OECD Social, Employment and Migration Working Papers
No. 138

Effects of Reducing Gender Gaps in Education and Labour Force Participation on Economic Growth in the OECD

Olivier Thévenon,
Nabil Ali,
Willem Adema,
Angelica Salvi del Pero

https://dx.doi.org/10.1787/5k8xb722w928-en

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Organisation de Coopération et de Développement Économiques
Organisation for Economic Co-operation and Development **10-Dec-2012**

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JEL Classification: J16 (Economics of Gender), J21 (Labor Force and Employment, Size and Structure), J24 (Human Capital), O4 (Economic growth and productivity)

Key words: Gender, human capital, Solow growth model, labour force participation, economic growth

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ACKNOWLEDGEMENTS

We thank Stefano Scarpetta, Andrea Bassanini, Monika Queisser, Lucie Davoine and Nuria Diez Guardia for helpful discussions and for providing us with valuable comments on an earlier draft of the paper. Thanks also to Martina Portanti for her contribution to data preparation, and Yvan Guillemette for help with data on long-term economic projections. This study was part of a larger project investigating the gender differences in education, employment and entrepreneurship. This publication has been produced with the assistance of the European Union. The contents of this publication can in no way be taken to reflect the views of the European Union. The views expressed in this paper are those of the authors and do not necessarily reflect those of the OECD or its member countries.

ABSTRACT

This paper assesses the extent to which the increase in women's human capital, as measured by educational attainment, has contributed to economic growth in OECD countries over the past five decades. Using cross-country/time series data covering 30 countries from 1960 to 2008 on education (the Barro-Lee dataset) and growth (update of OECD data), our results point out a positive and significant impact of the increase in women's educational attainment relative to men on output per capita growth – as measured by GDP per capita. This increase in female educational attainment implies that the comparative advantage of men relative to women regarding educational attainment has weakened over time, and has even reversed in many countries. We find that the increase in the years of education of the total population has a positive influence on output per capita growth (around 10% of GDP per capita increase per additional year of education on average), and that a more equal ratio of education by gender boosts economic growth. Our results are robust to the use of estimation procedures that do not impose homogeneity restrictions on the speed of adjustment and short-run parameters, to control for endogenetiy due to possible reverse causality and to several other robustness tests. Last, but not least, we look at the potential effect of increased female labour force participation on economic growth. The size of the effect is dependent on the rate at which male and female labour force participation will converge, with a potential gain of 12% to the size of the total economy by 2030, on average across OECD countries, if complete convergence occurs in the next 20 years.

RÉSUMÉ

Ce papier évalue dans quelle mesure la croissance du capital humain détenu par les femmes, tel qu'il est mesuré par les années d'éducation, a contribué à la croissance économique des pays de l'OCDE au cours des cinq dernières décennies. Mobilisant des données couvrant 30 pays de 1960 à 2008 sur l'éducation (Base de données de Barro et Lee) et la production économique (données OCDE actualisées), nos résultats pointent un effet significatif et positif de l'augmentation du nombre relative d'années d'éducation des femmes par rapport aux hommes sur la croissance du PIB par tête. Cette montée de l'éducation des femmes implique que l'avantage comparatif des hommes relativement aux femmes en matière d'éducation s'est ainsi réduit au cours du temps et s'est même inversé dans de nombreux pays. Nous estimons que la croissance du nombre d'années d'éducation de l'ensemble de la population a induit un effet positif sur la croissance du PIB par tête (en moyenne, environ 10% de croissance du PIB par tête pour chaque année d'éducation supplémentaire), et qu'un ratio d'éducation plus égal entre les sexes a renforcé la croissance. Nos résultants sont robustes à l'utilisation de procédures d'estimation qui n'imposent pas de conditions d'homogénéité sur la vitesse d'ajustement et la dynamique de court terme, ou de procédures traitant les problèmes d'endogénéité possible en raison d'une causalité inverse. Enfin, on s'intéresse aux effets possibles d'une hausse de la participation des femmes à l'emploi sur la croissance économique. L'ampleur de l'effet dépend du taux auquel les taux de participation des hommes et des femmes vont converger, avec un gain potentiel de production de 12% d'ici 2030 en moyenne dans l'OCDE, si une convergence totale a lieu dans les 20 prochaines années.

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THE EFFECTS OF REDUCING GENDER GAPS IN EDUCATION AND LABOUR FORCE PARTICIPATION ON ECONOMIC GROWTH IN THE OECD

INTRODUCTION

1. This paper presents the main findings of the econometric analysis of the determinants of female labour supply. We look at aggregate labour force participation rates of prime-age women (25-54 years old) and covers 18 countries from 1980 to 2007. Changes in the composition of the female population through age cohorts are to some extent captured by the evolution of the number of years spent by women in education and by other socio-cultural markers such as the number of children and the proportion of married women.

2. Investment in human capital improves the economic and social opportunities of young individuals, thereby helping to reduce poverty and foster technical progress. In addition to the direct effects of education on economic participation, education also affects other societal outcomes such as child mortality, fertility, personal health outcomes, and greater investment in the education and health of future generations. In this context, investing in women's human capital is key to economic growth and social cohesion, especially in developing countries where the gender gap in education is still large. In all, greater gender equality in investment in education gives both men and women the means to contribute to a better society.

3. A large body of theoretical and empirical analysis exists on the link between investment in human capital and economic growth. Recent empirical evidence conducted for this report strongly suggests a strong positive effect of human capital accumulation and economic growth *and* a further positive influence of a more equal distribution of education between the genders. To test the relationship in an internationally comparative perspective the empirical analysis is based on a human capital augmented growth model in which output per capita is a function of the propensity to accumulate both physical and human capital, the population growth rate, the level and growth rates of technological and economic efficiency. The model is estimated using pooled cross-country time series data covering 30 OECD countries over the 1960-2008 period and is augmented to include the effect of gender inequality in educational attainment on growth.

4. The growth models allow for an assessment of the overall effect of education and gender equality on long-run economic growth, but do not allow to identify the mechanisms at work; *i.e.* the positive employment and productivity effects associated with higher levels of education and reduced gender gaps and/or the effects of female education on fertility rates and the old-age dependency ratio. In order to gauge the potential effect of increased labour force participation of women on economic growth, further analysis was undertaken, based on the long-term growth scenario outlined in *OECD Economic Outlook 91* (OECD 2012a), and different scenarios of convergence between male and female labour force participation are considered to illustrate the effects growing female labour force participation may have on GDP-growth.

5. The next section provides a review of the relevant literature; section 2 describes the growth model; section 3 discusses the econometric approach for the growth model; data used in the growth model is reviewed in section 4; section 5 provides the results of the growth model; section 6 discusses the potential effect of increasing (female) labour force participation on labour supply and section 7 the effects on growth.

1. Education and growth since the 1960s

6. It has now become a widespread argument in developing but also in more economically advanced countries that the economic gains from educating girls are greater than those from educating boys (Schultz, 2002). The increase in female educational attainment can only adds to the stock of better qualified workers, but it also generates externalities that ultimately promote economic growth. However in many countries men on average enjoy considerably larger access to formal education than women, which results into a significant gender gap in educational attainment and thus in a suboptimal mix of investment in female and male education. Trends have partly reversed over the past decades, however, especially in the EU and other OECD countries where women have benefited from growing access to post-elementary and post-secondary education (OECD, 2012b). Yet, there is so far not much evidence on the extent to which the reduction in the gender gap in education has contributed to foster economic growth.

7. There a various reasons to believe that female and male education affect output levels and growth in different ways. Female education, just as male education, can improve productivity when better-educated female participate in paid work (Mammen and Paxson, 2000) both directly – by raising output levels – and indirectly – through the increase in physical capital investment and in technological change that follow from higher output levels (Barro and Sala-i-Martin, 1995). A balanced distribution of education among men and women is also likely to foster economic growth if male and female human capital are production factors with diminishing returns and are imperfectly substitutable (Knowles *et al*., 2002). Moreover, higher education levels among women are argued to produce additional social gains by reducing fertility and infant mortality, increasing life-expectancy, and increasing the quantity and quality of investments in children education, which in turn can affect growth patterns (Schultz, 1988). This *spillover* effect would happen even if all educated women do not enter the labour market and female participation rates remain lower than those of males.

8. While there is ample empirical evidence on the positive effect of human capital accumulation on women's earnings at the individual level, there is much less evidence and consensus on the macroeconomic effects of the gender gap in education. Empirical results strongly depend on the chosen data and econometric strategy and are, therefore, often subject to *ad hoc* interpretation.

9. For instance, Barro and Lee (1994) and Barro and Sala-i-Martin (1995) – based on a panel of 138 countries – report the «puzzling» finding that years of schooling have an effect on economic growth that is positive for men but negative for women. They suggest that this is related to the fact that a high spread between male and female secondary attainment is a measure of «backwardness» in the returns of education, and that higher female education attainment signifies that countries have reached a stage of economic development from which no rewards can be expected from an additional increase in years of education (Barro and Lee, 1994). Their interpretation of the coefficients of male and female human capital is not straightforward, however, since they may reflect not only the incidence of sex-specific human capital, but also the incidence of the gender gap (see below).

10. There are few other reasons that can explain this gender-differentiated effect of education. One is that gender differences in the quality of education and training still remain large. The scope of this argument has greatly weakened over the past decades, however, since there is now evidence that girls

outperform boys on several dimensions of school aptitudes (OECD, 2012b). By contrast, there is a large body of evidence showing persistent segregation in the chosen field of education and therefore on the returns to educational investment that can be expected for each sex. Moreover, differences in the returns to education in the labour market still persist.

11. Furthermore, the relationship between education, female employment and growth changes over time and through the process of economic development. The extent to which the aggregate economic output responds to female education and to the increase in female labour market participation is found to be U-shaped, *i.e.* positive only after countries have reached the "industrial" stage of development and women have gained access to more productive sectors of economic activity (Goldin 1995; Esteve-Volart, 2000; Mammen and Paxson, 2000; Lincove, 2008 and Tam, 2011). The increase in girls' access to post-elementary education is certainly a driver of this process, as suggested by the evidence of a convex relationship between the decrease in gender discrimination in primary schooling and growth reported by Esteve-Volart (2000).

12. The Barro and Lee (1994) results have been challenged by several other empirical analyses. Dollar and Gatti (1999) show, for example, that the negative association between the years of schooling completed by girls and per capita output growth disappears once country-specific factors are controlled for. Even more challenging are those results of Caselli *et al*. (1996) and Forbes (2000) who come to the opposite of Barro and Lee's conclusion. Using a Generalized Methods of Moment estimation to control for the potential endogenity of human capital variables and measurement errors, female schooling is associated with a statistically significant positive coefficient while a negative coefficient is obtained for male schooling. The authors interpret the positive sign for female education as the net effect of a positive impact due to the influence of education on fertility which outweighs the negative "direct" effect of human capital found by Barro and Lee. The negative coefficient for males, by contrast, reflects only the human capital effect. Yet, the negative human capital effect remains 'puzzling' as it runs against most theoretical arguments (Topel, 1999; and, Krueger and Lindhal, 2001).

13. Esteve-Volard (2000), Klasen (2002) and Knowles *et al*. (2002) instead emphasize the problems affecting the empirical identification of effect of male and female education due to the multicollinearity caused by their close correlation. Their suggested empirical strategy involves using a direct measure of the gender gap in educational attainment in the growth equation instead of separate measures for men and women. Klasen (2002) finds that gender inequality in the initial levels and in the expansion of education significantly reduces economic growth; the results – which are robust to different specifications of the education variables and control for possible simultaneous determination of human capital stocks and economic growths – are consistent with those of Knowles *et al*. (2002) and the older results by Hill and King (1995). Knowles *et al*. (2002) further suggest that female education has a statistically significant positive effect on the productivity per worker, while the role of male education is less clear and depends on the inclusion of benchmark (base-period) values of human capital and other control variables.

14. Many other reasons can explain the conflicting results in this literature. Differences in stage of economic development can be one factor: less developed countries may experience higher growth rates in spite of lower educational attainment due to convergence mechanisms. Thus, the Barro and Lee (1994) results may be essentially driven by the inclusion of the four East Asian Tigers and countries in Sub-Sahara Africa (Stokey, 1994; and, Lorgelly and Owen, 1999). This drawback motivates our choice to limit our sample to OECD countries, which are relatively homogeneous in terms of stage of development and education trends.

15. Controlling for the short-run effects of variations in physical and human capital on growth trajectories is also essential for the estimation of the long-run effects of the development of human capital on economic growth. This issue is even more important when the analysis relies on panels of data with a

short time span and/or focusing on growth rates. It is therefore crucial to check the validity of results in a context of non-stationarity or cross-section dependence in the data and of potential reverse causality between economic growth and education.

16. As mentioned above, the choice of data and indicators used to measure educational attainments and compare them across gender is also crucial in driving results. To illustrate this point, Barro (1999) uses an updated version Barro and Lee (1996) data set on education and no longer finds a negative role for female education.[1] A usual practice is to measure education as the average number of years of schooling attained by the adult male and female population. Differentiating between levels of education also may have an impact on results. Barro and Lee (1996) identify a strong effect of secondary and higher schooling on growth.

17. This paper attempts to reassess the influence of gender differences in educational expansion on the long-run steady-state of economic output. There are different reasons for doing so.

18. First, we want to update the conclusions and allow for longer term assessment by taking into account the information available on recent trends in education. Our sample covers the 30 OECD countries from 1960 to 2008 and we use the education data published in the revised and cleaned Barro-Lee dataset (Barro and Lee, 2010). We also use the updated version of the data GDP per capita published by the OECD.

19. Our goal is also to address some of the econometric issues that were overlooked by many of the previous assessments. Firstly, we tackle the assumption that the effect of the determinant of growth (including physical and human capital) is homogenous across countries. This assumption can be weakened by considering that countries will converge towards the same set of economic steady-states in the long-run, albeit at a different pace. However, this might still be an oversimplification for countries that are very heterogeneous in terms of stage of development, specialization, technological and institutional settings (Pesaran and Smith 1995; Durlauf *et al.*, 2005; Pedroni, 2007; and, Eberhardt and Teal, 2011). Economies in the OECD can, however, be expected to be rather homogeneous as they have access to common technologies and share intensive intra-industry trade and foreign direct investment (Arnold *et al.*, 2011, p. 6).

20. Against this backdrop, we model the steady-state level of output per capita as a function of the propensity to accumulate physical and human capital, the population growth rate, the level and growth rates of technological and economic efficiency, and the (constant) rate of depreciation of capital, as set by Mankiw *et al*. (1992) in the human capital augmented Solow growth model. The model is then tested with estimation procedures based on more or less flexible assumptions regarding the convergence process towards steady-states. We control for the incidence of country-specific and time-constant (but unobservable) factors shaping economic efficiency by means of a fixed-effect panel approach. The inclusion of country-specific time trends also allows us to capture changes in technologies or social institutions that affect economic efficiency, even though they are not explicitly modelled (Pedroni, 2007). We thus follow quite closely the perspective adopted by Bassanini and Scarpetta (2002) and Arnold *et al*., (2010), but we add the gender dimension to the impact of educational attainment.

[1] This result stems to a large extent from the revision of the education data to improve its quality and make the necessary adjustements to obtain consistent time series. The influence of data quality is also emphasized by De la Fuente and Domenech (2006) who find overall a positive correlation between the quality of data and the significance of human capital coefficients in growth regressions. Crespo Cuaresma (2005) finds important differences in the distribution and evolution of education in OECD countries across different datasets (namely the data collected respectively by Barro-Lee, Cohen-Soto and De la Fuente-Domenech).

21. The next two sections present respectively the theoretical framework and the empirical setting. Basic statistics and data properties are then discussed, before we present the regression results.

2. Theoretical background: the growth equation

22. The human-capital-augmented Solow growth approach first presented by Mankiw *et al*. (1992) provides an adequate framework to model the influence of education on growth. Given straightforward assumptions on how the factors of production evolve over time, this framework implies that the steady-state level of output per capita can be expressed as a function of the propensity to accumulate physical and human capital, the population growth rate, the level and growth rates of technological and economic efficiency, and the (constant) rate of depreciation of capital. If countries were at their steady state - or if deviations from the steady state were random – the growth equation could be simply based on the relationship linking steady-state output to its determinants. However, actual data may well include out-of-steady-state dynamics, thus observed changes in output per capita at any point in time are likely to include technological progress, as well as a convergence component and a level component due to shifts in the steady-state output per capita arising from other factors than technology.

