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The Great Shift: Macroeconomic projections for the world economy at the 2050 horizon

Jean Fouré, Agnès Bénassy-Quéré & Lionel Fontagné

This working paper is a revised version of "The world economy in 2050: a tentative picture", CEPII working paper 2010-27.

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THE GREAT SHIFT: MACROECONOMIC PROJECTIONS FOR THE WORLD ECONOMY AT THE 2050 HORIZON

Jean Fouré, Agnès Bénassy-Quéré & Lionel Fontagné

NON-TECHNICAL SUMMARY

It is tempting perhaps to extrapolate current growth rates to figure out how the global economy will be reshaped in the next decades. On this measure, an 8% growth rate in China over the next 40 years would produce a 21-fold increase in the Chinese economy by 2050, and a 2% growth rate in the European Union would result in 121% economic growth over the same period. However, back-of-the-envelope calculations based on past trends can be extremely misleading.

Based on a three-factor production function of labour, capital and energy, plus two forms of technological progress, we propose a long-run growth scenario for 147 countries and a time horizon of 2050 relying on the model MaGE (Macroeconometrics of the Global Economy). Our model is fitted with United Nations and International Labour Office labour projections, and econometric estimations of (i) capital accumulation, (ii) savings rate, (iii) relationship between savings and investment rate, (iv) education, (v) female participation, and (vi) technological progress (which includes energy and total factor productivity). Our study provides five novelties. First, we account for energy constraints by including its consumption in the production function and by taking account of rents accruing to oil exporting countries. Second, we estimate a non-unitary relationship between savings and investment, departing from assumptions of either a closed economy or full capital mobility. Third, we model female participation rates consistently with education catch-up. Fourth, we account for the 2008-09 global crisis by initialising our projection model in 2013 while relying on IMF short-term forecasts between 2010 and 2012. Finally, we disentangle real gross domestic product (GDP) growth rates from relative price effects through a consistent Balassa-Samuelson effect.

Our results suggest that the Chinese and Indian economies could grow 8-fold between 2010 and 2050 at constant relative prices. Over the same period, the US and EU economies would inflate by 80-90%. Adjusting for relative prices results in a 18-fold increase in China's economy and a 16-fold increase for India between 2010 and 2050.

Taking account of relative price variations, China would represent 33% of the world economy in 2050, dominating the United States (9%), India (8%), the European Union (12%) and Japan (5%). Our results suggest that in approximately 2020 (or c. 2040 at constant relative prices) China could overtake the United States. However, in terms of living standards, measured as GDP per capita in purchasing power parity, China would still lag 10 percent behind the United States at the 2050 horizon. Finally, from 2040 onwards, Sub-Saharan Africa would become the geographical area with the most dynamic economies, with an annual average growth rate of more than 5%.

As is the case with any exercise that produces projections over a long horizon, the work presented here should be considered tentative. We made it transparent, and relied on sound foundations for the determination of savings, investment and productivity growth. Although our results should be taken with a certain amount of caution, we believe they could be useful benchmarks for downstream studies on world commodity demand, international trade, financing capacity, global power, etc.

ABSTRACT

We present growth scenarios for 147 countries to 2050, based on MaGE (Macroeconometrics of the Global Economy), a three-factor production function that includes capital, labour and energy. We improve on the literature by accounting for the energy constraint through dynamic modelling of energy productivity, and departing from the assumptions of either a closed economy or full capital mobility by applying a Feldstein-Horioka-type relationship between savings and investment rates.

Our results suggest that, accounting for relative price variations, China could account for 33% of the world economy in 2050, which would be much more than the United States (9%), India (8%), the European Union (12%) and Japan (5%). They suggest also that China would overtake the United States around 2020 (2040 at constant relative prices). However, in terms of standards of living, measured through GDP per capita in purchasing power parity, China would still lag 10 percent behind the United States at the 2050 horizon.

JEL Classification: *E23, E27, F02, F47*
Key Words: *GDP projections, long run, global economy.*

LE GRAND BASCULEMENT : PROJECTIONS MACROECONOMIQUES POUR L'ECONOMIE MONDIALE A L'HORIZON 2050

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RESUME NON TECHNIQUE

Il est toujours tentant d'extrapoler les taux de croissance observés pour imaginer comment l'économie mondiale pourrait se transformer au cours des décennies à venir. Avec un taux de croissance de 8% par an pendant quarante ans, l'économie chinoise serait multipliée par 21 à l'horizon 2050 tandis qu'une Europe croissant à 2% par an ne verrait sa taille augmenter que de 121%. Ce type de calcul de coin de table, fondé sur le prolongement des tendances passées, peut cependant être largement trompeur.

Nous proposons ici un scénario de croissance de long terme pour 147 pays à l'horizon 2050 à l'aide du modèle MaGE (Macroeconometrics of the Global Economy). Notre modèle est fondé sur une fonction de production à trois facteurs (capital, travail et énergie) et deux formes de progrès technique. Nous utilisons les projections démographiques de l'ONU et de l'OIT ainsi que différentes estimations économétriques. Ces estimations portent sur (1) l'accumulation du capital, (2) les taux d'épargne, (3) le lien entre épargne et investissement et (4) le progrès technique (qui couvre à la fois la productivité énergétique et celle des facteurs travail et capital). Nous apportons plusieurs améliorations à la littérature existant dans ce domaine. Nous accordons un traitement particulier à l'énergie, considérée comme contrainte sur la production (l'énergie est l'un des trois facteurs de production) et comme source de rente pour les pays producteurs (nous corrigeons le biais de productivité induit par la rente pétrolière). La relation entre épargne et investissement que nous retenons tient compte de l'imparfaite mobilité internationale des capitaux et de l'existence d'un biais domestique. Nous séparons explicitement la croissance réelle des variations de prix relatifs, à travers un effet Balassa-Samuelson cohérent avec le modèle de croissance. Enfin, pour prendre en compte l'impact de la crise de 2008-2009, nous utilisons les projections du Fonds monétaire international pour les années 2010 à 2012 et ne démarrons notre propre projection qu'en 2013.

Selon nos résultats, les économies chinoise et indienne pourraient toutes deux être multipliées par 8 entre 2008 et 2050 à prix constants tandis que les économies américaine et européenne augmenteraient de seulement 80%-90%. En tenant compte du rattrapage progressif des prix par rapport au niveau actuel des prix américains, les économies chinoise et indienne seraient multipliées respectivement par 18 et 16. Ainsi, la Chine pourrait représenter 33% de l'économie mondiale en 2050, soit autant que l'Union Européenne (12%), les Etats-Unis (9%), l'Inde (8%) et le Japon (5%) réunis. La Chine dépasserait les Etats-Unis vers 2020 (vers 2040 à prix relatifs constants). Cependant, en termes de niveaux de vie, mesurés par le PIB par habitant en standard de pouvoir d'achat, la Chine serait encore 10% derrière les Etats-Unis à l'horizon 2050. Enfin, à compter de 2040 environ, l'Afrique subsaharienne deviendrait la zone du monde à l'économie la plus dynamique, avec une croissance réelle supérieure à 5% par an.

Nous avons tenté de rendre cet exercice de projection le plus transparent possible et de nous appuyer sur des résultats robustes de la littérature relatifs à la détermination des taux d'épargne, de l'investissement et de la productivité. Il reste que, comme toute projection sur longue période, ce travail doit être interprété avec beaucoup de précautions. Ses résultats constituent cependant des repères utiles pour les études prospectives sur la demande mondiale de matières premières, le commerce international, les capacités de financement, les puissances mondiales, etc.

RESUME COURT

Nous présentons des projections de croissance à l'horizon 2050 réalisées pour 147 pays avec le modèle MaGE (*Macroeconometrics of the Global Economy*) à partir d'une fonction de production à trois facteurs – capital, travail et énergie. La prise en compte de la contrainte énergétique (avec une modélisation dynamique de la productivité énergétique), et de l'imparfaite mobilité des capitaux (grâce à une modélisation de type Feldstein-Horioka de la relation entre épargne et investissement) constituent nos principaux apports à la littérature.

Nos résultats suggèrent que, en tenant compte des évolutions de prix relatifs, la Chine pourrait représenter 33% de l'économie mondiale en 2050, soit autant que l'Union Européenne (12%), les Etats-Unis (9%), l'Inde (8%) et le Japon (5%) réunis. La Chine dépasserait les Etats-Unis vers 2020 (vers 2040 à prix relatifs constants). Cependant, en termes de niveaux de vie, la Chine serait encore 10% derrière les Etats-Unis à l'horizon 2050.

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Mots-clefs : *projections de PIB, long terme, économie mondiale.*

THE GREAT SHIFT: MACROECONOMIC PROJECTIONS FOR THE WORLD ECONOMY AT THE 2050 HORIZON

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All results by country and year ("BASELINE") are publicly available at the following address:
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INTRODUCTION

The way that limited growth differentials have the ability to re-shape the world economy in few decades is quite striking. A growth differential of a single percentage point per year, cumulated over 40 years, for example, results in a 49% income gap, while a differential of two percentage points results in a gap of 121% and three percentage points a gap of 226%. Based on the same arithmetic and simple assumptions about productivity and demographic trends, Fogel (2007) predicts that the three largest economies in the world in 2040 will be China (40%), ahead of the United States (US) (14%) and India (12%).

However, the growth process is far from being mechanical. Accumulation of physical and human capital, growth in total factor productivity (TFP) and energy constraints may vary over time. For instance, assuming a constant annual 8% growth rate, China's economy will grow 21-fold in the next 40 years, while assuming a linear convergence of China's annual growth rate from 8% to 3% in 40 years would result in 'only' 8-fold growth. These two scenarios would have entirely different implications for the world in terms of commodity markets, multinationals' strategies, carbon emissions, the political order, etc. Although a very risky exercise, projecting the long run world economy is useful since it is indicative of magnitudes

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that can change the face of the world. It also provides a useful baseline for global economic policy models, since the results of these simulations are often heavily dependent on the baseline path of the world economy.[4]

This paper describing the model MaGE (Macroeconometrics of the Global Economy) and its projections contributes to the literature (Wilson and Purushothamam, 2003; Poncet, 2006; Duval and de la Maisonneuve, 2010) in various ways.

On the theoretical side, we rely on a three-factor production function: labour, capital and energy, plus two forms of technological progress. We derive explicitly TFP and energy productivity. Capital-income and capital-labour ratios are determined in an original framework that links investment and savings through a function that assumes imperfect international mobility of capital and savings determined by a life-cycle hypothesis. Finally, valuation effects are introduced through a Balassa-Samuelson specification that is fully consistent with the growth model.

On the empirical side, we propose a long-run growth scenario for 147 countries to 2050. The model is fitted with United Nations (UN) population projections as well as econometric estimations for (i) capital accumulation, (ii) education and female participation to the labour force, and (iii) technological progress (which covers both energy productivity and TFP). We account for the energy constraint by including this factor in the production function. We assume a positive but non-unitary relationship between savings and investment thus departing from the assumptions of either full capital mobility or a closed-economy. Finally, we account for the 2008-09 global crisis by initialising our projection model in 2013, but relying on International Monetary fund (IMF) short-term forecasts from 2010 to 2012 (*World Economic Outlook*, September 2011).

The paper is organised as follows. Section 1 presents the theoretical framework. Section 2 describes the data and econometric estimations for the period 1980-2009. Section 3 reports projections up to 2050. Section 4 provides some assessment exercises. Section 5 concludes.

1. THEORETICAL FRAMEWORK

1.1. Production function

Long-run growth analyses are generally based on a Cobb-Douglas production function (see, e.g., Wilson and Purushothaman, 2003; Poncet, 2006; Duval and de la Maisonneuve, 2010;

[4] This is the case of MIRAGE, a computable general equilibrium model developed at CEPII for the analysis of trade policies. See Decreux and Valin (2007).

Wilson et al., 2011). This has several advantages, including that assuming constant returns to scale, the parameters of the function match the distribution of income across different production factors.

This paper improves on the literature on long-run growth by introducing energy as a critical production factor. This means that the unitary elasticity of substitution implied by the Cobb-Douglas production function is no longer adequate: capital and labour can barely substitute for the scarcity of energy in the economy. We retain a Constant Elasticity of Substitution (CES) function with two factors: energy and a Cobb-Douglas combination of capital and labour. Therefore, we retain the traditional unitary elasticity of substitution between capital and labour, but embody this composite factor in a CES function with relatively low substitution between energy and the composite factor. The use of such nested CES production function was proposed by David and van de Klundert (1965) to encompass different kinds of input-augmenting technical change, and is employed also in van der Werf (2008) and Markandya and Pedrosso-Galinato (2007).

If we denote energy, capital and labour by $E_{i,t}$, $K_{i,t}$ and $L_{i,t}$, respectively, for country *i* at time *t*, real GDP can be written as:

$$Y_{i,t} = \left[\left(A_{i,t}.K_{i,t}{}^{\alpha}L_{i,t}{}^{1-\alpha}\right)^{\frac{\sigma-1}{\sigma}} + \left(B_{i,t}.E_{i,t}\right)^{\frac{\sigma-1}{\sigma}}\right]^{\frac{\sigma}{\sigma-1}}, \quad 0 < \alpha < 1, \quad 0 < \sigma < 1 \tag{1.1}$$

In this formula, $Y_{i,t}$ denotes GDP, in volume. In oil-producing countries, $Y_{i,t}$ is taken net of the oil rent in order to avoid a biased measure of productivity (see Annex A). $A_{i,t}$ is the usual TFP, which in this case is the efficiency of the combination of labour and capital, and $B_{i,t}$ is a measure of energy productivity.

In line with the literature (see, e.g., Mankiw, Romer and Weil, 1992), we set $\alpha = 0.31$. In turn, we calibrate the elasticitity of substitution between energy and the composite factor based on the simulated elasticity of substitution recovered from the MIRAGE model: $\sigma = 0.136$, hence $\rho = \frac{\sigma-1}{\sigma} = -6.353$.

Oil production is assumed to be a pure rent: the volume of production is constant, but its real value (in terms of the GDP deflator) increases depending on the relative price of oil. The oil rent is ultimately added to the non-oil GDP which is modeled as described above.

1.2. Labour and capital

We need to project each variable in Equation (1.1) to 2050. For the labour force, we combine UN projections of the working-age population to 2050 (medium fertility variant) to International Labor Organization (ILO) and own projections of participation rates. Specifically, our methodology differs for males and females:

- Male participation rates by age group are taken from ILO, up to 2020. From 2021 to 2050, they are projected based on ILO's methodology. Specifically, the participation rate of males of age a in country i at time t is $l_{a,i,t}^{M}$ such as:

$$l_{a,i,t}^{M} = \underline{l}_{a,i}^{M} + \frac{\bar{l}_{a,i}^{M} - \underline{l}_{a,i}^{M}}{1 + e^{\alpha_{a,i} + \beta_{a,i} \cdot t}} \tag{1.2}$$

where $\underline{l}_{a,i}^{M}$ and $\bar{l}_{a,i}^{M}$ are age and country-specific minimum and maximum participation rates, and $\alpha_{a,i}$ and $\beta_{a,i}$ are the parameters of the process.[5]

- Female participation rates by age group are projected from 2010 to 2050 based on an econometric relation between female participation rates and education. This choice allows us to account for the anticipated rise in female participation rates for a number of developing countries, in line with projected catch-up in terms of education.

Education is captured through school attainment by age group, based on Barro and Lee (2010) database. It is projected based on a simple catching-up process, with the leader country following a logistic scheme.

[5] Since these parameters are not published by ILO, we recover them through a reverse engineering method.

Capital stock is accumulated through a permanent-inventory process:

$$K_{i,t} = (1-\delta)K_{i,t-1} + I_{i,t} \qquad (1.3)$$

where $I_{i,t}$ denotes the gross fixed capital investment of country i at time t, and δ is the depreciation rate, which is set here at 0.06 (the value in the MIRAGE model).

In the literature, the projection of gross fixed capital investment sometimes relies on the assumption of a closed economy, which allows gross investment to equal gross savings (see Poncet, 2006; Wilson et al., 2011). This assumption is at odds with the large current-account imbalances observed especially in the 2000s. In the present paper, we rely on estimated error-correction, Feldstein-Horioka-type relationships between savings and investment rates, which allows for some discrepancy between these variables. Gross saving rates are derived from an econometric equation based on the life-cycle hypothesis.[6]

We next describe our theoretical framework accounting for energy productivity and TFP (Section 1.3), and relative prices (Section 1.4), before turning to the econometric relationships in Section 2.

1.3. Energy and TFP

Energy consumption projection is based on energy price, assuming that firms maximise profit along their nested CES production function (for greater clarity, country and time subscripts are dropped here):

$$max(Y - p_E E - p_K K - p_L L) \quad s.c.\ Y^\rho = (AK^\alpha L^{1-\alpha})^\rho + (BE)^\rho \qquad (1.4)$$

where p_E, p_K and p_L denote the real prices of energy, capital and labour, respectively, relative to output. This programme yields the following relation (see Appendix A):

$$E = Y\frac{B^{\sigma-1}}{p_E^\sigma}, \text{ with } \sigma = \frac{1}{1-\rho} > 0 \qquad (1.5)$$

[6] Alternatively, Wilson and Purushothaman (2003) assume exogenous investment rates, while Duval and de la Maisonneuve hypothesise a convergence of capital-to-GDP ratios to the US level, the latter country being assumed to be on its balance growth path.

Replacing E by this expression in the production function yields:

$$Y = \left[1 - \left(\frac{B}{p_E}\right)^{\sigma-1}\right]^{\frac{\sigma}{1-\sigma}} AK^{\alpha}L^{1-\alpha} \qquad (1.6)$$

We use oil-price forecasts to 2035 provided by the Energy Information Administration (EIA).[7] For 2035 to 2050, the price of energy is set to increase at a constant rate equal to its average growth rate over the 2030-2035 period.[8]

Within this framework, energy intensity E/Y varies based on two different mechanisms: first, the level of energy-related technological progress B (or energy productivity) determines the number of units of GDP that is produced with one barrel of energy at given relative prices; second, energy can be substituted depending on its real price p_E and the elasticity of substitution σ.

Past values of the two forms of technological progress A and B are computed according to the theoretical model described above (Equation 1.5 for B, and then Equation 1.6 for A). Based on the recovered series and to obtain a formula that can be projected, we estimate two catch-up models (see Section 2). Specifically, we estimate a two-dimensional catch-up process for energy productivity that results in a U-shaped relationship between economic development and energy productivity. TFP, in its turn, is supposed to follow an estimated Nelson-Phelps catch-up model in which speed of catch-up is related to human capital (see Section 2).

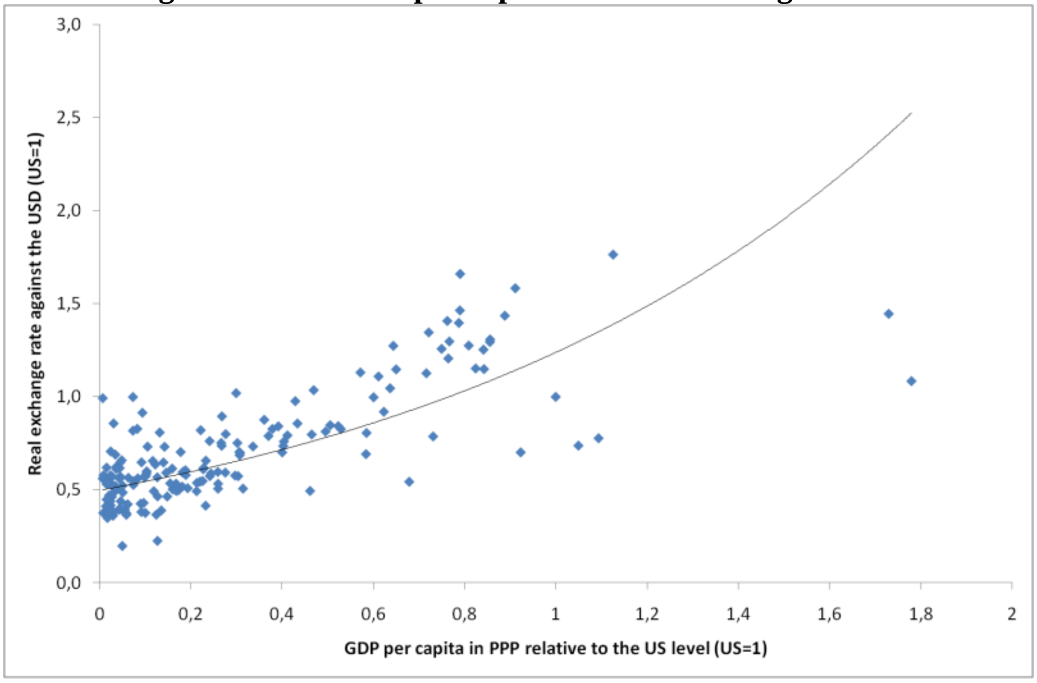
1.4. Real exchange rate and the Balassa-Samuelson effect

The long-run growth model presented above depicts the evolution of GDP at constant prices. It is sufficient to study the possible impact of global growth on commodity and energy markets. However, the relative sizes of the different countries and regions in terms of markets and financial power depend also on the relative valuations of their incomes. For instance, the weight of China in the world economy is likely to increase due to both high real growth rates, and to a progressive real appreciation of the renminbi (China's official currency). Hence, we need to model long run real exchange rates. The underlying theory is the Balassa-Samuelson effect, which relates TFP growth to progressive appreciation of the relevant currency in real terms. Currency appreciation is based on diverging evolutions of the prices for non-traded and traded activities. Figure 1 shows that there is a positive relationship between the purchasing power of per capita GDP and the real exchange rate.

[7] http://www.eia.gov/forecasts/ieo/liquid_fuels.cfm

[8] The sensitivity to this assumption is tested in Section 4.

Figure 1 - PPP GDP per capita and real exchange rate in



Source: IMF, World Economic Outlook, April 2010, and own calculations.

In the Balassa-Samuelson framework, the real appreciation of catching-up countries derives from an increase in the relative price of non-tradables to tradables. Consistent with this, and following Obstfeld and Rogoff (1996), we assume that every national economy has two sectors: traded-goods (denoted by *T*), and non-traded goods (denoted by *N*). Both sectors have the same production functions as above. However, their productivity diverges in terms of both primary factors and energy:

$$\begin{cases} Y_T = [(A_T Q_T)^\rho + (B_T E_T)^\rho]^{1/\rho} = F(A_T Q_T, B_T E_T,) \\ Y_N = [(A_N Q_N)^\rho + (B_N E_N)^\rho]^{1/\rho} = F(A_N Q_N, B_N E_N) \end{cases} \quad (1.7)$$

where Q denotes the Cobb-Douglas combination of capital and labour ($Q = K^\alpha L^{1-\alpha}$). Let p denote the relative price of non-tradables to tradables: $p = P_N / P_T$. Writing the first order-conditions and assuming that the share of energy in income (denoted by μ) is the same across the two sectors, we get (see Appendix B):

$$\dot{p} = (1 - \mu)(\dot{A}_T - \dot{A}_N) + \mu(\dot{B}_T - \dot{B}_N) \quad (1.8)$$

where $\dot{X} = \frac{dX}{X}dt$. Assuming a Cobb-Douglas consumption bundle ($C = Y_T^{\gamma} Y_N^{1-\gamma}$ $0<\gamma<1$), the consumer price index, in terms of the tradable good can be written as: $P = p^{1-\gamma}$. If we ignore productivity growth in the non-traded sector, we get:

$$\dot{p} = \frac{1}{\gamma}\left(\mu\dot{B} + (1-\mu)\dot{A}\right) \tag{1.9}$$

Finally, if we denote the real exchange rate (i.e. the relative price of the home consumption basket to the foreign one) by RER, and the foreign country by an asterisk, we get:

$$R\dot{E}R = \frac{1-\gamma}{\gamma}\left[(1-\mu)\dot{A} + \mu\dot{B}\right] - \frac{1-\gamma^*}{\gamma^*}\left[(1-\mu^*)\dot{A}^* + \mu^*\dot{B}^*\right] \tag{1.10}$$

Hence, real-exchange rate appreciation is based on TFP and energy productivity catch-up, and the effect is magnified by a higher share of non-tradables in the consumption basket. The latter is projected based on its econometric relationship with economic development (see Section 2.8).[9]

2. Data and econometric estimations

We referred above to the seven relationships that need to be estimated:

- a life-cycle model of the gross savings rate;
- the relationship between savings and investment rates;
- a model for female participation to the labour force;
- a catch-up model for education;
- a Nelson-Phelps catch-up model for TFP;
- a double catch-up model for energy productivity.
- a model linking the share of tradable goods in consumption and production to economic development.

[9] In oil-exporting countries, the real exchange-rate appreciation along economic catch-up may result from a Dutch disease rather than TFP growth in the tradable, non-oil sector. We are not able to distinguish the two effects in our estimations.

After describing the data used in the econometric estimations, this section presents the econometric strategy and results for each of these seven relationships in turn.

2.1. Data for used in estimations

Our estimations cover the period 1980-2009. In addition to increasing data collection problems, earlier data are unlikely to be meaningful for emerging economies, and also less significant in relation to international capital mobility (cf. the relationship between savings and investment rates).

We recovered GDP series in 2005 constant US dollars of 2005 from (i) GDP in current dollars for 2005, and (ii) GDP growth rates in real terms for the period 1960-2009 (sources: World Bank and IMF databases).[10]

These GDP series are then corrected for oil production by deducing the amount of oil rents (% of GDP), as measured in the World Development Indicators database of the World Bank (1970-2009).

