24***
Euro area[a]	1975q4	1995q1(-)	22.20***
France[b]	1965q1	1983q4(-)	14.76***
Germany	1960q2	1976q4(-)	13.93***
Germany-WR	1960q2	1977q1(-)	12.93***
Italy	1961q3	1973q3(-),1997q2(-)	60.00***
Japan	1970q2	1978q3(-)	7.88*
Netherlands	1969q1	1975q4(-)	25.35***
United Kingdom[c]	1960q2	1968q1(-)	11.54**
United States[c]	1961q1	1972q2(-),1995q4(+)	22.02***

Note: In parentheses are presented the sign of trend break. In the case of the test one break versus none, the critical values for SupF are 7.63, 9.31, and 12.69 for respectively 10%(*), 5%(**), and 1%(***) significant value. In the case of two breaks versus none, these critical values are 6.93, 7.92, and 10.14 for respectively 10%(*), 5%(**), and 1%(***) significant value.

[a] Age elasticity has been calibrated to -0.005106329 according to the mean value for France, Germany, Italy, and the Netherlands.

[b] Data corrected of 1968 impact on TFP.

[c] For the U.K. and the U.S., age of capital stock has been disregarded as a non significant variable.

Generally speaking, the tests were all highly significant, but to a lesser extent for Japan and United Kingdom. For Italy and the US, the tests showed high significance with two trend breaks instead of one. For the whole panel, we found out a negative trend break in the TFP occurring roughly in the middle of the sample. For Germany, Italy, Japan, the Netherlands, and the United States, this negative break happened in the mid-1970s, and may be caused by the oil shock.[19] As for Italy, a second negative break

[18] This issue was expertly discussed by Stock (2004).

[19] Regarding the impact of oil shock on TFP, Bruno and Sachs (1985) find that the rise in raw material prices acts as a negative shock on Hicks-neutral technological progress. Moreover, the oil shock was also associated with a slowdown

occurred in 1997q2, which may be viewed as the lasting effect of the 1993 recession and the 1992 monetary crisis. As for United Kingdom, the negative break took place quite early in 1968q1, though it is less significant than in other economies. In France, the negative break occurs later than expected as regards the oil shock. However, we do capture in our tests a break during the mid-70's, but the test statistic is smaller than the one associated with 1983, which could reflect the predominance over the sample of the monetary crisis that took place at this time. For the euro area, the negative break happened in the mid-1990s. Obviously, this result is not consistent with what we find for the four economies composing the main part of the euro area. But we preferred to start our estimates for the euro area sufficiently late (in 1975q4), because of better properties in terms of stability, even though the break appears quite late. Two economies appear to show significant positive trend breaks, namely, Canada in 1989q4 and the United States in 1995q4. As for the former, the break date corresponds roughly to the end of the severe recession in the late 1980s and early 1990s, and the beginning of the recovery. This is normal since we start the estimate in 1982q4, because of better statistical properties. As for the US economy, the positive trend break in 1995q4 (+0.6 %) is consistent with several results from the literature.[20]

Estimation by ordinary least squares (OLS) of the TFP parameters of regression (4) are presented in Table 3 for the panel of economies. Most coefficients are significant. However, we found that the

Table 3: Estimation results

Country	γ_0 $const.$	γ_1 g_{t-1}	γ_2 $cur_t - \overline{cur}$	γ_3 $\tau_t - \overline{\tau}$	γ_4 t	γ_5 t_1	γ_6 t_2	N	R^2
Canada	−2.82	0.62	0.15	−7.1E-3	−0.9E-3	1.4E-3	–	89	.993
	(−6.73)	(10.97)	(5.94)	(−3.51)	(−5.21)	(6.88)			
Euro area[a]	−2.56	0.67	0.07	−5.1E-3	1.1E-3	−0.5E-3	–	117	.998
	(−4.57)	(9.48)	(2.99)	–	(4.48)	(−4.47)			
France	−2.28	0.72	0.08	−7.8E-3	1.9E-3	−1.0E-3	–	160	.999
	(−5.08)	(13.26)	(4.08)	(−4.36)	(4.84)	(−4.69)			
Germany	−3.11	0.63	0.11	−2.4E-3	2.9E-3	−1.7E-3	–	179	.998
	(−6.39)	(10.97)	(4.57)	(−2.41)	(6.21)	(−6.13)			
Germany-WR	−3.17	0.62	0.12	−1.9E-3	2.9E-3	−1.8E-3	–	179	.998
	(−6.53)	(10.73)	(4.90)	(−2.19)	(6.36)	(−6.30)			
Italy	−3.89	0.53	0.15	−5.5E-3	4.1E-3	−2.3E-3	−2.1E-3	174	.998
	(−7.67)	(8.51)	(5.70)	(−2.79)	(7.43)	(−7.03)	(−7.22)		
Japan	−1.36	0.71	0.06	−6.0E-3	1.6E-3	−0.4E-3	–	139	.995
	(−4.85)	(12.07)	(3.90)	(−3.91)	(4.40)	(−2.74)			
Netherlands	−3.81	0.53	0.22	−4.7E-3	5.0E-3	−3.8E-3	–	144	.993
	(−6.94)	(7.78)	(5.07)	(−3.47)	(6.29)	(−5.95)			
United Kingdom	−2.42	0.72	0.04	–	1.6E-3	−0.6E-3	–	179	.998
	(−5.35)	(13.50)	(2.20)		(5.28)	(−4.08)			
United States	−2.80	0.64	0.08	–	1.6E-3	−0.7E-3	0.6E-3	176	.998
	(−5.63)	(10.10)	(4.11)		(5.10)	(−4.31)	(4.58)		

Note: For estimation start date, see Table 2. Estimations end in 2004q4. t-stat values are given in parentheses and are robust to residual autocorrelation and heteroscedasticity following Newey and West (1987)'s procedure.
[a] Age elasticity has been calibrated to −0.005106329 according to the mean value for France, Germany, Italy, and the Netherlands.

in business investment, implying an increase in the age of capital equipment, which in turn affects negatively total factor productivity. Finally, this is consistent with sectoral anaysis and the possibility that TFP might accelerate once the effects of the shock fade out (Nordhaus, 2004).

[20]See for instance Oliner and Sichel (2002); Belorgey et al. (2004).

coefficient related to age of MES capital stock was not significantly different from zero for the UK and the US; hence we omitted this variable for these two countries in our estimates. This can be due, especially for the US, to better properties of quality adjusted investment deflators, as discussed in section 2. The signs of estimated parameters are consistent with our expectations: coefficients are positive for the trend and the capacity utilisation rate, negative for the age gap. With regard to the estimation of parameter related to the age of capital, France is the only country for which we are aware of a comparable assessment in the related literature. In Baghli et al. (2006) and Cette and Szpiro (1989), a one year younger MES stock leads to an increase of the TFP by respectively +6.4 % and +3.6 %, against +3.1 % in our study when considering age in years instead of quarters as presented in Table 3.

