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GLOBAL TRENDS OF MULTI-FACTOR PRODUCTIVITY: ESTIMATION AND APPLICATION

ABSTRACT

Multi-factor productivity (MFP) compares the growth of gross domestic product with the growth of combined capital and labor inputs. The growth rate of MFP assumes theoretical significance because it represents the slope of the steady-state growth path, and hence is a major determinant of the long-term growth trend. This paper offers a balanced panel of the estimated growth rates of MFP for 24 OECD countries over 1986-2011. Based on the estimates of MFP growth, a number of notable trends in productivity growth are identified for the entire OECD area as well as for three major economies – the US, the Eurozone and Japan – within the OECD. In addition, this paper presents panel estimation results confirming that research and development (R&D) is a key determinant of MFP growth.

Key words: Economic Growth, Multi-factor Productivity, R&D, OECD

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The Organization for Economic Co-operation and Development (OECD) has published time series of productivity measures constructed at the level of entire economies since 2003. Among the available measures, multi-factor productivity (MFP) compares the growth of gross domestic product (GDP) with the growth of combined capital and labor inputs. Accordingly, MFP growth represents an improvement in the level of economy-wide efficiency with which capital and labor inputs are used in production. Viewed in this way, the growth rate of MFP is the slope of the steady-state growth path, and hence a major determinant of the long-term growth trend.

The key role of MFP in long-term economic growth is conceptually clear, but MFP is not something directly observable. As a result, the growth rate of MFP has to be estimated in an indirect way. The indirect estimation inevitably involves restrictive assumptions, and the OECD estimates of MFP growth also are not free from such limitations. However, these estimates hold clear advantages over most other MFP measures for the purpose of international comparisons because a common set of assumptions are behind OECD estimates for all member countries. At least within the OECD area, therefore, the OECD estimates present a sensible indication of relative productivity among member countries.

Although the OECD Productivity database provides MFP measures valuable for international comparisons, the measures are not available for all member countries and for all years. Therefore, this paper tries to fill this gap by constructing a balanced panel of MFP estimates for 24 OECD member countries over 1986-2011, using input and output data from various databases of the OECD. This balanced panel of MFP estimates allows us to identify some notable productivity growth trends – both cross-sectional and time-series – in the OECD area over the past 25 years. The estimates of MFP growth rates presented in this study are also particularly useful for an empirical analysis of productivity growth that requires balanced panel data. Among others, this paper shows simple panel estimation that tests one of the major theoretical predictions of endogenous growth models. The reduced form equation used in estimation is obtained from a variant of endogenous growth models in which technological progress shows up as an expansion of the number of varieties of products. The estimation results clearly support the model's prediction that research and development (R&D) is a key determinant of MFP growth.

The next section briefly reviews how the growth rate of MFP determines the slope of the steady-state growth path and serves as the main determinant of long-term economic growth. Section 3 describes data used in estimation, followed by the report of the balanced

panel of MFP estimates. Based on these estimates, Section 4 highlights some notable productivity trends in the OECD area. Section 5 presents panel estimation that examines the link between MFP growth and R&D based on an endogenous growth model. Section 6 concludes.

MULTI-FACTOR PRODUCTIVITY AND ECONOMIC GROWTH

This section illustrates the role of multi-factor productivity in economic growth using a standard theoretical model that traces back to Solow (1956) and Swan (1956).¹ The aggregate production function is assumed to be described by the Cobb-Douglas function,

$$Y_t = F_t K_t^\alpha L_t^{1-\alpha} \tag{1}$$

where Y is aggregate output, K is aggregate capital, and L is total labor. $F > 0$ measures the shift in the production function at given levels of capital and labor, and hence represents the level of MFP. α is a constant with $0 < \alpha < 1$.

It is supposed that the economy is closed and there are no government expenditures on goods and services. Accordingly, aggregate output is either consumed or invested in this model. Investment is used to create new units of capital which is assumed to depreciate at the constant rate $\delta > 0$. In addition, it is assumed that a constant fraction of aggregate output is saved at the rate of s ($0 \leq s \leq 1$). Since saving equals investment in a closed economy, the investment rate is also s in this economy. Finally, total labor is assumed to grow at a constant, exogenous rate of $n \geq 0$.

Eq. (1) can be rewritten in intensive form as

$$y_t = F_t k_t^\alpha \tag{2}$$

where $y \equiv Y/L$ and $k \equiv K/L$.

The steady state value of k for the given level of MFP, $F\tau$, is indicated as $\bar{k}\tau$, and satisfies the following condition:

¹ The framework used in this section directly comes from Lee (2009, 2011). For a more detailed exposition of the framework, see Barro and Sala-i-Martin (2004).

$$sF_{\tau}\bar{k}_{\tau}^{\alpha} = (n + \delta) \cdot \bar{k}_{\tau} \quad (3)$$

Subsequently, \bar{k}_{τ} is determined as

$$\bar{k}_{\tau} = [sF_{\tau} / (n + \delta)]^{1/(1-\alpha)} \quad (4)$$

With the given level of MFP, the economy eventually reaches its steady state all the time. If the economy starts with k below its steady-state level of \bar{k}_{τ} , k rises over time as the economy invests until it reaches \bar{k}_{τ} . Along the transition to the steady state, the growth rate of k at t for the given level of MFP, F_{τ} , can be described by

$$\dot{k}_t/k_t = (n + \delta) \cdot \left[\left(\frac{k_t}{\bar{k}_{\tau}} \right)^{\alpha-1} - 1 \right] \quad (5)$$

Eq. (5) shows that the growth rate of k approaches 0 as k increases and approaches \bar{k}_{τ} . Given that the growth rate of capital per labor equals the growth rate of income per labor, the level of income per labor is bound to cease to grow in the long run. However, the economy may achieve sustained growth in the level of income per labor by constantly improving MFP and hence resisting the gravity of diminishing returns. The level of \bar{k}_{τ} depends crucially on the level of MFP, F_{τ} , in Eq. (4), suggesting that an improvement in the level of MFP will raise the steady-state level of capital per labor when the economy's saving rate, depreciation rate, and labor growth rate remain constant. Therefore, Eq. (4) clearly shows that the growth rate of MFP determines the slope of the steady-state growth path.

Besides its effect on the steady-state growth path, a change in the growth rate of MFP also has a more immediate effect on the current pace of economic growth. To see this, we turn to Eq. (5). Along the transition to the steady state, the economy's growth rate of capital per labor at t depends on the distance between the t period level of capital per labor, k_t , and its steady-state level, \bar{k}_{τ} . Subsequently, an improvement in MFP is expected to have an immediate effect on the current growth rate of capital per labor by raising the steady-state level of capital per labor and hence widening the distance between the current and the steady-state levels of capital per labor.

MULTI-FACTOR PRODUCTIVITY: DATA AND ESTIMATION

A sample of 24 countries is chosen from OECD member countries. These include: Australia, Austria, Belgium, Canada, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Israel, Italy, Japan, Republic of Korea, the Netherlands, New Zealand, Norway, Portugal, Spain, Sweden, Switzerland, the UK, and the US. Germany represents unified Germany from 1991 and the entire West and East Germany before 1991. For the years up to 1990, the OECD data for the entire Germany are estimates based on data for West Germany. For estimation, MFP for each country is defined, in line with Eq. (1), as

$$F_t = Y_t / [K_t^\alpha L_t^{(1-\alpha)}] \quad (6)$$

where Y is aggregate output represented by constant price GDP, K is aggregate capital represented by productive capital stock measured in volume, and L is total labor measured by total hours worked. The coefficient $(1 - \alpha)$ is the share of labor income. Hulten (2001) provides a summary of issues related to the estimation of MFP. Y is GDP adjusted in 2005 prices from the OECD Annual National Accounts database.² The variable is converted to an index with 2005 = 1, and reported in Table 1 for 24 sample countries over 1985-2011.

In the absence of directly observable flows of capital services, the flow of capital services is widely assumed to be proportional to the productive stock at the end of the previous period (see Schreyer, 2003: 166). The productive capital stock for each type of asset is constructed using the perpetual inventory method. The construction begins with a time series of investment expenditure, and this investment expenditure series is deflated using producer price indices of investment goods to obtain constant-quality volume measures of vintage investment. Retirement patterns and age-efficiency patterns are also defined to account for, respectively, discarded assets and the loss of productive capacity of aging capital goods.

² Data was extracted on Jan 17, 2013.

GLOBAL TRENDS OF MULTI-FACTOR PRODUCTIVITY

Table 1. Gross domestic product (in 2005 prices, 2005 = 1)