23. Following Arnold *et al*. (2011), we consider a human-capital-augmented Solow model with a standard Cobb-Douglas production function. At time t output per capita Y is given by:

$$Y(t) = K(t)^{\alpha} H(t)^{\beta} (A(t)L(t))^{1-\alpha-\beta} \qquad [1]$$

where K and H are physical and human capital respectively, L is labor, A captures the level of technology and α and β are the partial elasticities of output with respect to physical and human capital. The evolution of the economy is determined by

$$\dot{k}(t) = s_k y(t) - (n + g + \delta)k(t) \qquad [2]$$

$$\dot{h}(t) = s_h y(t) - (n + g + \delta)h(t)$$

$$y(t) = k(t)^{\propto} h(t)^{\beta}$$

$$\dot{A}(t) = g \cdot A(t)$$

$$\dot{L}(t) = n \cdot L(t)$$

where $(t) = (Y(t)) \,/\, (A(t)L(t))$ and $k(t) = (K(t)) \,/\, (A(t)L(t))$ are the output and physical capital quantities per effective unit of labor. $h(t) = (H(t)) \,/\, (A(t)L(t))$ stands for the average human capital which sums the contribution of formal education completed by men and women; s_k and s_h are the investment rate in physical and human capital, n is the growth rate of labor, g is the rate of technological change and d is the common depreciation rate.

24. Under the assumption of decreasing returns to capital ($\propto + \beta < 1$), equation [2] implies that the economy converges to a steady state obtained when $\dot{k} = 0$ and $\dot{h} = 0$ and defined by :

$$k^* = \left(\frac{s_k^{1-\beta} s_h^{\beta}}{n+g+\delta}\right)^{\frac{1}{1-\propto-\beta}} \quad \text{and} \quad h^* = \left(\frac{s_k^{\propto} s_h^{1-\propto}}{n+g+\delta}\right)^{1/(1-\propto-\beta)} \qquad [3]$$

25. Substitution [3] into the production function and taking logs gives the equation for the steady state of income per capita which is a function of the rate of investment in physical capital, the rate of population growth, and the (steady state) level of human capital:

$$lny^*(t) = lnA(0) + gt + \frac{\propto}{1-\propto} lns_k - \frac{\propto}{1-\propto} \ln(n+g+\delta) + \frac{\beta}{1-\alpha} lnh^* \quad [4]$$

26. The steady-state level of output per capita is thus expressed as a function of the initial development of technology A(0), the propensity to accumulate physical capital s_k, the population growth rate n, the level and growth rates of technological and economic efficiency g and g_t, the constant rate of depreciation of capital δ, and human capital accumulation h^*; while the latter is unobservable, lnh^* can be approximated with $lnh(t) + \varphi\Delta_s lnh(t)$.

27. In addition, the transitional dynamics towards the steady state values are described by the following equation (Romer, 1996):

$$\frac{dlny(t)}{dt} = -\lambda(lny(t) - lny^*)$$

where$\lambda = (1-\propto -\beta)(g+n+d)$. The path of convergence of output towards its steady state is consequently given by:

$$lny(t) - lny(t-s) = \emptyset(\lambda)(lny(t-s) - lny^*), \text{ with } \emptyset(\lambda) = 1 - e^{-\lambda s} \quad [5]$$

Inserting the expressions of y^* and h^* in [5] yields:

$$\Delta_s lny(t) = -\emptyset(\lambda)\left(lny(t-s) - \frac{\propto}{1-\propto} lns_k - \frac{\beta}{1-\alpha} lnh(t) - \frac{\beta\varphi}{1-\alpha}\Delta_s lnh(t) + \frac{\propto}{1-\propto}\ln(n+g+\delta)\right) \quad [6]$$

28. Equation [6] thus describes the convergence process, which can be estimated for any time interval. As discussed further in the next section, short-run components have to be accounted for as annual data will be used to estimate the model. Assuming that the maximum lag is one year and allowing all right-hand side variables to be time invariant, the equation can be written in the general error correction form (Pesaran and Smith, 1995; Bassanini and Scarpetta, 2002; and, Arnold *et al*. 2011):

$$\Delta lny(t) = -\emptyset(\lambda)\{lny(t-1) + \theta_1 lns_k(t) - \theta_2 lnh(t) - \theta_3 ln[n(t) + g(t) + \delta(t)]\}$$

$$+b_1\Delta lns_k(t) + b_2\Delta lnh(t) + b_3\Delta ln((n(t) + g(t) + d(t)) + \varepsilon(t)$$

where θ_s are the long-run coefficients corresponding to the combination of theoretical parameters of equation [6], b are the coefficient for the short-run dynamics, and ε is the usual error term. To the extent that g and δ are not observable, it is usual to substitute $ln(n+g+\delta)$ with n.

29. Since technology is not observable, we assume that technological change is accounted by a constant term and a trend. The former equation can thus be re-written as:

$$\Delta lny(t) = a_0 - \emptyset[lny(t-1) + \theta_1 \ln s_k(t) + \theta_2 lnh(t) - \theta_3 lnn(t)] + \gamma t + b_1\Delta lns_k(t) \quad [7]$$

$$+b_2\Delta lnh(t) + b_3\Delta lnn(t) + \varepsilon(t)$$

30. Yet, Arnold *et al*. (2011) demonstrated that this reduced form of output growth is also compatible with a two-sector AK model à la "Uzawa-Lucas" model of economic growth. The distinction between the

two approaches concerns essentially the hypothesis made on the production function, that is assumed to have decreasing returns in the augmented-Solow model and constant returns of human capital (θ_2) in the AK model (Barro and Sala-i-Martin, 1995). The latter also implies a permanent effect of the investment rate on long-term growth which is thereby endogenous; in the Solow model the impact of the investment rate is only transitory so the only driver of growth is the exogenous change in technology. The two-sector model also makes a distinction between human capital formation, which is set to be time-varying and determined by intertemporal preferences, and the other aggregated production sector. The production of human capital is assumed to involve no physical capital, and is thus relatively intensive in human capital compared with the aggregated production sector. Under these assumptions, the process of accumulation of human capital in the two-sector is the main driver of growth, whereas in the augmented Solow model it has only a transitory impact on growth.[2] As a consequence, the speed of convergence to the steady state is assumed to be more rapid under the Uzawa-Lucas approach than in augmented Solow model (Arnold *et al.*, 2011).

31. In this context, the incidence of gender differences in education can be captured by including a log-ratio (*lnR*) measuring the difference in years spent on average in education by women compared to men:

$$\Delta lnY(t) = a_0 - \emptyset\left[lnY(t-1) + a_1 lnS_k(t) + a_2 lnH(t) + a_3 lnR^{f/m}(t) - a_4 lnN(t)\right] \quad [8]$$

$$+\gamma t + b_1 \Delta lns_k(t) + b_2 \Delta lnH(t) + b_3 \Delta lnn(t) + \varepsilon(t)$$

3. Econometric approach

32. The growth equation described in [7] can be re-written within an error-correction model where growth rates are expressed as a function of the long-run evolution of the steady-state and of short-run variations, as appropriate for an empirical estimation based on pooled cross-country annual data:

$$\Delta lnY_{it} = a_{0i} - \emptyset_i lnY_{it-1} + a_{1i}\, lns_{kit} + a_{2i} lnh_{it} - a_{3i} n_{it} + a_{i4} t + b_{i1} \Delta lns_{kit} + b_{i2} \Delta lnh_{it} + \quad [9]$$

$$b_{i3} \Delta lnn_{it} + \varepsilon_{it}$$

where subscripts indicate country (i) and time (t), We thus assume that the steady-state of the growth rate of per capita output depends on country-specific factors that may shift the long-run path of economic development and/or produces short-run differences in the convergence towards the steady state of the economy.

33. The same equation can be re-written to take into account the gender distribution of years of education:

$$\Delta lnY_{it} = -\emptyset_i\left(lnY_{it-1} + \theta_1 lnk_{it} + \theta_{2S} lnH_{it} + \theta_{2R} R^{f/m}{}_{it} + \theta_{3m} \Delta lnN^m{}_{it} + \theta_{3f} \Delta lnN^f{}_{it} - \propto_i . t - \theta_i\right)$$

[2] The Uzawa-Lucas model indeed predicts that growth rates tend to rise if human capital is abundant relative to physical capital, but they tend to fall if human capital is scarce relative to physical capital (Barro and Sala-i-Martin, 1995). If human capital is relatively scarce, then the marginal product of human capital in the goods sector is high and growth is expected to occur mainly because of the high growth rate in human capital. However, a relatively scarce human capital also implies high wage rates and therefore high costs of operation for the education sector. In other words, this effect motivates people to allocate human capital to production of goods rather than to education, thus reducing the economy's growth rate.

$$+b_{1i}\Delta k_{it} + b_{2Si}\Delta lnH_{it} + b_{2Ri}\Delta lnR^{f/m}{}_{it} + b_{3mi}\Delta^2 lnN^m{}_{it} + b_{3fi}\Delta^2 lnN^f{}_{it} + \varepsilon_{it}$$

where $R^{f/m}$ is the female-to male ratio in the average number of years spent in the education system by men and women aged 25 to 64. As explained above, the ratio is used to capture gender gaps to avoid the multicollinearity problems encountered when the average years of education of men and women are included separately.

34. The use of annual data requires that short-run components are singled out from the long-run relationship between economic growth and its determinants. In practice, the latter can be estimated in different ways, with more or less accuracy depending on the size of the panel and the quality of data (see Eberhardt and Teal (2011) for an up-to-date discussion). A common technique to reduce the influence of short-run variation is to take averages of the data, typically over 5 years (Islam, 1995; Caselli *et al*., 1999; and, Bond *et al*. 2001). The downside of this approach is that it does not fully take advantage of the complete set of information provided by the annual data. An alternative approach, which we will use here, involves the simultaneous estimation of long-run relations and he short-run variations within a linearised error correction model (Lee *et al*., 1997; Bond *et al*. 2004; Bassanini and Scarpetta, 2002; and, Arnold *et al*., 2011):

$$\Delta lnY_{it} = -\emptyset_i(lnY_{it-1} + \theta_1 lnk_{it} + \theta_2 lnH_{it} + \theta_3\Delta lnN_{it} - \propto_i . t - \theta_i) + b_{1i}\Delta lnk_{it} + b_{2i}\Delta lnH_{it} \quad [10]$$

$$+b_{3i}\Delta^2 lnN_{it} + \varepsilon_{it}$$

where $\emptyset_i$ is the country-specific speed of adjustments, with $a_{ki}/\emptyset_i = \theta_k$.

35. This approach has the desirable feature of estimating a dynamic specification with country-idiosyncratic speed of convergence and deviations from the steady-state, while still allowing for country-specific production levels and growth rates. Another advantage is to overcome the fact that the output steady-states are unobservable, while observed changes in output per capita may well depend on shifts in the steady-state output per capita arising from other factors than technology. These circumstances make it necessary to have an empirical setting that clearly separate the long-run evolution of the steady states levels of output from their transitory variations.

36. Estimation of equation [10] also requires a choice on the degree to which cross-country heterogeneity is allowed. Typically, dynamic fixed-effect estimators (DFE) control for country-specific effects that may shift the steady states of the economy but the influence of an increase in physical and human capitals is assumed to be the same across countries. The validity of such restrictions critically depends on the assumptions of common technology and common convergence parameter, which in turn assume technological change and population growth to be homogeneous across countries. As pointed out by Pesaran and Smith (1995), aggregating and pooling data in dynamic panels where there is "slope" heterogeneity in the impact of broad (physical and human) capital on per capita output will give inconsistent estimates, unless the coefficients vary randomly across countries and are independent of the regressors. These are particularly strong hypotheses in a context of where population and productivity growth patterns vary considerably across countries (Lee *et al*., 2007 ; Bassanini and Scarpetta, 2002b; and, Eberhardt and Teal, 2011).

37. By contrast, Mean Group (MG) estimators assume that the influence of broad physical and human capital on economic output is country-specific and regressions are separately estimated for each country and taking then the average of the country-specific coefficients (Pesaran and Smith, 1995).

38. In between these two extremes, Pooled Mean Group (PMG) estimators assume that countries converge towards the same steady-state but the speed of adjustment can differ across countries (Lee *et al*.,

1997; and, Pesaran *et al.*, 1999). The PMG estimator is therefore more restrictive than the MG in the sense that it imposes long-run coefficients to be the same across countries, but it allows short-run variations in the pace of adjustment. This approach is consistent with the fact that the production functions of OECD countries are progressively becoming more homogenous on account of access to common technologies, intensive intra-industry trade and large foreign intra-OECD direct investment (Arnold *et al*. 2011). Another advantage of the PMG estimator is that it is not affected by the 'downward bias' in the estimated coefficients produced by DFE or MG when the lagged dependent variable is endogenous to the fixed effect in the error term (Nickell, 1981).

39. Exogenous changes in the production technology as well as in the institutions that condition the efficiency of the production function can also introduce cross-country heterogeneity in the pace of convergence towards the steady-state. These differences can not all be observed nor quantified and are therefore proxied by default by country-specific trends, which we define through a sequence of 5-years dummies.

40. There are limits, however, in the extent to which time trends can accurately account for the unobservable changes, for example if technology parameters don't vary randomly across countries and are correlated with the regressors and/or the errors terms (Durlauf *et al*., 2005). This misspecification can have serious implications if the observable and/or unobservable variables are non-stationary: spurious results may come from a failure to account for heterogeneity in the technology parameter, which leads to a breakdown of the cointegrating relationship between inputs and output (Kao, 1999; Smith and Fuertes, 2007; and, Eberhardt and Teale, 2011). This can occur, for example, when countries experience a common shock or are exposed to same processes, albeit not necessarily with the same strength and create cross-section dependence between panel units. An appropriate strategy to account for these common unobserved factors is the Common Correlated Estimator proposed by Pesaran (2006), which includes cross-section averages of the dependent and independent variations in the regression equation. The accuracy of such a procedure has to be checked by performing a test for the cross-section independence of the residuals (Pesaran, 2004).

41. Long-run growth accounting equations are relations between variables in levels, which may not be stationary. Regressions are likely to be spurious if the production function relating the variables in the long run is not a cointegrating vector, and the standard statistics used to assess the quality of adjustment (R^2 and standard errors) no longer apply (Philipps and Perron, 1999; and, Kao, 1999). For this reason, we employ an ECM which encompasses the true model: the levels terms are dropped out if there is no cointegration whereas they form a stationary relationship if there is cointegration. We also check that all panel residuals are stationary with the unit root test assuming that panel units are cross-section independent (Im *et al*., 2003) or not (Pesaran, 2007).

42. Last, as in any panel regression on macro-level data, attention should be paid to possible endogenity between economic growth and the accumulation of human and physical capital. Using stock data for human capital, lagged values of the explanatory variables and a rather long panel mitigates the reverse causality problem but it does not settle the issue completely since ΔY_{it-1} and ε_{it} might be correlated. The generalized method of moments estimator of Arellano and Bond (1991) (GMM-difference) can overcome this issue by using moment conditions on levels to instrument the variables expressed in differences in the right hand-side of equation [6]. GDP per capita and physical capital formation are instrumented by their lagged values up to 5 periods backwards ; in contrast, education variables are instrumented by their levels 5 years before and not by the values in between since we interpolated them to get a complete set of data.

4. Data overview

43. One of the key features of the past decades is the drastic rise in women's educational attainment and the decline of gender inequalities in education that took place in most regions of the world. In the OECD primary school enrolment is nowadays nearly universal and gender equal (OECD, 2012b), but the picture is more mixed at secondary and post-secondary level. Similarly, in the past decades the increase in post-secondary education graduation rates has been greater among women than among men across OECD countries, and – except for Turkey – boys are nowadays more likely than girls to drop out before completing secondary education. As a result, younger women are increasingly better educated than young men in the OECD (OECD, 2011).

44. Qualitative differences in education still prevail. PISA data show that boys lag behind girls in reading skills at the end of compulsory education to the equivalent of a year of schooling, on average, and are far less likely to spend time reading by pleasure. Boys are ahead instead in mathematics, but the gender gap is overall small compared with reading. Differences in the field of study are also quite large: girls are significantly less likely to choose scientific and technological fields of study, and when they do are then less likely to take up a career in these fields.