4.2 Medium term potential growth

Table 4 shows the different contributions to potential growth in the medium term over the 1991-2004 period.[21] In the medium term, potential growth breaks down between four components: growth in capital stock, growth in labour input (hours worked), TFP growth and changes in the age of MES equipment. Over the period 1991-2004,the average annual growth rate of potential output ranges between 1.3 (Italy) and 3.2 (United States). The main contributors to potential growth are capital stock and TFP. The contribution of capital stock lies between 0.8 (Italy) and 1.1 (Canada). The contribution of TFP ranges between 0.5 (Canada) and 1.5 (Japan). A point worth mentioning is that, when Canada and Italy are stripped out, the panel shows a rather stable contribution of TFP growth, between 0.9 and 1.5. On the contrary, there are substantial differences within the panel with respect to the contribution of labour. For some economies, labour has a higher contribution to medium-term growth (Canada, the Netherlands and the United States) whereas for the rest of the panel labour input has hardly contributed, or even negatively, to potential growth (Germany and Japan.) Unsurprisingly, the economies with the highest medium-term potential growth are also those with the highest labour contribution. Finally, the contribution of age appears to be very small or even negative, as for France and Japan. . For the euro area as a whole, our results show a relatively robust potential growth (2.2% over 1991-2004), especially supported by solid contributions of TFP and capital, whereas the contribution of labour remained marginal, as for France and Germany. The results for the euro area as a whole appear to be consistent with the aggregation of France, Italy, Germany and the Netherlands (which represent about 73% of the euro area), although a simple weighted average of these four countries would lead to a slightly slower potential growth that measured for the euro area (2.0% against 2.2%). This can be attributed to the fact that among euro area countries not included in the panel are those - such as Ireland, Spain, Greece, Austria - which have experienced the fastest growth rates over 1991-2004, whereas euro area countries included in the panel, which are also the largest, have experienced relatively slower growth. All in all, the results would suggest that euro area countries not included in the panel contributed to increase euro area potential growth, especially through labour and capital accumulation, by roughly 0.2

[21] We present in Appendix B paths of the medium term potential growth in Figure 3.

Table 4: Sources of medium term potential growth

Economy	Growth	Capital	Labour	TFP	Age
	Period 1991–1995				
		Contributions			
Economy	Growth	Capital	Labour	TFP	Age
Canada	2.1	1.1	0.4	0.5	0.1
Euro area	2.3	0.9	0.0	1.3	0.1
France	1.8	1.0	0.0	1.3	-0.5
Germany	2.3	0.9	0.1	1.3	0.0
Germany-WR	2.5	1.1	0.1	1.2	0.0
Italy	1.4	0.8	-0.7	1.5	-0.2
Japan	2.3	1.3	-0.1	1.5	-0.3
Netherlands	2.7	0.8	1.0	1.0	-0.1
United Kingdom	1.9	0.9	-0.4	1.4	-
United States	2.7	0.9	0.9	1.0	-
	Period 1995–2000				
		Contributions			
Economy	Growth	Capital	Labour	TFP	Age
Canada	3.2	1.1	1.1	0.5	0.6
Euro area	2.0	0.8	0.3	0.8	0.1
France	2.2	0.8	0.4	1.3	-0.3
Germany	1.8	0.8	-0.3	1.3	0.0
Germany-WR	1.9	1.0	-0.3	1.2	0.0
Italy	1.4	0.7	0.1	0.6	0.0
Japan	1.3	0.9	-0.4	1.5	-0.7
Netherlands	3.0	0.9	1.1	1.0	0.0
United Kingdom	2.8	0.9	0.4	1.4	-
United States	3.6	1.1	1.0	1.5	-
	Period 2000–2004				
		Contributions			
Economy	Growth	Capital	Labour	TFP	Age
Canada	3.0	1.2	0.9	0.5	0.4
Euro area	2.2	0.9	0.4	0.7	0.2
France	2.0	0.9	-0.2	1.3	0.1
Germany	2.0	0.7	-0.1	1.3	0.0
Germany-WR	1.9	0.8	-0.1	1.2	0.0
Italy	1.1	0.8	0.5	-0.3	0.1
Japan	0.6	0.7	-0.6	1.5	-0.9
Netherlands	2.6	0.8	0.8	1.0	0.0
United Kingdom	2.7	1.0	0.3	1.4	-
United States	3.2	1.2	0.4	1.6	-
	Period 1991–2004				
		Contributions			
Economy	Growth	Capital	Labour	TFP	Age
Canada	2.8	1.1	0.8	0.5	0.3
Euro area	2.2	0.9	0.2	0.9	0.1
France	2.0	0.9	0.1	1.3	-0.3
Germany	2.1	0.8	-0.1	1.3	0.0
Germany-WR	2.1	1.0	-0.1	1.2	0.0
Italy	1.3	0.8	0.0	0.6	0.0
Japan	1.5	1.0	-0.4	1.5	-0.6
Netherlands	2.8	0.8	1.0	1.0	0.0
United Kingdom	2.5	0.9	0.1	1.4	-
United States	3.2	1.0	0.8	1.4	-

pp on average over 1991-2004 (based on a simple weighted average calculation of the residual potential growth). However, by contrast with capital and labour accumulation, one could put forward the key role of Germany and France concerning TFP growth in the euro area: the contribution of TFP amounted to 1.3 pp over 1991-2004, 0.4 pp higher than for the euro area as a whole.

Table 4 also shows the changes in medium-term potential growth over the 1991-2004 period. Some economies, namely Canada and United States, witnessed a sharp acceleration in medium-term potential growth in the mid 1990s, by roughly one percentage point. The annual growth rate of the potential output in the United States and Canada stood at respectively 2.7% and 2.1% over 1991-1995, against respectively 3.6%, and 3.2% over 1995-2000 period. For the United States, the faster growth rate was mainly due to the acceleration in TFP growth (+0.5 pp), while, in the case of Canada, it was due to the labour contribution. On the contrary, medium-term potential growth in European economies remained stable (France and Netherlands) or even decreased (Germany and Italy). As for Italy, this was mainly due to a significant deceleration of TFP growth over the period. However the decrease in the contribution of TFP was partly offset by the increase in the contribution of labour (from -0.7 between 1991 and 1995 to 0.5 pp between 2000 and 2004).[22]

5 Discussion

The previous section suggests that in the medium-term, cross-country differences in potential growth were mostly driven by differences in TFP and labour contributions. Moreover, differences in the contribution of labour play a key role in explaining the lower potential growth in European economies and Japan as compared with the US. This section digs deeper into the sources of these differences.