	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998
AUS	0.510	0.524	0.553	0.575	0.596	0.594	0.596	0.621	0.646	0.672	0.699	0.726	0.759	0.796
AUT	0.608	0.622	0.630	0.651	0.677	0.706	0.730	0.745	0.749	0.767	0.788	0.807	0.826	0.857
BEL	0.637	0.649	0.664	0.695	0.719	0.742	0.755	0.767	0.759	0.784	0.803	0.814	0.844	0.861
CAN	0.574	0.588	0.613	0.643	0.660	0.661	0.648	0.653	0.669	0.701	0.720	0.732	0.763	0.794
DEN	0.677	0.710	0.713	0.712	0.716	0.727	0.737	0.751	0.750	0.792	0.816	0.839	0.866	0.885
FIN	0.607	0.623	0.645	0.678	0.713	0.716	0.673	0.650	0.645	0.668	0.695	0.719	0.764	0.802
FRA	0.649	0.663	0.679	0.711	0.741	0.760	0.768	0.779	0.774	0.791	0.808	0.816	0.834	0.862
DEU	0.681	0.697	0.706	0.733	0.761	0.801	0.842	0.858	0.850	0.871	0.885	0.892	0.908	0.925
GRE	0.612	0.615	0.601	0.627	0.651	0.651	0.671	0.676	0.665	0.678	0.692	0.709	0.735	0.759
ISL	0.540	0.574	0.623	0.622	0.624	0.631	0.629	0.608	0.616	0.638	0.639	0.670	0.703	0.747
IRL	0.304	0.303	0.317	0.334	0.353	0.383	0.390	0.403	0.414	0.438	0.480	0.525	0.585	0.637
ISR	0.411	0.428	0.459	0.472	0.475	0.509	0.549	0.591	0.616	0.662	0.705	0.744	0.767	0.800
ITA	0.696	0.716	0.739	0.770	0.796	0.812	0.825	0.831	0.824	0.842	0.866	0.876	0.893	0.906
JPN	0.660	0.679	0.707	0.757	0.798	0.842	0.870	0.878	0.879	0.887	0.904	0.927	0.942	0.923
KOR	0.260	0.292	0.327	0.366	0.390	0.426	0.468	0.495	0.526	0.572	0.623	0.668	0.707	0.666
NLD	0.582	0.598	0.609	0.630	0.658	0.686	0.702	0.714	0.723	0.745	0.768	0.794	0.828	0.861
NZL	0.591	0.603	0.606	0.615	0.616	0.617	0.610	0.617	0.655	0.689	0.717	0.739	0.761	0.769
NOR	0.573	0.596	0.607	0.606	0.612	0.623	0.643	0.665	0.684	0.718	0.749	0.787	0.829	0.851
PRT	0.544	0.566	0.602	0.647	0.689	0.716	0.748	0.756	0.740	0.748	0.780	0.808	0.844	0.887
ESP	0.519	0.536	0.565	0.594	0.623	0.646	0.663	0.669	0.662	0.678	0.697	0.713	0.741	0.774
SWE	0.628	0.646	0.668	0.686	0.705	0.712	0.704	0.696	0.681	0.709	0.737	0.748	0.769	0.801
CHE	0.727	0.741	0.753	0.777	0.811	0.841	0.833	0.833	0.832	0.842	0.846	0.850	0.868	0.891
GBR	0.559	0.581	0.608	0.638	0.653	0.658	0.646	0.652	0.672	0.703	0.725	0.747	0.776	0.804
USA	0.541	0.559	0.577	0.601	0.622	0.634	0.632	0.654	0.672	0.700	0.718	0.745	0.779	0.813
	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	
AUS	0.827	0.843	0.875	0.903	0.941	0.971	1	1.038	1.077	1.092	1.117	1.140	1.166	
AUT	0.888	0.920	0.928	0.944	0.952	0.977	1	1.037	1.075	1.091	1.049	1.071	1.100	
BEL	0.891	0.924	0.931	0.944	0.952	0.983	1	1.027	1.056	1.067	1.037	1.062	1.081	
CAN	0.838	0.882	0.898	0.924	0.941	0.971	1	1.028	1.051	1.058	1.029	1.062	1.087	
DEN	0.908	0.940	0.946	0.951	0.954	0.976	1	1.034	1.050	1.042	0.983	0.999	1.010	
FIN	0.834	0.878	0.898	0.915	0.933	0.972	1	1.044	1.100	1.103	1.009	1.042	1.071	
FRA	0.891	0.923	0.940	0.949	0.958	0.982	1	1.025	1.048	1.047	1.014	1.031	1.049	
DEU	0.942	0.971	0.985	0.986	0.982	0.993	1	1.037	1.071	1.083	1.027	1.070	1.102	
GRE	0.785	0.820	0.855	0.884	0.937	0.978	1	1.055	1.092	1.090	1.056	1.004	0.932	
ISL	0.778	0.811	0.843	0.844	0.865	0.933	1	1.047	1.110	1.123	1.049	1.007	1.033	
IRL	0.707	0.783	0.825	0.871	0.905	0.944	1	1.054	1.111	1.088	1.029	1.021	1.035	
ISR	0.826	0.898	0.896	0.895	0.909	0.953	1	1.058	1.120	1.166	1.179	1.238	1.295	
ITA	0.919	0.952	0.970	0.974	0.974	0.991	1	1.022	1.039	1.027	0.971	0.988	0.993	
JPN	0.922	0.942	0.946	0.948	0.964	0.987	1	1.017	1.039	1.028	0.972	1.015	1.007	
KOR	0.738	0.803	0.835	0.894	0.919	0.962	1	1.052	1.105	1.131	1.135	1.206	1.250	
NLD	0.901	0.937	0.955	0.955	0.959	0.980	1	1.034	1.074	1.094	1.054	1.071	1.082	
NZL	0.810	0.829	0.858	0.900	0.935	0.969	1	1.022	1.051	1.040	1.048	1.058	1.064	
NOR	0.869	0.897	0.915	0.929	0.938	0.975	1	1.023	1.050	1.051	1.034	1.039	1.051	
PRT	0.923	0.960	0.979	0.986	0.977	0.992	1	1.014	1.038	1.038	1.008	1.028	1.012	
ESP	0.811	0.852	0.883	0.907	0.935	0.965	1	1.041	1.077	1.087	1.046	1.043	1.047	
SWE	0.838	0.876	0.887	0.909	0.930	0.969	1	1.043	1.078	1.071	1.017	1.084	1.124	
CHE	0.904	0.937	0.949	0.951	0.951	0.974	1	1.038	1.077	1.101	1.079	1.112	1.134	
GBR	0.829	0.864	0.889	0.911	0.945	0.973	1	1.026	1.063	1.053	1.011	1.029	1.039	
USA	0.853	0.889	0.898	0.914	0.938	0.970	1	1.027	1.046	1.042	1.010	1.034	1.053	

Note: AUS, Australia; AUT, Austria; BEL, Belgium; CAN, Canada; DEN, Denmark; FIN, Finland; FRA, France; DEU, Germany; GRE, Greece; ISL, Iceland; IRL, Ireland; ISR, Israel; ITA, Italy; JPN, Japan; KOR, Korea; NLD, Netherlands; NZL, New Zealand; NOR, Norway; PRT, Portugal; ESP, Spain; SWE, Sweden; CHE, Switzerland; GBR, United Kingdom; USA, United States.

The resulting productive capital stocks of different types of asset are weighted by their relative productivity in production to estimate a country's overall productive capital stock.³ K is the overall productive capital stock from the OECD Economic Outlook database.⁴ The OECD Economic Outlook database has gaps in data for the productive capital stock of Germany (1985-90), Greece (1985-94), and Ireland (1985-89) over the study period of 1985-2011. Subsequently, those missing observations were filled in by assuming the perpetual inventory model with a constant scrapping rate. To determine the constant scrapping rate for each of the three countries, annual scrapping rates were estimated using constant price non-residential fixed capital formation for the years in which data on productive capital stock are available, and then each country's first five-year average was calculated. The resulting scrapping rate was respectively 0.036 (Germany), 0.032 (Greece), and 0.086 (Ireland). Table 2 converts the productive capital stocks of 24 countries to indices with 2005 = 1.

L is "total hours actually worked" from the OECD Productivity database. The measure covers total employment comprising wage and salary earners as well as the self-employed (including contributing family members), and it is corrected for paid holidays, sick leave and annual leave.⁵ During 1985-2011, there are missing values of L for Austria (1985-94) and Portugal (1985) that were filled in using the estimated growth rate of L . To estimate the growth rate of total hours worked (L), it was assumed to be the sum of the growth rates of total employment measured by the number of persons (TE) and average hours worked per person (AH). While the OECD Productivity database provides data on TE for all years during 1985-2011, data on AH at the level of the total economy is not available from the OECD for Austria (1985-94) and Portugal (1985). In estimation, therefore, the growth rates of AH for manufacturing wage earners in Austria and AH for total employees in Portugal were used instead. These data on AH were from International Labour Office (ILO) LABORSTA Internet. Table 3 presents the values of L that have been converted to indices with 2005 = 1.

³ For a more formal presentation of the construction, see OECD (2001: Annex 4).

⁴ Data was extracted from OECD Economic Outlook No. 92 on May 20, 2013. The OECD also provides other types of internationally comparable capital stock data. Schreyer, Dupont, Koh, and Webb (2011) discuss the issues associated with different types of capital stock data available at the OECD.

⁵ See OECD (2001: Chapter 4) for details. OECD (2003) provides a summary of various issues associated with the measurement of total hours worked.

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Table 2. Productive capital stock (in volume, 2005 = 1)