45. There is now a large body of evidence suggesting that the increase in the initial level of education of the population has had a positive influence on economic development and growth rates in the OECD (Benhabib and Spiegel, 1994; Temple, 2001; Stevens and Weale, 2004; Bassanini and Scarpetta, 2002; Cohen and Soto, 2007; L'Angevin and Laib, 2005; and, Arnold *et al*., 2011).[3] There is, however, no consensus yet in the empirical evidence because several other studies failed to find a positive relationship between human capital accumulation and economic growth (Krueger and Lindahl, 2001; Pritchett, 2001; and, Delgado *et al*., 2011). The arguments set by authors to explain this differ. Pritchett (2001) suggests that a relationship between human capital accumulation and growth is not found because of the institutional characteristics of countries where the most significant increases in education have taken place.[4] By contrast, other authors argue that it might be just the result of measurement errors in education (Krueger and Lindahl, 2001) or estimation problems due to multicollinearity between variables (Soto, 2002). The same issue affects other empirical work that failed to identify a positive effect of women's increase in education on aggregate economic output (Lorgelly, 2000; Knowles *et al.*, 2002; and, Klasen, 2003).

46. Results are sensitive to data quality and to the variables used to measure educational attainment and gender differences. Different dataset can be used,[5] but only two of them provide data disaggregated by

[3] However, the literature has not reached yet a consensus regarding the relationships between changes in educational attainment and subsequent economic growth, with several studies finding an insignificant influence of the years of schooling on economic growth (see especially Islam, 1995; Maasoumi *et al*., 2007 and the review made by Delgado *et al*. 2011). This lack of consensus led to a number of studies trying to assess the problem by improving the available data on education. Temple (1999) claims that the lack of relationship may be due to outliers, but most of the literature attributes it to deficiencies on the education dataset (Krueger and Lindhal, 2001; De la Fuente and Domenech, 2006; and, Cohen and Soto, 2007). Delgado *et al*. (2011) compared the results obtained by using six leading educational databases in conjunction with econometric techniques that are robust to functional form misspecification and data measurements. They find that, in general, estimates of the mean years of schooling bear no or little relevance in predicting per capita growth rates. However, they find different results depending on the education dataset used and country coverage. In particular, a positive and significant influence of years of schooling on growth rates in OECD countries is found by estimations based on the revised 2010 Barro-Lee dataset, but not with the alternative information sources.

[4] The main arguments provided by Pritchett are that education has been of low quality and so has not generated real increases in human capital; he also argues that the expansion in supply of educated labour has surpassed demand, leading to a decrease in the return of education, and that educated workers may have gone to privately lucrative but socially unproductive activities.

[5] See in particular de la Fuente and Domenech (2006) for a review of available data, and the data collected by Cohen and Soto (2007), Lutz *et al*. (2007) or Morrisson and Murtin (2009).

gender with sufficiently long time series: the data collected by Lutz *et al*. (2007) and those collected by Barro and Lee and updated recently (Barro and Lee, 2010). This paper uses the latter because it provides longer time series – from 1960 to 2010 instead of 1970-2000 in the Lutz *et al*. (2007) – and because data have been revised to address most of the concerns raised by critics on the former versions, including those of Cohen and Soto (2007) and de la Fuente and Domenech (2006).[6] The data are broken down into 5-year age intervals and reported at 5-year intervals from 1950 to 2010. The observations missing between two points in time have been estimated by linear interpolation to match the other variables that are available on an annual basis.[7]

47. Two indicators of gender differences in educational attainment are considered: years of education completed by adults and the proportion of adults who completed secondary education. The years of completed education are measured for men and women from 25 to 64 years of age in order to limit the bias due to incomplete education. This indicator is preferred to enrolment rates because it captures the stock of education and because data on enrolment rates are affected by to cross-country differences and changes over time in the classification of educational attainment. Table 4.1 reports the average evolution of years in education for men and women in the 30 OECD countries[8] from 1960 to 2008, *i.e.* the period preceding the current economic crisis.[9] The average number of years spent in education by men and women has steeply increased, and there are small gender differences in the level of education (11.19 years for men and 11.21 for women). Yet, the increase has been steeper for women than for men.

48. Qualitative differences in educational attainment and trends are not completely captured by the evolution of years in education. For this reason, we also look at the proportion of men and women with completed secondary education[10] (Table 4.1). By this indicator, gender differences are quite significant (Annex Figure A1.2), although the gap is closing on average. Overall, the increase in completion of secondary education has been slightly steeper for women than for men: in the OECD the percentage of women aged 25 to 64 with completed secondary education was 11.7% in 1960 (vs. 16.6% for men), while the proportion in 2010 is at 54.5% slightly higher than for men (Table 4.1). The two indicators show overall that qualitative differences in educational attainment across gender seem to remain important despite the decrease in gender gap in terms of quantity of education.

49. Data on GDP, physical capital and working age population are taken from the OECD's Economic Outlook (No 90) data series. GDP per capita and Gross fixed capital formation (physical capital) are expressed in 2005 USD, taking advantage of the OECD's update of calculated time series which changed the base reference year from 2000 to 2005.

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[6] More precisely, the data on education are derived from census and survey data obtained from Unesco and Eurostat used to contruct estimates of various levels of educational attainment. Missing observations are estimated by extrapolating backwards and forwards from census and survey data. Thes estimates are corrected for morality rates that are allowed to differ across different education cohorts. Preliminary testing shows, for OECD countries, that this version provides smoother time profiles for educational attainment in Norway and the United States than the former versions of the dataset (Barro and Lee, 2010).

[7] Note that from the statistical point of view, this interpolation is likely to smooth the trends in educational attainment, and to some extent limit the remaining erratic movements which might be due to error measurement.

[8] The countries covered are: Australia, Austria, Belgium, Canada, Chile, the Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Israel, Italy, Japan, Korea, Luxembourg, Mexico, the Netherlands, New Zealand, Norway, Poland, Portugal, the Slovak Republic, Slovenia, Spain, Sweden, Switzerland, Turkey, the United Kingdom, and the United States. Country level figures are provided in Annex Figure A1.1.

[9] Data series on GDP per capita and capital formation show indeed important breaks for years 2009 to 2010, as expected from the consequences of the economic crunch.

[10] The same information could have been used for people with tertiary education. However, it is frequently the case that this latter is not completed before the age of 25, therefore introducing bias in the measurement.

50. Table 4.1 also reports the average values of main variables entering in the growth equation. The dependent variable (ΔlnY), measured as the growth in real GDP per head of population aged 15-64 years; the convergence variable (lnY_{t-1}), measured as the lagged real GDP per head of population aged 15-64 years; the propensity to accumulate physical capital (lnS_K), proxied by the ratio of real private non-residential fixed capital formation to real private GDP; population growth (ΔlnN), measured in the working age population (15-64 years).

Table 4.1. Basic Statistics

Variables	Year	Sample mean	Standard deviation
GDP per capita (in USD at 2005 PPP)	1960	16295	5711
	1990	35503	10622
	2010	45202	17948
Average years of education - Men	1960	6.49	2.16
	1990	9.65	1.72
	2010	11.19	
Average years of education - Women	1960	5.79	2.31
	1990	9.01	2.02
	2010	11.21	1.56
% of men age 25-64 with completed secondary education and above	1960	16.6	11.6
	1990	40.4	14.8
	2010	53.2	18.1
% of women age 25-64 with completed secondary education and above	1960	11.7	10.7
	1990	36.2	13.9
	2010	54.5	15.4
% per capita annual growth rate of capital		2.13	8.51
% annual growth of male working age population		1.00	0.85
% annual growth of female working age population		0.91	0.94

51. Table 4.2 assesses the multicollinearity between male and female years of education. A very high correlation is found (0.99); on the other hand, although still high, the correlation is far less weaker (0.63) when we consider the total average together with the female-to-male ratio.

Table 4.2. Covariance matrix between education variables

	Male average years of education	Female average years of education	Total average years of education	Gender ratio in average years of education
Male average years of education	1.00	-	-	-
Female average years of education	0.99	1.00	-	-
Total average years of education	0.99	0.96	1.00	-
Gender ratio in average years of education	0.73	0.82	0.63	1.00

52. The issue of multicollinearity between our independent variables is investigated further with the computation of the Besley, Kuh and Welsh (1980) statistics reported in Table 4.3, which clearly suggests that multicollinearity might be serious (condition index greater than 30) because the intercept and the variable measuring the formation of physical capital are collinear. Collinearity between the average years of education and the gender ratio appears to be less a concern despite relatively high correlation coefficient.

Table 4.3. Assessment of multicollinearity between the independent variables

	Condition index	Intercept	Years of education	Physical capital	Gender gap in education
1	1.00	0.00	0.00	0.00	0.01
2	2.18	0.00	0.00	0.00	0.37
3	24.51	0.08	0.94	0.04	0.57
4	60.08	0.92	0.05	0.96	0.06

5. Model specifications and results

53. Table 5.1 reports the regression results obtained from the baseline specification where the incidence of the total average years in education on economic growth is modeled with no distinction by gender. The results of the different estimation procedures are shown: MG, PMG, and GMM. Two estimations are presented for each estimation procedure, one with no control for time trends and another including 5-years dummies[11] that are expected to capture the country-specific changes in the efficiency of the production function.[12]

[11] Eight (out of the potential ten) time dummies defined for sequence of 5 years are thus included in the set of the short-run regressors, their limited number thereby allowing the estimation without running out of degrees of freedom. Moreover, this way of doing does not impose time influence to be continuously linear. Assuming linear trends would here also be problematic because of the collinearity that would be created with the linear interpolation years of education to complete the time series. In

54. All estimation procedures identify a convergence parameter with a negative sign, which is consistent with the assumption that variables converge to a long-run equilibrium. The speed of convergence varies significantly depending on the restrictions imposed: imposing long-run homogeneity to all but the time trend (*i.e.* moving from MG to PMG) reduces significantly the estimated speed of convergence and the parameters' standard errors (as already found by Lee *et al.*, 1997). It also affects the size, statistical significance and in a few cases the sign of the long-run parameters.

55. Estimation results appear to be sensitive to the treatment of time. Models that include period effects yield significantly higher speed of convergence. The coefficients associated with physical capital also decrease when time controls are included, while those of human capital increase. In other words, the economic returns to education appear to be higher once other changes in the production function are controlled for, suggesting that economic growth is progressively more dependent on the prolongation of education.

56. Results obtained in the PMG estimation, imposing long-run homogeneity to all slope coefficients but the time trend, are preferred for a number of reasons. First, PMG estimators lower standard errors and therefore more precise parameters compared to MG. The measured speed of convergence is also significantly reduced, without changing the sign of the estimated long-run coefficients. Furthermore, a Hausman test comparing the PMG restrictions against the parameters obtained by the MG estimation does not reject the former at the conventional statistical levels.[13] The coefficient for education obtained with the PMG is much lower than those estimated by the MG, but significantly positive even when time dummies are included. The coefficient for education also remains highly positive when it is estimated by a GMM procedure to tackle the bias that reverse causality or omitted variables can potentially induce. Last but not least, only the PMG estimates yield stationary residuals.

57. However, all models show evidence of a cross-section dependence between residuals: the absolute correlation value is very high (ranging from 0.77 to 0.89), and the CD-Pesaran (2004) test constantly rejects the null assumption of cross-section independence. Also, this assumption is rejected when cross-section averages of the dependent and independent variables are added as regressors in the C-MG specification. This specification, which is expected to sort out the issue raised by unobserved but correlated factors, fails to completely remove cross-section dependence although correlation is reduced – which is not surprising because the years of education have followed very similar trends in most countries and thus adding cross-section averages to the set of regressors generates multicollinearity of variables more than it helps wiping out the incidence of unobserved correlated factors.

58. Looking at the PMG coefficients, the range of variation of the estimated partial elasticity of output with respect to physical capital ($\hat{\alpha}$) is relatively limited from 0.22 to 0.32, and it is consistent with previous findings.[14] By contrast, the estimated output elasticity with respect to human capital ($\hat{\beta}$) varies much more across the different specification (from 0.22 to 0.83). Overall, one additional year of schooling in the population is estimated to raise output per capita by around 10% per annum (as estimated from Table

fact, the regression including linear time trends instead of our set of time dummies prove to bias the estimate of the coefficient of years of education as part if its influence is in fact absorbed by the time trend.

[12] Note that, in the PMG specification, the time effects are assumed to capture differences in the diffusion of technologies that affect the speed of convergence, while countries are assumed to converge towards the same production function in the long-run.

[13] Results from a dynamic fixed effect model (DFE) are reported in Annex Table A1.2. The estimators obtained yield a much lower speed of convergence, which is consistent with the expected downward bias in dynamic heterogeneous panels. Moreover, restricting the short term dynamic to be homogenous (as with DFE) affects the sign and significance of the long-run coefficients.

[14] As a benchmark, Mankiw *et al*. (1992) produced regression estimates $\hat{\alpha}$=0.48 and $\hat{\beta}$=0.23 based on data from a group of 98 countries over the period 1960 to 1985. For OECD countries, Bassanini and Scarpetta (2002) and Arnold *et al*. (2011) found respectively values between 0.13 and 0.22 for $\hat{\alpha}$, and between 0.52 and 0.82 for $\hat{\beta}$.

4 column 5 and Table 5 column 3). This is slightly higher than the 7-9% estimated by Arnold *et al*. (2011) [15], very close to estimates from Eberhardt and Teal (2010), and in the lower bound of the 11-15% estimated by Toppel (1999) or Canton (2007).

59. Two additional features emerge from Table 5.1, which only partially corroborate the assumptions of the Solow human-capital-augmented framework. First, the assumption of decreasing return to scale for factors of production cannot be rejected by the specification without time trends, while the estimation including time trends rather suggests that return to scale are constant (*i.e.* $\hat{\lambda}$ is close to 1 and the test does not reject the null assumption of constant returns to broad physical and human capital). Secondly, the estimated speed of convergence parameter (respectively 0.21 to 0.33) is quite higher than the predicted speed predicted by the Solow model.[16] Arnold *et al.* (2011) suggest that the combination of high elasticities and high convergence is more consistent with an endogenous growth model. Moreover, we checked the robustness of results to different lag structures in the independent variables and results are not different from those presented here (see the Annex –detailed results available on request).[17]

[15] The fact that the estimates are slightly higher here than those of Arnold *et al*. (2011) is not surprising since we cover a longer period and a larger number of countries, including those where both the growth in educational attainment and in output per capita were steeper. Overall, we found that the increase in both GDP per capital and in years of education has been steeper from 1960 to 1990 than in the period following after. Arnold *et al*. (2011)'s analysis cover the period from 1971 to 2004, and 21 countries but not countries like Chile, Estonia, Mexico, Slovenia and Turkey where there has been strong increase in education and output per capita.

[16] These values are again close to those estimated by Bassanini and Scarpetta (2002) and Arnold *et al*. (2011) which for $\widehat{\emptyset}$ range between 0.25 and 0.36.

[17] As shown in Annex Table A1.1, the best model according to the Schwartz Bayesian Information Criterion (BIC) would include one lag of the physical and human capital and the population growth. Only minor parameter differences emerge from this and our baseline specifications. Moreover, the key test statistics are robust to this type of changes in the specification.