Labour force (1980-2008) data are built based on UN population estimates by five-year age group (2010 revision) and activity rates by gender and age groups from the ILO. Human capital is proxied by the share of the working-age population having a secondary or tertiary diploma. It is calculated based on Barro & Lee dataset (2010, revision 1.2) of education attainment for each five-year-age-group. This data is available for 146 countries, every five years from 1950 to 2010.

Energy consumption is taken from the World Bank (World Development Indicators) and corresponds to “primary energy use before transformation”.[11] Annual average oil prices for 1980-2009 are from EIA, expressed in 2005 constant US dollars.[12] We assume that the price of energy is indexed on the oil price, and that this price is common across the world. Although a crude approximation, this assumption is consistent with the fact that the variance in real energy prices is related mostly to oil price fluctuations.

[10] CEPII-CHELEM and van Ark et al. (1998) were also used to fill the gaps of former USSR countries, Slovakia and the Czech Republic.

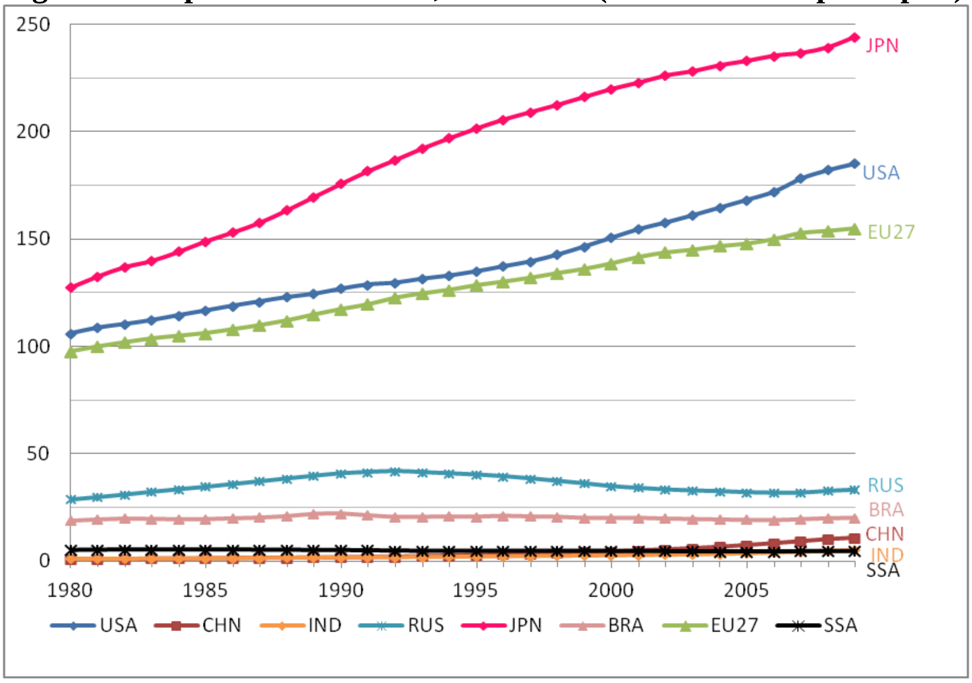
[11] It is calculated as domestic production plus imports and stock changes, minus exports and fuels used for international transport. See http://data.worldbank.org/indicator/EG.USE.COMM.KT.OE.

[12] Converted from 2008 US dollars by applying a deflation factor of $\frac{1}{1.102}$.

The ratios of savings and investments to GDP are from the World Development Indicators. They cover private and public savings and investments. We use both gross *fixed* capital formation, and gross capital formation (see Section 2.3).

Our capital-stock series from 1960 to 2009 is constructed using the permanent inventory method (see Equation 1.3 in Section 1). Where data on initial capital stock are not available, we set it to three times GDP in 1960. Since our econometric estimations start in 1980, when most of the 1960 stock had been scrapped, this crude assumption is benign. Figure 2 reports the implied capital-labour ratios for a selection of large economies.

Figure 2 - Capital-labour ratios, 1980-2009 (2005 USD '000 per capita)



USA=United States of America; CHN=People's Republic of China; IND=India; RUS=Russia; JPN=Japan; BRA=Brazil; EU27=European Union 27 (composition in annex F); SSA=Sub-Saharan Africa (composition in annex F).

Source: own calculations.

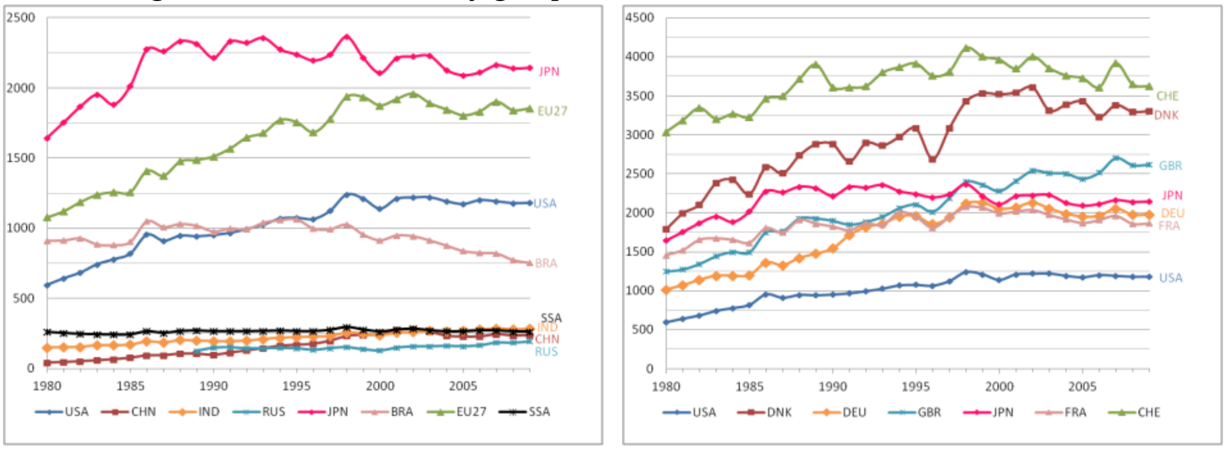
Energy productivity for 1980-2009 is obtained by inverting the relation between optimal energy consumption *E* and the price of energy p_E (Equation (1.5) in Section 1), with *Y* denoting the non-oil GDP:

$$B = (p_E)^{\frac{\sigma}{\sigma-1}} \left(\frac{E}{Y}\right)^{\frac{1}{\sigma-1}} \qquad (2.1)$$

For oil-producting countries, we calculate energy productivity based on the corrected GDP series (see Appendix A). Figure 3a depicts the resulting series for a selection of large economies and country groups, whereas Figure 3b shows energy productivity in the countries displaying the highest levels (the leaders being Denmark and Switzerland over 1980-2009). The declining energy productivity of Brazil over the period may be related to this country's specific energy mix. Its main energy source is biomass, whose price has not evolved in line with world oil prices: for this country, the oil price may overestimate the price of energy, resulting in an underestimation of energy productivity being underestimated (remember that $\sigma < 1$ in Equation 2.1).

Figure 3 - Energy productivity, 1980-2009 (2005 USD per barrel)

a. Large economies and country groups b. USA and leader countries



Notations: see Figure 2; DNK=Denmark; DEU=Germany; GBR=United Kingdom; FRA=France; CHE=Switzerland.

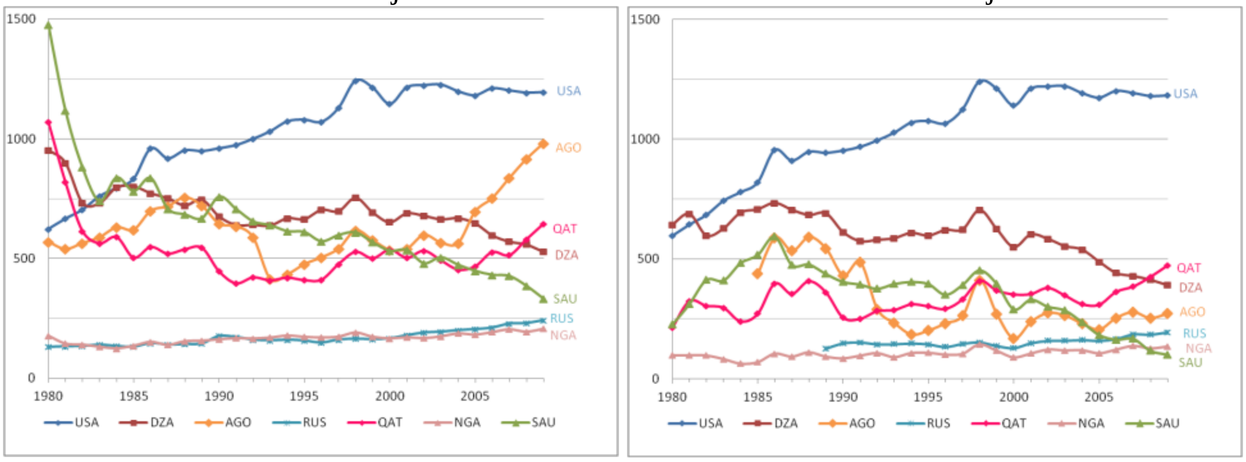
Note: For aggregated regions (EU27 and SSA), energy productivity is an arithmetic average weighted by energy consumption.

Source: own calculations.

Figure 4 depicts the importance of correcting energy productivity for the oil rent in heavy oil producers. In Angola, for instance, the apparent rise in energy productivity in the 2000s disappears when energy productivity is corrected for the oil rent.

Figure 4 - Energy productivity, USA and oil producing countries, 1980-2008

a. Non-adjusted b. Adjusted



Notations: see Figure 2; AGO=Angola; DZA=Algeria; TCD=Chad; QAT=Qatar; NGA=Nigeria; SAU=Saudi Arabia.

Source: own calculations.

Finally, we estimate TFP by inverting the production function:

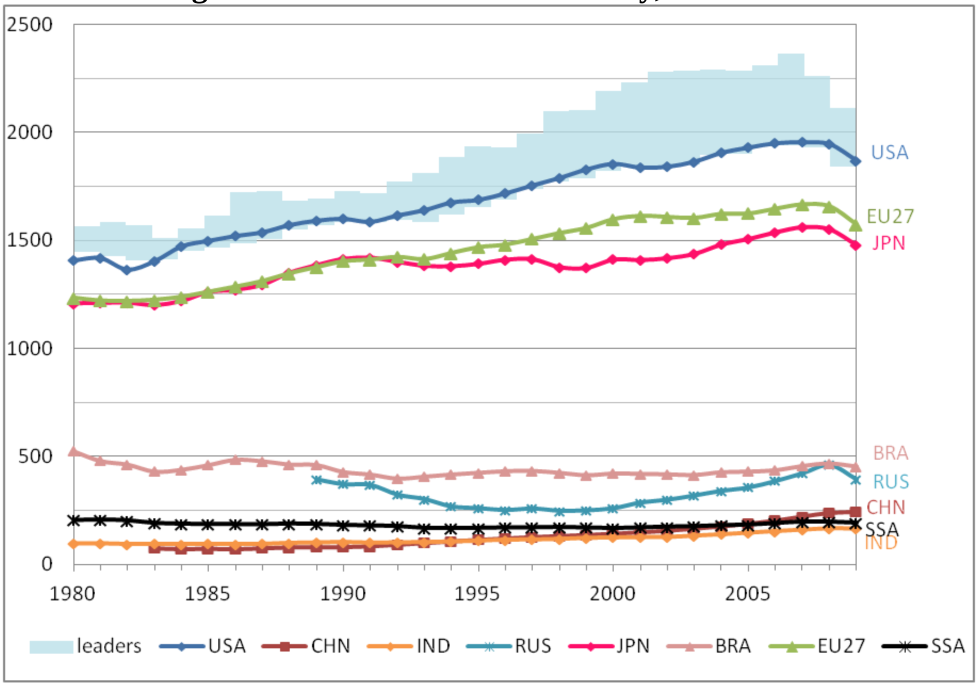
$$A_{i,t} = \frac{\left[Y_{i,t}^{\rho} - (B_{i,t}E_{i,t})^{\rho}\right]^{\frac{1}{\rho}}}{K_{i,t}^{\alpha} L_{i,t}^{1-\alpha}} \tag{2.2}$$

Again, apparent TFP needs to be corrected for the oil rent in heavy oil producers (see Appendix A) and equation (2.2) is computed with the corrected GDP.

Figure 5 depicts the resulting TFP series for the usual selection of countries and country groups. Furthermore, the shaded area around the US schedule represents the TFP interval amongst the five best-performing countries (the United States, Denmark, Sweden, Ireland, Belgium, France, the Netherlands and Germany, depending on the year). TFP generally increases over 1980-2009, except in periods of crises (Russia following the breakdown of the USSR, or the 2007-2009 financial crisis).

In turn, Figure 6 provides the TFP evolutions for a selection of oil-producing countries, in comparison with the United States. Figure 6a reports the non-adjusted measure while Figure 6b shows the adjusted one. Unsurprisingly, the adjustment for oil production lowers the level of TFP. For instance, the correction uncovers a fall in TFP in Saudi Arabia in the 2000s, whereas the non-adjusted measure shows a slight increase during this period.

Figure 5 - Total Factor Productivity, 1980-2009



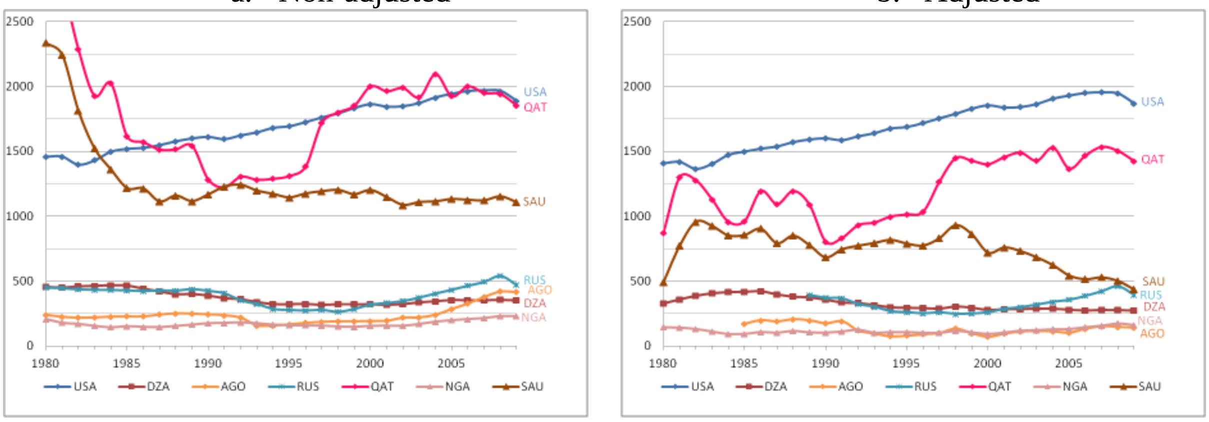
Notations: see Figure 2.

Note: For aggregated regions, TFP is an arithmetic average weighted by the K-L Cobb-Douglas aggregates.

Source: own calculations.

Figure 6 - TFP, oil-producing countries and the USA, 1980-2009

a. Non-adjusted b. Adjusted



Notations: see Figure 2 and Figure 4.

Source: own calculations.

Finally, real exchange rates are recovered using local currency to dollar and local currency to PPP conversion factors from the World Development Indicators (World Bank Database). Based on the International Comparison Project (ICP), this dataset has received a number of criticisms, notably following the large downward revision of Chinese PPP GDP in 2008. In fact, key methodological choices such as the coverage of price surveys (either urban or also rural), the weighting schemes of price indices, or the calibration of productivity in services or the valuation of imports and exports, may heavily impact on the results (see Deaton and Heston, 2010, Feenstra et al., 2012). We nevertheless rely on this database which is readily available for a large number of countries over our estimation period. Given the uncertainty surrounding the data, our results in terms of evolutions may be more meaningful than those in terms of absolute values.

The share of traded sectors for each country is calibrated based on the Global Trade Analysis Project (GTAP) database[13] for production, consumption and trade in year 2004, at the industry level. We consider all the 57 GTAP sectors (including services).

We next estimate the behavioural equations.

2.2. Savings rate

To project savings rates, we rely on Masson, Bayoumi and Samiei's (1998) life-cycle approach, already employed in Poncet (2006). In this approach, the gross savings rate depends on the age-structure of the population and the GDP-per-capita gap with the leading economy. We employ the methodology proposed in Higgins (1998) to characterise the age-structure through a simple polynomial of age groups, estimating on five years averages. The estimated equation is as follows:

$$\left(\frac{S}{Y}\right)_{i,t} = \alpha_i + \beta_1 \frac{y_{i,t-1}}{y_{US,t-1}} + \beta_2 \left[\frac{y_{i,t-1}}{y_{US,t-1}}\right]^2 + \beta_3 g_{i,t-1} + \sum_{k=1}^{K} \varphi_k \, d_{i,t}^k + \sum_{k=1}^{K} \eta_k \, d_{i,t}^k . g_{i,t-1} + \varepsilon_{i,t} \quad (2.3)$$

where $(S/I)_{i,t}$ is the savings rate in country *i* at time *t*, $y_{i,t}$ is country i's per capita GDP, $g_{i,t}$, is the rate of growth of per capita GDP,[14] and the variables $d_{i,t}^k$ are demographic factors constructed as follows (for simplicity, country and year subscripts are dropped):

$$d^k = \left(\sum_{j=1}^{J} j^k p_j - \frac{1}{J}\sum_{j=1}^{J} j^k\right) \quad (2.4)$$

[13] See www.gtap.agecon.purdue.edu.

[14] Both per capita GDP and its growth rate are lagged so that the equation can be used non-recursively in a projection exercise.

where $j = 1, \dots, J$ are the J population cohorts (0-4, 5-9, ..., 65-69 and 70+), and p_j is the proportion of cohort j in the population. This specification allows us to summarise the distribution of the population using only a few variables (see Appendix C). The number of demographic variables (K) is determined by an Akaike information criterion.

The behaviour underpinning Equation (2.3) is structural. However it may omit important determinants of savings rates, such as institutions, governance or culture, which move only slowly, hence cannot be introduced in a panel regression. These considerations led us to the following choices. Firstly, all variables are expressed as 5-year averages (hence the lags correspond to the previous 5-year average) in order to correct for business cycles. Secondly the equation is estimated on the whole sample with country fixed effects in order to account for time-invariant heterogeneities not controlled for by right-hand side variables.[15] Omitting such key covariates could otherwise lead to a large bias in estimating the effects of our included variables. Still, these important underlying factors may well change gradually over such a long period. We address this issue in our robustness check exercises in Section 4.

The econometric results are presented in Table 1. An increase in per capita GDP relative to the US, or a higher per capita GDP growth rate, implies a rise in the savings rate. In terms of the demographic factors, only their interaction with growth has a significant impact on the savings rate. Hence our preferred specification is the one in Column (2) of Table 1, where additive demographic factors are dropped.

Appendix C describes how the impacts of the different cohort shares (p_j) on the savings rate can be deduced from the estimated coefficients of the d^k variables. These impacts are plotted in Figure 7, which assumes a 2% per capita GDP growth rate. Figure 7 shows that there is a strong, negative impact of ageing on the aggregate savings rate, which is consistent with life-cycle theory.

[15] Preliminary estimations tended to reject any systematic heterogeneity in the determinants of saving rates between OECD and non-OECD countries.

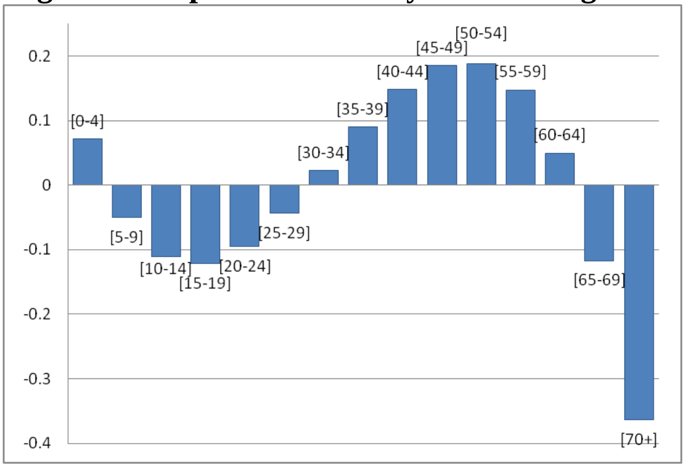
Table 1 - Determinants of the savings rate, five-year-averages

	(1) Savings rate	(2) Savings rate
Lagged GDP per cap. rel. to the USA	0.169***	0.131***
	(0.0586)	(0.0194)
Lagged squared GDP per cap. rel. to the USA	-0.00413	
	(0.0119)	
Lagged GDP per cap. growth	0.995***	1.103***
	(0.286)	(0.238)
d^1	0.194	
	(0.197)	
d^2	-0.0127	
	(0.0337)	
d^3	-0.000208	
	(0.00156)	
d^1 x GDP per cap. growth	-12.77***	-11.71***
	(3.777)	(3.222)
d^2 x GDP per cap. growth	2.238***	2.111***
	(0.617)	(0.524)
d^3 x GDP per cap. growth	-0.103***	-0.0980***
	(0.0270)	(0.0230)
Constant	0.0460	0.137***
	(0.0294)	(0.00574)
N	917	917
R-sq.	0.173	0.155

Standard errors in parentheses. * p<0.1, ** p<0.05, *** p<0.01

Source: own calculations.

Figure 7 - Impact of the life cycle on savings rate



Note : Assuming a 2% GDP per capita growth rate.
Source: own calculations.

2.3. From savings to investment: The Feldstein-Horioka relationship

Projecting gross investment raises difficult methodological issues. Indeed, fixed capital investment, with inventories, is the most unstable component of demand. In the short run, it is driven mostly by an accelerator effect. In the long run, it is deemed to depend on capital stock and real interest rates. However, it is difficult to identify a robust, econometric relationship. The problem is magnified for developing countries where the cost of capital is a rather blurred concept. One solution is to rely on a model of savings rather than investment, and assume a long-run savings-investment balance (see Poncet, 2010; Wilson et al., 2011). However, this assumption of a closed economy would be at odds with the recently observed savings-investment imbalances in the global economy. Here, we estimate an error-correction, Feldstein-Horioka-type relationship between the savings and the investment rates.

The basis of the contribution made by Feldstein and Horioka (1980, FH hereafter) is that the relationship between savings and investment depends on financial openness: in a closed economy, domestic investment is constrained by domestic saving, whereas perfect capital mobility would require domestic investment being uncorrelated with domestic savings. The most general specification of the FH relationship is the following (see Herwartz and Xu, 2010):

$$\left(\frac{I}{Y}\right)_{i,t} = \alpha_i + \beta_i \left(\frac{S}{Y}\right)_{i,t} + u_{i,t} \quad (2.5)$$

where (I/Y) and (S/Y) respectively denote the investment and savings to GDP ratios. The lower β, the higher capital mobility. For a sample of 16 OECD countries between 1960 and 1974, Feldstein and Horioka found that, on average, a one percentage point increase in the savings rate was related to a 0.89 percentage point increase in the investment rate ($\beta = 0.89$), meaning limited *de facto* international financial integration despite *de jure* liberalisation (hence the FH puzzle). Some subsequent estimations find lower values for β, especially within the Eurozone, but generally the coefficient remains relatively high.[16]

Measuring the link between savings and investment rates raises three issues. First, measuring capital formation is far from straightforward. Second, a FH-type estimation can be spurious if investment or saving rates are non-stationary. Third, non-stationarity requires the correct model to be implemented. These three points are developed below.

a. Measuring investment

There are two ways to measure capital formation: 'gross *fixed* capital formation' (GFCF), which corresponds to the purchase of fixed assets, and 'gross capital formation' (GCF), which includes changes to inventories:

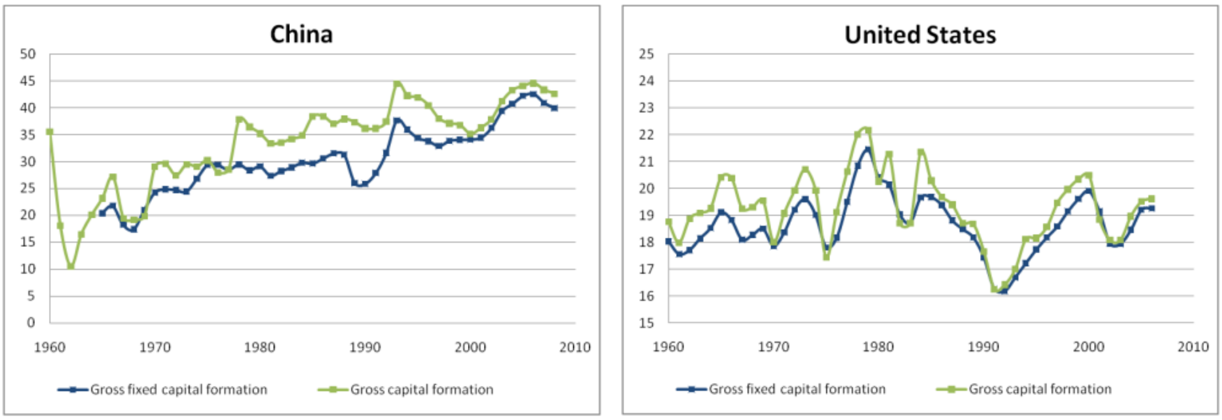
$$GCF = GFCF + \Delta Inventories \quad (2.6)$$

Our production function includes only fixed assets, and our capital accumulation, permanent inventory equation relies on GFCF. However, savings (the source of investments) are used to buy fixed assets and to accumulate inventories, so that the FH relationship holds only for GCF and savings. Hence, we need to use the GCF series to estimate our FH relationship, and then correct projected GCF to recover GFCF.