	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998
AUS	0.587	0.603	0.620	0.640	0.659	0.673	0.682	0.691	0.701	0.715	0.730	0.748	0.768	0.788
AUT	0.656	0.668	0.681	0.695	0.711	0.730	0.752	0.771	0.788	0.806	0.821	0.836	0.851	0.867
BEL	0.707	0.716	0.727	0.743	0.762	0.786	0.806	0.824	0.841	0.855	0.868	0.881	0.896	0.911
CAN	0.464	0.486	0.510	0.538	0.567	0.593	0.617	0.637	0.655	0.675	0.695	0.715	0.741	0.768
DEN	0.611	0.633	0.654	0.674	0.695	0.714	0.731	0.745	0.756	0.768	0.784	0.800	0.819	0.842
FIN	0.666	0.690	0.715	0.745	0.781	0.812	0.831	0.841	0.843	0.842	0.847	0.856	0.868	0.883
FRA	0.689	0.702	0.715	0.730	0.748	0.766	0.784	0.800	0.813	0.824	0.835	0.846	0.856	0.869
DEU	0.647	0.656	0.667	0.678	0.691	0.706	0.807	0.830	0.848	0.864	0.880	0.893	0.906	0.920
GRE	0.619	0.623	0.621	0.619	0.617	0.621	0.627	0.634	0.640	0.645	0.650	0.666	0.682	0.704
ISL	0.472	0.489	0.511	0.534	0.552	0.570	0.590	0.603	0.611	0.617	0.625	0.641	0.663	0.706
IRL	0.353	0.409	0.453	0.487	0.512	0.530	0.543	0.554	0.563	0.573	0.588	0.609	0.636	0.672
ISR	0.361	0.372	0.387	0.401	0.413	0.429	0.450	0.476	0.514	0.558	0.602	0.652	0.700	0.744
ITA	0.616	0.634	0.652	0.673	0.695	0.718	0.740	0.759	0.771	0.782	0.797	0.812	0.827	0.845
JPN	0.518	0.541	0.565	0.593	0.625	0.661	0.697	0.731	0.763	0.792	0.820	0.845	0.871	0.894
KOR	0.184	0.203	0.227	0.254	0.286	0.324	0.368	0.410	0.453	0.504	0.564	0.627	0.683	0.707
NLD	0.676	0.692	0.707	0.725	0.742	0.759	0.777	0.793	0.806	0.818	0.831	0.847	0.864	0.884
NZL	0.625	0.641	0.658	0.672	0.687	0.698	0.701	0.704	0.712	0.725	0.743	0.762	0.779	0.794
NOR	0.640	0.658	0.677	0.694	0.704	0.712	0.720	0.727	0.733	0.741	0.754	0.772	0.795	0.823
PRT	0.513	0.510	0.512	0.524	0.538	0.556	0.577	0.600	0.617	0.637	0.658	0.682	0.714	0.752
ESP	0.397	0.410	0.426	0.447	0.472	0.500	0.529	0.556	0.578	0.600	0.625	0.649	0.676	0.708
SWE	0.635	0.653	0.673	0.694	0.720	0.745	0.762	0.773	0.778	0.789	0.805	0.822	0.838	0.857
CHE	0.601	0.619	0.638	0.660	0.684	0.710	0.735	0.754	0.769	0.787	0.807	0.826	0.844	0.866
GBR	0.559	0.568	0.580	0.596	0.615	0.636	0.654	0.671	0.688	0.704	0.722	0.741	0.762	0.792
USA	0.575	0.595	0.613	0.632	0.651	0.669	0.684	0.698	0.712	0.727	0.745	0.764	0.787	0.813
	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	
AUS	0.808	0.825	0.844	0.869	0.902	0.945	1	1.049	1.109	1.176	1.237	1.302	1.375	
AUT	0.884	0.906	0.927	0.943	0.963	0.982	1	1.018	1.037	1.055	1.066	1.079	1.095	
BEL	0.925	0.940	0.953	0.963	0.970	0.984	1	1.016	1.036	1.058	1.073	1.086	1.103	
CAN	0.799	0.830	0.862	0.891	0.923	0.958	1	1.047	1.095	1.143	1.176	1.221	1.270	
DEN	0.862	0.885	0.907	0.928	0.946	0.970	1	1.028	1.055	1.083	1.099	1.113	1.126	
FIN	0.898	0.914	0.934	0.950	0.965	0.982	1	1.019	1.048	1.079	1.098	1.113	1.131	
FRA	0.886	0.906	0.927	0.944	0.961	0.980	1	1.021	1.046	1.071	1.088	1.106	1.125	
DEU	0.936	0.954	0.969	0.978	0.985	0.992	1	1.013	1.028	1.044	1.047	1.052	1.062	
GRE	0.735	0.774	0.816	0.860	0.909	0.960	1	1.036	1.120	1.195	1.257	1.301	1.324	
ISL	0.745	0.791	0.828	0.851	0.880	0.923	1	1.110	1.185	1.238	1.236	1.234	1.237	
IRL	0.717	0.764	0.808	0.853	0.895	0.943	1	1.059	1.133	1.201	1.243	1.266	1.273	
ISR	0.789	0.829	0.875	0.911	0.943	0.971	1	1.037	1.086	1.138	1.183	1.233	1.299	
ITA	0.864	0.886	0.909	0.934	0.956	0.978	1	1.023	1.048	1.068	1.077	1.088	1.098	
JPN	0.916	0.936	0.952	0.966	0.977	0.988	1	1.009	1.018	1.026	1.030	1.035	1.039	
KOR	0.740	0.787	0.829	0.873	0.916	0.958	1	1.045	1.094	1.136	1.173	1.220	1.264	
NLD	0.907	0.929	0.948	0.963	0.976	0.988	1	1.016	1.043	1.071	1.088	1.100	1.114	
NZL	0.812	0.832	0.855	0.880	0.913	0.953	1	1.044	1.093	1.134	1.159	1.190	1.221	
NOR	0.851	0.875	0.899	0.925	0.947	0.970	1	1.038	1.089	1.144	1.183	1.217	1.251	
PRT	0.794	0.838	0.880	0.916	0.945	0.976	1	1.025	1.055	1.087	1.111	1.130	1.140	
ESP	0.744	0.783	0.823	0.863	0.906	0.950	1	1.055	1.116	1.174	1.218	1.257	1.291	
SWE	0.880	0.905	0.927	0.945	0.961	0.978	1	1.027	1.059	1.092	1.107	1.126	1.150	
CHE	0.888	0.911	0.931	0.949	0.964	0.981	1	1.023	1.049	1.075	1.093	1.116	1.140	
GBR	0.821	0.852	0.881	0.910	0.938	0.967	1	1.037	1.082	1.127	1.161	1.193	1.220	
USA	0.843	0.877	0.907	0.930	0.952	0.975	1	1.028	1.059	1.087	1.102	1.121	1.141	

Note: AUS, Australia; AUT, Austria; BEL, Belgium; CAN, Canada; DEN, Denmark; FIN, Finland; FRA, France; DEU, Germany; GRE, Greece; ISL, Iceland; IRL, Ireland; SR, Israel; ITA, Italy; JPN, Japan; KOR, Korea; NLD, Netherlands; NZL, New Zealand; NOR, Norway; PRT, Portugal; ESP, Spain; SWE, Sweden; CHE, Switzerland; GBR, United Kingdom; USA, United States.

Table 3. Total hours actually worked (in annual hours, 2005 = 1)

	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998
AUS	0.709	0.725	0.751	0.783	0.808	0.792	0.783	0.782	0.802	0.837	0.856	0.861	0.873	0.883
AUT	0.856	0.860	0.861	0.869	0.882	0.900	0.914	0.920	0.916	0.918	0.919	0.926	0.933	0.943
BEL	0.924	0.918	0.917	0.928	0.937	0.955	0.937	0.923	0.892	0.888	0.917	0.904	0.918	0.941
CAN	0.741	0.764	0.793	0.822	0.840	0.842	0.817	0.808	0.817	0.836	0.848	0.865	0.877	0.895
DEN	0.971	0.996	0.979	0.961	0.946	0.937	0.928	0.929	0.915	0.907	0.917	0.922	0.945	0.969
FIN	1.079	1.063	1.072	1.088	1.096	1.071	0.998	0.930	0.876	0.873	0.889	0.901	0.930	0.942
FRA	0.945	0.947	0.962	0.977	0.985	0.992	0.987	0.982	0.963	0.961	0.956	0.962	0.963	0.972
DEU	1.020	1.027	1.028	1.039	1.043	1.060	1.077	1.071	1.046	1.043	1.036	1.023	1.018	1.025
GRE	0.876	0.874	0.856	0.865	0.886	0.888	0.880	0.905	0.921	0.923	0.924	0.910	0.890	0.926
ISL	0.840	0.863	0.911	0.887	0.874	0.860	0.860	0.867	0.853	0.853	0.887	0.901	0.891	0.918
IRL	0.676	0.684	0.682	0.684	0.687	0.713	0.700	0.687	0.688	0.710	0.742	0.771	0.793	0.823
ISR	0.519	0.526	0.541	0.547	0.557	0.568	0.597	0.647	0.678	0.739	0.796	0.839	0.868	0.889
ITA	0.909	0.920	0.931	0.943	0.942	0.951	0.965	0.960	0.934	0.916	0.915	0.927	0.925	0.943
JPN	1.110	1.118	1.122	1.133	1.137	1.134	1.139	1.133	1.102	1.099	1.095	1.100	1.092	1.066
KOR	0.803	0.840	0.877	0.890	0.892	0.901	0.922	0.932	0.950	0.974	1.005	1.023	1.019	0.922
NLD	0.775	0.786	0.792	0.804	0.823	0.845	0.856	0.872	0.869	0.880	0.906	0.929	0.952	0.969
NZL	0.795	0.790	0.795	0.767	0.741	0.738	0.718	0.723	0.760	0.790	0.824	0.847	0.846	0.841
NOR	0.941	0.969	0.971	0.968	0.938	0.925	0.914	0.919	0.923	0.935	0.943	0.959	0.984	1.008
PRT	0.935	0.921	0.954	0.977	1.008	1.064	1.005	0.951	0.935	0.938	0.961	0.952	0.958	0.978
ESP	0.656	0.677	0.702	0.725	0.744	0.763	0.769	0.755	0.730	0.717	0.721	0.732	0.758	0.793
SWE	0.972	0.976	0.991	1.017	1.031	1.038	1.014	0.980	0.939	0.952	0.970	0.970	0.960	0.976
CHE	0.819	0.833	0.853	0.875	0.891	0.914	0.988	0.979	0.969	0.974	0.962	0.946	0.939	0.956
GBR	0.899	0.907	0.919	0.971	0.989	0.986	0.958	0.917	0.905	0.917	0.929	0.937	0.954	0.961
USA	0.777	0.786	0.807	0.831	0.854	0.856	0.844	0.844	0.864	0.891	0.913	0.924	0.951	0.972
	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	
AUS	0.913	0.915	0.913	0.938	0.955	0.978	1	1.029	1.060	1.071	1.072	1.106	1.122	
AUT	0.960	0.972	0.979	0.979	0.984	0.988	1	1.017	1.036	1.058	1.048	1.055	1.074	
BEL	0.955	0.952	0.986	0.986	0.982	0.976	1	1.012	1.025	1.048	1.034	1.042	1.074	
CAN	0.920	0.938	0.941	0.954	0.966	0.991	1	1.015	1.035	1.047	1.010	1.034	1.051	
DEN	0.984	0.999	1.011	1.007	0.994	0.990	1	1.025	1.043	1.061	1.019	0.997	0.995	
FIN	0.967	0.980	0.983	0.988	0.984	0.991	1	1.014	1.035	1.051	1.013	1.016	1.029	
FRA	0.988	0.989	0.998	0.978	0.977	0.997	1	0.996	1.018	1.028	1.001	1.004	1.007	
DEU	1.035	1.038	1.029	1.015	1.002	1.005	1	1.001	1.016	1.028	1.001	1.024	1.038	
GRE	0.946	0.951	0.952	0.968	0.977	0.990	1	1.004	1.006	1.020	0.990	0.982	0.923	
ISL	0.980	1.007	1.003	0.969	0.969	0.973	1	1.044	1.078	1.089	0.976	0.966	0.993	
IRL	0.862	0.898	0.923	0.929	0.931	0.961	1	1.038	1.068	1.036	0.916	0.880	0.864	
ISR	0.920	0.959	0.955	0.966	0.964	0.970	1	1.026	1.083	1.129	1.137	1.170	1.207	
ITA	0.951	0.962	0.972	0.982	0.994	0.998	1	1.017	1.031	1.026	0.992	0.987	0.989	
JPN	1.033	1.033	1.018	1.000	1.001	1.000	1	1.009	1.014	1.002	0.954	0.961	0.915	
KOR	0.941	0.988	1.003	1.016	0.998	1.004	1	1.011	1.006	0.985	0.976	0.970	0.943	
NLD	0.992	1.013	1.026	1.020	1.010	0.999	1	1.016	1.039	1.058	1.044	1.039	1.040	
NZL	0.860	0.872	0.889	0.918	0.940	0.980	1	1.011	1.017	1.015	0.996	1.015	1.034	
NOR	1.016	1.009	0.995	0.988	0.967	0.986	1	1.032	1.080	1.117	1.098	1.107	1.125	
PRT	0.999	0.993	1.014	1.019	0.998	1.010	1	1.008	0.991	1.006	0.965	0.948	0.917	
ESP	0.830	0.871	0.903	0.924	0.945	0.971	1	1.032	1.054	1.055	0.991	0.969	0.960	
SWE	1.001	1.012	1.018	1.004	0.990	0.998	1	1.013	1.045	1.057	1.027	1.059	1.083	
CHE	0.977	0.983	0.977	0.971	0.975	0.996	1	1.015	1.035	1.054	1.055	1.072	1.072	
GBR	0.969	0.971	0.982	0.977	0.980	0.991	1	1.007	1.019	1.015	0.994	0.997	0.984	
USA	0.991	1.004	0.992	0.979	0.974	0.985	1	1.018	1.025	1.014	0.958	0.958	0.973	