Table 5.1. Growth equation with total human capital - baseline estimates

	Mean Group (MG)			Pooled Mean Group (PMG)		Diff-GMM
Dependent variable: Δlog Y	(1) No time effects	(2) with 5-year dummies	(3) C-MG	(4) No time effects	(5) with period effects	(6) With period effects
Convergence coefficient						
$logY_{t-1}$	-0.18***	-0.38***	-0.36	-0.09***	-0.28***	0.42***
	(0.05)	(0.06)	(0.22)	(0.02)	(0.04)	(0.05)
Long-run coefficients						
log K	0.45***	0.41***	0.26***	0.47***	0.28***	0.14**
	(0.12)	(0.09)	(0.04)	(0.02)	(0.01)	(0.06)
log H	1.88**	2.28	0.74***	0.32***	1.07***	0.70***
	(0.81)	(1.55)	(0.26)	(0.04)	(0.06)	(0.13)
Δlog N	-4.82	0.13	-1.52	-5.00***	-1.57***	-0.17
	(21.83)	(15.9)	(3.89)	(1.15)	(0.70)	(0.21)
Hausman test of long-run slope homogeneity (p-value)				0.28	0.45	
Estimated returns to scale	1.60	-		0.54	1.06	-
Test for constant returns to scale (p-value)	0.30	-		0.000	0.24	-
Diagnostics of residuals:						
Test of cross- section independence abs. ρ (p-value)[1]	0.89 (0.00)	0.89 (0.00)	0.83 (0.00)	0.77 (0.00)	0.86 (0.00)	-
Stationarity - unit root test[2]	0.06	0.19	0.00	0.00	0.00	-
Hansen test of overidentification (p-value)						0.384
Arellano-Bond test for Autocorrelation						
AR(1)						0.161
AR(2)						0.924
Implied α[3]	0.31	0.29	0.21	0.32	0.22	-
Implied β[3]	1.30	1.61	0.59	0.22	0.83	-
Implied λ[3]	0.20	0.48	0.45	0.09	0.33	-
Speed of convergence test (p-value)[4]						
(1)				0.002	0.000	
(2)				0.14	0.000	
N. of countries	30	30	30	30	30	30
N. of obs.	1150	1150	1150	1150	1150	1137
N. of instruments	-	-	-	-	-	20
Log likelihood	3266	3512		3114	3184	

Notes: Only long-run parameters are presented. Period effects are assumed to be linear or not and captured by 5-years time dummies. Standard errors in brackets. ***, **, *: significant at the 1%, 5% and 10% level, respectively.
1) Pesaran (2004) CD test, the null hypothesis assuming that all residuals are cross-section independent. Absolute correlation and p-value of the test are reported; a p-value below 0.05 leads the rejection of cross-section independence.
2) Results of the Pesaran (2007) CIPS tests which assume cross-section dependence between panel units; a p-value below 0.05 does not reject the assumption that all residuals are stationary.
3) Implied α is equal to $\widehat{\theta_1}/(1+\widehat{\theta_1})$; β= $\widehat{\theta_2}/(1+\widehat{\theta_1})$; λ speed of convergence is given by : -ln(1-$\widehat{\emptyset}$)/s, with s taken at 1.
4) Test for estimated speed of convergence to be compatible with the value predicted by the Solow augmented model. Predicted values are computed on the basis of plausible values for population growth rate, the depreciation rate and the rate of technological progress. (1) assumes a standard value of 2% for depreciation rate; for technological progress, we consider the average estimated time trend (-0.3%) or the average annual shift implied by the five-year dummies (0.1%), depending on the specification. For population growth, we take the average value of our sample (0.9%). (2) assumes a much higher value of capital depreciation (10%) and allow technological progress to growth at higher 3%.

60. Moving to the model specification that includes gender differences in education, these are measured by the ratio $R^{f/m}$ of the average years of education of women relative to men (Table 5.2). All the results reported in the table include 5-years dummies to control for country-specific change in the production context. Once again, the estimates obtained with the MG estimation exhibit larger standard errors and coefficients not significantly different from zero for both the average education of the

population and for the gender gap. By contrast, the same two coefficients are positive and highly significant when estimated with a PMG procedure; as before, the restrictions on the long-run convergence are not rejected by a Hausman test.

61. The estimated effect of the average years of education is slightly smaller than the one estimated for the Table 4 model, but is balanced by a significant and quite large effect of greater equality in education between women and men. The results suggest that a balanced gender ratio in education ($R^{f/m}$=1) increases output per capita by around 0.8% in comparison to a scenario where women have no access to education.

62. The average years in education has increased on average by 1.2% per annum (from 6.1 years in 1960 to 11.1 in 2008). The second model presented in Table 5.2 suggests a growth-elasticity to the years of education of 0.94, suggesting that human capital accumulation induced an increase in growth of 1.1% (=0.94*1.2) per annum. As GDP per capital actually grew by 2.1% per annum on average, the model implies that the increase in years of education accounts for about 50% of economic growth, of which just over half was due to the increase of educational attainment among women.

63. Output per capita growth is increased by a better gender composition of educational attainment (Table 5.2). The elasticity of the output per capita growth to an increase in the average number of years of education is slightly lower than in the former specification: hence, the increase in years of education is estimated here to have raised GDP per capita by 1.13% annually. But the higher ratio of years of female education to males has had a positive and highly significant influence on growth: the 0.09% average annual growth in the gender ratio of education increased is estimated to have contributed to raising annual economic growth by an additional 0.07% per annum (*i.e.* 0.09%*0.81).

Table 5.2. Results with female-to-male ratio in education

Dependent variable: Δlog Y	Mean Group (MG)	Pooled Mean Group (PMG)	Diff-GMM
Convergence coefficient			\
logY_{t-1}	-0.55***	-0.33***	0.40***
	(0.07)	(0.06)	(0.07)
Long-run coefficients			
log K	0.31***	0.30***	0.18***
	(0.04)	(0.01)	(0.06)
log H	-0.74	0.94***	0.53***
	(1.73)	(0.07)	(0.12)
log $R^{f/m}$	0.87	0.81***	1.08**
	(2.40)	(0.16)	(0.54)
Δlog N^m	-2.25	0.82	0.10
	(6.30)	(1.05)	(0.46)
Δlog N^f	6.26	-4.57***	-0.30
	(5.79)	(1.34)	(0.49)
Hausman test of long-run slope homogeneity (p-value)		0.654	
Diagnostics of residuals:			
Test of cross- section independence abs. ρ (p-value)[1]	-		
Stationarity - Unit root test[2]	0.00	0.00	
Hansen test of overidentification (p-value)			0.174
Arellano-Bond test for Autocorrelation			
AR(1)			0.340
AR(2)			0.839
N. of countries	30	30	30
N. of obs.	1127	1127	1114
N. of instruments	-	-	22
Log likelihood		3184	

Note: All models include 5-years dummies to control for country-specific trends. Standard errors in brackets. ***, ** and * indicate significance at 1%, 5% and 10%, respectively.
1) Pesaran (2004) CD test: the null hypothesis assumes that all residuals are cross-section independent. Absolute correlation and p-value of the test are reported; a p-value below 0.05 leads the rejection of cross-section independence. The test cannot be performed.
2) Results of the Pesaran (2007) CIPS tests which assume cross-section dependence between panel units; a p-value below 0.05 does not reject the assumption that all residuals are stationary.

6. Labour market effects

64. The analysis undertaken previously (chapters 1-5) supplements the large body of theoretical and empirical evidence on the link between human capital accumulation and economic growth, and further demonstrates the additional positive influence of a more equal distribution of education among men and women. The basis of this analysis was an augmented growth model which allows for an assessment of the overall effect of education and gender differences on long-run economic growth, but cannot separately identify to what extent education induces growth through employment effects such as greater labour force participation. In addition to increased labour force participation by women, a better allocation of female workers across occupations and economic sectors can further contribute to growth. For example, Hsieh *et al* (2011) suggest that between 17 and 20% of US economic growth between 1960 and 2008 might be due to the changing allocation of underrepresented groups in the workforce, including women. In chapters 6

and 7 we will assess the potential effect of increasing (female) labour force participation on labour supply and growth.

65. Figure 6.1 shows the effects that narrowing gender gaps in labour market participation may have on the potential size of the labour force. These projections consider three different scenarios of male and female labour market participation over the next 20 years and the effects on the total labour force:

- A no-change scenario: Male and female participation rates remain at their 2010 levels over the whole period.
- Convergence in participation rates: The male participation rate remains constant at its 2010 level, while the female participation rate increases over the period to the male participation levels in 2030.
- Convergence in intensity of labour market participation: This scenario accounts for the difference in usual working hours between the genders and assumes that the male participation rate remains constant at its 2010 level, while the female full-time equivalent participation rate (see notes to Figure 1.1.2) increases to equal the full-time equivalent rate for men by 2030.

66. Ageing populations and/or persistently low fertility rates over the past few decades imply that many countries are expected to face a shrinking labour force over the next 20 years. The projected decrease of the labour force would be particularly severe (over 10%) in the Czech Republic, Germany, Japan, Poland, the Russian Federation, the Slovak Republic and Slovenia assuming constant male and female labour force participation rates at the current levels.

67. The convergence in participation rates scenario is projected to have the largest effect in Brazil, Chile, the Czech Republic, Greece, Ireland, Italy, Japan, Korea, Luxembourg, Mexico, Poland, the Slovak Republic and Spain. Because there are currently large gender gaps in participation in these countries, the projected increase in the size of the labour force by 2030 exceeds 10%.

68. Figure 6.1 also illustrates the further effect of convergence in the intensity of labour force participation. Significant additional increases in the labour force are projected under this scenario for Australia, Austria, Belgium, Germany, Ireland, Luxembourg and the United Kingdom. In these countries more than 30% of employed women work part-time; labour force gains are potentially even higher in the Netherlands and Switzerland where the incidence of part-time employment is highest among OECD countries.

69. These projections involve assumptions on future population patterns that may not materialise. Nevertheless, they clearly show the size of the potential female labour force and its potential effect in counteracting the decline in labour supply resulting from the ageing of populations. In this context, a key challenge for both government and employers is to promote working conditions and pay that make being in work more attractive to women in the future. The ageing of populations will also increase the demand for long-term care (OECD, 2011b), which often fall on women's shoulders. In many emerging economies the fulfilment of family obligations such as caring for aging relatives is a priority for women regardless of their personal career ambitions. In China this issue is of particular concern due to the prevailing one-child policy which, amongst other things, means that such care obligations cannot be shared between siblings (Hewlett and Rashid, 2011). There needs to be greater gender equality in both paid and unpaid work participation and paid and unpaid workplace practices will have to become more efficient to meet the demand for formal and informal labour.

Figure 6.1. Effect of converging participation rates between men and women on total labour force

Projected number of persons aged 15-64 in the labour force, thousands, 2011-2030

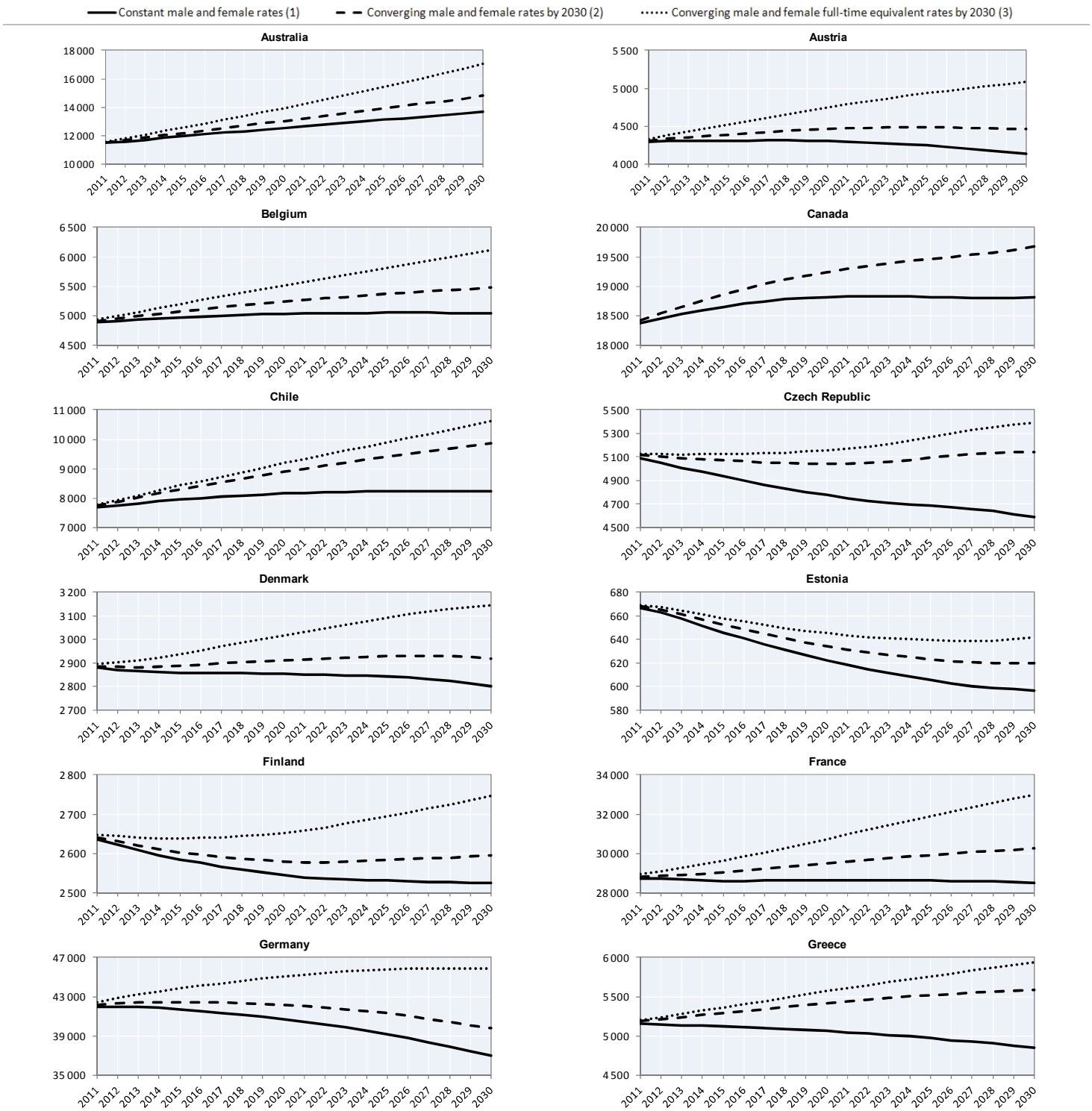


Figure 6.1. Effect of converging participation rates between men and women on total labour force (cont.)

Projected number of persons aged 15-64 in the labour force, thousands, 2011-2030

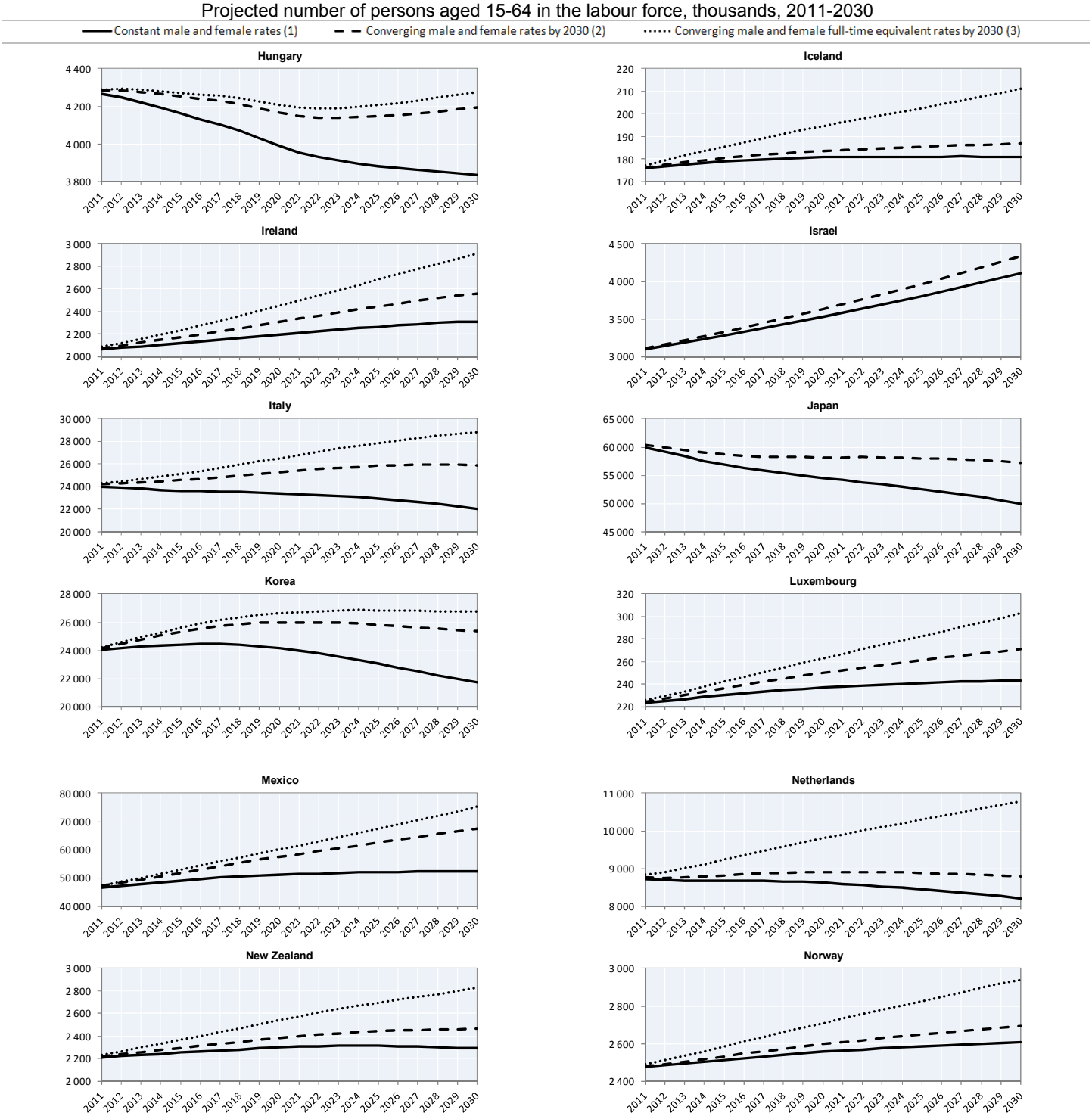


Figure 6.1. Effect of converging participation rates between men and women on total labour force (cont.)
Projected number of persons aged 15-64 in the labour force, thousands, 2011-2030