5.1 What could explain TFP gaps among these economies?

As shown by our results, a large part of the potential output growth is mainly explained by TFP developments which could imply various gaps among the economies studied in this paper. Let $\Delta\tilde{g}_t^{LT}$ denotes a measure of the long-term contribution of TFP to potential growth according to:

$$\Delta\tilde{g}_t^{LT} = \frac{1}{\alpha}\left(\frac{\gamma_4 + \gamma_5\mathbb{I}(t > T_1) + \gamma_6\mathbb{I}(t > T_2)}{1-\gamma_1}\right).$$

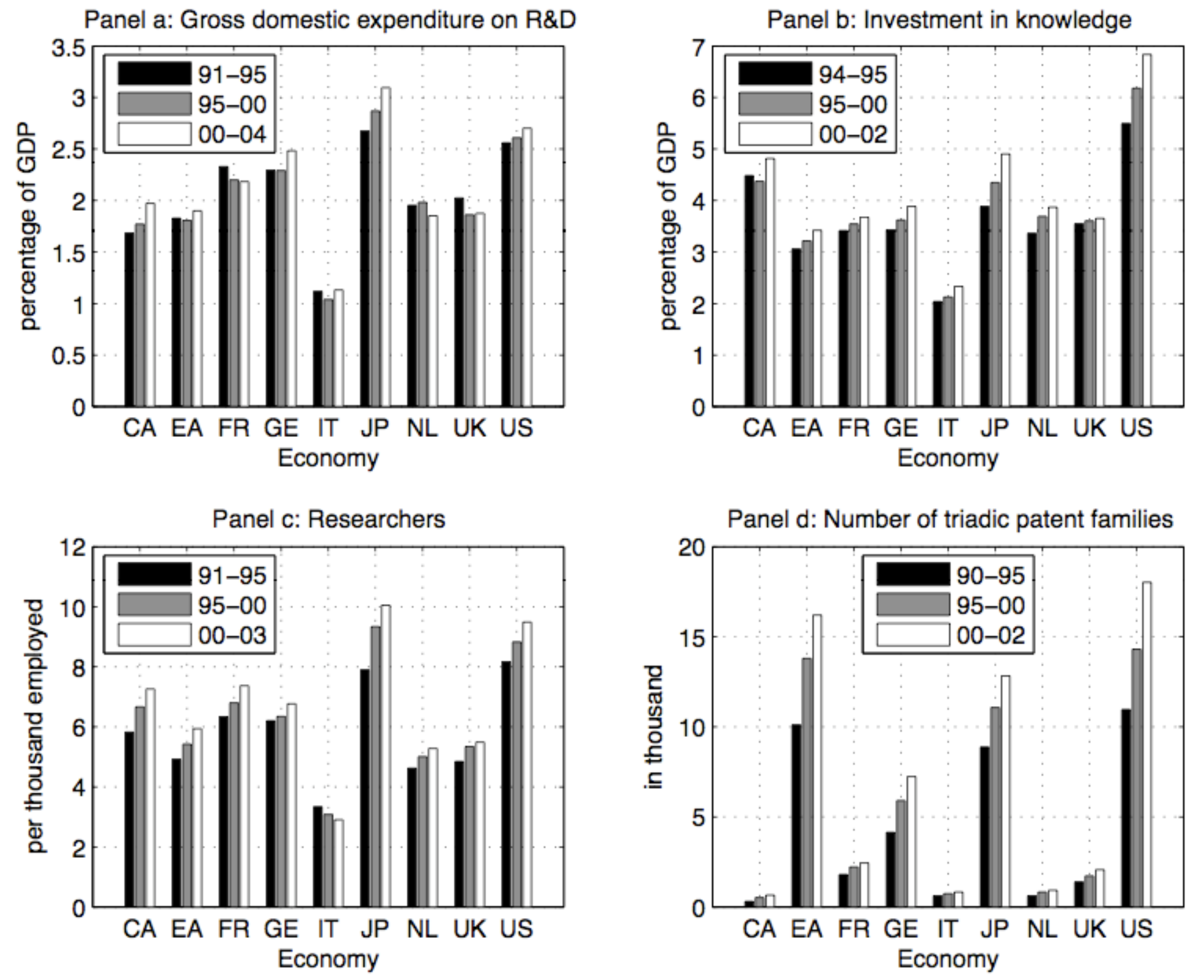
With respect to this measure, Japan, the UK, and the US appear to be some of the front runners with contributions of 2.1-2.2 percentage points over the 1991-2004 period. At the other end of the scale, Italy seems to be as a laggard in the panel, with a TFP contribution of 0.7 percentage point for the same period.

An interesting way to understand these differences is to focus on one of the modern engines of growth, i.e. innovation activities. Indeed, given the efforts by economic theorists to model endogenous, in particular R&D-driven, growth processes since the mid-1980s, activities of research, development, and innovation play a key role as economic growth determinants. In this respect, we can glance at some available innovation indicators to ascertain differences among economies. Figure 1 depicts such indicators for the panel.

A point worth mentioning is that over a similar period, Japan and the US showed greater efforts in innovation activities than the other economies of the panel. Once more, Italy appears to lag behind other countries, as its efforts are far smaller than is the case for the rest of the panel. A brief cross-country correlation with respect to the effect of gross domestic expenses on R&D on the long-run TFP contribution is shown in Figure 2. One can see the positive correlation between R&D efforts and TFP contribution. In the last quarter of Figure 2, which covers the whole period of investigation, we identify four blocks: the first consists in the Japanese and US economies, for which TFP contributions are among the highest and R&D efforts are close to 3% of GDP. The second relies on Italy, which presents a lower