Note: AUS, Australia; AUT, Austria; BEL, Belgium; CAN, Canada; DEN, Denmark; FIN, Finland; FRA, France; DEU, Germany; GRE, Greece; ISL, Iceland; IRL, Ireland; SR, Israel; ITA, Italy; JPN, Japan; KOR, Korea; NLD, Netherlands; NZL, New Zealand; NOR, Norway; PRT, Portugal; ESP, Spain; SWE, Sweden; CHE, Switzerland; GBR, United Kingdom; USA, United States.

GLOBAL TRENDS OF MULTI-FACTOR PRODUCTIVITY

Table 4. Average share of labor income (2005-2008)

	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998
AUS	0.425	0.425	0.425	0.425	0.425	0.425	0.425	0.425	0.425	0.425	0.425	0.425	0.425	0.425
AUT	0.338	0.338	0.338	0.338	0.338	0.338	0.338	0.338	0.338	0.338	0.338	0.338	0.338	0.338
BEL	0.326	0.326	0.326	0.326	0.326	0.326	0.326	0.326	0.326	0.326	0.326	0.326	0.326	0.326
CAN	0.397	0.397	0.397	0.397	0.397	0.397	0.397	0.397	0.397	0.397	0.397	0.397	0.397	0.397
DEN	0.306	0.306	0.306	0.306	0.306	0.306	0.306	0.306	0.306	0.306	0.306	0.306	0.306	0.306
FIN	0.370	0.370	0.370	0.370	0.370	0.370	0.370	0.370	0.370	0.370	0.370	0.370	0.370	0.370
FRA	0.328	0.328	0.328	0.328	0.328	0.328	0.328	0.328	0.328	0.328	0.328	0.328	0.328	0.328
DEU	0.334	0.334	0.334	0.334	0.334	0.334	0.334	0.334	0.334	0.334	0.334	0.334	0.334	0.334
GRE	0.361	0.361	0.361	0.361	0.361	0.361	0.361	0.361	0.361	0.361	0.361	0.361	0.361	0.361
ISL	0.309	0.309	0.309	0.309	0.309	0.309	0.309	0.309	0.309	0.309	0.309	0.309	0.309	0.309
IRL	0.405	0.405	0.405	0.405	0.405	0.405	0.405	0.405	0.405	0.405	0.405	0.405	0.405	0.405
ISR	0.373	0.373	0.373	0.373	0.373	0.373	0.373	0.373	0.373	0.373	0.373	0.373	0.373	0.373
ITA	0.331	0.331	0.331	0.331	0.331	0.331	0.331	0.331	0.331	0.331	0.331	0.331	0.331	0.331
JPN	0.400	0.400	0.400	0.400	0.400	0.400	0.400	0.400	0.400	0.400	0.400	0.400	0.400	0.400
KOR	0.231	0.231	0.231	0.231	0.231	0.231	0.231	0.231	0.231	0.231	0.231	0.231	0.231	0.231
NLD	0.333	0.333	0.333	0.333	0.333	0.333	0.333	0.333	0.333	0.333	0.333	0.333	0.333	0.333
NZL	0.501	0.501	0.501	0.501	0.501	0.501	0.501	0.501	0.501	0.501	0.501	0.501	0.501	0.501
NOR	0.483	0.483	0.483	0.483	0.483	0.483	0.483	0.483	0.483	0.483	0.483	0.483	0.483	0.483
PRT	0.326	0.326	0.326	0.326	0.326	0.326	0.326	0.326	0.326	0.326	0.326	0.326	0.326	0.326
ESP	0.367	0.367	0.367	0.367	0.367	0.367	0.367	0.367	0.367	0.367	0.367	0.367	0.367	0.367
SWE	0.343	0.343	0.343	0.343	0.343	0.343	0.343	0.343	0.343	0.343	0.343	0.343	0.343	0.343
CHE	0.351	0.351	0.351	0.351	0.351	0.351	0.351	0.351	0.351	0.351	0.351	0.351	0.351	0.351
GBR	0.311	0.311	0.311	0.311	0.311	0.311	0.311	0.311	0.311	0.311	0.311	0.311	0.311	0.311
USA	0.348	0.348	0.348	0.348	0.348	0.348	0.348	0.348	0.348	0.348	0.348	0.348	0.348	0.348
	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	
AUS	0.425	0.425	0.425	0.425	0.425	0.425	0.425	0.425	0.425	0.425	0.425	0.425	0.425	
AUT	0.338	0.338	0.338	0.338	0.338	0.338	0.338	0.338	0.338	0.338	0.338	0.338	0.338	
BEL	0.326	0.326	0.326	0.326	0.326	0.326	0.326	0.326	0.326	0.326	0.326	0.326	0.326	
CAN	0.397	0.397	0.397	0.397	0.397	0.397	0.397	0.397	0.397	0.397	0.397	0.397	0.397	
DEN	0.306	0.306	0.306	0.306	0.306	0.306	0.306	0.306	0.306	0.306	0.306	0.306	0.306	
FIN	0.370	0.370	0.370	0.370	0.370	0.370	0.370	0.370	0.370	0.370	0.370	0.370	0.370	
FRA	0.328	0.328	0.328	0.328	0.328	0.328	0.328	0.328	0.328	0.328	0.328	0.328	0.328	
DEU	0.334	0.334	0.334	0.334	0.334	0.334	0.334	0.334	0.334	0.334	0.334	0.334	0.334	
GRE	0.361	0.361	0.361	0.361	0.361	0.361	0.361	0.361	0.361	0.361	0.361	0.361	0.361	
ISL	0.309	0.309	0.309	0.309	0.309	0.309	0.309	0.309	0.309	0.309	0.309	0.309	0.309	
IRL	0.405	0.405	0.405	0.405	0.405	0.405	0.405	0.405	0.405	0.405	0.405	0.405	0.405	
ISR	0.373	0.373	0.373	0.373	0.373	0.373	0.373	0.373	0.373	0.373	0.373	0.373	0.373	
ITA	0.331	0.331	0.331	0.331	0.331	0.331	0.331	0.331	0.331	0.331	0.331	0.331	0.331	
JPN	0.400	0.400	0.400	0.400	0.400	0.400	0.400	0.400	0.400	0.400	0.400	0.400	0.400	
KOR	0.231	0.231	0.231	0.231	0.231	0.231	0.231	0.231	0.231	0.231	0.231	0.231	0.231	
NLD	0.333	0.333	0.333	0.333	0.333	0.333	0.333	0.333	0.333	0.333	0.333	0.333	0.333	
NZL	0.501	0.501	0.501	0.501	0.501	0.501	0.501	0.501	0.501	0.501	0.501	0.501	0.501	
NOR	0.483	0.483	0.483	0.483	0.483	0.483	0.483	0.483	0.483	0.483	0.483	0.483	0.483	
PRT	0.326	0.326	0.326	0.326	0.326	0.326	0.326	0.326	0.326	0.326	0.326	0.326	0.326	
ESP	0.367	0.367	0.367	0.367	0.367	0.367	0.367	0.367	0.367	0.367	0.367	0.367	0.367	
SWE	0.343	0.343	0.343	0.343	0.343	0.343	0.343	0.343	0.343	0.343	0.343	0.343	0.343	
CHE	0.351	0.351	0.351	0.351	0.351	0.351	0.351	0.351	0.351	0.351	0.351	0.351	0.351	
GBR	0.311	0.311	0.311	0.311	0.311	0.311	0.311	0.311	0.311	0.311	0.311	0.311	0.311	
USA	0.348	0.348	0.348	0.348	0.348	0.348	0.348	0.348	0.348	0.348	0.348	0.348	0.348	

Note: AUS, Australia; AUT, Austria; BEL, Belgium; CAN, Canada; DEN, Denmark; FIN, Finland; FRA, France; DEU, Germany; GRE, Greece; ISL, Iceland; IRL, Ireland; SR, Israel; ITA, Italy; JPN, Japan; KOR, Korea; NLD, Netherlands; NZL, New Zealand; NOR, Norway; PRT, Portugal; ESP, Spain; SWE, Sweden; CHE, Switzerland; GBR, United Kingdom; USA, United States.