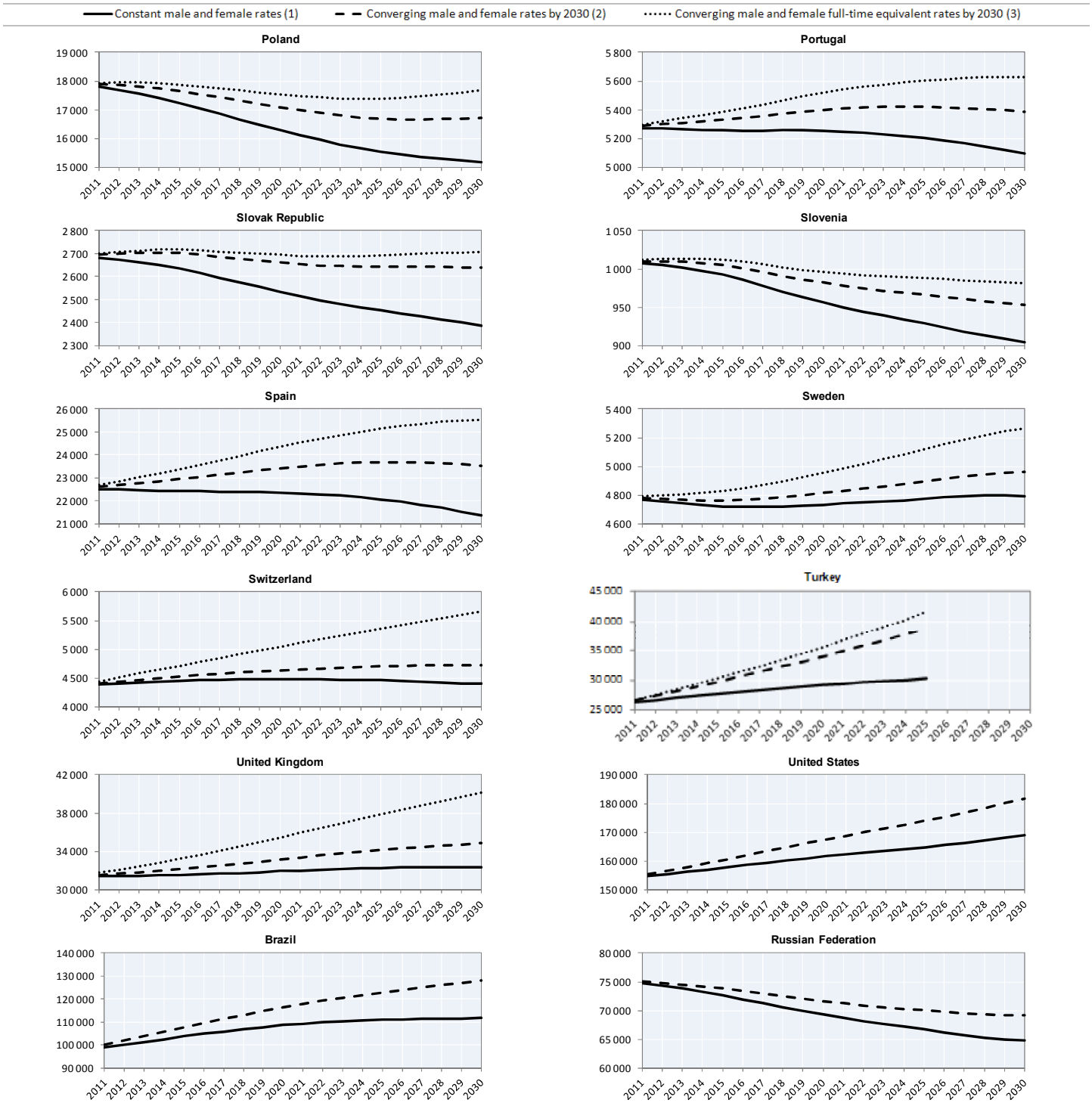
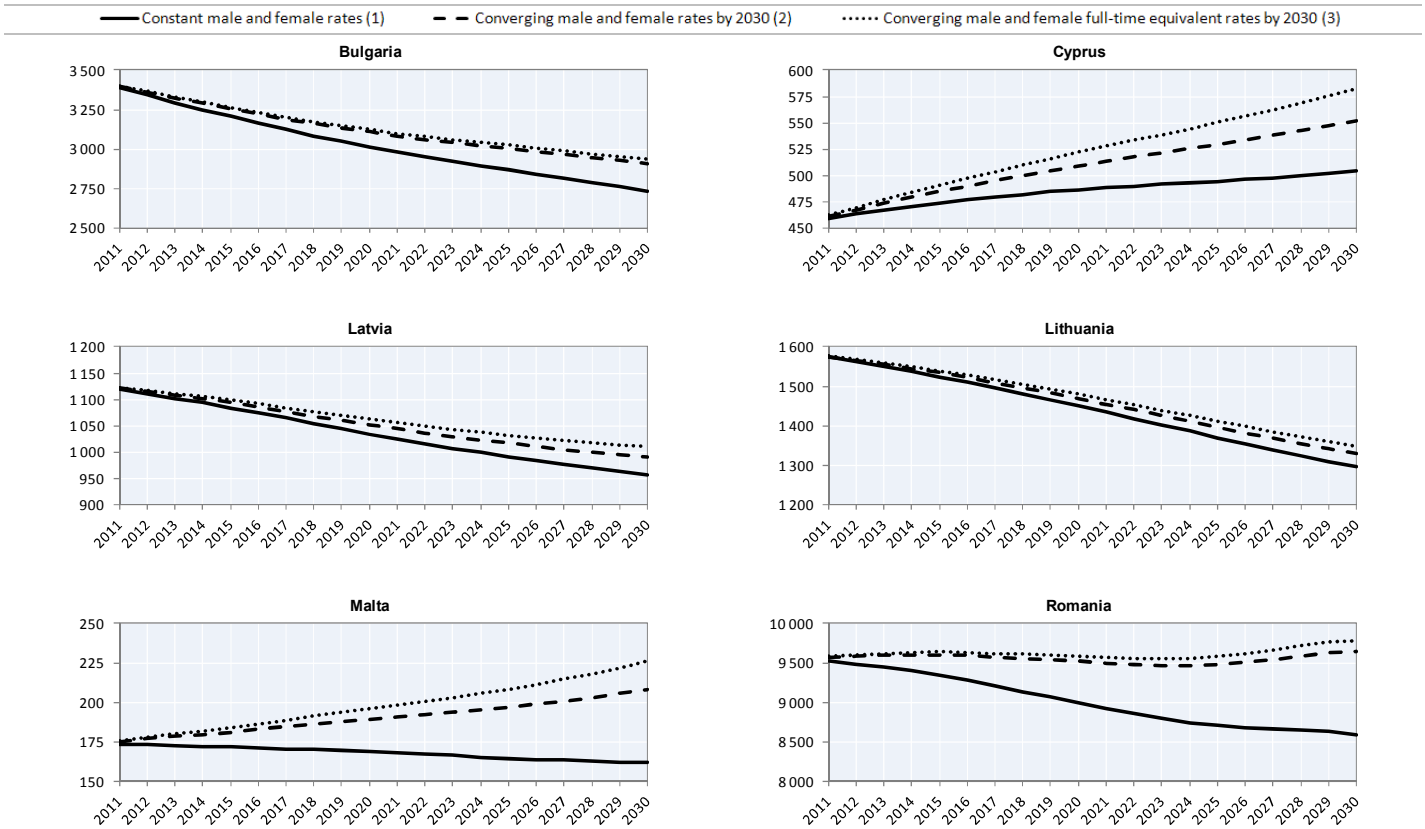


Figure 6.1. Effect of converging participation rates between men and women on total labour force (cont.)

Projected number of persons aged 15-64 in the labour force, thousands, 2011-2030



Notes: The labour force projections are based on population projections for persons aged 15-64 years as reported by the OECD Demography and Population database.

(1) Constant rate scenario: The projected size of the total labour force aged 15-64 years, if the labour force participation rates for men and women remain constant from 2011 to 2030 at the rates observed in 2010. (2) Converging rate scenario: The projected size of the total labour force aged 15-64 years, if the labour force participation rate for men remains constant from 2011 to 2030 at the rate observed in 2010, and the rate for women show a gradual increase (steady growth rate) from 2011 to 2030 reaching the rate observed for men in 2010, in 2030. (3) Converging rate scenario, accounting for differences in male and female working hours: The projected size of the total labour force aged 15-64 years, if the labour force participation rate for men remains constant from 2011 to 2030 at the rate observed in 2010, and the full-time equivalent rate for women show a gradual increase (steady growth rate) from 2011 to 2030 reaching the full-time equivalent rate observed for men in 2010, in 2030. The full-time equivalent rate is calculated as the labour force participation rate, multiplied by the average usual hours worked per week by all employed men and women respectively, and divided by 40.

Note on Israel: The statistical data for Israel are supplied by and under the responsibility of the relevant Israeli authorities. The use of such data by the OECD is without prejudice to the status of the Golan Heights, East Jerusalem and Israeli settlements in the West Bank under the terms of international law. Information on data http://dx.doi.org/10.1787/888932315602

Source: OECD's Secretariat's calculations based on the OECD Population and Demography database and the OECD Employment database.

7. Convergence in male and female labour force participation and economic growth

70. This section attempts to gauge the potential effect of increased labour force participation of women on economic growth, based on modified long-term growth scenarios outlined in the OECD Economic Outlook 91 long-term database. The long-term growth scenarios are underpinned by an economic model which extends OECD's short-term projections based on an overall assumption that each country converges to its own steady-state trajectory of GDP per capita. This convergence scenario is determined by the interface between global technological development and country-specific structural conditions and policies – the so-called 'conditional convergence' (OECD, 2012a).

71. The backbone of the model is a consistent set of long-run projections for potential output, where potential output is based on a Cobb-Douglas production function with constant returns to scale featuring physical capital, human capital and labour as production factors plus labour-augmenting technological progress:

$$Y_{it} = K_{it}^{\alpha}(A_{it}\, h_{it} L_{it})^{1-\alpha}$$

where Y, K, A, h and L denote output, physical capital, technical progress, human capital per worker, employment respectively and subscript *t* and *i* denotes year and country.

72. The share of capital (α) is set equal to 1/3. GDP and GDP per capita can be written, respectively, as:

$$Y_{it} = (K_{it}/Y_{it})^{\alpha/(1-\alpha)} A_{it}\, h_{it} L_{it}$$

$$Y_{it}/Pop_{it} = (K_{it}/Y_{it})^{\alpha/(1-\alpha)} A_{it}\, h_{it} (L_{it}\,/Pop_{it})$$

where K/Y refers to the capital-output ratio. Employment is further decomposed into trend population (POP), trend labour force participation rate (LFPR) and trend unemployment rate (u) according to:

$$L_{it} = POP_{it} * LFPR_{it} * (1 - u_{it})$$

73. By projecting trends in input components, assuming a degree of convergence in total factor productivity, potential output is also projected over a 40-year horizon. For the purposes of our analysis, the trend labour force participation rate (LFPR) is modified so as to present four scenarios of convergence between male and female labour force participation over the next 20 years:[18]

- Current gender gaps: The gap between male and female labour force participation rate remains at the levels observed in 2010 (this is identical to the baseline growth scenario presented in the OECD Economic Outlook 91 long-term database).
- Gender gaps reduce by 50%: The gap between male and female labour force participation levels observed in 2010 is reduced by 50% by 2030, based on a steady growth rate of female labour force participation.
- Gender gaps reduce by 75%: The gap between male and female labour force participation levels observed in 2010 is reduced by 75% by 2030, based on a steady growth rate of female labour force participation.

[18] Projected participation rates can be found in Table A1.3 in the Annex.

- Convergence in participation rates: The gap between male and female labour force participation levels observed in 2010 disappears by 2030, based on a steady growth rate of female labour force participation. Thus, in this scenario it is assumed that the female labour force participation rate will reach the levels observed for men by 2030.

74. The effect of converging male and female working hours is not considered in this analysis, as changes in working hours have potential effects on multi-factorial productivity which cannot be properly accounted for in this model. All other input components are taken from the OECD Economic Outlook 91 long-term database, with the projections based on assumptions outlined in OECD, 2012a.

75. Despite assuming no reduction in the gap between male and female labour force participation rates, GDP per capita is still expected to grow in the baseline projections estimate, at an average annual rate of between 0.8% (Luxembourg) to 3.4% (Estonia) among OECD economies (Table 3) over the next 20 years. This is primarily due to an increase in multi-factorial productivity which will continue to be the main driver of growth over this period (OECD, 2012a).

76. Nonetheless, there are potential gains from converging male and female labour force participation. On average the gain among OECD economies from a 50% decrease in the gender gap is a 0.3 percentage point increase in the average annual growth rate in GDP per capita, and 0.6 percentage points if full convergence occurs by 2030. The largest increase (more than 0.5 percentage points) from full convergence are projected in the Czech Republic, Greece, Hungary, Japan, Korea, Luxembourg, Poland, the Slovak Republic, and especially in Italy where the increase is expected to be more than 1.0 percentage points. To a large extent this reflects (i) persistently low birth rates in these countries which curtail growth of the working age population in future and (ii) the large existing gender gaps in participation and thus a greater potential for growth with better utilisation of the female labour supply.

77. The effect of increased female labour force participation is also expected to lead to substantial increases in the total size of the economy, as measured by GDP, in many OECD countries (Table 4). On average, across the OECD, a 50% reduction in the male and female participation levels is expected to lead to additional gain in GDP of 6% by 2030, with a further 6% gain (12% in total) if complete convergence occurs. As with growth rates the largest gain is expected in Italy, where a complete convergence will lead to an increase in GDP of more than 20%, while the gains will be more limited in Finland, Iceland and Sweden at less than 5%. In these three Nordic economies the gap between male and female labour force participation are small and the growth potential from a reduction in this gap is limited.

Box 1. Labour force projection and economic gains in European countries

There is considerable variation in the existing population and labour force structure among European countries, but most face the dual problem of an ageing population and persistently low fertility rates over recent decades. Combined, these factors imply a shrinking labour force in most countries over the next 20 years if the male and female labour force participation rates remain constant (Figure 6.1: Austria, Bulgaria, the Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Italy, Latvia, Lithuania, Malta, the Netherlands, Poland, Portugal, Romania, the Slovak Republic, Slovenia and Spain). However, the "shortfall" in the labour supply may in part be addressed by an increase in the female labour force participation with all countries projected to increase the size of the labour force if the female labour force participation rates reach the male rates over the next 20 years. This increase would be greater still if there is further convergence between the male and female working hours.

On average across the EU21[19], GDP per capita is projected to grow by an annual average of 1.9% under the considerable influence of rising multi-factorial productivity even with no change in male and female participation rates (Table 7.1). However, further gains can be expected from an increase in female labour force participation (and, therefore, from a convergence between male and female rates). On average, the projected gain from a 50% decrease in the gender gap is a 0.3 percentage point increase in the average annual growth rate in GDP per capita, and 0.6 percentage points if female labour force participation converges fully towards male rates, similar to the gains expected on average among the OECD countries. The projected gain of full convergence in participation rates are substantially higher (more than 0.6 percentage points) in the Czech Republic, Greece, Poland, the Slovak Republic, and especially in Italy where the gender gap in labour force participation is currently high.

