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Saving, investment, capital  
stock and current account  
projections in long-term  
scenarios

**Yvan Guillemette,  
Andrea De Mauro,  
David Turner**

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**SAVING, INVESTMENT, CAPITAL STOCK AND CURRENT ACCOUNT  
PROJECTIONS IN LONG-TERM SCENARIOS**

**ECONOMICS DEPARTMENT WORKING PAPERS No. 1461**

**By Yvan Guillemette, Andrea de Mauro and David Turner**

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## *Table of contents*

<b>SAVING, INVESTMENT, CAPITAL STOCK AND CURRENT ACCOUNT PROJECTIONS IN LONG-TERM SCENARIOS .....</b>	<b>6</b>
1. Introduction and summary .....	6
2. Aggregate saving rate .....	7
2.1. Saving determinants and data sources .....	8
2.2. Empirical model and results .....	12
2.3. Implementation in the long-term model and illustrative projections .....	18
3. Capital stock and investment .....	21
3.1. Framework .....	21
3.2. Government sector capital stock and investment .....	22
3.3. Business sector capital stock and investment .....	23
3.4. Total capital stock .....	36
3.5. Housing investment .....	37
3.6. Total investment .....	37
4. Current account balance .....	38
4.1. Current account balance and net investment position for individual countries in the model ..	38
4.2. Current account balance for the rest of the world .....	39
4.3. Global current account balance and equilibrating mechanism .....	40
<b>References .....</b>	<b>42</b>
<b>Annex A. Descriptive statistics for saving rate equation .....</b>	<b>45</b>
<b>Annex B. Robustness tests .....</b>	<b>60</b>
<b>Annex C. Oil and shipping sectors investment in Norway .....</b>	<b>61</b>
<b>Annex D. Summary of section 3 .....</b>	<b>62</b>

### Tables

Table 1. Regression results for general specifications .....	13
Table 2. Regressions results for more parsimonious specifications .....	14
Table 3. Estimation results for capital stock equation in [16] .....	26
Table 4. Model calibration (unless otherwise stated in the figures) .....	32

## Figures

Figure 1. National saving rates, % of GDP.....	8
Figure 2. Old-age dependency rates, % .....	9
Figure 3. Oil trade balance, % of GDP .....	10
Figure 4. Relative influence of aggregate saving determinants .....	18
Figure 5. Projected changes in aggregate saving rates between 2020 and 2060.....	20
Figure 6. Steady-state ratios of government sector capital stock to potential output in 2018.....	23
Figure 7. The Chinn-Ito index of capital account openness, 2014.....	25
Figure 8. Impact of a one percentage point fall in the domestic saving rate.....	33
Figure 9. Impact of a one percentage point increase in trend labour efficiency/employment growth ...	34
Figure 10. Impact of a 0.3 point fall in the ETCR or EPL indices.....	34
Figure 11. Impact of a one percentage point cut in the statutory corporate income tax rate .....	35
Figure 12. Impact of a one percentage point fall in domestic and global corporate borrowing rates ....	35
Figure 13. Impact of a temporary (5 year) 1% negative output gap .....	36

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**ABSTRACT/RÉSUMÉ****Saving, investment, capital stock and current account projections in long-term scenarios**

The paper describes the framework used in long-term economic scenarios for the projection of the saving rate, investment, capital stock and current account. The saving rate is determined according to an estimated equation which suggests that demographics, captured by the old-age dependency rate and life expectancy, is a major driver, with additional effects from the fiscal balance, labour productivity growth, the net oil trade balance, the availability of credit and the level of social protection. The evolution of the business sector capital stock depends on the economy's cyclical position, product market regulation, employment protection legislation and the user cost of capital, and may be constrained by current account deficits depending on the degree of capital account openness. Business sector investment is derived from the capital stock projection via the usual stock-flow identity. The public sector capital stock-to-output ratio is assumed to be constant in the baseline scenario, but a public investment shock can be simulated in alternative scenarios. The current account balance is obtained as the difference between national investment and saving, and in turn determines the evolution of the net international investment position. A global interest rate premium helps to bring global saving and investment into balance.

*JEL classification:* E21, E22, E27, F37

*Keywords:* Saving rate, capital stock, investment, current account, projection, long-term model, long-term scenarios

\*\*\*\*\*

**Projections d'épargne, d'investissement, du stock de capital et des comptes courants dans les scénarios à long terme**

L'étude décrit le cadre utilisé dans les scénarios économiques à long terme pour la projection du taux d'épargne, de l'investissement, du stock de capital et du compte courant. Le taux d'épargne est obtenu à partir d'une équation estimée qui suggère que la démographie, capturée par le taux de dépendance des personnes âgées et l'espérance de vie, est un facteur important, avec des effets additionnels venant du solde fiscal, de la croissance de la productivité du travail, de la balance commerciale en produits pétroliers, de la disponibilité du crédit et du niveau de protection sociale. L'évolution du stock de capital dans le secteur des affaires dépend de la position de l'économie dans le cycle, de la réglementation des marchés des produits et de l'emploi, du coût du capital, et peut être contraint par le degré d'ouverture aux capitaux étrangers. L'investissement dans le secteur des affaires est dérivée de la projection du stock de capital via l'identité stock-flux usuelle. Le ratio stock de capital du secteur publique sur la production est gardé constant dans le scénario de base, mais un choc d'investissement public peut être simulé dans des scénarios alternatifs. Le solde au compte courant est obtenu par différence entre épargne et investissement nationaux, et détermine à son tour l'évolution du bilan des investissements internationaux. Une prime globale sur les taux d'intérêts aide à équilibrer l'épargne et l'investissement au niveau mondial.

*Classification JEL:* E21, E22, E27, F37

*Mots clefs :* Taux d'épargne, stock de capital, investissement, compte courant, projection, modèle long terme, scénarios à long terme

## SAVING, INVESTMENT, CAPITAL STOCK AND CURRENT ACCOUNT PROJECTIONS IN LONG-TERM SCENARIOS

by Yvan Guillemette, Andrea de Mauro and David Turner<sup>1</sup>

### 1. Introduction and summary

1. This paper is the last of the three main modules describing methodological revisions to the model underlying OECD long-term scenarios and deals with the projection of the productive capital stock.<sup>2</sup> Given that investment projections are derived from the capital stock and that ensuring some form of consistency between saving and investment is an important consideration in the context of long-run growth projections, the paper also presents revisions to the aggregate saving rate equation. Considering the determination of both saving and investment together also facilitates the discussion of feedback mechanisms which limit the build-up of imbalances between the two in the long-run projections. As with other modules describing revisions to the model, a major concern has been to increase the number of policy channels which can influence the projections.

2. The main features of the revised saving and investment framework described herein are the following:

- Unlike the previous vintage of the model, which differentiated how the aggregate saving rate was computed depending on the country (on roughly an OECD/non-OECD split), the new framework uses a common equation specification for all countries.
- Reflecting lengthening working lives, the new aggregate saving rate equation defines the old-age dependency ratio using the 75+ age threshold as opposed to the 65+ one. In addition, the effect of life expectancy on the aggregate saving rate is now estimated jointly with other saving determinants as opposed to being calibrated from results in another study, and is much larger than in the previous version of the equation.
- Preliminary simulations to 2060 show that in most countries, rising life expectancy offsets most, but not all, of the negative pressure on aggregate saving

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<sup>1</sup> Yvan Guillemette and David Turner are members of the OECD Economics Department's Macroeconomic Analysis Division. Andrea De Mauro was formerly consultant for the division and is now PhD candidate at Oxford University's Economics Department. They would like to thank Jean Chateau, Olivier Durand-Lasserve and Catherine Mann for comments on previous drafts; and Veronica Humi for editorial support.

<sup>2</sup> Each of these three modules corresponds to one of the three inputs in the Cobb-Douglas production function sitting at the core of the framework. The first module of the revisions described how the trend labour efficiency projection equation was re-specified and re-estimated to include more policy and structural determinants (Guillemette et al., 2017<sub>[26]</sub>). The second module described revisions to the cohort-based model used to project trend employment, which now also includes more policy influences (Cavalleri and Guillemette, 2017<sub>[38]</sub>). The present paper takes up the task of projecting the third and final component, namely the capital stock.

rates coming from rising old-age dependency, leaving only a modest projected decline in saving rates. However, the combined demographic effect is more negative in countries where population ageing is expected to be very sharp, such as Korea, and can even be positive in countries where life expectancy is projected to increase rapidly, such as South Africa.

- As was the case in the previous version of the equation, the importance of private credit in the economy and the level of social protection are found to affect the aggregate saving rate negatively. Conversely, the oil trade balance and labour productivity growth are positively associated with savings. The new estimations also support the assumption of a 40% Ricardian-equivalence offset from private saving to changes in public saving.
- The future evolution of the capital-stock-to-output ratio is now based on a partially estimated equation that includes a cyclical effect and follows the convention that the capital-to-output ratio should be stable in the steady state. This last feature helps to keep the contribution of capital accumulation to growth relatively modest in the baseline scenario, respecting a stylised fact of growth decomposition exercises.
- The main novelty of the new capital stock projection equation is to allow current account deficits to constrain capital accumulation, and therefore investment, according to the degree of capital account openness. As estimated empirically, this effect is small in countries with highly open capital accounts, but much larger in countries that are mostly closed to foreign capital. This feedback mechanism helps to moderate the build-up of imbalances over time, alongside two other such mechanisms that kick in when a country has a negative net international investment positions (NIIP). The first is an interest rate risk premium that lowers investment via the user cost of capital. The second is a wealth effect that pushes up the saving rate when a negative NIIP position builds up.
- The new capital stock equation includes influences from product market regulation and employment protection legislation based on estimated coefficients from the Quantification of Structural Reforms Workstream (Égert, 2017<sup>[11]</sup>). The statutory corporate tax rate also now enters the specification of the user cost of capital and so represents a further additional policy transmission mechanism.
- The total productive capital stock is now notionally split between private and public sector capital stocks, allowing public investment shocks to be simulated.

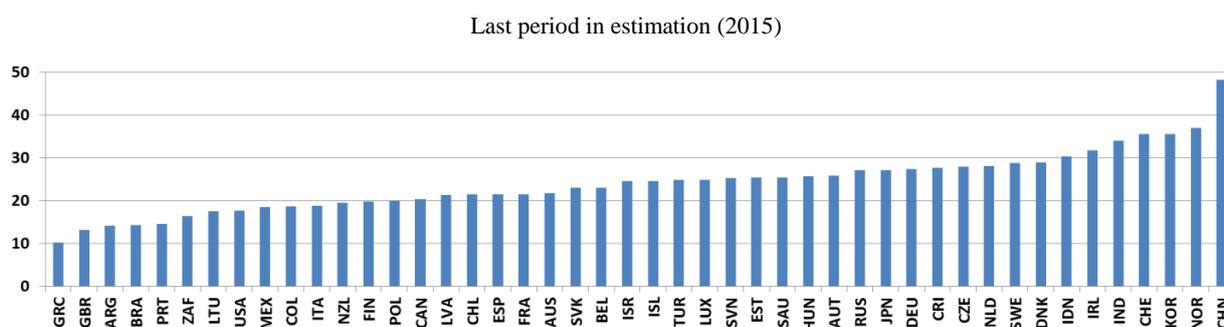
3. The paper is structured as follows: section 2 presents the re-estimation of the aggregate saving rate equation; section 3 details the specification and partial estimation of the new capital stock equation and explains how investment is derived; and section 4 explains the determination of the current account for countries in the model, for oil-producing countries not individually in the model, and for the world as a whole, as well as the mechanism used to ensure global saving/investment balance.

## 2. Aggregate saving rate

4. This section details the estimation work behind the revised aggregate saving rate equation. The 2013 vintage of the long-term model used different saving rate equations depending on whether the country had a detailed fiscal block or not (Johansson A. et al., 2013<sup>[2]</sup>). Countries with a fiscal block (most OECD countries) used an estimated equation for the private saving rate, and total savings was calculated by adding up private and public savings. Countries without a fiscal block (non-OECD and a few OECD countries)

used only an estimated total saving rate equation. The current revision uses an aggregate saving rate equation that is common to all countries, except that the government saving rate enters as an explanatory variable for countries with a fiscal block.<sup>3</sup> Across the countries included in the model, the aggregate national saving rate ranged from about 10% of GDP in Greece to nearly 50% of GDP in China in 2015 (Figures 1 and AA.1).

**Figure 1. National saving rates, % of GDP**



Source: OECD Economic Outlook No. 100 database.

5. The first subsection describes the dataset used in the estimation work and the rationale behind the selection of variables for the model. The following subsection presents the estimation framework and results, starting from a general specification incorporating as many potential saving determinants as possible, before progressively reaching a pared-down equation through standard model selection techniques. A final subsection explains how the equation is implemented in the model and illustrates its workings with some preliminary projections.

### 2.1. Saving determinants and data sources

6. Several different theories have been proposed to account for consumption and saving behaviour, but they sometimes yield ambiguous or conflicting predictions for the influence of various factors on saving rates. More recent theoretical developments, adding uncertainty, human capital, borrowing constraints, risk aversion and other considerations to the conventional frameworks, layer on yet more complexity to theory-based predictions. At the same time, a great deal of empirical work exists on the determinants of saving rates, informing researchers as to which of the theoretical predictions appear to dominate in practice. Drawing on theory and previous empirical studies to assess both overall importance and likely direction of influence, while keeping to indicators that are available for a large number of countries, the following variables are investigated as potential determinants of the aggregate saving rate:

- a. *Old-age dependency rate.* The idea that the age structure of the population should influence the saving rate is mainly related to the life-cycle hypothesis (Modigliani, 1966<sub>[3]</sub>). If, as this theory predicts, individuals tend to borrow early in life, accumulate wealth mostly in middle age, and draw down wealth in

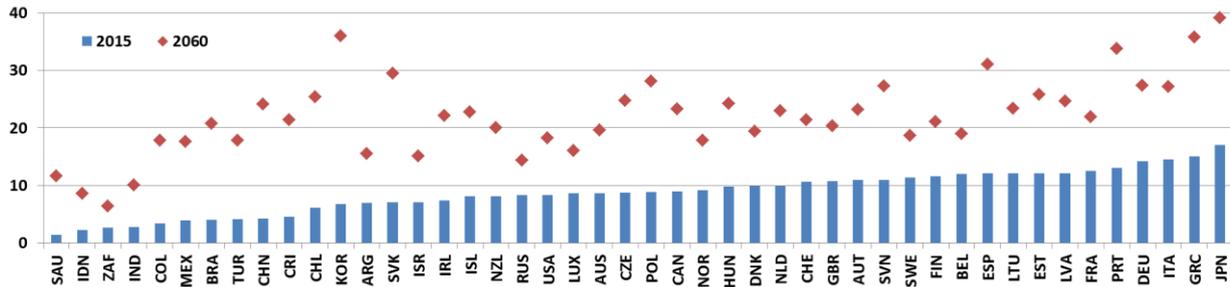
<sup>3</sup> Specifically, in the current version of the long-term model, 13 of the 46 countries do not have a fiscal block (Argentina, Brazil, China, Colombia, Costa Rica, Chile, India, Indonesia, Mexico, Russia, Saudi Arabia, Turkey and South Africa).

retirement, then the individual saving rate should follow an inverted U-shaped pattern (Jappelli and Modigliani, 2003<sup>[4]</sup>). By extension, the aggregate private saving rate should be lower for relatively older populations, and likewise for the total saving rate, unless offset by a higher public saving rate (Curtis, Lugauer and Mark, 2015<sup>[5]</sup>). To take into account the demographic structure of the population, the old-age dependency rate for country  $i$  in year  $t$  ( $DROLD_{i,t}$ ) is defined as the population aged 75 and above as a percentage of the population aged 15 to 74:

$$DROLD_{i,t} = \frac{(\text{population aged 75 or over})_{i,t}}{(\text{population aged 15 to 74})_{i,t}} * 100 \quad [1]$$

This definition is a change from the 2013 vintage of the long-term model, and from most similar studies, which typically use an old-age cut-off of 65 years (Poterba, 2004<sup>[6]</sup>; Loayza, Schmidt-Hebbel and Servén, 2000<sup>[7]</sup>; Mirer, 1979<sup>[8]</sup>; Leff, 1969<sup>[9]</sup>). The change reflects the increasing tendency for older people to work longer, a trend that may well continue in the future and is thus important for long-term scenarios. Japan and European countries have the highest old-age dependency rates, while large EMEs typically have lower rates (Figures 2 and AA.2).

Figure 2. Old-age dependency rates, %



Source: Eurostat for European countries and United Nations' World Population Prospects database for other countries.

- b. *Life expectancy.* Keeping with the life-cycle hypothesis, expectations about life expectancy should play an important role in private saving behaviour. The expected length of retirement, which varies both with the expected retirement age and with the expected age of death, is the variable that should matter. Ideally, such a variable could be constructed using data on effective retirement age and life expectancy. Unfortunately, such a variable can be constructed for only a limited set of countries, and attempts to use it in the regression analysis were not fruitful. Nevertheless, life expectancy captures an important dimension of expected retirement length and is expected to enter the equation with a positive sign (Bloom, Canning and Graham, 2003<sup>[10]</sup>) (Figure AA.5).
- c. *Urbanisation.* The effect of urbanisation on saving behaviour is mixed both in theory and in the empirical literature (Schmidt-Hebbel, Webb and Corsetti, 1992<sup>[11]</sup>; Loayza, Schmidt-Hebbel and Servén, 2000<sup>[7]</sup>). On the one hand, lower rates of urbanisation could be associated with higher saving rates because of more volatile incomes (e.g. farming) and less insurance possibilities in rural areas. China's low rate of urbanisation (though now rising) has been cited as a reason

behind its very high historical saving rate (Ma and Yi, 2010<sub>[12]</sub>). On the other hand, less urbanised countries tend to be poorer, which might lead to lower saving rates. So the ultimate effect of the urbanisation rate is ambiguous and would depend on what other variables (e.g. income) are included in the regression (Figure AA.14).

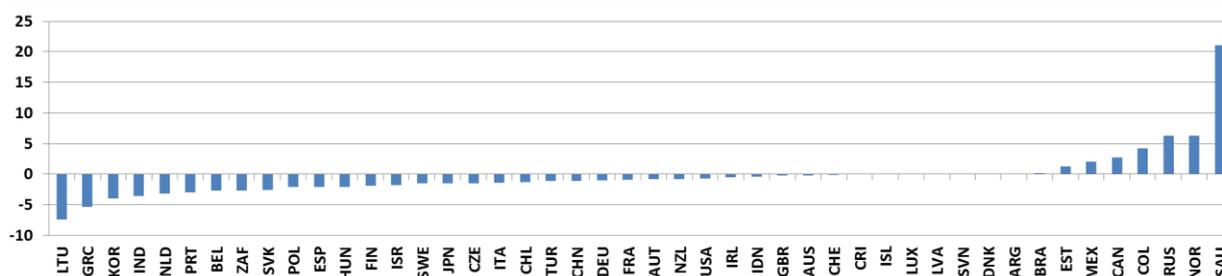
- d. *Financial environment.* Financial conditions influence savings through quantity and price mechanisms. As regards quantity, domestic credit as a percentage of GDP is used to capture credit availability, which would tend to lessen the need for precautionary saving and is thus expected to correlate negatively with saving rates (Loayza, Schmidt-Hebbel and Servén, 2000<sub>[7]</sub>) (Figure AA.3). As regards price, the real interest rate is included in the general specification and is expected to enter with a positive sign as it measures the reward to saving (Figure AA.11).
- e. *Oil trade balance.* Countries with significant oil revenues, such as Norway and Saudi Arabia, are known to save a significant portion of these revenues given their non-renewable nature, which would tend to boost the national saving rate compared to other countries. In addition, as regards the time dimension, unexpected fluctuations in the oil price would tend to affect saving rates as windfalls might be saved in times of high prices and savings spent in times of low prices (Van der Ploeg and Venables, 2011<sub>[13]</sub>). A measure of the oil trade balance ( $OILBALQ_{i,t}$ ) is thus constructed and used as an explanatory variable (Figures 3 and AA.4). It is defined as the difference between the value of exports and imports of crude oil as a percentage of GDP:

$$OILBALQ_{i,t} = \frac{(CRUDEEXP_{i,t} - CRUDEIMP_{i,t}) * \frac{WPBRENT_t}{EXCH_{i,t}}}{GDP_{i,t}} * 100 \quad [2]$$

where  $CRUDEEXP_{i,t}$  and  $CRUDEIMP_{i,t}$  are annualised crude oil export and import volumes in barrels;  $WPBRENT_t$  is the benchmark price of one barrel of oil in US dollars;  $EXCH_{i,t}$  is the US dollar to local currency exchange rate; and  $GDP_{i,t}$  is gross domestic product at current prices. This variable is expected to enter the equation with a positive sign. Future extensions of the model could consider also other natural resources, especially minerals, which are important for some countries.

**Figure 3. Oil trade balance, % of GDP**

Last period used in estimation (2015).



Source: International Energy Agency's Oil information database, OECD Economic Outlook No. 100 database and authors' calculations.

- f. *Social protection.* The level of public social protection spending should be negatively associated with saving rates because greater social protection reduces the need for precautionary savings by individuals (Feldstein, 1985<sub>[14]</sub>). In addition, individuals benefitting the most from social protection (low- and middle-income households) typically exhibit a higher marginal propensity to consume, so the positive wealth effect associated with social insurance would tend to lower the national saving rate. Unfortunately, comparable social protection expenditure data are limited in both time and country dimensions, so government primary expenditure as a percentage of GDP is used as a proxy instead (Figure AA.6).
- g. *Public saving rate.* A change in the government saving rate should directly affect the national saving rate, of which it is part, although less than one-for-one according to the theory of Ricardian equivalence (Ricardo, 1888<sub>[15]</sub>). Previous OECD work has found that movements in the private saving rate indeed tend to offset about 40% of the variation in the public saving rate (Röhn, 2010<sub>[16]</sub>). The government fiscal balance as a percentage of GDP (a close proxy for the public saving rate, Figure AA.8) is therefore expected to enter the aggregate saving equation with a positive sign and a magnitude of about 0.6.
- h. *International investment position.* Through wealth effects, a country's net stock of financial claims vis-à-vis the rest of the world is expected to correlate positively with consumption, and therefore negatively with the national saving rate (Figure AA.10). Such an effect would build in a feedback mechanism via which sustained saving-investment imbalances, implying large current account deficits (or surpluses) and a deteriorating (improving) international investment position, would partially self-correct over the long term.
- i. *Income inequality.* The expected impact of income inequality on saving rates is ambiguous, but generally expected to be positive as people at the top of the income distribution tend to save more. Some have also suggested the possibility of a threshold effect whereby inequality only has a significant (positive) impact above a certain level (Bofinger and Scheuermeyer, 2016<sub>[17]</sub>). Income inequality is investigated through the inclusion of the Gini coefficient (Figure AA.9).
- j. *Other controls.* A number of other standard variables are also included, namely terms of trade (Figure AA.12), GDP per capita at purchasing power parity (Figure AA.13), as well as the growth rate of labour productivity (Figure AA.7). The first two are expected to enter the equation with a positive sign. The effect of labour productivity growth is more ambiguous because rising productivity signals more lifetime income, entailing both substitution and income effects.