Table 5. Multi-factor productivity (2005 = 1)

	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998
AUS	0.780	0.781	0.799	0.800	0.804	0.803	0.808	0.836	0.853	0.858	0.873	0.895	0.918	0.946
AUT	0.777	0.788	0.793	0.808	0.825	0.842	0.854	0.860	0.861	0.873	0.891	0.902	0.913	0.935
BEL	0.753	0.766	0.781	0.805	0.821	0.827	0.847	0.862	0.868	0.894	0.891	0.908	0.927	0.925
CAN	0.933	0.921	0.921	0.926	0.919	0.902	0.886	0.888	0.893	0.912	0.919	0.913	0.930	0.943
DEN	0.804	0.820	0.823	0.826	0.831	0.844	0.854	0.865	0.870	0.919	0.934	0.951	0.957	0.953
FIN	0.672	0.688	0.698	0.717	0.737	0.741	0.722	0.725	0.746	0.775	0.795	0.813	0.843	0.872
FRA	0.761	0.773	0.778	0.800	0.823	0.834	0.839	0.849	0.850	0.866	0.883	0.885	0.900	0.920
DEU	0.778	0.788	0.794	0.813	0.837	0.865	0.861	0.873	0.872	0.889	0.902	0.912	0.927	0.935
GRE	0.792	0.795	0.789	0.818	0.837	0.834	0.862	0.849	0.823	0.836	0.851	0.872	0.908	0.905
ISL	0.768	0.792	0.817	0.820	0.823	0.833	0.822	0.785	0.801	0.827	0.803	0.826	0.864	0.883
IRL	0.585	0.546	0.549	0.560	0.579	0.605	0.618	0.641	0.653	0.673	0.711	0.749	0.807	0.840
ISR	0.907	0.926	0.961	0.969	0.953	0.996	1.021	1.025	1.007	0.994	0.984	0.973	0.957	0.962
ITA	0.871	0.881	0.893	0.913	0.935	0.937	0.933	0.936	0.940	0.969	0.991	0.988	1.001	0.996
JPN	0.805	0.812	0.829	0.866	0.891	0.921	0.930	0.923	0.924	0.919	0.927	0.937	0.945	0.929
KOR	0.454	0.482	0.510	0.549	0.569	0.599	0.627	0.642	0.657	0.684	0.709	0.731	0.761	0.768
NLD	0.785	0.793	0.799	0.811	0.828	0.841	0.848	0.846	0.853	0.867	0.872	0.882	0.898	0.916
NZL	0.838	0.847	0.837	0.857	0.863	0.860	0.860	0.865	0.891	0.910	0.917	0.921	0.937	0.942
NOR	0.733	0.741	0.743	0.735	0.749	0.765	0.789	0.811	0.828	0.860	0.884	0.911	0.935	0.931
PRT	0.707	0.745	0.773	0.812	0.839	0.832	0.892	0.924	0.906	0.904	0.918	0.946	0.970	0.988
ESP	0.950	0.951	0.967	0.979	0.989	0.989	0.989	0.991	0.988	1.010	1.018	1.019	1.019	1.017
SWE	0.748	0.759	0.770	0.769	0.773	0.769	0.766	0.770	0.774	0.794	0.809	0.817	0.839	0.858
CHE	0.990	0.987	0.977	0.981	0.999	1.005	0.936	0.933	0.931	0.932	0.936	0.943	0.959	0.965
GBR	0.720	0.741	0.763	0.765	0.765	0.765	0.759	0.783	0.809	0.831	0.844	0.858	0.872	0.888
USA	0.773	0.784	0.787	0.795	0.801	0.807	0.806	0.827	0.832	0.843	0.844	0.861	0.874	0.890
	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	
AUS	0.954	0.962	0.991	0.995	1.009	1.007	1	1.000	0.997	0.980	0.981	0.962	0.953	
AUT	0.951	0.969	0.966	0.976	0.975	0.991	1	1.019	1.038	1.032	0.995	1.007	1.017	
BEL	0.943	0.974	0.955	0.965	0.973	1.004	1	1.013	1.027	1.014	0.991	1.006	0.998	
CAN	0.963	0.987	0.987	0.995	0.993	0.992	1	1.001	0.993	0.976	0.959	0.961	0.960	
DEN	0.960	0.976	0.967	0.968	0.975	0.992	1	1.008	1.003	0.976	0.943	0.969	0.977	
FIN	0.886	0.920	0.931	0.939	0.954	0.984	1	1.028	1.058	1.040	0.966	0.992	1.005	
FRA	0.934	0.961	0.966	0.982	0.985	0.991	1	1.020	1.021	1.006	0.986	0.995	1.004	
DEU	0.941	0.962	0.977	0.983	0.985	0.993	1	1.032	1.050	1.047	1.011	1.035	1.054	
GRE	0.909	0.929	0.949	0.953	0.984	0.999	1	1.039	1.045	1.009	0.979	0.923	0.887	
ISL	0.864	0.868	0.892	0.907	0.919	0.975	1	0.984	1.000	0.991	0.999	0.967	0.972	
IRL	0.884	0.931	0.943	0.971	0.988	0.990	1	1.007	1.016	0.989	0.992	1.001	1.024	
ISR	0.951	0.988	0.969	0.947	0.950	0.983	1	1.027	1.034	1.030	1.022	1.038	1.044	
ITA	0.997	1.017	1.020	1.009	0.993	0.999	1	1.003	1.003	0.988	0.952	0.970	0.969	
JPN	0.936	0.949	0.954	0.962	0.973	0.992	1	1.008	1.023	1.017	0.987	1.025	1.046	
KOR	0.828	0.856	0.870	0.912	0.940	0.968	1	1.033	1.078	1.111	1.114	1.180	1.239	
NLD	0.936	0.951	0.955	0.955	0.960	0.984	1	1.017	1.033	1.030	0.996	1.012	1.016	
NZL	0.969	0.974	0.984	1.001	1.010	1.002	1	0.995	0.998	0.970	0.975	0.963	0.947	
NOR	0.931	0.952	0.966	0.970	0.979	0.996	1	0.988	0.969	0.930	0.908	0.896	0.888	
PRT	0.996	1.021	1.011	1.002	0.996	0.994	1	1.001	1.027	1.007	0.998	1.023	1.028	
ESP	1.017	1.017	1.012	1.007	1.005	1.002	1	1.000	1.001	0.990	0.979	0.978	0.979	
SWE	0.875	0.899	0.899	0.924	0.949	0.978	1	1.025	1.027	1.002	0.965	1.002	1.016	
CHE	0.957	0.979	0.988	0.987	0.979	0.983	1	1.019	1.036	1.037	1.011	1.023	1.035	
GBR	0.901	0.927	0.937	0.953	0.978	0.989	1	1.010	1.024	1.004	0.969	0.977	0.987	
USA	0.910	0.927	0.934	0.951	0.970	0.988	1	1.005	1.009	1.003	1.004	1.022	1.024	

Note: AUS, Australia; AUT, Austria; BEL, Belgium; CAN, Canada; DEN, Denmark; FIN, Finland; FRA, France; DEU, Germany; GRE, Greece; ISL, Iceland; IRL, Ireland; SR, Israel; ITA, Italy; JPN, Japan; KOR, Korea; NLD, Netherlands; NZL, New Zealand; NOR, Norway; PRT, Portugal; ESP, Spain; SWE, Sweden; CHE, Switzerland; GBR, United Kingdom; USA, United States.

