Revisions to the production function underlying OECD long-term scenarios with some preliminary results

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1. The OECD Economics Department periodically publishes economic scenarios that extend the normal two-year short-run horizon of the *OECD Economic Outlook* (henceforth EO).[2] These long-run scenarios have become very popular products[3], perhaps because few scholars or institutions have the temerity to attach numbers to a distant future. This state of affairs was recently decried by Nordhaus (2017) in the context of his work on climate change modelling. He writes that "… economic projections are the least precise parts of [integrated assessment models] and deserve much greater study than has been the case up to now, especially careful studies of long-run economic growth". Indeed, for many economic issues – including the environment, but also population ageing, fiscal sustainability, the catch-up of emerging economies and the effects of structural reforms – a long-term perspective is essential.

2. This paper outlines ongoing revisions to the 2013 vintage of the production function at the heart of the long-term model. These revisions were undertaken with a view to adding more policy and institutional determinants to each of the components of the production function, so as to enrich the scenarios that could be produced with the model. The paper also provides some illustrative examples for the types of scenarios that these revisions will allow.

3. The paper is structured as follows. Section 1 briefly outlines the production function approach as background for the rest of the paper. Sections 2, 3 and 4 summarize the revised approaches to project,

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2 . The projection horizon and methodology has evolved over the years. The first instances were largely produced manually, with some assistance from the OECD's now-retired INTERLINK global model (Richardson, 1988), and went only a few years beyond the short-run horizon. Eventually the approach changed to simple rules based on the production function underlying potential output. The main projection was then known as the 'medium-term reference scenario' but the horizon remained only a few years (e.g. Downes et al., 2003). Later, a more systematic methodology was developed to extend the short-run horizon by some 15 years. The projection became known as the OECD's medium-term baseline (MTB) and was published once a year in the spring (e.g. OECD, 2010 and 2011). As part of a project in 2011 and 2012, the Economics Department further developed and extended this methodology with a horizon to 2060 (Johansson et al., 2013). Projections to 2060 were published in OECD (2012a, 2012b, 2013 and 2014a).

3 . Since its publication in 2012 up to March 2017, the policy paper describing the first set of long-run projections to 2060 (OECD, 2012a) was the third most downloaded OECD Economics Department paper on OECD iLibrary, with close to 15 000 downloads. Immediately next on the list is another paper focused on long-term challenges (OECD, 2014b), which relied largely on the long-run projections. And the working paper describing the long-term model (Johansson et al., 2013) is also in the top-25.

respectively, trend labour efficiency, trend employment and the capital stock out to 2060. Section 5 presents mostly aggregate-level results from a baseline long-term projection using the revised production function and discusses preliminary findings regarding the evolution of the world economy. Finally, section 6 presents the results of a few simulations with institutional/policy changes to illustrate the types of scenarios made possible by the revised framework.

1. The production function underlying the long-term model

4. The backbone of the underlying model is a consistent set of long-run projections for potential output which are also consistent with the short-term potential output projections prepared for the twice-yearly EO. By projecting each of the trend input components – employment, labour efficiency and physical capital – potential output is projected out to 2060 for each of the 46 countries in the model: the 35 OECD member countries, eight non-OECD G20 countries (Argentina, Brazil, China, India, Indonesia, Russia, Saudi Arabia and South Africa) and three other accession or partner countries (Colombia, Costa Rica and Lithuania).

5. Potential output is based on an aggregate production function approach assuming a constant-returns-to-scale Cobb-Douglas specification with Harrod-neutral labour-augmenting technical progress. Thus real GDP (*GDPV*) is related to total employment (*ET)* and the whole-economy productive capital stock (*KPTV*) by the following expression, assuming that the share of national income accruing to labour (α) is 0.67 in all countries,[4] with labour efficiency (*EFFLAB)* calculated as the unknown residual:[5]

$$GDPV_t = (EFFLAB_t \cdot ET_t)^{\alpha}\ KTPV_t{}^{1-\alpha} \qquad [1]$$

To compute potential output, labour efficiency and employment are replaced by their estimated trend counterparts. The calculation of these trend components over history relies on filtering techniques but also on cyclical adjustments using business cycle measures external to the production function methodology to mitigate well-known end-point bias problems associated with filtering.[6]

2. Projecting trend labour efficiency

6. Historical experience suggests that, for most countries and over most periods, total factor productivity/labour efficiency is more important than labour and capital accumulation in explaining both growth in GDP per capita and differences in GDP per capita across countries (Jones, 2015). Thus, consistency with historical experience implies that the determination of labour efficiency is a key part of the model.

2.1. The conditional convergence framework

7. The empirical work is based on a widely recognised framework in the literature, namely Robert Barro's work on income convergence in GDP per capita. The estimation procedure, described in full in Guillemette et al. (2017), starts by using this framework with GDP per capita as the dependent variable in

4. This parameter roughly corresponds to the wage share in advanced economies and has proven to be quite stable in time. This is less true of emerging economies, however, and future work could consider the consequences of allowing the wage share to vary across country, through time, or both.

5. In this framework, labour efficiency (*EFFLAB*) and total factor productivity (*TFP*) – that part of output not explained by factor inputs – are closely related but distinct concepts: $TFP = EFFLAB^{\alpha}$.

6. See Turner et al. (2016) for details on this cyclical adjustment procedure and for more on potential output estimation in general.

order to provide a recognisable base for comparison. The estimation then moves sequentially from explaining GDP per capita to labour productivity and finally to labour efficiency. The focus in this paper is on the final equation used in the model to explain labour efficiency.

8. The specification chosen comes from a framework developed by Barro (1991, 1997, 2003, 2015), where the estimated panel equation can be expressed in error-correction form as follows:

$$\Delta y_{i,t} = \gamma_t + \rho\left(y_{i,t-1} - \alpha - \sum_{k=1}^{K} \boldsymbol{\beta}_k \boldsymbol{X}_{i,t-1,k}\right) + \varepsilon_{i,t} \quad [2]$$

where Δ is the first-difference operator, $y_{i,t}$ is the log of labour efficiency for country i in year t, γ_t are time fixed effects, ρ is the convergence speed (which should take a negative value), α is a constant, $\boldsymbol{X}$ is a vector containing K explanatory variables, $\boldsymbol{\beta}$ is its vector of coefficients, and ε is the error term. To minimize the influence of economic cycles, and following Barro (2015), the equation is estimated using non-overlapping 5-year period averages. The actual equation estimated is a transformed version of the ECM specification which is linear in the coefficients and is estimated using Ordinary Least Squares (OLS).[7]

9. An important question is whether the speed at which conditional convergence happens is the same across countries, as implied by [2], or is influenced by policy settings. Previous OECD research suggests that the speed of convergence is a function of openness (Johansson et al., 2013).[8] The existence of such effects can be tested by adding interaction effects to the original equation in [2]. The new equation can be expressed in error-correction form as:

$$\Delta y_{i,t} = \gamma_t + (\rho_1 + \sum_{j=1}^{J} \rho_j \boldsymbol{X}_{i,t-1,j})\left(y_{i,t-1} - \alpha - \sum_{k=1}^{K} \widehat{\boldsymbol{\beta}}_k \boldsymbol{X}_{i,t-1,k}\right) + \varepsilon_{i,t} \quad [3]$$

where $\rho_1$is the base speed of convergence and ρ_j measures the effect of indicator j on this speed, with $J \subseteq K$.

10. An alternative approach is to first estimate the long-term relationship and recover the associated residuals, which correspond to the expression in the second set of parentheses in [3], and then estimate speed-of-convergence effects in a second-stage regression. This alternative method has the advantage of keeping long-term effects ($\widehat{\boldsymbol{\beta}}_k$) independent of any interaction terms on the speed of convergence, thus providing a robustness check on the one-step method. Estimation results from the two-step method are broadly consistent with those from the one-step procedure (see Appendix 6 of Guillemette et al., 2017).

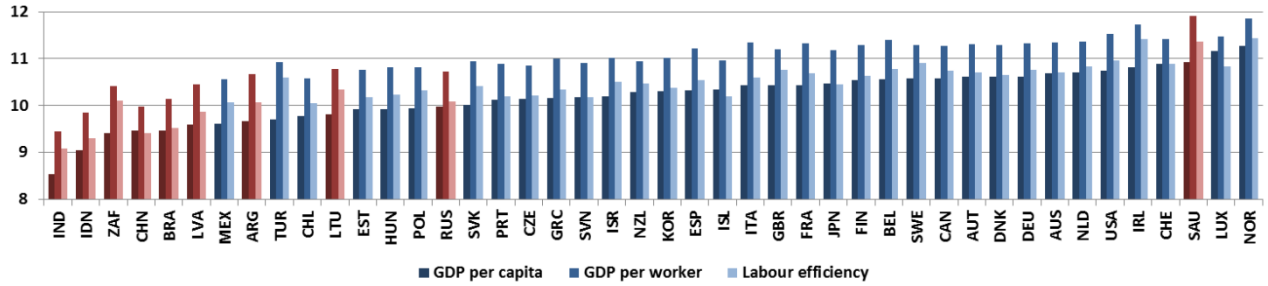
7. Coefficient estimates from this specification are possibly biased by the endogeneity of essentially all of the right-hand side variables (structural indicators). However, it has typically proven difficult in growth studies to find valid instruments for these variables. Also, when trying a two-stage regression setup with longer or additional lags of the regressors as instruments, Barro (2015) finds that coefficient estimates change little, in particular the convergence speed. On this basis, the results reported here use OLS, although variant equations using alternative estimation procedures give similar results (see Appendix 6 of Guillemette et al., 2017).

8. Westmore (2013) and Andrews and Westmore (2014) find that, in addition to openness, the speed of convergence is an increasing function of two enabling factors: managerial quality and business R&D expenditure. However, limited data availability prevents these two particular indicators from being tested in the current estimation framework.

11. In order to have as large a sample of countries as possible from a consistent data source, the labour efficiency series used in estimation are obtained following the same decomposition methodology outlined in section 1, but using data from the Penn World Tables (v8.1) (Figure 1).[9]

Figure 1. GDP per capita, labour productivity and labour efficiency

Average log values for the last period used in estimation (2006 to 2010)



Source: Penn World Tables v8.1. Labour efficiency is obtained by decomposition using a Cobb-Douglas production function with a fixed wage share of two thirds, following EO methodology.

2.2. The main explanatory variables considered

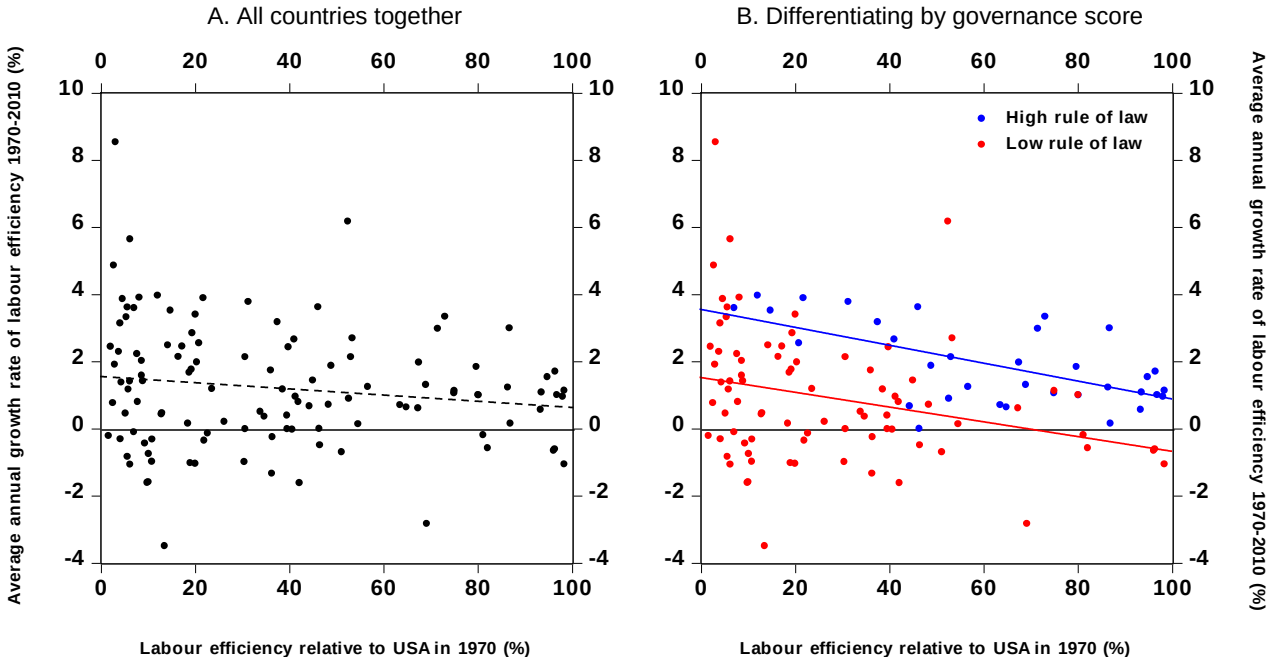
12. The main determinants of the convergence process considered in the estimations are inspired from the existing empirical growth literature, and include the following:

1. *The initial level of labour efficiency*. Countries with lower initial labour efficiency levels tend to exhibit higher growth rates over the subsequent period (Figure 2, Panel A). This justifies the presence of the lagged level of labour efficiency in the productivity growth determinants as in the error-correction specification. At the same time, the relationship is not as strong as one might expect, as illustrated by the wide dispersion of points around the regression line in Figure 2, Panel A. In other words, absolute convergence is not a strong feature of the data, which is why the convergence process is next conditioned on a number of other characteristics.

2. *Governance and institutions*. The economic history of the past two centuries, and much recent work on the economics of institutions, has established a strong theoretical and empirical case that the quality of governance and institutions matters a great deal for growth (see Hall and Jones, 1999; Acemoglu et al., 2001; Acemoglu et al., 2005). Free markets, protection for property rights and respect for the rule of law are fundamental conditions for growth. For instance, a legal environment that allows entrepreneurs to protect their intellectual and physical property and appropriate a significant fraction of the revenues generated by their innovations should encourage innovative investments and productivity growth. In the estimation, a World Bank measure of the 'rule of law' was chosen as the most appropriate variable (Figure 3), although it is highly correlated with other measures of governance and should be interpreted more broadly as being representative of good governance (see Appendix 7 of Guillemette et al., 2017). Countries that scored better on the rule of law indicator have tended to converge faster historically to leading labour efficiency levels, while many countries with a poor rule of law score have not converged at all or even diverged relative to US labour efficiency levels (Figure 2, Panel B).

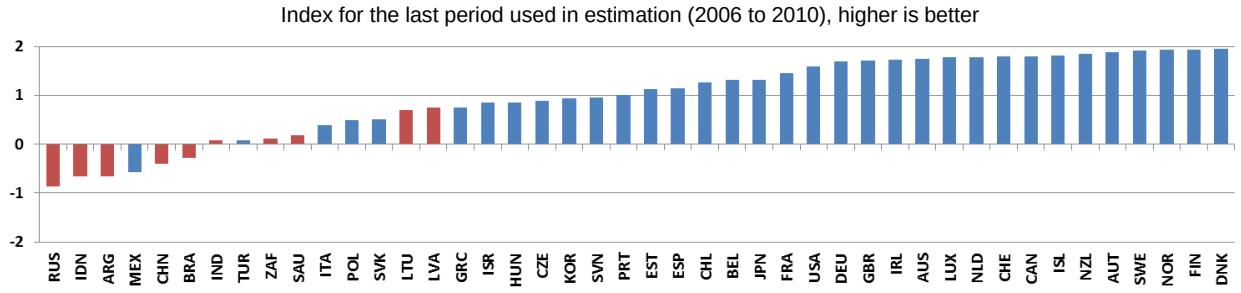
9. While the PWT data are available for a wide range of countries, a drawback is that the series end in 2011 and do not perfectly match EO estimates. The consistency of the series used in estimation and the transition to the model projection equation, which key off EO estimates, are discussed in Guillemette et al. (2017).