7. To maximise country and time coverage, the data are extracted from a variety of sources, including the IMF's World Economic Outlook and Balance of Payments Statistics databases, the World Bank's World Development Indicators database, and the United Nations' World Population Prospects database (see Annex A). The initial dataset includes 142 countries and covers the 1960-to-2016 period, but with varying time and country coverage across variables. Subsequent adjustments to eliminate outliers reduce the number of observations by 1.9% (see Table AA.1 for details on final country coverage). This concerns in particular labour productivity growth and net international investment positions, for which, respectively, 4.1% and 5.4% of observations are dropped. In addition, the Gini coefficients are backcasted linearly to extend their time coverage.

The final sample extends from 1980 to 2015 for a maximum of 110 countries, although the estimation samples can be shorter and narrower given patchy coverage for some variables. This is many more countries than are included in the long-term model itself but as large a sample as possible is preferred to maximise degrees of freedom.

## 2.2. Empirical model and results

### 2.2.1. Empirical framework

8. The aggregate national saving rate as a percentage of GDP for country  $i$  at time  $t$  ( $s_{i,t}$ ) is assumed to depend linearly on its own lag, on the determinants discussed above, and on time ( $\gamma_t$ ) and country ( $\theta_i$ ) fixed effects following:

$$s_{i,t} = \alpha s_{i,t-1} + \mathbf{X}_{i,t} \boldsymbol{\beta} + \gamma_t + \theta_i + \varepsilon_{i,t} \quad [3]$$

where  $\mathbf{X}_{i,t}$  is a vector of explanatory variables,  $\boldsymbol{\beta}$  a vector of coefficients and  $\varepsilon_{i,t}$  is the error term. This equation is estimated using Ordinary Least Squares (OLS). The long-term effects of the explanatory variables ( $\boldsymbol{\beta}^*$ ) are obtained after estimation by looking at the steady-state version of [3]:

$$s_i^* = \mathbf{X}_i^* \boldsymbol{\beta}^* + \frac{\gamma^*}{1 - \alpha} + \frac{\theta_i}{1 - \alpha} \quad [4]$$

where  $\mathbf{X}_i^*$  is the vector of steady-state values for the explanatory variables, and  $\boldsymbol{\beta}^* = (1 - \alpha)^{-1} \boldsymbol{\beta}$ .

### 2.2.2. Estimation results

9. The most general model is estimated on the full set of countries (Table 1, column 1) and, for comparability purposes with previous OECD studies, on the smaller set of OECD countries (column 2). Most variables are statistically significant and have the expected signs. One notable exception is the real interest rate, which has a negative sign, but this counterintuitive finding is common in the literature (Loayza, Schmidt-Hebbel and Servén, 2000<sub>[7]</sub>). The terms of trade, the urbanisation rate and GDP per capita are not statistically significant. For the other variables, coefficients on the restricted sample are close to their full-sample counterparts, a sign of robustness. The goodness-of-fit, as represented by the *R-squared*, is high, but this is common for specifications with a lagged dependent variable and a full set of fixed effects.<sup>4</sup>

<sup>4</sup> Dynamic panel regressions with fixed effects may produce biased results when the time dimension of the panel ( $T$ ) is small relative to the number of cross sections ( $N$ ), as is the case here (Nickell, 1981<sub>[35]</sub>). However, the coefficients on the lagged dependent variable is around 0.7 in the regressions using the OECD sample, similar to that found by Kerdrain, Koske and Wanner (2010<sub>[21]</sub>) in regressions with a larger  $T$  and a smaller  $N$ . Therefore, dynamic bias does not seem to be a significant issue.

**Table 1. Regression results for general specifications**

Dependent variable: Aggregate saving rate, % of GDP

	(1)	(2)	(3)	(4)
	All countries	OECD countries	All countries	All countries
Lagged Aggregate Saving Rate, % of GDP	0.651*** (0.046)	0.703*** (0.049)	0.662*** (0.043)	0.678*** (0.037)
Old-Age Dependency Rate, %	-0.434** (0.220)	-0.215* (0.158)	-0.388* (0.224)	-0.347*** (0.146)
Private Credit, % of GDP	-0.018** (0.009)	-0.007* (0.005)	-0.016** (0.008)	-0.017*** (0.006)
Oil Trade Balance, % of GDP	0.224*** (0.093)	0.283** (0.139)	0.230*** (0.094)	0.266*** (0.066)
Life Expectancy, years	0.460*** (0.169)	0.509** (0.235)	0.456*** (0.169)	0.506*** (0.155)
Government Primary Expenditure, % of GDP	-0.238*** (0.050)	-0.084*** (0.036)	-0.237*** (0.050)	-0.251*** (0.041)
Labour Productivity Growth, %	0.077* (0.043)	0.068* (0.045)	0.076* (0.044)	0.099*** (0.037)
Income Inequality (Gini Coefficient)	0.025*** (0.010)	0.009* (0.007)	0.026*** (0.011)	0.013* (0.009)
Net International Investment Position, % of GDP	-0.012* (0.009)	0.008 (0.009)	-0.011* (0.009)	
Real Interest Rate, %	-0.062** (0.029)	-0.081* (0.048)	-0.062** (0.030)	
Log Terms of Trade	0.096 (0.210)	0.151 (0.141)		
Log GDP per Capita	-0.178 (0.266)	1.019 (1.322)		
Urbanisation Rate, %	-0.036 (0.086)	0.027 (0.045)		
R-squared	0.889	0.941	0.888	0.893
Number of observations	1344	541	1344	1816
Number of countries	95	31	95	110

*Note:* Asterisks (\*, \*\*, \*\*\*) indicate the statistical significance level (10%, 5%, 1%) of the coefficients. Figures in parentheses are heteroscedasticity-consistent standard errors. All equations are estimated with OLS and include country and period fixed effects. Columns 1, 3, and 4 use a maximum number of countries, while column 2 restricts the sample to OECD countries. See Table AA.1 in Annex A for data sources.

10. Next, the variables with unsatisfactory coefficients are eliminated, namely GDP per capita, terms of trade and the urbanisation rate (column 3). The real interest rate effect remains negative. The net international investment position has the correct sign but is only weakly statistically significant and the effect is not robust to restricting the sample to OECD countries (in column 2). So both the real interest rate and the net international investment position are dropped (column 4).

11. As in the case of the net international investment position, although income inequality has the expected sign and is statistically significant, its long-run coefficient is too small to be economically meaningful. A 10-point rise in the Gini coefficient – a large

increase – would raise national savings by between 0.3 and 0.8 percentage points of GDP in the long term, depending on which of equations 1 to 4 is used. Furthermore, the literature remains split as to the expected sign of the coefficient (Schmidt-Hebbel and Servén, 2000<sub>[18]</sub>), with some finding evidence of a hump-shaped relationship between inequality and savings in OECD countries (Bofinger and Scheuermeyer, 2016<sub>[17]</sub>). Further estimations (not shown) did not corroborate this hypothesis, however. Income inequality is therefore excluded from the preferred specification.

12. The preferred specification appears in column 1 of Table 2. It includes a one-year lag of the dependent variable and the six explanatory variables retained from the general-to-specific procedure just described, all of which are highly statistically significant, economically meaningful and have signs matching the expectations outlined above, which in turn were based on past literature and economic intuition. For further comparability with past results, the preferred equation is also estimated using an OECD-only sample (column 2). As previously suggested, the coefficients are robust to changes in country coverage.

**Table 2. Regressions results for more parsimonious specifications**

Dependent variable: Aggregate saving rate, % of GDP

	(1)	(2)	(3)
	All countries	OECD countries	All countries
Lagged Aggregate Saving Rate, % of GDP	0.680*** (0.037)	0.726*** (0.050)	0.662*** (0.042)
Old-Age Dependency Rate, %	-0.353*** (0.151)	-0.316** (0.139)	-0.372*** (0.164)
Private Credit, % of GDP	-0.017*** (0.006)	-0.009* (0.007)	-0.019*** (0.006)
Oil Trade Balance, % of GDP	0.266*** (0.066)	0.383*** (0.119)	0.194*** (0.064)
Life Expectancy, years	0.511*** (0.154)	0.487*** (0.184)	0.511*** (0.160)
Government Primary Expenditure, % of GDP	-0.251*** (0.042)	-0.183*** (0.048)	-0.154*** (0.046)
Labour Productivity Growth, %	0.096*** (0.038)	0.176*** (0.074)	0.090*** (0.040)
Government Budget Balance, % of GDP			0.198*** (0.067)
R-squared	0.892	0.928	0.895
Number of observations	1816	746	1799
Number of countries	110	35	110

*Note:* Asterisks (\*, \*\*, \*\*\*) indicate the statistical significance level (10%, 5%, 1%) of the coefficients. Figures in parentheses are heteroscedasticity-consistent standard errors. All equations are estimated with OLS and include country and period fixed effects. Columns 1 and 3 use a maximum number of countries, while column 2 restricts the sample to OECD countries. See Table AA.1 in Annex A for data sources.

13. Using this preferred equation, the *long-term effects* of permanent changes in saving determinants are as follows:

- A one-percentage point increase in the old-age dependency rate lowers the aggregate saving rate by 1.1 percentage points of GDP. The effect is, in absolute value, in the upper tail of estimates from other studies, which range from 0.3 (Aizenman, Cheung and Ito, 2016<sub>[19]</sub>), 0.6 (Kageyama J., 2003<sub>[20]</sub>; Kerdrain, Koske and Wanner, 2010<sub>[21]</sub>), 0.7 (Loayza, Schmidt-Hebbel and Servén, 2000<sub>[7]</sub>), to 1.3 and 1.5 (Bloom, Canning and Graham, 2003<sub>[10]</sub>; Bloom et al., 2006<sub>[22]</sub>).<sup>5</sup> The previous versions of the aggregate saving rate equation incorporated the Kerdrain, Koske and Wanner (2010<sub>[21]</sub>) estimate. However, in the context of population ageing, this effect will be partly offset by the new life expectancy effect (see below).
- A one-percentage point of GDP increase in private credit lowers the aggregate saving rate by 0.05 percentage points of GDP, similar to the Kerdrain, Koske and Wanner (2010<sub>[21]</sub>) estimate of -0.04 used previously.
- A one-percentage point of GDP increase in the oil trade balance raises the aggregate saving rate by 0.83 percentage points of GDP. This effect is larger than previously estimated (0.3 in Kerdrain, Koske and Wanner (2010<sub>[21]</sub>)) and signifies that some 80% of a permanent change in the oil trade balance would flow through to the long-run saving rate.
- A one-year increase in life expectancy raises the aggregate saving rate by 1.6 percentage points of GDP. This coefficient is much larger than the 0.2 coefficient used previously in the model, which was based on the findings of Li, Zhang and Zhang (2006<sub>[23]</sub>). Other studies have typically found smaller effects as well. For instance, using an unbalanced quinquennial panel of 68 countries amounting to 410 observations, Bloom, Canning and Graham (2003<sub>[10]</sub>) find that a one-year increase in life expectancy raises the saving rate by 0.46 percentage points. Similarly, Bloom et al. (2006<sub>[22]</sub>) report long-term effects of 0.39 and 0.13 for, respectively, countries with universal pension coverage and the full sample of 57 countries.<sup>6</sup> The large size of the effect in the preferred equation above may appear surprising and the upward time trend in life expectancy raises the possibility of spurious correlation, but the inclusion of time dummies in all specifications largely discounts this possibility. Another possibility is that life expectancy stands in for an omitted factor, such as wealth, but when log GDP per capita is added (as in some of the specifications in Table 1) it is not statistically significant. In addition, the country dummies pick up any constant differences between countries that could be correlated with life expectancy. The large estimated effect appears robust across the different specifications in Tables 1 and 2 and may be due to the wider sample coverage of the present study. It is also supported by recent simulations of a calibrated model for the United States, which shows that increasing life expectancy can explain about 175 basis points of the decline in the equilibrium real interest rate in the United States (Carvalho, Ferrero and Nechio, 2017<sub>[24]</sub>). While this effect is not directly comparable to the one estimated here, it

<sup>5</sup> The coefficients from other studies (all statistically significant) were transformed from dynamic equations in the same fashion as described in equation [4].

<sup>6</sup> See also Li, Zhang and Zhang (2006<sub>[23]</sub>), Kinugasa and Mason (2007<sub>[36]</sub>) and Kageyama (2003<sub>[20]</sub>) for more results and different estimation methods.

is large and, as the authors explain, comes through because of the additional incentive to save that a longer life creates for a given retirement age.

- A one-percentage point of GDP increase in social protection expenditure (proxied by government primary spending) lowers the aggregate saving rate by 0.8 percentage points of GDP. The previous effect, based on Kerdrain, Koske and Wanner (2010<sub>[21]</sub>), was double the size at -1.9.
- A one-percentage point increase in labour productivity growth raises the aggregate saving rate by 0.3 percentage points of GDP, similar to the previous version of the equation based on Kerdrain, Koske and Wanner (2010<sub>[21]</sub>).

14. The main advantages of the new coefficient estimates over those used previously are that they incorporate information from a larger set of countries and are jointly estimated instead of being collated from different studies.

### 2.2.3. *Capturing partial Ricardian effects*

15. As explained previously, for countries in the long-term model that have a fiscal block, and for which a projection of the government fiscal balance is available, an extra term is added to the simulation equation to take the impact of changes in government saving on national saving into account, following the Ricardian equivalence hypothesis. Ricardian equivalence is a long-debated concept first introduced by David Ricardo (1888), and according to which fiscal stimulus fails to boost demand as forward-looking agents internalise the government's budget constraint and respond to foreseen tax increases by saving more. Nevertheless, the implied one-to-one negative relationship between public and private saving rates depends on a number of assumptions, including perfect foresight and perfect capital markets (Buchanan, 1976<sub>[25]</sub>). Instead, it seems more reasonable to expect partial Ricardian effects, whereby a rise in private saving only partly offsets a deepening government deficit, resulting in a fall in the total saving rate, but less than one for one.

16. To test the degree of Ricardian equivalence in the current empirical set-up, the government budget balance, a close proxy for the government saving rate, is added to the regression model of column 1. The estimated coefficient is positively signed, highly statistically significant, and implies that a one percentage point increase in the government saving rate raises the long-run national saving rate by 0.59 percentage points, almost exactly the same as the 0.60 coefficient used in the previous vintage of the model and consistent with Röhn (2010<sub>[16]</sub>), as expected. Therefore, the 0.6 pass-through coefficient from government saving to national saving is added to the preferred specification (column 1) for countries with a fiscal block.

### 2.2.4. *Other variables tested and robustness tests*

17. In addition to the saving determinants presented in Tables 1 and 2, a number of other variables were also tested but ultimately not retained. These decisions usually hinged on a lack of statistical or economic significance, counterintuitive signs and/or lack of robustness. For instance, the young dependency rate – the population aged 0 to 14 as a percentage of the population aged 15 to 74 – was considered to capture another dimension of the population age distribution, but did not work well. The inflation rate, which has a theoretically ambiguous sign, was also considered but estimation was not conclusive. A novel approach that was investigated but ultimately abandoned sought to create a country-specific measure of the dependency rate by redefining the upper age limit of the active population as the country-specific average retirement age. Unfortunately, such a measure

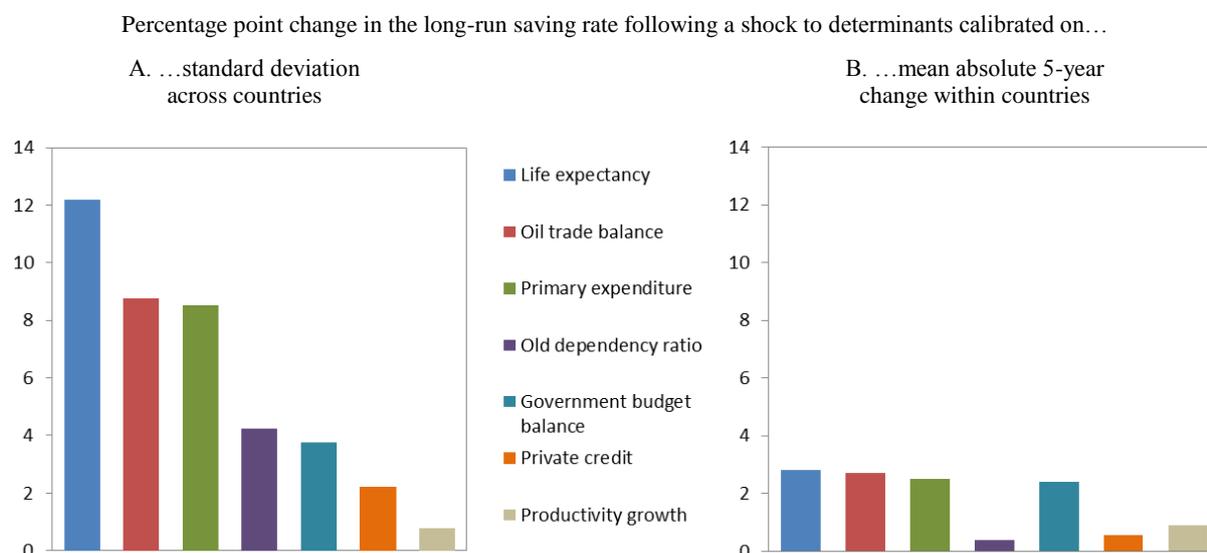
could only be created for a small number of countries due to a lack of comparable data on average retirement age, and did not perform well in estimation.

18. A number of additional regressions, presented in Annex B, show that the preferred specification is quite robust to changing the country coverage, although less robust to removing the time and country fixed effects. This latter finding is not surprising considering that, in such a parsimonious specification, estimated coefficients are almost certainly subject to omitted variable bias in the absence of fixed effects.

#### 2.2.5. *Long-term effects of saving determinants*

19. Besides the long-run effects given above for a unit change in the saving determinants, it is also useful to illustrate the size of the estimated effects for ‘typical’ changes in the determinants. One way of defining ‘typical’ is to take the standard deviation of an explanatory variable in the cross-sectional dimension, that is, across countries in a given year. The relative sizes of the estimated effects indicate to what extent each determinant helps to explain observable differences in aggregate saving rates across countries. Life expectancy, the oil trade balance, and social protection are the key drivers of cross-sectional savings differences (Figure 4, Panel A). On the other hand, this comparison likely understates the importance of some variables in a projection spanning decades, especially life expectancy and the old-age dependency ratio, for which there is likely to be gradual but persistent change in one direction (see section 2.4.2 below).

20. Alternatively, when considering the likely contribution of the different saving determinants to changing saving rates over time, it is more realistic to measure the ‘typical’ variation along the time dimension and within countries. Taking the mean absolute change in saving determinants within countries over all historical 5-year periods, the simulated effects of explanatory variables are much smaller, except for productivity growth (Figure 4, Panel B). The oil trade balance, primary expenditure and the fiscal balance become relatively more important as they are more volatile variables, while old-age dependency takes on less importance.

**Figure 4. Relative influence of aggregate saving determinants**

*Note:* Long-term coefficients are calculated with equation [4], based on the estimates in column 1 of Table 2, with the exception of the government budget balance, which is based on column 3 of the same table.

### 2.3. Implementation in the long-term model and illustrative projections

21. The preferred equation estimated above (Table 2, column 1) is implemented in the long-term model in first-difference form using the long-term value of the coefficient estimates. Using the first-difference transformation means not having to worry about discrepancies between the equation's predicted values and observed saving rates (i.e. residuals) at the end of the historical period. It also means that the equation's dynamics are ignored: the full long-term effects of changes in saving determinants over the projection period are assumed to be immediately reflected in the aggregate saving rate. Given the high estimated convergence speed and the long-term nature of the model this is not problematic, except perhaps for labour productivity growth, which is a highly cyclical variable. This problem is alleviated by the use of potential labour productivity growth in the model as opposed to actual labour productivity growth.

#### 2.3.1. Adding an effect from the net international investment position

22. The net international investment position (NIIP) was found to be correctly-signed but of only marginal statistical significance in the estimations above. Nevertheless, it is included in the simulation equation for both theoretical and practical reasons. Changes in a country's NIIP imply, *ceteris paribus*, changes in households' net total wealth and there is an established empirical literature showing that changes in net wealth influence consumption behaviour. Based on this literature, estimates of the marginal propensity to consume out of wealth for major OECD countries typically vary between 0.03 and 0.06.<sup>7</sup> The lower end of the range is consistent with some results reported earlier in Table 1,

<sup>7</sup> This range is derived from estimates of the elasticity of consumption with respect to total net wealth for major OECD countries reported in Barrell and Davis (2007<sub>[37]</sub>).

although the upper-end of the range is selected for inclusion in the model because it helps to prevent persistent large current account deficits or surpluses in the simulations.

### 2.3.2. Preliminary projections and contributions to changes in saving rates

23. To illustrate the relative importance of the saving determinants in driving aggregate saving rates to 2060 in the baseline long-run scenario, the final equation is simulated in the context of the full long-term model. The explanatory variables are projected in the following way:

- Projections for the old-age dependency ratio are computed from population projections by age and sex. These are sourced from Eurostat for most European countries and the United Nations Population Division for other countries.
- Projections of life expectancy at birth are from the United Nations Population Division for all countries.
- Private credit as a share of GDP is assumed to remain constant in the baseline projection and thus does not influence projections of the aggregate saving rate.
- Net oil trade volumes are assumed to remain constant at their last historical observations.<sup>8</sup> Therefore, projected changes in the net oil trade balance as a percentage of GDP occur solely because of changes to the price of oil – assumed to increase by 1% per year in real terms.
- Trend labour productivity growth depends on the evolution of trend labour efficiency (Guillemette et al., 2017<sub>[26]</sub>) and capital intensity (see section 3). Projected changes in this determinant are relatively small and therefore contribute little to changing saving rates.
- Social protection expenditure could be assumed to remain fixed following the general no-policy change philosophy of the baseline scenario. However, for illustrative purposes, it is assumed here to increase gradually to 15% of GDP (the low end of the range for OECD countries) in countries where the last historical observation is below this threshold (typically emerging market economies). In other countries, it is assumed to remain constant over the projection period at the last historical observation.
- The government's fiscal balance is projected under the assumption that primary revenue as a share of GDP adjusts gradually so as to stabilise the government debt-to-GDP ratio at its current level, taking into account projected increases in expenditure due to demographic change (Guillemette and Turner, 2017<sub>[27]</sub>).
- The net international investment position follows the evolution of the current account balance, which is determined by the difference between aggregate savings and aggregate investment (see section 4).