78. The reader should bear in mind that this analysis does not present a definitive scenario, but rather the *potential* economic gain that may arise from increased female labour force participation. The projections demonstrate that the extent of the effect is very much dependent on the rate of convergence between male and female participation rates, both in the level of gap reduction and the time frame over which this takes place. There are various factors that may affect the rate of convergence between male and female labour force participation, which are beyond the scope of the analysis carried out in this paper.

19. The EU21 countries include Austria, Belgium, the Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Luxembourg, the Netherlands, Poland, Portugal, the Slovak Republic, Slovenia, Spain, Sweden and the United Kingdom.

Figure 7.1. Effect of converging participation rates between men and women on economic growth

Projected size of the economy in GDP, USD 2005 PPP, in 1 000 000 000s, 2011-2030

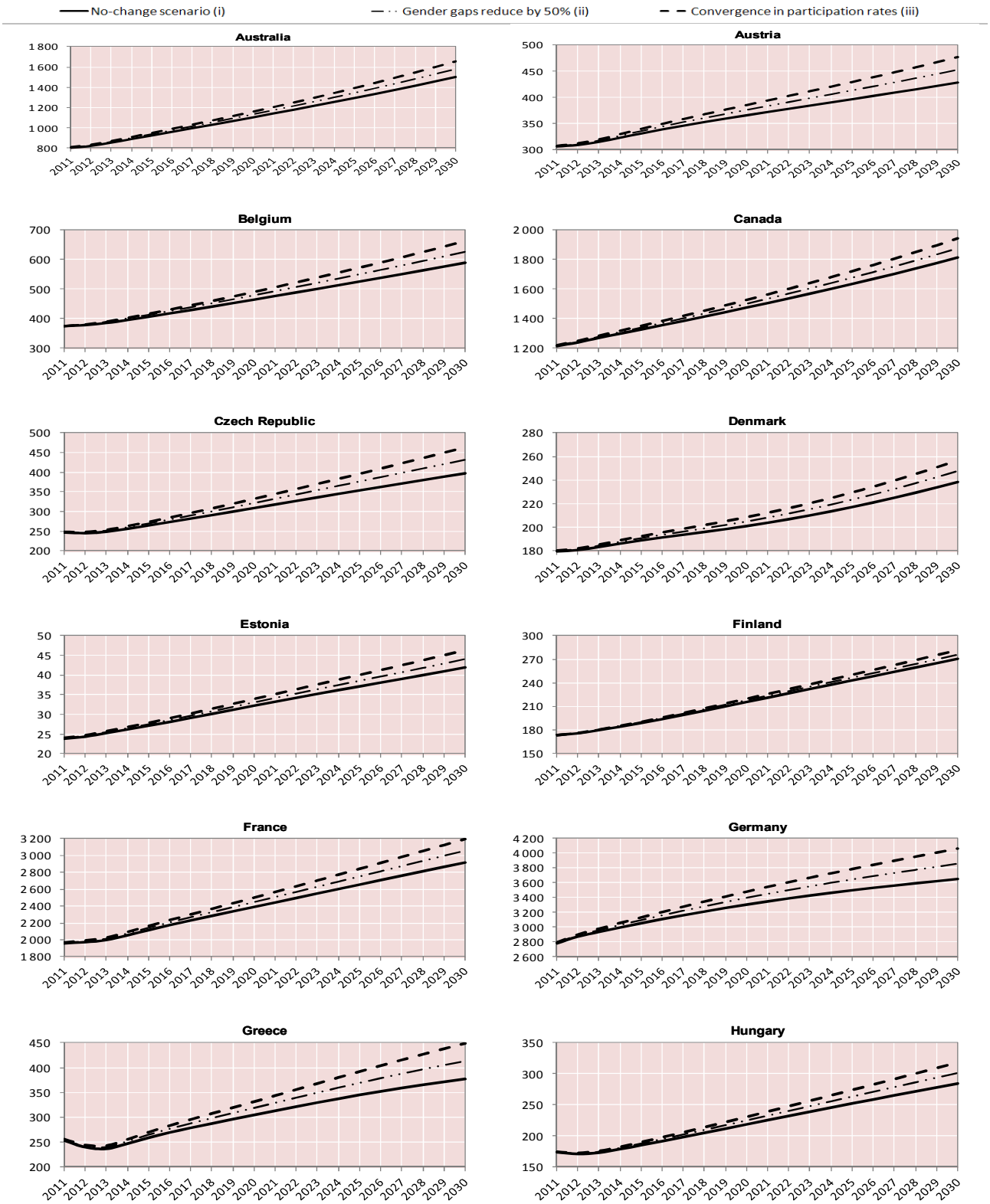


Figure 7.1. Effect of converging participation rates between men and women on economic growth (cont.)

Projected size of the economy in GDP, USD 2005 PPP, in 1 000 000 000s, 2011-2030

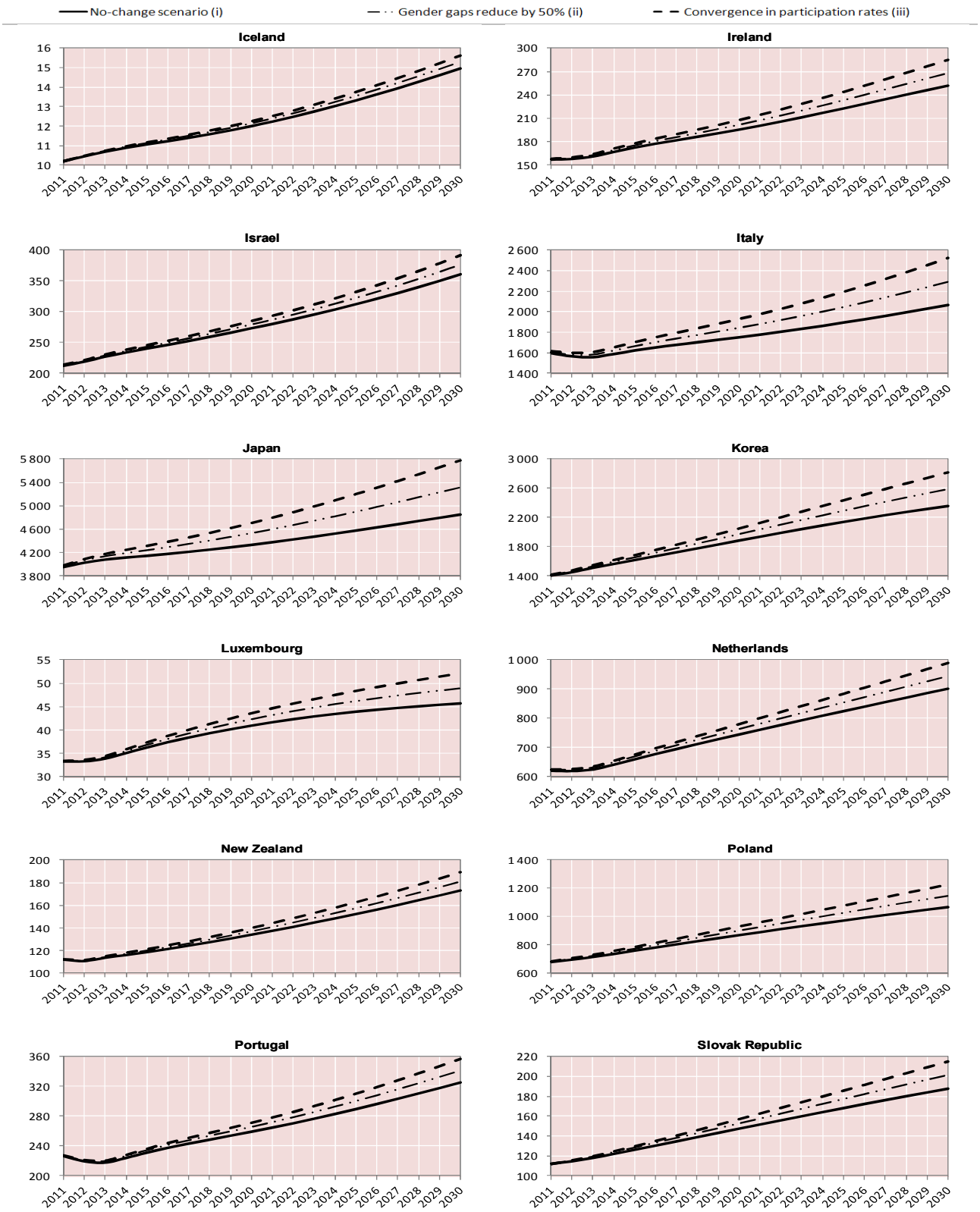
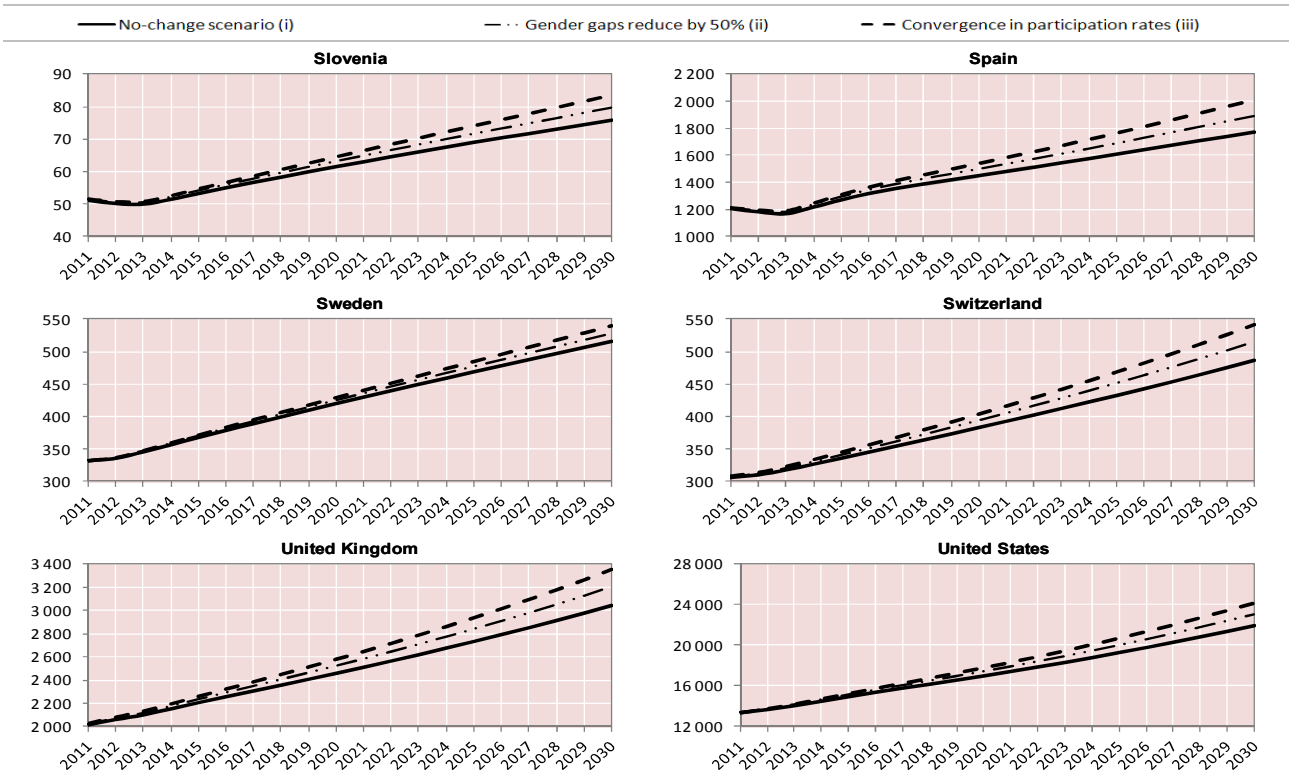


Figure 7.1. Effect of converging participation rates between men and women on economic growth (cont.)

Projected size of the economy in GDP, USD 2005 PPP, in 1 000 000 000s, 2011-2030



Notes: The labour force projections are based on population projections for persons aged 15-64 years as reported by the OECD Demography and Population database.

(i) No-change scenario: The gap between male and female labour force participation rate remains at the levels observed in 2010 (this is identical to the baseline growth scenario presented in the OECD Economic Outlook 91 long-term database). (ii) Gender gaps reduce by 50%: The gap between male and female labour force participation levels observed in 2010 is reduced by 50% by 2030, based on a steady growth rate of female labour force participation. (iii) Convergence in participation rates: The gap between male and female labour force participation levels observed in 2010 disappears by 2030, based on a steady growth rate of female labour force participation. Thus, in this scenario it is assumed that the female labour force participation rate will reach the levels observed for men by 2030.

Note on Israel: The statistical data for Israel are supplied by and under the responsibility of the relevant Israeli authorities. The use of such data by the OECD is without prejudice to the status of the Golan Heights, East Jerusalem and Israeli settlements in the West Bank under the terms of international law. Information on data http://dx.doi.org/10.1787/888932315602

Source: OECD's Secretariat's calculations based on the OECD Population and Demography database and the OECD Employment database.

Table 7.1. Projected average annual growth rate in GDP and GDP per capita in USD 2005 PPP, 2011-2030

	(1) No change in Labour force particpation rate (LFPR)		(2) Male and female LFPR gap reduced by 50%, by 2030			(3) Male and female LFPR gap reduced by 75%, by 2030			(4) Male and female LFPR gap reduced by 100%, by 2030		
	GDP (a)	GDP per capita (b)	GDP (c)	GDP per capita (d)	Increase in GDP per capita: (d) -	GDP (e)	GDP per capita (f)	Increase in GDP per capita: (f) -	GDP (g)	GDP per capita (h)	Increase in GDP per capita: (h) -
Australia	3.3	2.0	3.5	2.2	0.2	3.7	2.4	0.4	3.8	2.5	0.5
Austria	1.9	1.5	2.1	1.8	0.3	2.3	1.9	0.4	2.4	2.1	0.6
Belgium	2.5	1.8	2.8	2.1	0.3	2.9	2.3	0.5	3.1	2.4	0.6
Canada	2.1	1.4	2.2	1.6	0.2	2.3	1.7	0.3	2.4	1.8	0.4
Czech Republic	2.4	2.6	2.8	3.0	0.4	3.0	3.2	0.6	3.2	3.4	0.8
Denmark	1.5	1.2	1.6	1.4	0.2	1.7	1.5	0.3	1.8	1.5	0.3
Estonia	3.2	3.4	3.5	3.7	0.3	3.6	3.8	0.4	3.7	3.9	0.5
Finland	2.4	1.9	2.5	2.0	0.1	2.5	2.1	0.2	2.6	2.2	0.3
France	2.1	1.7	2.3	1.9	0.2	2.5	2.0	0.3	2.6	2.1	0.4
Germany	1.5	1.6	1.8	1.8	0.2	1.9	2.0	0.4	2.0	2.1	0.5
Greece	1.7	1.7	2.1	2.1	0.4	2.4	2.4	0.7	2.6	2.6	0.9
Hungary	2.6	2.8	2.9	3.1	0.3	3.1	3.3	0.5	3.2	3.4	0.6
Iceland	1.9	1.5	2.0	1.6	0.1	2.0	1.7	0.2	2.1	1.7	0.2
Ireland	2.3	1.6	2.6	1.9	0.3	2.7	2.1	0.5	2.9	2.2	0.6
Israel	2.9	1.2	3.1	1.4	0.2	3.2	1.5	0.3	3.3	1.6	0.4
Italy	1.2	1.4	1.7	1.9	0.5	2.0	2.2	0.8	2.2	2.4	1.0
Japan	1.0	1.5	1.5	1.9	0.4	1.7	2.1	0.6	1.9	2.3	0.8
Korea	2.8	2.5	3.3	3.0	0.5	3.5	3.2	0.7	3.7	3.4	0.9
Luxembourg	1.4	0.8	1.7	1.1	0.3	1.9	1.3	0.5	2.0	1.4	0.6
Netherlands	1.9	1.6	2.2	1.9	0.3	2.3	2.0	0.4	2.4	2.1	0.5
New Zealand	2.3	1.8	2.5	2.0	0.2	2.6	2.1	0.3	2.7	2.2	0.4
Poland	2.4	2.7	2.8	3.0	0.3	3.0	3.2	0.5	3.1	3.4	0.7
Portugal	1.8	1.6	2.0	1.9	0.3	2.1	2.0	0.4	2.2	2.1	0.5
Slovak Republic	2.8	2.9	3.1	3.2	0.3	3.3	3.4	0.5	3.5	3.6	0.7
Slovenia	1.9	1.9	2.2	2.2	0.3	2.3	2.3	0.4	2.4	2.4	0.5
Spain	1.8	1.9	2.1	2.2	0.3	2.3	2.4	0.5	2.4	2.5	0.6
Sweden	2.4	1.9	2.6	2.1	0.2	2.6	2.1	0.2	2.7	2.2	0.3
Switzerland	2.5	1.9	2.7	2.2	0.3	2.9	2.3	0.4	3.0	2.4	0.5
United Kingdom	2.1	1.4	2.3	1.7	0.3	2.4	1.8	0.4	2.6	1.9	0.5
United States	2.6	1.7	2.9	1.9	0.2	3.0	2.0	0.3	3.1	2.2	0.5
EU21 total	1.9	1.7	2.2	2.0	0.3	2.3	2.2	0.5	2.5	2.3	0.6
OECD30 total	2.2	1.8	2.5	2.1	0.3	2.6	2.2	0.4	2.8	2.3	0.5
EU21 average	2.1	1.9	2.4	2.2	0.3	2.5	2.3	0.4	2.6	2.5	0.6
OECD30 average	2.2	1.8	2.4	2.1	0.3	2.6	2.3	0.5	2.7	2.4	0.6