Figure 2. Convergence in labour efficiency from 1970 to 2010



Source: Penn World Tables v8.1, World Bank Governance Indicators and authors' calculations. Labour efficiency is obtained by decomposition from a Cobb-Douglas production function with fixed factor shares and expressed at 2010 PPP rates. The threshold between 'high' and 'low' rule of law score is assumed to be 0.5. Countries with greater labour efficiency levels than the benchmark (USA) in 1970 were dropped from the sample as they are either oil-based economies or idiosyncratic in other ways.

Figure 3. Rule of law

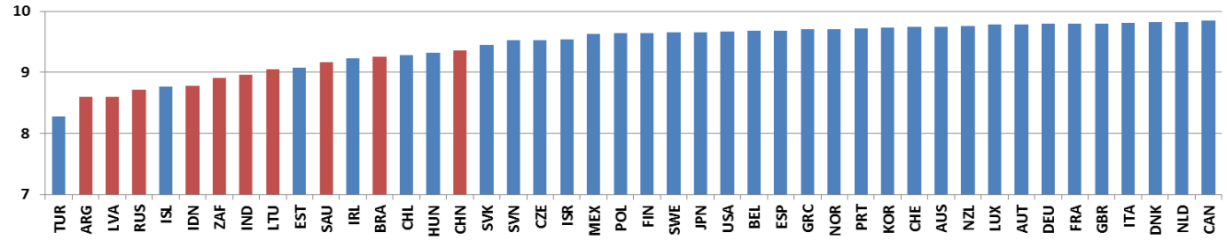


Source: World Bank Worldwide Governance Indicators database. See Appendix 7 in Guillemette et al. (2017) for why this indicator was chosen among the various governance variables that exist.

3. *Macroeconomic environment*. The quality of macroeconomic management is thought to be important in setting the conditions for investment and growth. This can include fiscal and various other policy areas, but the growth literature has found that low and stable inflation is particularly important. Accordingly, an index for low and stable inflation was constructed giving equal weights to both aspects of the inflation process (Figure 4; see Guillemette et al., 2017 for details of how the index is constructed).

Figure 4. Low and stable inflation

Index for the last period used in estimation (2006-10), higher is better



Source: World Bank World Development Indicators database.

4. *Human capital*. Despite the important role often attributed to human capital in growth theory, empirical evidence has long been mixed (for an overview see Hanushek and Woessmann, 2010). Cross-country growth studies usually measure human capital as average schooling attainment in the working-age population, and often find a weak impact on growth. Some authors have had stronger results when using quality-adjusted measures, for instance using average scores on standardised tests to measure quality (e.g. Islam et al., 2014; Barro and Lee, 2015). The reasons for this are unclear, but may be related to measurement issues, including the difficulty of assessing the quality, as well as the quantity, of schooling (de la Fuente and Doménech, 2000; Pritchett, 2000). Some experimentation reveals that a measure of human capital based on average educational attainment in the population but featuring decreasing marginal returns to additional years of schooling is the most successful in producing correctly-signed and statistically significant effects in the labour productivity equations (Figure 5; for details see Appendix 5 of Guillemette et al., 2017).

Figure 5. Measure of human capital based on educational attainment

Index for the last period used in estimation (2006 to 2010), higher is better

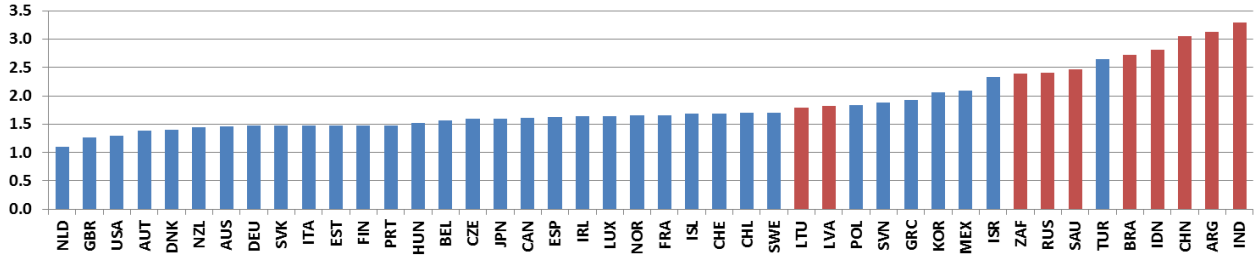


Source: Barro and Lee (2013) based on Morrison and Murtin (2010).

5. *Product market regulation*. Numerous studies suggest that relatively light product market regulation that fosters competition tend to promote productivity (Arnold et al., 2008; Bouis et al., 2011; Bourlès et. al., 2013; Cette et al., 2013 and 2014; Conway et al., 2006; Nicoletti and Scarpetta, 2005). Unfortunately, reliable and comparable indicators of the quality of regulation are hard to come by for a wide range of countries. In the estimations below, the aggregate OECD Product Market Regulation (PMR) indicator is used when available and a proxy measure is constructed using a similar World Bank indicator for countries and years where the OECD PMR is not available (Figure 6, for details on how the measure is constructed see Appendix 4 of Guillemette et al., 2017). Labour market regulation is not considered as little data on such regulation are available for non-OECD countries and recent OECD work has found that labour market policies do not have a robust empirical relation to total factor productivity (Égert and Gal, 2017a).

Figure 6. Product Market Regulation

Official and proxy indices for the last period used in estimation (2006-10), higher value means more stringent regulation

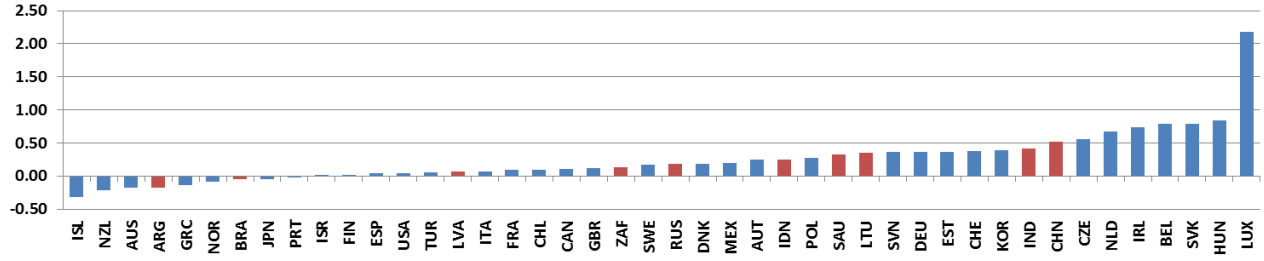


Source: OECD Product Market Regulation database (see Koske et al., 2015).

6. *Openness*. Trade is a well-documented channel for technology transfers and spillovers between countries, so more open economies are expected to catch up more quickly to the technology frontier (Saia et al., 2015). More open economies also tend to grow faster as stronger external competition and a higher threat of entry tends to encourage innovation by incumbent firms. By this logic, openness should benefit small countries to a greater extent than large ones as the latter already have internal markets big enough to breed competition and achieve economies of scale. For this reason and to provide consistency with other OECD work (e.g. Égert, 2016), openness is a population-adjusted measure calculated using OECD methodology (Figure 7, see Appendix 3 of Guillemette et al., 2017 for the construction of the measure).

Figure 7. Population-adjusted trade openness

Index for the last period used in estimation (2006-10), positive values mean that a country trades more than predicted by its population size



Source: Penn World Tables v8.1 and authors' calculations.

13. Other explanatory variables common in the literature, such as life expectancy and fertility, were initially included when explaining GDP per capita, but when the focus shifted to explaining labour productivity these variables became statistically insignificant, presumably because their main role is in explaining differences in labour input rather than productivity. Similarly, an important role was found for the investment ratio in explaining both GDP per capita and labour productivity, but it became insignificant as the focus shifted to labour efficiency. This finding is intuitive: if workers are given more capital to work with, labour productivity is expected to increase, but not necessarily labour efficiency as it is purged of the effect of capital intensity. While investment might embody recent technical progress and so boost labour efficiency, little robust empirical evidence was found to support such an effect.

2.3. Estimation results

14. In the preferred specification explaining labour efficiency, nearly all the explanatory variables – rule of law, openness, human capital, low and stable inflation and product market regulation – are statistically significant (column 1 in Table 1). The sole exception is the investment ratio for which the coefficient becomes much smaller and statistically insignificant, for reasons discussed above, so it is subsequently dropped (columns 2 and up).

Table 1. Regressions for conditional convergence in labour efficiency

Dependent variable: Annual growth rate of labour efficiency in USD at fixed PPPs averaged over five-year periods

	(1)	(2)	(2a)	(2b)	(2c)	(3)
log(Lagged labour efficiency)	-0.024***	-0.024***	*-0.024*	*-0.024*	*-0.024*	-0.019***
	(0.0022)	(0.0022)				(0.0025)
Investment ratio	0.031					
	(0.0221)					
Rule of law	0.085***	0.090***	*0.090*	*0.090*	*0.090*	0.004
	(0.0161)	(0.0156)				(0.0023)
Population-adjusted openness	0.076*	0.080**	*0.080*	*0.080*	*0.080*	0.011***
	(0.0390)	(0.0387)				(0.0023)
Human capital	0.017***	0.017***	*0.017*	*0.017*	*0.017*	0.018***
	(0.0042)	(0.0042)				(0.0044)
Low and stable inflation	0.002***	0.002***	*0.002*	*0.002*	*0.002*	0.002**
	(0.0007)	(0.0007)				(0.0008)
Product market regulation	-0.006**	-0.006**	*-0.006*	*-0.006*	*-0.006*	-0.005
	(0.0027)	(0.0027)				(0.0032)
R&D expenditures, % of GDP			-0.002			
			(0.0015)			
Patent applications per 1000 pop				-0.000		
				(0.0000)		
Income inequality (GINI index)					-0.0003**	
					(0.00014)	
Rule of law *	-0.008***	-0.009***	*-0.009*	*-0.009*	*-0.009*	
log(Lagged labour efficiency)	(0.0016)	(0.0016)				
Population-adjusted openness *	-0.007*	-0.007*	*-0.007*	*-0.007*	*-0.007*	
log(Lagged labour efficiency)	(0.0037)	(0.0037)				
Longest time period	1966-2010	1966-2010	1996-2010	1966-2010	1981-2010	1966-2010
Adjusted R-squared	0.300	0.298	0.306	0.293	0.292	0.241
Observations	722	722	244	627	373	722
Countries	121	121	99	104	108	121

Notes: Asterisks (*, **, ***) indicate the statistical significance level (10%, 5%, 1%) of the coefficients. Figures in parentheses are standard errors (White) robust to arbitrary heteroskedasticity and within-country serial correlation. All equations are estimated over non-overlapping five-year periods and all variables are period averages (NAs are not propagated) except for the (lagged) level of labour efficiency which is the end-of-period value. The dependent variable is expressed in USD at fixed 2010 Purchasing Power Parity. All equations are estimated with OLS and include time fixed effects but no country fixed effects other than dummy variables for Norway and Russia. Coefficients in italics were imposed rather than estimated. A test (Kao) for cointegration between the level of labour efficiency and its determinants rejects the null hypothesis of no cointegration at the 1% level in all equations. See Appendix 2 in Guillemette et al. (2017) for data sources.

15. Testing among explanatory variables which might plausibly influence the convergence speed suggested a role for both the rule of law and openness.[10] Thus, for countries with a strong rule of law and high openness (for instance Belgium and many other OECD countries) the convergence speed can be

10. In these equations, the indicators being interacted with lagged labour efficiency were de-meaned to prevent the estimated base speed of convergence ($\hat{\rho}_1$) from being re-scaled. This estimated base speed now corresponds to the convergence speed that would occur if interaction effects were zero (i.e. at the sample means for rule of law and openness).

around 4%, whereas for countries with a weaker rule of law and lower openness (for instance Argentina) the convergence speed can be as low as 1.5%.

16. The equation in column 2 of Table 1 provides a basis for testing the importance of other structural variables for which data coverage is more limited, in particular different measures of innovation and a measure of income inequality. As the time and country coverage of the new variables are limited relative to the other regressors and to ensure coherence with the influence of variables estimated on the full sample, the coefficient estimates of the variables with a wider coverage are constrained to remain as estimated in column 2.

2.3.1. Adding a measure of innovation

17. Two different measures of innovation intensity are tested in columns 2a and 2b. The first is total R&D expenditures as a share of GDP and the second is the total number of patent applications by residents and non-residents per 1 000 population. Neither measure has an effect on labour efficiency that is statistically distinguishable from zero in the estimated models.

18. One reason why the innovation indicators tested do not perform well could be that they are flow measures, whereas it seems more intuitive that it should be the accumulated stock of technology that matters for labour efficiency. Moreover, countries do not just draw on internally-generated technologies to improve their prospects, they can also replicate a large foreign stock of technologies. The role of the innovation process in driving labour efficiency convergence is therefore incorporated into the long-term simulation model via accumulation equations for the stock of domestic and foreign technologies. Specifically, data on R&D expenditures as a share of GDP in country i and year t ($RD_E_{i,t}$) are used to construct a domestic stock of R&D capital ($RD_K_{i,t}$) according to the usual stock-flow equation:

$$RD_K_{i,t} = (1-\delta)RD_K_{i,t-1} + RD_E_{i,t} \quad [4]$$

where δ is the depreciation rate, assumed to be 5%, a figure at the upper end of the range estimated using direct observations by de Rassenfosse and Jaffe (2017), but at the lower end of previous estimates. For simplicity, and because R&D expenditure series have short histories for many countries, stocks are initialised for the simulations by assuming that they are in a steady-state, given the assumed depreciation rate and a moving average of the last few observations on R&D expenditures. In other words, initial stocks are set so that observed R&D expenditures just cover depreciation. Hence, initial stocks are proportional to recent average levels of R&D spending across countries. Then, a global stock of R&D is constructed by summing domestic stocks across countries, all measured in USD at 2010 PPPs. Both stock variables are then added to the estimated long-run labour efficiency equation, with elasticities drawn from a recent meta-analysis of the effects of R&D capital on productivity (Donselaar and Koopmans, 2016). They are 0.135 for the (log) domestic R&D stock and 0.154 for the (log) global stock.[11] These productivity elasticities imply output elasticities not far from the 0.11 reported in Bom and Ligthart's (2014) literature review for an increase in public capital, and indeed R&D can be thought of as public capital.

19. This implementation ensures that a country's equilibrium labour efficiency level increases when innovation intensity rises above the level needed to cover depreciation. An increase in a small country's R&D stock, if it is maintained through continued investment, boosts that country's equilibrium labour efficiency level, but as it contributes little to raising the global R&D stock, foreign economies are not much affected. On the other hand, the global stock of R&D can rise noticeably when a large economy raises its

11. The particular elasticities cited come from the subsection of the meta-analysis that uses macro-level studies only (there are 15 such studies).

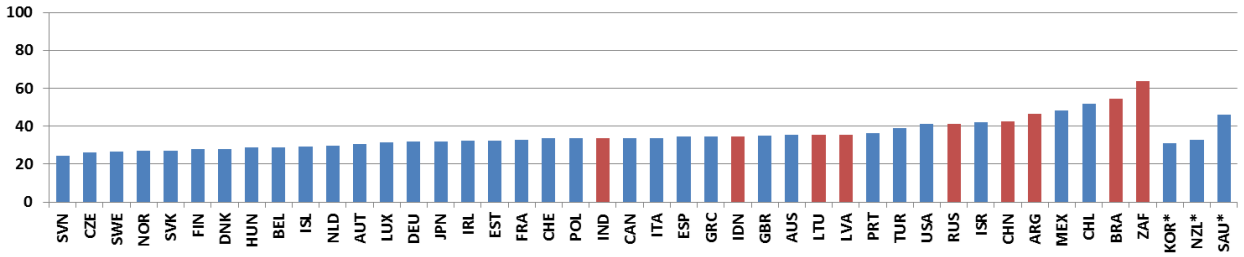
domestic R&D capital stock, with externalities on smaller countries' labour efficiency levels. R&D spending is thus the only variable that will affect both a country's own equilibrium labour efficiency level as well as those of other countries. At the mean initial level of R&D spending across countries in the model (1.7% of GDP), the average domestic R&D capital stock comes out to 34.3% of GDP. A permanent increase in R&D spending of 1 percentage point of GDP, which also corresponds to the standard deviation of R&D spending intensities across the countries in the model, would raise the equilibrium R&D capital stock by 60% (0.47 log points), which translates into a 6% gain in equilibrium labour efficiency.