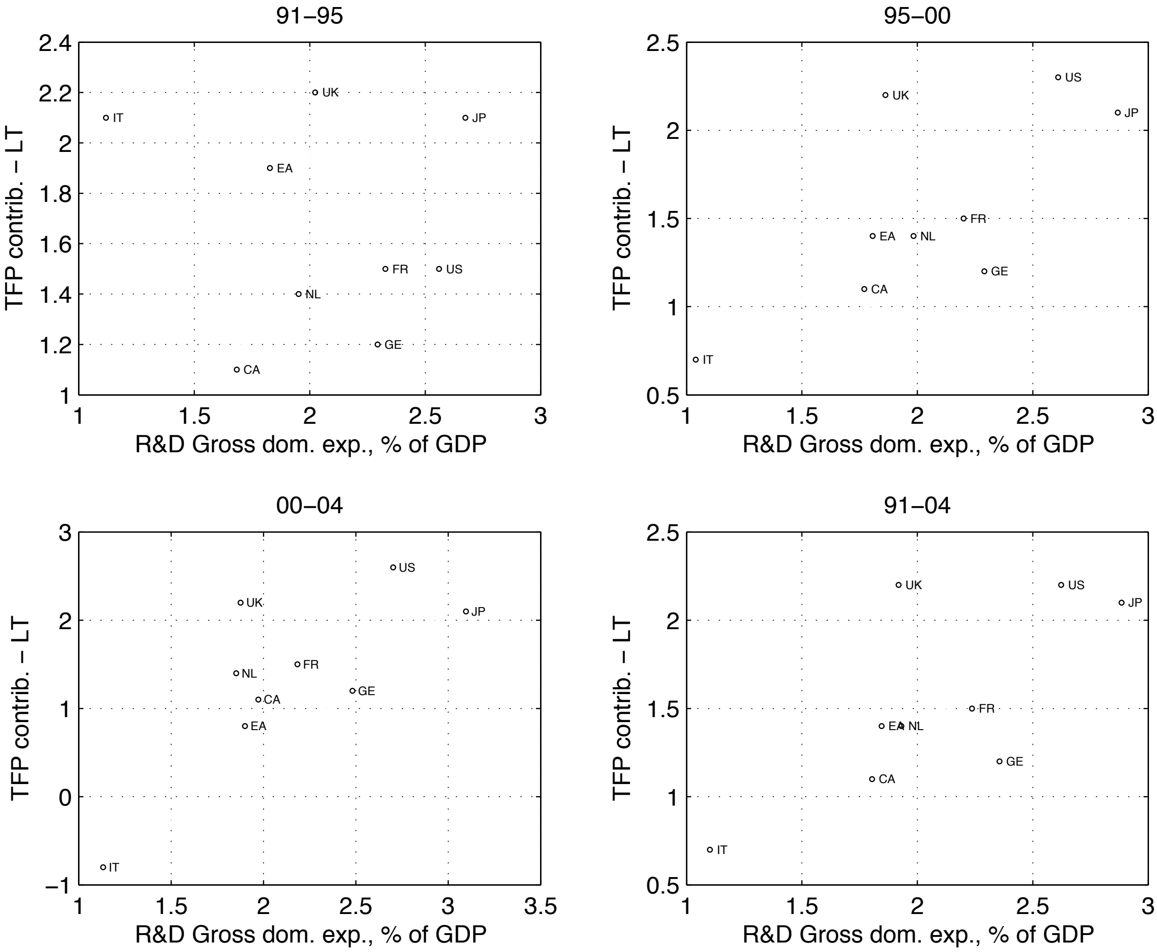
[22]This reflects partly a specific phenomenon, namely the increase in the participation rate in the late 1990s in Italy (see Table 5). This increase could be due to the inclusion of workers in the informal economy into National Accounts' measures of the labour force.

Figure 1: Innovation indicators



Source: OECD (2006). Panel a: Gross domestic expenditure on R&D as a percentage of GDP; Panel b: Investment in knowledge as a percentage of GDP, sub-periods over 94-02 only. Investment in knowledge is defined and calculated as the sum of expenditure on R&D, on total higher education (public and private) and on software, having been adjusted to exclude the overlaps between components; Panel c: Researchers per thousand employed, defined as professionals engaged in the conception and creation of new knowledge, products, processes, methods and systems as well as those who are directly involved in the management of projects, full-time equivalent, sub-periods over 91-03 only; Panel d: Number of triadic patent families according to the residence of the inventors, sub-periods over 90-02 only. The euro are data are proxied by EU15, except in Panel b for which investment in knowledge is proxied by the GDP-weighted average among France, Germany, Italy, and the Netherlands. Missing values are proxied by mean of previous and following periods, except for UK in Panel c, for which figures have been kept constant since 1999. We highly recommand the reader to refer to OECD (2006) website for definitions.

Figure 2: Gross domestic expenses on R&D and long term TFP contribution



R&D effort and a lower TFP contribution. A third group consists of Canada, France, Germany, and the Netherlands, with R&D efforts amounting to about 2% of GDP. As a particular exception, the UK that makes up the fourth block, experienced a high TFP contribution for a relatively low level of expenses on R&D.

To conclude on this issue, these rapid considerations add credence to the predominant and consensual view on the positive impact of an increase in R&D expenditure on economic growth.[23] It can be seen that an increase in the R&D drive of roughly 1% of GDP in the euro area could allow the area to catch up with the first block, and would potentially increase the TFP contribution by about 0.5 percentage point. From a more general perspective, one could think that all measures aiming at to enhance innovationnal activites —reducing credit constraints related to structural investment, increasing competition in product markets depending on the distance to frontier,...— could impact positively the TFP contribution to potential growth.[24]

[23] As far as France is concerned, this view was largely discussed and debated among French parliament, and especially in the Senate. See for instance Brécart at al. (2003) and Bourdin (2004).

[24] Another field of interest would concern the impact of product market regulation. On the one hand, regulatory reforms that liberalize entry into the good market could be deemed very likely to spur investment (see Alesina et al., 2003). On the other hand, recent studies including Acemoglu et al. (2006) rely on the nexus between distance to frontier and economic

5.2 What could explain differences in labour contributions?

Differences in labour contributions are important in terms of explaining differences in potential growth within the panel. For instance, the country with the highest average potential growth, namely the United States, shows a very positive labour contribution, whereas European countries, except for the Netherlands, record very low labour contributions over the 1991-2004 period. One may look for an explanation for these differences. Table 5 shows the breakdown of labour contribution in the medium run. The growth of labour input in the medium term splits up into four components: growth in the working age population, the so-called “population contribution”; changes in the participation rate, or participation; changes in the employment rate, or employment; and, lastly, changes in hours worked per worker in the whole economy, or hours.

First, a noteworthy point is that the contribution of hours is not the main source of differences in potential growth. Indeed in most OECD countries, hours worked declined over the period from 1990 to 2004 as shown in Table 6. This is why the contribution of hours has remained negative for the whole panel during this period. Japan and France show a relatively higher negative contribution of hours (-0.6 and -0.4).[25] In Japan, as pointed out by the ILO, Article 32 of the Labor Standards Law, which was revised in 1987, provided for a 40-hour working week. The general introduction of the 40-hour week occurred gradually in the 1990s. Another reason why the contribution of hours is negative for all the economies considered here is the increase in part-time employment in OECD countries during the 1991-2004 period (see Table 6). This is particularly true for Germany, Italy, the Netherlands, and Japan.

Second, differences in demographic developments play a crucial role in explaining differences in potential growth. The United States and Canada, which have a relatively high medium-term labour contribution compared with other countries, record high growth in the working age population, due to favourable demographic conditions (see Table 6.)