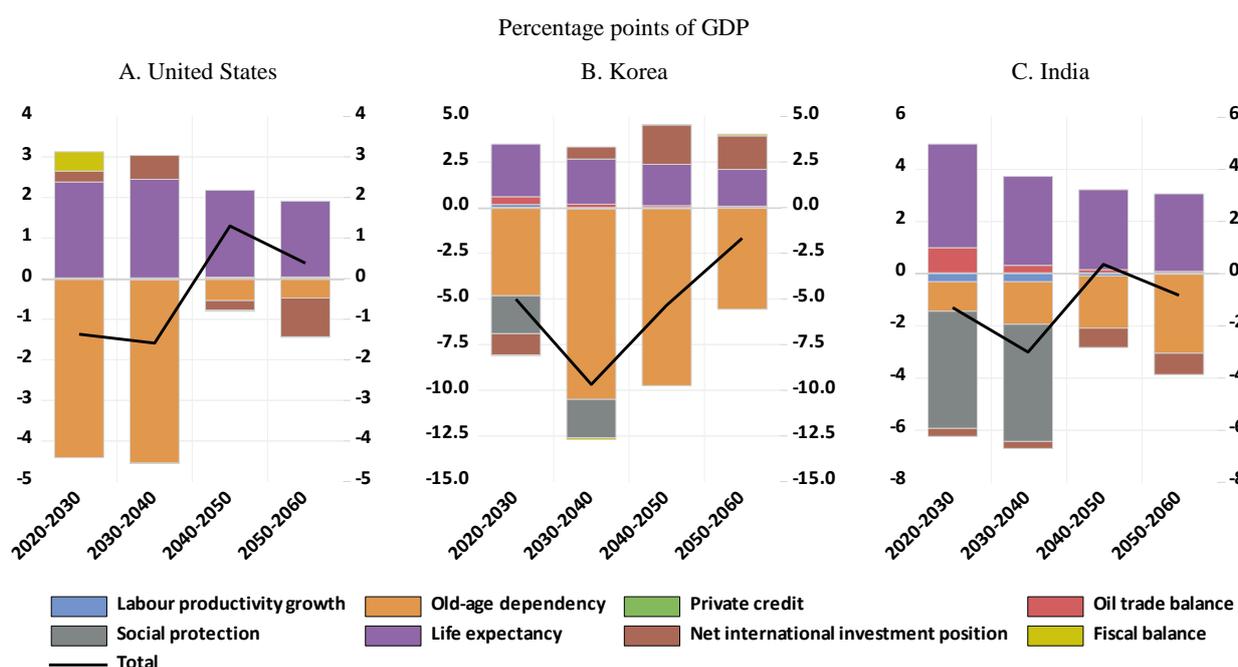
24. The upshot is that demographic change, in the form of rising old-age dependency and life expectancy, drives most of the projected changes in aggregate saving rates in the baseline scenario (Figure 5). On average across countries, rising old-age dependency cumulatively subtracts 14.1 percentage points to the aggregate saving rate by 2060, but rising life expectancy offsets 10 of those points, for a 'demographic differential' of 4.1 percentage points on average. The United States is a typical example, with rising old-age dependency pulling down the saving rate in the next few decades, but rising life

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<sup>8</sup> Net oil trade volume projections shall eventually be aligned with oil supply and demand projections underlying the International Energy Agency's *World Energy Outlook*.

expectancy dominating thereafter, leading to a small negative total demographic effect by 2060 (Panel A). This cumulative differential varies a lot across countries, however. It is projected to be largest in Korea (-20.9, Panel B), followed by Slovakia (-15.1), Japan (-13.9) and Greece (-13.7), all countries where population ageing is expected to be sharp. By contrast, the differential is projected to be large and positive in India (6.6, Panel C) and South Africa (16.6), and positive but much smaller in a number of other countries. The Korea and India examples also illustrate the potential impact on saving rates of expanding government social protection.

Figure 5. Projected changes in aggregate saving rates between 2020 and 2060



25. Besides demographics, other factors contribute much less to the projected change in aggregate saving rates. By assumption, rising social protection expenditure – where such spending is relatively weak – would subtract on average 5 percentage points to aggregate saving rates, and as much as 10 points in India (Panel C) and Indonesia. Changes to governments' fiscal positions typically contribute little to the total changes in saving rates: while in most countries some fiscal consolidation is necessary at the beginning of the projection period to stabilise the public debt ratio, it is typically followed by modest fiscal easing once that ratio is stable, so the net change to the fiscal balance is small. Finally, changes to net international investment positions could matter greatly if large current account balances persist for a long time.

### 2.3.3. Saving rate identities

26. With the aggregate gross saving rate as a percentage of GDP ( $SAVTGQ$ ) determined by the estimated equation described above, the flow of aggregate savings in local currency can be obtained with gross domestic product ( $GDP_t$ ) by inverting the definition for the saving rate:

$$SAVTG_t = \frac{SAVTGQ_t}{100} \cdot GDP_t \quad [5]$$

Next, for countries with a fiscal block in the model, private gross saving ( $SAVTG_t$ ) is obtained by identity:

$$SAVPG_t = SAVTG_t - SAVGG_t \quad [6]$$

where  $SAVGG_t$  is gross government saving. The latter is calculated from the fiscal concepts defined in Guillemette and Turner (2017<sub>[27]</sub>) as:

$$SAVGG_t = NLG_t + CAPOG_t + CFKG_t \quad [7]$$

where  $NLG_t$  is government net lending,  $CAPOG_t$  is net capital outlays of the government and  $CFKG_t$  is government consumption of fixed capital. Private and government saving rates expressed as percentages of GDP are also calculated in the model ( $SAVPGQ_t$  and  $SAVGGQ_t$ ).

### 3. Capital stock and investment

27. This section describes the step-by-step construction and partial estimation of the equations used to project the productive capital stock and investment. As the discussion makes use of a large number of symbols, a list with definitions, a summary of sources and estimation/projection methods can be found in Table AD.1 in Appendix D.

#### 3.1. Framework

28. The long-term model is based on the same Cobb-Douglas production function underlying historical potential output estimates and short-run projections in the *OECD Economic Outlook*, such that potential output ( $Y_t^*$ ) is a function of trend labour efficiency ( $A_t^*$ ), trend employment ( $L_t^*$ ) and the capital stock ( $K_t$ ):

$$Y_t^* = (A_t^* L_t^*)^\alpha K_t^{1-\alpha} \quad [8]$$

with the labour share of income ( $\alpha$ ) assumed to be constant at 0.67 in all countries. Using a dot over variables to denote growth rates and defining  $\dot{a}_t = \Delta \log(A_t^*)$ ,  $\dot{l}_t = \Delta \log(L_t^*)$ ,  $\dot{y}_t = \Delta \log(Y_t^*)$  and  $\dot{k}_t = \Delta \log(K_t^*)$ , the growth rate of potential output can be expressed as:

$$\dot{y}_t = \alpha(\dot{a}_t + \dot{l}_t) + (1 - \alpha) \dot{k}_t \quad [9]$$

from which it is clear that the capital-to-potential output ratio is stable if the capital stock (and incidentally potential output) is growing at rate  $\dot{a}_t + \dot{l}_t$ .

29. The capital stock used in this production function covers the entire economy but excludes housing, which means that it includes both business sector structures and equipment as well as government sector capital assets. For the purposes of the long-term

model, notably to allow simulating shocks to government investment, the future capital stock is notionally split between a government sector capital stock ( $K_G$ ) and a business sector capital stock ( $K_B$ ).

### 3.2. Government sector capital stock and investment

30. In the absence of historical data on public sector capital stock, some simplifying assumptions are made. An estimate is needed only for the last year of the historical period, that is, for the jump-off point between the historical period and the long-term simulation period. The assumption made is that the government sector capital stock ratio (to potential output) is at its steady-state value in the last year of the historical period. An expression for this steady-state value can be obtained by starting from the conventional perpetual inventory capital stock dynamic equation:

$$K_{G_t} = (1 - \delta_t)K_{G_{t-1}} + IGV_t \quad [10]$$

where  $IGV_t$  is the volume of government investment, and  $\delta_t$  is the capital stock depreciation rate. Dividing through by potential output ( $Y_t^*$ ):

$$\frac{K_{G_t}}{Y_t^*} = \frac{(1 - \delta_t)K_{G_{t-1}}}{(1 + \dot{y}_t)Y_{t-1}^*} + \frac{IGV_t}{Y_t^*} \quad [11]$$

where, as above,  $\dot{y}_t$  is the growth rate of potential output. In the steady-state (indexed by  $SS$ ), the capital-output ratio ( $k_{g_t}^{SS}$ ) is stable, so after some re-arranging:

$$k_{g_t}^{SS} = \left( \frac{1 + \dot{y}_t}{\delta_t + \dot{y}_t} \right) \frac{IGV_t}{Y_t^*} \quad [12]$$

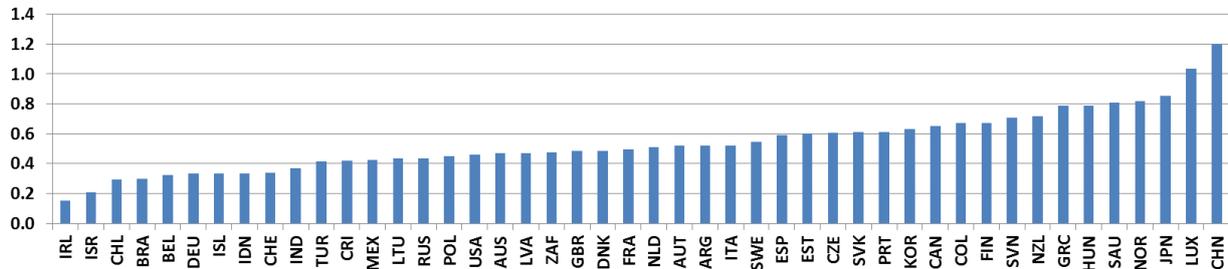
This expression requires the depreciation rate for the government sector capital stock, which for simplicity is assumed to be the same as estimated for the overall capital stock in the *OECD Economic Outlook* (EO)<sup>9</sup>; the potential output growth rate, which is estimated for all countries in the EO; and government investment volume, which is available in the EO database for 17 of the countries in the model. For the other countries, government investment-to-output ratios are sourced from the Investment and Capital Stock database of the IMF's Fiscal Affairs Division.<sup>10</sup> When applied to the last year of the historical period, [12] yields steady-state government sector capital stock ratios between 0.15 and 1.2, depending on the country (Figure 6). Not surprisingly, given the very high level of public

<sup>9</sup> In reality, the information and communication technology component of government investment is probably lower than for business investment, therefore the depreciation rate for government capital assets is likely lower in the government than in the business sector. Because the data required to get a more precise estimate of depreciation in the government sector are lacking, and because differentiating depreciation rates across sectors is likely to have only second-order effects in any simulation, for simplicity the same scrapping rate is used in both sectors.

<sup>10</sup> See <http://www.imf.org/external/np/fad/publicinvestment/data/info122216.pdf>. The EO database being one of the primary sources behind the IMF's database, the two references should be comparable.

investment in China in recent years, it has the highest estimated government sector capital stock ratio.

**Figure 6. Steady-state ratios of government sector capital stock to potential output in 2018**



Source: OECD Economic Outlook No. 100 database, IMF's Investment and Capital Stock database and authors' calculations.

31. Over the projection period, absent any shock, the government capital stock ratio is assumed to remain stable. This is done by treating  $k_{g_t}^{SS}$  computed above as a fixed parameter, and inverting [12] to calculate government investment ( $IGV_t$ ) as a function of potential output ( $Y_t^*$ ):

$$IGV_t = \left( k_{g_t}^{SS} \left( \frac{\delta_t + \dot{y}_t}{1 + \dot{y}_t} \right) + IGV\_shock_t \right) Y_t^* \quad [13]$$

where  $IGV\_shock_t$  is assumed to be zero in the baseline scenario, but can be used to shock the government investment ratio in alternative scenarios. Again the depreciation rate is the same as that projected for the business sector capital stock (see below for how this is done). Then, the government sector capital stock is calculated using [10]. This set-up ensures that the government sector capital stock affects the long-term projection only if government investment is assumed to rise or fall from the ratio measured (or assumed) in the last year of the historical period. Otherwise, including in the baseline scenario, the government sector capital stock grows at the same rate as potential output.

### 3.3. Business sector capital stock and investment

32. Having defined a government sector capital stock ( $K_{G_t}$ ) at the jump-off point between the historical and simulation periods, the business sector capital stock ( $K_{B_t}$ ) must be defined by identity from the total economy capital stock ( $K_t$ ):

$$K_{B_t} = K_t - K_{G_t} \quad [14]$$

Like the government sector capital stock on which it depends, this business sector capital stock concept is only defined for the last historical year and the projection period. Because the government sector capital stock concept is a steady-state one, it would not make sense to compute it over the whole historical period and then compute historical business sector capital stock with [14]. Both would be too volatile.

33. The projection equation for the business sector capital stock is obtained in several steps:

- First, the influence of the economy's cyclical position, the natural inertia in the capital accumulation process and the effect of the external balance are estimated econometrically. The estimated equation also ensures that in steady state, the capital-to-output ratio is stable, so that the growth contribution from changing capital intensity is usually modest, in line with stylised fact from growth decompositions (Jones, 2015<sub>[28]</sub>). The speed of convergence to this equilibrium is also econometrically estimated.
- Second, an equilibrium capital stock concept is defined and used to incorporate influences on capital accumulation that are taken from other studies, namely those of product market regulation, employment protection legislation and the user cost of capital.
- Third, the equilibrium concept is inserted into the estimated equation, thus allowing the long-run equilibrium to respond to changes in policy and in the user cost of capital, but using the speed of convergence estimated in the first step.
- Finally, business sector investment is derived from the capital stock projection via the stock-flow identity using a simple projection rule for the depreciation rate.

### 3.3.1. Estimation framework

34. Conceptually, the growth rate of the business sector capital stock in country  $i$  and year  $t$  ( $\dot{k}_b$ ) is posited to depend on two of its own lags, on the change in the output gap ( $\Delta GAP_{i,t}$ ), on the sum of trend labour efficiency and employment growth defined previously ( $\dot{a}_{i,t} + \dot{l}_{i,t}$ ), and on any discrepancy between last period's capital-to-potential output ratio ( $K_{B_{i,t}}/Y_{i,t}$ ) in logs and its long-run equilibrium. In turn, the long-run equilibrium is assumed to depend on a constant ( $\theta_1$ ) and on the current account balance as a share of GDP ( $CB_{i,t}$ ).

$$\begin{aligned} \dot{k}_b = & \beta_1 \Delta GAP_{i,t} + \beta_2 \dot{k}_b_{i,t-1} + \beta_3 \dot{k}_b_{i,t-2} + \beta_4 (\dot{a}_{i,t} + \dot{l}_{i,t}) \\ & + \rho \left( \log \left( \frac{K_{B_{i,t-1}}}{Y_{i,t-1}^*} \right) - \theta_1 - \theta_2 CB_{i,t-1} \right) + \varepsilon_{i,t} \end{aligned} \quad [15]$$

with  $\rho$  representing the speed of convergence to the long-run equilibrium. The dependent variable in this equation, the growth rate of the capital stock, is closely related to investment, which is known to be one of, if not the most, cyclical demand component. The output gap term captures these cyclical effects. Lags of the dependent variable capture short-run dynamics which help to ensure a smooth investment profile when turning to projections. Having in the equation the sum of trend labour efficiency and employment growth – the two other components of potential output besides the capital stock – ensures that the capital stock growth rate converges to this value at the steady-state as long as  $\beta_2 + \beta_3 + \beta_4 = 1$ , so it is important to check that this condition is met in the estimated coefficients, or to impose it with coefficient restrictions.

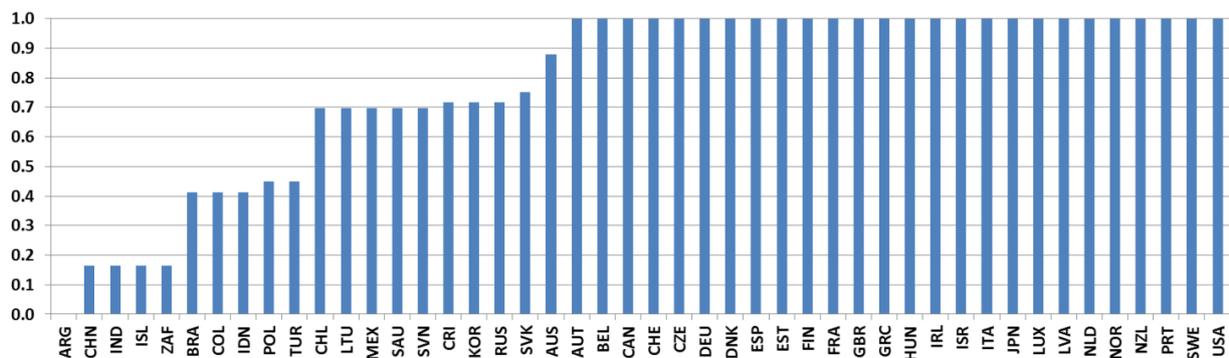
35. In the absence of cross-border capital flows, investment would be exactly equal to domestic savings, as it is in the canonical Solow growth model. In reality, however, cross-border capital flows allow investment to differ from domestic savings. The specification of the long-term equilibrium part of the estimated equation therefore posits that capital accumulation is affected by the external balance. But before estimation, [15] is amended

in a number of ways to more carefully distinguish the influence of the external balance for different cases.

36. First, a positive current account balance – an excess of domestic savings over investment – might be expected not to have an effect on capital accumulation in and of itself (although it may signal a lack of investment prospects at home). On the other hand, a negative current account balance – an excess of domestic investment relative to savings – might be expected to eventually constrain capital accumulation. For this reason, [16] introduces a tweak to [15] by allowing the coefficient on the current account balance to differ for negative ( $CB_{i,t} < 0$ ) versus positive ( $CB_{i,t} > 0$ ) balances.

37. Second, the influence of the current account balance on domestic investment might depend on the degree of capital account openness. The lower the degree of openness, the more difficult it might be for a country to run a sustained current account deficit. On the other hand, a current account deficit might not be as constraining if the capital account is fully opened. To test this hypothesis, the degree of capital account openness ( $open_{i,t}$ ) is added in [16] using the measure of Chinn and Ito (2006<sub>[29]</sub>).<sup>11</sup> The countries in the long-term model can be slotted into four broad groupings according to their score on this measure which varies between zero and one (Figure 7): a first group, including China, where capital account openness is zero or very low; a second group, including Brazil and Turkey, with somewhat higher openness scores; a third group, including Mexico and Russia, but also more developed countries like Korea, with openness higher still; and finally a large group, comprising most OECD countries, where the capital account is considered fully open.

**Figure 7. The Chinn-Ito index of capital account openness, 2014**



Source: Chinn, M.D. and H. Ito (2006), "What Matters for Financial Development? Capital Controls, Institutions, and Interactions," *Journal of Development Economics*, Vol. 81, Issue 1, Pages 163-192 (October).

38. Third, a weight ( $\omega$ ) on the openness variable is added in [16] to tailor the extent to which the capital account openness variable matters in the estimation; so that  $\omega=1$  implies that capital account openness has a strong effect on the feedback from current account balances to capital accumulation, whereas  $\omega=0$  implies that it is irrelevant.

<sup>11</sup> The index is based on the binary dummy variables that codify the tabulation of restrictions on cross-border financial transactions reported in the IMF's Annual Report on Exchange Arrangements and Exchange Restrictions (AREAER).

39. Finally, the specification in [16] is made linear in the coefficients:

$$\begin{aligned} \dot{k}_{i,t} = & \alpha + \beta_1 \Delta GAP_{i,t} + \beta_2 \dot{k}_{i,t-1} + \beta_3 \dot{k}_{i,t-2} + \beta_4 (\dot{a}_{i,t} + \dot{l}_{i,t}) \\ & + \beta_5 [(1 - \omega \cdot open_{i,t}) CB_{i,t-1} < 0] \\ & + \beta_6 [(1 - \omega \cdot open_{i,t}) CB_{i,t-1} > 0] + \rho \log \left( \frac{K_{i,t-1}}{Y_{i,t-1}^*} \right) + \varepsilon_{i,t} \end{aligned} \quad [16]$$

where, compared to [15],  $\alpha = -\rho\theta_1$  while  $\beta_5$  and  $\beta_6$  are related to  $-\rho\theta_2$ .

### 3.3.2. Estimation results

40. The dataset on which equation [16] is estimated comprises 42 of the 46 countries in the long-term model and is an unbalanced panel with data for most countries covering at least the period 1993-2016. The equation is estimated using panel least squares with standard errors clustered at the country level (Table 3). The dependent variable is the total capital stock, which is used here as a proxy for the business sector capital stock given the lack of historical series on government sector capital stocks for a sufficient number of countries.

**Table 3. Estimation results for capital stock equation in [16]**

The dependent variable is the one-period change in the log capital stock:  $\Delta \log(K_{i,t})$

	(1)	(2)	(3)	(4)	(5)
	$\omega = 1$	$\omega = 1$	$\omega = 0.8$	$\omega = 0.5$	$\omega = 0$
Change in the output gap ( $\beta_1$ )	0.140***	0.140***	0.140***	0.141***	0.142***
First lag of dependent variable ( $\beta_2$ )	1.361***	1.361***	1.370***	1.378***	1.380***
Second lag of dependent variable ( $\beta_3$ )	-0.423***	-0.423***	-0.429***	-0.435***	-0.437***
Sum of trend labour efficiency and employment growth ( $\beta_4$ )	0.062***	0.062***	0.058***	0.054***	0.052***
Openness-weighted lagged negative current account balance ( $\beta_5$ )	0.038***	0.039***	0.036***	0.024***	0.013**
Openness-weighted lagged positive current account balance ( $\beta_6$ )	0.002				
Lagged log capital-to-potential output ratio ( $\rho$ )	-0.003***	-0.003***	-0.003***	-0.003***	-0.002***
$R^2$	0.982	0.982	0.982	0.982	0.982

*Note:* All equations estimated with panel least squares on a sample of 42 countries and over the period 1993-2016. Asterisks indicate statistical significance at the 1% (\*\*\*), 5% (\*\*) or 10% (\*) levels. Standard errors (White) are robust to arbitrary heteroscedasticity and within-country serial correlation. All data are from the OECD Economic Outlook No. 100 database. The output gap and the current account balance are divided by 100 so as to correspond to the scale of the dependent variable. Trend labour efficiency and trend employment growth are calculated as first differences in logs like the dependent variable. In all columns, the estimated constant is not reported.