2.3.2. Adding a measure of income inequality

20. A rapidly-expanding body of work suggests that, in addition to being undesirable for its own sake, rising income inequality, at least beyond a certain threshold, may also be bad for growth (Cingano, 2014; Ostry et al., 2014; Dabla-Norris et al., 2015). The mechanisms through which this growth effect would occur are not well understood, but could include health effects on the poor, economic or financial instability, or declining public confidence in policies that boost growth, such as trade openness. The measure of inequality used in column 2c of Table 3 is the World Bank's GINI coefficient (Figure 8). Given limited data coverage, as for the innovation indicators, the effect of this variable on labour efficiency is estimated while constraining coefficients for the other variables to their magnitudes in column 2. Unlike for the R&D indicators, however, the effect of income inequality is statistically significant and suggests that a 10-point increase in the GINI index would lower long-run labour efficiency by about 13%. Given the estimated speed of convergence, this corresponds to a fall in the average growth rate of GDP by about a fifth of a percentage point per year over the first 25 years.[12]

Figure 8. Measure of income inequality

GINI index used in the last estimation period (2006-10), higher index means greater income inequality



* These indices are from different datasets and years and are not directly comparable to other countries'. The New Zealand and Korean indices are calculated from the Standardized World Income Inequality Database. The index for Saudi Arabia is from the online CIA World Factbook and refers to 2013. The indices for these three countries were not used in estimation (Table 1) but they will be necessary to initialise the long-term simulations.

Sources: World Bank's World Development Indicators (WDI), Standardised World Income Inequality Database and CIA World Factbook.

2.4. The final preferred model equation

21. For the long-term simulation model, the preferred specification is taken to be equation 2c in Table 1, which is basically column 2 but supplemented by the estimated effect of income inequality on the smaller sample. To this equation are added the domestic and global R&D capital stocks as described above, with their associated elasticities. The coefficient estimates on the terms interacting rule of law and

12. Other estimations (not shown) confirm that the result in column 2c is robust to using different sources for the GINI data, although the effect is about one sixth of the magnitude found by Cingano (2014).

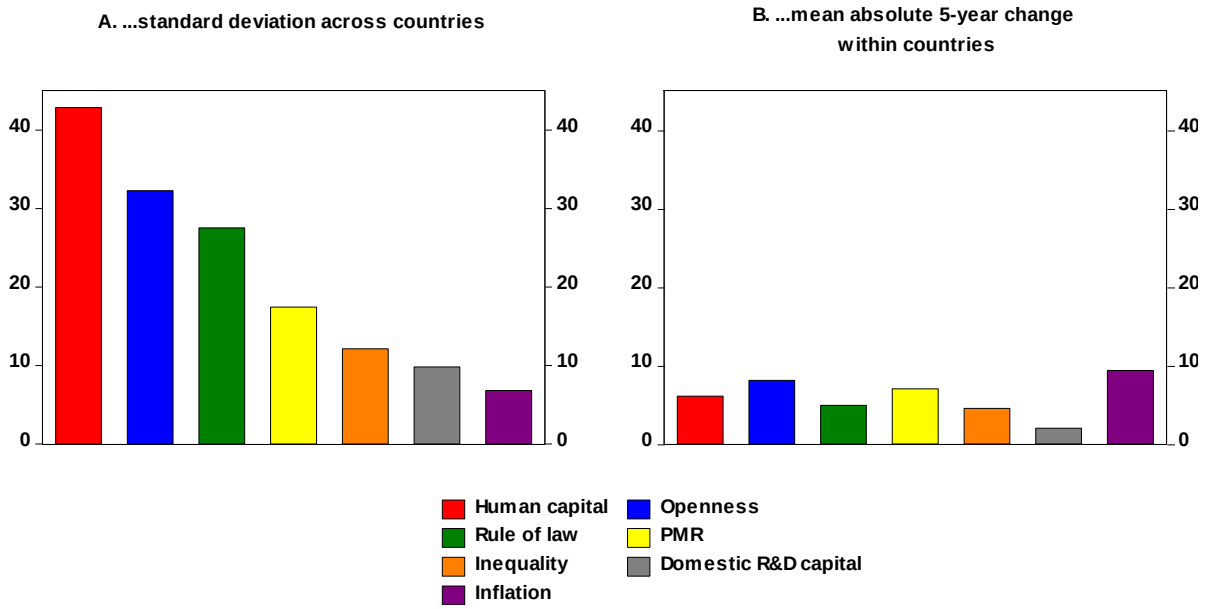
openness with lagged labour efficiency are interpreted solely as speed-of-convergence effects, while the long-term effects of structural indicators are taken to be the same no matter the initial level of labour efficiency.

2.5. Long-term policy effects

22. To assess the relative economic importance of the explanatory variables it is useful to compare the long-run effects on labour efficiency of standardised changes, initially calculated as standard deviations in the cross-sectional dimension for the most recent estimation period (2006-2010). These long-term effects illustrate the relative importance of the structural indicators in explaining observed differences in labour efficiency levels across countries (Figure 9, Panel A). But while human capital, for instance, is able to explain a large share of productivity differences across countries, it is not realistic to expect that a given country could improve its human capital by one standard deviation over a short time frame, and likewise for the other productivity determinants. So another useful way to express the relative impacts of improvements in structural indicators is to show the long-term effects of 'typical' changes in these determinants along the time dimension, calculated here as the mean absolute five-year change within countries (Figure 9, Panel B). Except for the inflation indicator, these effects are much smaller than those calculated based on standard deviations across countries. A comparison of these effects with other results in the literature including other OECD work is reported in Guillemette et al. (2017).

Figure 9. Relative influence of productivity determinants

Per cent increase in equilibrium labour efficiency following an improvement in the determinants calibrated on…

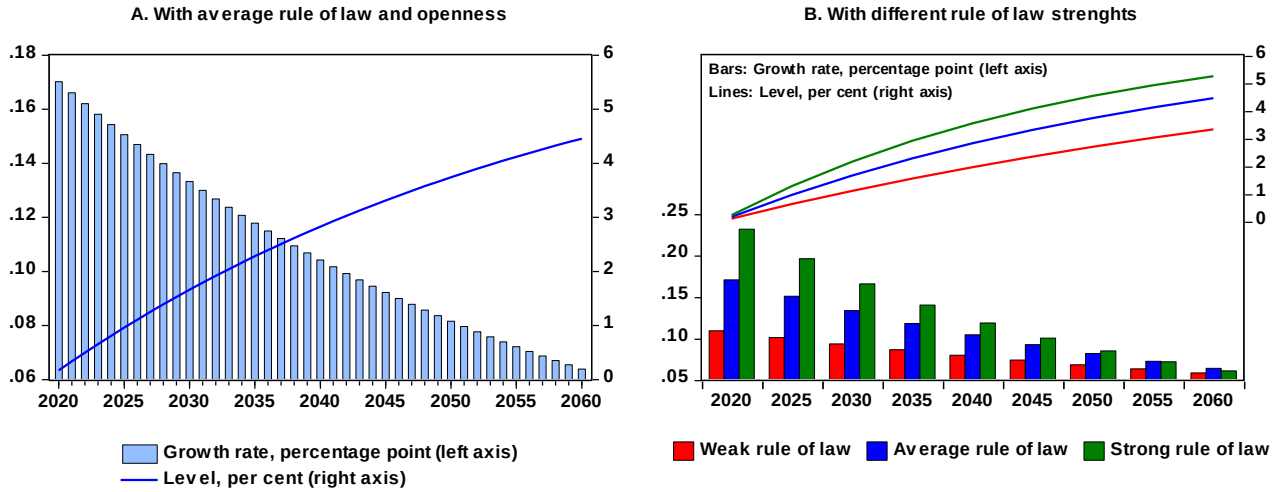


Note: The effects are calculated from the estimates in column 2c of Table 1.

23. Given the low convergence speed, the long-term effects shown in Figure 9 take a long time to be fully phased in. But the near and medium-term effects of shocks are not negligible. Taking the PMR effect as an example, the same-size shock as shown in Figure 9 Panel B (fall of 0.27 points) would immediately raise labour efficiency growth by 0.17 percentage points (Figure 10, Panel A). This growth effect declines gradually thereafter but persists for decades. A third of the full long-term level effect would manifest within 15 years, and half within 30 years. Given the influence of rule of law and openness on the speed of convergence, the dynamics are conditional on the values of these indicators. A weak rule of law for

instance could cut the near-term positive effects by a third; and vice-versa for a strong one (Figure 10, Panel B).

Figure 10. Differences from baseline labour efficiency following PMR reform (fall of 0.27 points)



Note: The effects are calculated from the estimates in column 2c of Table 1. In Panel B, rule of law is lowered by one point relative to the sample average for the 'weak' scenario; and raised by one point for the 'strong' scenario.

3. Projecting trend employment

24. The evolution of trend employment (*ETPT*) is central to any long-run economic projection and is primarily the result of three sets of dynamics: the evolving size of the working-age population, its age composition and trends in the employment rates of different age/sex groups. The size and composition of the working age population (here taken to be 15-74 year-olds) varies according to changes in fertility, mortality and migration. For the purposes of the long-term scenarios, population projections are sourced externally (from Eurostat and United Nations) and considered exogenous.[13] This section is thus concerned with identifying and projecting trends in the employment rates of existing and future birth cohorts. These generational trends reflect societal changes such as rising female employment rates, but also structural changes such as higher educational attainment. Projections must also be able to take into account the impact of recent and future policy changes on trend employment rates. For this purpose, the proposed approach integrates recent OECD empirical work on the quantification of structural reforms (QSR) (Égert and Gal, 2017a).

25. The approach can be summarised in the following steps, with the complete methodology and all estimation details presented in Cavalleri and Guillemette (2017):

1. Historical data on employment rates by age and sex are cyclically adjusted to obtain estimates of trend employment rates. The cyclical adjustment uses estimated equations linking age/sex-specific employment rates to the country-level employment gap (actual less trend) from the EO.

13 . The latest Eurostat population projections (medium scenario) are generally used for European countries and United Nations population projections are used for other countries.

2. The trend employment rates by age and sex are used to calculate trend rates of entry and exit into/from employment using a cohort-based approach. For future years and cohorts, trend entry and exit rates are assumed to remain fixed at their last estimated values.

3. Trend entry and exit rates are used to project trend employment rates by age and sex into the future.

4. Policy effects are added to the projected age/sex-specific trend employment rates.

5. The disaggregated age/sex-specific trend employment rates are weighted by the relevant population shares/totals to obtain an aggregate trend employment rate/total.

This revised approach introduces two main changes to the 2013 vintage of the model: 1) to align with the QSR exercise and be able to use its estimated elasticities for policy effects, the new approach is based on employment rates as opposed to participation rates; and 2) the piecewise linear regression method used to separate trend and cyclical components in historical employment rates is replaced by a simpler linear regression method based on the aggregate employment gap (step 1 above), which should ensure greater consistency with the corresponding EO estimates and projections.

3.1. Cyclically adjusting age/sex-specific employment rates

26. Entry and exit rates estimated directly on raw employment rates would risk being biased by the economy's cyclical position and would not be a solid basis for projecting future employment trends, particularly at the end points of the employment rate series. Therefore, it is desirable to remove the cyclical component from raw employment rates so as to isolate the employment trends that will form the basis of projections.

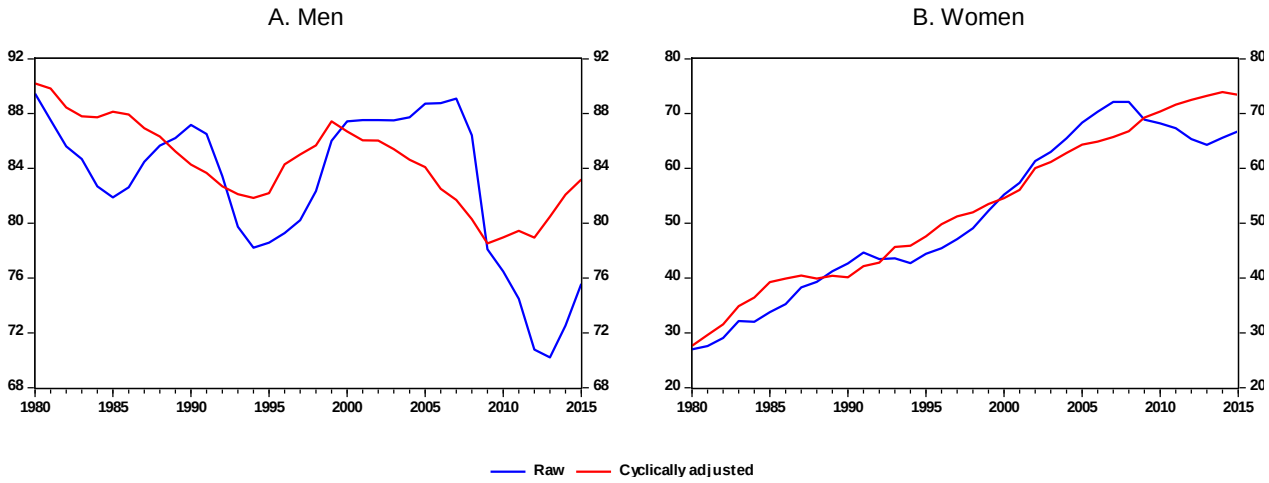
27. The approach used here exploits the correlation between the cyclical component of employment rates and independent estimates of the degree of slack in the economy. More specifically, the economy's cyclical position is measured by the country-level employment gap from the EO, and simple regression equations measure the historical correlation between this country-level indicator and age/sex-specific employment rates. Essentially, then, the approach decomposes the country-level employment gap into age/sex-specific employment gaps. A simpler alternative would be to assume that all age/sex-specific employment gaps were equal to the country-level gap, but the approach used here recognises that different age/sex groups probably have different sensitivities to cyclical conditions.

28. Estimated coefficients for age groups 15-19 to 55-59 are generally positive, with some above one and others below, and most are statistically significant. They are generally higher for younger age groups relative to prime-age groups, an intuitive result considering that younger people typically have more tenuous attachment to the labour market, while prime-age workers generally have more stable jobs and are less affected by cyclical fluctuations. For age groups 60-64 to 70-74, however, estimated coefficients are sometimes negative and, even when they are positive, are often small and not statistically significant. They indicate that the employment status of older workers is much less sensitive to the economic cycle and, in some cases, perhaps even countercyclical. Countercyclical employment rates could be explained by the propensity of older workers to retire earlier in good times, and to keep working longer in bad times, perhaps to make up for shortfalls in housing and pension wealth in view of nearing retirement. Because of conflicting signs for coefficients and their general lack of statistical significance, age groups 60-64 and over are left out of the cyclical adjustment method. In other words, structural employment rates for people aged 60 and over are assumed equal to observed employment rates.

29. The impact of this cyclical adjustment is illustrated for Spanish men and women aged 30 to 34 in Figure 11. Spain is used as an example because it experienced a strong economic boom in the years leading

up to the global financial and economic crisis, followed by a deep slump. This pattern is visible in raw employment rates, particularly for men, but is much less visible in the cyclically-adjusted rates. For instance, despite falling actual employment rates for both men and women in the 30-34 age group from 2009 to 2013, the estimated structural employment rate for men is roughly flat over this period and that of women remains on the same uptrend as before the crisis. The use of cyclically-adjusted employment rates in the rest of the analysis therefore helps to reduce imprecision due to cyclical noise, although it does not eliminate it completely. Checks are made to verify that aggregating the resulting age/sex-specific gaps yields an overall employment gap measure close to the original country-level gap. This is generally the case for all countries.