Third, differences in the contribution of participation rate explain why the Netherlands stands out as a European exception with respect to potential growth. This economy shows the highest potential growth when compared with other European countries, due to increases in the participation rate in the period from 1991 to 2004 and thus higher participation contributions. (0.7% for 1991-1995 and 0.8% for 1995-2000). This reflects the important economic reforms carried out in this country during the 1980s, *inter alia* the general agreement for a wage restraint policy in the Netherlands that started in 1982 (Wasenaar agreements) and whose effects on the participation rate appear to be exceptionally positive. A striking feature of these effects is seen in the female employment rate. Table 6 shows that all the economies considered witnessed a rise in the employment rate of women in the 1991-2004 period but the Netherlands shows the most important increase among the panel. To some extent, one may

growth based on the degree of rigidity in the product and stock markets. According to this literature, the greater the economy's distance to technological frontier is, the marginal gain of deregulation is potentially lower. As we do not draw on comparative measures of TFP in absolute terms in this paper, we could not deal with this promising issue.

[25] As previously analysed, long-run potential growth in Japan is driven by a relatively high TFP only as compared with the other countries. But medium-term potential growth is one percentage point lower than in the long run because of the negative contributions of age and labour.

Table 5: Breakdown of labour contributions to medium term potential growth (in percentage point)

	Period 1991–1995				
Economy	Total	Population	Participation	Employment	Hours
Canada	0.4	0.7	-0.2	0.0	-0.1
Euro area	0.0	0.2	0.1	-0.1	-0.2
France	0.0	0.2	0.2	-0.2	-0.1
Germany	0.1	0.2	0.1	0.0	-0.2
Germany-WR	0.1	0.2	0.1	0.0	-0.2
Italy	-0.7	0.1	-0.4	-0.2	-0.2
Japan	-0.1	0.2	0.5	0.0	-0.8
Netherlands	1.0	0.3	0.7	0.3	-0.3
United Kingdom	-0.4	0.1	-0.2	0.1	-0.3
United States	0.9	0.6	0.1	0.1	0.1
	Period 1995–2000				
Economy	Total	Population	Participation	Employment	Hours
Canada	1.1	0.7	0.1	0.2	0.0
Euro area	0.3	0.2	0.4	0.0	-0.3
France	0.4	0.2	0.4	0.1	-0.3
Germany	-0.3	0.0	0.3	-0.2	-0.5
Germany-WR	-0.3	0.0	0.3	-0.2	-0.5
Italy	0.1	0.0	0.3	-0.1	-0.1
Japan	-0.4	0.0	0.3	-0.1	-0.5
Netherlands	1.1	0.3	0.8	0.2	-0.2
United Kingdom	0.4	0.2	0.0	0.2	0.0
United States	1.0	0.8	0.1	0.1	0.2
	Period 2000–2004				
Economy	Total	Population	Participation	Employment	Hours
Canada	0.9	0.8	0.4	-0.1	-0.2
Euro area	0.4	0.2	0.5	0.1	-0.4
France	-0.2	0.3	0.3	0.1	-0.8
Germany	-0.1	-0.2	0.5	-0.1	-0.4
Germany-WR	-0.1	-0.2	0.5	-0.1	-0.4
Italy	0.5	0.0	0.6	0.1	-0.2
Japan	-0.6	-0.2	0.0	-0.1	-0.3
Netherlands	0.8	0.3	0.4	0.2	-0.1
United Kingdom	0.3	0.4	0.0	0.1	-0.3
United States	0.4	0.9	-0.1	0.0	-0.3
	Period 1991–2004				
Economy	Total	Population	Participation	Employment	Hours
Canada	0.8	0.7	0.1	0.0	-0.1
Euro area	0.2	0.2	0.3	0.0	-0.3
France	0.1	0.2	0.3	0.0	-0.4
Germany	-0.1	0.0	0.3	-0.1	-0.3
Germany-WR	-0.1	-0.0	0.3	-0.1	-0.3
Italy	0.0	0.0	0.1	0.0	-0.2
Japan	-0.4	0.0	0.3	-0.1	-0.6
Netherlands	1.0	0.3	0.7	0.2	-0.2
United Kingdom	0.1	0.2	-0.1	0.1	-0.2
United States	0.8	0.8	0.0	0.1	0.0

conclude that, had other European countries implemented such labour market policies, they would have experienced more rapid potential and actual growth paths over the period from 1991 to 2004, as much as 0.5 point higher or even more, due to higher participation and employment contributions.

5.3 Actual versus potential GDP growth

One additional feature of this method is to allow for a breakdown of the gap between actual and medium-term potential growth, that could give support to economic analysis with policy implications. For such purpose, table 7 shows the contributions of each production input to actual GDP growth and the differences with their potential counterpart. Such differences can be mainly explained either by cyclical fluctuations that disappear in potential variables, either by various shocks that are not captured in our

Table 6: OECD indicators on labour market and population

	demography[a]	women' employment rate[b]			hours worked[c]	part-time[d]
Economy	90-04	1990	2004	90-04	90-04	90-04
Canada	1.06	62.7	68.4	5.7	-6	1.5
France	0.43	50.3	56.7	6.4	-156	1.2
Germany	0.39	52.2	59.9	7.8	-98	6.7
Italy	0.14	36.2	45.2	9.0	-71	6.0
Japan	0.24	55.8	57.4	1.6	-242	6.3
Netherlands	0.61	47.5	64.9	17.5	-99	6.9
United Kingdom	0.31	62.8	66.6	3.7	-98	4.0
United States	1.17	64.0	65.4	1.3	-37	-0.9
EU15	0.40	48.7	56.7	8.1	-	4.1
Panel's average	0.53	53.3	60.1	6.8	-101	4.0

Note: [a] annual average growth rate of population over 1990-2004, [b] levels in 1990 and 2004 and change in percentage point, [c] change in yearly worked hours per head over 1990-2004, [d] as a percentage of total employment, change in percentage point over 1990-2004 ("+" = increase)

model.[26]

Over the 1991-1995 period, although actual GDP growth ranges from 1.2% (France, Italy) to 2.4% (Germany, United States), the panel's economies remained overall below their potential growth. Conversely, the 1995-2000 period shows an inverse phenomena with actual GDP growth fairly above its potential, and where high growth levels are attained, especially for the Canada and the US. Lastly, the 2000-2004 period is a mixture of the previous, showing discrepancies among the panel as regards the actual position of the economy with respect to its potential. Such a feature behaviour prevails if we look at the whole sample period.