The labour force projections are based on population projections for persons aged 15+ years, rather than persons aged 15-64, to be consistent with the growth model outlined in OECD Economic Outlook 91
The EU21 and OECD30 average are unweighted (all countries are given equal weighting).
(1) Current gender gaps: The gap between male and female labour force participation rate remains at the levels observed in 2010 (this scenario is identical to the baseline growth scenario presented in the OECD Economic Outlook 91 long-term database). (2) Gender gaps reduce by 50%: The gap between male and female labour force participation levels observed in 2010 is reduced by 50% by 2030, based on a steady growth rate of female labour force participation. (3) Gender gaps reduce by 75%: The gap between male and female labour force participation levels observed in 2010 is reduced by 75% by 2030, based on a steady growth rate of female labour force participation. (4) Convergence in participation rates scenario: The gap between male and female labour force participation levels observed in 2010 disappears by 2030, based on a steady growth rate of female labour force participation. Thus, in this scenario it is assumed that the female labour force participation rate will reach the levels observed for men by 2030 (similar to scenario 2 outlined in section 5) and the gender gap not longer exists.
Note on Israel: The statistical data for Israel are supplied by and under the responsibility of the relevant Israeli authorities. The use of such data by the OECD is without prejudice to the status of the Golan Heights, East Jerusalem and Israeli settlements in the West Bank under the terms of international law. Information on data http://dx.doi.org/10.1787/888932315602

Source: OECD's Secretariat's calculations based on the OECD Economic Outlook 91 long-term database (version 6 June 2012), OECD Population and Demography database and the OECD Employment database.

Table 7.2. Projected GDP in USD 2005 PPPs, millions, 2020 and 2030

	CURRENT	(1) No change in Labour force particpation rate (LFPR)		(2) Male and female LFPR gap reduced by 50%, by 2030			(3) Male and female LFPR gap reduced by 75%, by 2030			(4) Male and female LFPR gap reduced by 100%, by 2030		
	2010	2020 (a)	2030 (b)	2020 (c)	2030 (d)	% gain by 2030: (d) / (b)	2020 (e)	2030 (f)	% gain by 2030: (f) / (b)	2020 (g)	2030 (h)	% gain by 2030: (h) / (b)
Australia	787 677	1 103 725	1 499 260	1 132 147	1 578 592	5.3%	1 145 798	1 618 259	7.9%	1 159 114	1 657 925	10.6%
Austria	296 571	366 028	428 998	376 020	453 117	5.6%	380 812	465 176	8.4%	385 482	477 236	11.2%
Belgium	363 807	464 547	590 432	478 477	626 957	6.2%	485 126	645 220	9.3%	491 588	663 483	12.4%
Canada	1 205 278	1 475 420	1 813 020	1 500 800	1 876 699	3.5%	1 513 162	1 908 538	5.3%	1 525 321	1 940 378	7.0%
Czech Republic	249 088	309 079	398 130	321 287	431 020	8.3%	327 025	447 465	12.4%	332 555	463 910	16.5%
Denmark	178 731	201 428	238 668	205 109	247 565	3.7%	206 899	252 013	5.6%	208 657	256 462	7.5%
Estonia	22 248	32 199	41 876	33 027	44 051	5.2%	33 426	45 139	7.8%	33 817	46 226	10.4%
Finland	168 784	215 543	270 070	217 852	275 903	2.2%	218 988	278 819	3.2%	220 112	281 735	4.3%
France	1 924 322	2 390 455	2 920 002	2 445 586	3 057 422	4.7%	2 472 214	3 126 132	7.1%	2 498 271	3 194 842	9.4%
Germany	2 709 921	3 307 827	3 654 202	3 397 560	3 858 410	5.6%	3 440 588	3 960 514	8.4%	3 482 517	4 062 619	11.2%
Greece	272 668	304 931	377 598	318 620	413 269	9.4%	324 986	431 105	14.2%	331 088	448 941	18.9%
Hungary	170 098	218 119	284 050	224 622	301 391	6.1%	227 733	310 062	9.2%	230 760	318 732	12.2%
Iceland	10 337	12 002	14 978	12 128	15 298	2.1%	12 190	15 459	3.2%	12 252	15 619	4.3%
Ireland	161 219	195 733	251 754	201 898	268 185	6.5%	204 831	276 400	9.8%	207 677	284 615	13.1%
Israel	203 651	273 544	361 112	279 117	376 063	4.1%	281 817	383 539	6.2%	284 465	391 014	8.3%
Italy	1 634 919	1 752 386	2 062 120	1 845 278	2 294 082	11.2%	1 887 925	2 410 063	16.9%	1 928 532	2 526 043	22.5%
Japan	3 962 739	4 334 823	4 850 222	4 530 121	5 312 484	9.5%	4 621 099	5 543 614	14.3%	4 708 365	5 774 745	19.1%
Korea	1 356 587	1 888 264	2 359 168	1 975 076	2 589 371	9.8%	2 015 336	2 704 473	14.6%	2 053 864	2 819 574	19.5%
Luxembourg	34 817	40 861	45 625	42 251	48 849	7.1%	42 909	50 461	10.6%	43 547	52 073	14.1%
Netherlands	614 886	745 198	900 762	762 827	944 508	4.9%	771 325	966 381	7.3%	779 631	988 253	9.7%
New Zealand	110 672	134 014	173 101	137 041	181 098	4.6%	138 503	185 096	6.9%	139 933	189 095	9.2%
Poland	659 719	869 235	1 065 297	900 243	1 144 181	7.4%	914 924	1 183 622	11.1%	929 130	1 223 064	14.8%
Portugal	229 636	259 102	324 850	265 274	340 670	4.9%	268 252	348 580	7.3%	271 165	356 490	9.7%
Slovak Republic	108 617	147 171	187 537	152 312	201 158	7.3%	154 748	207 968	10.9%	157 107	214 779	14.5%
Slovenia	51 801	61 496	75 717	63 054	79 647	5.2%	63 803	81 612	7.8%	64 534	83 577	10.4%
Spain	1 242 300	1 450 797	1 769 654	1 498 142	1 889 635	6.8%	1 520 646	1 949 626	10.2%	1 542 466	2 009 617	13.6%
Sweden	318 671	419 650	515 569	424 468	527 489	2.3%	426 836	533 449	3.5%	429 176	539 409	4.6%
Switzerland	300 186	383 625	487 121	393 912	513 984	5.5%	398 847	527 415	8.3%	403 657	540 847	11.0%
United Kingdom	2 027 321	2 456 837	3 043 261	2 519 320	3 199 790	5.1%	2 549 347	3 278 055	7.7%	2 578 642	3 356 319	10.3%
United States	13 031 760	16 977 717	21 924 279	17 388 073	23 013 113	5.0%	17 585 799	23 557 531	7.4%	17 779 013	24 101 948	9.9%
EU21 total	13 440 144	16 208 622	19 446 172	16 693 227	20 647 299	6.2%	16 923 343	21 247 862	9.3%	17 146 454	21 848 425	12.4%
OECD30 total	34 409 031	42 791 756	52 928 433	44 041 642	56 104 001	6.0%	44 635 894	57 691 786	9.0%	45 212 438	59 279 570	12.0%
EU21 average	640 007	771 839	926 008	794 916	983 205	6.2%	805 873	1 011 803	9.3%	816 498	1 040 401	12.4%
OECD30 average	1 146 968	1 426 392	1 764 281	1 468 055	1 870 133	6.0%	1 487 863	1 923 060	9.0%	1 507 081	1 975 986	12.0%

The labour force projections are based on population projections for persons aged 15+ years, rather than persons aged 15-64, to be consistent with the growth model outlined in OECD Economic Outlook 91
(1) - (4) See notes 1-4 for Table 7.1.
The EU21 and OECD30 average are unweighted (all countries are given equal weighting).
Note on Israel: The statistical data for Israel are supplied by and under the responsibility of the relevant Israeli authorities. The use of such data by the OECD is without prejudice to the status of the Golan Heights, East Jerusalem and Israeli settlements in the West Bank under the terms of international law. Information on data http://dx.doi.org/10.1787/888932315602

Source: OECD's Secretariat's calculations based on the OECD Economic Outlook 91 long-term database (version 6 June 2012), OECD Population and Demography database and the OECD Employment database.

8. Conclusions

79. This paper provides an assessment of the extent to which the dynamics of economic growth over the past four decades prior to the ongoing recession are related to the increase in educational attainment of women. Both men and women have experienced an important increase in the number of years spent in education since the early 1960s. In many countries, the increase in the average numbers of years in education spent by women and men aged 25-64 has been roughly equivalent – the average number of years in education increased from 6.5 in 1960 to 11.2 in 2010 for men, and from 5.8 to 11.2 for women.

80. There are several reasons to argue that greater gender equality in education boosts economic growth. Assuming that boys and girls have a similar distribution of innate abilities and that children with more abilities are more likely to receive better quality and/or longer education, gender inequality in education implies that boys with lower abilities than girls are more likely to be enrolled in education. As a result, the average level of human capital in the economy would be lower than in a context of equal opportunities in education for boys and girls, which in turn might slow down economic growth. By the same reasoning, gender inequality in education reduces the impact of male education on economic growth and raises the impact of female education (Dollar and Gatti, 1999 and, Knowles *et al*., 2002). Side-effects on investment rate might also contribute to reduce growth, because of smaller returns on investments. Finally, greater gender balance in human capital will also lead to higher growth if male and female human capital are imperfect substitutes and if the marginal returns to education are declining (Knowles *et al*., 2002).

81. Our analysis is based on new OECD data series on GDP per capita and the updated version of the Barro and Lee (2010) data set on educational attainment of men and women. Our results support the assumption that the increase in the number of years spent in formal education by the working age population in OECD countries has shifted up the steady-state of economic growth. Convergence to this steady state takes place at different pace, however, depending on population growth and investments in physical capital, technological and institutional change. The empirical specification of the model we retained, based on a Pooled Mean Group Estimation, suggests that one additional year of schooling in the population is estimated to raise output per capita by around 10% per annum, which is close to the estimate obtained by Arnold *et al*. (2011) or Eberhardt and Teale (2010) but lower than the upper bound suggested by Canton (2007). Overall, our estimation implies that the increase in years of education accounts for slightly more than 60% of output per capita growth, of which 34 percentage points result from the increase in years of education of women. These estimates, however, do not provide a fully satisfactory control of the unobserved but correlated country characteristics that potentially alter the influence of human capital on growth.

82. Although we found evidence that a more equal access to prolonged education raises growth rates, we are not able to explicitly identify the causes. One possibility, as suggested by Knowles *et al.* (2002), is that male and female human capital are both characterized by decreasing returns but are complementary, so that for certain values of the average of human capital stock, years of education of women are more rewarding than men. Another possibility is that women now perform better and are less likely to lack basic skill than boys and are thus more valuable in the labour market, despite persistent discrimination and professional segregation (OECD, 2012b and, Hanushek and Woessmann, 2010). Other positive externalities of female education on the quality of life and productivity might also be at play, above and beyond their greater integration in the labour market. There is therefore much scope for further research on the subject.

83. Last, but not least, we look at the potential effect of increased female labour force participation on economic growth. The econometric model used to estimate the impact of gender differences in education on growth cannot be extended to capture the effect of the gender composition of the labour force, so these are analyzed through projections based on long-term growth scenarios. The size of the effect is dependent on the rate at which male and female labour force participation will converge, with a potential gain of 12% to the size of the total economy by 2030, on average across OECD countries, if complete convergence occurs in the next 20 years.

ANNEX

Figure A 1.1. Evolution of years in education – men and women aged 25-64

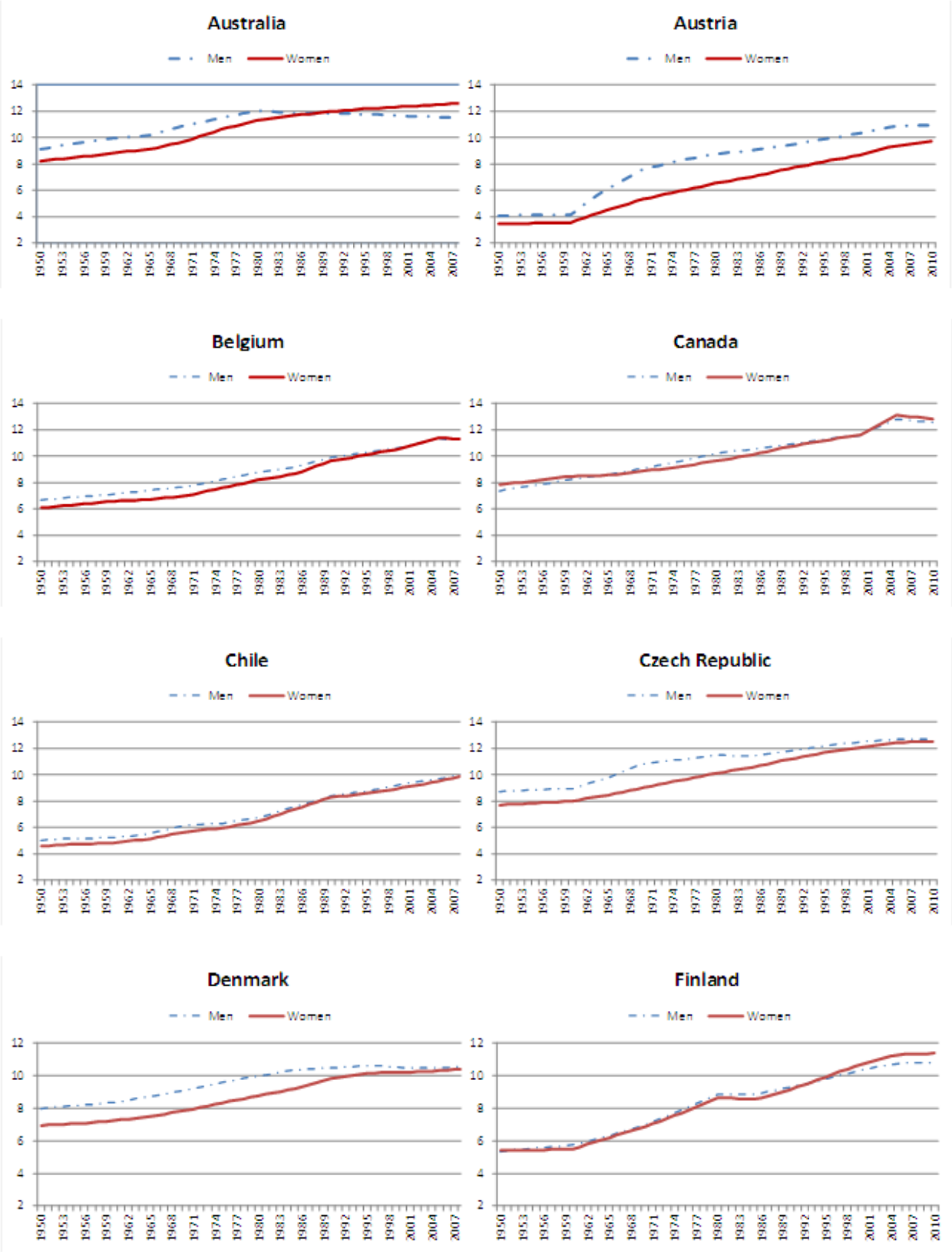


Figure A 1.1. Evolution of years in education – men and women aged 25-64 (cont.)