Figure 11. Employment rates for 30-to-34-year-olds in Spain, per cent



3.2. Computing historical trend entry and exit rates from trend employment rates and projecting them into the future

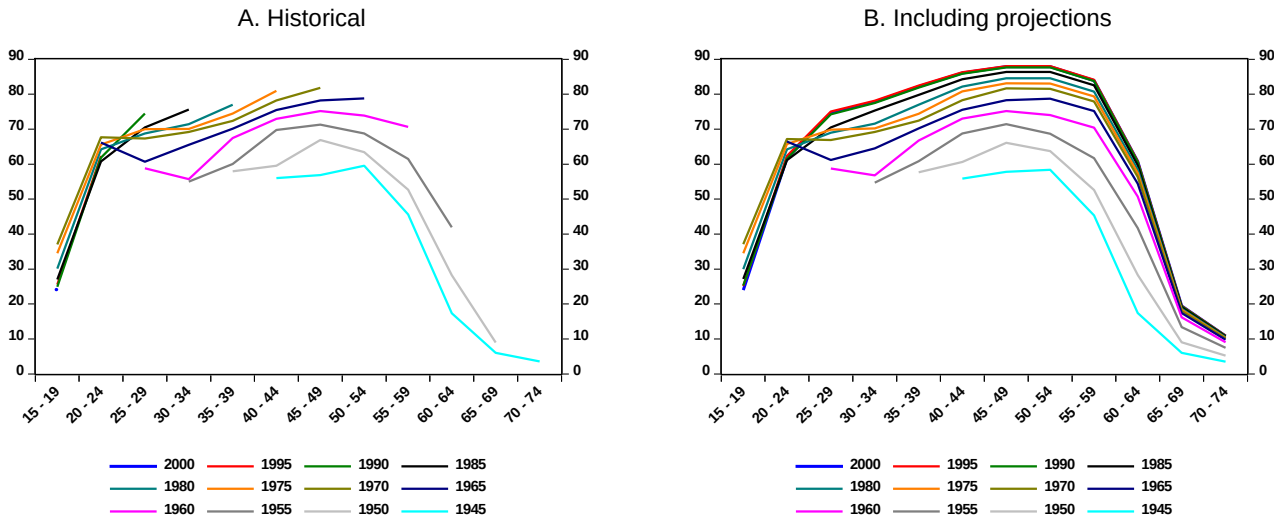
30. The trends left over in age/sex-specific employment rates after cyclical adjustment can be exploited to tease out how employment behaviours differ across generations. Albeit to a lesser extent than across countries or age groups, employment patterns also vary within individual age/sex groups in a given country for people born in different years (so-called 'cohorts'). Successive cohorts may respond to evolving social norms (for example, the increasing tendency for women to work), display varying aptitudes to work (depending on education levels for instance), or respond differently to changes in the structure and functioning of labour markets. Such trends have implications for the evolution of future employment rates.

31. To capture these trends, a cohort approach is used based on the original work of Burniaux et al. (2004) and similar to the one applied to labour force data in the previous iteration of the long-term model. A cohort here refers to a group of people born over a five-year period. Entry and exit rates into and out of work are calculated by comparing structural employment rates for a given cohort across two subsequent five-year periods. This requires using employment rates for two different age groups, because a given cohort will have aged into the following five-year age group over this five-year period. The procedure yields historical net entry/exit rates into/from employment, which can be interpreted as structural given the previous cyclical adjustment. These historical entry and exit rates then serve as bases for projecting future employment rates.

32. For the projections, the cohort approach keeps constant the rates at which individuals have recently been entering and exiting employment at various life stages.[14] All future (as yet unborn) cohorts are assumed to exhibit the same entry and exit rates as those measured from the most recent observations of existing cohorts. Projected changes in potential employment arise from differences in the employment propensities of different cohorts combined with shifts in the demographic structure of the population. Consequently, cohorts born in different years may show similar dynamics in the future, but the employment rate of each cohort remains unique. The main advantage of the cohort approach is that it allows recently observed differences in employment propensities across different cohorts to persist, potentially affecting projections for decades to come.

33. Panel A of Figure 12 shows German female workers as an example. Each line in the left-hand chart shows the evolution through time of the employment rate of a specific cohort spanning five birth years, referred to by the earliest possible birth year (in the legend). All these birth cohorts were present in the German labour market in 2015. The most recent observation is the rightmost point of each line. Clearly, successive cohorts have systematically had higher prime-age employment rates than their predecessors. Panel B of Figure 12 shows the same data but including projections for the cohorts still of working age. Looking for instance at the oldest age group (70-74), the cohort approach predicts a rising employment rate as successive cohorts reach this age range.

Figure 12. Cyclically-adjusted employment rates for different cohorts of German women, per cent

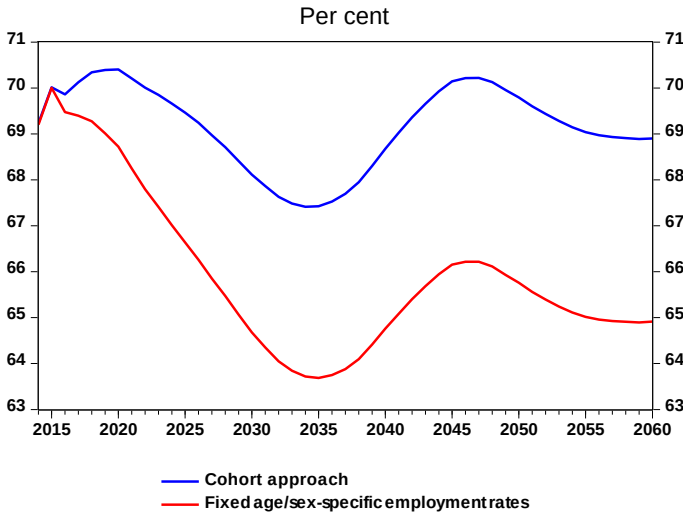


Note: The legend indicates the first year of five-year spans separating different cohorts. All of the cohorts shown were last observed in 2015. For the youngest cohort (i.e. those born in 2000), only one data point is available, since this group just entered the labour market in 2015, when they were 15 years old.

34. Ignoring trends such a rising female participation would risk under-predicting employment in the long-run scenarios. And indeed, keeping with Germany as an example, the cohort-based aggregate employment rate projection is noticeably higher than if age/sex-specific employment rates were simply kept constant into the future (Figure 13).

14. For a few countries for which data are insufficient to apply the full cohort approach (China, India, Indonesia, Argentina and Saudi Arabia), future age/sex-specific structural employment rates are assumed to remain constant at their last observed values. This means that the projected aggregate (structural) employment rate changes only to the extent that the age structure of the working-age population changes according to external demographic projections.

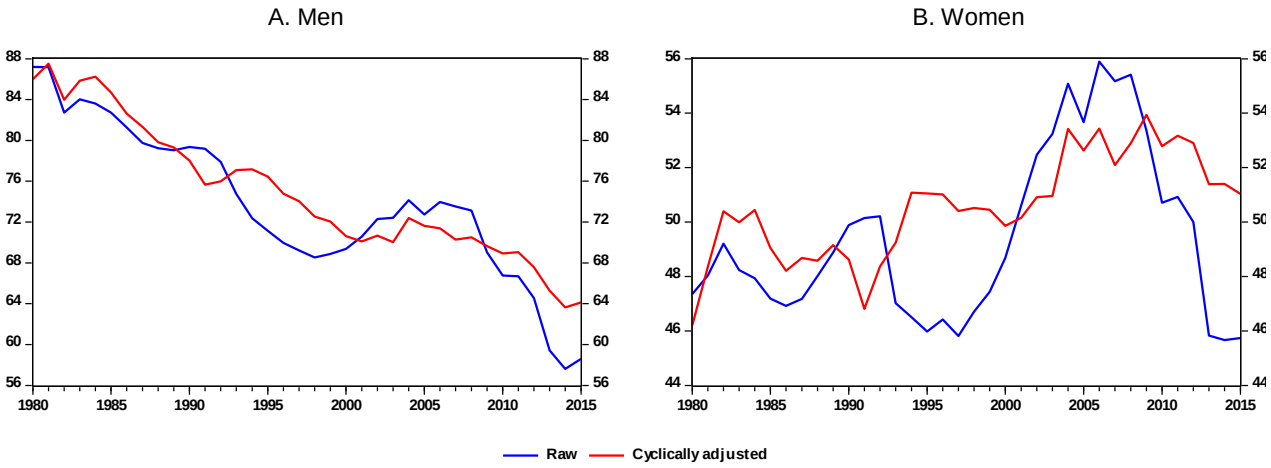
Figure 13. Projections of aggregate[1] employment rate (15-74) in Germany



1. The aggregate is a weighted sum of age/sex-specific employment rates, using Eurostat population projections.

35. The Spanish example above showed that the cyclical adjustment step could result in significantly different structural employment rates compared to the unadjusted series. Figure 14 illustrates the case of Italy where, as in Spain, the economic crisis dramatically lowered the employment rates of younger age groups, and particularly women. Once adjusted for the cycle using the aggregate employment gap, employment rates for men and women aged 25 to 29 in 2015 are some five percentage points higher than the unadjusted series. If the position of the business cycle were not taken into account when calculating entry rates for this and other age groups, they would be too low. Similarly, estimated exit rates for older age groups would be too high. In turn, the aggregate employment rate projection would be heavily biased downward.

Figure 14. Employment rates for 25-to-29-year-olds in Italy, per cent

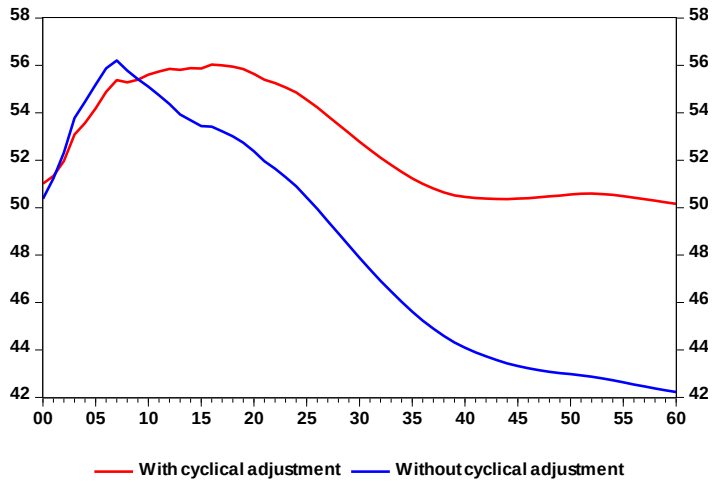


36. Indeed, the effects of the cyclical adjustment carry through to estimates of trend entry and exit rates and also affect projections of future employment rates substantially. The aggregate cyclically-adjusted employment rate is 2½ percentage points higher in 2015 than the unadjusted rate and, instead of being on a sharp downward trend, is on a slight upward trend (Figure 15). So not only the starting point of the aggregate series, but also its near-term dynamics, are affected by the cyclical adjustment. The level gap

between the two employment rate projections keeps widening and reaches 8 percentage points by the end of the projection period, demonstrating the importance of the cyclical adjustment.

Figure 15. Aggregate[1] employment rate in Italy, per cent

Observations/estimates to 2015 and projections thereafter



1. The aggregate is a weighted sum of age/sex-specific employment rates, using Eurostat population projections.

37. While less extreme than in Spain and Italy, which is why these two countries were used as illustrations, depressed employment conditions were found in almost all advanced economies over the period 2010 to 2015, over which structural entry and exit rates are currently estimated. In this post-crisis period, then, it is all the more important to work with structural entry and exit rates calculated using cyclically adjusted employment rates.

3.3. Structural and policy effects on employment rates

38. The policy effects included in the model are summarised in Table 2. Most of them come from the recent QSR work mentioned previously (Égert and Gal, 2017a; Gal and Theising, 2015). Specifically:

- The unemployment (UE) benefits replacement rate affects employment rates of all workers negatively, but especially the elderly.
- Spending on active labour market policies (ALMPs) affects employment rates of all workers positively, but especially the young.
- The labour tax wedge on single earners affects youth employment rates negatively, while the tax wedge on couples affects employment rates of prime-age men and the elderly negatively.
- Excess coverage of wage bargaining agreements affects employment rates of prime-age women negatively.
- The level of the minimum wage affects employment rates of youth and prime-age women negatively.
- Spending on in-kind benefits for families, as well as the number of weeks of maternity leave, affect employment rates of prime-age women positively.

- A higher legal retirement age is estimated to raise elderly employment rates.

- Higher average educational attainment is estimated to raise prime-age employment rates but depress those of youth (see Cavalleri and Guillemette, 2017 on the latter finding).

- The electricity, transport and communications regulation (ETCR) indicator, used as a proxy for product market regulation (PMR), has a statistically significant effect in the reference studies only for prime-age women. However, plenty of studies, using both micro and macro data, support the hypothesis that more restrictive product market regulation depresses long-run employment rates (Fiori et al., 2012; Bouis et al., 2016; De Serres and Gal, 2015; Gal and Hijzen, 2016; Bassanini, 2015; OECD, 2016). On this basis, a PMR effect with the same magnitude for both men and women of prime age is calibrated so that the effect of a typical reform (a reduction of 0.3 points in ECTR) yields the same improvement in the aggregate employment rate that is reported in Égert and Gal (2017a), taking into account the typical share of prime-age employment in total employment. The resulting effects, reported in Table 2, mean that a one-point reduction in the ETCR index raises the employment rates of prime age workers by ¾ of a percentage point.

- The speeds at which policies affect employment rates are specific to the different age/sex groups as estimated in the reference studies. They are relatively slow (about 15% per annum) for prime-age women and elderly workers and relatively fast (about 30% per annum) for youth and prime-age men. Each year, these percentages of any remaining difference between current and predicted long-run employment rates (i.e. those predicted on the basis of policy changes) are eliminated.

Table 2. Long-run effects of policy and structural variables on employment rates

Percentage point change in age/sex-specific employment rate for a one-unit change in indicator

	Standard deviation[1]	Youth (15-24)	Prime-age women	Prime-age men	Elderly (55+)
UE benefit replacement rate (in pp)	9.5	-0.183	-0.204	-0.147	-0.343
ALMP spending (pp of GDP per capita)	20.8	0.147	0.092	0.047	0.063
Tax wedge single (pp of labour costs)	9.4	-0.866			
Tax wedge couple (pp of labour costs)	11.9			-0.274	-0.26
Excess coverage (pp of workforce)	23.6		-0.171		
Minimum wage (pp of median wage)	12.3	-0.311	-0.421		
Family benefits in kind (pp of GDP)	0.6		4.698		
Number of weeks of maternity leave	9		0.265		
Legal age for pensions	3.8				0.851
ETCR (index, higher is more restrictive)[2]	1.5		-0.762	-0.762	
Educational attainment (years of schooling)[3]	2.3	-2.83	1.706	0.582	

1. Except for educational attainment, standard deviations are from Table 5 in Gal and Theising (2015). All figures include both within- and between-country variation and generally cover OECD countries.
2. In Égert and Gal (2017a), the ETCR effect is only statistically significant for prime-age women. Here it is assumed to apply equally to men and women but is calibrated to match the overall effect reported by these authors.
3. The educational effects for prime-age men and women are from the empirical work underlying Égert and Gal (2017a), even though these effects are not reported in the paper. The youth effect is from estimation work described in Cavalleri and Guillemette (2017).

Source: Égert and Gal (2017a), Gal and Theising (2015) and Cavalleri and Guillemette (2017).

39. The policy effects shown in Table 2 are applied to the preliminary age/sex-specific employment rates obtained from the cohort approach. The coefficients pertaining to youth are assumed to apply equally to the 15-19 and 20-24 age groups for both men and women; the prime-age coefficients are applied equally to adults aged 25 to 54 of the corresponding sex, and the elderly coefficients are assumed to apply equally to age groups 55 and over for both women and men.