Table 6. Growth rate of multi-factor productivity (in percent)

	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998
AUS	0.14	2.31	0.13	0.47	-0.05	0.48	3.61	1.95	0.63	1.72	2.51	2.56	3.10	0.14
AUT	1.38	0.62	1.95	2.07	2.03	1.43	0.77	0.04	1.48	1.97	1.34	1.21	2.39	1.38
BEL	1.77	1.91	3.18	1.90	0.81	2.32	1.85	0.71	2.95	-0.32	1.88	2.13	-0.25	1.77
CAN	-1.25	0.01	0.55	-0.81	-1.74	-1.82	0.27	0.57	2.12	0.76	-0.68	1.88	1.37	-1.25
DEN	1.97	0.45	0.28	0.72	1.46	1.21	1.29	0.55	5.64	1.68	1.80	0.67	-0.42	1.97
FIN	2.26	1.54	2.71	2.82	0.50	-2.58	0.42	2.96	3.88	2.55	2.29	3.61	3.52	2.26
FRA	1.52	0.69	2.86	2.82	1.36	0.55	1.17	0.18	1.89	1.98	0.18	1.70	2.25	1.52
DEU	1.30	0.84	2.39	2.98	3.33	-0.51	1.35	-0.11	1.95	1.56	1.10	1.61	0.83	1.30
GRE	0.41	-0.82	3.72	2.29	-0.36	3.35	-1.48	-3.04	1.54	1.78	2.52	4.12	-0.34	0.41
ISL	3.11	3.17	0.35	0.36	1.27	-1.28	-4.57	2.01	3.32	-2.94	2.88	4.63	2.13	3.11
IRL	-6.78	0.52	2.02	3.46	4.53	2.13	3.71	1.92	3.01	5.69	5.35	7.76	4.00	-6.78
ISR	2.11	3.79	0.86	-1.70	4.51	2.58	0.32	-1.77	-1.25	-1.04	-1.04	-1.65	0.44	2.11
ITA	1.16	1.36	2.25	2.41	0.22	-0.46	0.32	0.46	3.03	2.32	-0.38	1.38	-0.50	1.16
JPN	0.67	2.10	4.47	2.94	3.38	0.96	-0.76	0.08	-0.48	0.81	1.07	0.83	-1.61	0.67
KOR	5.99	5.89	7.59	3.64	5.40	4.64	2.29	2.46	4.02	3.64	3.21	4.00	0.98	5.99
NLD	1.05	0.73	1.53	2.03	1.56	0.80	-0.20	0.88	1.65	0.55	1.10	1.90	1.91	1.05
NZL	1.11	-1.20	2.31	0.80	-0.43	0.00	0.57	3.07	2.17	0.67	0.43	1.82	0.46	1.11
NOR	1.06	0.30	-1.14	1.89	2.14	3.17	2.79	2.11	3.83	2.83	3.04	2.57	-0.36	1.06
PRT	5.47	3.75	5.01	3.32	-0.87	7.19	3.63	-1.91	-0.21	1.49	3.10	2.49	1.89	5.47
ESP	0.10	1.70	1.18	1.09	-0.01	-0.06	0.25	-0.28	2.15	0.80	0.10	0.07	-0.20	0.10
SWE	1.55	1.43	-0.14	0.57	-0.58	-0.38	0.58	0.49	2.57	1.93	0.91	2.70	2.35	1.55
CHE	-0.33	-1.01	0.37	1.84	0.64	-6.93	-0.31	-0.17	0.11	0.42	0.75	1.71	0.63	-0.33
GBR	2.94	2.93	0.29	-0.06	0.02	-0.72	3.15	3.23	2.82	1.52	1.65	1.69	1.80	2.94
USA	1.43	0.30	1.06	0.70	0.77	-0.09	2.65	0.63	1.29	0.11	2.03	1.51	1.79	1.43
	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	
AUS	0.79	0.89	3.04	0.34	1.41	-0.16	-0.70	0.03	-0.36	-1.69	0.07	-1.91	-0.91	
AUT	1.66	1.94	-0.37	1.09	-0.17	1.66	0.93	1.91	1.82	-0.55	-3.57	1.22	1.01	
BEL	1.95	3.34	-1.95	1.00	0.82	3.25	-0.44	1.33	1.36	-1.24	-2.35	1.53	-0.76	
CAN	2.16	2.45	0.05	0.80	-0.28	-0.01	0.76	0.06	-0.80	-1.65	-1.79	0.26	-0.18	
DEN	0.72	1.66	-0.89	0.06	0.71	1.82	0.76	0.79	-0.44	-2.72	-3.43	2.74	0.85	
FIN	1.57	3.80	1.26	0.86	1.65	3.04	1.64	2.77	2.94	-1.72	-7.07	2.67	1.30	
FRA	1.55	2.83	0.49	1.69	0.36	0.53	0.95	2.05	0.01	-1.47	-1.96	0.92	0.90	
DEU	0.64	2.21	1.63	0.62	0.21	0.73	0.75	3.22	1.70	-0.22	-3.49	2.43	1.77	
GRE	0.45	2.23	2.16	0.41	3.26	1.46	0.15	3.87	0.58	-3.40	-3.04	-5.64	-3.94	
ISL	-2.12	0.50	2.68	1.70	1.39	6.01	2.61	-1.61	1.58	-0.82	0.77	-3.25	0.54	
IRL	5.28	5.33	1.28	2.95	1.72	0.27	0.99	0.73	0.84	-2.61	0.30	0.91	2.26	
ISR	-1.08	3.91	-1.94	-2.27	0.31	3.41	1.78	2.73	0.61	-0.31	-0.81	1.56	0.60	
ITA	0.12	2.00	0.31	-1.12	-1.59	0.64	0.07	0.26	0.00	-1.46	-3.59	1.82	-0.04	
JPN	0.74	1.40	0.50	0.80	1.17	1.97	0.80	0.78	1.53	-0.62	-2.89	3.85	2.01	
KOR	7.86	3.35	1.61	4.81	3.07	3.03	3.26	3.26	4.41	3.00	0.29	5.92	5.03	
NLD	2.18	1.70	0.39	-0.02	0.52	2.54	1.58	1.74	1.50	-0.26	-3.34	1.62	0.46	
NZL	2.88	0.51	1.08	1.75	0.81	-0.71	-0.24	-0.51	0.27	-2.79	0.58	-1.31	-1.66	
NOR	-0.01	2.27	1.40	0.49	0.94	1.78	0.32	-1.17	-1.99	-3.99	-2.35	-1.29	-0.93	
PRT	0.82	2.48	-1.00	-0.87	-0.58	-0.26	0.65	0.07	2.61	-1.97	-0.89	2.59	0.41	
ESP	-0.06	-0.02	-0.46	-0.54	-0.17	-0.26	-0.22	0.04	0.04	-1.08	-1.16	-0.03	0.03	
SWE	1.97	2.74	0.01	2.75	2.70	3.08	2.22	2.46	0.20	-2.43	-3.63	3.78	1.46	
CHE	-0.84	2.28	0.94	-0.10	-0.82	0.41	1.73	1.93	1.63	0.12	-2.54	1.21	1.17	
GBR	1.43	2.91	1.02	1.75	2.58	1.21	1.07	0.99	1.44	-1.99	-3.47	0.77	1.07	
USA	2.25	1.89	0.74	1.80	2.07	1.87	1.16	0.47	0.43	-0.56	0.07	1.78	0.16	

Note: AUS, Australia; AUT, Austria; BEL, Belgium; CAN, Canada; DEN, Denmark; FIN, Finland; FRA, France; DEU, Germany; GRE, Greece; ISL, Iceland; IRL, Ireland; ISR, Israel; ITA, Italy; JPN, Japan; KOR, Korea; NLD, Netherlands; NZL, New Zealand; NOR, Norway; PRT, Portugal; ESP, Spain; SWE, Sweden; CHE, Switzerland; GBR, United Kingdom; USA, United States.

Based on Eq. (6), the MFP index with 2005 = 1 was calculated using the values of Y , K and L reported in Tables 1 through 3. The coefficient $(1 - \alpha)$ is the average share of labor income from 2005-2008 (Table 4).⁶ The calculated MFP indices are reported in Table 5. Finally, Table 6 presents the balanced panel of the growth rates of MFP for 24 OECD countries over 1986-2011.

PRODUCTIVITY GROWTH TRENDS IN OECD

Based on the estimates of MFP growth rates presented in the previous section, this section outlines some notable productivity growth trends in the OECD area over the past 25 years. We start with dividing our study period 1986-2011 into five sub-periods, each half-decade-long, and calculating the average growth rates of MFP for each sub-period. The results, reported in Table 7, clearly show erratic variation in the pace of OECD-wide productivity growth over time. For example, OECD countries as a whole were found to achieve the highest pace of MFP growth in the second half of the 1990s, but this strong productivity growth sharply decelerated – cut by more than 40 percent – in the subsequent sub-period. In fact, productivity slowdown was extensive all over the OECD area during 2001-2005; Iceland, Israel, Japan, and Sweden were the only countries in our sample of 24 countries that did not experience a slowdown in MFP growth in this sub-period.

The pace of OECD productivity growth that already became visibly sluggish during 2001-2005 slowed even further in the following sub-period. The average growth rate in fact came to be negative – representing productivity deterioration – in many countries during 2006-2011. It is very likely that this sharp slowdown was at least partly due to cyclical effects since the period includes the worldwide great recession following the global financial crisis of 2007-2008. Against this backdrop, it is worth to take note of the productivity trend in Korea because the country managed to accelerate the average growth rate of MFP during 2006-2011 in contrast with most other OECD countries, thereby keeping up its productivity growth at a much higher pace vis-à-vis other OECD countries.

The productivity growth trend for three major economies – the US, the Eurozone, and Japan – is presented in Figure 1. The Eurozone includes: Austria, Belgium, Finland, France, Germany, Greece, Ireland, Italy, the Netherlands, Portugal, and Spain. The growth rate of MFP in the Eurozone is constructed using a real GDP weighted average of MFP

⁶ Data on the share of labor income was extracted from OECD.Stat (Unit labour Costs – Annual Indicators) on May 24, 2013.

growth rates in 11 member countries. The trend for the Eurozone is shown for our entire study period of 1986-2011 even though the euro was officially introduced only in 1999.