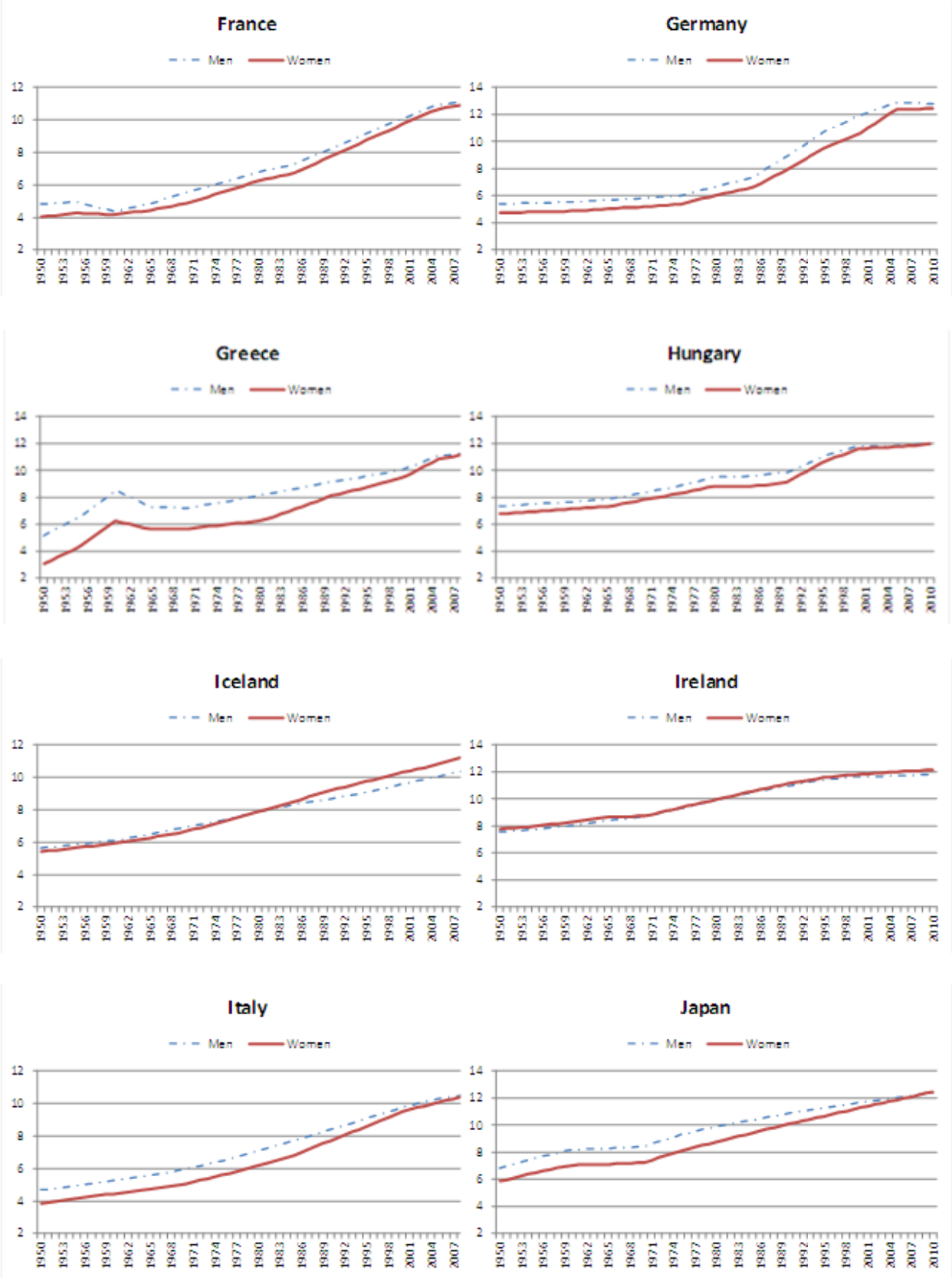


Figure A 1.1. Evolution of years in education – men and women aged 25-64 (cont.)

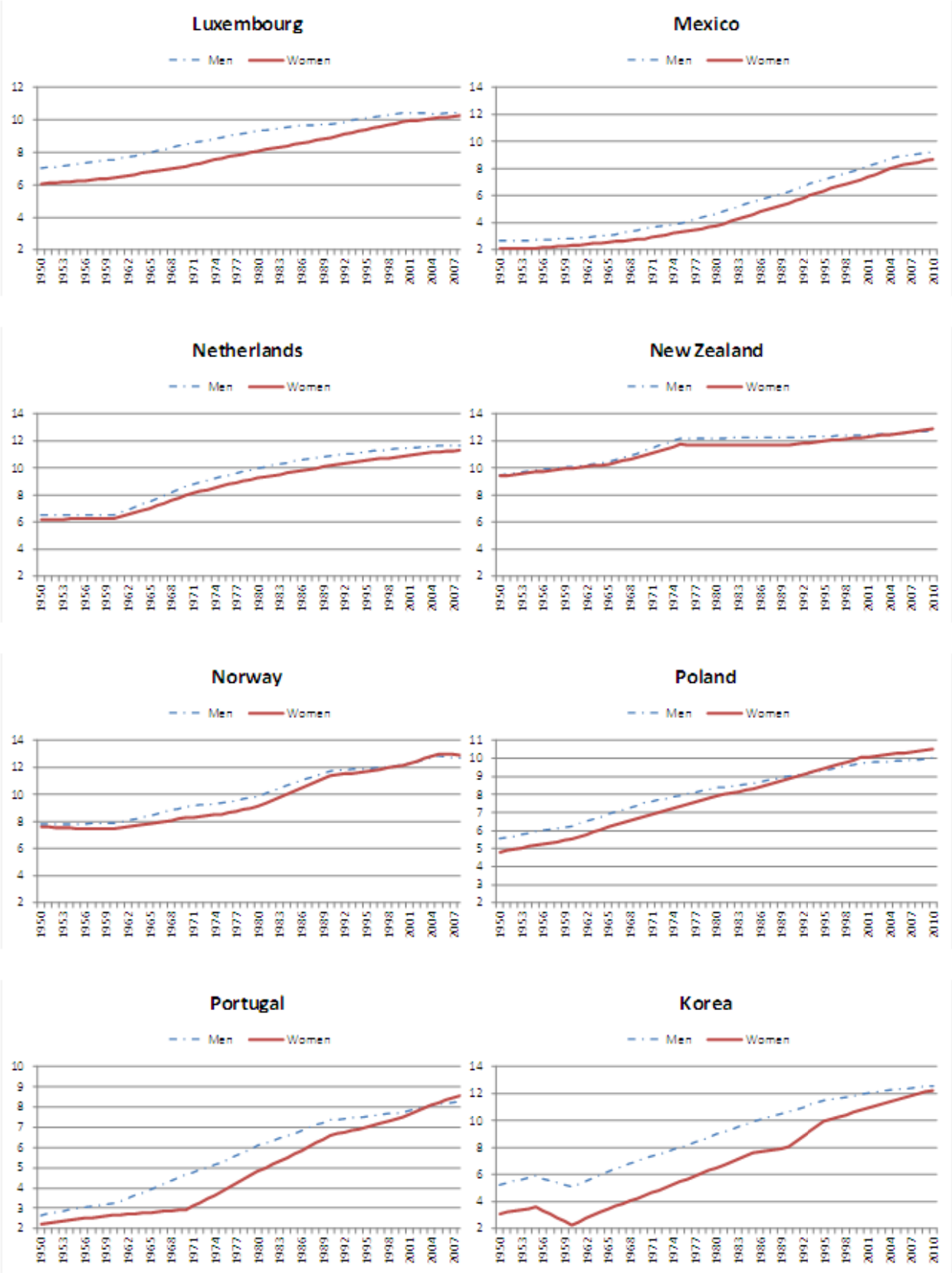


Figure A 1.1. Evolution of years in education – men and women aged 25-64 (cont.)

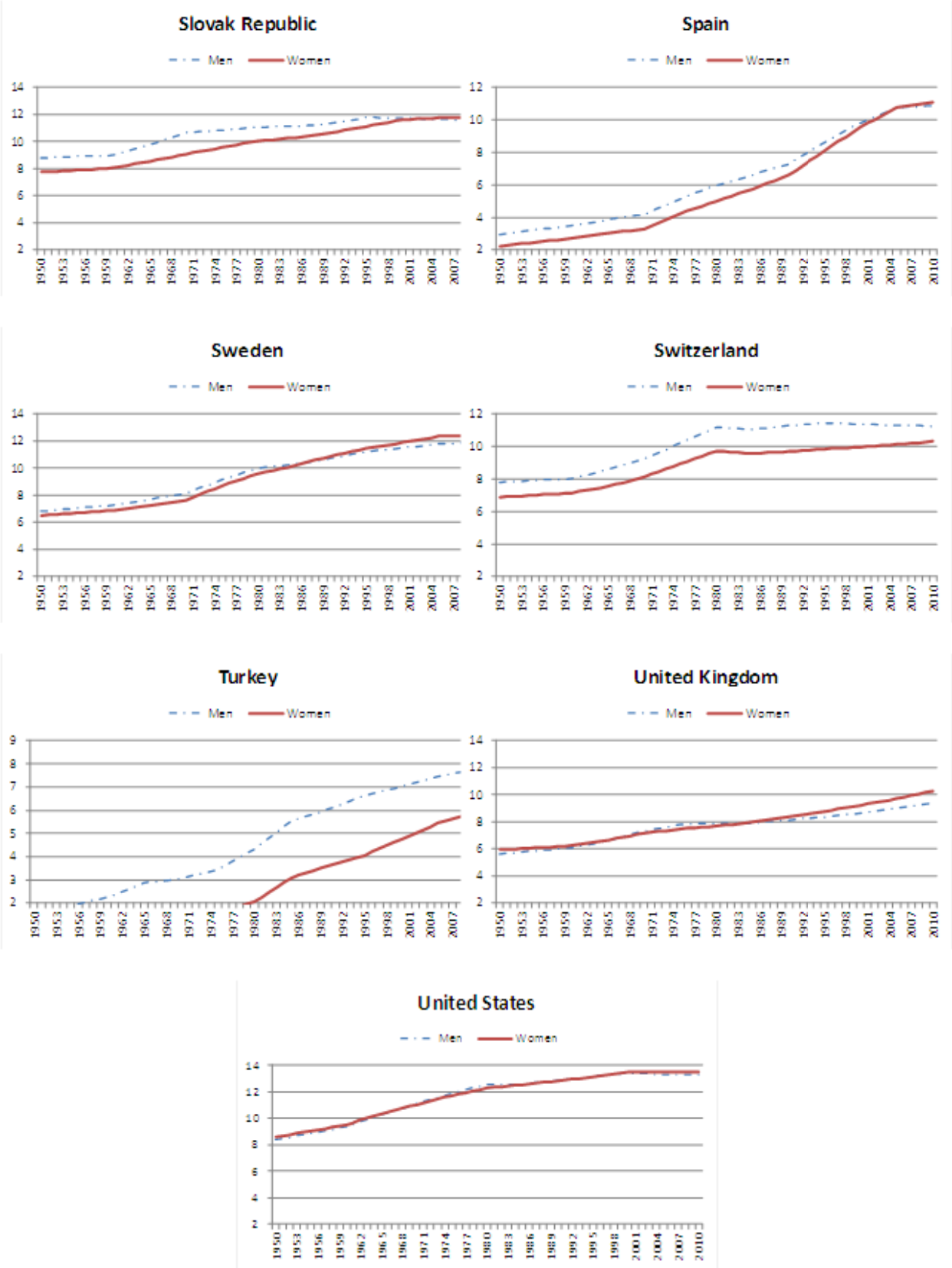


Table A 1.1. Comparison of specifications based on the Schwartz Bayesian Information Criterion (BIC)

Specification	Number of lags for the short-run dynamics			
	Human cap	Physical cap	Population growth	BIC
a (baseline)	1	1	2	-6656.247
B	1	2	2	-6701.624
C	2	2	2	-6753.304
D	1	1	1	-6737.156
E	1	2	1	-6699.823
F	2	2	1	-6553.937

Table A 1.2. Growth equation estimated with pooled mean estimator

	Baseline – balanced panel sample		Specification c	
Convergence coefficient				
logYt-1	-0.31*** (0.05)	-0.32*** (0.04)	-0.26*** (0.05)	-0.29*** (0.04)
Long-run coefficients				
log K	0.27*** (0.01)	0.29*** (0.01)	0.31*** (0.01)	0.36*** (0.02)
log H	1.09*** (0.06)	1.02*** (0.07)	0.87*** (0.7)	0.85*** (0.07)
log $R^{f/m}$	-	0.75*** (0.19)	-	0.83*** (0.17)
Δlog N	-1.78*** (0.67)	-2.29*** (0.65)	-2.26*** (0.74)	-2.81*** (0.63)
Estimated returns to scale for reproductible factors	1.07	-		
Test for constant returns to scale (p-value)	0.132	-		
Diagnostics of residuals:				
Test of cross- section independence ρ (p-value)[3]	0.92 (0.00)	0.88 (0.00)		
Pesaran (2007) unit root test[4]	0.00	0.00		

Table A 1.3. Projected labour force participation rates, all persons aged 15+, 2020 and 2030

	CURRENT	(1) No change in Labour force particpation rate (LFPR)		(2) Male and female LFPR gap reduced by 50%, by 2030		(3) Male and female LFPR gap reduced by 75%, by 2030		(4) Male and female LFPR gap reduced by 100%, by 2030	
	2010	2020	2030	2020	2030	2020	2030	2020	2030
Australia	66	66	66	67	69	68	71	69	72
Austria	61	61	61	63	64	64	66	64	68
Belgium	54	54	54	56	57	56	59	57	61
Canada	67	67	67	68	69	69	70	69	72
Czech Republic	58	58	58	61	63	62	66	63	68
Denmark	65	65	65	66	67	66	68	67	69
Estonia	61	61	61	62	64	63	65	64	67
Finland	66	66	66	67	68	68	69	68	69
France	57	57	57	58	60	59	61	59	62
Germany	60	60	60	61	63	62	65	63	66
Greece	54	54	54	56	59	58	62	59	64
Hungary	55	55	55	57	59	58	60	58	62
Iceland	81	81	81	82	83	82	84	83	84
Ireland	61	61	61	63	65	64	67	65	69
Israel	57	57	57	59	60	59	61	60	62
Italy	48	48	48	51	54	52	57	53	59
Japan	60	60	60	63	66	64	69	66	72
Korea	61	61	61	64	67	65	70	67	73
Luxembourg	58	58	58	60	62	61	64	61	66
Netherlands	65	65	65	67	68	67	70	68	71
New Zealand	68	68	68	70	71	70	73	71	74
Poland	56	56	56	58	60	59	62	60	64
Portugal	62	62	62	63	65	64	66	65	68
Slovak Republic	60	60	60	62	64	63	66	64	69
Slovenia	59	59	59	61	62	61	64	62	65
Spain	60	60	60	62	64	63	66	64	68
Sweden	71	71	71	71	72	72	73	72	74
Switzerland	68	68	68	70	72	70	73	71	75
United Kingdom	63	63	63	65	66	65	68	66	70
United States	65	65	65	66	68	67	70	68	71
OECD average	**62**	**62**	**62**	**63**	**65**	**64**	**67**	**65**	**69**

Notes: The labour force projections are based on population projections for persons aged 15+ years, rather than persons aged 15-64, to be consistent with the growth model outlined in OECD Economic Outlook 91. The OECD average is the unweighted average (all countries are given equal weighting) of 30 OECD countries for which data are available.
(1) - (4) See notes 1-4 for Table 7.1.
Note on Israel: The statistical data for Israel are supplied by and under the responsibility of the relevant Israeli authorities. The use of such data by the OECD is without prejudice to the status of the Golan Heights, East Jerusalem and Israeli settlements in the West Bank under the terms of international law. Information on data http://dx.doi.org/10.1787/888932315602
Source: OECD's Secretariat's calculations based on OECD Population and Demography database and the OECD Employment database.

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