40. Once education and policy effects have been applied to the disaggregated initial employment rate series, an aggregate series is obtained by weighting and adding up the age/sex-specific employment rate

projections by age/sex-specific population projections. This aggregate potential employment series enters the calculation of aggregate potential output with a weight of two-thirds given the assumed Cobb-Douglas production function.

4. Projecting the capital stock

41. The approach chosen for developing the capital stock equation of the long-term model is to successively add to it the desired components, while respecting both theory and the policy effects estimated in the QSR exercise. A simplified version of the resulting equation is tested empirically to check its validity. Once the evolution of the capital stock is set, investment is derived by identity using a simple assumption for the depreciation rate.

4.1. Building up from theory and empirics

42. The starting point is the capital-output ratio equilibrium condition in the Solow growth model, which relates the equilibrium capital output ratio to the domestic saving rate (s_t^d), the growth rates of labour efficiency (g_t) and employment (n_t) and the capital stock depreciation rate (δ_t). The expression is differenced and assumed to apply to the evolution of the equilibrium capital stock (K_t^*). To this expression are added influences from employment protection legislation (*EPL*) and product market regulation (*PMR*), with elasticities sourced from the recent QSR project (Égert and Gal, 2017a and 2017b). More stringent product market regulation is associated with lower long-term capital-to-output ratios and likewise for more stringent employment protection legislation. The change in the user cost of capital is also added to the expression, the user cost being a function of the difference between investment and output price inflation ($drpi$), the corporate borrowing rate (the risk-free rate plus a spread), the corporate tax rate (τ_t) and the depreciation rate. Finally, instead of using domestic saving (s_t^d) and interest rates (i_t^d), weighted averages of domestic and global rates (s_t^g and i_t^g) are used to reflect the existence of cross-border capital flows, with the weights (ω) being calibrated on the Chinn-Ito index of capital account openness (Chinn and Ito, 2006).

$$\begin{aligned}\Delta log(K_t^*) = {} & g_t + n_t + 1.5\,\Delta log\left(\omega s_t^d + (1-\omega)s_t^g\right) - 1.5\,\Delta log(g_t + n_t + \delta_t) - 0.457\,\Delta PMR \\ & - 0.227\,\Delta EPL - drpi - \Delta log\left((1-\tau_t)\left(\omega i_t^d + (1-\omega)i_t^g\right) + \delta_t\right) \\ & + \Delta log(1-\tau_t)\end{aligned} \quad [5]$$

43. The actual productive capital stock (K_t) is assumed to converge to the equilibrium level in [5] following:

$$\Delta log(K_t) = \theta \Delta log(K_{t-1}/Y_{t-1}^*) + g_t + n_t + \gamma GAP_t + \varphi[\log(K_{t-1}) - \log(K_{t-1}^*)] \quad [6]$$

where φ is the convergence speed, taken to be -0.03, roughly an average of the speeds in empirical tests of the equation and also close to the convergence speeds estimated in the QSR project. The first term on the right-hand side helps to ensure that the capital stock evolves smoothly at the beginning of the projection period.

44. Investment is obtained via the stock/flow identity linking it and the capital stock with the projected depreciation rate:

$$I_t = K_t - (1-\delta_t)K_{t-1} \quad [7]$$

Over the projection period, the depreciation rate follows

$$\Delta\delta_t = 0.9 \cdot \Delta\delta_{t-1} \quad [8]$$

ensuring that any recent trend in the measured depreciation rate over history carries over into the first few years of the projection period, but also that the depreciation rate eventually stabilises. In most countries for which historical data are available, the depreciation rate has been trending up for many years, presumably because of the rising share of ICT equipment in firms' capital stocks, which depreciates faster than more traditional capital goods.

45. Equations [5] and [6] determine the *evolution* of the equilibrium and actual capital stocks from initial levels at the start of the long-term projection period. But while actual capital stock estimates, however imperfect, are available, the equilibrium capital stock is unobservable. Therefore, it is calibrated to simultaneously achieve, as best as possible, two objectives:

1. Keep the contribution of capital accumulation to long-term growth in the baseline scenario relatively small. Historical growth decomposition exercises typically find only a small role for capital accumulation when looking over long time periods, and development accounting exercises similarly find that only a small share of differences in living standards are due to differences in capital intensity (e.g. Jones, 2015).

2. Keep any implied change in investment in the first simulation period modest to prevent implausible sudden changes to investment itself, but also to the current account balance, which is obtained as the difference between saving and investment.

4.2. Empirical tests

46. To check whether the specifications [5] and [6] are empirically valid, an equation combining the two expressions is tested empirically, but without the PMR and EPL effects as those already come from empirical work, as mentioned above (Table 3). The sample consists of (a maximum of) 43 of the 46 countries in the long-term model for which all data series are available. All data series are from the EO database except for the corporate income tax rate, a component of the user cost of capital, which is sourced from the OECD Tax Database, and the Chinn-Ito index of capital account openness mentioned above.

47. Estimated coefficients on the weighted domestic/global saving rate, and on the sum of trend labour efficiency growth (g), trend employment growth (n) and depreciation (d), match the expected coefficients from theory closely (1 and -1 respectively in column 5 of Table 3). The user cost of capital coefficient is not statistically significant in most specifications, but this finding is not surprising as many studies have failed to pick up this effect in aggregate macro data. The output gap effect has the expected positive sign – consistent with the strong procyclicality of investment – and is statistically significant. The speed of convergence to the long-term equilibrium is estimated at about 3% per year, close to that of other studies (e.g. Égert and Gal, 2017b).

48. When a version of the equation that includes only the domestic saving rate is tested on the half of the sample with the richest countries (column 3), the coefficient on the domestic saving rate is lower than in the full sample (column 1), which is consistent with the idea that richer countries tend to be more opened to capital flows, and therefore that the domestic saving rate would have only limited influence on capital stock formation. Alternatively, when only the other half of the sample with the poorest 19 countries is considered (column 4), the coefficient on the domestic saving rate is substantially higher than in the rich-only sample or the common sample. Again this is consistent with cross-border capital flows being less important in financing capital formation in these countries. Furthermore, in the full equation which uses an equally-weighted average of the domestic and global saving rates, interaction terms indicate a negative and statistically significant interaction effect between capital account openness and the domestic saving rate, and a positive and statistically significant interaction effect between capital account openness and the global saving rate (column 6). These findings all support the functional form proposed in [5] in which

domestic saving yields to global saving in importance as capital account openness rises. The user cost of capital coefficient is based on both theory and micro-empirics, supporting an elasticity of -1 (Gilchrist and Zakrajsek, 2007).

Table 3. Estimation results for capital stock equation

$$\Delta \log\left(\frac{K}{Y}\right) = \alpha + \gamma GAP + \rho[\log(\frac{K}{Y})_{-1} - \beta_1 \log(s_{-1}) - \beta_2 \log(g_{-1} + n_{-1} + d_{-1}) - \beta_3 \log(ucc_{-1})]$$

	(1)	(2)	(3)	(4)	(5)	(6)
Long-run						
Log domestic saving rate (*s*)	0.507***	0.506***	0.230**	0.736***		
Log weighted average of domestic and global saving rates					1.074**	1.286***
log(*g* + *n* + *d*)	-1.127***	-1.121***	-1.289***	-0.880***	-1.151***	-1.209***
Log user cost of capital (*ucc*)	0.0591	0.0615	-0.236**	-0.0684***	0.0939	-0.048
Interaction of log domestic saving rate and capital account openness						-0.200**
Interaction of log global saving rate and capital account openness						0.295***
Short run						
Output gap (*GAP*)	0.00124***	0.00143***	0.00132***	0.00124***	0.00124***	0.00139***
Speed of convergence	-0.0293***	-0.0304***	-0.0264	-0.0402***	-0.0299***	-0.0326***
Time fixed effects	No	Yes	No	No	No	No
Number of countries	43	43	Rich 24	Poor 19	43	42
Estimation period	1992-2016	1992-2016	1992-2016	1992-2016	2005-2016	2005-2014
Observations	875	875	568	307	504	408
R^2	0.540	0.593	0.577	0.691	0.509	0.634

4.3. Simulation properties of the equation

49. Using a small simulation model with equations [5], [6] and [7], together with a Cobb-Douglas production function, and a calibration respecting conventional values for the parameters, the capital stock/investment equations have the following simulation properties:

- A permanent increase in the domestic saving rate permanently raises capital intensity (i.e. the capital-to-output ratio), the investment ratio (investment over output) and the level of potential output relative to a no-change baseline, but it raises potential output growth only temporarily. The sizes of these effects depend on the home bias parameter (i.e. on capital account openness). For instance, in a relatively closed country with a home bias parameter of 0.8, a one percentage point increase in the domestic saving rate raises long-run capital intensity by over 4½ per cent and output by about 2.3%, whereas in a relatively open economy with a home bias parameter of 0.2, the increase in long-run output is only about 0.4%. Also, the global saving rate in the long-term model being an aggregate of all domestic saving rates, a shock to the domestic saving rate of a large country has knock-on effects on all countries in the model via the global rate.

- A permanent increase in trend labour efficiency or employment growth permanently lowers capital intensity. During the transition period to the new steady state, potential output growth rises by slightly less than the full amount of the shock to trend labour efficiency or employment, because capital intensity is falling, but once capital intensity settles to its new lower level, potential output growth is higher by the full amount of the shock, relative to the baseline.

- A permanent increase in the capital stock depreciation rate affects capital intensity negatively. Potential output growth declines temporarily during the transition period to the new lower capital intensity level, so the level of potential output declines permanently relative to baseline. For instance, a one percentage point increase in the depreciation rate lowers long-run capital intensity by about 17% and long-run output by about 8%.

- Product market or labour market liberalisation (fall in PMR or EPL indices) raise investment and capital intensity permanently. Potential growth rises temporarily during the transition period to higher capital intensity. The effect on the long-run level of potential output is about twice as large for a one-point PMR decline (15%) as for a one-point EPL fall (7.5%).

- A cut to the statutory corporate income tax rate has the same qualitative effects as PMR or EPL liberalisation, but quantitatively it is much smaller. For a one-point cut, long-run output increases by about 0.3%.

- A fall in domestic and/or global interest rates also has the same qualitative effects as PMR or EPL liberalisation, or a corporate tax cut. Like the domestic saving rate effect, the effect of a fall in only domestic or global interest rates varies according to the degree of capital account openness. Also, as for the saving rate, the global interest rate in the long-term model is an aggregate of domestic interest rates, so a shock to the domestic interest rate of a large country has knock-on effects on all countries in the model via the global rate. To give an order of magnitude, a fall of one percentage point in both domestic and global interest rates raises capital intensity by nearly 6% and long-run output by about 2.8%.

- In the long-term model, the long-running historical trend of relatively lower investment price inflation is assumed to continue into the future: every year the investment price deflator is assumed to increase by 0.5 percentage point less than the output price deflator. This assumption introduces permanent positive trends in capital intensity and in the investment ratio. In so doing, it also raises potential output growth permanently, but gradually. Over the forty-some year time horizon of the long-term model, capital intensity increases by only about 6% and the investment ratio by a little less than 2 percentage points of GDP.

- A temporary negative output gap has a temporary negative effect on the investment ratio, on capital intensity and on potential output, but no hysteresis-like permanent effect.

- The slow estimated convergence speed (3%) means that over the projection horizon of the long-term model, only about two thirds of the full long-term effects mentioned above are phased in.

5. A preliminary baseline long-term projection

50. This section presents a preliminary no-policy change baseline scenario using the revised production function along with the rest of the model, which remains as described in Johansson et al. (2013). The main influences on the evolution of output in the different countries in the model, via each of the three components of the production function, are:

- Trend labour efficiency

  - The exogenous rate of technological progress – corresponding to the time fixed effect (γ_t) in [2] – is assumed to be 1% per year. In all countries labour efficiency growth would eventually converge to this assumption once labour efficiency had reached its equilibrium level.

- Gradual correction of initial disequilibrium vis-à-vis predicted equilibrium labour efficiency level.

- Gradual elimination of unexplained trend labour efficiency growth residual. The portion of trend labour efficiency growth that the equation cannot account for is assumed to decline gradually to zero. High-growth emerging-market economies tend to have large positive residuals.

- Rising educational attainment as projected by Barro and Lee (2015). Even with no assumed change in policy, educational attainment in the adult population rises mechanically as less-educated workers leave the working-age range and more educated younger people come to represent a larger share of the workforce.

- Trade openness: Even with no assumed change in trade tariffs, trade openness depends positively on real GDP per capita.[15] As a country gets richer, trade intensity tends to increase and this has a positive but small effect on labour efficiency.

- Trend employment

  - Projected working-age population growth.

  - Cohort effects, both positive (e.g. rising female employment) and negative (lower employment rates at older ages).

  - Rising educational attainment (although the aggregate effect is very small).

- Capital stock

  - In most countries the saving rate declines under the effect of population ageing and this tends to lower equilibrium capital intensity.

  - The gradual normalisation of interest rates puts upward pressure on the user cost of capital, and downward pressure on equilibrium capital intensity.[16]

  - The assumed continued decline in relative investment prices puts downward pressure on the user cost of capital and upward pressure on equilibrium capital intensity.

51. Perhaps the most salient feature of the baseline projection is the expected continued slowdown in world output growth (Figure 16, Panel A). From today's rate of just over 3%, world trend output growth is expected to decelerate for the next three decades, driven partly by slowing growth in the OECD area but mostly in the non-OECD area.[17] Nevertheless, growth in the non-OECD area is projected to remain

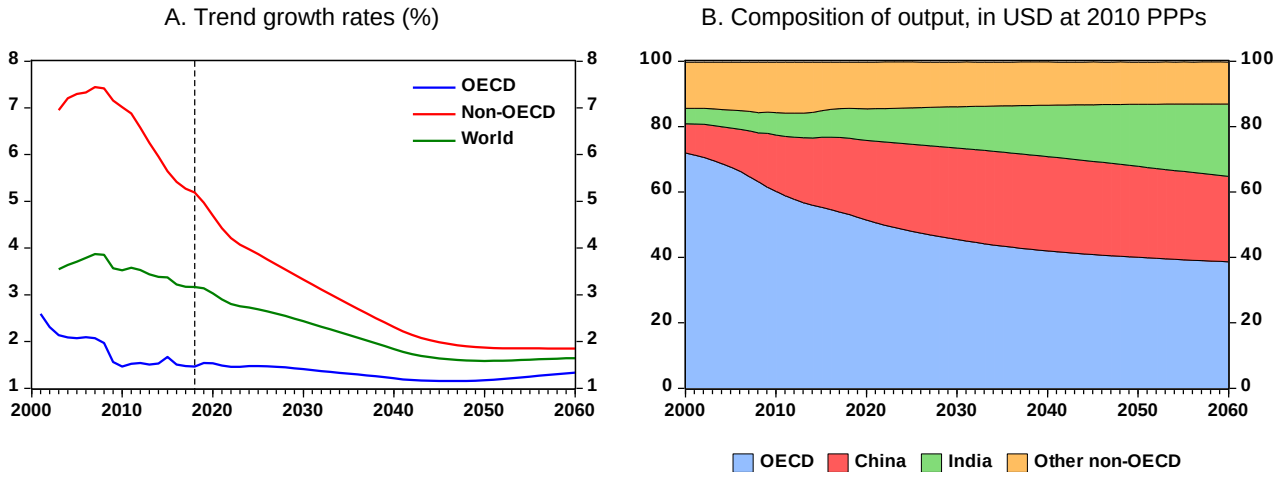
15. See Appendix 4 of Haugh et al. (2016) for the equation determining long-term trade openness in the model.

16. Not all of the near-term predicted normalization of interest rates is assumed to pass through to the user cost of capital. Otherwise the negative effect on investment would be implausibly large given that investment is already weak by historical standards.

17. Here the 'world' refers to an aggregate of the 46 countries included in the long-term model (see above for the list), which today account for about 90% of world output measured at purchasing power parities. The non-OECD aggregate includes the large non-OECD G20 countries but miss several highly-populated emerging markets (for instance Nigeria) that could potentially change the long-term picture significantly.

significantly above that of the OECD area. As a consequence, the share of OECD output in world output, which has already fallen from 72% in 2000 to just over 50% now, is projected to keep falling (Figure 16, Panel B). China's share of world output is projected to keep rising, but not as much as India's, which by 2060 approaches the same size as China.