Figure 8 shows that the two series are fairly similar, although GCF is more volatile than GFCF, due to inventory changes. Still, inventory changes are positive on average, hence we generally have GCF>GCFC. For simplicity, we subtract the median of the distribution of average inventory changes (0.87% of GDP, see Figure 9) from GCF to recover GFCF. Note, however, that this choice is not crucial since the correction is very small compared to the capital formation levels.

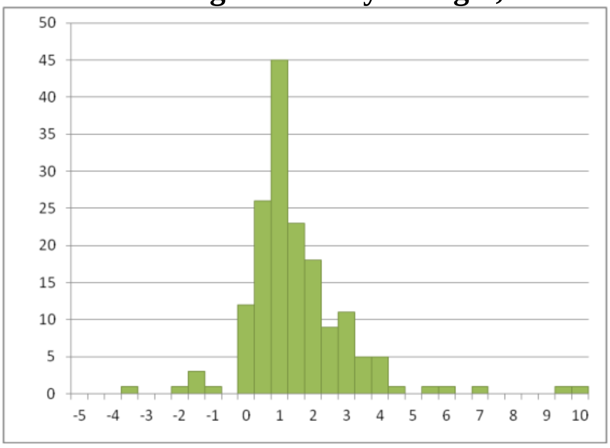
[16] E.g., Obstfeld and Rogoff (1996) found a coefficient of 0.69 for a sample of 22 OECD countries over the period 1982–91 and Blanchard and Giavazzi (2002) obtained a 0.58 coefficient for the 30 OECD countries in the period 1975–2001. It is interesting that in their estimation the coefficient is lower and declining in the euro area at only 0.14 in 1991–2001, down from 0.41 in 1975–90.

Figure 8 - Gross capital formation and gross fixed capital formation, % of GDP, 1960-2008



Source: World Development Indicators (World Bank).

Figure 9 - Distribution of average inventory changes, 1980-2008 (% of GDP)

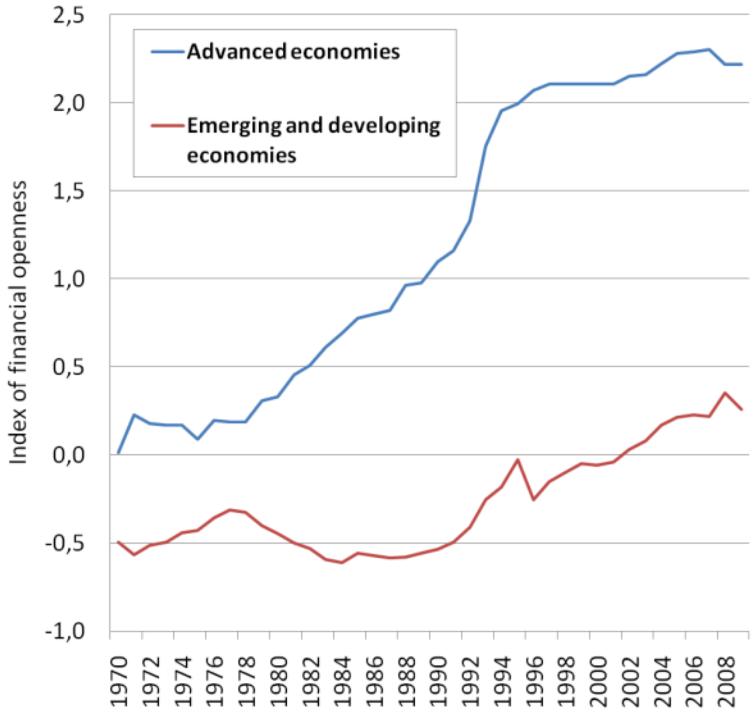


Source: own calculations.

b. Stationarity

As noted, e.g. by Coiteux and Olivier (2000), savings and investment rates are often non-stationary, requiring cointegration rather than simple ordinary least squares (OLS) regressions. However, the breadth of our sample means that it is likely to include both stationary and non-stationary series. In addition, for some countries we have missing or unreliable data. For these reasons, we prefer a panel to a country-by-country approach. We follow Chakrabarti (2006) and divide our sample into OECD and non-OECD countries and implement panel unit-root tests. This choice is motivated by the large differences in financial openness between the two types of countries (see Figure 10).

Figure 10 - Financial openness, 1970-2009



Note: The index is computed as the non-weighted average of 24 advanced economies and 128 emerging and developing economies of capital mobility index (taking into account exchange rates, restrictions on transactions and export parameters).

Source: Chinn and Ito (2008), based on the IMF Annual Report on Exchange Arrangements and Exchange Restrictions, 1970-2009 (2011 update).

Panel unit root tests, first proposed by Levin and Lin (1992), have been developed by several scholars, resulting in five different tests that can be implemented in Stata. Four of these tests (Levin Lin and Chu, Im Pesaran and Shin, Breitung and Fisher) consider the null hypothesis of a unit root (common or country-specific). The fifth (Hadri) sets the null as stationarity. The results of all five tests are presented in Appendix D, run for both series and country groups.

For both the OECD and the non-OECD sub-samples the null of non-stationarity is generally accepted (the null of stationarity is rejected). Non-stationarity of the series is less compelling for savings rates than for capital formation, and especially for the OECD countries. Nevertheless, we can consider both savings and investment rates to be non-stationary. We check next for cointegration.

c. Cointegration

We implement two sets of panel-cointegration tests based on four tests in Westerlund (2007) and seven tests from Pedroni (1997), which differ in terms of the heterogeneity allowed within panels. For all these tests, the null hypothesis is of no cointegration. The results are reported in Appendix D.

It is important to note that Pedroni's tests assume that all countries are independent, which is not the case since the world sum of investment automatically equals the world sum of savings (with no statistical, world discrepancy). Although Westerlund tests are less frequent in the literature, they do not make this assumption of independence. Hence, we rely on the Westerlund tests, which all reject the null of no cointegration (at the 1% level for OECD countries, and at the 5% level for the non-OECD group). The results of the Pedroni tests are more mixed, but still tend to favour cointegration. Therefore, we need to estimate an error-correction model.

d. Error-correction model

The error-correction model is estimated using the Engle and Granger two-step method (see e.g. Coiteux and Olivier, 2000, or Herwartz and Xu, 2009). First, the long run relation (Equation 2.5) is estimated in panel, leading to estimates of α_i and β. This allows us to estimate on yearly data the following relation:

$$\Delta\left(\frac{I}{Y}\right)_{i,t} = a_i + \theta_i\left(\left(\frac{I}{Y}\right)_{i,t-1} - \hat{\alpha}_i - \hat{\beta}\left(\frac{S}{Y}\right)_{i,t}\right) + b\,\Delta\left(\frac{S}{Y}\right)_{i,t} + \varepsilon_{i,t} \qquad (2.7)$$

where Δ is the first-difference operator, $\hat{\alpha}_i$ and $\hat{\beta}$ are estimates from the first estimation, and θ_i is the speed of adjustment towards the long-run relationship.

Some authors estimate this relationship on a country-by-country basis (see Pelgrin and Schich, 2004 for a review). However, the coefficients obtained can be insignificant, especially among developing countries (Mamingi, 1997). Using panel data estimation techniques increases the degrees of freedom for the estimation.

Table 2 reports the cointegration vector for each panel of countries (OECD, and non-OECD). The FH coefficient obtained for the OECD panel (0.685) is in line with the literature (see Footnote 16, and Table 3). However, for the developing countries it is significantly lower, and lower than that obtained in Chakrabarti (2006) (see Table 3): despite lower *de jure* capital mobility, emerging and developing countries seem to display higher *de facto* capital mobility. In the period 1980-2008, the non-OECD countries tend to display larger current-account imbalances (in proportion to GDP) than the OECD group. The absolute value of their current accounts, on average, is 9.7% of GDP, compared to only 4% for the OECD countries.[17]

Table 2 - The FH relation, cointegration vector

	(1) OECD	(2) Non-OECD
Savings rate	0.685***	0.205***
	(0.0180)	(0.00982)
Constant	0.0747***	0.186***
	(0.00450)	(0.00180)
R-sq	0.547	0.0819
N	1232	5028
Groups	30	139
F-stat	36.96	24.78

Standard errors in parentheses
* p<0.1, ** p<0.05, *** p<0.01
Note: yearly data

Source: own calculations.

Table 3 - FH coefficient : comparison with the cointegration literature

Data	Own	Chakrabarti (2006)	Coiteux and Olivier (2000)	Jansen (1998)+	Pelgrin and Schich (2004)
OECD	0.685***	0.81***	0.63***	0.731	0.93***
Non OECD	0.205***	0.79***	-	-	-

+ In Jansen 1998, the coefficient is the average of yearly coefficients between 1955 and 1994

The results of the error-correction models (ECM) are presented in Table 4. The Fisher test cannot reject the null hypothesis that all fixed effects are equal to zero. Hence, the ECMs are finally estimated with neither fixed effects nor a constant. The error correction coefficient θ is found to be significant and negative for both groups of countries, with similar magnitude: each year, 20-25% of the discrepancy between the lagged investment rate and its (lagged) long-run value is erased. However, the impact of the short-term dynamics of the savings rate on the investment rate is higher for the OECD than in non-OECD group of countries.

[17] Calculation based on the IMF, *World Economic Outlook* database, April 2010. In addition, our developing countries sample is larger than the sample in Chakrabarti (2006) and our results for the non-OECD group might be hiding some heterogeneity. In the following, we keep different FH coefficients for OECD and non-OECD countries. In results not reported here, we checked that the sensitivity of our results to this assumption was limited.

Table 4 - Error correction model

	(1) OECD	(2) OCDE	(3) Non-OECD	(4) Non-OCDE
Delta Savings rate	0.769***	0.767***	0.175***	0.175***
	(0.0214)	(0.0211)	(0.00985)	(0.00969)
Error correction term	-0.210***	-0.212***	-0.243***	-0.245***
	(0.0183)	(0.0181)	(0.00938)	(0.00926)
Constant	-0.000635		0.000703	
	(0.000615)		(0.000612)	
R-sq	0.564	0.563	0.172	0.172
N	1202	1202	4876	4876
Groups	30		139	
F-stat	0.197		0.194	

Note: Standard errors in parentheses
* p<0.1, ** p<0.05, *** p<0.01
Yearly data
Source: own calculations.

2.4. Education

Projections of human capital are needed as a component of TFP growth and as a determinant of female participation rates. We rely on a catch-up model of school attainment for two successive age groups: 15-19, and 20-24 years, and three education levels - primary, secondary and tertiary.[18] In order to project school attainment, we need two relations: one for the evolution of the leader level, and one for the behaviour of countries with respect to the leader level. We first estimate the latter, catch-up process, on five-year-interval data:

$$ln\left(\frac{h^l_{a,i,t}}{h^l_{a,i,t-1}}\right) = \lambda^l_r ln\left(\frac{h^{l*}_{a,t-1}}{h^l_{a,t-1}}\right) + \epsilon_{i,t} \quad (2.8)$$

where $h^l_{a,i,t}$ is the proportion of the age-group a in country i having a level of education of at least l ($l = 1, 2, 3$) in year t, $h^{l*}_{a,t}$ is the corresponding level of schooling in the leader country, $h^l_{a,i,t-1}$ and $h^{l*}_{a,i,t-1}$ are the corresponding variables five year before, and $\lambda^l_r > 0$ is

[18] Barro and Lee (2010) follow the UNESCO "ISCED" classification that defines the first tertiary level diploma (level 5) as "comprising education which begins at the age of 17 or 18, lasts about four year, and leads to an award not equivalent to a first university degree." Hence we can safely assume that this first level of tertiary education (which is a minimum requirement for our tertiary-education category) is completed before 24 years old, so we can concentrate on the 15-19 and 20-24 age groups.

the catch-up coefficient that is assumed to vary across regions r.[19] We perform a weighted estimation of Equation (2.8) (using the population shares within each region as a weighing device) and clustered residuals.

The results are reported in Table 5. There is evidence of a significant catching up for all regions and all education levels. The speed varies across regions, with former USSR and Eastern Europe being the fastest and Indian region and Sub-Saharan Africa being the slowest. We can also note that tertiary catch-up speeds are lower than for primary and secondary education.

Table 5 - Education cath-up process, by education level, age group and region

	Primary		**Secondary**		**Tertiary**	
	(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**
	Age 4	**Age 5**	**Age 4**	**Age 5**	**Age 4**	**Age 5**
Western Europe	0.130***	0.273***	0.220***	0.200***	0.402**	0.217***
	(0.0393)	(0.0826)	(0.0558)	(0.0132)	(0.157)	(0.0277)
Eastern Europe and former USSR	0.250***	0.326***	0.143***	0.273***	0.324***	0.235***
	(0.0304)	(0.0710)	(0.0534)	(0.0337)	(0.0261)	(0.0172)
North America, Oceania and Japan	0.205***	0.173***	0.456***	0.275***	0.188***	0.289***
	(0.0637)	(0.0249)	(0.0755)	(0.0146)	(0.0618)	(0.0301)
Latin America	0.192***	0.204***	0.136***	0.148***	0.181***	0.133***
	(0.00658)	(0.0194)	(0.0147)	(0.00794)	(0.0169)	(0.00870)
Mediterranean region	0.178***	0.177***	0.188***	0.156***	0.211***	0.132***
	(0.0139)	(0.00917)	(0.0162)	(0.00945)	(0.0338)	(0.00937)
Chinese region	0.148***	0.265***	0.140***	0.196***	0.191***	0.0852***
	(0.0193)	(0.0294)	(0.0122)	(0.0169)	(0.0188)	(0.00523)
Sub-Saharan Africa	0.125***	0.111***	0.0763***	0.0950***	0.0430	0.0601***
	(0.0156)	(0.0106)	(0.00798)	(0.00803)	(0.0264)	(0.00544)
India region	0.120***	0.114***	0.154***	0.136***	0.102***	0.0892***
	(0.00655)	(0.00974)	(0.0302)	(0.00497)	(0.00541)	(0.00503)
R-sq	0.529	0.488	0.323	0.485	0.273	0.186
N	1669	1663	1626	1662	1054	1630
Clusters	140	140	140	140	138	140

Standard errors in parentheses. * p<0.1, ** p<0.05, *** p<0.01
Note : five-year intervals.
Source : own calculations.

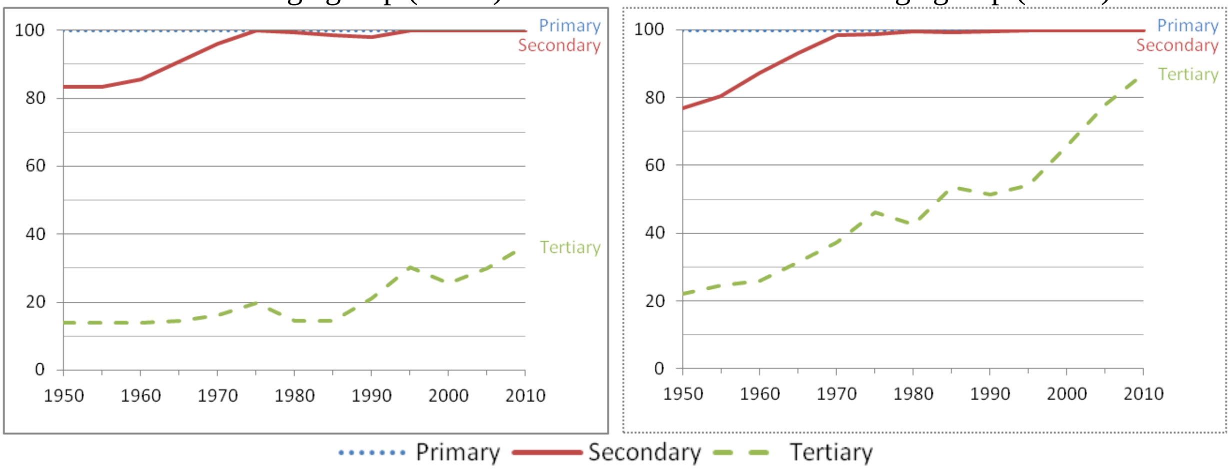
[19] Here regions are defined according to INGENUE, an international General Equilibrium, Overlapping-Generation model focusing on ageing and growth, co-developed by CEPII, CEPREMAP and OFCE, sett Borgy et al. (2009). Papua-New Guinea is excluded here because it is an outlier in its region (North America, Japan and Oceania).

Turning to leadership, the leader country is defined as the country displaying the highest share of educated people for each age group and each level of education. It may vary over time.[20] For primary and secondary education, we will assume the leader level to remain fixed at 100% of both age groups, consistent with the attainment in 2010 (see Figure 11). As for tertiary education, we fit a logistic functional form such that tertiary education for age-group 5 (20-24 years) increases over time without ever exceeding 100%:

$$\ln\left(\frac{h_{5,t}^{3\ *}}{1-h_{5,t}^{3\ *}}\right) = \zeta_0 + \zeta_1 t + \epsilon_t \qquad (2.9)$$

Figure 11 - Leader level school attainment by age group, 1950-2010

a. Fourth age group (14-19) b. Fifth age group (20-24)



Source: own calculations based on Barro and Lee (2010, version 1.2).

The estimation results are displayed in Table 6. As expected, tertiary education rises steadily over time in the leader country for the 20-24 year group.

[20] Several countries can appear the leader level at least for one age group during a sub-period. The main primary education leaders are Austria, Japan, France and Switzerland. The main secondary education leaders are the United States, Australia, Norway and New Zealand. The main tertiary education leaders are the United States, Australia, New Zealand and the Russian Federation.

Table 6 - Tertiary education frontier for age group 5 (20-24 years)

	(1)
	Logistic transf. of $h_{5,t}^{3\ *}$
Year	0.0462***
	(0.00418)
Constant	-91.51***
	(8.271)
R-sq	0.917
N	13

Standard errors in parentheses.
* p<0.1, ** p<0.05, *** p<0.01
Note: five-year intervals
Source: own calculations.

For all countries, the proportion of primary, secondary and tertiary education attainment in each of our 11 age groups (from 15-19 to 64-69) is then obtained based on the size and ageing process of the 15-19 and 20-24 groups.[21] The share of different levels of education in the working-age population is ultimately recovered from a weighted average:

$$h_{i,t}^{l} = \frac{\sum_{a=4}^{14} h_{a,i,t}^{l} pop_{a,i,t}}{\sum_{a=4}^{14} pop_{a,i,t}} \qquad l = 2,3 \qquad (2.10)$$

Where $pop_{a,i,t}$ is the size of age group *a* in country *i* at period *t*.

2.5. Female participation to the labour force

Unlike for men, the participation of females to the labour force is very unequal across countries. In 2010, for example, close to 80 percent of working-age females did participate to the labour force in the United States, 90 percent in China but only 40 percent in India and 35 percent in Morocco. The literature on female participation to the labour force points fertility, urbanization and education as key factors (see, e.g., Bloom et al. (2009)). However, the estimation of participation rates encounters a massive reverse-causality problem. In particular, fertility rates depend on activity. Bloom et al. circumvent this problem by instrumenting fertility with abortion laws. However abortion laws do not change frequently, so controlling with country fixed effects can also do the job. Here we want our projected participation rates

[21] For the leader country, tertiary education of the 15-19 age group is recovered from that of the 20-24 group, based on the observed correlation of 97 percent between the two: a one percent increase in tertiary education for the 20-24 group leads to a 0.41 percent increase in that of the 15-19 group.

to be consistent with the upgrading of education described in Section 2.4. Consistently, we estimate the following logistic equation on our 5-year-interval education data:[22]

$$ln\left(\frac{l^F_{a,i,t}}{1-l^F_{a,i,t}}\right) = \sigma_{a,i} + \beta^2_a h^2_{a,i,t} + \beta^3_a h^3_{a,i,t} \quad (2.11)$$

where, $l^F_{a,i,t}$ represents the participation rate of females of age a in country i at time t. Like in the previous section, $h^2_{a,i,t}$ is the proportion of age-group a (of both genders)[23] in year t that has at least a secondary diploma, $h^3_{a,i,t}$ is the proportion holding a tertiary diploma and $\sigma_{a,i}$ is a country-age group fixed effect.

Equation (2.11) is estimated for each age group separately, for our panel of 140 countries over 1980-2009. The results are reported in Table 7. We find a positive, significant impact of both levels of education on participation between 20 and 59 years old, and a negative impact before 20 (secondary and tertiary education), between 20 and 24 (tertiary education) and after 60 (secondary education). The negative impact of education on participation of the 15-19 and 20-24 groups can easily be explained by the length of the studies. As for the negative impact of education on participation of elder groups, it may be related to the ability of educated workers to retire, in contrast with non-educated ones, especially in developing countries. Concerning the working-age population, it can be inferred from

Table 7 that a country having a 30% female participation rate and moving from 60 to 100 percent secondary school attainment, would raise the female participation rate by 2%.

[22] In a preliminary step, we have checked that education accounts for a larger share of the variance, especially the time variance, of female labour participation rates, as compared to other factors investigated by Boom et al. (2009): fertility rates, infant mortality and capital per capita. The results are available from the authors.

[23] Bloom et al. (2009) show the female participation rate to depend on both genders' education attainment.

Table 7 - Female participation rates estimation by age group, five-year intervals

	(1) 15-19	(2) 20-24	(3) 25-29	(4) 30-34	(5) 35-39	(6) 40-44
age-specific secondary education	-0.148***	0.110***	0.284***	0.265***	0.250***	0.241***
	(0.0164)	(0.0184)	(0.0193)	(0.0202)	(0.0184)	(0.0184)
age-specific tertiary education	-0.326***	-0.149***	0.164***	0.277***	0.254***	0.252***
	(0.0653)	(0.0259)	(0.0347)	(0.0418)	(0.0470)	(0.0525)
Constant	40.86***	52.15***	44.34***	46.15***	48.72***	50.33***
	(0.863)	(1.055)	(1.018)	(0.946)	(0.749)	(0.653)
N	980	980	980	980	980	980
Groups	140	140	140	140	140	140
R-sq.	0.144	0.0568	0.295	0.324	0.351	0.360
F-stat	70.24	25.25	175.1	200.8	226.9	235.5
p-value	52.47	59.60	56.26	65.00	79.11	87.19

	(7) 45-49	(8) 50-54	(9) 55-59	(10) 60-64	(11) 65-69
age-specific secondary education	0.200***	0.169***	0.150***	-0.0253	-0.0529***
	(0.0201)	(0.0215)	(0.0214)	(0.0191)	(0.0157)
age-specific tertiary education	0.308***	0.387***	0.557***	0.459***	0.164***
	(0.0609)	(0.0644)	(0.0636)	(0.0561)	(0.0479)
Constant	50.59***	46.00***	35.18***	29.41***	17.83***
	(0.595)	(0.545)	(0.461)	(0.363)	(0.260)
N	980	980	980	980	980
Groups	140	140	140	140	140
R-sq.	0.320	0.305	0.386	0.128	0.0154
F-stat	197.2	183.6	263.6	61.76	6.557
p-value	81.46	83.94	97.97	122.6	147.2

Standard errors in parentheses.
* p<0.1, ** p<0.05, *** p<0.01.
Source: own calculations.

2.6. TFP growth

For TFP growth, we rely on Vandenbussche et al. (2006) and Lodigiani (2009). In these papers, TFP growth is explained by a pure catch-up effect, a pure (tertiary) education effect, and an interaction term between education and catch up. The latter effect refers to the impact of tertiary education on the ability of a country to move the technological frontier itself (see Aghion and Howitt, 1992). Here, we slightly depart from the two cited papers by introducing both secondary and tertiary education in the equation. As noted for instance by Benhabib and Spiegel (1994), secondary education is crucial when it comes to technology diffusion. Aghion and Howitt (1992) argue that secondary education tends to favor imitation-type catch up, whereas tertiary education favors innovation. Hence, we interact the catching-up term with secondary rather than tertiary education, and keep tertiary education as a separate term.[24] We estimate the following relation, again on five-year intervals due to the periodicity of education data:

$$\Delta \ln(A_{i,t}) = \alpha_{0,r} + \alpha_1 a_{i,t-1} + \alpha_2 h^3_{i,t-1} + \alpha_3 a_{i,t-1}(h^2_{i,t-1} - h^3_{i,t-1}) + \epsilon_{j,t} \quad (2.12)$$

where $A_{i,t}$ denotes the TFP of country *i* in year *t*, $a_{i,t-1} = \ln\left(\frac{A_{i,t-1}}{A^*_{t-1}}\right)$ represents the distance to the TFP frontier A^* in year t-1, $h^3_{j,t-1}$ is the proportion of the working-age population with a tertiary diploma, $h^2_{j,t-1} - h^3_{j,t-1}$ is the proportion of the working-age population with a secondary diploma but no tertiary diploma, and $\alpha_{0,r}$ is a regional fixed effect. We expect $\alpha_1<0$ (TFP growth is lower when country *i* is closer to the frontier), $\alpha_2>0$ (more tertiary education is beneficial to innovation), and $\alpha_3<0$ (more secondary education tends to reduce the negative effect of being closer to the TFP frontier).