Interestingly, we found the same pattern over the subperiods when coping with labour contributions. During the 1991-1995 period, acual labour contribution remained below potential, while over the 1995-2000 period, these contributons are higher than their potential counterpart. Besides, this pattern is correlated with the sign of the contribution itself, namely negative during 1991-1995 and positive during 1995-2000. The behaviour of this labour contribution is mainly driven by the dynamics of the unemployment gap - the difference between unemployment rate and the NAIRU - during all the subperiods; growing for the panel's economies between 1991 and 1995, then decreasing in the following five years, except for Japan. Anglo-Saxon economies as well as Netherlands and Germany faced an increase in their unemployment rate concomitant with a decline in the NAIRU during the first subperiod, whereas for the other countries both conjonctural and structural unemployement increased. Over the 1995-2000 period, all economies except Japan exhibited decreasing or stagnating unemployment rate, with a declining or slightly growing NAIRU. Finally, the 2000-2004 subperiod appears quite stable.

Concerning TFP contributions to actual GDP growth, no clear behaviour for the panel as a whole emerges. A large part of the difference between potential and actual contributions come from the fluctuations related to the capacity utilisation rate, that are not taken into account in potential TFP. Nevertheless, some countries such as Germany and the Netherlands experienced relative strong contribution of actual TFP to GDP growth despite a declining CUR over the 1991-1995 subperiod, that a quick

[26]More precisely, several potential variables are obtained by smoothing techniques. Hence, actual versus potential differences are mainly due to this trend-cycle decomposition, except for capital contribution for which actual values equal potential ones.

look at the residuals of TFP equation confirms.

Table 7: Sources of actual GDP growth and measures comparison

		Period 1991–1995					
		Contributions			Measures comparison		
Economy	Growth	Capital	Labour	TFP	Prod. func.	HP	Trend
Canada	1.6(-.5)	1.1	-0.1(-.5)	0.6(—)	2.1	1.8	2.8
Euro area	1.6(-.7)	0.9	-0.4(-.4)	1.1(-.3)	2.3	1.9	2.3
France	1.2(-.6)	1.0	-0.3(-.3)	0.5(-.3)	1.8	1.5	2.1
Germany	2.4(+.1)	0.9	-0.1(-.2)	1.6(+.3)	2.3	2.3	2.2
Germany-WR	2.4(-.1)	1.1	-0.1(-.2)	1.4(+.2)	2.5	2.3	2.2
Italy	1.2(-.2)	0.8	-0.9(-.2)	1.3(—)	1.4	1.4	1.5
Japan	1.6(-.7)	1.3	-0.2(-.1)	0.5(-.7)	2.4	2.0	2.1
Netherlands	2.2(-.5)	0.8	0.4(-.6)	1(+.1)	2.7	2.5	2.7
United Kingdom	1.5(-.4)	0.9	-1.1(-.7)	1.7(+.3)	1.9	1.8	2.6
United States	2.4(-.3)	0.9	0.6(-.3)	0.9(-.1)	2.7	2.7	3.1
		Period 1995–2000					
		Contributions			Measures comparison		
Economy	Growth	Capital	Labour	TFP	Prod. func.	HP	Trend
Canada	3.9(+.7)	1.1	1.4(+.3)	1.4(+.5)	3.2	3.7	2.8
Euro area	2.6(+.6)	0.8	0.6(+.3)	1.2(+.3)	2.0	2.3	2.3
France	2.6(+.4)	0.8	0.7(+.3)	1.0(—)	2.2	2.3	2.1
Germany	2.0(+.2)	0.8	-0.1(+.2)	1.3(—)	1.8	1.7	2.2
Germany-WR	2.0(+.1)	1.0	-0.1(+.2)	1.1(-.1)	1.9	1.7	2.2
Italy	2.1(+.7)	0.7	0.3(+.2)	1.1(+.5)	1.4	1.8	1.5
Japan	1.0(-.3)	0.9	-0.5(-.1)	0.6(-.2)	1.2	0.8	0.9
Netherlands	3.6(+.6)	0.9	1.4(+.3)	1.3(+.3)	3.0	3.2	2.7
United Kingdom	3.2(+.4)	0.9	0.8(+.4)	1.4(—)	2.8	3.1	2.6
United States	3.9(+.3)	1.1	1.4(+.4)	1.4(-.1)	3.6	3.6	3.2
		Period 2000–2004					
		Contributions			Measures comparison		
Economy	Growth	Capital	Labour	TFP	Prod. func.	HP	Trend
Canada	3.2(+.2)	1.2	1.2(+.3)	0.8(-.1)	3.0	3.3	2.8
Euro area	2.0(-.2)	0.9	0.4(—)	0.7(-.2)	2.2	2.0	2.3
France	2.2(+.2)	0.9	-0.2(—)	1.5(-.1)	2.0	2.2	2.1
Germany	1.3(-.7)	0.7	-0.2(-.1)	0.8(-.5)	2.0	1.2	2.2
Germany-WR	1.3(-.6)	0.8	-0.2(-.1)	0.7(-.5)	1.9	1.2	2.2
Italy	1.4(+.3)	0.8	0.7(+.2)	-0.1(+.1)	1.1	1.3	1.5
Japan	1.4(+.8)	0.7	-0.5(+.1)	1.3(+.6)	0.6	1.1	0.9
Netherlands	1.5(-.9)	0.8	0.6(-.2)	0.0(-1.0)	2.6	1.7	2.7
United Kingdom	2.8(+.1)	1.0	0.3(—)	1.5(+.1)	2.7	2.7	2.6
United States	2.6(-.6)	1.2	0.1(-.3)	1.4(-.2)	3.2	2.9	3.3
		Period 1991–2004					
		Contributions			Measures comparison		
Economy	Growth	Capital	Labour	TFP	Prod. func.	HP	Trend
Canada	2.7(-.1)	1.1	0.7(-.1)	0.9(+.1)	2.8	2.9	2.8
Euro area	2.0(-.2)	0.9	0.2(—)	0.9(-.1)	2.2	2.1	2.3
France	1.9(-.1)	0.9	0.1(—)	0.9(-.1)	2.0	2.0	2.1
Germany	1.7(-.4)	0.8	-0.2(-.1)	1.1(-.2)	2.1	1.8	2.2
Germany-WR	1.7(-.4)	1.0	-0.2(-.1)	0.9(-.3)	2.1	1.8	2.2
Italy	1.4(—)	0.8	0.0(—)	0.6(—)	1.3	1.5	1.5
Japan	1.3(-.1)	1.0	-0.5(-.1)	0.8(-.1)	1.4	1.3	1.3
Netherlands	2.4(-.4)	0.8	0.8(-.2)	0.7(-.3)	2.8	2.5	2.7
United Kingdom	2.4(-.1)	0.9	-0.1(-.2)	1.5(+.1)	2.5	2.5	2.6
United States	2.9(-.3)	1.0	0.6(-.2)	1.2(-.2)	3.2	3.1	3.2

Note: This table shows the c ontributions of capital, labour in hours worked, and TFP to the actual GDP growth. Figures in parentheses give the difference between actual and medium-term contributions from Table 6. A '+' means that actual values are higher than potential ones. Discrepancies may appear due to rounding errors. Since we assume that actual equals potential capital stock, no difference are reported for capital contributions.