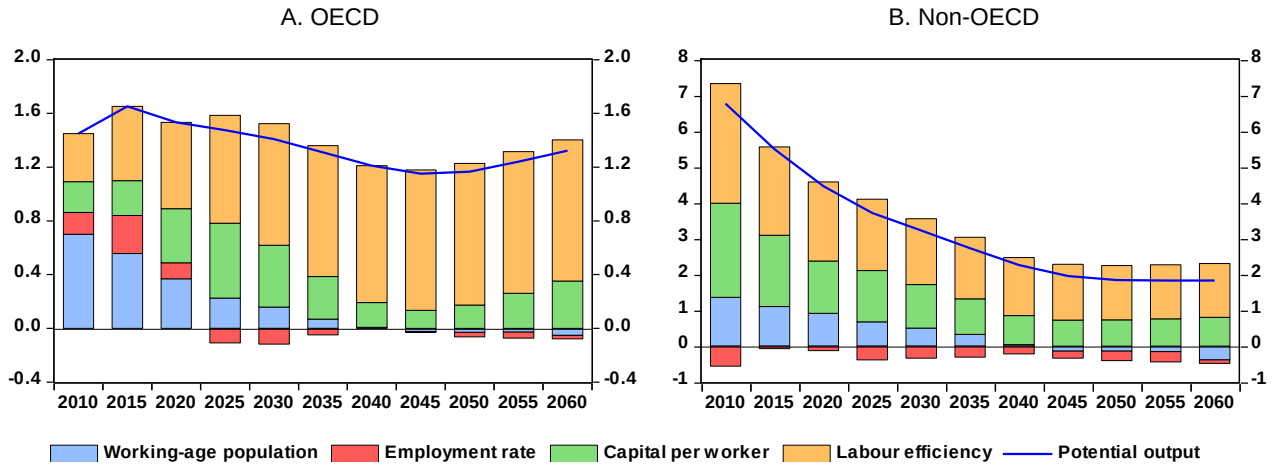
Figure 16. Baseline growth rates and composition of world output



Note: The "world" and "non-OECD" in these charts are defined in terms of the countries included in the model.

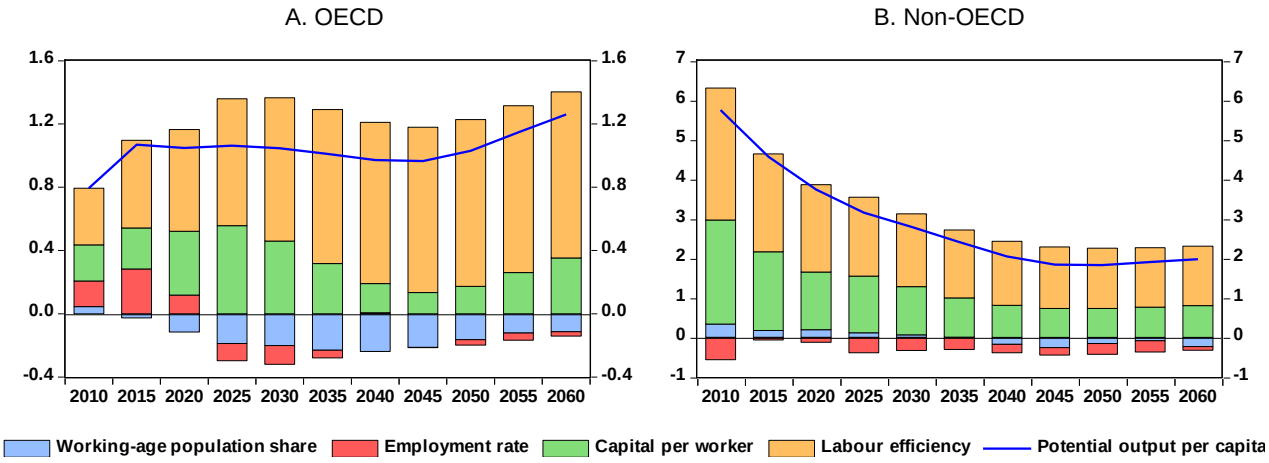
52. In the case of the OECD area, the projected decline in potential growth in the coming decades is driven mostly by demographic factors. Working-age population growth falls substantially and eventually turns slightly negative and the positive contribution of the employment rate also turns negative (Figure 17, Panel A). In the non-OECD area, population ageing also weighs down potential growth, but most of the decline is instead due to slowing growth in capital intensity and labour efficiency (Figure 17, Panel B). Some of the decline in capital intensity is due to the effect of population ageing on saving rates as pointed out above, while the decline in labour efficiency growth occurs largely as a result of the convergence process bringing productivity in catching-up countries more in line with advanced countries, thereby reducing the catch-up impetus to growth.

Figure 17. Decomposition of potential output growth (%)



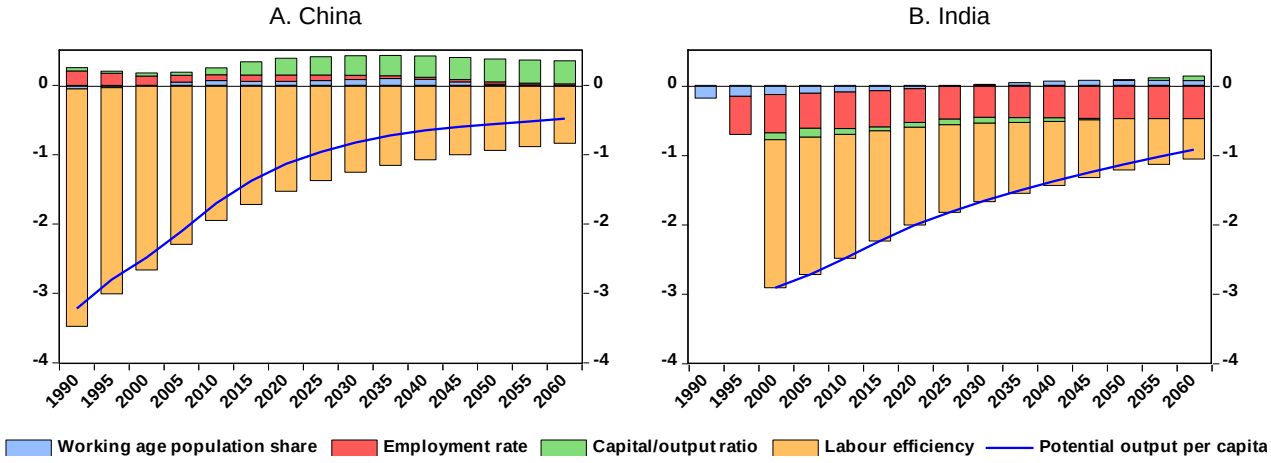
53. When looking at a per-capita metric, which is more relevant to assess living standards, the outlook is somewhat less ominous, particularly for the OECD. Potential growth per capita barely falls over the next few decades in the OECD area, although compared to around 2% in the 1990s and 1.5% in the 2000s it is much weaker (Figure 18, Panel A). Here it is the share of the working-age population in total population that matters, and its contribution to growth is already negative. While it becomes more negative over the first part of the projection period, it is less marked than in the case of the total working-age population. In the non-OECD area, the projected decline in per capita potential output is slightly less marked than when looking at total output, but is still very substantial given that the driving factor – convergence in labour efficiency growth – is not related to demographics (Figure 18, Panel B).

Figure 18. Decomposition of potential output growth per capita (%)



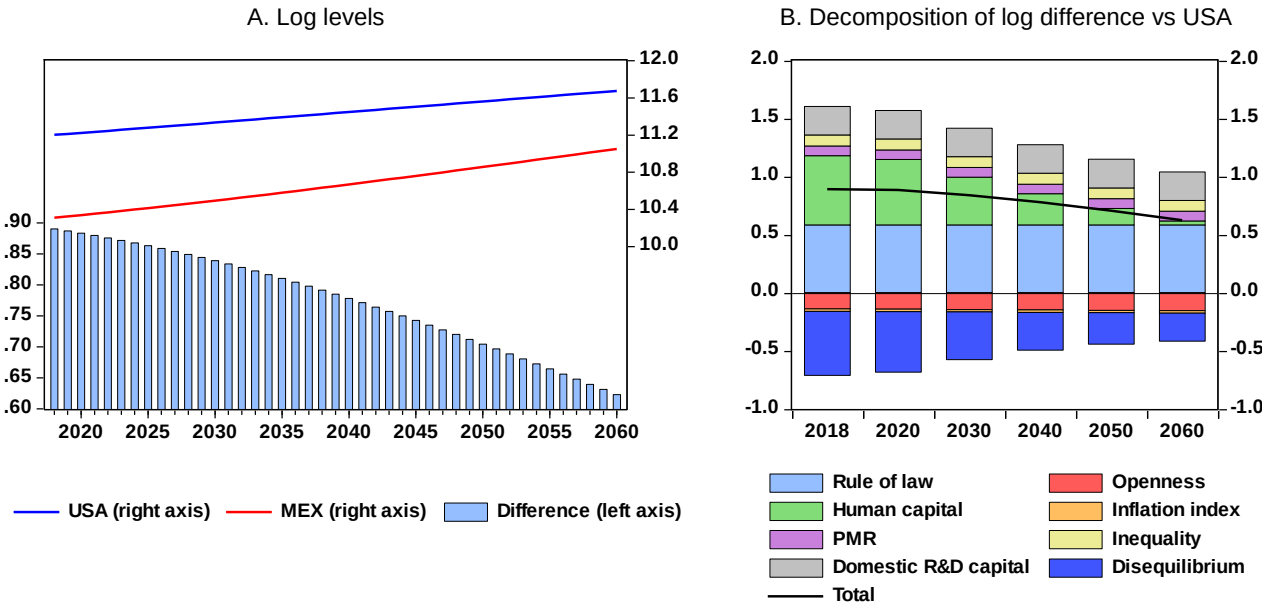
54. As is well-known from decomposition exercises (e.g. Jones, 2015), differences in living standards across countries are mostly due to differences in labour efficiency (equivalent to TFP). Taking China as an example, and using the United States as a reference country, more than the entire gap in living standards is due to lower labour efficiency, as other components, such as the capital/output ratio, lessen the gaps (Figure 19, Panel A). In India, about ¾ of the gap is due to labour efficiency (Figure 19, Panel B). Accordingly, projected convergence in living standards for countries far behind the leading ones happen mostly through convergence in labour efficiency.

Figure 19. Decomposition of potential output per capita gaps with the United States, at 2010 PPPs (log points)



55. The labour efficiency equation outlined in section 2 allows a decomposition of differences in labour efficiency levels, again using the United States as a reference. In Mexico for instance, the low initial level of labour efficiency relative to the United States in 2018 is attributed by the equation mostly to a lower score on the rule of law and less human capital, but also to more stringent product market regulation, higher inequality and lower domestic R&D (Figure 20, Panel B). These factors are only partly compensated by a higher degree of trade openness in Mexico. Conditional on current institutional and policy settings, Mexico is also estimated to be above its long-run equilibrium labour efficiency level, hence the negative contribution of the initial 'disequilibrium' to the labour efficiency gap.

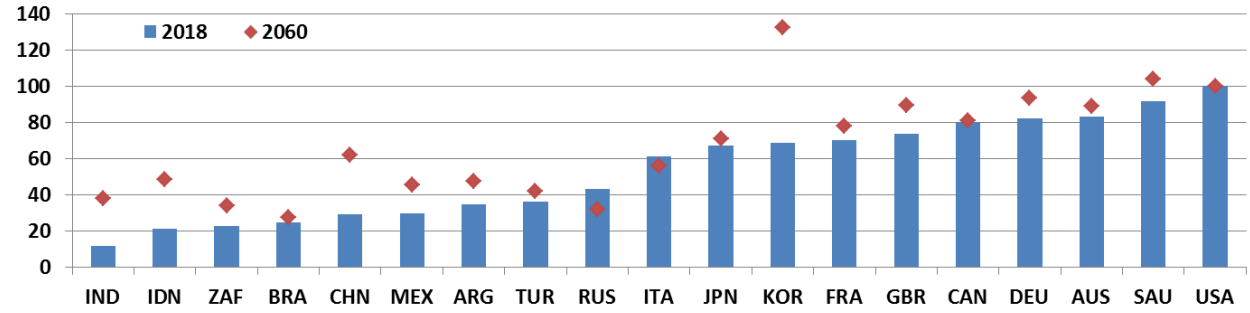
Figure 20. Projected labour efficiency convergence in Mexico, at 2010 PPPs



56. In the baseline Mexico projection, about one third of the initial gap in labour efficiency with the United States is eliminated by 2060 (Figure 20, Panel A). This is entirely the result of human capital almost fully converging to the US level over this time span. Correction of initial disequilibria (in both Mexico and the United States) slows the convergence process down in this case.

57. The degree of convergence in living standards toward those of the United States in the baseline scenario varies a lot across G20 countries (Figure 21). In an absolute convergence framework, one would expect to see greater convergence among the poorest countries as those have the most catching up to do. In a conditional productivity convergence framework, however, this is not necessarily the case because convergence is conditional on own-country characteristics, and not on distances relative to a frontier. Nevertheless, it is generally the case that countries which are poorer today show greater convergence in living standards by 2060. This is driven mostly by the projected improvements in human capital, which are generally greatest for the countries that are poorest today. Relative living standards in some EMEs (Brazil, Turkey and South Africa) converge to a lesser extent than in other EMEs, or even regress (Russia, Italy), either because labour efficiency levels are estimated to already be significantly above what institutional and policy determinants would predict, and/or because of slower convergence speeds in labour efficiency, which, as explained previously, are conditional on the rule of law and openness indicators. Living standards are projected to progress the most in Korea, even surpass those in the United States by a significant margin by 2060, as labour efficiency differences vanish, while capital intensity and employment rates remain higher than in the United States.

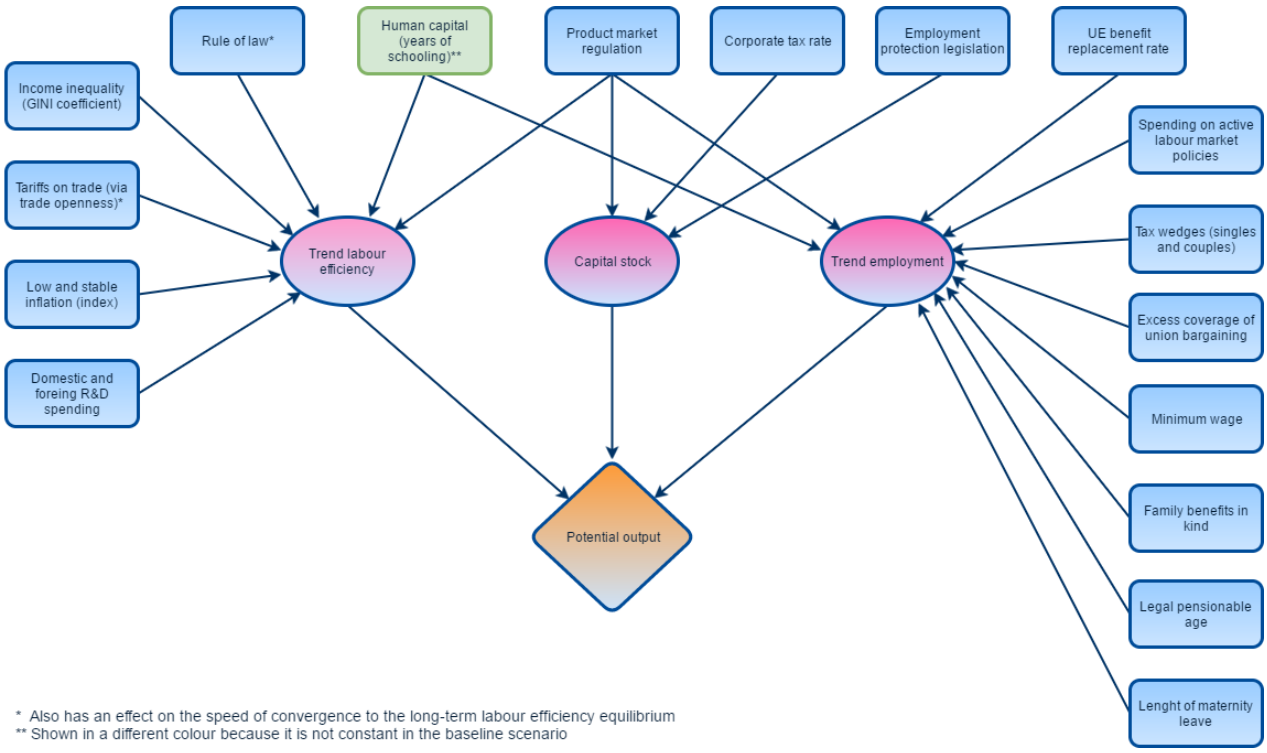
Figure 21. Convergence in trend real GDP per capita for G20 countries, USA = 100



6. Illustrative policy reform scenarios

58. Taking the simulation of the previous section as baseline, this section illustrates with a few examples how alternative scenarios can be constructed using the institutional and policy channels available in the revised model, some of which affect more than one component of potential output (Figure 22).