41. The coefficient on the change in the output gap indicates, as expected, that investment is procyclical and implies a strong accelerator effect (column 1 of Table 3). A one percentage point increase in the output gap is associated with a 0.14 percentage point increase in the growth rate of the capital stock, which translates via the law of motion into a substantial boost to investment. The estimated speed of convergence is low, at 0.3% per year, but this is compensated by strong persistence in short-run dynamics (see simulations

below). The condition  $\beta_2 + \beta_3 + \beta_4 = 1$  is respected, implying that in a steady-state the capital stock grows at rate  $\dot{a}_t + \dot{l}_t$ .

42. The positive coefficient on a negative current account balance ( $\beta_5$ ) in column 1 indicates that, as expected, current account deficits tend to constrain capital stock accumulation. In this instance, the weight parameter on capital account openness is equal to 1, so this constraint only applies to countries with less than full capital account openness (i.e. it excludes most OECD countries). But for a country with capital account openness of 0.4, such as Brazil, a 5% current account deficit would lower the equilibrium capital-to-output ratio by about 8%, bringing about an immediate change in investment. Also as expected, a positive current account balance does not affect capital stock accumulation, no matter the degree of capital account openness, because the coefficient on this variable ( $\beta_6$ ) is very small and statistically insignificant. So in columns 2 and up, the positive current account variable is dropped. Other coefficients change only negligibly.

43. The importance of capital account openness in the equation is tested by trying alternative weight parameters ( $\omega$ ). By lowering this parameter to 0.8 (in column 3) and 0.5 (in column 4), current account deficits are allowed to have an impact on capital accumulation even in countries with full capital account openness. As expected, the estimated coefficient on current account deficits falls. When the parameter is set to zero (in column 5), the coefficient is no longer statistically significant at the 1% level. To recognise that current account deficits can be unsustainable, and investment negatively affected, even in countries with fully opened capital accounts, column 3 is chosen as the preferred specification ( $\omega = 0.8$ ). It allows for a small current account deficit effect on capital accumulation in countries with highly opened capital accounts, but much larger effects on countries that are mostly closed to foreign capital.

### 3.3.3. Additional effects on long-run equilibrium

44. The next step is adding to the estimated capital stock equation influences from employment protection legislation ( $EPL_t$ ), product market regulation ( $ECTR_t$ ) and the user cost of capital ( $UCC_t$ ). For this purpose, the concept of an equilibrium business sector capital stock is introduced to allow for gradual adjustment of the actual capital stock when one of the three variables just mentioned is shocked. Because this ‘optimal’ concept is unobservable, in practice its initial value (i.e. for the last historical year before the projection period) is set to the value of the actual business sector capital stock (defined in [14]). Consequently, the projection equation can determine the change to the equilibrium stock. As a point of departure, the equilibrium capital-to-output ratio is assumed to remain constant absent any changes to EPL, ECTR or UCC. This means that its growth rate should be the sum of trend labour efficiency growth ( $\dot{a}_t$ ) and trend employment growth ( $\dot{l}_t$ ). Defining  $K\_B_t^*$  as the equilibrium business sector capital stock,  $k\_b_t^* = \Delta \log(K\_B_t^*)$ , and ignoring country subscripts:

$$k\_b_t^* = \dot{a}_t + \dot{l}_t \quad [17]$$

45. Based on the QSR work reported in Égert (2017<sub>[11]</sub>), more stringent product market regulation (a higher ETCR score) is associated with a lower equilibrium capital stock and

likewise for more stringent employment protection legislation.<sup>12</sup> So two terms are added to [17] with the relevant long-run semi-elasticities:

$$k'_b{}^* = \dot{a}_t + \dot{i}_t - 0.031 \Delta ECTR_t - 0.118 \Delta EPL_t \quad [18]$$

46. The next step is to include an effect from the user cost of capital into the expression. It seems intuitive that the user cost of capital should affect the equilibrium capital-to-output ratio. However, previous work for the QSR project was not able to identify this effect precisely, probably due to data limitations when working at the aggregate macro level. Other strands of empirical work based on firm-level data, however, typically find an important effect for the user cost of capital, for instance Gilchrist and Zakrajsek (2007<sub>[30]</sub>). From equation (2) in their paper, and ignoring expected capital gains, investment tax credits and depreciation allowances for lack of comparable cross-country data, the user cost of capital ( $UCC_t$ ) is given by:

$$UCC_t = \frac{P_t^I ((1 - \tau_t)i_t + \delta_t)}{P_t^Y (1 - \tau_t)} \quad [19]$$

where  $P_t^I$  is the investment price index,  $P_t^Y$  the output price index,  $\tau_t$  the statutory corporate income tax rate and  $i_t$  the nominal interest rate. The interest rate should be a corporate borrowing rate, but the long-term model only has government benchmark borrowing rates. Therefore, a fixed spread of 200 basis points is added to the 10-year government benchmark rate to proxy for the corporate rate. Taking logs and differencing this expression:

$$\Delta \log(UCC_t) = \Delta \log(P_t^I) - \Delta \log(P_t^Y) + \Delta \log((1 - \tau_t)i_t + \delta_t) - \Delta \log(1 - \tau_t) \quad [20]$$

$$= drpi_t + \Delta \log((1 - \tau_t)i_t + \delta_t) - \Delta \log(1 - \tau_t) \quad [21]$$

47. The first two terms on the right-hand side of [20] measure the difference between investment and output price inflation. In the long-term model, this difference is a constant parameter ( $drpi$ ), set by assumption to a negative value to reflect the expectation of a continuing trend decline in relative investment prices. As shown in Gilchrist and Zakrajsek (2007<sub>[30]</sub>), with a Cobb-Douglas production function such as the one underpinning the long-term model, the long-run elasticity of the capital stock with respect to the user cost of capital is unity. Therefore, [21] is added to [18] with a coefficient of minus one:

$$k'_b{}^* = \dot{a}_t + \dot{i}_t - 0.031 \Delta ECTR_t - 0.118 \Delta EPL_t - \Delta \log(UCC_t) \quad [22]$$

$$= \dot{a}_t + \dot{i}_t - 0.031 \Delta ECTR_t - 0.118 \Delta EPL_t - drpi_t - \Delta \log((1 - \tau_t)i_t + \delta_t) + \Delta \log(1 - \tau_t) \quad [23]$$

In this expression, the corporate borrowing rate ( $i_t$ ) is obtained by adding the aforementioned 200 basis point spread to the domestic government 10-year benchmark government bond rate. But while this rate might be a fair representation of the cost of borrowing for relatively small and domestically-oriented businesses, in reality many firms

<sup>12</sup> The ETCR and EPL elasticities are from column 3 of Table 6B in Égert (2017<sub>[11]</sub>).

have access to international capital markets to finance investment and do not necessarily face the domestic borrowing rate. To reflect these realities, [23] is amended by using a weighted average of the domestic and global interest rates ( $i_t^d$  and  $i_t^g$ ),

$$\begin{aligned} \dot{k}_t b_t^* = & \dot{a}_t + \dot{l}_t - 0.031 \Delta ECTR_t - 0.118 \Delta EPL_t - drpi_t \\ & - \Delta \log \left( (1 - \tau_t)(\gamma_t i_t^g + (1 - \gamma_t) i_t^d) + \delta_t \right) + \Delta \log(1 - \tau_t) \end{aligned} \quad [24]$$

with the weight parameter ( $\gamma_t$ ) on the global interest rate also calibrated on the Chinn-Ito measure of capital account openness mentioned previously:

$$\gamma_t = \text{Min}(\text{open}_t, 0.5) \quad [25]$$

The calibration recognizes that even in countries with fully open capital accounts, many firms do not have the size and sophistication to borrow in international capital markets and investors still exhibit a high degree of home bias (Philips, Kinniry Jr. and Donaldson, 2012<sub>[31]</sub>). Therefore, [25] effectively sets a ceiling of 0.5 on the weight put on the global interest rate. At the same time, the weight could be as low as zero in countries with closed capital accounts, implying that only domestic interest rates influence capital accumulation.

#### 3.3.4. Implementation in the long-term model and investment projection

48. For implementation in the long-term model, [16] is modified to include the difference between the log actual capital-to-output ratio and the log equilibrium value resulting from any change in product market regulation, employment protection legislation or the user cost of capital following [24]:

$$\begin{aligned} \dot{k}_t b_t = & \hat{\beta}_1 \Delta GAP_t + \hat{\beta}_2 \dot{k}_t b_{t-1} + \hat{\beta}_3 \dot{k}_t b_{t-2} + \hat{\beta}_4 (\dot{a}_t + \dot{l}_t) \\ & + \hat{\beta}_5 [(1 - 0.8 \cdot \text{open}_t) CB_{t-1} < 0] \\ & + \hat{\rho} [\log(K_{B_{t-1}}) - \log(K_{B_{t-1}}^*)] \end{aligned} \quad [26]$$

The coefficient estimates are those of Table 3, column 3. However, this expression requires the level of  $K_{B_t}^*$ , whereas [24] only determines its evolution from an initial value. As explained previously, in practice the initial value (i.e. for the last historical year before the projection period) is set to the value of the actual business sector capital stock (defined in [14]) and replaces the estimated constant ( $\hat{\alpha}$ ) from [16] which does not appear in [26]. This means that, in the absence of a current account deficit, and without changes to ETCR, EPL or UCC in the projection period, the capital stock-to-output ratio rapidly converges to a steady state, after any initial output gap is eliminated (this happens over the first few years in the long-term projection). It also implies that this steady state is close to the capital-to-output ratio in the last historical period. In theory, the fixed factor share assumption made for the long-term model implies that equilibrium capital-to-output ratios should eventually be the same in all countries. In practice, measurement issues prevent them from being perfectly comparable across countries. Setting the initial equilibrium ratio equal to the most recent observation allows for this reality.

49. Business sector investment for the projection period ( $IBV_t$ ), more precisely private non-residential gross fixed capital formation, is obtained via the law of motion linking it to the business sector capital stock with an assumed depreciation rate ( $\delta_t$ )<sup>13</sup>:

$$IBV_t = K_{B_t} - (1 - \delta_t)K_{B_{t-1}} \quad [27]$$

Over the projection period, the depreciation rate follows:

$$\Delta\delta_t = 0.9 \cdot \Delta\delta_{t-1} \quad [28]$$

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.

At equilibrium,

$$K_{B_t}^* = K_{B_{t-1}}^*(1 + \dot{a}_t + \dot{l}_t) \quad [29]$$

Therefore, business investment in equilibrium can be derived as follows:

$$IBV_t^* = K_{B_{t-1}}^*(1 + \dot{a}_t + \dot{l}_t) - (1 - \delta_t)K_{B_{t-1}}^* = (\dot{a}_t + \dot{l}_t + \delta_t) K_{B_{t-1}}^* \quad [30]$$

In words, when the capital stock has reached its equilibrium level, investment is just sufficient to replace depreciated capital and also reflects any growth (positive or negative) in trend employment and labour efficiency. This is consistent with a stable capital-to-output ratio.

50. To summarise, the equations determining the business sector capital stock and investment projections in the long-term model are [24] to [28] with, importantly, the assumption that the initial equilibrium business sector capital stock to output ratio is equal to the ratio in the last historical period. This set-up helps to achieve the following objectives:

1. Keep the contribution of capital accumulation to long-term growth in the baseline scenario relatively small. For most countries, historical data show fairly stable capital-to-output ratios over long periods of time. For instance, the capital-to-output ratio of the United States has been around 2.5 for many decades. As explained previously, stable capital-to-output ratios are consistent with the assumption of fixed factor shares made in the Cobb Douglas production function. In addition, historical growth decomposition exercises typically find only a small

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<sup>13</sup> In the case of Norway, [27] determines investment excluding the oil and shipping sectors ( $IOBV_t$ ), because these sectors are excluded from the definition of potential output and must thus also be excluded from the capital stock concept.

role for capital accumulation when looking over several decades, and development accounting exercises similarly find that only a small share of differences in living standards across countries are due to differences in capital intensity (Jones, 2015<sub>[28]</sub>).

2. Keep any implied change in investment at the beginning of the simulation period modest and smooth, to prevent implausible sudden changes to investment itself, but also to the current account balance, which in the long-term model is obtained as the difference between domestic saving and investment (see section 4).
3. Incorporate policy effects from product market regulation, employment protection legislation, corporate taxes as well as interest rates.
4. Incorporate a feedback mechanism, so that sustained current account deficits, particularly in countries with relatively closed capital accounts, would tend to reduce capital accumulation and hence the original imbalance. This also implies that factors which impinge on domestic saving may also influence capital accumulation and so growth.

### 3.3.5. *Simulation results*

51. To illustrate the workings of the equations, a small simulation model, with equations [9], [24] to [28] as well as the identity for the current account balance (saving minus investment), is calibrated as indicated in Table 4. For simplicity, the model assumes that the equations determine the total productive capital stock rather than just the business sector part, and it ignores housing and inventory investment. The initial capital-to-output ratio is set to 2.18, a typical value for advanced economies, and the domestic saving rate is set to 15% and assumed to be exogenous. Given the assumed parameters (see table), the baseline investment ratio (investment to potential output) is also 15% and the current account balance is zero. Potential output grows at 2% per year. The sets of charts below show the effects of various shocks on investment, capital-output ratios and potential output.<sup>14</sup> The simulations begin in 2015 and the shocks are assumed to occur in 2020. Results are shown up to 2100 to show the full dynamics given the slow convergence speed. All charts show differences from the baseline scenario just described.

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<sup>14</sup> It should be noted that these simulations do not reflect exactly what will occur in the full long-term model, because apart from the simplifications already mentioned, the small model used here does not incorporate any feedback effects on the domestic saving rate and on interest rates that might occur from the global saving/investment balance in the full model. Here, saving and interest rates are exogenised for simplicity (and for this reason the effect of shocks on the current account balance is exactly the negative of the effect on the investment ratio). For most countries, such feedback effects are likely to be second-order, however.

**Table 4. Model calibration (unless otherwise stated in the figures)**

Initial capital-to-potential output ratio ( $K_t/Y_t^*$ )	2.18
Trend labour efficiency growth ( $\dot{\alpha}_t$ )	0.01
Trend employment growth ( $\dot{l}_t$ )	0.01
Capital account openness ( $open_t$ )	1.0 or 0.5
Domestic saving rate ( $s_t$ )	0.15
Depreciation rate ( $\delta_t$ )	0.05
Product market regulation index ( $ETCR_t$ )	4
Employment protection legislation index ( $EPL_t$ )	4
Relative investment price inflation ( $drpi_t$ )	0
Statutory corporate income tax rate ( $\tau_t$ )	0.3
Domestic corporate borrowing rate ( $i_t^d$ )	0.04
Global corporate borrowing rate ( $i_t^g$ )	0.06
Output gap ( $GAP_t$ )	0
Labour share of income ( $\alpha$ )	0.67

52. A permanent increase in the domestic saving rate has no effect in this set-up. Because the current account is zero in the baseline, the higher saving rate leads to a current account surplus which has no effect on investment. On the other hand, a permanent fall in the saving rate opens up a current account deficit and this depresses capital intensity (i.e. the capital-to-output ratio) and the investment ratio permanently (Figure 8). Potential output growth slows down temporarily. The sizes of the effects depend on the degree of openness of the capital account, with somewhat larger effects for lower capital account openness for the reasons mentioned previously.

53. A permanent increase in trend labour efficiency or employment growth naturally raises potential growth, but at first by less than the full amount of the shock (Figure 9). This is because capital intensity starts declining and the investment ratio gradually rises to match the supply shock and stabilise the capital intensity level. When the new steady state is reached, potential growth is higher by the full amount of the shock, the investment ratio is permanently higher and the capital-to-output ratio is marginally lower than in the baseline. In a country with less than full capital account openness (not shown in the chart), the investment and capital-to-output ratios would eventually settle somewhat lower than shown in this simulation because the current account deficit resulting from the investment boost would feed back into capital accumulation. But the effect on potential output would be only marginally different and temporary. This difference in impacts occurs only if the shock creates or deepens a current account deficit.

54. Product market or labour market liberalisation (fall in ETCR or EPL indices) raises investment and capital intensity permanently (Figure 10). Potential growth rises temporarily during the transition period to higher capital intensity. The effect on the long-run level of potential output is nearly five times larger for a 0.3 point EPL decline as for the same reduction in the ETCR score, shocks that correspond to the sizes of typical reforms as calculated by Égert and Gal (2017<sub>[32]</sub>). Again, the effects would be somewhat weaker in a country with less than full capital account openness (not shown in the chart) because of feedback from the resulting current account deficit.

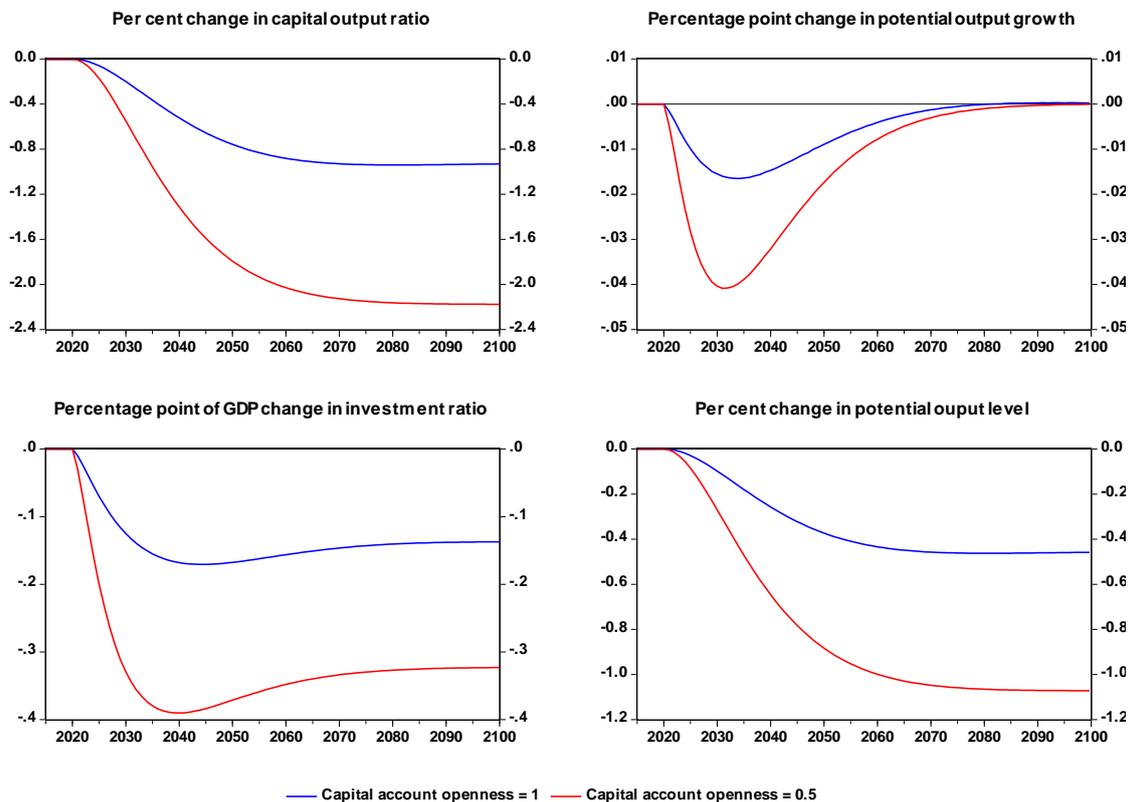
55. A cut to the statutory corporate income tax rate has the same qualitative effects as EPL or ETCR liberalisation, and quantitatively the effect is similar to the ETCR shock above (Figure 11). For a one-point cut, the investment ratio increases by less than a tenth of one percentage point of GDP and long-run output increases by about ¼ per cent. These

modest effects are corroborated by much statistical evidence indicating that investment is relatively insensitive to statutory tax rates (Gravelle and Marples, 2014<sub>[33]</sub>).<sup>15</sup>

56. A fall in domestic and/or global interest rates also has the same qualitative effects as EPL or ETCR liberalisation or a corporate tax cut (Figure 12). 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 would have knock-on effects on all countries in the model via the global rate.

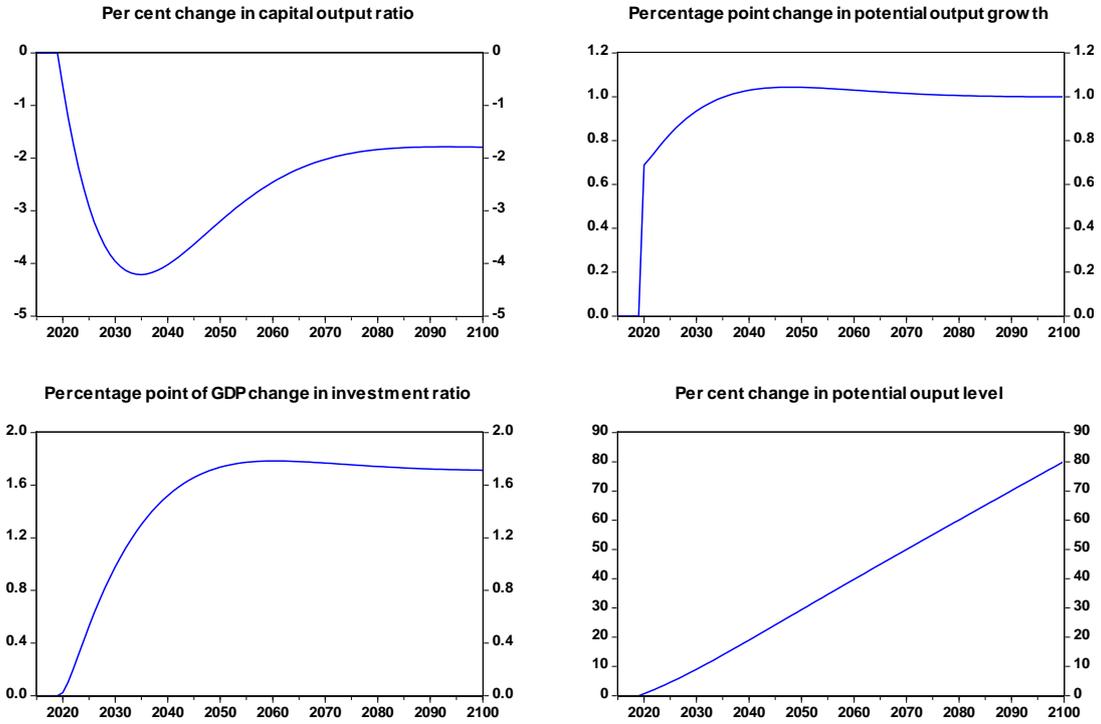
57. Finally, a temporary negative output gap has temporary negative effects on the investment ratio and capital intensity (Figure 13). The impact on the level of potential output is similarly negative and temporary, meaning that potential growth first falls when the negative output gap opens up, and then rises above the baseline when it closes back up. In other words, a negative output gap produces no hysteresis-like permanent effect, although the effects from just a 5-year shock take a long time to fully die down, so that even 20 years after the shock potential output is still ½ per cent lower than in the baseline.