Finally, Table 7 compares also the production function estimates with two statistical univariate methods, namely a smoothing technique (Hodrick and Prescott, 1997) and a trend estimation including possible trend breaks.[27] In fact, the production function approach gives results that are close to those obtained from these univariate methods, suggesting that this structural approach acts as a filtering process at business cycle frequency.

To conclude, actual growth appears to be lower than medium term growth over the whole period. This result suggests that all the economies considered lost growth opportunities between 1991 and 2004.

[27]Dates of breaks are presented in AppendixB, Table 8.

This finding holds for all the countries, though with different magnitudes. An interesting point is that, even though the US economy remained under its potential growth rate in the 1991-2004 period, its actual growth was higher than posted by other economies. The US economy, despite actual growth amounting to 2.9% in annual terms, lost 0.3 percentage point in growth per year when compared with its medium-term potential growth.

6 Conclusion

The analysis of output growth in a panel of major economies undertaken in this paper confirms that European economies, as well as Japan, have lagged behind North American, especially the US, over the last 15 years. Within the euro area, France and Germany experienced quite identical average potential output growth over the period considered, while Italy went through a period of exceptionally low potential growth. On the contrary, the Netherlands, thanks to favourable conditions on the labour market, has outperformed other economies in the euro area in terms of potential growth. An interpretation of these divergent growth rates found in the major euro area economies may be found, in addition to differences in economic performances, in differing macroeconomic policies, above all with regard to the labour market. The foregoing points to the need for more structural reforms in the euro area. Indeed, several empirical studies suggest a positive impact of product and labour markets reforms on employment and TFP growth.[28] Using a variety of models, Arpaia et al. (2007) find that reforms in areas such as unemployment benefits, taxes, and the ease of entry for new firms have reduced the structural unemployment rate by 1.4 p.p. and boosted GDP in the EU15 by 2% since 1995. Similarly, by conducting panel data analysis on a wide range of OECD countries, Aghion et al. (2007) find that TFP growth is positively impacted by structural reforms on product and labour markets, and these effects appear to be especially significant for countries close to the technological frontier. Moreover their main findings suggests that product market reforms are complementary to labour market reforms. In case there is too little competition on product market, firms lack incentives to innovate, no matter how important is the degree of liberalization on the labour market.

Interestingly, a possible further path of research would focus on a comparison of TFP levels that our methodology could allow. Indeed, after homogenizing the data—*i.e.* taking into account differences in exchange rates or purchasing power parity for example— one should be able to compare levels of TFP and to better distinguish the sources of differences in TFP developments and their impacts on the economy.[29] A possible future research project would consist in seeking to identify the technological frontier by comparing levels of TFP at each date for the whole panel, and then estimating relationships between TFP and the technological frontier. Such a project could shed light on the sources of technological progress based either on purely country-specific innovation or on imitation and catching-up effects. Should this research project be fruitful, it would provide extremely interesting information for the medium-term

[28] See Arpaia et al. (2007), Pichelmann and Roeger (2002), Pichelmann (2003), Aghion et al. (2007).

[29] Although initial results have been achieved in this sense, we set this issue out of the scope of this paper, leaving it for further research.

diagnosis of the process of economic convergence among the countries studied in this paper.

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A Technical appendix

A.1 Real capital stock and age series

Starting from the law of capital accumulation with a constant depreciation rate, we have:

$$\begin{aligned} K_t &= (1-\delta)K_{t-1} + I_t \\ &= (1-\delta)^{t-1}(I_t + k) + \sum_{j=0}^{t-2}(1-\delta)^j I_{t-j} \\ &= k(1-\delta)^{t-1} + \sum_{j=0}^{t-1}(1-\delta)^j I_{t-j}, \end{aligned}$$

where k is the initial capital stock value.

To identify k, we suppose that the economy is on a balanced growth path, where capital stock and investment grow at the same constant rate g. On such a path, the capital stock/investment ratio is as follows :

$$\frac{K_t}{I_t} = \frac{1+g}{g+\delta}.$$

We calculate k such as the ratio K_t/I_t equals $(1+\bar{g})/(\bar{g}+\delta)$, where $\bar{g}$ is the mean growth rate of investment on the same period, namely:

$$\frac{1}{T}\sum_{t=1}^{T}\frac{K_t}{I_t} = \frac{1+\bar{g}}{\bar{g}+\delta}.$$

From this assumption, we have:

$$k = \frac{T\frac{1+\bar{g}}{\bar{g}+\delta} - \sum_{t=1}^{T} \frac{\sum_{j=0}^{t-1}(1-\delta)^j I_{t-j}}{I_t}}{\sum_{t=1}^{T} \frac{(1-\delta)^{t-1}}{I_t}}.$$

The age of capital stock is given by:

$$\sum_{j=0}^{t-1}(1-\delta)^j \frac{I_{t-j}}{K_t} j$$

A.2 Derivation of the Productive Capital Stock

Assume that productive capital $\tilde{K}_t$ consists in the accumulated investment flows for which we take into account an improvement in productivity, increasing each capital services by a factor $1+\epsilon$, with $\epsilon > 0$ and sufficiantly lower than 1. Introducing the capacity utilisation rate which modulates the level of productive stock, we can write:

$$\begin{aligned}
\tilde{K}_t &= CUR_t \left[\underbrace{k(1-\delta)^{t-1}}_{\text{negligible}} + \sum_{j=0}^{t-1}(1-\delta)^j I_{t-j}(1+\epsilon)^{t-j} \right] \\
&= CUR_t \left[\sum_{j=0}^{t-1}(1-\delta)^j I_{t-j}(1+\epsilon)^{t-j} \right] \frac{K_t(1+\epsilon)^{t-\tau_t}}{K_t(1+\epsilon)^{t-\tau_t}} \\
&= CUR_t K_t (1+\epsilon)^{t-\tau_t} \left[\sum_{j=0}^{t-1}(1-\delta)^j \frac{I_{t-j}}{K_t}(1+\epsilon)^{-j+\tau_t} \right] \\
&= CUR_t K_t e^{(t-\tau_t)\ln(1+\epsilon)} \left[\sum_{j=0}^{t-1}(1-\delta)^j \frac{I_{t-j}}{K_t} \underbrace{(1+\epsilon(-j+\tau_t))}_{1^{\text{st}}\text{order approx.}} \right] \\
&= CUR_t K_t e^{(t-\tau_t)\epsilon} \left[(1+\epsilon\tau_t) \underbrace{\sum_{j=0}^{t-1}(1-\delta)^j \frac{I_{t-j}}{K_t}}_{\simeq 1} - \epsilon \underbrace{\sum_{j=0}^{t-1}(1-\delta)^j \frac{I_{t-j}}{K_t} j}_{\simeq \tau_t} \right] \\
&= CUR_t K_t e^{(t-\tau_t)\epsilon},
\end{aligned}$$

which gives equation (1).