Figure 22. Direct institutional and policy influences on long-term output



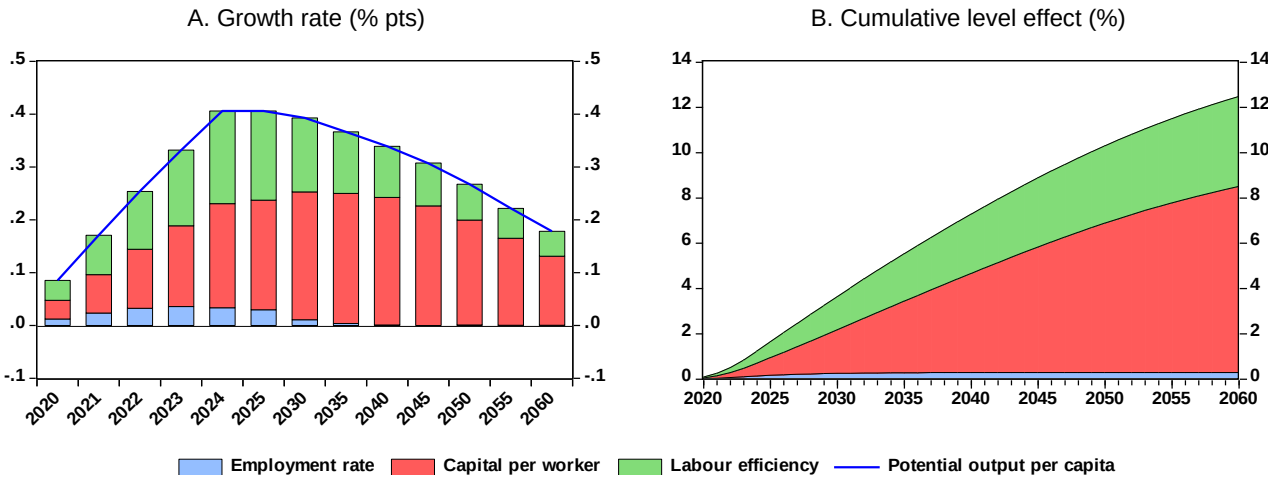
6.1. Product market liberalisation

59. Product market liberalisation affects potential output through all three components of the production function.[18] A typical-size reform – measured as in Figure 9 Panel B by the mean absolute 5-

18. The effect occurs through the ETCR variable in the employment equation rather than through PMR, but the PMR effect is translated into an equivalent ETRC effect using $\Delta PMR = 0.45 \cdot \Delta ETCR$. This relationship is based on a simple linear regression between official estimates of both indicators.

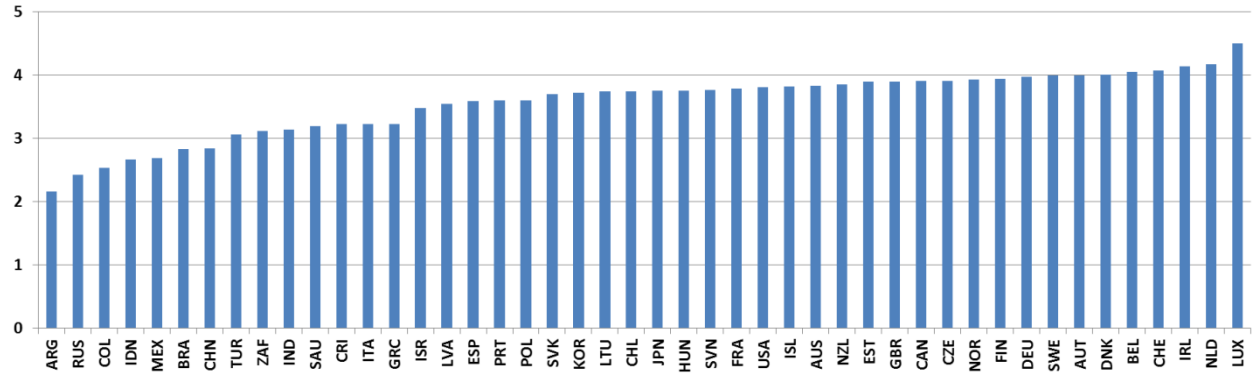
year change along the within-country dimension – is a reduction of 0.27 points of the PMR index. Taking Germany as an example and assuming it occurs over a 5-year period from 2019 to 2023, such a PMR reform is associated with a 0.4 percentage points boost to growth in trend GDP per capita once the reform is fully phased in (Figure 23, Panel A). Most of the total effect occurs through stronger investment and faster growth in labour efficiency. The employment effect is small and is fully phased in within about 15 years given the faster convergence speed estimated for employment effects. By 2060, the cumulative total effect of the reform on real GDP per capita amounts to a little over 12%, but the full long-term effect would take longer given the slow convergence speeds estimated for labour efficiency and capital stock adjustments (Figure 23, Panel B).

Figure 23. Impact of PMR reform on per capita potential GDP in Germany



60. As explained in section 2, a country's score on the rule of law governance indicator and its trade openness affect the speed at which labour efficiency converges to its equilibrium level, and hence the speed at which institutional/policy changes filter through to living standards. In the PMR shock just described, the boost to labour efficiency in Germany contributes nearly 4 percentage points to the increase in living standards by 2060. For countries with poorer governance and/or lower trade openness, however, this contribution would be smaller: between 2 and 3 percentage points for Argentina, Russia and Colombia for instance (Figure 24). Most OECD countries score highly and similarly to Germany on governance, but a few countries, like Italy and Greece, score relatively poorly and would thus benefit more slowly from product market reform.

Figure 24. Contribution of labour efficiency to per capita real GDP increase by 2060 with PMR shock (% pts)



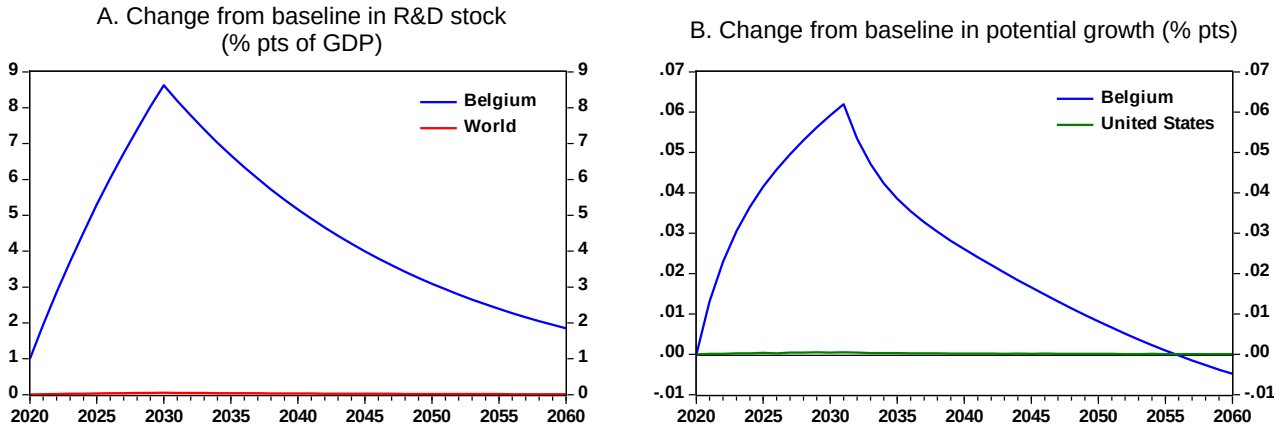
61. While there are no such countries in the model, it is conceptually possible for labour efficiency not to converge toward the equilibrium level if a country simultaneously trades little (low openness) and has poor governance (low rule of law), making the convergence speed close to zero. A corollary is that any institutional/policy reform that boosts the equilibrium level of labour efficiency would have no impact on labour efficiency growth. The intuition behind this feature of the model is that without some minimum quality of governance and external competitive pressure, reforms would have little traction on the economy.

6.2. Impact of R&D spending shocks

62. An innovation shock is interesting to illustrate because it not only has an impact on the country where the additional innovation takes places, but also on other countries via spillovers. This is consistent with the idea that the products of innovation are often non-rival and non-excludable and tend to diffuse across borders. As outlined in section 2, the flow of innovation is measured in the model by total spending on R&D as a share of GDP. Each country accumulates a stock of R&D and the global stock of R&D is aggregate of individual country stocks.

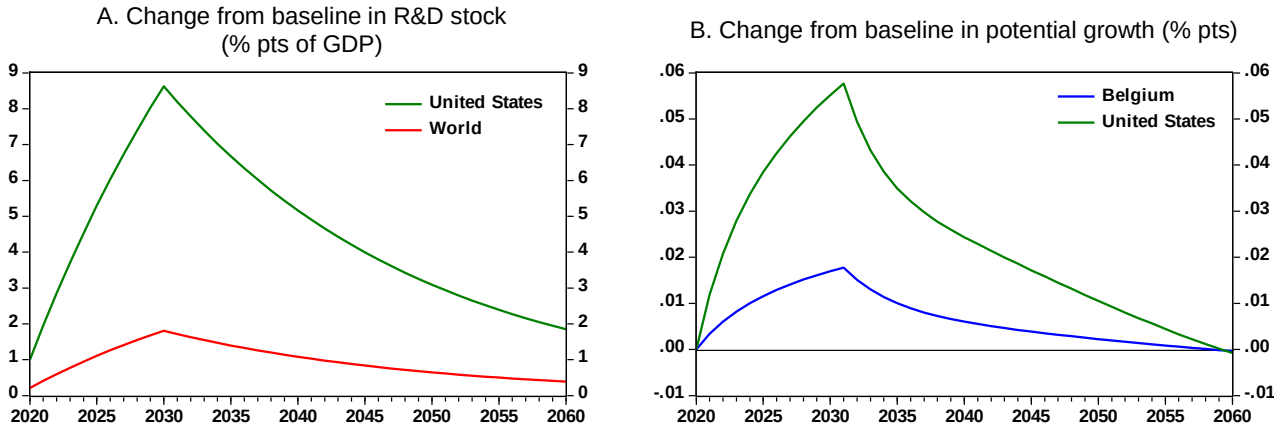
63. If a small country, for instance Belgium, raises R&D spending by one percentage point of GDP in 2020 for a period of 10 years, its R&D stock eventually rises by close to 9 percentage points of GDP, but the impact on the global stock of R&D is not discernible (Figure 25, Panel A). The increase in the Belgian R&D stock has a positive impact on labour efficiency growth and, consequently, potential growth rises by up to 0.06 percentage point after 10 years, remaining above baseline for almost the entire projection period given the inertia in the R&D stock (Figure 25, Panel B). By 2060 Belgian potential output is 1% higher than in the baseline. Given the small relative size of Belgium, the spillovers to other countries – for instance here the United States – are small and not visible in potential growth (Figure 25, Panel B).

Figure 25. Impact of innovation shock (1 pp of GDP more in R&D spending over 10 years) in Belgium



64. The same innovation shock in a bigger country, for instance the United States, has the same impact on the domestic R&D stock, but a noticeable impact also on the global R&D stock, which rises by 1.8 percentage points of global GDP at the peak, given the size of the United States in the world economy (Figure 26, Panel A). Consequently, the growth spillovers to other countries are more important. Potential growth in Belgium rises slightly though still much less than when it was the source of the shock (Figure 26, Panel B).

Figure 26. Impact of innovation shock (1 pp of GDP more in R&D spending over 10 years) in the United States



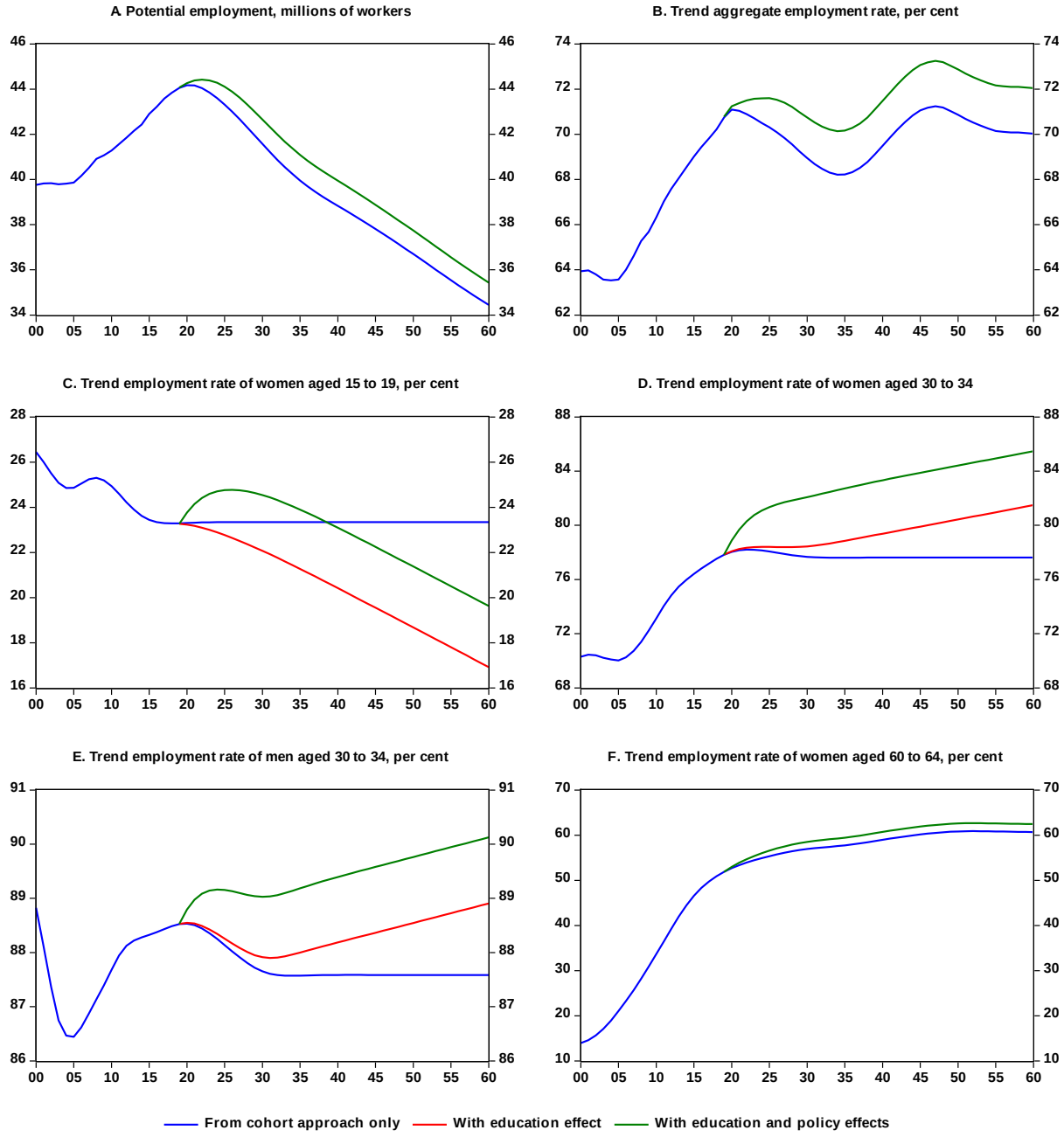
6.3. Illustrative policy package for the labour market

65. Employment policy reforms differ from other types of shocks in that they affect different age/sex groups differently. Also, as in the case of labour efficiency, the predicted evolution of human affects the baseline projection. Using Germany as an example, the influence of education and policies in the revised trend employment equation can be illustrated with the help of a scenario in which a permanent policy package is assumed to be implemented, as of 2020, with the magnitudes of the policy changes matching those of typically-observed reforms as estimated by Égert and Gal (2017a):

- Public spending on active labour market policies per unemployed person goes up by 3.18 percentage points of GDP per capita.
- Product market reforms lower the ETCR index by 0.31 points.
- Union bargaining excess coverage declines by 1.89 percentage points of the workforce.
- The minimum wage falls by 2.48 percentage points of the median wage (not necessarily via a fall in the legal minimum but maybe through increases in other wages).
- Public spending on family benefits in kind increase by 0.11 percentage point of GDP and maternity leave is extended by 4.83 weeks.
- The legal pension age is raised by 0.57 years over the 2020-to-2025 period.
- The tax wedges for singles declines by 1.39 percentage points of labour costs and that of couples by 2.28 percentage points.
- The unemployment benefits replacement rate is cut by 1.42 percentage points.