**Figure 8. Impact of a one percentage point fall in the domestic saving rate**

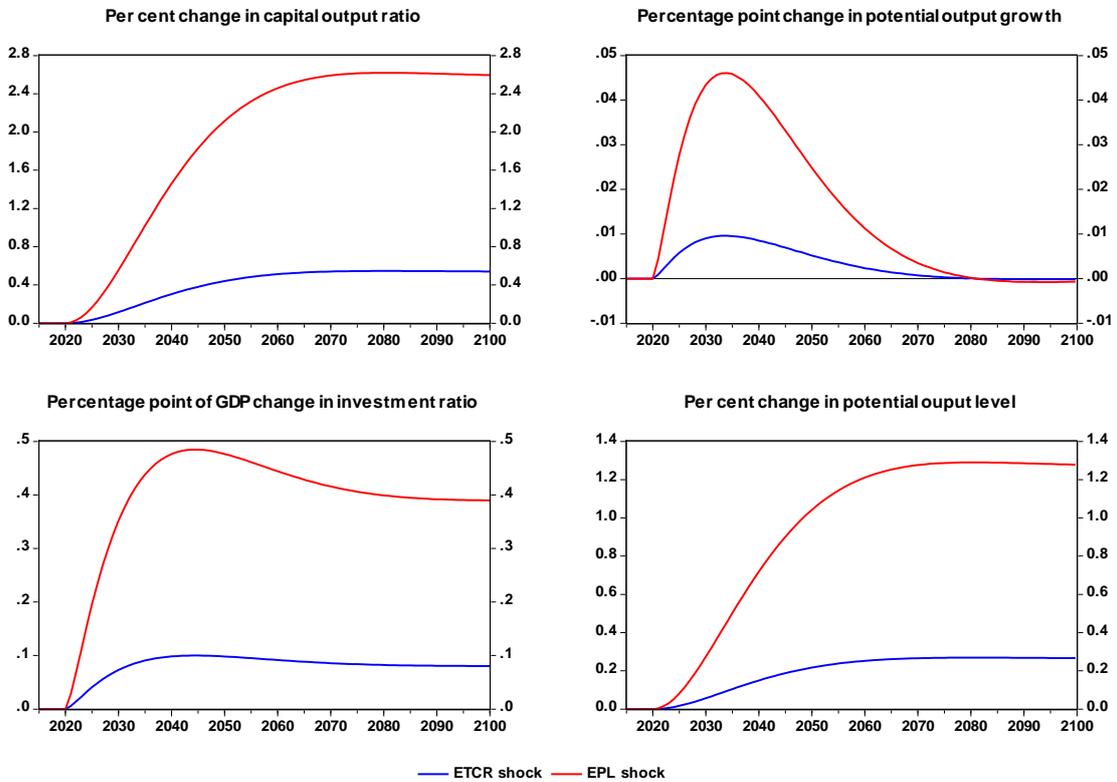


<sup>15</sup> In addition, the user cost of capital definition used here ignores typical provisions that reduce the corporate tax burden in most countries, such as tax credits, depreciation allowances, etc. (see the definition above). If these aspects were taken into account, the impact of changes to the statutory rate on investment and output would be even weaker.

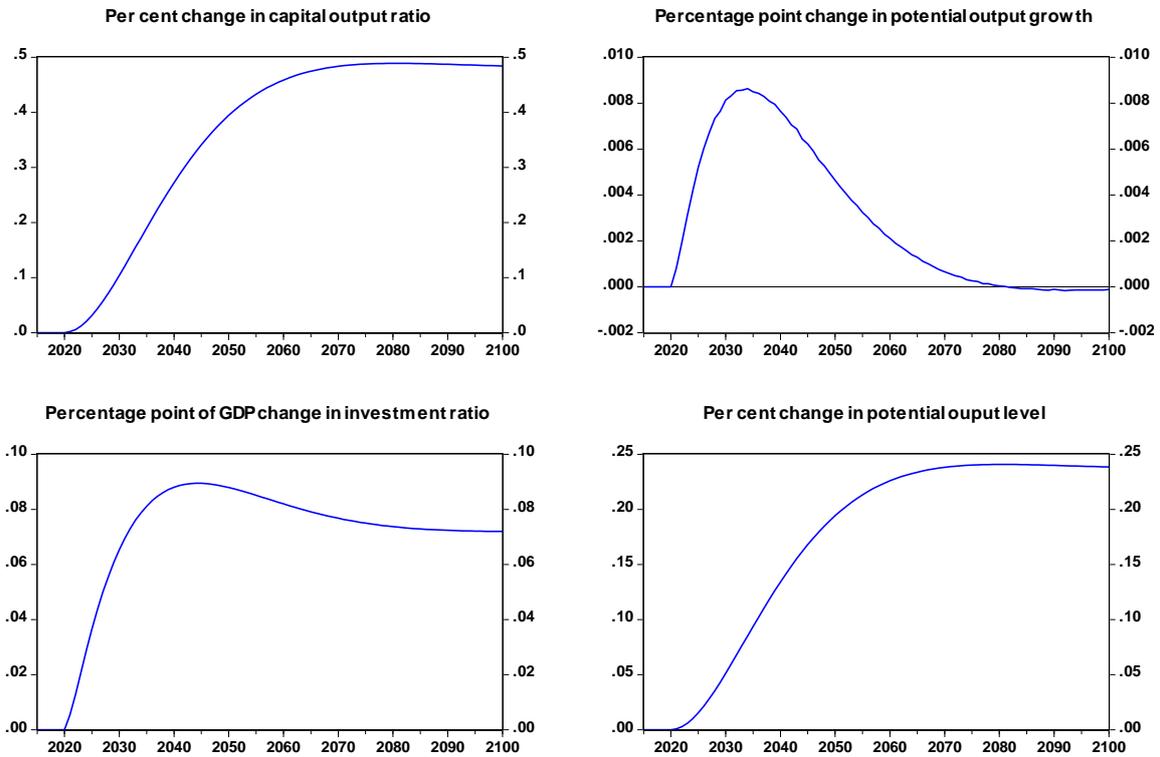
**Figure 9. Impact of a one percentage point increase in trend labour efficiency/employment growth**



**Figure 10. Impact of a 0.3 point fall in the ETCR or EPL indices**



**Figure 11. Impact of a one percentage point cut in the statutory corporate income tax rate**



**Figure 12. Impact of a one percentage point fall in domestic and global corporate borrowing rates**

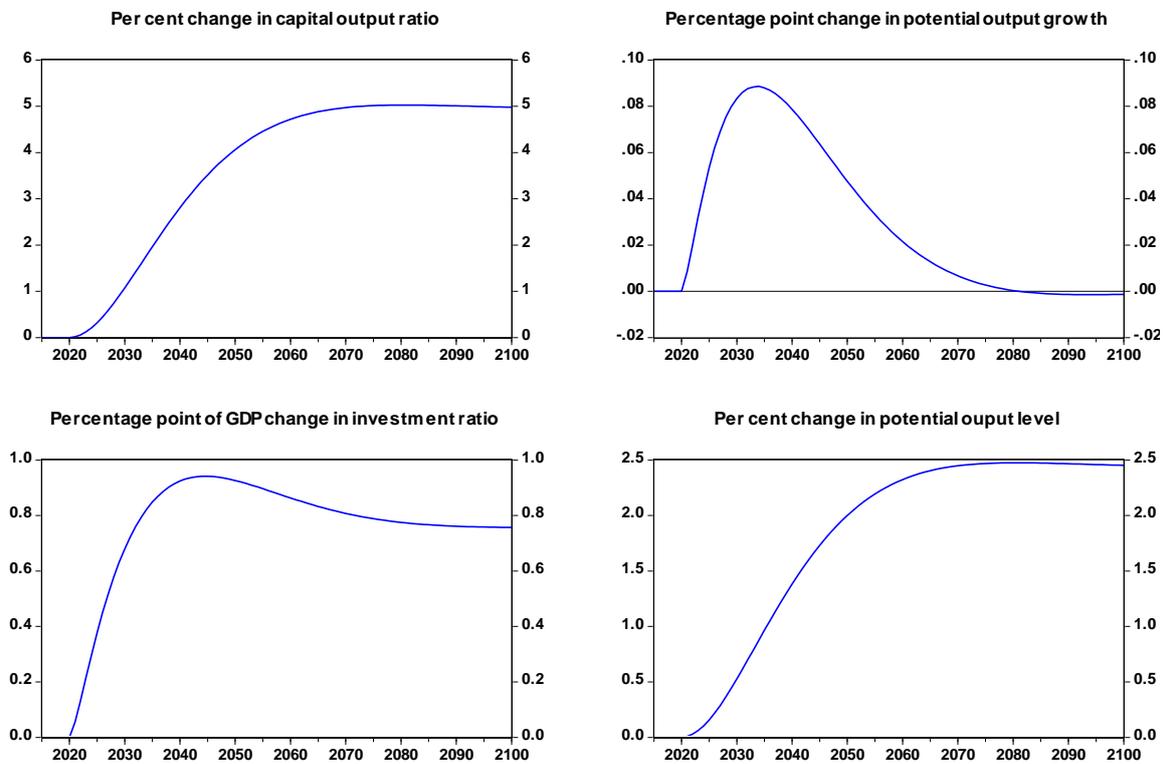
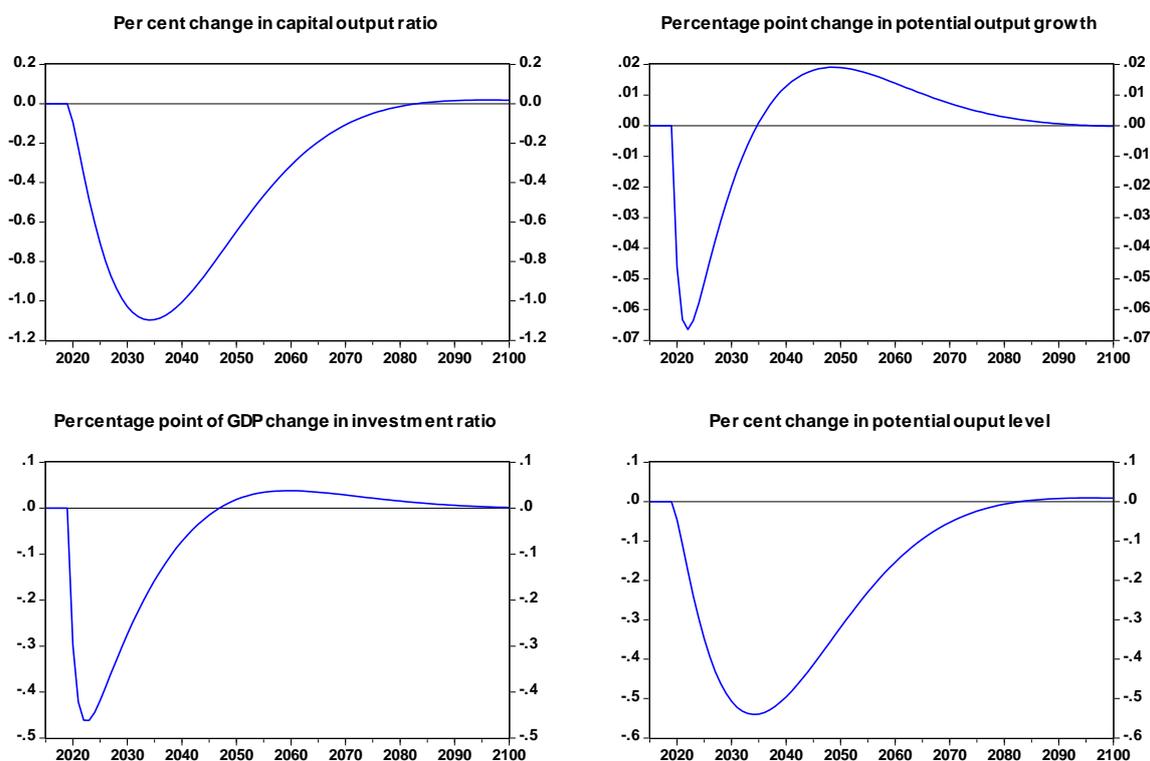


Figure 13. Impact of a temporary (5 year) 1% negative output gap



### 3.4. Total capital stock

58. To recap, the total productive capital stock over history ( $K_t$  in [8] and  $KTPV\_AV$  in EO mnemonics) is split between government sector capital and business sector capital stocks as of the last year of the historical period, following the method described previously. Then, over the projection period, the two types of capital stocks are projected using different methodologies. The total capital stock measure entering the production function is then obtained with:

$$K_t = K_{B_t} + K_{G_t} \quad [31]$$

This way of proceeding implicitly assumes that the output sensitivity of one unit of government sector capital in the production function is the same as one unit of business sector capital. This in turn implies that the respective output elasticities are proportional to the relative sizes of government and business sector capital stocks. Depending on the country, the business sector capital stock is estimated to be between two and six times larger than the government sector's, with the central estimate around four. Therefore, output elasticities range between 0.22 and 0.28 for the business sector capital stock, and 0.05 to 0.11 for the government sector, with central estimates respectively around 0.25 and 0.08 (their sum having to be 0.33 as in [8]). By comparison, Bom and Ligthart (2014<sub>[34]</sub>) estimate the output elasticity of public capital at about 0.11, which corresponds in the framework used here to a ratio of business to government sector capital of two – the low end of the range.

### 3.5. Housing investment

59. As explained previously, housing does not enter the capital stock concept used in the production function. But housing investment ( $IHV_t$ ) is nevertheless needed to obtain total investment, which is used for instance in the current account balance identity (see section 4). In typical OECD countries housing investment accounts for approximately a quarter of total investment, or about 5% of GDP, with large cyclical variations. It is projected by assuming that its ratio to real GDP ( $GDPV_t$ ) gradually converges to the average ratio over the last 20 years of the historical period ( $IHV\_ratio\_avg$ ):

$$\Delta \log(IHV_t) = \Delta \log(GDPV_t) - \theta \left( \log \left( \frac{IHV_{t-1}}{GDPV_{t-1}} \right) - \log(IHV\_ratio\_avg) \right) \quad [32]$$

where  $\theta$  is the speed at which convergence takes places, usually assumed to be 0.1. A long period is used to compute the long-run target because housing investment is subject to large and elongated cycles, with long periods of boom (for instance in the pre-2007 period in many countries) and long periods of slumps (for instance in the post-2007 period). Future improvements to the model could seek to connect housing investment to demographics or to interest rates.

### 3.6. Total investment

#### 3.6.1. Total fixed investment

60. Putting together projections for business sector fixed investment, government sector investment and housing investment yields the total volume of fixed investment ( $ITV_t$ ), also called gross fixed capital formation, by identity<sup>16</sup>:

$$ITV_t = IBV_t + IGV_t + IHV_t \quad [33]$$

As explained previously, the assumption is that investment prices ( $P_t^I$ ) increase by less than output prices ( $P_t^Y$ ) by a constant (negative) parameter ( $drpi$ ) each year:

$$\Delta \log(P_t^I) = \Delta \log(P_t^Y) + drpi \quad [34]$$

As this same investment price index is assumed to apply to all three investment categories, total fixed investment in nominal terms ( $IT_t$ ) is obtained with:

$$IT_t = ITV_t \cdot P_t^I \quad [35]$$

<sup>16</sup> This identity is different in the case of Norway to account for investment in the oil and shipping sectors, see Annex C.

### 3.6.2. Inventory investment and total investment

61. In a way similar to housing investment, inventory investment as a percentage of GDP ( $ISKQ_t$ ) is projected by assuming that it converges to its average over the last 10 years of the historical period ( $ISKQ_{avg}$ ):

$$ISKQ_t = \vartheta ISKQ_{t-1} + (1 - \vartheta)ISKQ_{avg} \quad [36]$$

where  $\vartheta$  is a parameter controlling the speed at which the long-term target is reached, assumed to be 0.8. Inventory investment in nominal terms ( $ISK_t$ ) is then obtained by identity using nominal GDP ( $GDP_t$ ):

$$ISK_t = \frac{ISKQ_t}{100} \cdot GDP_t \quad [37]$$

62. Total investment in nominal terms ( $ITISK_t$ ), also called gross capital formation, is obtained by combining fixed investment and inventory investment:

$$ITISK_t = IT_t + ISK_t \quad [38]$$

This investment aggregate is the one that enters the current account balance identity.

## 4. Current account balance

### 4.1. Current account balance and net investment position for individual countries in the model

63. As mentioned previously, the current account balance in local currency ( $CB_t$ ) is calculated as the difference between flows of aggregate savings ( $SAVTG_t$ , from section 2) and investment ( $ITISK_t$ , from section 3) following the identity:

$$CB_t = SAVTG_t - ITISK_t + CBR_t \quad [39]$$

where  $CBR_t$  is a statistical discrepancy that reconciles the different concepts in the System of National Accounts. The value of this discrepancy – often not negligible – is assumed to remain constant at its value in the last historical period, which means that it declines slowly as a percentage of GDP over the projection period. The current account balance as a percentage of GDP ( $CBGDPR_t$ ) is then:

$$CBGDPR_t = \frac{CB_t}{GDP_t} \cdot 100 \quad [40]$$

For constructing aggregates, it is also useful to have a current account balance expressed in US dollars ( $CBD_t$ ), which is obtained with:

$$CBD_t = CB_t \cdot EXCH_t \quad [41]$$

where  $EXCH_t$  is the USD per national currency exchange rate.

64. Historical data on net international investment positions in US dollars are sourced from the IMF's Balance of Payments database and converted to percentages of GDP. Over the projection period, the net international investment position as a percentage of GDP ( $NIIPQ_t$ ) follows:

$$NIIPQ_t = NIIPQ_{t-1} \cdot \frac{GDP_{t-1}}{GDP_t} + CBGDPR_t \quad [42]$$

It is also necessary to apply this equation to the last few years of the historical period to extend the net international investment position series up to the end of the *OECD Economic Outlook* (EO) horizon, which is used as the jump-off point for the long-run projections. To this end the short-run GDP and current account balance projections of the EO are used. The net international investment position projection enters the aggregate saving rate equation (see section 1) and determines a long-term interest rate risk premium, which feeds back into investment via the user cost of capital. Both mechanisms help to limit the build-up of within-country and international imbalances.

#### 4.2. Current account balance for the rest of the world

65. While countries not included in the model account for about 10% of current global GDP, the omitted countries include several important oil producers responsible for a disproportionate share of cross-border flows. Therefore, it is important to include them in a global aggregate of the current account balance, especially since this aggregate is used to balance flows of savings and investment at the global level (see next subsection). For this purpose, the current account balance of the *OECD Economic Outlook* region called Oil Producers (OIL) is modelled explicitly.<sup>17</sup> The baseline assumption is that net oil trade volumes remain constant for this region. Next, an error-correction equation linking the aggregate current account balance for the region ( $OIL\_CBD_t$ , expressed in US dollars) to the net volume of oil trade ( $OIL\_OILNETEXPB_t$ ) and the oil price ( $WPBRENT_t$ ) is estimated using historical data.<sup>18</sup> The estimated equation is:

$$\Delta OIL\_CBD_t = 0.73 \cdot \Delta(OIL\_OILNETEXPB_t \cdot WPBRENT_t) - 0.36 \cdot (OIL\_CBD_{t-1} - 0.29 \cdot OIL\_OILNETEXPB_{t-1} \cdot WPBRENT_{t-1}) + \varepsilon_t \quad [43]$$

where  $\varepsilon_t$  is a residual that is assumed to decline to zero by 2030 in the projection. The equation indicates that, in the short-run, about three quarters of the variation in the oil

<sup>17</sup> This region includes Azerbaijan, Kazakhstan, Turkmenistan, Brunei, Timor-Leste, Bahrain, Iran, Iraq, Kuwait, Libya, Oman, Qatar, United Arab Emirates, Yemen, Ecuador, Trinidad and Tobago, Venezuela, Algeria, Angola, Chad, Republic of Congo, Equatorial Guinea, Gabon, Nigeria and Sudan.

<sup>18</sup> The equation is estimated using data from the OECD Economic Outlook No. 101 database and data on oil trade volumes from the International Energy Agency. The estimation period is 1991 to 2016. All three coefficient estimates are statistically significant at the 1% level. A constant is included in the estimation but is not statistically significant. The  $R^2$  is 0.95 and the Durbin-Watson statistic is 1.96.

trade balance in value passes through into the current account balance; while in the longer run, after savings from other sources and investment have had time to adjust, the oil region's current account balance is equal to about 30% of the value of the oil trade balance. The speed of convergence to the long-run is high: more than a third of the gap relative to equilibrium is eliminated each year.

#### 4.3. Global current account balance and equilibrating mechanism

66. The global current account balance expressed in US dollars is the sum of the 42 individual country current account balances (index by  $i$ ), to which is added the oil region's:

$$WORLD\_CBD_t = \sum_i CBD_{i,t} + OIL\_CBD_t \quad [44]$$

and its counterpart expressed as a percentage of global GDP is computed using market exchange rates ( $EXCH_i$ ):

$$WORLD\_CBGDPR_t = \frac{WORLD\_CBD_t}{\sum_i (GDP_{i,t} \cdot EXCH_{i,t})} \cdot 100 \quad [45]$$

Conceptually, the global current account balance should always be zero. Because of imperfect measurement, however, this is typically not the case. Also, the balance as computed here does not cover all countries in the world, so one would expect a non-zero value. Furthermore, there is a discrepancy between the numerator of [45], which includes the current account balance of the oil region, and its denominator, which only sums over the nominal output of the countries included in the model. This is unavoidable without a projection of nominal output for the oil region, which is currently outside the scope of the model.