Like Vandenbussche et al. (2006) and Lodigiani (2009), we have to deal with endogeneity problems when estimating Equation (2.12). We use lagged values of $a_{i,t-1}$, $h^3_{i,t-1}$, $a_{i,t-1}(h^2_{i,t-1} - h^3_{i,t-1})$, $a_{i,t-1}h^2_{i,t-1}$, $a_{i,t-1}h^3_{i,t-1}$ (i.e. twice-lagged variables) as our five instrumental variables, in line with the literature.

In order to select our specification, we follow the methodology and tests proposed by Baum et al. (2003). We first run the Durbin-Wu-Hausman joint-endogeneity test, which rejects, at the 5 percent confidence level, the null of joint exogeneity of secondary education, tertiary education and distance to frontier. Regarding instrumentation, our goodness-of-fit tests suggest that these instruments are relevant (they are correlated with the instrumented variables), and the different validity tests performed all fail to reject the null of orthogonality at the 5% confidence level, hence confirming the orthogonality of the instruments with the error terms.[25]

We finally conduct the estimation considering the three TFP and education variables as endogenous, and instrumenting them with the five above-mentioned instruments. We consider the oil price as exogenous. We follow Vandenbussche in using region-specific effects that are based jointly on geographical and income criteria. We therefore use our geographical zones in

[24] Introducing the interaction between secondary education and distance to TFP leader in the formulation by Vandenbussche et al. (2006) and Lodigiani (2009) would mathematically imply the addition of a "secondary and more" term, but preliminary tests showed that this term was not significantly different from 0.

[25] The results from these different tests are available from the authors.

conjunction with the World Bank classification of income levels (High- (H), Medium- (M) and Low- (L) income). We then need to cluster the residuals by country. The results are reported in Table 8. All coefficients are significant at the 5 percent level, with expected signs. Ceteris paribus, being 10 percent below the TFP frontier induces a 0.2 percent extra growth of TFP, for a median level of secondary education. In turn, a rise of tertiary education by 10 percentage points raises TFP growth by 0.5 percentage points.

Table 8 - TFP estimation results, 5-year intervals

	Log TFP growth
Distance to the TFP frontier	-0.0158***
	(0.00438)
Tertiary education	0.0534***
	(0.0180)
Interacted distance to frontier and secondary education	-0.0117***
	(0.00452)
Hansen J-stat	4.033
p-value	0.133
N	643
Clusters	131

Standard errors in parentheses. * $p<0.1$, ** $p<0.05$, *** $p<0.01$.
Source: own calculations.

2.7. Energy productivity

Energy productivity, like TFP, can be seen as the result of cumulated innovation. The data seem to emphasise two determinants of energy productivity catch-up. In addition to the distance to the energy-productivity frontier, we need to consider the distance to the development frontier. The latter tends to impact negatively on energy-productivity growth, whereas the catch up of energy productivity is accelerated by higher distance to the energy-productivity frontier.

The underlying empirical evidence shows a U-shaped relation between economic development and energy productivity: low income countries are very energy-efficient because their economies are based on the primary sector. For developing countries, the industry sector, which is very energy demanding, becomes more important, making energy productivity lower; after industrial transition is completed, the technological efficiency of these countries tends to improve, and this is accompanied by the organisation of their economies around the services sector, which means that energy productivity starts to increase.

Thus, we estimate the following relationship on five-year intervals:

$$\Delta \ln(B_{i,t}) = \mu_{0,i} + \mu_1 ln\left(\frac{B^*_{t-1}}{B_{i,t-1}}\right) + \mu_2 ln\left(\frac{y_{US,t-1}}{y_{i,t-1}}\right) + \varepsilon_{i,t} \qquad (2.13)$$

where B^*_{t-1} denotes the energy-productivity frontier. In our sample, Switzerland appears the most energy-productive country over the whole 1980-2008 period. However, due to its specificities (small landlocked country based mainly on the service sector), this country cannot be used as the energy-efficiency frontier. We define the frontier based on the mean of the next four most energy productive countries (United Kingdom, Japan, Germany and France). The estimation results are presented in Table 9. For both OECD and non-OECD countries, the distance to the most efficient countries has the expected, negative impact on energy productivity growth. For non-OECD countries, this catch-up effect is compounded by a positive, significant impact of the distance to US GDP per capita on energy productivity growth: closing the gap to the US in terms of GDP per capita leads to *lower* energy productivity growth. Hence, the data support the idea of a double-catch-up process. In the following, we retain the OECD/non-OECD grouping for energy productivity.

Table 9 - Energy productivity growth: estimation results

	(1) OECD	(2) OECD	(3) Non-OECD
Lagged distance to efficiency leader	-0.0564***	-0.0568***	-0.0877***
	(0.00935)	(0.00926)	(0.00604)
Lagged distance to US GDP per capita	-0.00662		0.0115*
	(0.0174)		(0.00694)
Constant	-0.0186**	-0.0157***	-0.113***
	(0.00854)	(0.00373)	(0.0193)
N	163	163	777
Groups	25	25	137
F-stat	2.122	2.716	2.716

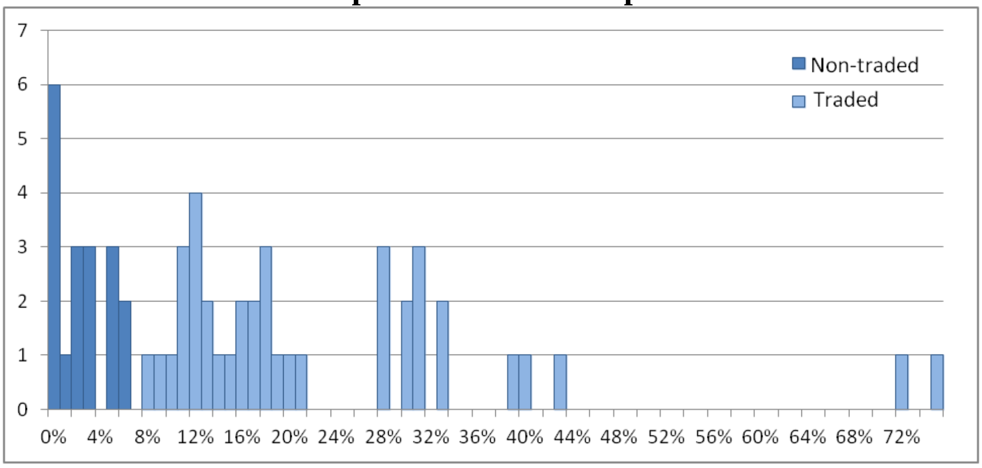
Note: Standard errors in parentheses. * p<0.1, ** p<0.05, *** p<0.01. *Source: own calculations.* Five years intervals

2.8. The Balassa-Samuelson effect

As described in Section 1, the evolution of real exchange rates for each country compared to the US can be expressed as a simple function of productivity and energy-productivity catch up, with proportionality factors that depend on the share of the traded sector in GDP, on the share of tradable goods in consumption and on the distribution of income across production factors in each country and in the United States. We first calculate, for each of the 57 GTAP sector, the share of global exports over global production.

The distribution of these export rates is displayed in **Figure** 12. It shows several modes. We select 8% as our threshold: any sector with an export share over 8% will be considered as tradable. This leaves services and a few goods (cattle, paddy rice, raw milk and sugar cane) under the threshold. Having identified traded and non-traded goods, we then calculate the share of the former in each country's production and consumption. Finally, the share of energy in income (the μ coefficient in Equation (1.10) of Section 1) is derived from the simulation itself.

Figure 12 - Distribution of export share in world production for GTAP sectors



Source: own calculations based on GTAP data for year 2004.

We need then to account for changes in the shares of traded goods in the economy along the catch-up process. Consistently, we estimate two cross-section, logistic relationships between the share of tradable goods in consumption (resp. production) in country i, τ_i, and GDP per capita in Purchasing Power Parity, Y_i/Pop_i:

$$\ln\left(\frac{\tau_i}{1-\tau_i}\right) = \kappa_0 + \kappa_1 \ln\left(\frac{Y_i}{Pop_i}\right) + \epsilon_i \qquad (2.14)$$

We exclude from the sample those countries that appear as outliers, such as oil-producing and financially-oriented countries (which have both high shares of tradable goods and very high GDP per capita).[26] The results of the estimation are presented in Table 10. They show that a

[26] Namely, we drop Qatar, Luxemburg, United Arab Emirates, Kuweit, Singapore, Bahrein, Norway and Iceland.

rise in GDP per capita tends to reduce the share of tradable goods both in consumption and in production, and more the former than the latter.

Table 10 - Share of tradable goods estimation

	(1) Consumption	(2) Production
Log of GDP per Capita	-0.169*** (0.0360)	-0.102*** (0.0223)
Constant	0.961*** (0.311)	0.818*** (0.193)
Obs	159	159
R-sq	0.123	0.116

Source: own calculations.

3. THE WORLD ECONOMY IN 2050

Using MaGE allows us to make long-run economic projections for 147 countries. It relies on the assumption that in the long run, only supply-side factors (labour, capital, TFP, energy productivity) matter for economic growth. Thus, the starting point for the projections should be a year when GDP was at its potential level in most countries. However, we are left with the problem of the 2008-09 global crisis. We could take as our starting point a pre-crisis year – say 2007, but the crisis involved falls in production and income and also a collapse in investments, which is likely to have a long-lasting impact on potential output. Therefore, we (i) rely on IMF GDP forecasts (Autumn 2011) to 2012, (ii) assume that the output gap has been closed at that date, (iii) adjust TFP levels accordingly, based on factor projections during the crisis, and (iv) perform GDP projections for 2013 to 2050. This methodology may overstate the drop in TFP during the crisis since we are unable to account for the temporary fall in investment rates and the rise in unemployment, whose effects could extend beyond 2012. However, this feature is benign since our interest is in GDP, not employment or TFP.

3.1. Key assumptions

Our projections rely on the econometric estimations presented in Section 2 (education, female participation, TFP, energy productivity, savings rate, investment rate, share of tradables). One difficulty however is that, when included in the estimations, fixed effects are not always significant. Hence, it may be unwise to rely on fragile fixed effects that may considerably affect the results, especially over a long horizon. To circumvent this problem, our projections are based on differences from a reference period.

Let $Z_{i,t}$ denote a projected variable for country i in year t, $X_{i,t}^{k}$ (k=1 to K) its explanatory variables, α_k the corresponding coefficients. Denoting by $\alpha_{0,i}$ the country fixed effects, we have:

$$Z_{i,t} = \alpha_{0,i} + \sum_{k=1}^{K} \alpha_k X_{i,t}^{k} + \epsilon_{i,t} \tag{3.1}$$

Denoting by $\bar{Z}_i$ the average value of $Z_{i,t}$ over a reference period, and by $\bar{X}_i^k$ the average value of $X_{i,t}^{k}$ over the same period, we have:

$$Z_{i,t} = \bar{Z}_i + \sum_{k=1}^{K} \alpha_k \left(X_{i,t}^{k} - \bar{X}_{i,t}^{k}\right) + \left(\epsilon_{i,t} - \bar{\epsilon}_i\right) \tag{3.2}$$

Equation (3.2) no longer relies on fixed effects, hence it can be used whatever the level of significance of the fixed effects.[27] Here we choose 1995-2008 as the reference period. This period corresponds to the post-transition era. It follows important structural reforms in China and corresponds to the emergence of a number of large, developing economies.[28] The error term is dropped in the projection exercise. When the estimation is run on 5-year *intervals* (education, TFP, energy productivity), the projections are turned into yearly data by considering constant growth rates (productivity) or levels (education) over each 5-year window. When estimations are conducted on 5-year *averages* (savings rate), we build yearly data by using each year the estimated relation.

Using an average of five countries as the TFP frontier raises a difficulty since some of the leaders may nevertheless experience some catch up and drive the frontier further up. To avoid this problem, we constraint TFP growth to 0.92 percent per year (the leader group's average over 1995-2008) as soon as a country becomes part of the leading group. In order to avoid sudden switches from catching-up to leader status, we allow for a smooth transition between the two statuses, starting when the country reaches 90 percent of the frontier level.[29]

Though we also have an average of five countries for energy productivity, this group is stable across time. We assume that the five countries (Denmark, the United Kingdom, Japan, Germany and France) will be the same over the projection period.

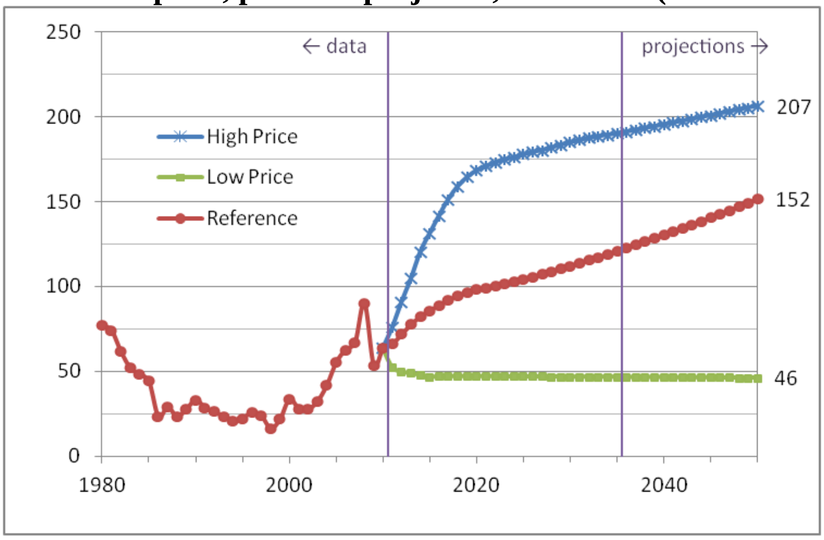
[27] The same reasoning applies in the case of region-specific effects. In that case, the fixed effects are the same for all the countries of a same region.

[28] Alternatively, we could have chosen the entire 1980-2008 period as the reference. This would have been equivalent to working with fixed effects. The non-significance of some fixed effects can then be easily understood given the heterogeneity of this long period for a large number of countries.

[29] Finally, we choose not to include financial centers such as Luxembourg, Switzerland or Iceland in the leaders group, even when they appear in the top-five list. Their TFP is then simply assumed to grow at the same pace as that of the frontier.

A key assumption in our projections then is the (real) price of oil. As mentioned in Section 1, we use EIA projections up to 2035 (International Energy Outlook, 2010). From 2036 onwards, we assume that oil price will continue to grow at its average growth rate over the period 2030-2035. We apply the same methodology to the three different EIA scenarios (see Figure 13). In our base case, we use the medium projection ('reference'). We test the sensitivity of our results to the oil price in Section 4.

Figure 13 - Real oil price, past and projected, 1980-2050 (constant 2005 USD)



Source: EIA (1980-2035), own calculations (2036-2050).

For saving and investment, we are faced with the n[th] country problem: with *n* countries in the world, there are only *n*-1 independent savings-investment imbalances. In other words, savings-investment imbalances should sum to zero across our 147 countries (assuming that the weight is negligible for the remaining world countries). Rather than dropping the savings and investment equations for one country that might be considered the 'rest of the world', we choose to distribute the discrepancy across all 147 countries, proportional to their share in world investments. Denoting by $I_{i,t}$ the projected GCF of country *i* at time *t* and by $S_{i,t}$ its volume of savings, the world-consistent volume of investment $\tilde{I}_{i,t}$ is such that:

$$\tilde{I}_{i,t} = \frac{I_{i,t}}{\sum_j I_{j,t}} \sum_j S_{j,t} \qquad (3.3)$$

Finally, we need to smooth out the share of tradable goods in consumption and production, because for many countries the value for 2004 $\tau_{i,04}$ is far from the model-predicted value $\tau^*_{i,04}$. We chose to use a yearly error-correction-type update according to the formula:

$$\tau_{i,t} = \tau_{i,t-1} + \theta\left(\tau^*_{i,t-1} - \tau_{i,t-1}\right) \tag{3.4}$$

With θ being calibrated to $\theta = 0.015$ such that the half-life of the convergence process is 46 years.[30]

We now turn next to the projections, starting with the different production factors (Section 3.2) and to GDP at constant relative prices (3.3) and variable relative prices (3.4). At each step, the results for a few large economies are displayed and discussed. The detailed results are reported in Appendix E.

3.2. Production factors

a. The labour force

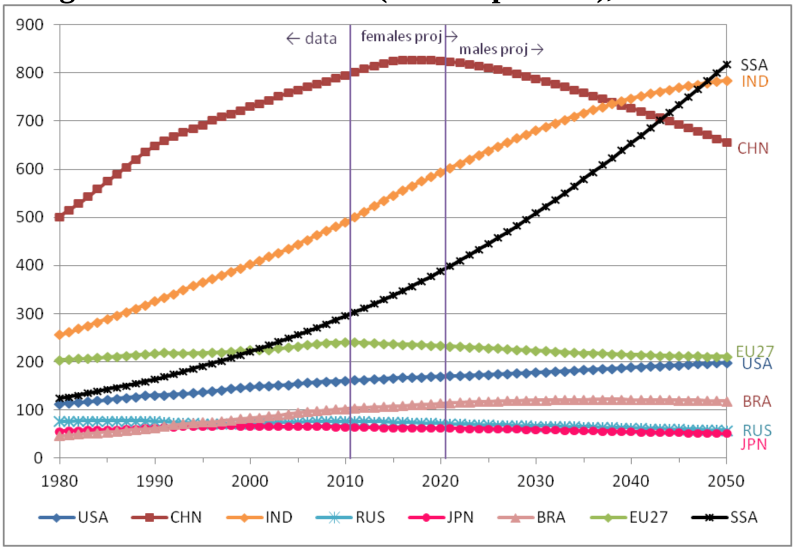
Figure 14 depicts the evolution of the labour force for a few large economies. China's labour force starts to decline around 2015, while India's and Sub-saharan Africa's continue to grow. At the 2050 horizon, India's active population exceeds the Chinese one by around 130 million and Sub-saharan African active population is 30 million greater than India's.

Over the same period, the US labour force is fairly dynamic, with a 34% increase between 2008 and 2050. In 2050, the US labour force meets the European one at around 200 million individuals, which is 3.5 times smaller than China or SSA.

Japan and Russia, on the other hand, show a large decrease in their labour force, along the 2008-50 period, which will make it more difficult for them to maintain positive growth rates.

[30] Here the half-life is given by T=-ln2/ln(1-θ).

Figure 14 - Labour force (million persons), 1980-2050

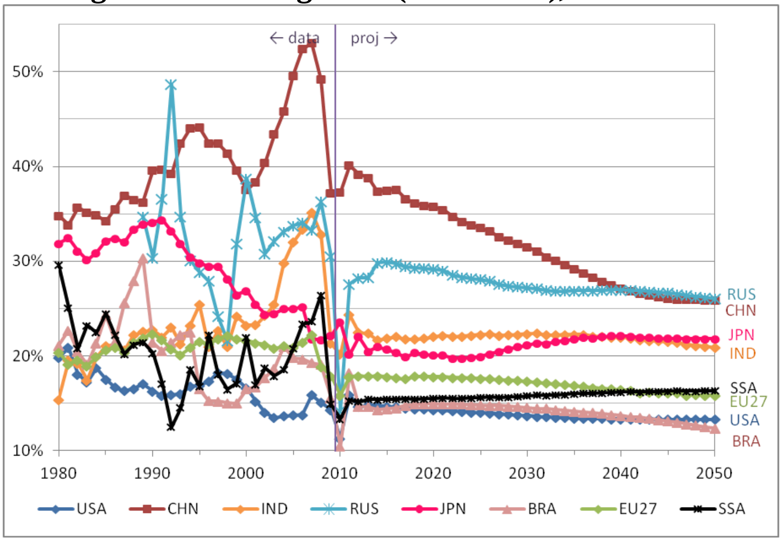


Notations: see Figure 2. Source: own calculations.

b. Saving and investment

According to our estimated equations, the savings rate is an increasing function of GDP per capita level (relative to the US) and GDP growth rate, and a decreasing function of the share of older people in the population. The progressive ageing of China's population triggers a dramatic reduction in China's savings rate (Figure 15). The impact of ageing is evident for Russia and to a lesser extent for the other countries in Figure 15. In India, the savings rate increases slightly up to 2030, and then declines.

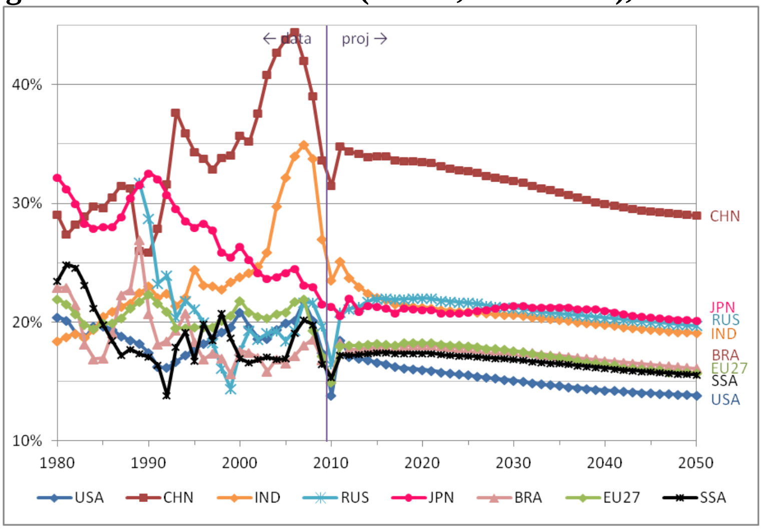
Figure 15 - Savings rate (% of GDP), 1980-2050



Notations: see Figure 2. Source: own calculations.

The decline in savings rates implies a decline in investment rates, although not necessarily in parallel with savings rates (Figure 16). For example, in China, the investment rate declines by 5 percent of GDP while the savings rate falls by more than 15 pp of GDP. In India, the rate of investment falls steadily while savings rates increases slightly. In the US and in the UK, the rate of investment falls much more than the savings rate.

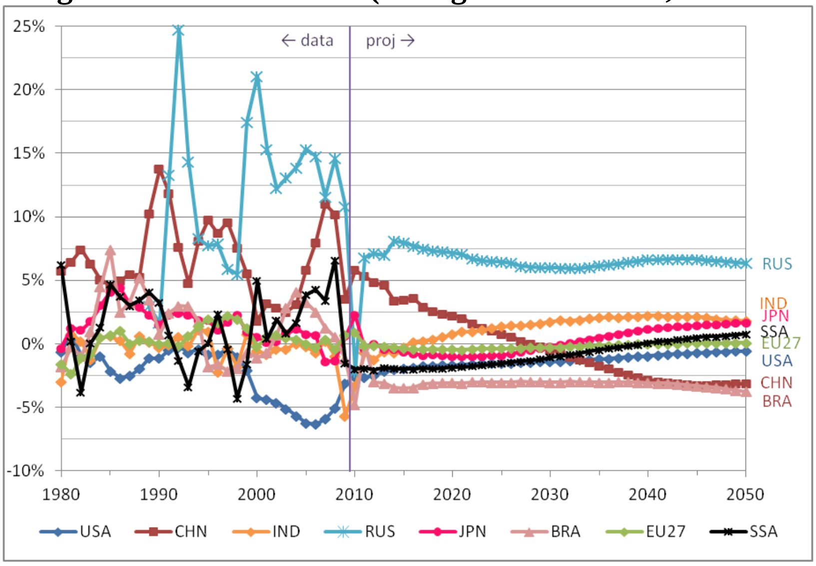
Figure 16 - Investment rate (GFCF, % of GDP), 1980-2050



Notations: see Figure 2. Source: own calculations.

Figure 17 plots the implications of savings and investment developments for current accounts. Between 2020 and 2040 China's surplus and the US deficit disappear. In contrast, India has a current-account surplus after 2020 and Russia has a large surplus over the whole projection period.

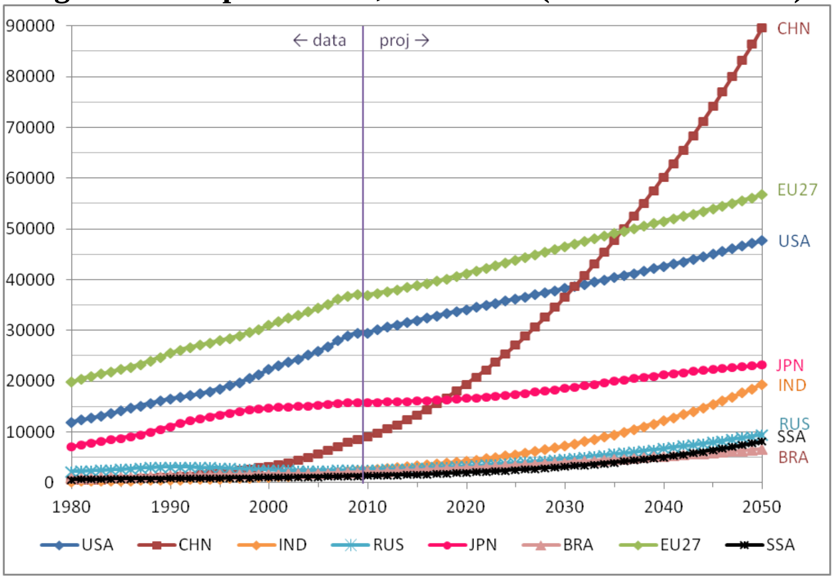
Figure 17 - Savings-Investment balance (savings minus GFCF, % of GDP), 1980-2050



Notations: see Figure 2. Source: own calculations.