A.3 Medium-term TFP

In this section, we present in detail the calculations which lead to equation (5). Let us assume that the logarithm of medium-term TFP evolves as $\tilde{g}_t = \tilde{g}_{t-1} + \rho$, where ρ is the constant growth rate of TFP. A combination with eqution (4) gives:[30]

$$\begin{aligned}
\tilde{g}_t = \tilde{g}_{t-1} + \rho &= \gamma_0 + \gamma_1 g_{t-1} + \gamma_3(\tau_t - \overline{\tau}) + \gamma_4 t + \gamma_5 t_1 + \gamma_6 t_2 \\
&= \gamma_0 + \gamma_1 g_{t-1} + \gamma_3(\tau_t - \overline{\tau}) + \gamma_4 t + \gamma_5 \mathbb{I}(t > T_1)(t - T_1) + \gamma_6 \mathbb{I}(t > T_2)(t - T_2) \\
\Longrightarrow (1-\gamma_1)\tilde{g}_{t-1} &= (\gamma_0 - \rho + \gamma_4 + \gamma_5(1 - T_1)\mathbb{I}(t > T_1) + \gamma_6(1 - T_2)\mathbb{I}(t > T_2)) \\
&\quad + \gamma_3(\tau_t - \overline{\tau}) + (\gamma_4 + \gamma_5 \mathbb{I}(t > T_1) + \gamma_6 \mathbb{I}(t > T_2))\,(t-1),
\end{aligned}$$

which gives the following period:

$$\begin{aligned}
(1-\gamma_1)\tilde{g}_t &= (\gamma_0 - \rho + \gamma_4 + \gamma_5(1 - T_1)\mathbb{I}(t+1 > T_1) + \gamma_6(1 - T_2)\mathbb{I}(t+1 > T_2)) \\
&\quad + \gamma_3(\tau_{t+1} - \overline{\tau}) + (\gamma_4 + \gamma_5 \mathbb{I}(t+1 > T_1) + \gamma_6 \mathbb{I}(t+1 > T_2))\;\; t.
\end{aligned}$$

This last equation defines the medium term TFP:

$$\begin{aligned}
\tilde{g}_t = &\frac{\gamma_0 - \rho + \gamma_4 + \gamma_5(1 - T_1)\mathbb{I}(t > T_1 - 1) + \gamma_6(1 - T_2)\mathbb{I}(t > T_2 - 1)}{1 - \gamma_1} \\
&+ \frac{\gamma_3}{1-\gamma_1}(\tau_{t+1} - \overline{\tau}) + \left(\frac{\gamma_4 + \gamma_5 \mathbb{I}(t > T_1 - 1) + \gamma_6 \mathbb{I}(t > T_2 - 1)}{1 - \gamma_1}\right) t.
\end{aligned}$$

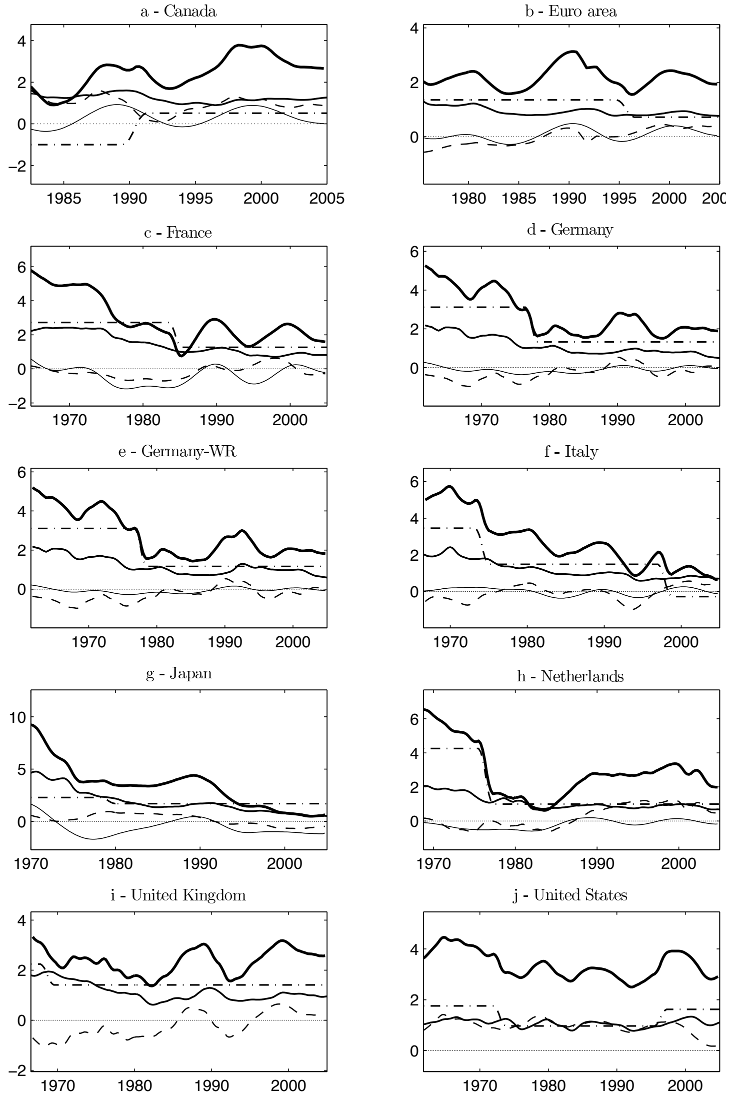
B Additional table and figure

Table 8: Breaks on GDP potential growth trend

	Start date	Break 1	Break 2
Canada	1962q2	1975q2(-)	
Euro area	1963q2	1973q3(-)	
France	1963q2	1974q1(-)	
Germany	1960q2	1972q4(-)	
Germany-WR	1960q2	1972q4(-)	
Italy	1960q2	1973q4(-)	1989q3(-)
Japan	1970q1	1992q1(-)	
United Kingdom	1960q2	1973q3(-)	1982q2(+)
United States	1960q1	1966q3(-)	1996q1(+)

[30] One should keep in mind that we consider in the medium term $cur_t = \overline{cur}$.

Figure 3: Medium term potential growth and contributions



Legend : (▬▬▬) medium term potential growth, (——) capital stock, (- - -) labour, (- · · · -) TFP, and (——) age of MES capital stock.