Table 7. Growth rate of multi-factor productivity: Sub-period average (in percent)

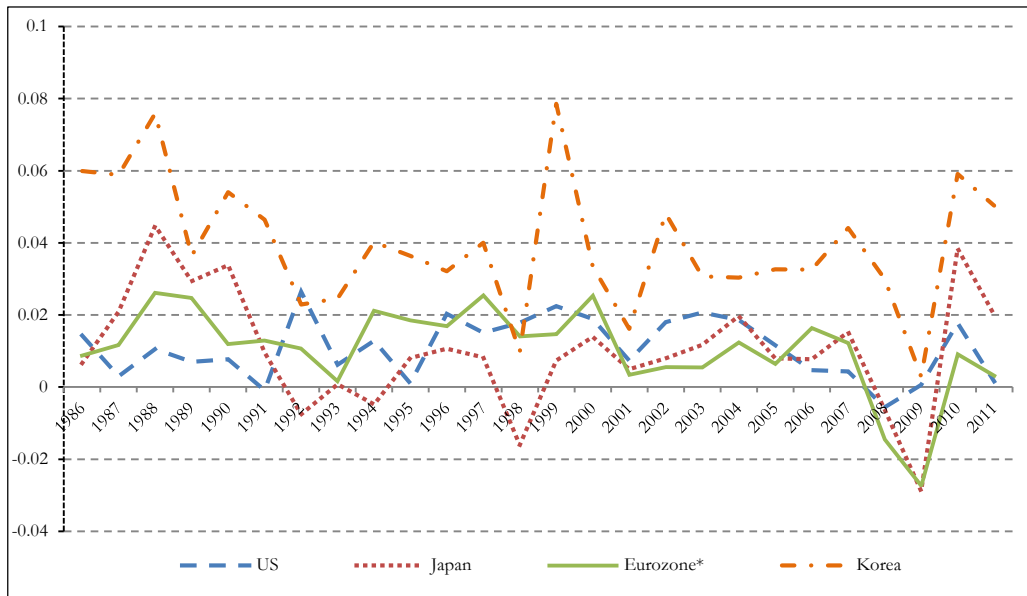
	1986-1990	1991-1995	1996-2000	2001-2005	2006-2011
Australia	0.60	1.68	1.97	0.79	-0.79
Austria	1.60	1.14	1.71	0.63	0.31
Belgium	1.91	1.50	1.81	0.54	-0.02
Canada	-0.65	0.38	1.44	0.26	-0.68
Denmark	0.98	2.07	0.89	0.49	-0.37
Finland	1.97	1.45	2.96	1.69	0.15
France	1.85	1.15	1.70	0.80	0.07
Germany	2.17	0.85	1.28	0.79	0.90
Greece	1.05	0.43	1.79	1.48	-1.93
Iceland	1.65	-0.69	1.60	2.88	-0.46
Ireland	0.75	3.29	5.54	1.44	0.41
Israel	1.91	-0.23	0.12	0.26	0.73
Italy	1.48	1.13	0.52	-0.34	-0.50
Japan	2.71	0.12	0.48	1.05	0.77
Korea	5.70	3.41	3.88	3.16	3.65
Netherlands	1.38	0.74	1.76	1.00	0.29
New Zealand	0.52	1.29	1.22	0.54	-0.90
Norway	0.85	2.95	1.50	0.99	-1.95
Portugal	3.34	2.04	2.15	-0.41	0.47
Spain	0.81	0.57	-0.02	-0.33	-0.36
Sweden	0.57	1.04	2.13	2.15	0.31
Switzerland	0.30	-1.38	0.91	0.43	0.59
United Kingdom	1.22	2.00	1.90	1.53	-0.20
United States	0.85	0.92	1.89	1.53	0.39
Average	1.51	1.14	1.70	0.98	0.07

Figure 1 indicates that productivity growth in the US was relatively weak, often trailing behind that of the Eurozone and Japan, until it accelerated to a much higher pace during the second half of the 1990s that also coincided with the period of exploding Information and Communication Technology (ICT) investment. As this investment boom collapsed in 2000, MFP growth in the US somewhat slowed compared with the robust growth in the previous boom period. Nonetheless, US productivity growth remained to be relatively strong and consistently outpace productivity growth in the Eurozone and Japan at least until 2005.

Turning to the Eurozone, it is clear from Figure 1 that the common currency area has been generally lagging behind the US as well as Japan in promoting productivity growth since its start in 1999. Prior to the official launching of the Eurozone, however, its current member countries as a whole managed to consistently reap a relatively high pace of MFP growth, surpassing the US rate of MFP growth in most years throughout the late 1980s and

the 1990s. It should be noted that Eurozone countries carried out structural reform to meet the euro convergence criteria in the areas of budget deficit, public debt, inflation and interest rates. Those reform measures were likely to help potential member countries to improve their multi-factor productivity during their preparation to join the Eurozone.

Figure 1. Growth rate of multi-factor productivity



* Real GDP weighted average of MFP growth rates of Eurozone countries.

Figure 1 also illustrates that Japan followed a much more erratic path of productivity growth than the US and the Eurozone. After showing particularly strong growth in the second half of the 1980s, Japan's MFP growth began to sharply slow down as the country suffered the bursting of the asset bubble and subsequently entered the so-called lost decade. Throughout the 1990s, Japan's MFP growth was found to be close to virtual stagnation on average, and consistently behind productivity growth of the U.S. and the Eurozone. However, there was a brief recovery of productivity growth in the country over the period 2003-2007 with Japan's MFP growth rate consistently higher than that of the Eurozone during the time. Following the global financial crisis of 2007-2008, a sharp downturn followed by a sharp rebound in productivity growth was common for all three

major economies as shown in Figure 1, but Japan's path exhibited far greater variation than the paths taken by the other two economies.

In addition to the productivity growth trend for the three major economies, the trend for Korea is also included in Figure 1. It is evident that Korea consistently achieved a higher pace of MFP growth than the other three economies over the entire period between 1986-2011. Except for 1992 when Korea was slightly behind the US, the growth of MFP in Korea trailed behind contemporaneous paces for other major economies only in 1998, in the midst of financial crisis, but it strongly rebounded in the following year. Korea also showed a more robust recovery of productivity growth than the other three economies in the wake of the global financial crisis of 2008-2009.

MULTI-FACTOR PRODUCTIVITY AND R&D

The standard neoclassical framework presented in Section 2 clearly identifies MFP as the main driver of long-term economic growth. In the framework, the growth rate of MFP represents the slope of the steady-state growth path. However, the standard neoclassical framework is not effective in explaining what determines the growth rate of MFP since it treats MFP changes as purely exogenous. A series of more recent theoretical models of economic growth explain MFP changes within the model by endogenizing technological progress. These so-called endogenous growth models are broadly grouped into two categories: the product-variety type (e.g., Romer, 1990) and the product-quality type (e.g., Aghion and Howitt, 1992). In the former, technological progress shows up as an expansion of the number of varieties of products, whereas the latter models technological progress as quality improvements for existing kinds of products.

Using the estimates of MFP growth rates obtained for OECD countries, this section attempts to empirically test main theoretical predictions of endogenous growth models in relation to the determinants of multi-factor productivity. Of the two types of endogenous growth models, this section adopts the product-variety approach in which the shift parameter F in Eq. (1) depends on the number of variety of capital inputs as well as exogenous factors. That is, F is characterized by

$$F_t = A_t N_t^{(1-\alpha)} \tag{7}$$

where \mathcal{A} is an exogenous technology factor, and N is the number of varieties of capital inputs that are currently known to and used by all producers.

Subsequently, this section considers the following aggregate production function.⁷

$$Y_t = F_t K_t^\alpha L_t^{(1-\alpha)} = A_t N_t^{(1-\alpha)} K_t^\alpha L_t^{(1-\alpha)} \quad (8)$$

where Y is constant price GDP, L is aggregate labor input measured by total hours worked, K is productive capital stock representing the aggregate quantity employed of capital inputs, and α is a constant with $0 < \alpha < 1$.

From Eq. (8), the growth rate of constant price GDP can be written as

$$\dot{Y}_t/Y_t = \dot{A}_t/A_t + (1 - \alpha) \cdot (\dot{N}_t/N_t) + (1 - \alpha) \cdot (\dot{L}_t/L_t) + \alpha \cdot (\dot{K}_t/K_t) \quad (9)$$

Suppose producers face perfect competition in output markets. Then, the marginal product of labor equals to the wage rate, and the marginal product of each type of capital inputs equals to the price of capital inputs. In the competitive output market, therefore, the share of labor income is expressed as $\theta_L = 1 - \alpha$, and the share of income paid out to N capital inputs is expressed as $\theta_K = (1/\alpha) \cdot (K/Y) = \alpha$. Hence, MFP growth rate can be computed from Eq. (9) as

$$\tilde{M}_t = \dot{Y}_t/Y_t - \theta_L \cdot (\dot{L}_t/L_t) - \theta_K \cdot (\dot{K}_t/K_t) = \dot{A}_t/A_t + (1 - \alpha) \cdot (\dot{N}_t/N_t) \quad (10)$$

In the product-variety approach, R&D expenditures promote technological progress by increasing N over time. Therefore, N indicates the current state of the leading technology that is endogenously determined as a result of R&D and that is embraced by all producers. The product-variety approach's standard models typically assume that a fixed amount of R&D, γ , is required to invent a new variety of capital inputs. That is, $\dot{N} = (1/\gamma) \cdot R$ where R is total R&D expenditures. It is worth to note that γN is the market value of past R&D expenditures since γ is the reproduction cost of each invention and N is the number of inventions. Subsequently, the growth rate of N is shown as

$$\dot{N}_t/N_t = (1/\gamma)(R_t/N_t) = R_t/(\text{market value of past R\&D expenditures})_t \quad (11)$$

⁷ For a more detailed exposition of the framework, see Barro and Sala-i-Martin (2004).

Using Eq. (11), MFP growth rate in Eq. (10) can be expressed as

$$\tilde{M}_t = \dot{A}_t/A_t + (1 - \alpha) \cdot R_t/(\text{market value of past R\&D expenditures})_t \quad (12)$$

Now introduce a measure of domestic R&D capital stocks, RS , that is calculated from total R&D expenditures, R , based on the perpetual inventory method in line with Lee (2014).

$$RS_t = (1 - \delta) RS_{t-1} + R_{t-1} \quad (13)$$

where the depreciation rate, δ , is assumed to be 5 percent. Data on total R&D expenditures, R , are from the OECD's Science, Technology, and Patents statistics. R&D expenditures are constant price (adjusted in 2005 prices) US dollar expenditures based on the 2005 purchasing power parity exchange rate in US dollars per local currency. In line with Coe, Helpman, and Hoffmaister (2009), missing observations for R&D expenditures are estimated using the predicted values from ordinary least squares (OLS) regressions relating real R&D expenditures to real GDP and real non-residential fixed capital formation (all in logarithms). A time trend and its square, if found to be statistically significant, are also included in the regressions. The benchmark is also calculated as

$$RS_0 = R_0 / (g + \delta) \quad (14)$$

where g is the annual average logarithmic growth rate of R&D expenditures, R , over the period for which published R&D data are available, and R_0 is R&D expenditures in the first year for which the data are available. The benchmarks for most countries in the sample are calculated for 1981 except for Belgium (1983) and Portugal (1982). For Israel and Korea for which R&D data are available only from 1991, the benchmarks are calculated for 1981 using the predicted values of R&D expenditures for 1981.