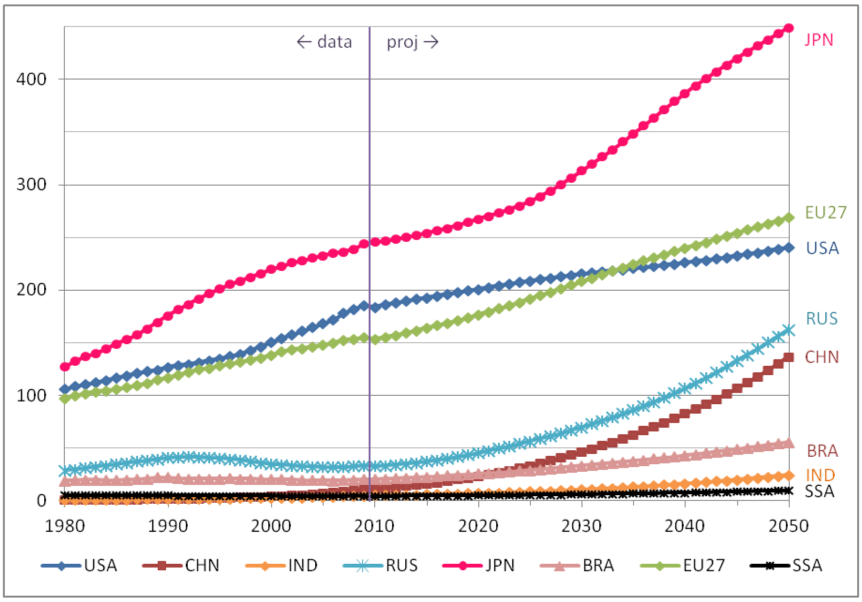
Since in China, GDP continues to increase rapidly over the period, even a falling investment rate fuels fast-growing capital stock. After 2030, China's capital endowment is larger than that of the US, at 2005 US dollar, and larger than the European one after 2035 (Figure 18). However, given the difference in the sizes of these countries' labour forces, China's capital intensity (K/L) is still half that of the US in 2050. Finally, Japan's leading position for capital intensity is unchallenged: steady investment and declining demography lead to a sharp increase in the K/L ratio.

Figure 18 - Capital stocks, 1980-2050 (2005 USD billions)



Notations: see Figure 2. Source: own calculations.

Figure 19 - Capital Intensity, 1980-2050 (2005 USD '000 per capita)

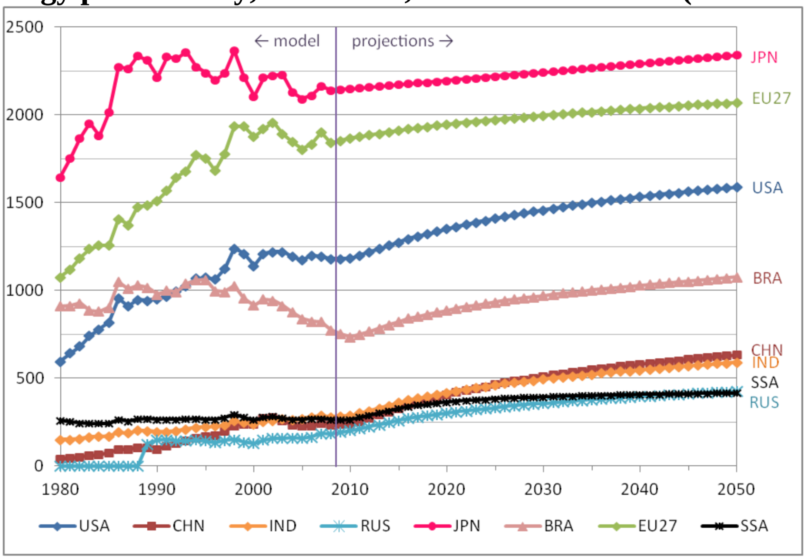


Notations: see Figure 2. Source: own calculations.

c. Energy productivity

In our projections, the energy productivity hierarchy remains broadly unchanged for the developed countries. The four frontier countries grow at a constant exogenous rate (+0.5 percent per year, which corresponds to their average growth rate over 1998-2008), with the remaining OECD countries catching up to this frontier. Brazil, India and China catch up to the energy productivity frontier at a similar rate to the US (Figure 20). As a consequence of the U-shaped relationship, Sub-Saharan countries, on average, do not catch-up due to industrialization.[31]

Figure 20 - Energy productivity, 1980-2050, OECD and BRICs (2005 USD per barrel)



Notations: see Figure 2. Source: own calculations.

d. Education

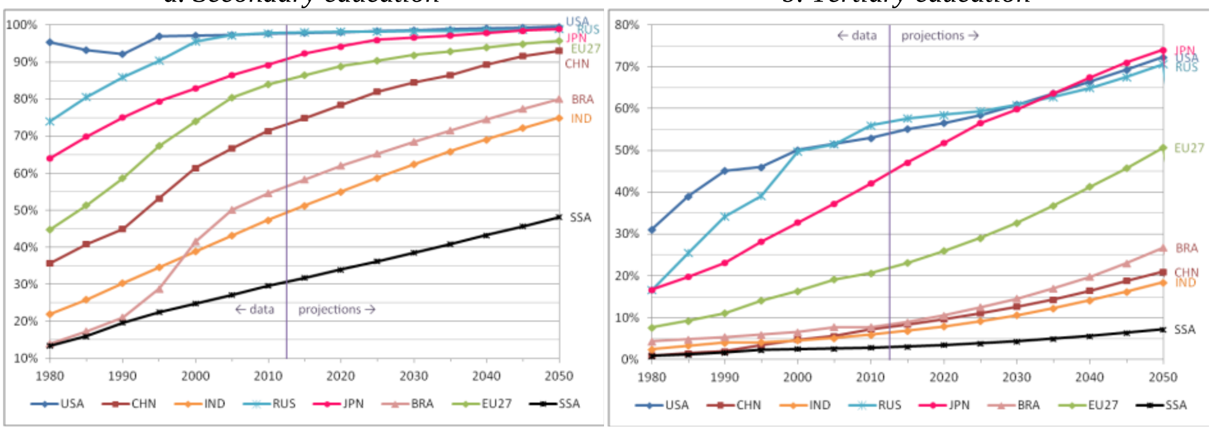
Education catch up is reported in Figure 21. Interestingly, Chinese secondary education attainment reaches almost the EU27 level in 2050, while tertiary education still lags behind (with only 20 percent of the working-age population in 2050, compared to 50 percent in the EU27 and over 70 percent in the United States, Japan and Russia). At the other end of the spectrum, the proportion of the working-age population that has a secondary diploma hardly reaches 50 percent by 2050 in Sub-Saharan Africa, and the proportion is still less than 10

[31] However no country of the sample experiences a fall in energy productivity in our projections, meaning that they all lie beyond the U-curve turning point at the start of the projection

percent for tertiary education. Brazil and India resemble China for the tertiary education path but they stay below 80 percent for secondary education, at the 2050 horizon.

Figure 21 - Human capital, secondary and tertiary education, 1980-2050 (% of working-age population)

a. Secondary education *b. Tertiary education*



Notations: see Figure 2. Source: own calculations.

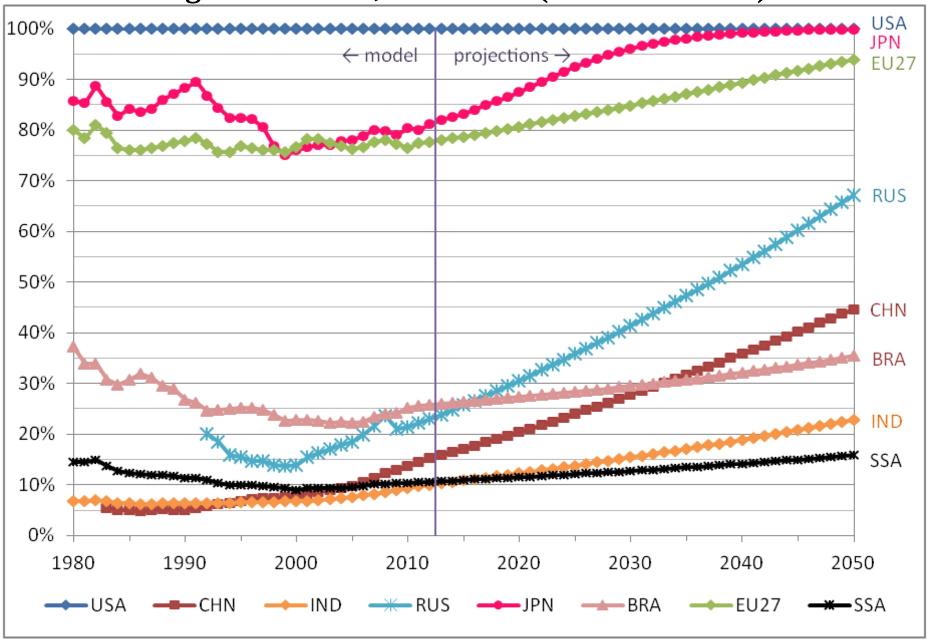
e. TFP

TFP growth results from a combination of education and catch up. Unsurprisingly, then, Japan, China and Russia enjoy fast catch-up towards the US TFP level (Figure 22). Brazil and India, which display less upgrade in terms of secondary education, clearly lag behind.[32] At the 2050 horizon, Japan is found to have almost fully caught up the United States in terms of TFP level, while EU27's TFP is still 5 percent below the US level, China being still 55 percent below the US. As for Sub-Saharan Africa, it shows very little catch up during the period due to both limited educational upgrade and poor past performance.[33]

[32] For these two countries, there is also an effect of the slow TFP growth rates observed during the 1995-2008 reference period.

[33] As already mentioned, the 2008-09 global crisis resulted in a dramatic drop in TFP in our model since we do not account for its impact on production factors (capital, labour, energy productivity). Because all countries are affected by the crisis, the effect on TFP growth rates is minor, but the impact on TFP levels is more substantial.

Figure 22 - TFP, 1980-2050 (% of USA level)

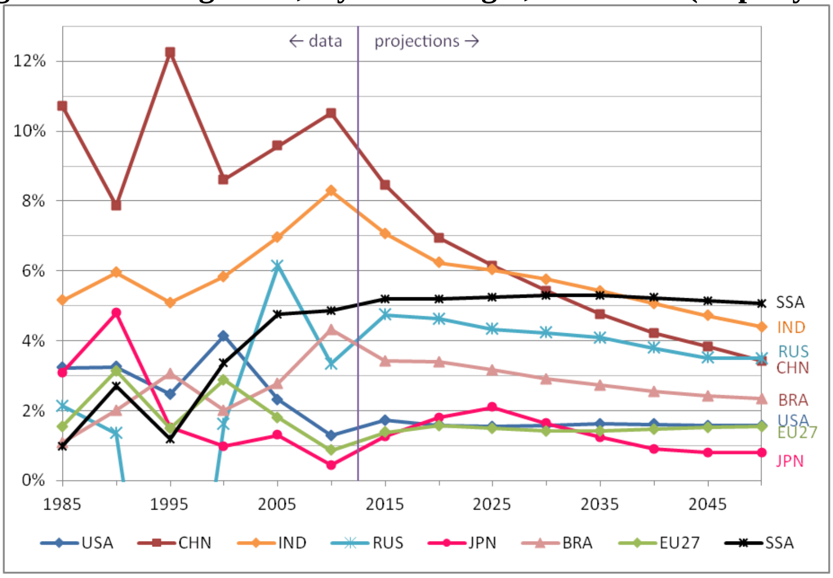


Notations: see Figure 2. Source: own calculations.

3.3. GDP in volume

To project volume of GDP for our sample of 147 countries from 2013 to 2050, we combine labour, capital, TFP and energy productivity. Figure 23 depicts GDP growth rates. Up to 2025, the highest growth rate is achieved by China, but from 2025 to 2050 it is overtaken by India and Sub-Saharan Africa on average, the latter outperforming the former around year 2040. After 2030 Japan experiences very low growth rates. This reflects its reduced labour force which is not fully compensated for by capital accumulation and TFP growth.

Figure 23 - GDP growth, 5 year averages, 1980-2050 (% per year)



Source: own calculations.

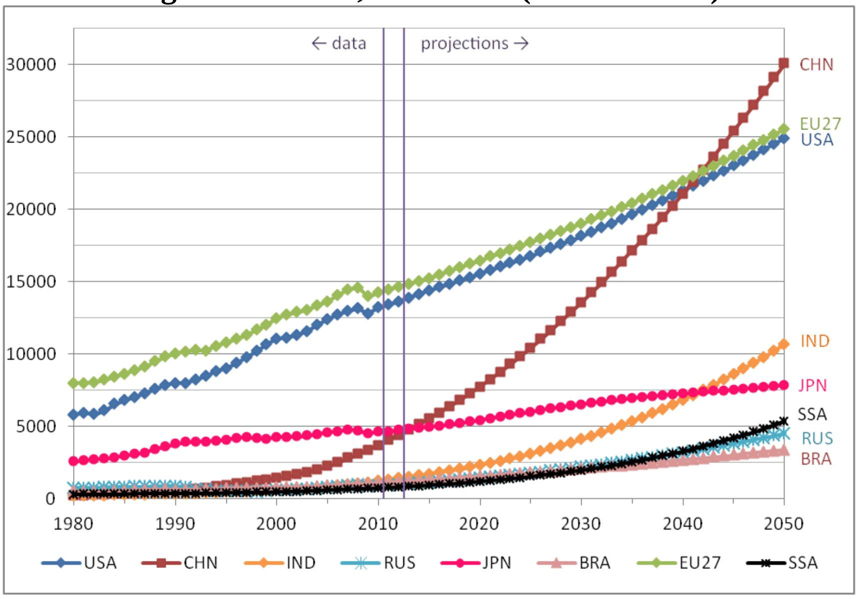
In the introduction to this paper, we showed that assuming a constant 8% GDP growth rate for China would result in this economy growing 21-fold in 40 years. Here, we project a reduction in this growth rate for China, from 8.6% per year in 2010-15 to 4.3% per year in 2025-2050, resulting in a 8-fold growth between 2010 and 2050 (see Figure 24). The actual order of magnitude of China's economic growth is a direct indication of this country's demand for global natural resources. According to our calculations, measured in 2005 US dollars, China could overtake the US as the largest world economy around 2040, and could be 22% larger than the US in 2050. This would make China six times larger than the largest EU country, i.e. the UK. At around the same time, 2050, India would be the third largest world economy – 36% larger than Japan's and a third of the Chinese one.

The corresponding shares of global GDP of the main economies in 2010, 2025 and 2050 are depicted in Notations: *see Figure 2. Source: own calculations.*

Figure 25. At constant relative prices, the US would account for only 17% of the world economy in 2050, compared to 27% in 2010. The loss of position of the US would occur between 2025 and 2050. By 2050, according to this projection, China would account for 20% of global GDP (compared to 7% in 2008) and India would have a 7% share in 2050 (compared to 2% in 2008). The shares of the European Union and Japan would also fall dramatically during this period while the shares Brazil and Russia would remain unchanged

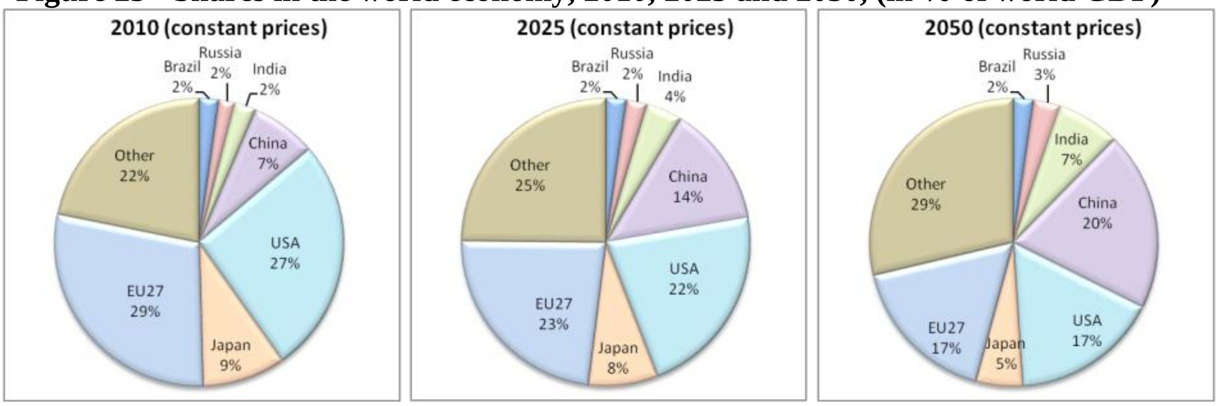
around 2-3% each. Hence, within the BRICs (Brazil, Russia, India, and China) group there are wide differences: while the shares of China and India are multiplied by a factor of at least three by 2050, Russia and Brazil manage only to keep their shares constant within a rapidly expanding world economy.[34]

Figure 24 - GDP, 1980-2050 (2005 USD bn)



Notations: see Figure 2. Source: own calculations.

Figure 25 - Shares in the world economy, 2010, 2025 and 2050, (in % of world GDP)



Source: own calculations.

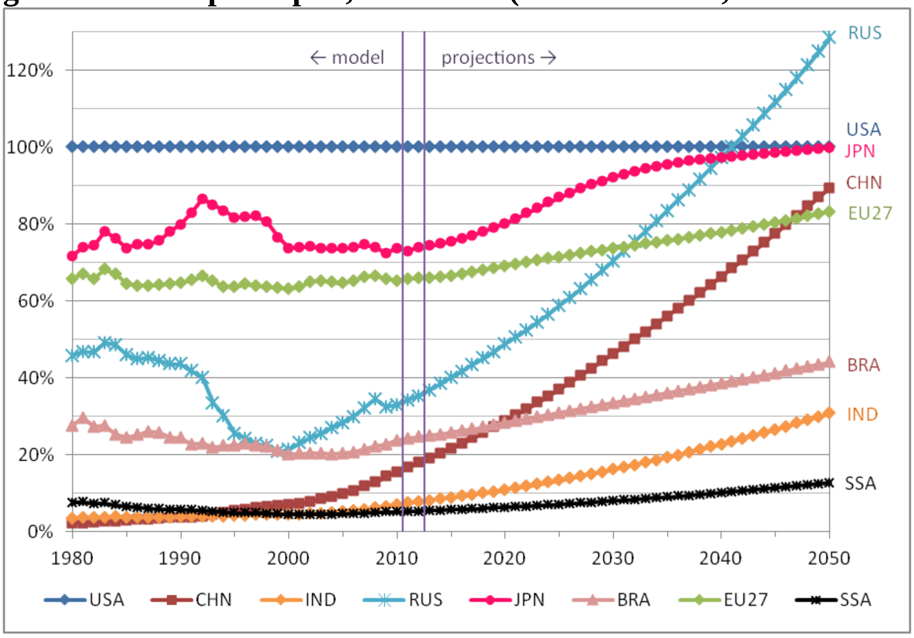
[34] Russia benefits from the steady rise in the oil price but suffers from a reduction in its labour force.

To estimate standards of living, we convert projected GDP into purchasing power parity (PPP) and divide this by projected population. Denoting by *PPP* the PPP conversion factor (taken from The World Bank for year 2005) and by *N* the total population, we have:

$$\text{GDPcap} = \frac{Y}{L} \times \frac{L}{N} \times PPP \qquad (3.2)$$

Hence, GDP per capita in PPP differs from labour productivity due to (i) the employment rate L/N, and (ii) the PPP conversion factor. Our calculations suggest that China's GDP per capita would reach 89% of the US level in 2050, despite still low TFP (45% of US level in 2050). This large gap between TFP and GDP per capita can be explained in China by a relatively high employment rate (84% of US level) and especially a very high conversion factor (2.4). Figure 26 shows that India tends to catch up with Brazil to be respectively 31% and 44% of the US level in 2050, while the EU stays 17 percent below the US level at that horizon. As for Russia, its GDP per capita exceeds that of the United States thanks to the oil rent that is distributed to a reduced number of inhabitants.

Figure 26 - GDP per capita, 1980-2050 (2005 PPP USD, % of US level)



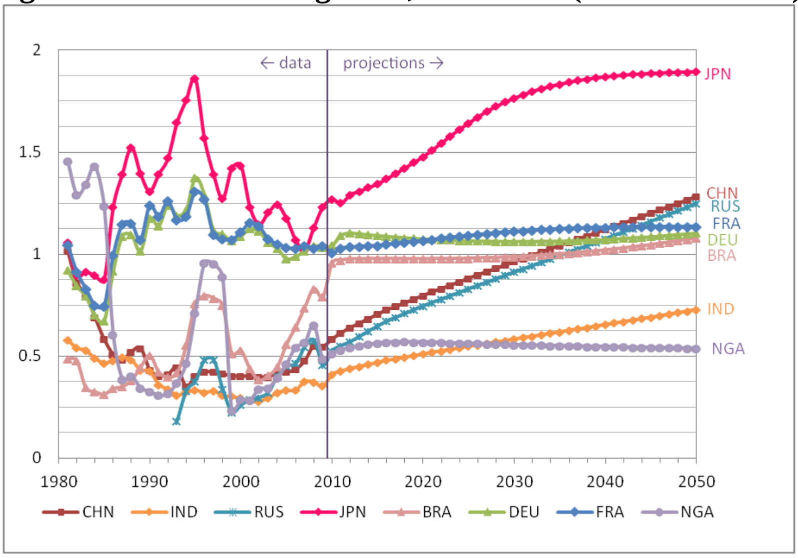
Notations: see Figure 2. Source: own calculations.

3.4. GDP with relative-price variations

In the scenarios so far, we have not included valuation effects, and GDP growth rates and levels have been presented at constant prices, in 2005 US dollars (for GDP) or 2005 PPP dollars (for per capita GDP). The figures we obtained are the key to how global production may be reshaped, and have massive implications for demand for production factors (especially energy and human and physical capital) and carbon emissions. However, they do not provide an indication of the weight of each country in terms of global purchasing or financial power. For instance, the fast catch up of China in terms of per capita GDP will trigger an increase in the prices of Chinese goods relative to other countries' goods. This real exchange-rate appreciation will contribute to income growth and result in greater international purchasing and financial power.

In the Balassa-Samuelson framework described in Section 1, TFP and energy productivity catch-up involve a real exchange-rate appreciation against the US dollar, at a speed that depends on the share of non-tradable goods in each economy (see Figure 27). As might be expected, India, China, Russia and especially enjoy strong real exchange-rate appreciation up to 2050. Japan also sees its real exchange rate appreciate steadily because its GDP growth heavily relies on TFP growth, in the context of a declining workforce.

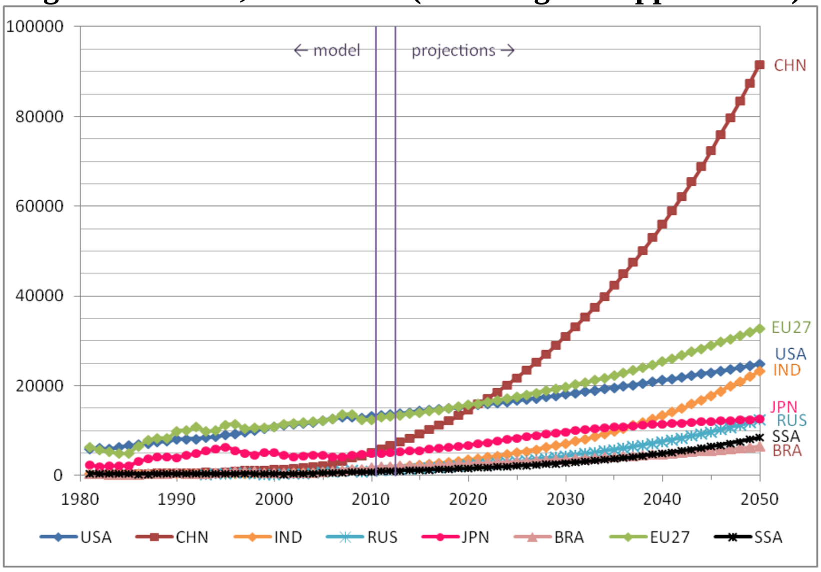
Figure 27 - Real exchange rate, 1980-2050 (versus the USA)



Notations: see Figure 2; FRA=France; DEU=Germany; NGA=Nigeria.
Source: own calculations.

Accounting for these relative price projections, China overtakes US GDP at around 2020 (against 2040 at constant relative prices), as shown in Figure 28. Hence, accounting for real exchange rate appreciation changes the relative levels but not the 2050 rankings of the four largest economies: China's economy is around four times that of the US or EU in 2050.

Figure 28 - GDP, 1980-2050 (including real appreciation)



Notations: see Figure 2. Source: own calculations.

The resulting shift in economic power between 2010 and 2050 is depicted in Figure 29. Adding valuation effects naturally increases the shift in the economy towards China and India. The US would account for 17% of world GDP in 2025 and 9% in 2050, compared to 25% in 2010; the European Union would drop from 23% of world GDP in 2010 to 17% in 2025 and 12% in 2050, and Japan would drop from 9% to 8% to 5% in the same periods. In contrast, the respective shares of China and India would grow from 10% in 2010 to 22% in 2025 and 33% in 2050, and 3% to 5% and then 8%. Brazil's and Russia's shares would remain relatively stable over the whole period at around 3% each.[35]

[35] Our projections for Brazil might appear conservative. This is because they are based on econometric relationships estimated for 1980-2009, a period when its average economic performance was relatively poor.

Figure 29 - Shares of the world economy, 2010, 2025 and 2050 (in% of world GDP, including real appreciation)

Source: own calculations.

4. Assessment

In this section we assess our projections in two ways. First, we perform sensitivity exercises to check the robustness of the projections to changes in certain key parameters. Second, we compare our projections with those in the literature.