67. The conceptual issues just mentioned are not of great importance because the level of the world's current account balance does not feature elsewhere in the model. Rather, it is the period-to-period change in this variable, as well as its cumulative change since the start of the projection period, that are used to assess the global equilibrium between saving and investment flows. These determine a global interest rate premium ( $WORLD\_RWEQ_t$ ) according to the following equation:

$$\Delta WORLD\_RWEQ_t = \varphi_1 \Delta WORLD\_CBGDPR_t + \varphi_2 (WORLD\_CBGDPR_{t-1} - \overline{WORLD\_CBGDPR}) \quad [46]$$

where  $\overline{WORLD\_CBGDPR}$  is the value of the world's current account balance as a percentage of world GDP in the last year of the historical period, while  $\varphi_1$  and  $\varphi_2$  are parameters controlling the relative weight placed on the two terms in determining the global interest rate premium. This premium is set to zero in the last year of the historical period and evolves following [46] only to the extent that the world's current account changes from its value at the end of the historical period. Interest rates in all countries are affected by changes in this premium, which in turn affects investment via the user cost of capital, so the balancing of savings and investment at the global level occurs primarily through changes in investment. For example, an *a priori* positive evolution of the world

current account balance indicates a surplus of saving over investment, triggering a fall in global interest rates, which boosts investment and therefore limits the *a posteriori* global current account imbalance. The parameters  $\varphi_1$  and  $\varphi_2$  must be calibrated so as to ensure that this global balance is roughly achieved. In the past, values like  $\varphi_1 = -0.05$  and  $\varphi_2 = -0.1$  were used.

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## Annex A. Descriptive statistics for saving rate equation

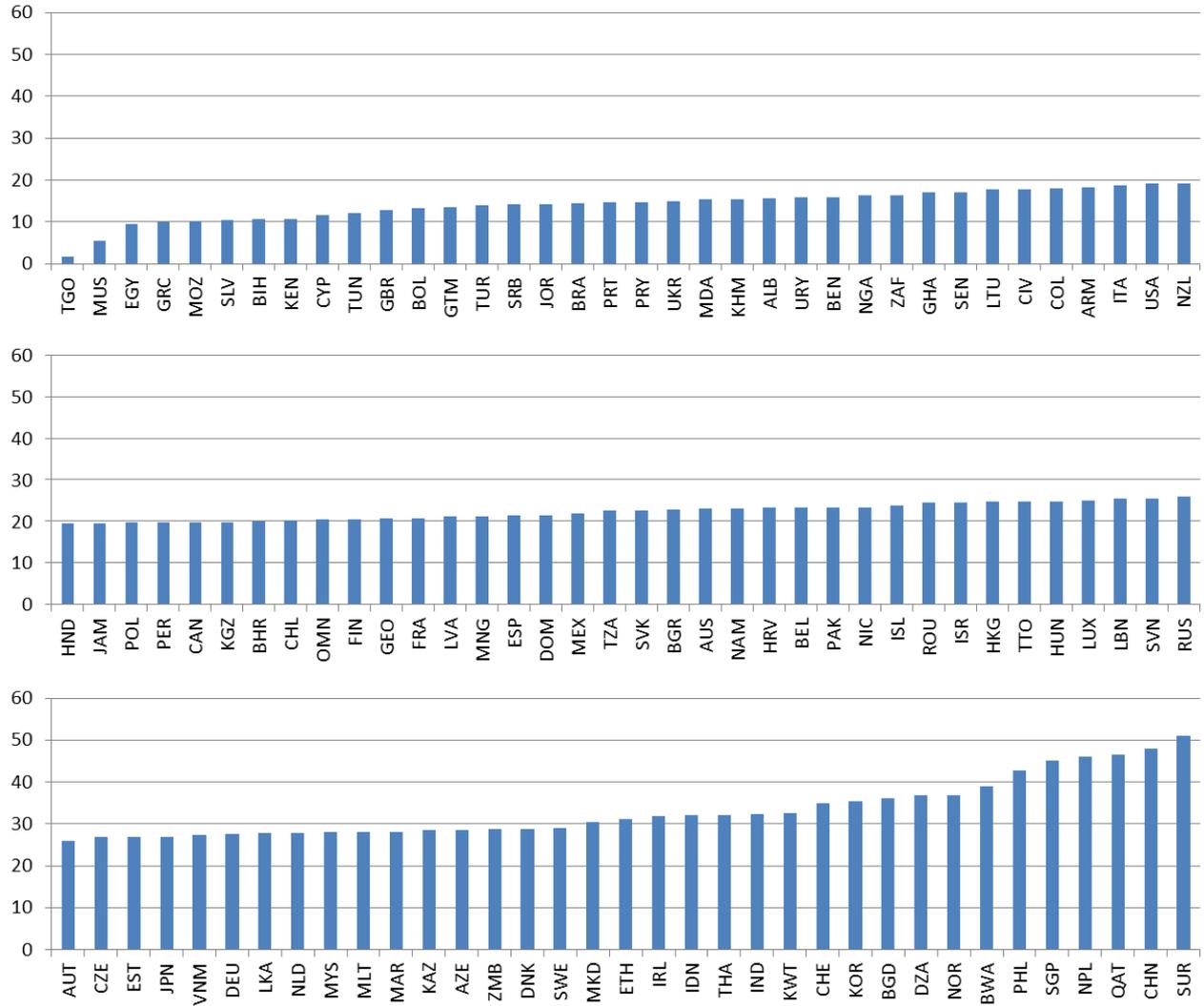
**Table A A.1. Descriptive statistics for the variables used in estimation**

Variable	Source	Countries	Full sample, 1980-2015					Cross-section, last period		
			Obs.	Mean	Std. Dev.	Min	Max	Obs.	Mean	Std. Dev.
Log GDP per Capita	WEO	139	8037	9.20	1.17	5.86	11.80	136	9.48	1.08
Gini Coefficient	WYD	121	5707	37.56	10.71	17.84	67.21	90	39.91	9.54
Government Budget Balance, % of GDP	WEO	139	3470	-2.21	6.85	43.30	-151.31	137	-2.97	6.43
Government Primary Expenditure, % of GDP	WEO	117	2175	30.99	11.62	5.01	59.24	105	31.39	10.85
Life Expectancy (years)	WDI	141	7727	65.44	10.62	19.27	84.28	140	73.02	7.64
National Saving, % of GDP	WDI	132	3998	22.46	10.19	0.03	77.34	118	23.56	11.48
Net International Investment Position, % of GDP	BOP	106	7598	-20.35	36.79	-99.91	98.41	92	-	38.72
									22.35	
Oil Trade Balance, % of GDP	IEA	138	5043	2.50	11.79	-47.08	59.69	133	2.14	10.54
Old-Age Dependency Rate (%)	WPP	142	7784	3.66	2.64	0.16	17.115	139	5.37	3.83
Private Credit, % of GDP	WDI	137	5703	41.23	36.72	1.046	199.24	124	60.66	42.01
Productivity Growth (%)	WEO	135	7701	1.67	3.24	-8.97	8.99	131	1.61	2.57
Real Interest Rate (%)	WDI	128	3417	5.59	13.38	-97.81	130.78	92	6.46	5.78
Log Terms of Trade	WDI	138	8037	4.69	0.30	3.06	6.58	136	4.74	0.36
Urbanisation Rate (%)	WDI	141	7806	53.62	23.82	3.06	100	139	63.57	21.47

*Note:* BOP refers to the IMF's Balance of Payments and International Investment Position Statistics database; IEA refers to the International Energy Agency; WDI refers to the World Bank's World Development Indicators database; WEO refers to the IMF's World Economic Outlook Database, April 2017 Edition; WPP refers to the United Nations' World Population Prospects; WYD refers to the World Bank's World Income Distribution database.

**Figure A A1. National Saving Rate, % of GDP**

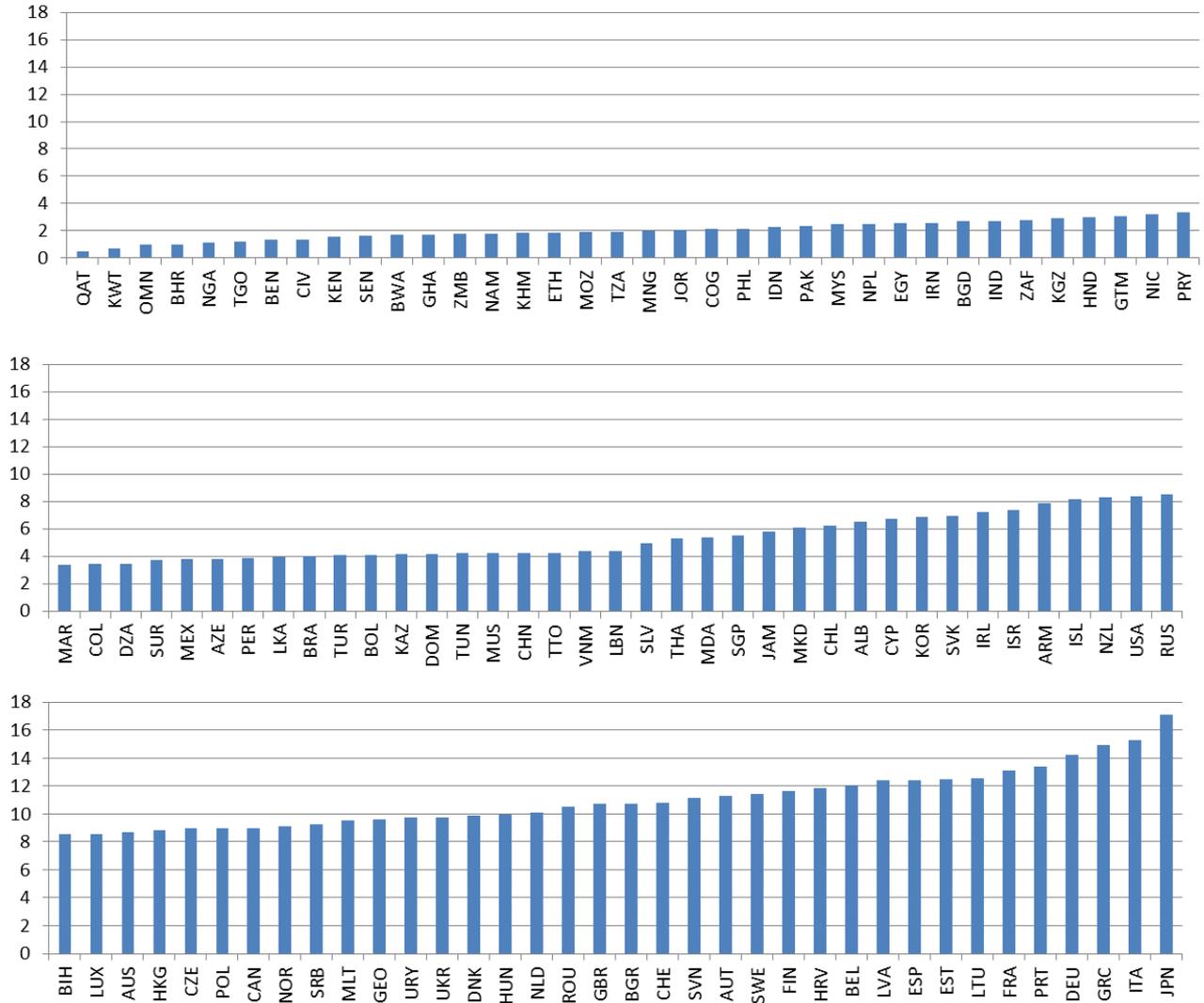
Last period used in estimation (2015)



Source: World Bank's World Development Indicators database.

**Figure A A.2 Old-Age Dependency Rate, %**

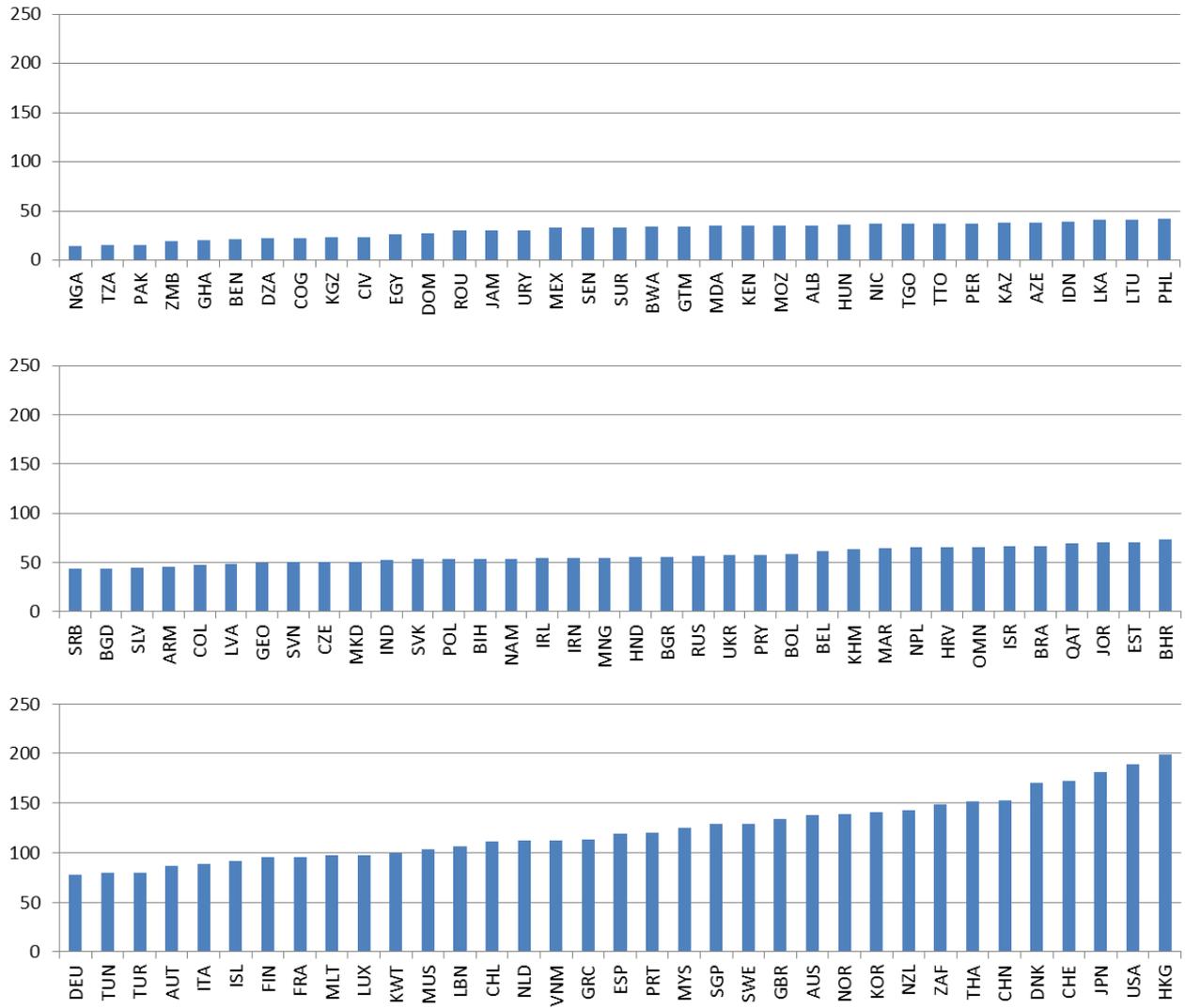
Last period used in estimation (2015)



Source: United Nations' World Population Prospects database.

**Figure A A.3. Private Credit, % of GDP**

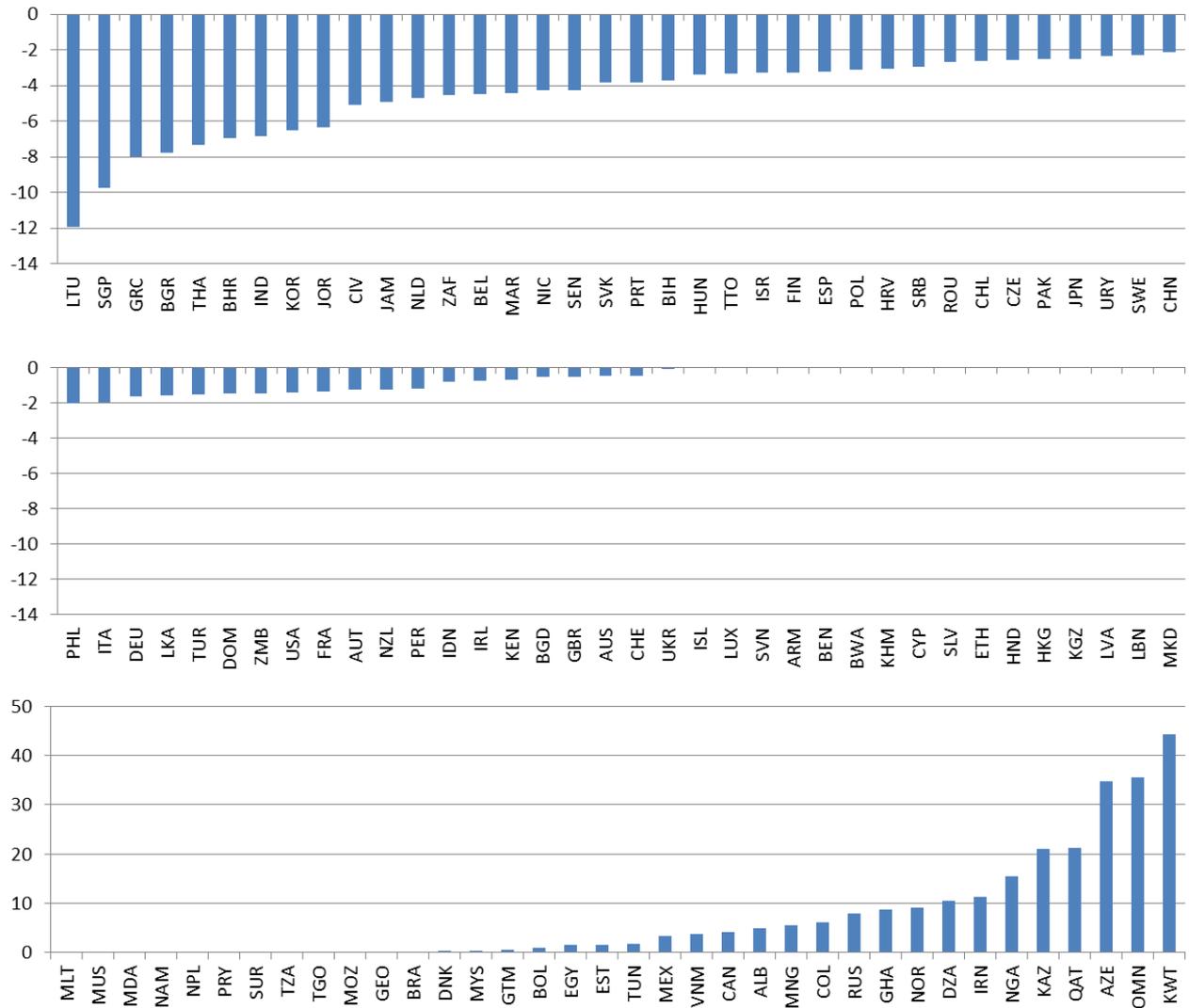
Last period used in estimation (2015)



Source: World Bank's World Development Indicators database.

**Figure A A.4. Oil Trade Balance, % of GDP**

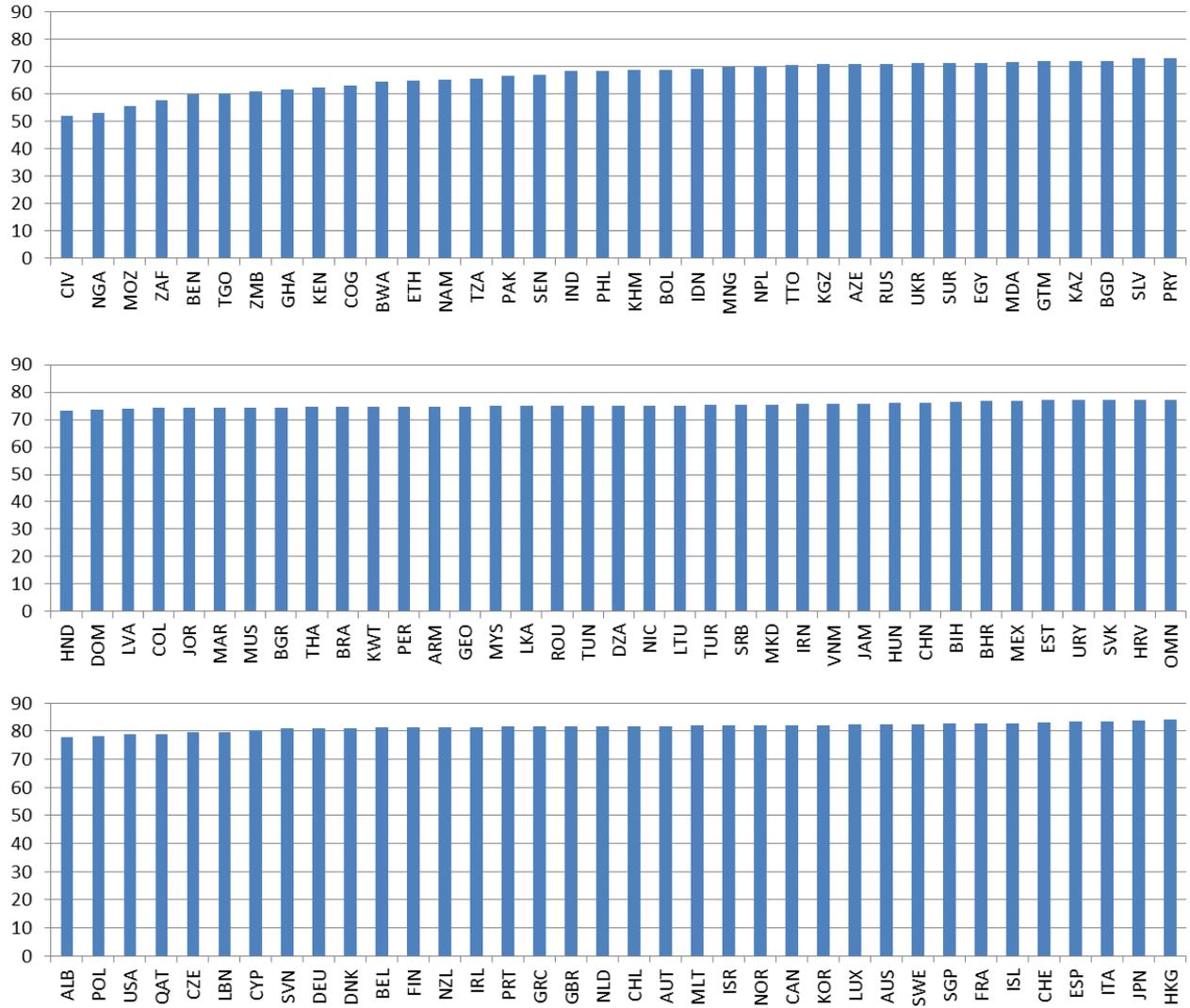
Last period used in estimation (2015)



Source: International Energy Agency's Oil information database, OECD Economic Outlook No. 100 database and authors' calculations.