In addition, average educational attainment in Germany is projected to increase by 2.4 years of schooling between 2020 and 2060. The simulation is not meant to be realistic, but only illustrative. Germany and the year 2020 are chosen because the initial projection without policy or education effects is for potential employment in Germany to start declining in 2021 (Figure 27, Panel A).

Figure 27. Impacts of example policy package on projections for Germany



Note: The projection with the education effect only is not shown for the 60-64 age group because there is no estimated education effect for elderly age groups (see Table 2). It is also not shown for the aggregates in Panels A and B because it has only a very small effect at the aggregate level given opposing effects for youth and prime-age workers (see main text).

66. Rising educational attainment by itself is projected to depress youth employment rates (illustrated with women aged 15 to 19 in Panel C), but the positive effects the policy package on the year-to-year change in the employment rate overcome the negative impact of rising educational attainment for a few years and raise youth employment rates significantly above the no-policy scenario. The biggest policy impacts are on prime-age women (illustrated with the 30-to-34 age group in Panel D). Their employment rates rise steeply in the first five years or so after the policy reforms. Thereafter, the shallower uptrend in the employment rate is due to rising educational attainment. Because several reforms, including those

pertaining to family benefits and maternity leave, do not affect prime-age men, their employment rates rise less than those of prime-age women (illustrated with the 30-to-34 age group in Panel E). Finally, while elderly employment rates are not affected by rising educational attainment, they are nevertheless positively impacted by policy reforms (illustrated with women aged 60 to 64 in Panel F). In aggregate, the trend employment rate rises significantly above the initial projection, by some 2 percentage points once policy effects are fully phased in (Panel B). Although potential employment is still expected to start declining soon given the exogenous population projections, the policy package is enough to delay the turnaround by two years and raise long-run trend employment by about one million workers (Panel A). The full long-term effects of the different policy reforms are shown in Table 4.

Table 4. Long-run effects of illustrative policy reform package on German employment rates

Percentage point change in age/sex-specific and total employment rates

	Size of reform[1]	Youth (15-24)	Prime-age women	Prime-age men	Elderly (55+)	Aggregate[2]
UE benefit replacement rate (in pp)	-1.42	0.260	0.290	0.209	0.487	0.306
ALMP spending (pp of GDP per capita)	3.18	0.467	0.293	0.149	0.200	0.234
Tax wedge single (pp of labour costs)	-1.39	1.204				0.109
Tax wedge couple (pp of labour costs)	-2.28			0.625	0.593	0.365
Excess coverage (pp of workforce)	-1.89		0.323			0.100
Minimum wage (pp of median wage)	-2.48	0.771	1.044			0.391
Family benefits in kind (pp of GDP)	0.11		0.517			0.159
Number of weeks of maternity leave	4.83		1.280			0.394
Legal age for pensions	0.57				0.485	0.119
ETCR (index, higher is more restrictive)	-0.31		0.236	0.236		0.156
Total	-	2.702	3.982	1.219	1.765	2.334

1. The magnitudes are those of typically observed reforms as estimated by Égert and Gal (2017a).

2. The reform-specific effects on the aggregate employment rate are calculated using fixed age/sex shares in potential employment (those of 2020). Consequently, the total (bottom right cell) does not correspond exactly to the total effect illustrated in Figure 27, Panel B, which is based on variable (projected) employment shares.

Source: Égert and Gal (2017a) and authors' calculations.

6.4. Can labour market reforms help offset demographic pressures on living standards?

67. The above finding that a package of labour market policy reforms could raise the aggregate participation rate substantially in a country like Germany suggests that such reforms could help offset a good part of the pressure that demographics will put on living standards across much of the world in the coming years. Already in the current decade, the evolution of the employment rate is contributing negatively to potential growth per capita in the United States and China (Figure 28). By next decade, assuming no policy change, this contribution is predicted to be negative in all the main areas, with the most significant change relative to this decade most important for the euro area, largely on account of Germany.

68. Indeed, in a scenario where it is implemented in all countries, the policy package described in the previous subsection would offset between 0.2 and 0.3 points of the negative employment contribution predicted for the next decade (Figure 29). This would be sufficient to make the employment contribution slightly positive in Japan and the non-OECD G20 (although not in China), and offset almost entirely the negative contribution predicted for the OECD area. Policy reforms would have to continue in later decades to offset post-2030 demographic headwinds. At the same time, the policy package could be even more ambitious. One area where it could be more ambitious is retirement age, given that it was only assumed to increase by 0.57 years in the previous scenario.

Figure 28. Average annual employment contribution to growth in potential output per capita (% pts), no policy change scenario

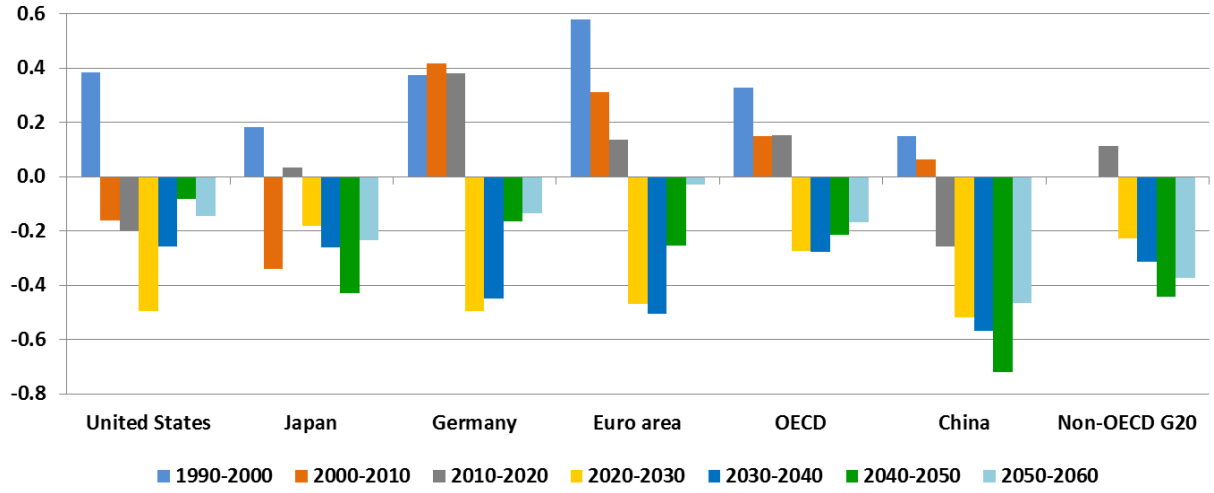
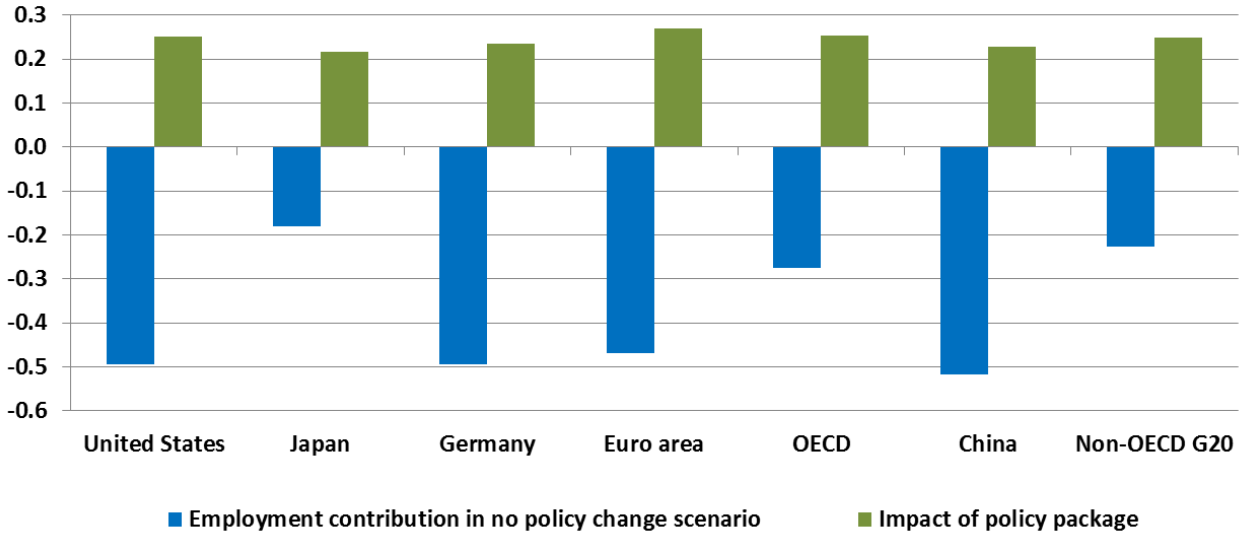


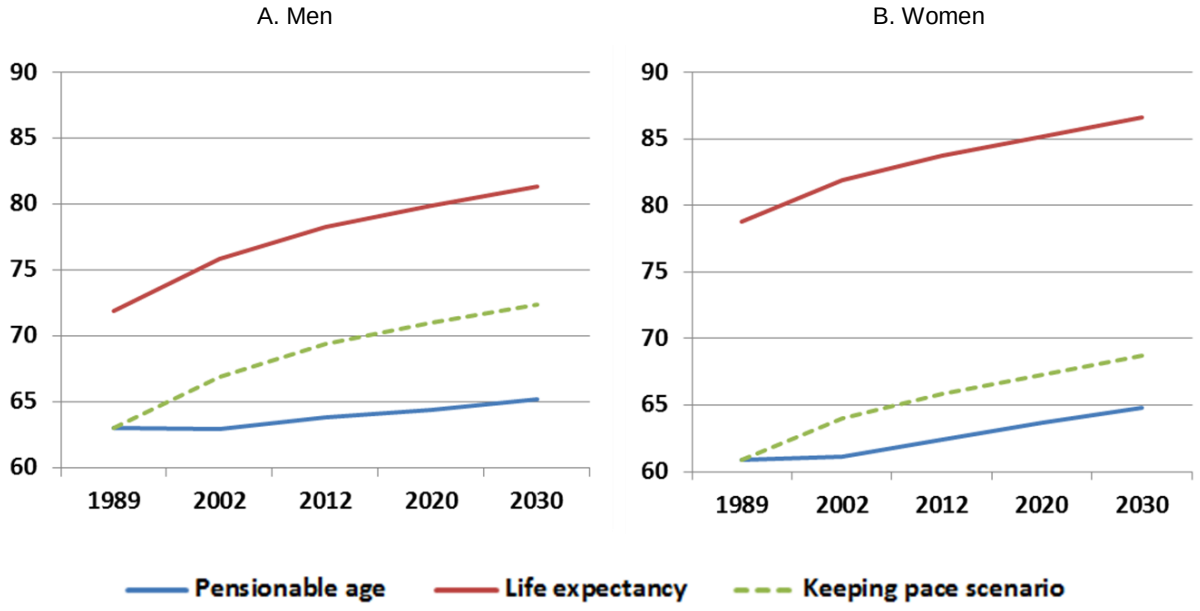
Figure 29. Employment contribution to GDP per capita growth and impact of illustrative policy package for 2020-to-2030 period (% pts)



6.5. Offsetting demographic headwinds by raising the retirement age?

69. On average in the OECD area, the legal pensionable age has not been keeping pace with increases in life expectancy (Figure 30). In the case of men for instance, it would be about 7 years higher had it increased at the same rate as life expectancy since 1989. There are both pros and cons to raising the retirement age. While it would help in many countries to ensure the sustainability of public pension systems, work is generally considered less desirable than leisure, so there are also welfare benefits to a longer retirement period. From the perspective of society a whole, one benefit of delaying retirement is that it would help reduce the downward pressure on material living standards brought on by demographic change. Longer working lives would attenuate increases in old-age dependency ratios that are expected nearly everywhere in the coming decades.

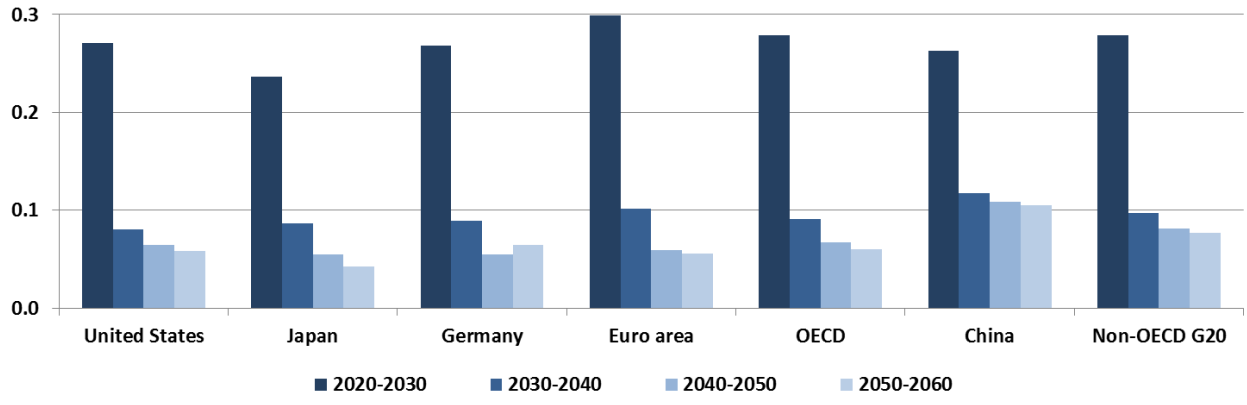
Figure 30. Average OECD pensionable age and life expectancy



Source: OECD (2014a) for pensionable ages, United Nations Population Prospects for life expectancy and authors' calculations.

70. In a scenario where the legal pensionable age increases in line with predicted improvements in life expectancy in the United Nations medium scenario, the employment rate contribution to per capita potential GDP growth is between 0.2 and 0.3 percentage points higher in the next decade than in a scenario with no further change in retirement ages (Figure 31). The magnitudes are similar to those obtained with the illustrative policy package in subsection 6.4, which included a much smaller increase in the legal retirement age over only five years. Therefore, combining the illustrative policy package with a policy of raising the legal retirement age one-for-one with life expectancy could more than completely offset the predicted negative employment contribution to living standards in the decade 2020-to-2030. Reforms to the retirement age could not do as much in subsequent decades, however, at least given currently-predicted increases in life expectancy.

Figure 31. Change in employment contribution to per capita potential GDP growth if legal pensionable age increases in line with life expectancy relative to no-change scenario (% pts)



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