4.1. Sensitivity analysis

First we test the robustness of our projections to changes in a number of key assumptions. Specifically, we simulate seven different world economy scenarios:

- the reference scenario is the one described above;
- a 'low energy price' scenario assumes a lower oil price, according to the EIA low price scenario up to 2030 (and a price of USD 46 per barrel in 2050, instead of USD 152 in the reference case, see Figure 13);
- a 'high energy price' scenario is based on the EIA high price scenario and USD 207 per barrel in 2050, see Figure 13;
- a 'substitutable E', where a permanent, technological shock in 2012 leads to higher substitutability between energy and other factors ($\sigma = 0.22$ instead of 0.136).

- a 'financially closed economy' scenario where the investment rate is set equal to the savings rate, for each country and each year, such that there is no capital mobility around the world.

- a 'converging behaviours' scenario whereby national idiosyncrasies in terms of institutions, preferences, governance would half-converge to the initial world average at the 2050 horizon. To this end, we linearly reduce half of the divergence of initial country differences (the $\bar{Z}_i$ terms in Equation (3.2) above). This last robustness check is warranted by the possibility that country fixed effects correspond to non-permanent idiosyncrasies, for instance due to institutional convergence.

Figure 30 provides comparisons of the various scenarios for three countries (the United States, China and India), two variables (energy intensity, average investment rate) and two time horizons (2025 and 2050). Average GDP growth rates over the projection periods are reported in

Table 11. As expected, in all three countries energy intensity is higher in the low energy price scenario than in the reference scenario, and is also lower in the high energy price scenario. However this does not translate into major differences in GDP growth over the projection period. In China, the low energy price scenario results in a 0.1 percentage point increase in GDP growth for 2012-2025, compared to the reference scenario, and a high energy price reduces GDP growth by 0.2 percentage point at the same time horizon. These limited effects point to the minor contribution of energy to GDP growth, as opposed to the contributions of capital accumulation, labour supply and productivity growth.[36]

The "converging behaviours" scenario leads to less investment in India and especially China, where the exceptional savings rate observed during the 1995-2008 period progressively hollows out. The impact on GDP growth is limited over 2012-25 but more substantial over 2025-50 where China's growth rate is reduced by 0.4 pp, while the US one is increased by 0.2 pp.

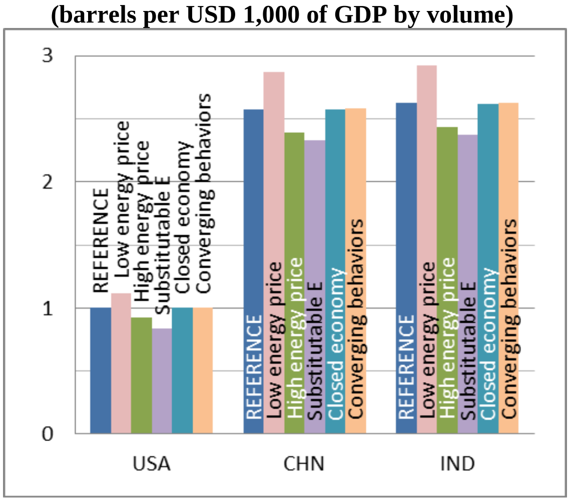
Finally, the "financially closed economy" scenario can be interpreted jointly with the current account imbalances depicted in Figure 17. This scenario is detrimental to the economies which face a current account deficit (e.g. the USA). They can no longer finance their capital accumulation through capital inflows. The loss for the USA is of 0.15 pp annually over 2012-2025 but less than 0.1 pp over 2025-2050. Symmetrically, China first benefits from investing

[36] Note that we do not take into account the impact of a low price of energy in terms of greenhouse gas emissions and the correlated impact on the climate and ultimately on GDP.

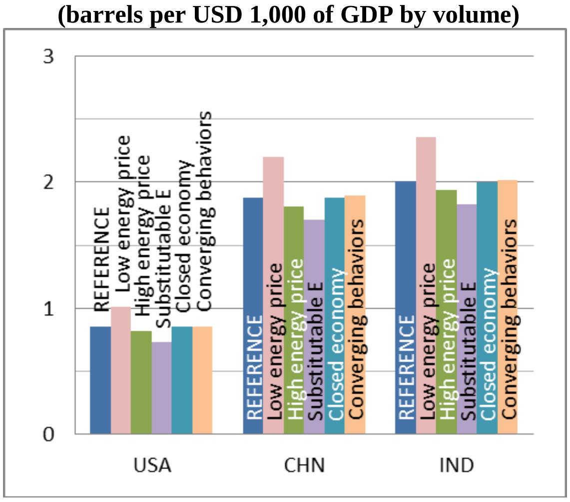
its entire savings domestically; but this effect is quickly erased by the dramatic drop in the Chinese savings rate. In the reference scenario, the investment rate does not fall as much as the savings one, turning the current account into deficit before 2030. In the closed-economy scenario, China invests less at this horizon in order to achieve a balanced current account. Over 2025-2050, Chinese growth is 0.3 pp lower in the closed-economy scenario than in the reference scenario. Finally two countries that keep a current account surplus over the period, India and Russia, benefit from the closed economy scenario. On the whole, though, the closed-economy scenario reduces global growth by an annual 0.1 percentage point.

Figure 30 - Sensitivity analysis of energy intensity and investment rate

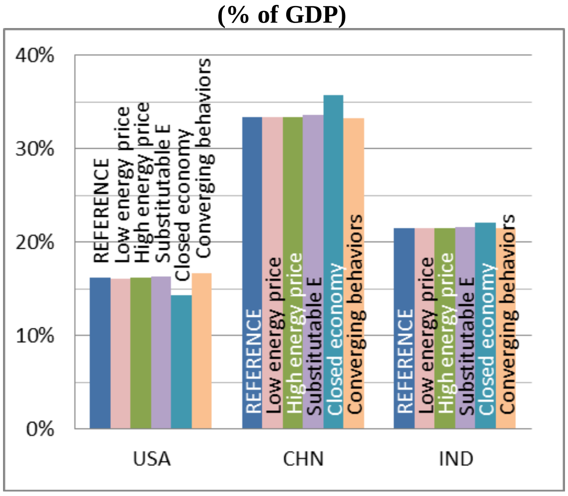
Energy intensity in 2025
(barrels per USD 1,000 of GDP by volume)



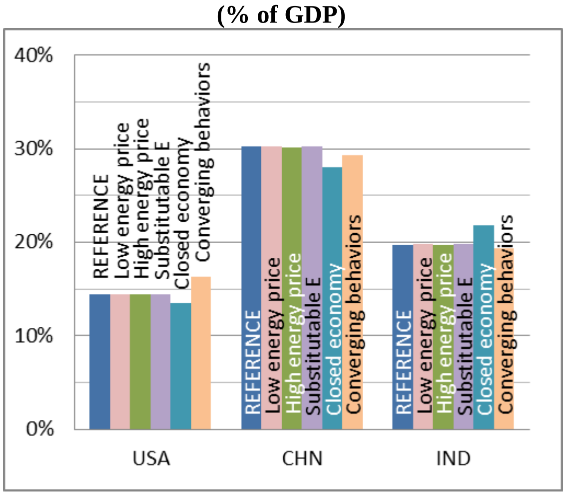
Energy intensity in 2050
(barrels per USD 1,000 of GDP by volume)



Investment rate, 2025
(% of GDP)



Investment rate, 2050
(% of GDP)



Source: own calculations.

Table 11 - Sensitivity analysis on average GDP growth, 2012-2025 and 2025-2050 (annual % change)

		Brazil	Russia	India	China	USA	Japan	EU	World
2012-2025	**REFERENCE**	3.32	4.57	6.45	7.18	1.62	1.72	1.48	2.91
	Low energy price	3.34	4.55	6.56	7.28	1.63	1.74	1.50	2.92
	High energy price	3.30	4.60	6.22	6.97	1.59	1.68	1.45	2.81
	Substitutable E	3.46	4.89	6.73	7.47	1.71	1.78	1.55	3.06
	Closed economy	2.94	4.92	6.52	7.16	1.47	1.60	1.34	2.81
	Converging behaviours	3.33	4.55	6.44	7.10	1.67	1.70	1.47	2.90
2025-2050	**REFERENCE**	2.59	3.82	5.07	4.33	1.59	1.07	1.48	2.72
	Low energy price	2.64	4.05	5.18	4.42	1.61	1.09	1.50	2.80
	High energy price	2.56	3.61	5.09	4.35	1.59	1.08	1.48	2.67
	Substitutable E	2.62	3.88	5.11	4.35	1.61	1.09	1.49	2.77
	Closed economy	2.35	3.92	5.10	4.03	1.51	1.00	1.35	2.62
	Converging behaviours	2.60	3.72	5.03	3.90	1.73	1.07	1.40	2.64

Source: own calculations.

4.2. Comparison with other projections

We compare our projections with those resulting from similar exercises conducted by Goldman Sachs (GS, Wilson et al., 2011), the OECD (based on Duval and de la Maisonneuve, 2010), Price Waterhouse Coopers (Hawksworth and Tiwari, 2011) and HSBC (Ward, 2010). Note that understanding the differences in projections is not straightforward as the projections used in comparison are not allways systematically documented.

HSBC projects the world economy in constant dollars, whereas OECD and PWC projections are in PPP (which, in terms of growth rates, is the same as constant dollars); GS projections take account of relative-price variations through a Balassa-Samuelson-like effect. GS and PWC projections provide GDP levels for 2008-50, whereas the OECD publishes average growth rates for 2005-15, 2015-25 and 2025-50 and HSBC average growth rates by decade. Provided the appropriate horizon and unit (without or with valuation effects) are considered, our results can be compared to each of these sources, with the additional assumption that, when time periods to not overlap exactly, the growth rate are constant within the period.

Figure 31 compares the average growth rates obtained in our exercise[37] to those obtained by the four other exercises, over the same time spans, and Figure 32 - Figure 33 report the composition of the global economy in 2025 and in 2050, according to these sources, when available. Although broadly in line with their projections (in terms of country rankings), our results show some differences, especially with OECD data.

Up to 2025, our projections for China and Russia are optimistic compared to OECD, PWC and HSBC projections at constant real exchange rates. Regarding Russia, one diverging point is the increase in GDP due to oil production that we account for. In contrast, our projections tend to underestimate growth in Brazil and India compared to the other sources. For the advanced economies, our results are slightly more optimistic for countries that show a current-account surplus (Japan, Germany) and slightly more pessimistic for those with deficits (the USA, the UK, France). These differences may be due to our more ambitious modelling of capital accumulation: while the OECD assumes convergence of all countries to the US capital-to-GDP ratio and GS assumes that the investment rate is directly linked to the dependency ratio, we relate investment to savings through a progressive closing of the savings-investment gap in each country. Hence, in our projection the US investment rate tends to fall over time, closing the current-account deficit.

After 2025, our growth rates for China are still more optimistic than the other sources, except HSBC that posts a higher growth rate. For India, our projections are now lower than all other sources including GS, which can be related with the importance we give to education in our model (TFP growth, female participation).[38] Finally, since its last update (December 2011), GS assumes a uniform econometrically-estimated convergence to PPP of the real exchange rate, whereas we use a country-by-country calibration based on the shares of traded goods and energy remuneration in each economy, which often diverge from PPP (see e.g. Japan).

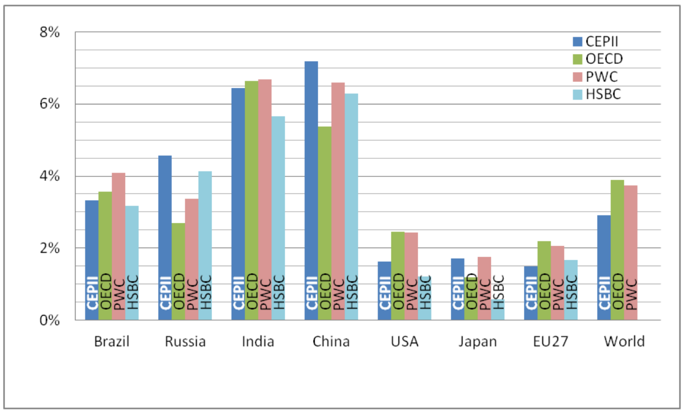
For Russia we are more optimistic than all other sources due to our modelling of the oil rent, which culminates in 2050 at 11% of the corrected GDP. For the advanced economies, we again show more optimism in surplus countries and more pessimism in deficit ones.

[37] Geometric averages.

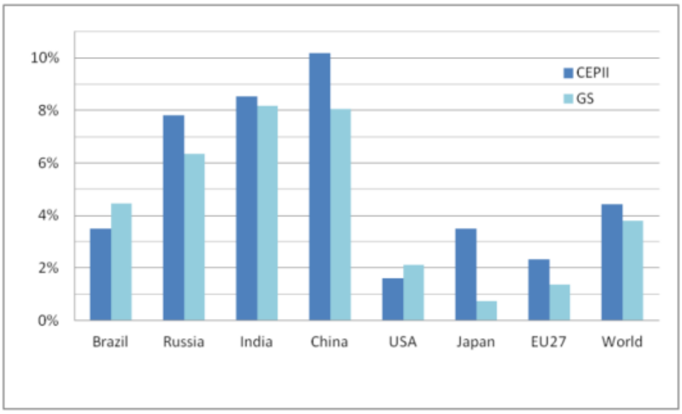
[38] Only HSBC takes human capital into account, but only for TFP growth.

Figure 31 - Average GDP growth rates comparison

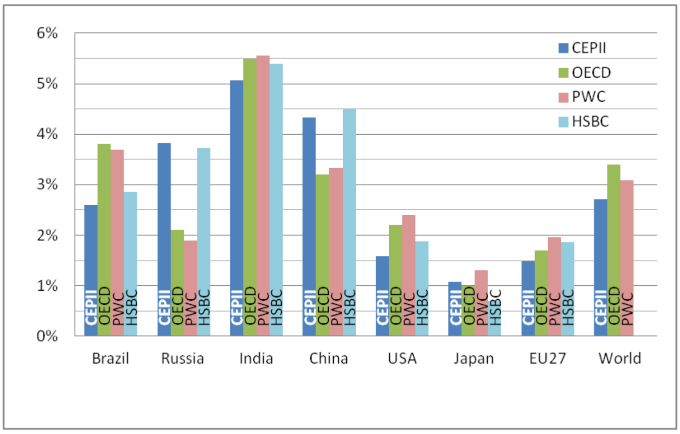
CEPII versus OECD, PWC, HSBC, 2010-25, constant USD



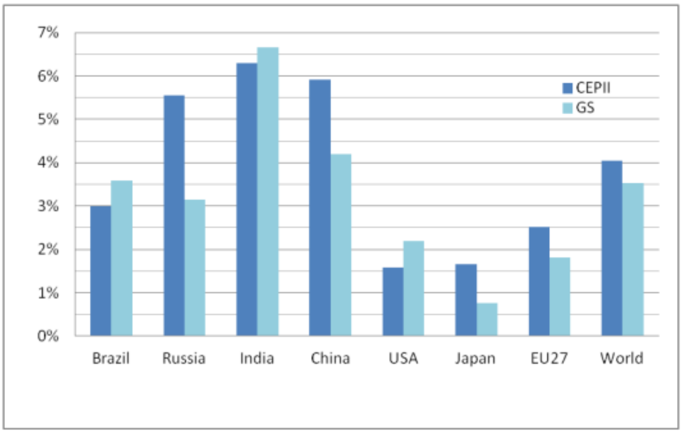
CEPII versus GS, 2010-25, current USD



CEPII versus OECD, PWC, HSBC, 2025-50, constant USD

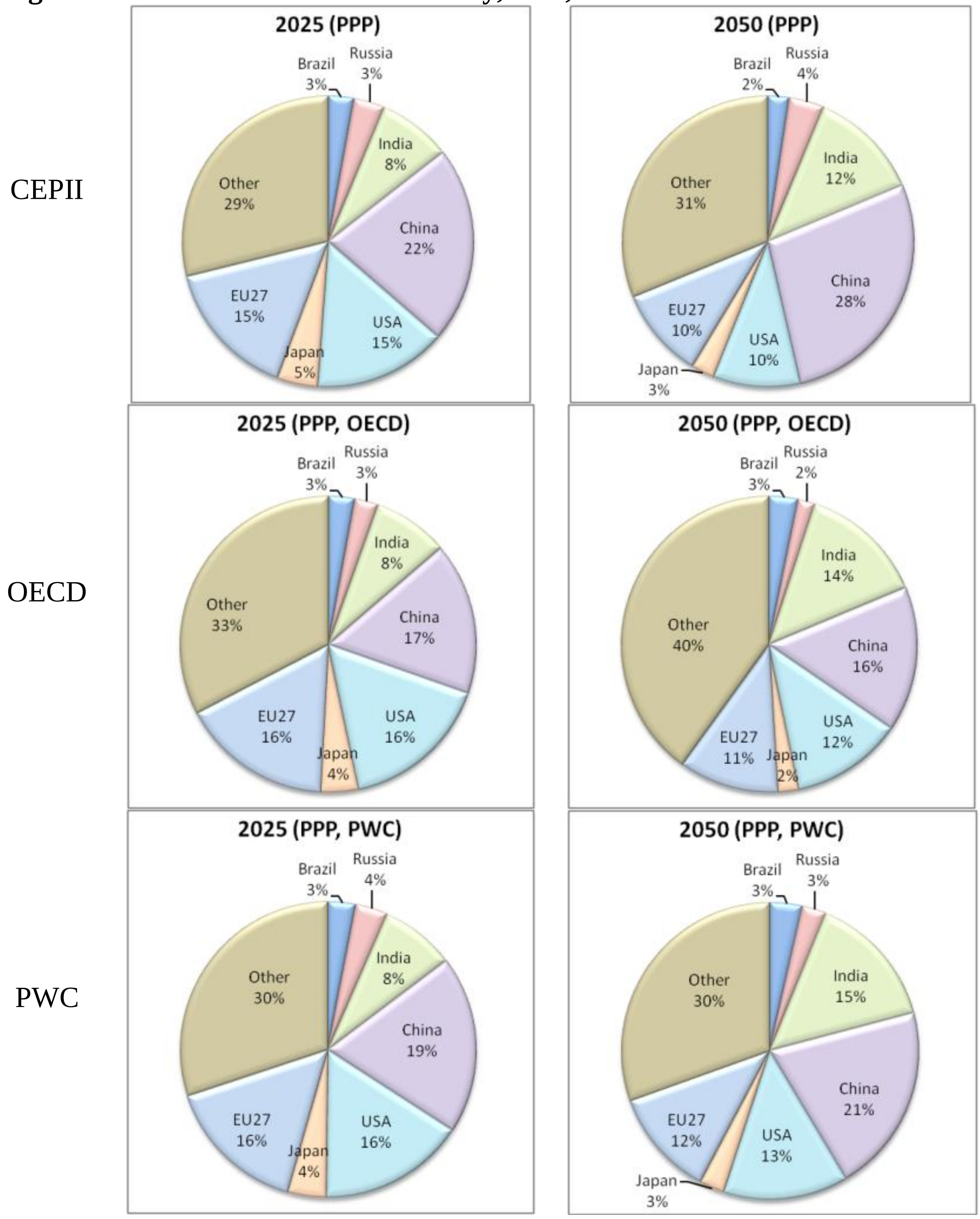


CEPII versus GS, 2025-50, current USD



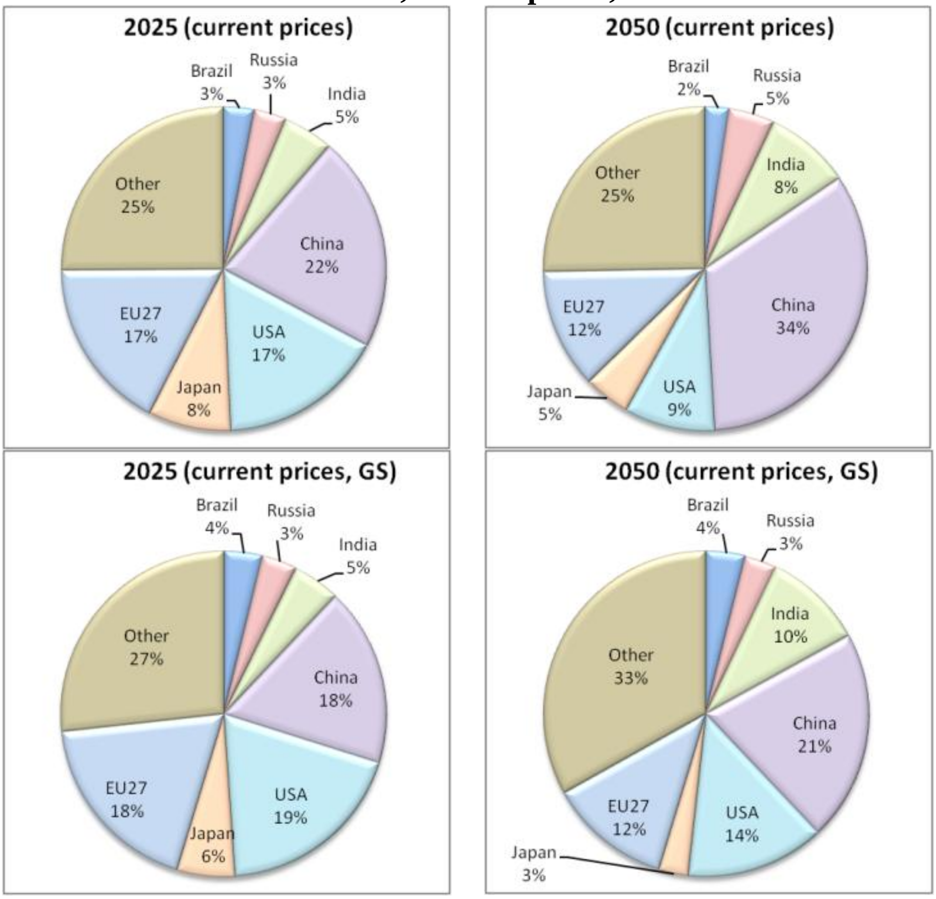
Sources: OECD, PWC, HSBC, GS and own calculations.

Figure 32 - Share in the world economy, PPP, CEPII versus OECD and PWC



Sources: OECD, PWC and own calculations.

Figure 33 - Share in the world GDP, current prices, CEPII versus GS



Sources:GS and own calculations.

CONCLUSION

A theoretically consistent model of world economic growth is especially important for projecting GDP in several countries over a long time period. To this purpose the CEPII has developed MaGE (Macroeconometrics of the Global Economy), a theoretically founded framework to project long-term growth.

As is the case with any projections over long time horizons, the work presented in this paper should be considered tentative. However, we have endeavoured to make it as transparent as possible and to rely on robust research concerning the determination of savings, investment and TFP growth. Detailed results are provided online to all interested users.

Our contribution to theory is that we include energy in the production function and explicitly derive not only TFP, but also energy productivity and education-consistent female participation rates. We also derive a fully fledged representation of the valuation effects based on the Balassa-Samuelson effects. In our view, we improve on the existing work by including an energy constraint in the projections, accounting for imperfect international capital mobility in the process of capital accumulation, and explicitly measuring the contribution of valuation effects.

These changes lead to somewhat different results compared to existing projections. Although our results, as any study of this type, should be treated with some caution, we believe that they provide useful benchmarks for downstream studies on world commodity demand, international trade, financing capacities, global power, etc. They also provide a fully-transparent and theoretically-grounded benchmark for comparing existing projections and discussing their underlying assumptions. Integrating environmental effects with GDP growth is not addressed in this study, but should remain on the research agenda.