**Figure A A.5. Life Expectancy, Years**

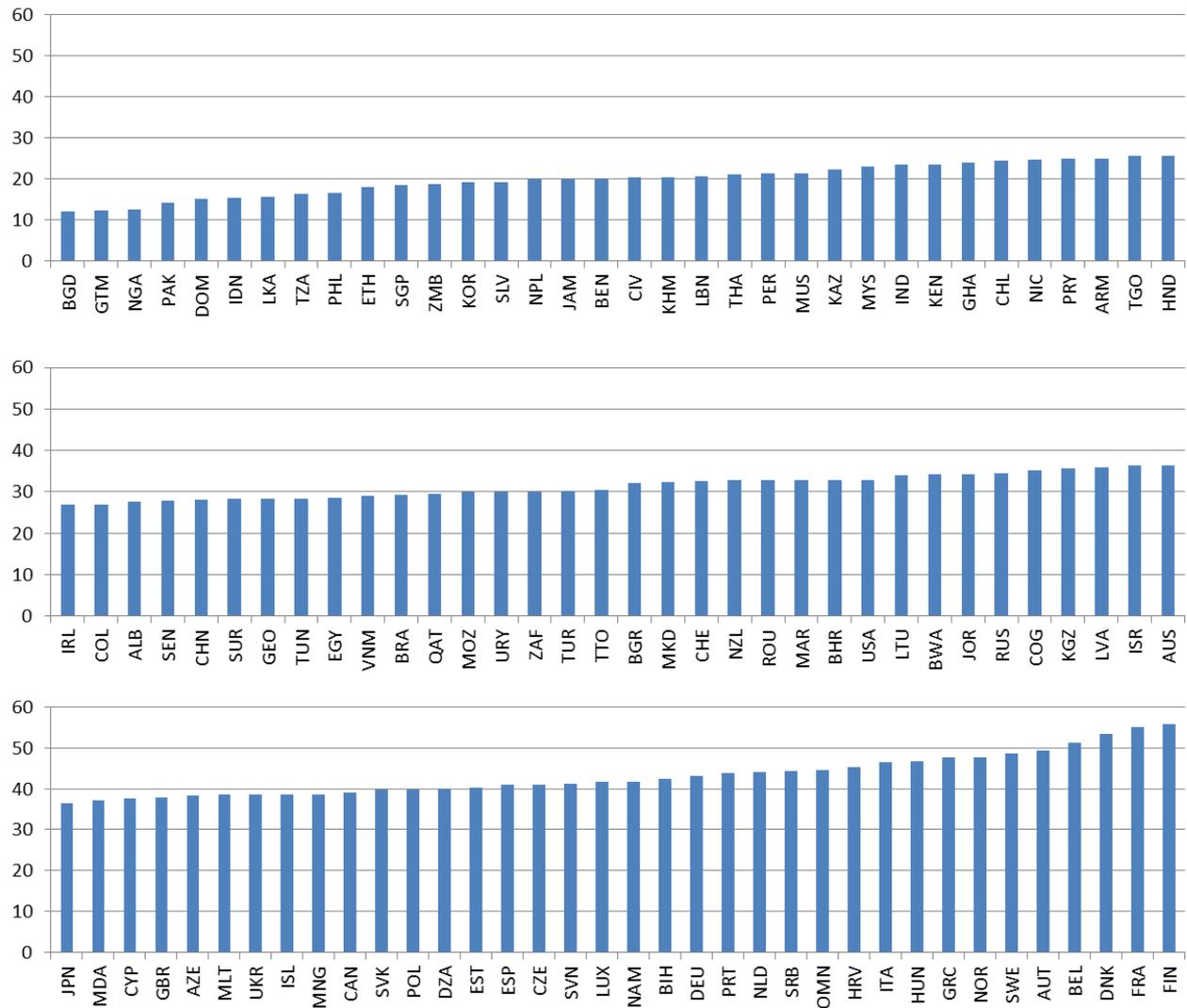
Last period used in estimation (2015)



Source: World Bank's World Development Indicators database.

**Figure A A.6. Government Primary Expenditure, % of GDP**

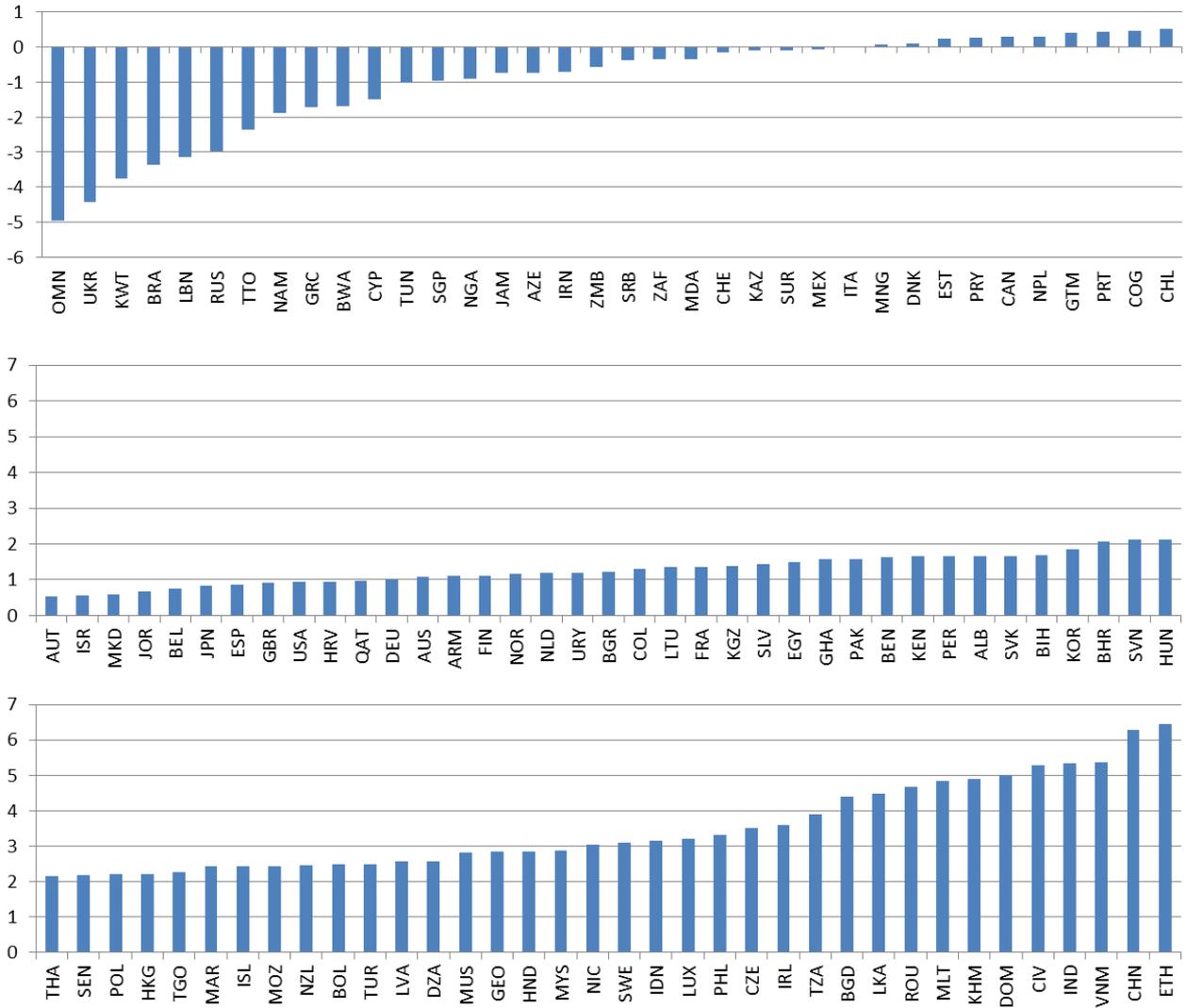
Last period used in estimation (2015)



Source: IMF's World Economic Outlook, April 2017 database.

**Figure A A.7. Labour Productivity Growth Rate, %**

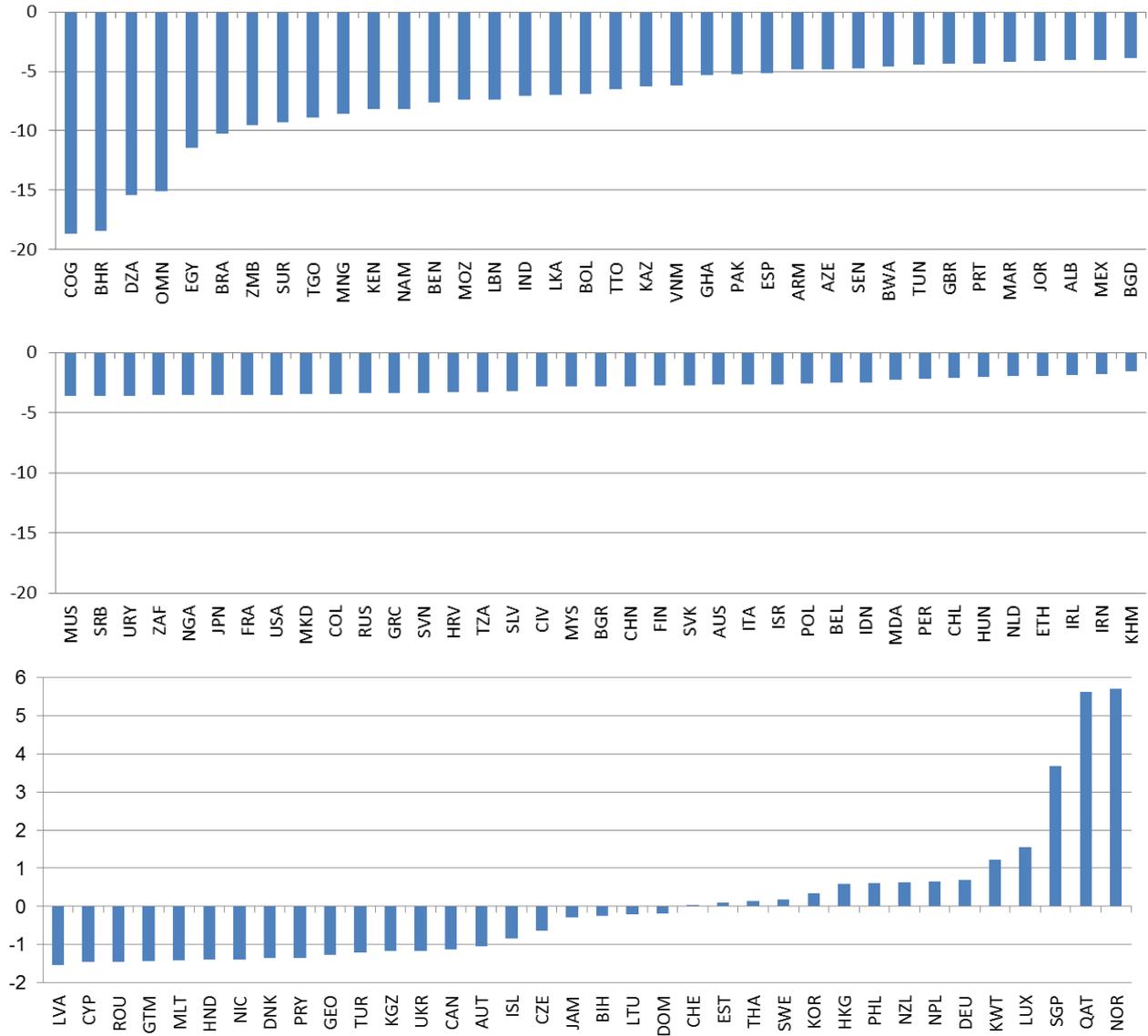
Last period used in estimation (2015)



Source: IMF's World Economic Outlook, April 2017 database.

**Figure A A.8. Government Budget Balance, % of GDP**

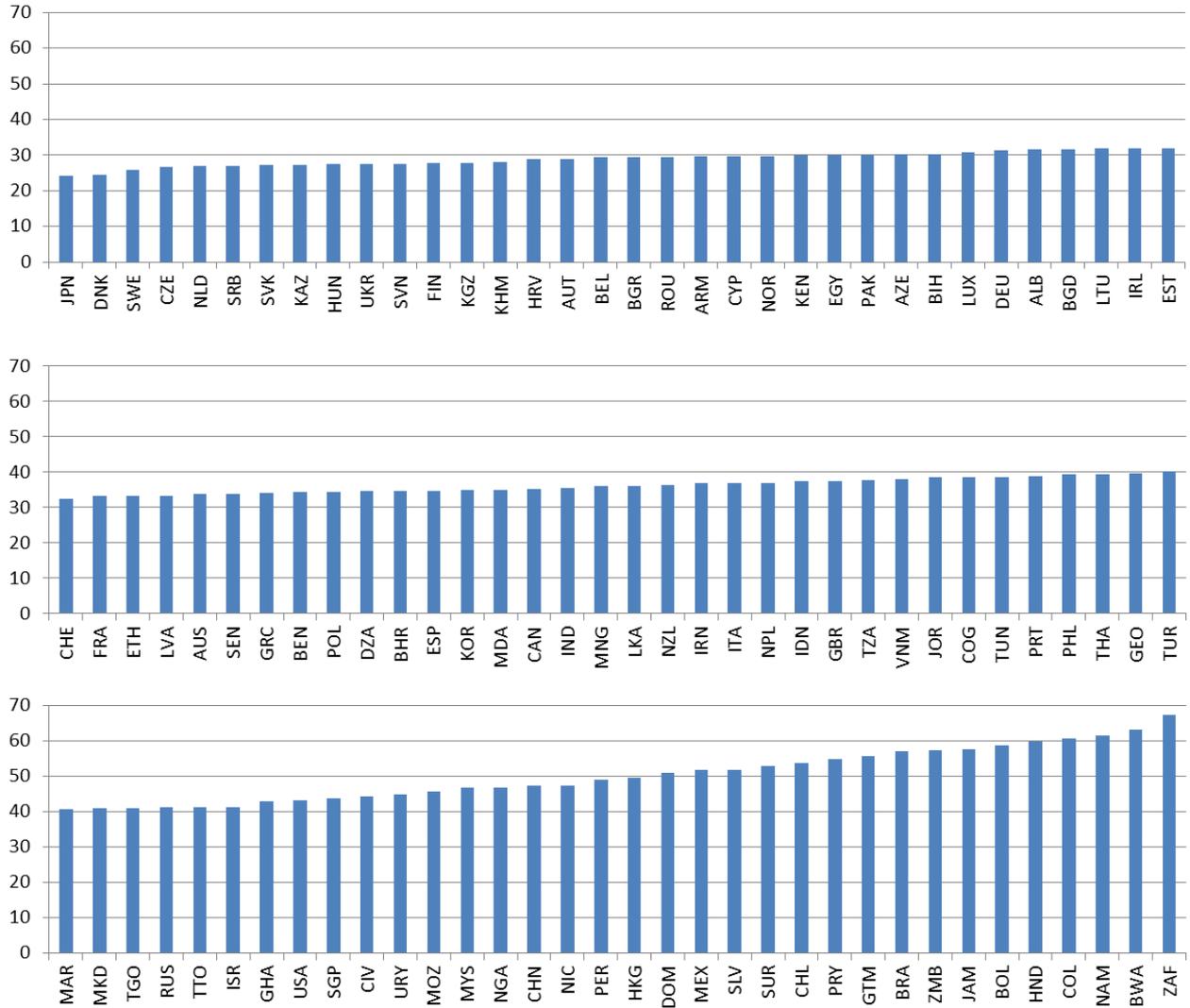
Last period used in estimation (2015)



Source: IMF's World Economic Outlook, April 2017 database.

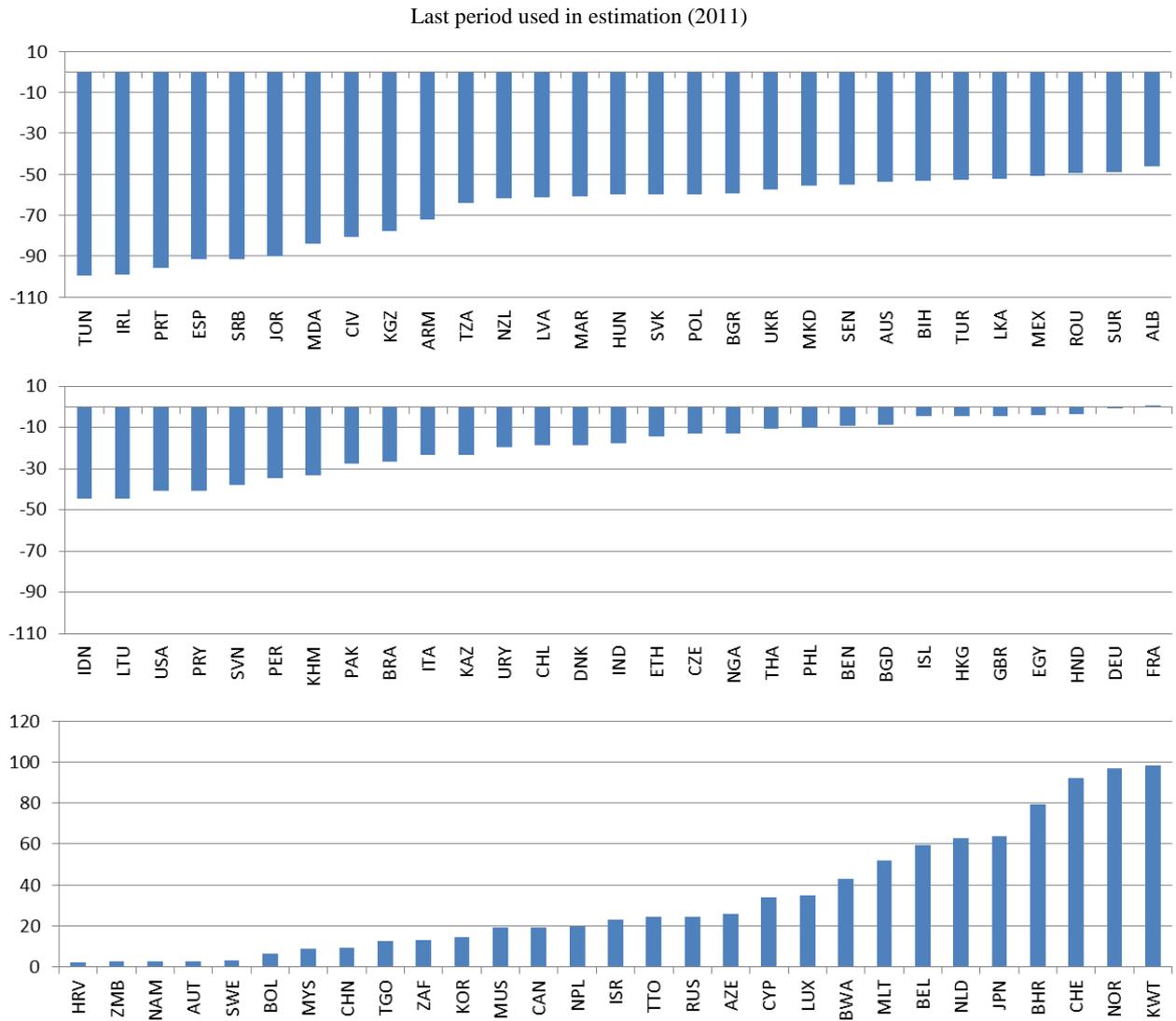
**Figure A A.9. Income Inequality, Gini Coefficient**

Last period used in estimation (2011)



Source: World Bank's World Income Distribution database.

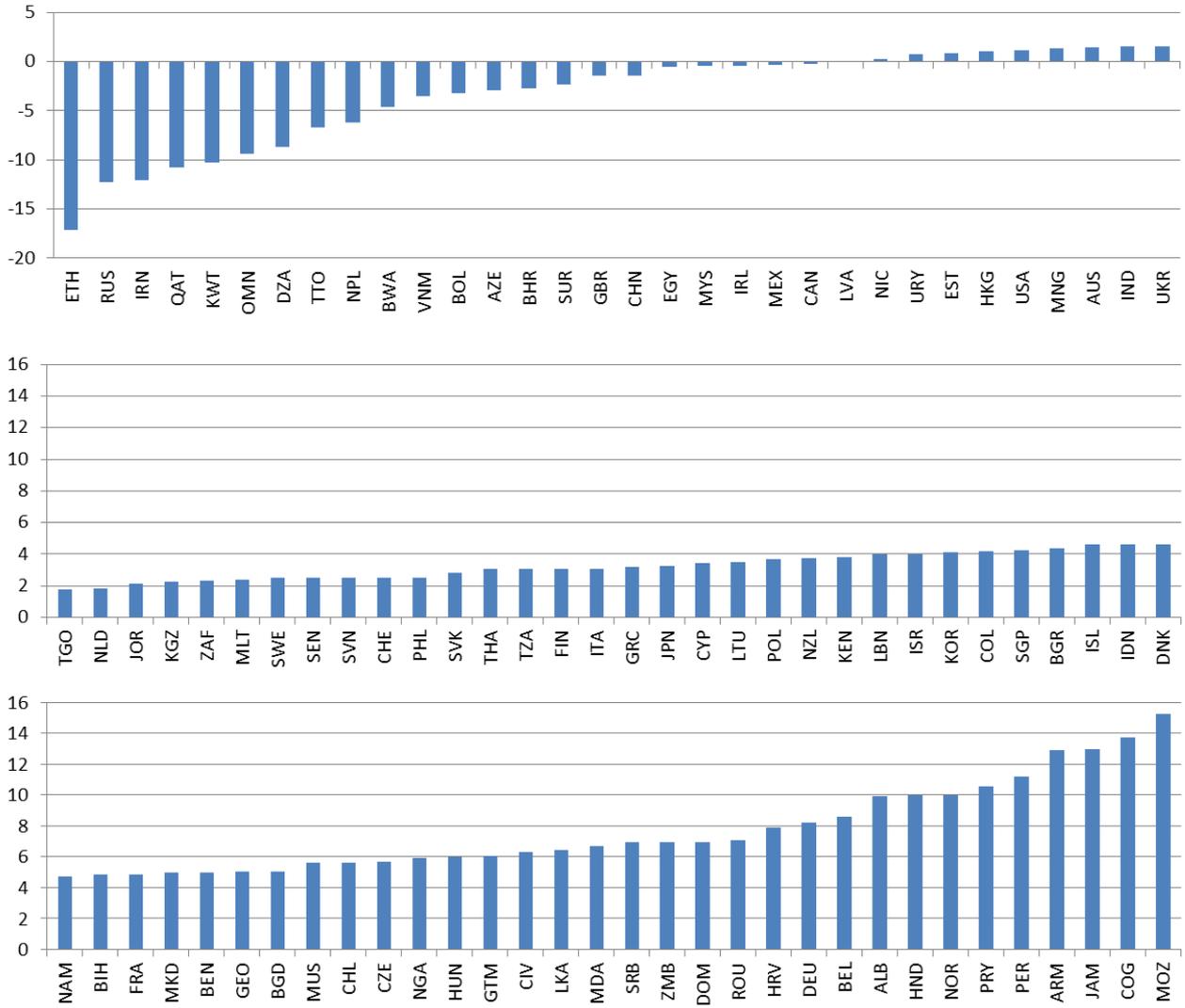
**Figure A A.10. Net International Investment Position, % of GDP**



Source: IMF's Balance of Payments and International Investment Position Statistics database.