Suppose RS is proportional to the market value of past R&D expenditures. Then, \tilde{M} in Eq. (12) can be expressed as a linear function of the ratio R/RS . This theoretical prediction is tested using the estimates of MFP growth rates reported in Table 6. The ratio R/RS is presented in Table 8. Since data on total R&D expenditures are available only up to 2010 for most countries, the testing is conducted for the period 1986-2010. A fixed

effects regression was run on the reduced form equation relating the growth rates of MFP to the ratio of total R&D expenditures to R&D stocks. The regression results presented in Eq. (15) below show that the estimated coefficient on the ratio of total R&D expenditures to R&D stocks is positive and significant in line with the theoretical prediction. The regression results also corroborate earlier findings that point to the importance of R&D in productivity growth based on the firm- and industry-level data (see Griliches, 1986; Griliches and Lichtenberg, 1984; Mansfield, 1980).

$$\tilde{M} = -0.004 + 0.138 R/RS \quad (15)$$

(0.611) (0.056)

where the number of observation is 600, and adjusted R-square is 0.13. The p-values are reported below the estimated coefficients.

The regression results in Eq. (15) identify a key determinant of the “changes” of MFP, whereas the existing empirical literature based on the endogenous growth models generally examines the factors that affect the “levels” of MFP (Coe and Helpman, 1995; Engelbrecht, 1997; Lichtenberg and van Pottelsberghe de la Potterie, 1998; Coe *et al.*, 2009). Since Eq. (4) indicates that productivity changes represent the slope of the steady-state growth path, one can derive more direct implications for the steady-state growth path by using a changes specification rather than a levels specification in empirical testing of MFP. A changes specification also helps to avoid the spurious correlation problem that can arise in a relationship between trended levels variables. However, there is a clear disadvantage of a changes specification in comparison with a levels specification. That is, the information embedded in the long-run relationship between the levels variables is lost with the use of a changes specification.

Table 8. Ratio of total R&D expenditures to R&D stocks

	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
AUS	0.12	0.12	0.12	0.12	0.11	0.11	0.12	0.12	0.11	0.12	0.12	0.12	0.11
AUT	0.20	0.21	0.20	0.20	0.21	0.21	0.22	0.23	0.21	0.23	0.23	0.23	0.23
BEL	0.10	0.11	0.10	0.11	0.11	0.11	0.12	0.13	0.12	0.13	0.14	0.14	0.14
CAN	0.04	0.04	0.04	0.04	0.04	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
DEN	0.31	0.32	0.31	0.30	0.30	0.30	0.31	0.32	0.30	0.32	0.32	0.32	0.31
FIN	0.35	0.36	0.33	0.33	0.32	0.31	0.33	0.33	0.30	0.33	0.33	0.33	0.32
FRA	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.02	0.02	0.02	0.02	0.02	0.02
DEU	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
GRE	1.44	1.47	1.38	1.35	1.32	1.27	1.30	1.31	1.18	1.24	1.20	1.19	1.13
ISL	11.84	12.26	11.67	11.52	11.29	10.91	11.24	11.24	10.02	10.57	10.30	10.19	9.43
IRL	1.33	1.37	1.30	1.29	1.29	1.28	1.33	1.34	1.21	1.26	1.21	1.18	1.09
ISR	0.49	0.50	0.47	0.46	0.44	0.43	0.44	0.43	0.38	0.40	0.38	0.38	0.35
ITA	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.04	0.03	0.04	0.04	0.04	0.04
JPN	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
KOR	0.14	0.14	0.13	0.12	0.12	0.11	0.11	0.11	0.09	0.09	0.09	0.08	0.08
NLD	0.05	0.05	0.05	0.05	0.05	0.06	0.06	0.06	0.06	0.07	0.07	0.07	0.07
NZL	0.56	0.61	0.60	0.62	0.64	0.66	0.72	0.76	0.73	0.81	0.83	0.87	0.87
NOR	0.25	0.26	0.25	0.26	0.26	0.26	0.28	0.29	0.27	0.30	0.30	0.31	0.31
PRT	1.28	1.31	1.23	1.20	1.17	1.12	1.12	1.10	0.96	1.01	0.99	0.99	0.95
ESP	0.16	0.16	0.15	0.15	0.14	0.14	0.14	0.14	0.12	0.13	0.13	0.13	0.13
SWE	0.08	0.09	0.08	0.08	0.08	0.09	0.09	0.10	0.09	0.10	0.10	0.10	0.10
CHE	0.07	0.08	0.08	0.08	0.08	0.08	0.09	0.09	0.09	0.10	0.10	0.10	0.10
GBR	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.01	0.02	0.02	0.02	0.02
USA	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
AUS	0.10	0.11	0.10	0.10	0.11	0.11	0.11	0.12	0.12	0.12	0.13	0.12	0.11
AUT	0.21	0.21	0.20	0.20	0.22	0.21	0.22	0.23	0.24	0.23	0.25	0.23	0.23
BEL	0.13	0.14	0.13	0.14	0.15	0.15	0.16	0.17	0.18	0.18	0.20	0.20	0.19
CAN	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.06	0.06	0.06	0.07	0.06	0.06
DEN	0.29	0.29	0.27	0.28	0.29	0.29	0.29	0.31	0.32	0.32	0.35	0.33	0.32
FIN	0.29	0.29	0.27	0.26	0.27	0.27	0.27	0.28	0.29	0.28	0.30	0.28	0.27
FRA	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.03	0.03	0.03	0.03	0.03
DEU	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.02	0.02	0.02	0.02	0.02
GRE	1.02	1.01	0.93	0.93	0.96	0.94	0.94	1.01	1.03	0.99	1.07	1.00	0.95
ISL	8.32	8.05	7.30	6.90	6.79	6.44	6.30	6.59	6.59	6.21	6.64	6.22	5.92
IRL	0.96	0.93	0.87	0.86	0.89	0.87	0.86	0.90	0.91	0.87	0.92	0.85	0.79
ISR	0.31	0.30	0.27	0.26	0.26	0.24	0.24	0.25	0.25	0.24	0.26	0.24	0.23
ITA	0.04	0.04	0.04	0.04	0.05	0.05	0.05	0.05	0.06	0.06	0.07	0.06	0.06
JPN	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
KOR	0.07	0.07	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.05
NLD	0.07	0.07	0.07	0.07	0.08	0.08	0.08	0.09	0.10	0.10	0.11	0.11	0.11
NZL	0.81	0.84	0.83	0.86	0.92	0.94	0.97	1.06	1.11	1.09	1.21	1.15	1.13
NOR	0.29	0.29	0.29	0.29	0.32	0.32	0.33	0.36	0.38	0.38	0.41	0.40	0.39
PRT	0.86	0.85	0.79	0.78	0.80	0.79	0.80	0.86	0.88	0.84	0.88	0.78	0.71
ESP	0.12	0.12	0.11	0.11	0.12	0.12	0.12	0.12	0.13	0.12	0.13	0.12	0.11
SWE	0.09	0.10	0.09	0.10	0.10	0.10	0.10	0.11	0.12	0.12	0.13	0.13	0.13
CHE	0.10	0.10	0.10	0.11	0.11	0.12	0.12	0.14	0.15	0.15	0.16	0.16	0.16
GBR	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.03	0.03	0.03	0.03	0.03	0.03
USA	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Note: AUS, Australia; AUT, Austria; BEL, Belgium; CAN, Canada; DEN, Denmark; FIN, Finland; FRA, France; DEU, Germany; GRE, Greece; ISL, Iceland; IRL, Ireland; SR, Israel; ITA, Italy; JPN, Japan; KOR, Korea; NLD, Netherlands; NZL, New Zealand; NOR, Norway; PRT, Portugal; ESP, Spain; SWE, Sweden; CHE, Switzerland; GBR, United Kingdom; USA, United States.

CONCLUDING REMARKS

This paper offers a balanced panel of the estimates of annual MFP growth rates for 24 OECD countries over 1986-2011. These estimates are expected to supplement the OECD estimates of MFP growth that are available in the OECD Productivity database but often have missing observations. For the purpose of international comparisons, the estimates presented in this paper hold clear advantages over most other estimates involving a single country or a small number of countries. Since a common set of assumptions are behind the estimates for all 24 countries, the estimates of MFP growth offered in this study provide a sensible indication of relative productivity growth among the 24 countries considered.

Based on the estimates of MFP growth, a number of notable trends in productivity growth are identified for the entire OECD area as well as for three major economies – the US, the Eurozone, and Japan. These trends are also shown to be accompanied by some meaningful economic developments. Their examples include the rise and collapse of the ICT investment boom, the launching of the Eurozone, and the great recession following the global financial crisis of 2007-2008. The formal analysis of a link between these developments and productivity growth can be a topic for further study.

Finally, this paper derives a reduced form equation from the standard product-variety type model. The empirical testing of the reduced form equation based on the estimates of MFP growth identifies a central role that the pace of R&D accumulation plays in promoting sustainable economic growth. The empirical results suggest that the ratio of total R&D expenditures to R&D stocks determines the growth rates of MFP and hence the slope of the steady-state growth path. Obviously, a wide range of factors, including government policy, other than investment on R&D may possibly affect the slope of the steady-state growth path. The reduced form equation presented in this study can serve as a baseline specification for testing additional factors.

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