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APPENDIX A: FIRMS OPTIMIZATION

Considering the combined capital-labour factor $Q = K^{\alpha}L^{1-\alpha}$, and p_Q its real price, the optimization programme of the representative firm (Equation (1.4) in Section 1) can be re-written as:

$$Max\left(Y - p_Q Q - p_E E\right) \quad s.t.\ Y^{\rho} = (AQ)^{\rho} + (BE)^{\rho}$$

The first order conditions are:

$$\begin{cases} \lambda\rho A^{\rho} Q^{\rho-1} = p_Q \\ \lambda\rho B^{\rho} E^{\rho-1} = p_E \end{cases}$$

where λ is the Lagrangian multiplier. Recall that $1/(1-\rho) = \sigma$, so we have:

$$\frac{E}{Q} = \left[\frac{p_Q}{p_E}\left(\frac{B}{A}\right)^{\rho}\right]^{\sigma} \qquad \text{(A 1)}$$

Assuming perfect competition, we have $Y - p_Q Q - p_E E = 0$. Additionally, the cost function yields: $Y^{\rho} = (AQ)^{\rho} + (BE)^{\rho}$. Then, we can rearrange by using the above expression for E/Q:

$$Y^{\rho} = \left(\frac{p_E}{B^{\rho}}\right)^{\sigma-1} E^{\rho}\left[(B^{\rho})^{\sigma} {p_E}^{1-\sigma} + (A^{\rho})^{\sigma} {p_Q}^{1-\sigma}\right] \qquad \text{(A 2)}$$

$$Y = \left(\frac{p_E}{B^{\rho}}\right)^{\sigma} E\left[(B^{\rho})^{\sigma} {p_E}^{1-\sigma} + (A^{\rho})^{\sigma} {p_Q}^{1-\sigma}\right] \qquad \text{(A 3)}$$

If we divide the two expressions (A.3/A.2), we get:

$$Y^{1-\rho} = \frac{p_E}{B^{\rho}} E^{1-\rho} \qquad \text{(A 4)}$$

And finally (recall that $\rho = 1 - 1/\sigma$):

$$\frac{E}{Y} = \left(\frac{B^{\rho}}{p_E}\right)^{\sigma} = \frac{B^{\sigma-1}}{p_E^{\sigma}} \qquad \text{(A 5)}$$

We can now derive TFP from the production function and equation (A.5):

$$A = \frac{Y}{K^{\alpha}L^{1-\alpha}}\left[1 - \left(\frac{B}{p_E}\right)^{\frac{\rho}{1-\rho}}\right]^{\frac{1}{\rho}} = \frac{Y}{K^{\alpha}L^{1-\alpha}}\left[1 - \left(\frac{B}{p_E}\right)^{\sigma-1}\right]^{\frac{\sigma}{\sigma-1}} \qquad \text{(A 6)}$$

THE CASE OF OIL PRODUCERS

Consider now that, aside from the manufacturing-type sector, there is a pure-rent oil sector, which produces Y_{oil} without any capital or labour and sells this production at the relative price p_E. GDP now writes:

$$Y_{tot} = Y + p_E Y_{oil} \tag{A 7}$$

where Y represents the production of the non-oil sector and Y_{oil} the exogenous production of the oil one. Now, the energy productivity $\tilde{B}$ and the TFP $\tilde{A}$ if computed as above are biased due to the value of oil production. Let B be the true energy productivity in the non-oil sector, given by equation (A.5):

$$B = \tilde{B}\left(1 + \frac{p_E Y_{oil}}{Y}\right)^{\frac{1}{\sigma-1}} \tag{A 8}$$

Let A be the *true* TFP in the non-oil sector, given by Equation (A.6):

$$A = \frac{Y}{K^\alpha L^{1-\alpha}}\left[1 - \left(\frac{B}{p_E}\right)^{\sigma-1}\right]^{\frac{\sigma}{\sigma-1}} \tag{A 9}$$

Replacing Y by its value $Y_{tot} - p_E Y_{oil}$, we get:

$$\tilde{A} = \frac{Y_{tot} - p_E Y_{oil}}{K^\alpha L^{1-\alpha}}\left[1 - \left(\frac{B}{p_E}\right)^{\sigma-1}\right]^{\frac{\sigma}{\sigma-1}} = \frac{Y}{K^\alpha L^{1-\alpha}}\left[1 - \left(\frac{B}{p_E}\right)^{\sigma-1}\right]^{\frac{\sigma}{\sigma-1}}\left(1 - \frac{p_E Y_{oil}}{Y}\right) \tag{A 10}$$

The second term can be linked to true energy productivity B by:

$$\left[1 - \left(\frac{B}{p_E}\right)^{\sigma-1}\right]^{\frac{\sigma}{\sigma-1}} = \left[1 - \left(1 + \frac{p_E Y_{oil}}{\tilde{Y}}\right)\left(\frac{\tilde{B}}{p_E}\right)^{\sigma-1}\right]^{\frac{\sigma}{\sigma-1}} = \left[1 - \left(\frac{\tilde{B}}{p_E}\right)^{\sigma-1}\right]^{\frac{\sigma}{\sigma-1}}\left[\frac{1-\left(1+\frac{p_E Y_{oil}}{Y}\right)\left(\frac{\tilde{B}}{p_E}\right)^{\sigma-1}}{1-\left(\frac{\tilde{B}}{p_E}\right)^{\sigma-1}}\right]^{\frac{\sigma}{\sigma-1}} \tag{A 11}$$

We finally obtain the following relation:

$$\tilde{A} = A\left(1 - \frac{p_E Y_{oil}}{Y}\right)\left[1 - \frac{p_E Y_{oil}}{Y}\frac{1}{\left(\frac{\tilde{B}}{p_E}\right)^{1-\sigma} - 1}\right]^{\frac{\sigma}{\sigma-1}} \tag{A 12}$$

APPENDIX B: THE BALASSA-SAMUELSON EFFECT

PRICES AND PRODUCTIVITY GROWTH

We assume that there are two sectors in a national economy: one producing tradable goods (denoted by T), and the other producing non-tradable goods (denoted by N). The two sectors have the same type of production function:

$$\begin{cases} Y_T = [(A_T Q_T)^\rho + (B_T E_T)^\rho]^{1/\rho} \\ Y_N = [(A_N Q_N)^\rho + (B_N E_N)^\rho]^{1/\rho} \end{cases} \quad \text{(B 1)}$$

Rewriting $(\text{B}.1)$ in Q-intensive terms gives:

$$\begin{cases} y_T = \frac{Y_T}{Q_T} = [A_T{}^\rho + (B_T e_T)^\rho]^{1/\rho} \\ y_N = \frac{Y_N}{Q_N} = [A_N{}^\rho + (B_N e_N)^\rho]^{1/\rho} \end{cases} \quad \text{(B 2)}$$

With $e = {}^{E}/_{Q}$.

The tradable sector

Here we adapt the approach proposed by Obstfeld and Rogoff (1996) to our particular production function. Denoting by p_E the price of energy in terms of the tradable good, we have:

$$\frac{\partial y_T}{\partial e_T} = p_E \Leftrightarrow B_T^\rho e_T^{\rho-1} y_T^{1-\rho} = p_E \quad \text{(B 3)}$$

Similarly, denoting by p_Q the price of the combined, capital-labour factor in terms of tradable goods yields:

$$\frac{\partial Y_T}{\partial Q_T} = p_Q \Leftrightarrow A_T^\rho y_T^{1-\rho} = p_Q \quad \text{(B 4)}$$

Assuming perfect competition, the zero-profit condition can be written as:

$$y_T = [A_T{}^\rho + (B_T e_T)^\rho]^{1/\rho} = p_Q + p_E e_T \quad \text{(B 5)}$$

Log-differentiating (B.5), we get:

$$\frac{1}{\rho}\left[\frac{d(A_T{}^\rho + (B_T e_T)^\rho)}{y_T^\rho}\right] = \frac{d(p_Q + p_E e_T)}{y_T} \quad \text{(B 6)}$$

$$\frac{1}{\rho}\left[\frac{d(A_T^\rho)}{y_T^\rho}+\frac{e_T^\rho d(B_T^\rho)+B_T^\rho d(e_T^\rho)}{y_T^\rho}\right]=\frac{dp_Q}{y_T}+\frac{p_E de_T}{y_T}+\frac{e_T dp_E}{y_T} \quad \text{(B 7)}$$

$$\frac{A_T^\rho}{y_T^\rho}\frac{dA_T}{A_T}+\frac{e_T^\rho B_T^\rho}{y_T^\rho}\frac{dB_T}{B_T}+\frac{e_T^\rho B_T^\rho}{y_T^\rho}\frac{de_T}{e_T}=\frac{p_Q}{y_T}\frac{dp_Q}{p_Q}+\frac{p_E e_T}{y_T}\frac{de_T}{e_T}+\frac{p_E e_T}{y_T}\frac{dp_E}{p_E} \quad \text{(B 8)}$$

From (B.3) we know that $\frac{e_T^\rho B_T^\rho}{y_T^\rho}=\frac{p_E e_T}{y_T}$ and from (B.4) we know that $\frac{A_T^\rho}{y_T^\rho}=\frac{p_Q}{y_T}$. Replacing the left hand-side of (B.6) and rearranging, we get:

$$\frac{p_Q}{y_T}\left(\frac{dA_T}{A_T}-\frac{dp_Q}{p_Q}\right)+\frac{p_E e_T}{y_T}\left(\frac{dB_T}{B_T}-\frac{dp_E}{p_E}\right)=0 \quad \text{(B 9)}$$

Let $\mu_{ET}=p_E e_T/y_T$ and $\mu_{QT}=p_Q/y_T$ be the share of energy and capital-labour factors in the income generated in the tradable sector, and let $\dot{x}_T=\frac{dx_T}{x_T}$ denote any variable x. Equation (B.9) can be re-written as:

$$\mu_{QT}(\dot{A}_T-\dot{p}_Q)+\mu_{ET}(\dot{B}_T-\dot{p}_E)=0 \quad \text{(B 10)}$$

The non-traded sector

The same derivation can be achieved for the non-tradable sector. Letting $p=P_N/P_T$ be the relative price of non-tradables, we have:

$$p\frac{\partial y_N}{\partial e_N}=p_E \Leftrightarrow p\left(B_N^\rho e_N^{\rho-1}y_N^{1-\rho}\right)=p_E \quad \text{(B 11)}$$

$$p\frac{\partial Y_N}{\partial Q_N}=p_Q \Leftrightarrow p\left(A_N^\rho y_N^{1-\rho}\right)=p_Q \quad \text{(B 12)}$$

The zero-profit condition for non-tradables is:

$$py_N=p[A_N{}^\rho+(B_N e_N)^\rho]^{1/\rho}=p_Q+p_E e_N \quad \text{(B 13)}$$

By log-differentiating (B.11) and using (B.9) and (B.10), we get:

$$\frac{dp}{p}+\frac{p_Q}{y_N}\left(\frac{dA_N}{A_N}-\frac{dp_Q}{p_Q}\right)+\frac{p_E e_N}{y_N}\left(\frac{dB_N}{B_N}-\frac{dp_E}{p_E}\right)=0 \quad \text{(B 14)}$$

Using the same notation as for tradables, we get:

$$\dot{p}+\mu_{QN}(\dot{A}_N-\dot{p}_Q)+\mu_{EN}(\dot{B}_N-\dot{p}_E)=0 \quad \text{(B 15)}$$

Relative price growth

To recover from (B.8) and (B.13) the variation in the relative price of non-tradables, we need to assume that the remuneration of energy (resp. capital-labour) represents the same share of income in the tradable as in the non-tradable sector:

$$\mu_{ET} = \mu_{EN} = \mu = \frac{E}{Y} \text{ and } \mu_{QT} = \mu_{QN} = 1 - \mu = \frac{Q}{Y} \quad \text{(B 16)}$$

We then have:

$$\dot{p} = (1-\mu)\left(\dot{A}_T - \dot{A}_N\right) + \mu\left(\dot{B}_T - \dot{B}_N\right) \quad \text{(B 17)}$$

THE REAL EXCHANGE RATE

Definition

The real exchange rate is defined here as the relative prices of the home and foreign consumption bundles. Denoting the domestic consumption price index as P, the foreign consumption price index as P^* and the nominal exchange rate as S, the real exchange rate can be written as:

$$RER = \frac{SP}{P^*} \quad \text{(B 18)}$$

Assuming a Cobb-Douglas consumption bundle, the price index can be written as:

$$P = P_T^{\gamma_c} P_N^{1-\gamma_c} = P_T p^{1-\gamma_c} \quad \text{(B 19)}$$

where γ_c is the share of tradable goods in domestic consumption. Similarly, the foreign consumption price index is:

$$P^* = (P_T^*)^{\gamma_c*}(P_N^*)^{1-\gamma_c*} = P_T^*(p^*)^{1-\gamma_c*} \quad \text{(B 20)}$$

where γ_c^* is the share of tradables in foreign consumption. Assuming that the law of one price holds in the tradable sector (hence $\dot{S} + \dot{P}_T - \dot{P}_T^* = 0$), the log-variation of the real exchange rate can be written as:

$$R\dot{E}R = \dot{S} + \dot{P} - \dot{P}^* = (1-\gamma_c)\dot{p} - (1-\gamma_c^*)\dot{p}^* \quad \text{(B 21)}$$

Aggregate technical progress

From (B.14) and (B.18), we get:

$$R\dot{E}R = (1-\gamma_c)\left[(1-\mu)\left(\dot{A}_T - \dot{A}_N\right) + \mu\left(\dot{B}_T - \dot{B}_N\right)\right] - (1-\gamma_c^*)\left[(1-\mu^*)\left(\dot{A}_T^* - \dot{A}_N^*\right) + \mu^*\left(\dot{B}_T^* - \dot{B}_N^*\right)\right] \quad \text{(B 22)}$$

As in the standard Balassa-Samuelson model, we assume that all technical progress occurs in the tradable sector: $\dot{A}_N = \dot{B}_N = \dot{A}_N^* = \dot{B}_N^* = 0$. We can estimate technical progress in the tradable sector from aggregate technical progress, based on the following aggregator, with the share of tradables in output being γ_p:

$$\dot{A} = \gamma_p \dot{A}_T + \left(1 - \gamma_p\right)\dot{A}_N = \gamma_p \dot{A}_T \tag{B 23}$$

$$\dot{B} = \gamma_p \dot{B}_T + \left(1 - \gamma_p\right)\dot{B}_N = \gamma_p \dot{B}_T \tag{B 24}$$

where *A* (resp. *B*) is TFP (resp. energy productivity) for the whole economy. The same relations can be written for the foreign economy, with γ_p^* denoting the share of tradables in foreign output. Plugging these relations into (B.19), we have:

$$R\dot{E}R = \frac{(1-\gamma_c)}{\gamma_p}\left[(1-\mu)\dot{A} + \mu\dot{B}\right] - \frac{(1-\gamma_c^*)}{\gamma_p^*}\left[(1-\mu^*)\dot{A}^* + \mu^*\dot{B}^*\right] \tag{B 25}$$

Equation (B.25) provides the evolution of the real exchange rate which is consistent with our long-run growth model. The γ parameters correspond to the share of tradables in the economy while the μ parameters are the share of the remuneration of energy in domestic income. We take the US as the foreign economy.

APPENDIX C: DEMOGRAPHIC FACTORS IN THE DETERMINANTS OF SAVINGS

Following Higgins (1998), we represent the age distribution through a polynomial. First consider the regression specification:

$$\left(\frac{S}{Y}\right)_t = x_t'\beta + \alpha_1 p_{1t} + \cdots + \alpha_J p_{Jt} + u_t \quad \text{(C 1)}$$

where x_t' is a vector of explanatory variables and $p_{1t}, \ldots, p_{Jt}$ represent the shares of age groups $1, \ldots, J$ in the total population.

If we assume that the α coefficients lie along a third order polynomial, which means specifying $\alpha_j = \gamma_0 + \gamma_1 j + \gamma_2 j^2 + \gamma_3 j^3$, the regression specification can be rewritten:

$$\left(\frac{S}{Y}\right)_t = x_t'\beta + \gamma_0 \sum_{j=1}^{J} p_{j,t} + \gamma_1 \sum_{j=1}^{J} j p_{j,t} + \gamma_2 \sum_{j=1}^{J} j^2 p_{j,t} + \gamma_3 \sum_{j=1}^{J} j^3 p_{j,t} + u_t \quad \text{(C 2)}$$

Now assume the additional restriction that the coefficients of the age distribution variables sum to zero, i.e. $\sum \alpha_j = 0$. This then implies the following relationship between γ_0, γ_1, γ_2, and γ_3:

$$\gamma_0 J + \gamma_1 \sum_{j=1}^{J} j + \gamma_2 \sum_{j=1}^{J} j^2 + \gamma_3 \sum_{j=1}^{J} j^3 = 0 \quad \text{(C 3)}$$

$$\gamma_0 = -\frac{\gamma_1}{J} \sum_{j=1}^{J} j - \frac{\gamma_2}{J} \sum_{j=1}^{J} j^2 - \frac{\gamma_3}{J} \sum_{j=1}^{J} j^3 \quad \text{(C 4)}$$

Thus, our final regression specification is given by:

$$\left(\frac{S}{Y}\right)_t = x_t'\beta + \gamma_1 d_t^1 + \gamma_2 d_t^2 + \gamma_3 d_t^3 + u_t \quad \text{(C 5)}$$

with

$$d^k = \left(\sum_{j=1}^{J} j^k p_{j,t} - \frac{1}{J} \sum_{j=1}^{J} j^k\right) \quad \text{(C 6)}$$

The main interest of this third-order polynomial representation lies in deriving the original α_j coefficients from the estimated triplet $(\gamma_1, \gamma_2, \gamma_3)$, after accounting for growth (which means replacing γ_i by $(\gamma_i + g_t)$ in the reasoning) :

$$\alpha_j = \gamma_0 + \gamma_1 j + \gamma_2 j^2 + \gamma_3 j^3 \quad \text{(C 7)}$$

APPENDIX D: STATIONARITY AND COINTEGRATION TESTS FOR SAVINGS AND INVESTMENT RATES

STATIONARITY

Methodology

Our stationarity tests rely on the following estimation:

$$\Delta X_{it} = \alpha_i + \beta t + \phi X_{i,t-1} + \sum_j \phi_j \Delta X_{i,t-j} + \epsilon_{it} \quad \text{(D 1)}$$

The number of lags J has to be sufficiently large to correct for autocorrelation of the residuals ϵ_{it}, . The number of lags is selected based on the method proposed by Campbell and Perron (1991). After setting a maximum p_{max} lags, we estimate (E.1) with a p_{max} number of lags. If $\phi_{p_{max}}$ is not significantly different from 0 (at the 1% level), we estimate the relation with $p_{max} - 1$ lags. We repeat this until the coefficient before the last lag included in the relation is significant. On the other hand, we determine whether we should include a time trend or not by observing the significance of the β coefficient in the last retained estimation.

The lag orders and time trends are reported in Table D 1, with $p_{max} = 6$ for yearly data. However, when using five-year averages, we only have 9 observations per country (once the gaps are removed, due to the necessity of a strongly balanced panel for unit-root tests). We therefore choose $p_{max} = 3$.

Table D 1 - Lag order and time trend choice

	Capital formation		Savings rate	
	Lag order	Time trend	Lag order	Time trend
OECD	4	×	6*	✓
Non-OECD	4	×	5	✓
5-year average			1	✓

* An additional tests with 7 lags have been conducted

Yearly data

We then compute unit root tests for yearly data, both for the OECD and non-OECD country groups. The seven tests we use have different null hypothesis, which are summarized in Table D 2, as well as the results of the tests (“u.r.” stands for “unit-root”).

Table D 2 - Yearly data unit root tests

	Test	Null hypothesis	Capital formation Statistic	Capital formation p-value	Capital formation 5% test	Savings Statistic	Savings p-value	Savings 5% test
OECD	Levin, Lin and Chu	At least 1 u.r.	-0.177	0.430	✓	7.388	1.000	✓
	Breitung	At least 1 u.r.	-1.688	0.046	×	-0.158	0.437	✓
	Im, Pesaran and Shin	All u.r.	-2.563	0.005	×	-0.629	0.265	✓
	Fisher Chi2	All u.r.	84.149	0.000	×	33.465	0.824	✓
	Fisher N	All u.r.	-2.120	0.017	×	0.941	0.827	✓
	Fisher logit	All u.r.	-2.984	0.002	×	0.984	0.836	✓
	Hadri	All stationary	14.362	0.000	✓	18.004	0.000	✓
Non-OECD	Levin, Lin and Chu	At least 1 u.r.	-0.096	0.462	✓	9.281	1.000	✓
	Breitung	At least 1 u.r.	-3.864	0.000	×	-0.089	0.465	✓
	Im, Pesaran and Shin	All u.r.	-2.337	0.010	×	0.781	0.782	✓
	Fisher Chi2	All u.r.	209.535	0.007	×	148.304	0.772	✓
	Fisher N	All u.r.	-1.282	0.100	✓	3.041	0.999	✓
	Fisher logit	All u.r.	-1.360	0.087	✓	2.853	0.998	✓
	Hadri	All stationary	46.324	0.000	✓	38.610	0.000	✓

Regarding savings rate, there is no doubt that we have to deal with non-stationarity, for all tests have the same conclusion. Results of the stationarity tests are more contrasted for capital formation. We can reject that all capital formation series have a unit root at a 5% confidence level but also we can reject that all series are stationary.

As a conclusion, we will treat all savings and capital formation series as non-stationary and we will have to check whether the two series are cointegrated (see below).

5-year average

As noted before, savings rate series tend to be non-stationary according to the unit root tests conducted, both for the OECD and non OECD groups. When it comes to estimating the dynamics of savings rate, an additional issue comes out: we have to correct for the business cycles by using 5-year means instead of annual data. We therefore conduct the stationarity tests also for these 5-year averages series.

Table D 3 - 5-year average savings rate unit root tests

	H_0	Value	p-value	5% test
Levin, Lin and Chu	At least 1 u.r.	-34.268	0.000	×
Breitung	At least 1 u.r.	-1.198	0.115	✓
Im, Pesaran and Shin	All u.r.	-17.015	0.000	×
Fisher Chi2	All u.r.	1 483.562	0.000	×
Fisher N	All u.r.	-14.379	0.000	×
Fisher logit	All u.r.	-34.611	0.000	×
Hadri	All stationary	5.933	0.000	×

The results of the unit-root tests are ambiguous: though we strongly reject that all series are non-stationary, Hadri test states that we also reject that all variables are stationary, which is contradictory with the Levin, Lin and Chu test. However, unlike with yearly capital formation, all tests with a null hypothesis of unit root for every series are unambiguous and with very little p-values. We will therefore consider the 5-year average savings rate series as stationary.

COINTEGRATION

We are left with one last test: we have to check whether savings and investment are cointegrated in order to choose between standard estimation and an error-correction model. We use two sets of tests respectively developed by Pedroni (2004) and Westerlund (2007).

Pedroni's tests are first generation tests, with a null hypothesis of no cointegration, both for homogenous or heterogeneous panels. Among those tests, four have an alternative hypothesis of a homogenous cointegration relation ("within", which are panel-ν, panel-ρ, panel-PP and panel-ADF) and the three other have an alternative hypothesis of heterogenous cointegration ("between", which are group-ρ, group-PP and group-ADF).

Westerlund tests are second-generation tests, with a null hypothesis of no cointegration for all countries. Ga and Gt statistics operate in panel context, with an alternative hypothesis of cointegration for at least one country. On the contrary, Pa and Pt operate on pooled data, and the alternative hypothesis of the test is that there is cointegration for all individuals. The difference between the "a" and "t" tests is that they respectively use weighted average of the ECM coefficients and t-ratios respectively.

Table D 4 - Cointegration tests for OECD group

Author	Name	H_0	H_a	Statistic	p-value	5% test
Pedroni (13 countries)	Panel-ν	*No coint.*	*All homogenous coint.*	-0.937	0.826	×
	panel-ρ	*No coint.*	*All homogenous coint.*	-2.247	0.012	✓
	panel-PP	*No coint.*	*All homogenous coint.*	-4.201	0.000	✓
	Panel-ADF	*No coint.*	*All homogenous coint.*	-5.239	0.000	✓
	group-ρ	*No coint.*	*All heterogenous coint.*	0.049	0.519	×
	group-PP	*No coint.*	*All heterogenous coint.*	-2.388	0.008	✓
	group-ADF	*No coint.*	*All heterogenous coint.*	-4.932	0.000	✓
Westerlund	Ga	*No coint.*	*At least 1 coint.*	-7.600	0.000	✓
	Gt	*No coint.*	*At least 1 coint.*	-1.847	0.000	✓
	Pa	*No coint.*	*All heterogenous coint.*	-9.048	0.000	✓
	Pt	*No coint.*	*All heterogenous coint.*	-4.862	0.000	✓

Table D 5 - Cointegration tests for non-OECD group

Author	Name	H_0	H_a	Statistic	p-value	5% test
Pedroni (37 countries)	Panel-ν	No coint.	All homogenous coint.	-1.323	0.9072	×
	panel-ρ	No coint.	All homogenous coint.	-4.561	0.0000	✓
	panel-PP	No coint.	All homogenous coint.	-5.551	0.0000	✓
	Panel-ADF	No coint.	All homogenous coint.	-7.376	0.0000	✓
	group-ρ	No coint.	All heterogenous coint.	-1.612	0.0534	×
	group-PP	No coint.	All heterogenous coint.	-6.310	0.0000	✓
	group-ADF	No coint.	All heterogenous coint.	-8.304	0.0000	✓
Westerlund	Ga	No coint.	At least 1 coint.	-4.660	0.019	✓
	Gt	No coint.	At least 1 coint.	-1.186	0.013	✓
	Pa	No coint.	All heterogenous coint.	-4.358	0.000	✓
	Pt	No coint.	All heterogenous coint.	-5.070	0.000	✓

The conclusion of these tests is straightforward: we are in front of two cointegrated variables for which we may assume homogenous cointegration relation (among the two groups). Note that these tests do not infer anything about the possibility of fixed effects in the estimated cointegration relations, heterogeneity is considered here for the coefficients.