**Figure A A.11. Real Interest Rate, %**

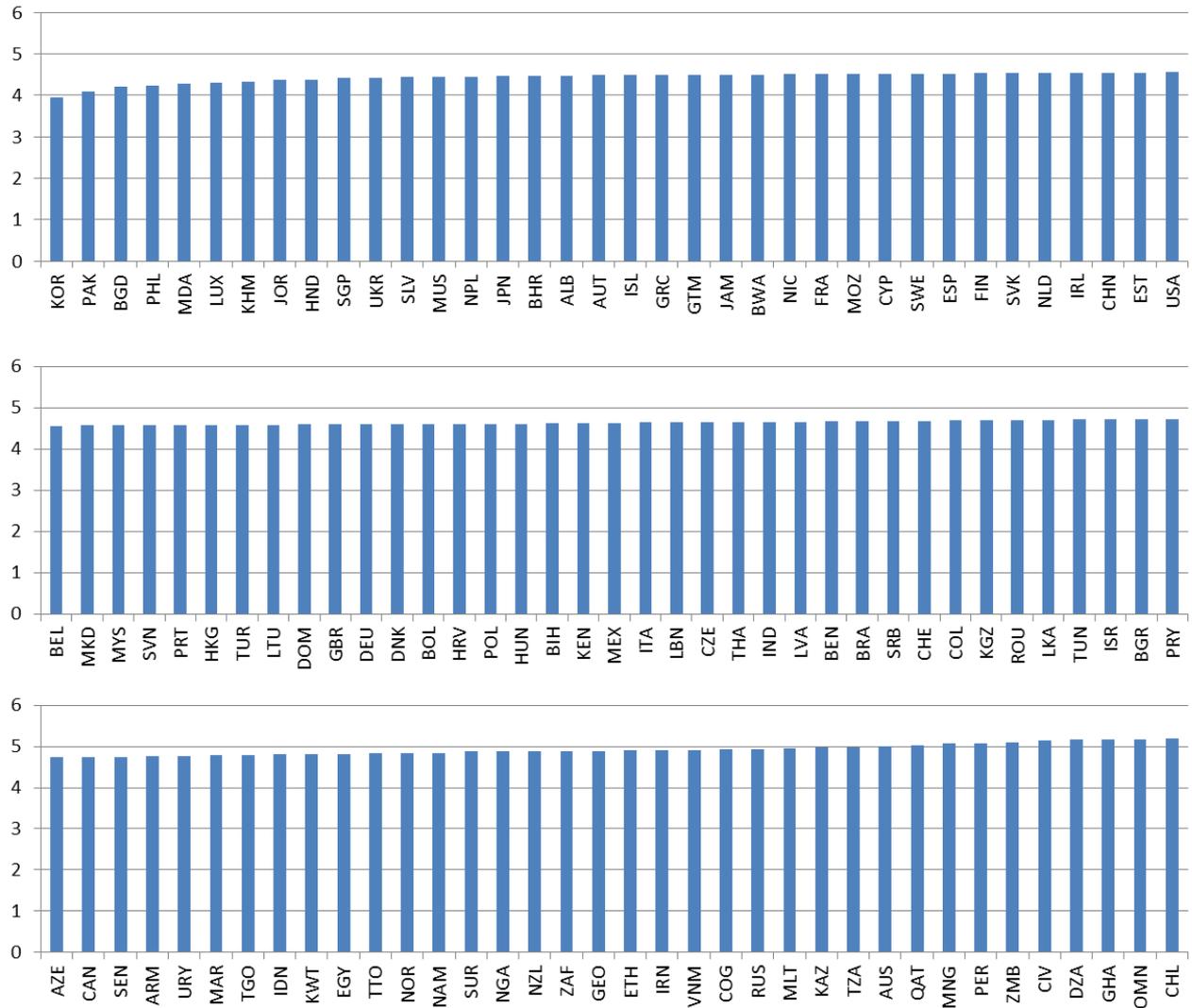
Last period used in estimation (2011)



Source: World Bank's World Development Indicators database.

**Figure A A.12. Log of Terms of Trade**

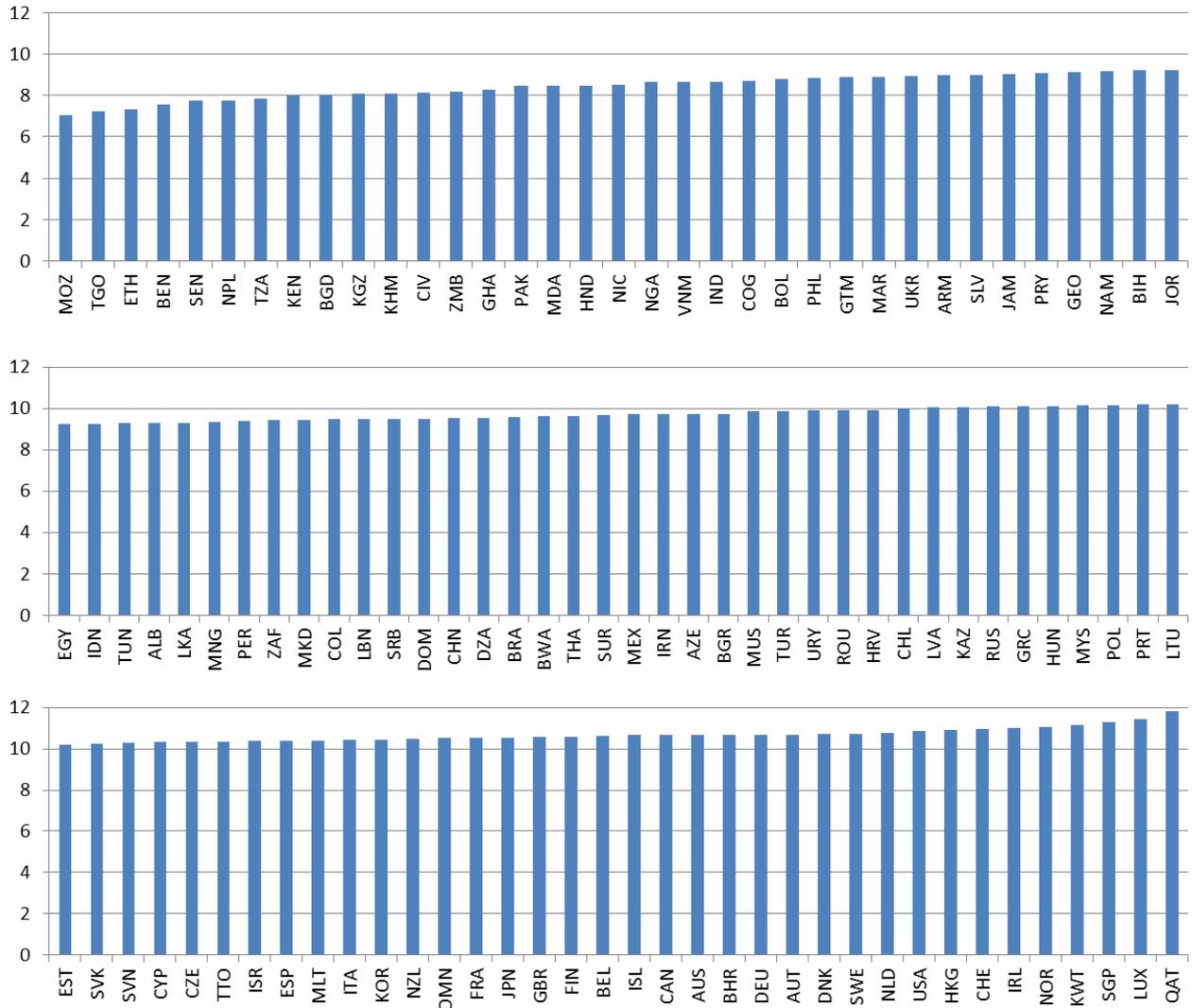
Last period used in estimation (2015)



Source: World Bank's World Development Indicators database and authors' calculations.

**Figure A A.13. Log GDP per Capita, USD at 2010 Purchasing Power Parity**

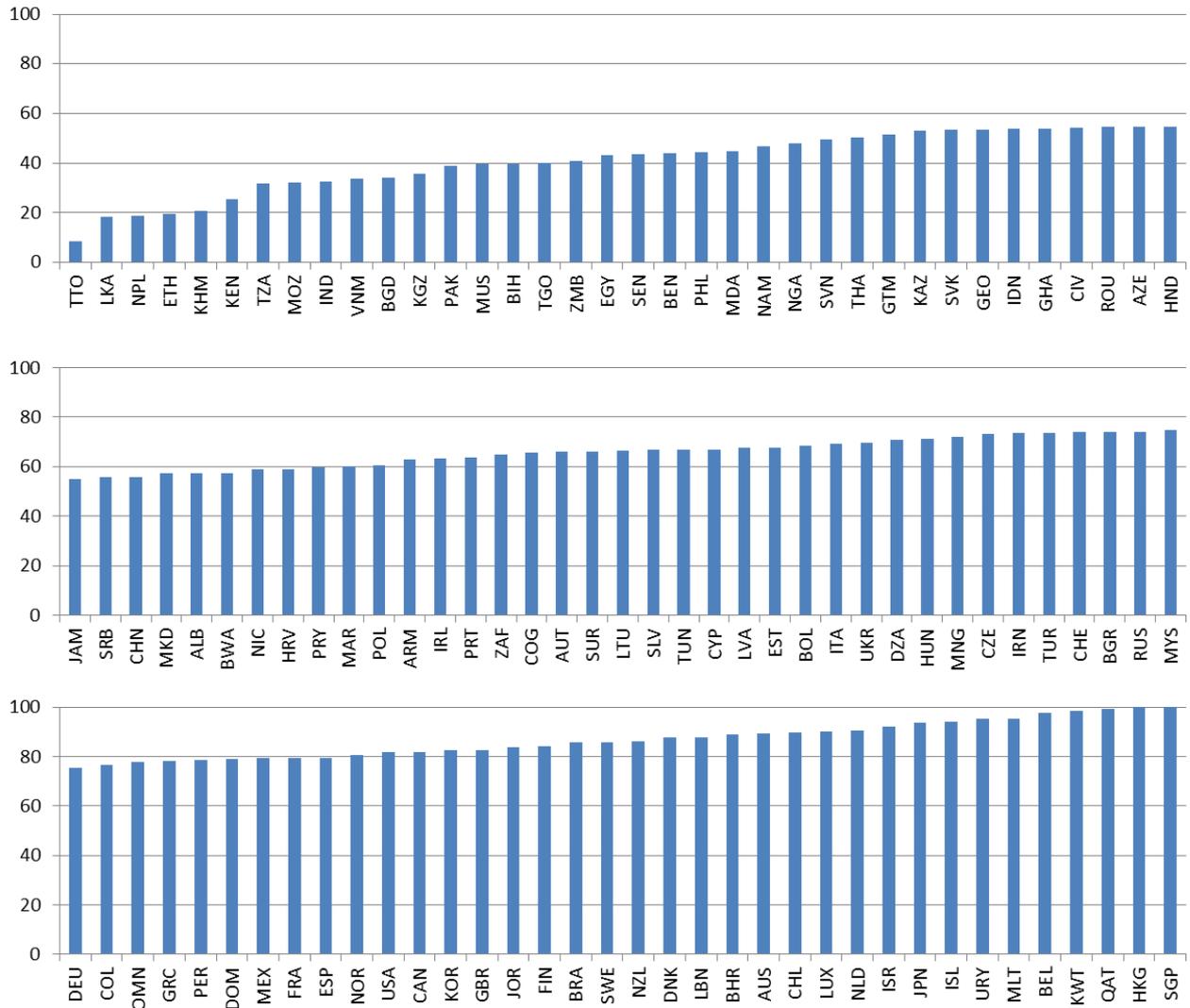
Last period used in estimation (2015)



Source: IMF's World Economic Outlook, April 2017 database and authors' calculations.

**Figure A A.14. Urbanisation Rate, %**

Last period used in estimation (2015)



Source: World Bank's World Development Indicators database.

## Annex B. Robustness tests

**Table A B.1. Robustness tests**

Dependent variable: National Saving Rate, % of GDP

	(1)	(2)	(3)	(4)
	Preferred equation	OECD only	Non-OECD only	Without fixed effects
Lagged National Saving Rate, % of GDP	0.680*** (0.037)	0.726*** (0.050)	0.671*** (0.042)	0.912*** (0.015)
Old-Age Dependency Rate, %	-0.353*** (0.151)	-0.316** (0.139)	-0.204 (0.286)	0.007 (0.034)
Private Credit, % of GDP	-0.017*** (0.006)	-0.009* (0.007)	-0.024* (0.016)	-0.002 (0.002)
Oil Trade Balance, % of GDP	0.266*** (0.066)	0.383*** (0.119)	0.262*** (0.071)	0.038*** (0.013)
Life Expectancy, Years	0.511*** (0.154)	0.487*** (0.184)	0.511*** (0.160)	0.038*** (0.007)
Government Primary Expenditure, % of GDP	-0.251*** (0.042)	-0.183*** (0.048)	-0.294*** (0.052)	-0.028*** (0.012)
Productivity Growth, %	0.096*** (0.038)	0.176*** (0.074)	0.078* (0.042)	0.154*** (0.029)
R-squared	0.892	0.928	0.888	0.854
Number of observations	1816	746	1070	1816
Number of countries	110	35	75	110

*Note:* Asterisks (\*, \*\*, \*\*\*) indicate the statistical significance level (10%, 5%, 1%) of the coefficients. Figures in the parentheses are heteroscedasticity-consistent standard errors. All equations are estimated with OLS, and columns 1 to 3 include country and time fixed effects. Columns 1 and 4 are estimated on the full sample, while columns 2 and 3 use restricted samples as indicated in the first row of the table. See Table AA.1 in Annex A for data sources.

## Annex C. Oil and shipping sectors investment in Norway

68. The total investment identity is different in the case of Norway as private sector non-residential investment in the oil and shipping sectors ( $IOILV_t$ ) enters separately from total private sector non-residential gross fixed capital formation ( $IOBV_t$ ), which excludes the oil and shipping sectors:

$$ITV_t = IOBV_t + IGV_t + IHV_t + IOILV_t \quad [C1]$$

69. The approach used to project oil and shipping sectors investment is similar to that for inventory investment in the main text. Oil and shipping investment as a share of total fixed investment ( $IOILV\_share_t$ ) is assumed to converge to its average over the last 10 years of the historical period ( $IOILV\_share\_avg$ ):

$$IOILV\_share_t = \vartheta IOILV\_share_{t-1} + (1 - \vartheta)IOILV\_share\_avg \quad [C2]$$

where  $\vartheta$  is a parameter controlling the speed at which the long-term target is reached, assumed to be 0.8. Oil and shipping investment in volume terms ( $IOILV_t$ ) is then obtained by applying this proportion to the total fixed investment volume ( $ITV_t$ ):

$$IOILV_t = IOILV\_share_t \cdot ITV_t \quad [C3]$$

Using [C1], this expression can be re-written as:

$$ITV_t = \frac{IOBV_t + IGV_t + IHV_t}{(1 - IOILV\_share_t)} \quad [C4]$$

### Annex D. Summary of section 3

**Table A D.1. Summary of symbols used in the capital stock and investment equations**

Parameters and coefficients			
Symbol	Description	Method / Source	
$\alpha$	Labour share of income	Set to 0.67	
$k_g^{SS}$	Steady-state government sector capital stock-to-output ratio at jump-off point	Equation 12	
$\beta_1$	Coefficient on output gap in estimated business sector capital stock growth equation	Estimated – see Table 3	
$\beta_2$	Coefficient on one-period lagged dependent in estimated business sector capital stock growth equation	Estimated – see Table 3	
$\beta_3$	Coefficient on two-period lagged dependent in estimated business sector capital stock growth equation	Estimated – see Table 3	
$\beta_4$	Coefficient on sum of trend labour efficiency and employment growth in estimated business sector capital stock growth equation	Estimated – see Table 3	
$\beta_5$ and $\beta_6$	Coefficients on current account balance in estimated business sector capital stock growth equation	Estimated – see Table 3	
$\rho$	Speed of convergence to equilibrium in estimated business sector capital stock growth equation	Estimated – see Table 3	
$open$	Degree of capital account openness	Chinn and Ito (2006)	
$\omega$	Weight on capital account openness in business sector capital stock growth equation	Different values considered – see Table 3. Value of 0.8 chosen as preferred specification for projection equation.	
$IHV\_ratio\_avg$	Equilibrium ratio of housing investment to GDP	Average ratio over last 20 years in OECD Economic Outlook database	
$\theta$	Speed of convergence of housing investment to equilibrium	Set to 0.1	
$ISKQ\_avg$	Equilibrium share of inventory investment in GDP	Average share over last 10 years in OECD Economic Outlook database	
$\vartheta$	Parameter controlling speed of adjustment to equilibrium inventory investment	Set to 0.8	
Variables			
Symbol	Description	Historical source / calculation	Projection / calculation method
$Y^*$ ( $\dot{y}$ )	Potential output (growth rate)	$GDPVTR$ in OECD Economic Outlook database	Equation 8 (9)
$A^*$ ( $\dot{a}$ )	Trend labour efficiency (growth rate)	$EFFLABS$ in OECD Economic Outlook database	See Guillemette et al. (2017)
$L^*$ ( $\dot{l}$ )	Trend employment (growth rate)	$ETPT$ in OECD Economic Outlook database	See Cavalleri and Guillemette (2017)
$K$ ( $\dot{k}$ )	Total productive capital stock excluding housing (growth rate)	$KTPV\_AV$ in OECD Economic Outlook database	Equation 31
$K\_G$	Government sector capital stock	$= k_g^{SS} \cdot Y^*$	Equation 10
$K\_B$ ( $\dot{k}_b$ )	Business sector capital stock (growth rate)	Equation 14	Equation 26
$\delta$	Capital stock scrapping rate	$RSCR$ in OECD Economic Outlook database	Equation 28

Symbol	Description	Historical source / calculation	Projection / calculation method
<i>IGV</i>	Government sector investment, volume	OECD Economic Outlook database	Equation 13
<i>IGV_shock</i>	Shocks to government investment	Not needed	Zero in baseline, assumptions in scenarios
<i>GAP</i>	Output gap	OECD Economic Outlook database	Assumed to close gradually in baseline scenario
<i>EPL</i>	Employment protection legislation indicator	OECD Indicators of Employment Protection	Assumed constant in baseline scenario
<i>ECTR</i>	Product market regulation indicator	OECD Indicators of Product Market Regulation	Assumed constant in baseline scenario
<i>UCC</i>	User cost of capital	Equation 19	Equation 21
<i>K_B*</i> ( <i>k_b*</i> )	Equilibrium business sector capital stock (growth rate)	Set equal to <i>K_B</i>	Equation 24
<i>p<sup>I</sup></i>	Investment price deflator	<i>PIT</i> in OECD Economic Outlook database	Equation 34
<i>p<sup>Y</sup></i>	Output price deflator	<i>PGDP</i> in OECD Economic Outlook database	Projection equation in the long-term model, see Johansson et al. (2013)
$\tau$	Statutory corporate income tax rate	OECD Tax database	Assumed constant in baseline scenario
<i>i<sup>d</sup></i>	Domestic interest rate for corporate borrowing	<i>IRL</i> in OECD Economic Outlook database + 200 bp	Long-term interest rate projection (see Johansson et al., 2013) + 200 bp
<i>i<sup>g</sup></i>	Global interest rate for corporate borrowing	Aggregate of <i>i<sup>d</sup></i>	Aggregate of <i>i<sup>d</sup></i>
<i>drpi</i>		$= \Delta \log(P_t^I) - \Delta \log(P_t^Y)$	Set by assumption
$\gamma$	Weight on global interest rate in user cost of capital	Equation 25	Equation 25
<i>IBV</i>	Business sector investment, volume	OECD Economic Outlook database	Equation 27
<i>IHV</i>	Housing investment, volume	OECD Economic Outlook database	Equation 32
<i>GDPV</i>	Gross domestic product volume	OECD Economic Outlook database	$= Y^* \cdot \left(1 + \frac{GAP}{100}\right)$
<i>ITV</i>	Total fixed investment, volume	OECD Economic Outlook database	Equation 33
<i>IT</i>	Total fixed investment	OECD Economic Outlook database	Equation 35
<i>ISKQ</i>	Inventory investment as a percentage of GDP	OECD Economic Outlook database	Equation 36
<i>ISK</i>	Inventory investment	OECD Economic Outlook database	Equation 37
<i>ITISK</i>	Total investment	OECD Economic Outlook database	Equation 38

*Note:* In some cases where the OECD Economic Outlook database is mentioned as source, it lacks data for some countries. In such cases missing countries are typically set to the average of countries for which data are available. This is the case of housing investment, for instance.