APPENDIX E: DETAILED RESULTS

E-1: GDP AND GDP GROWTH

	GDP (billion constant 2005 USD)			GDP (billion current USD)			GDP per capita (constant 2005 PPP)		
	2010	2025	2050	2010	2025	2050	2010	2025	2050
United States of America	13189	16773	24878	13176	16757	24854	42451	47909	61657
Japan	4653	6007	7847	5023	8397	12649	31283	41625	61502
European Union	14263	17782	25646	12509	17644	32710	27708	34228	51251
Brazil	1090	1780	3373	1870	3126	6530	10034	14768	27161
Russian Federation	901	1761	4499	1053	3247	12485	14003	28136	79180
India	1211	3092	10654	1495	5099	23346	2973	6372	18930
China	3686	10424	30049	5105	21838	91624	6531	17756	55125
Latin America	3211	5194	10558	3844	6525	13888	12415	17531	32084
Middle east and North Africa	2358	4230	9263	2749	5113	12522	10464	15850	31107
Sub-saharian Africa	790	1680	5934	940	2275	8802	2163	3361	7706
Rest of Asia	2632	4999	11467	3080	6850	18917	5226	8664	18821
Rest of the World	1899	2934	5815	2363	5085	16451	15063	24626	56497
Total World	49882	76656	149983	53206	101956	274776	10020	15115	29881

	average GDP growth (constant 2005 USD)		average GDP growth (current USD)		average GDP per capita growth (constant 2005 PPP)	
	2010-25	2025-50	2010-25	2025-50	2010-25	2025-50
United States of America	1.6	1.6	1.6	1.6	1.6	1.6
Japan	1.7	1.1	3.5	1.7	1.7	1.1
European Union	1.5	1.5	2.3	2.5	1.6	1.6
Brazil	3.3	2.6	3.5	3.0	3.3	2.6
Russian Federation	4.6	3.8	7.8	5.5	4.6	3.8
India	6.4	5.1	8.5	6.3	6.4	5.1
China	7.2	4.3	10.2	5.9	7.2	4.3
Latin America	3.3	2.9	3.6	3.1	3.4	3.0
Middle east and North Africa	4.0	3.2	4.2	3.6	4.1	3.4
Sub-saharian Africa	5.2	5.2	6.1	5.6	5.4	5.4
Rest of Asia	4.4	3.4	5.5	4.1	4.5	3.7
Rest of the World	2.9	2.8	5.2	4.8	3.7	3.6
Total World	2.9	2.7	4.4	4.0	3.8	3.3

ISO	Country name	GDP (billion 2005 USD)			GDP (billion current USD)			GDP per capita (2005 constant PPP)			GDP growth (2005 USD)		GDP growth (current USD)		GDP per capita growth (2005 PPP)	
		2010	2025	2050	2010	2025	2050	2010	2025	2050	2010-25	2025-50	2010-25	2025-50	2010-25	2025-50
North America		**15314**	**20059**	**31108**	**15486**	**20724**	**32768**	**34471**	**40159**	**55556**	**1.8**	**1.8**	**2.0**	**1.8**	**1.0**	**1.3**
USA	United States	13189	16773	24878	13176	16757	24854	42451	47909	61657	1.6	1.6	1.6	1.6	0.8	1.0
CAN	Canada	1209	1735	2939	1429	2586	5066	35416	44819	67118	2.4	2.1	4.0	2.7	1.6	1.6
MEX	Mexico	916	1551	3291	882	1382	2848	12351	18100	34964	3.6	3.1	3.0	2.9	2.6	2.7
Other America		**3217**	**5559**	**12352**	**4455**	**7554**	**17976**	**9173**	**13679**	**27281**	**3.7**	**3.2**	**3.6**	**3.5**	**2.7**	**2.8**
BRA	Brazil	1090	1780	3373	1870	3126	6530	10034	14768	27161	3.3	2.6	3.5	3.0	2.6	2.5
ARG	Argentina	254	435	855	333	573	1074	14389	21912	38675	3.6	2.7	3.7	2.5	2.8	2.3
COL	Colombia	180	275	517	254	314	481	8358	10775	17957	2.8	2.6	1.4	1.7	1.7	2.1
VEN	Venezuela, RB	174	272	529	350	466	750	10882	13970	22904	3.0	2.7	1.9	1.9	1.7	2.0
CHL	Chile	138	242	525	183	339	849	13541	21277	43943	3.8	3.1	4.2	3.7	3.1	2.9
PHL	Philippines	126	323	1367	172	492	2633	3422	6930	22342	6.5	5.9	7.2	6.9	4.8	4.8
PER	Peru	112	241	661	141	285	779	8557	15718	37729	5.2	4.1	4.8	4.1	4.1	3.6
DOM	Dominican Republic	47	104	341	46	130	691	8390	15751	46381	5.4	4.9	7.1	6.9	4.3	4.4
GTM	Guatemala	33	60	185	37	60	185	4321	5515	11114	4.1	4.6	3.2	4.6	1.6	2.8
CRI	Costa Rica	25	45	103	32	54	126	10381	15977	33524	4.1	3.4	3.5	3.5	2.9	3.0
URY	Uruguay	24	38	70	36	58	113	12961	19545	35409	3.1	2.5	3.2	2.7	2.8	2.4
PAN	Panama	23	51	149	24	72	316	12376	22868	55724	5.5	4.4	7.5	6.1	4.2	3.6
TTO	Trinidad and Tobago	18	35	76	17	54	142	21925	42713	97469	4.7	3.1	7.9	3.9	4.5	3.4
HND	Honduras	12	24	83	14	32	140	3512	5695	14888	5.1	5.0	5.9	6.0	3.3	3.9
BOL	Bolivia	11	25	87	17	37	126	4150	7233	18706	5.4	5.1	5.3	5.1	3.8	3.9
PRY	Paraguay	10	18	48	16	30	77	4645	6855	14194	4.2	3.9	4.1	3.8	2.6	3.0
BHS	Bahamas	6	9	15	9	12	21	25173	29954	45848	2.2	2.2	2.3	2.2	1.2	1.7
NIC	Nicaragua	6	11	35	6	12	39	2504	4222	11753	4.8	4.7	5.0	5.0	3.5	4.2
HTI	Haiti	4	8	17	6	11	26	998	1393	2682	3.5	3.4	4.2	3.3	2.2	2.7
BRB	Barbados	3	4	6	3	5	7	18248	23861	36681	2.0	1.5	2.7	1.7	1.8	1.7
SUR	Suriname	2	4	11	3	5	12	7331	12554	29447	4.4	3.7	3.7	3.3	3.7	3.5
LCA	St. Lucia	1	1	3	1	2	3	9171	12233	20772	2.8	2.3	2.8	2.4	1.9	2.1
GUY	Guyana	1	2	3	2	3	5	2664	4653	10566	4.1	3.2	3.2	2.7	3.8	3.3
VCT	St. Vincent and the Grenadines	1	1	2	1	1	4	8214	13779	34921	3.6	3.9	5.2	5.4	3.5	3.8
Oceania		**911**	**1420**	**2618**	**1237**	**2499**	**5166**	**26356**	**33708**	**50749**	**3.0**	**2.5**	**4.8**	**2.9**	**1.7**	**1.7**
AUS	Australia	787	1229	2179	1110	2262	4360	35933	47027	70587	3.0	2.3	4.9	2.7	1.8	1.6
NZL	New Zealand	113	172	371	114	209	636	24140	31783	60775	2.8	3.1	4.1	4.5	1.9	2.6
PNG	Papua New Guinea	6	13	51	8	22	149	2157	3110	8767	4.6	5.8	6.6	8.0	2.5	4.2
FJI	Fiji	3	4	10	3	4	12	3910	5296	11873	2.7	3.6	2.4	4.5	2.0	3.3
SLB	Solomon Islands	1	1	3	1	1	2	2392	3289	5652	4.5	3.9	3.0	3.5	2.1	2.2
VUT	Vanuatu	0	1	4	1	1	7	3751	5802	14243	5.3	5.4	5.8	6.5	2.9	3.7
European Union		**14263**	**17782**	**25646**	**12509**	**17644**	**32710**	**27708**	**34228**	**51251**	**1.5**	**1.5**	**2.3**	**2.5**	**1.4**	**1.6**
DEU	Germany	2939	3307	3920	2842	3267	4008	33104	38162	48594	0.8	0.7	0.9	0.8	1.0	1.0
GBR	United Kingdom	2312	3136	4683	2042	3256	5083	32698	40708	56432	2.1	1.6	3.2	1.8	1.5	1.3
FRA	France	2228	2771	3995	1953	2634	3951	30909	35912	48027	1.5	1.5	2.0	1.6	1.0	1.2
ITA	Italy	1752	1842	2175	1128	1085	1362	26871	27982	34144	0.3	0.7	-0.3	0.9	0.3	0.8
ESP	Spain	1187	1561	2610	766	1127	2734	27086	33161	53440	1.8	2.1	2.6	3.6	1.4	1.9
NLD	Netherlands	675	806	1081	563	725	1003	36798	42416	57043	1.2	1.2	1.7	1.3	1.0	1.2
BEL	Belgium	399	472	630	321	328	358	33308	37972	48637	1.1	1.2	0.1	0.4	0.9	1.0
SWE	Sweden	391	527	766	390	554	772	33200	41221	55896	2.0	1.5	2.4	1.3	1.5	1.2
POL	Poland	381	628	1224	409	927	2895	17214	28413	60719	3.4	2.7	5.6	4.7	3.4	3.1
AUT	Austria	325	405	517	286	383	501	35053	42791	55429	1.5	1.0	2.0	1.1	1.3	1.0
DNK	Denmark	260	315	423	257	304	399	32700	37702	49736	1.3	1.2	1.1	1.1	1.0	1.1
GRC	Greece	257	343	592	202	314	815	25381	33149	56938	1.9	2.2	3.0	3.9	1.8	2.2
FIN	Finland	206	259	347	215	295	381	31477	38151	50826	1.6	1.2	2.1	1.0	1.3	1.2
IRL	Ireland	204	270	418	137	161	227	36417	41732	55328	1.9	1.8	1.1	1.4	0.9	1.1
PRT	Portugal	189	219	335	143	158	345	20781	24593	41959	1.0	1.7	0.6	3.2	1.1	2.2
CZE	Czech Republic	143	214	438	172	304	883	22755	33227	68834	2.8	2.9	3.9	4.4	2.6	3.0
ROM	Romania	113	199	423	115	243	711	10143	18491	43833	3.8	3.1	5.1	4.4	4.1	3.5
HUN	Hungary	110	169	334	110	224	685	17127	26864	56073	2.9	2.8	4.9	4.6	3.0	3.0
SVK	Slovak Republic	60	106	220	84	183	539	20127	34690	76466	3.8	3.0	5.3	4.4	3.7	3.2
LUX	Luxembourg	41	58	87	41	64	106	68519	81632	105032	2.4	1.6	3.0	2.0	1.2	1.0
BGR	Bulgaria	31	49	92	35	65	144	10179	17993	41432	3.1	2.5	4.2	3.2	3.9	3.4
LTU	Lithuania	27	59	152	29	105	439	14314	33182	94435	5.3	3.8	9.0	5.9	5.8	4.3
LVA	Latvia	15	32	98	18	80	672	12043	26190	90865	4.9	4.6	10.5	8.9	5.3	5.1

EST	Estonia	14	30	80	244	845	3669	16676	36207	104418	5.2	4.1	8.7	6.0	5.3	4.3
MLT	Malta	3	4	8	8	12	28	21375	30759	60445	2.7	2.6	3.2	3.4	2.5	2.7
Former USSR		**1139**	**2325**	**6462**	**1397**	**4863**	**22577**	**11056**	**23026**	**68708**	**4.9**	**4.2**	**8.7**	**6.3**	**5.0**	**4.5**
RUS	Russian Federation	901	1761	4499	1053	3247	12485	14003	28136	79180	4.6	3.8	7.8	5.5	4.8	4.2
UKR	Ukraine	91	201	608	124	581	3061	6096	14674	51497	5.4	4.5	10.8	6.9	6.0	5.2
KAZ	Kazakhstan	77	188	718	133	623	3722	11100	23623	78049	6.1	5.5	10.9	7.4	5.2	4.9
BLR	Belarus	43	101	340	49	193	1252	12317	30620	117357	5.9	5.0	9.6	7.8	6.3	5.5
GEO	Georgia	8	22	85	10	75	942	4645	13665	65789	6.7	5.6	14.0	10.7	7.5	6.5
ARM	Armenia	6	17	75	8	53	600	4894	13684	65160	7.2	6.2	13.0	10.2	7.1	6.4
MDA	Moldova	3	9	26	5	24	131	2763	7478	27564	6.2	4.5	10.8	7.0	6.9	5.4
TJK	Tajikistan	3	9	36	5	18	93	1937	4256	14077	6.9	5.9	8.9	6.7	5.4	4.9
MNG	Mongolia	3	10	40	5	25	138	3307	8527	28235	8.0	5.7	11.4	7.0	6.5	4.9
KGZ	Kyrgyz Republic	3	8	35	4	22	154	2031	4787	16444	7.1	5.9	12.0	8.0	5.9	5.1
Other Europe		**756**	**967**	**1305**	**790**	**1015**	**1473**	**34650**	**42292**	**58589**	**1.7**	**1.2**	**1.7**	**1.5**	**1.3**	**1.3**
CHE	Switzerland	407	477	545	420	485	536	37865	42329	49454	1.1	0.5	1.0	0.4	0.7	0.6
NOR	Norway	323	446	669	349	477	694	47888	59765	79907	2.2	1.6	2.1	1.5	1.5	1.2
ISL	Iceland	16	22	34	12	18	27	31643	37470	49707	2.2	1.7	3.0	1.6	1.1	1.1
ALB	Albania	11	22	57	9	35	215	7086	14161	40684	4.9	3.9	9.2	7.5	4.7	4.3
Middle-East and North Africa		**2358**	**4230**	**9263**	**2749**	**5113**	**12522**	**10464**	**15850**	**31107**	**4.0**	**3.2**	**4.2**	**3.6**	**2.8**	**2.7**
TUR	Turkey	581	1105	2682	619	1273	4017	12919	21287	47356	4.4	3.6	4.9	4.7	3.4	3.3
SAU	Saudi Arabia	365	573	833	396	647	722	20695	24584	28809	3.0	1.5	3.3	0.4	1.2	0.6
IRN	Iran, Islamic Rep.	247	473	1003	305	704	1521	11212	19086	39408	4.4	3.1	5.7	3.1	3.6	2.9
SYR	Syrian Arab Republic	167	276	609	217	296	623	4671	6034	10485	3.4	3.2	2.1	3.0	1.7	2.2
ARE	United Arab Emirates	163	244	345	206	281	340	32735	37226	42778	2.7	1.4	2.1	0.8	0.9	0.6
ISR	Israel	163	274	619	198	315	719	26667	36071	62630	3.5	3.3	3.2	3.3	2.0	2.2
EGY	Egypt, Arab Rep.	126	285	1071	192	464	2065	5538	10088	31025	5.6	5.4	6.0	6.2	4.1	4.6
DZA	Algeria	117	192	381	145	225	424	7604	10533	18881	3.4	2.8	3.0	2.6	2.2	2.4
QAT	Qatar	97	225	374	99	250	350	73220	130277	190036	5.8	2.1	6.4	1.4	3.9	1.5
KWT	Kuwait	92	141	205	109	151	174	46122	51931	54260	2.8	1.5	2.2	0.6	0.8	0.2
MOR	Morocco	76	144	388	82	163	527	4315	7187	17976	4.4	4.0	4.7	4.8	3.5	3.7
OMN	Oman	42	71	127	41	72	130	24985	33808	56355	3.6	2.4	3.8	2.4	2.0	2.1
TUN	Tunisia	36	68	178	36	71	237	7738	12713	31413	4.3	3.9	4.7	4.9	3.4	3.7
LBN	Lebanon	29	52	106	34	59	136	12384	20186	40887	3.9	2.9	3.6	3.4	3.3	2.9
YEM	Yemen, Rep.	21	40	156	25	42	165	2385	2994	7002	4.4	5.6	3.3	5.7	1.5	3.5
BHR	Bahrain	18	27	43	19	31	45	21263	26070	35863	2.9	1.8	3.2	1.5	1.4	1.3
JOR	Jordan	17	41	142	25	69	327	5037	9609	26810	6.1	5.1	7.1	6.4	4.4	4.2
Sub-Saharan Africa		**790**	**1680**	**5934**	**940**	**2275**	**8802**	**2163**	**3361**	**7706**	**5.2**	**5.2**	**6.1**	**5.6**	**3.0**	**3.4**
ZAF	South Africa	280	465	951	317	583	1237	9175	14222	27506	3.4	2.9	4.1	3.1	3.0	2.7
NGA	Nigeria	155	391	1714	174	479	2011	2137	3712	9588	6.4	6.1	7.0	5.9	3.7	3.9
AGO	Angola	53	126	460	76	171	613	5453	8913	21270	5.9	5.3	5.6	5.3	3.3	3.5
SDN	Sudan	41	75	231	63	101	293	2105	2793	5746	4.2	4.6	3.3	4.3	1.9	2.9
KEN	Kenya	24	56	215	29	77	310	1512	2403	5663	5.8	5.6	6.8	5.7	3.1	3.5
ETH	Ethiopia	20	60	212	24	138	510	928	2109	5613	7.6	5.2	12.4	5.4	5.6	4.0
TZA	Tanzania	20	64	429	21	91	757	1256	2570	8849	8.1	7.9	10.4	8.8	4.9	5.1
CMR	Cameroon	19	40	134	20	47	179	2077	3186	7337	5.0	5.0	5.8	5.5	2.9	3.4
CIV	Cote d'Ivoire	18	33	99	20	34	90	1692	2234	4485	4.1	4.5	3.5	4.0	1.9	2.8
GHA	Ghana	14	34	109	28	74	227	1439	2495	5413	5.9	4.7	6.8	4.6	3.7	3.1
UGA	Uganda	13	37	202	14	53	358	1150	2053	6162	7.1	7.0	9.0	8.0	3.9	4.5
BWA	Botswana	11	25	63	13	41	159	11973	22671	53323	5.2	3.9	8.1	5.6	4.3	3.5
SEN	Senegal	10	19	61	11	23	80	1714	2263	4484	4.4	4.7	4.8	5.1	1.9	2.8
GAB	Gabon	10	15	24	12	15	17	13465	15568	18106	2.8	2.0	1.7	0.4	1.0	0.6
ZMB	Zambia	10	26	137	15	50	295	1384	2284	5617	6.7	6.9	8.5	7.4	3.4	3.7
MOZ	Mozambique	9	31	191	9	65	710	836	2034	8040	8.4	7.5	14.5	10.0	6.1	5.7
COG	Congo, Rep.	8	13	22	11	14	15	3812	4558	5003	3.4	2.2	1.8	0.2	1.2	0.4
MUS	Mauritius	8	14	26	9	19	38	11916	20213	38575	4.0	2.6	5.4	2.8	3.6	2.6
BFA	Burkina Faso	7	20	109	8	25	154	1104	2033	6162	7.2	7.1	8.1	7.5	4.2	4.5
MLI	Mali	7	16	76	8	22	101	953	1518	3945	6.1	6.3	6.6	6.4	3.2	3.9
TCD	Chad	7	11	24	7	12	16	1337	1597	2024	3.8	3.0	3.1	1.3	1.2	1.0
MDG	Madagascar	6	12	46	8	16	59	867	1191	2630	5.0	5.5	5.0	5.3	2.1	3.2
BEN	Benin	5	12	50	6	14	62	1399	2183	5501	5.7	5.9	6.2	6.0	3.0	3.8
MWI	Malawi	4	11	58	5	13	71	861	1357	3503	6.5	6.9	6.8	6.9	3.1	3.9
NER	Niger	4	11	55	5	14	63	640	1000	2295	6.7	6.5	7.1	6.3	3.0	3.4
GIN	Guinea	4	10	46	4	10	52	1005	1807	5341	6.5	6.4	7.2	6.8	4.0	4.4
RWA	Rwanda	3	10	56	5	18	132	972	1913	6524	7.4	7.1	9.4	8.3	4.6	5.0

SWZ	Swaziland	3	5	14	3	6	19	4628	7001	16520	4.0	4.2	4.5	4.5	2.8	3.5
TGO	Togo	2.4	5	17	3	7	21	879	1419	3416	5.2	4.9	6.1	4.7	3.2	3.6
MRT	Mauritania	2.3	5	16	3	7	23	1766	2701	5923	5.1	4.9	5.4	4.7	2.9	3.2
LSO	Lesotho	2	4	12	2	5	20	1457	2750	7569	5.3	4.6	6.9	5.3	4.3	4.1
SLE	Sierra Leone	2	6.4	26.9	1.7	9.7	42.7	742	2240	6653	9.8	5.9	12.2	6.1	7.6	4.4
CAF	Central African Republic	2	3.4	11.4	1.8	4.5	15.8	718	1160	2720	5.2	5.0	6.2	5.2	3.2	3.5
CPV	Cape Verde	1.4	3.0	7.9	1.5	3.6	9.5	3535	6814	15797	5.4	3.9	6.2	3.9	4.5	3.4
BLZ	Belize	1	2.4	7.1	1.2	2.6	8.8	6566	9741	21915	4.5	4.4	5.0	5.0	2.7	3.3
MDV	Maldives	1	1.9	4.5	1.1	3.6	12.1	4956	8190	17351	4.5	3.4	8.2	5.0	3.4	3.0
BDI	Burundi	1	1.8	5.1	1.3	2.6	6.9	366	540	1176	4.4	4.2	4.7	3.9	2.6	3.2
DJI	Djibouti	0.9	1.5	3.3	0.9	1.6	3.1	2051	2632	4293	3.5	3.3	3.7	2.8	1.7	2.0
GMB	Gambia, The	0.6	1.7	8.0	0.8	2.3	11.6	1369	2516	7441	6.8	6.4	7.5	6.7	4.1	4.4
GNB	Guinea-Bissau	0.3	0.6	1.7	0.4	0.7	1.6	551	737	1318	4.1	4.2	3.7	3.4	2.0	2.4
Asia		**12049**	**24180**	**58574**	**14522**	**41644**	**143609**	**5920**	**12067**	**30921**	**4.8**	**3.6**	**7.3**	**5.1**	**4.9**	**3.8**
JPN	Japan	4652.8	6006.8	7847.0	5023.1	8397.0	12648.8	31283	41625	61502	1.7	1.1	3.5	1.7	1.9	1.6
CHN	China	3685.9	10423.5	30048.5	5105.0	21838.1	91623.5	6531	17756	55125	7.2	4.3	10.2	5.9	6.9	4.6
IND	India	1211.1	3092.1	10653.6	1495.0	5098.8	23345.8	2973	6372	18930	6.4	5.1	8.5	6.3	5.2	4.5
KOR	Korea, Rep.	1016.8	1877.9	3560.9	944.6	2213.3	5157.8	27395	48534	98247	4.2	2.6	5.8	3.4	3.9	2.9
IDN	Indonesia	376.6	690.5	1447.5	633.7	1190.5	2366.1	3879	6276	12186	4.1	3.0	4.3	2.8	3.3	2.7
HKG	Hong Kong, China	215.7	325.9	517.6	201.4	366.0	679.6	41821	54614	76066	2.8	1.9	4.1	2.5	1.8	1.3
THA	Thailand	200.0	340.7	696.7	286.2	538.2	1224.2	7676	12402	26020	3.6	2.9	4.3	3.3	3.2	3.0
MYS	Malaysia	171.2	349.0	950.3	212.6	451.8	1281.0	13167	21664	47762	4.9	4.1	5.2	4.3	3.4	3.2
SGP	Singapore	162.3	292.2	465.8	189.6	350.8	518.0	49231	77719	117711	4.0	1.9	4.2	1.6	3.1	1.7
PAK	Pakistan	137.5	286.3	932.0	159.9	351.2	1238.2	2467	4043	10564	5.0	4.8	5.4	5.2	3.3	3.9
BGD	Bangladesh	78.3	178.3	527.2	89.8	330.0	1602.4	1495	2892	7706	5.6	4.4	9.1	6.5	4.5	4.0
VNM	Vietnam	74.2	176.6	516.8	95.3	284.5	989.4	2841	5981	16730	6.0	4.4	7.6	5.1	5.1	4.2
LKA	Sri Lanka	33.3	70.3	178.6	44.4	111.3	351.2	4555	8816	22009	5.1	3.8	6.3	4.7	4.5	3.7
NPL	Nepal	10.2	23.9	86.9	14.3	64.6	366.2	1071	1997	5887	5.8	5.3	10.6	7.2	4.2	4.4
BRN	Brunei Darussalam	9.9	9.6	9.4	9.6	6.5	3.9	45718	35733	28809	-0.2	-0.1	-2.5	-2.1	-1.6	-0.9
KHM	Cambodia	8.4	23.2	91.1	9.7	27.0	112.5	1903	4443	15381	7.0	5.6	7.0	5.9	5.8	5.1
LAO	Lao PDR	4.0	10.4	35.5	6.5	18.2	71.7	2280	4931	14919	6.6	5.0	7.1	5.6	5.3	4.5
BTN	Bhutan	1.2	3.0	8.3	1.4	6.3	29.1	4806	9686	24256	6.0	4.2	10.7	6.3	4.8	3.7

Source: own calculations.

E-2: Productivity

	Tertiary education (share of working age population)			Secondary education (share of working age population)			TFP		
	2010	2025	2050	2010	2025	2050	2010	2025	2050
United States of America	53	58	72	98	98	100	1939	2205	2750
Japan	42	57	74	89	96	99	1546	2018	2720
European Union	21	29	51	84	90	96	1474	1813	2564
Brazil	8	12	27	55	65	80	499	639	991
Russian Federation	56	59	71	98	98	99	492	907	2014
India	6	9	18	47	59	75	182	305	625
China	7	11	21	71	82	93	271	534	1236
Latin America	17	22	37	62	71	82	685	860	1254
Middle east and North Africa	12	19	35	53	65	80	641	801	1230
Sub-saharian Africa	3	4	7	29	36	48	198	263	436
Rest of Asia	10	14	24	45	56	73	306	414	666
Rest of the World	30	36	56	90	92	95	840	1168	1890
Total World	13	17	26	59	67	76	735	872	1252

	TFP growth		Energy productivity (2005 constant USD per barrel)			Energy Intensity growth	
	2010-25	2025-50	2010	2025	2050	2010-25	2025-50
United States of America	0.9	0.9	1196	1427	1609	1.2	0.5
Japan	1.8	1.2	2149	2219	2341	0.2	0.2
European Union	1.4	1.4	1891	1993	2091	0.4	0.2
Brazil	1.7	1.8	764	971	1112	1.6	0.5
Russian Federation	4.2	3.2	254	400	482	3.1	0.7
India	3.5	2.9	294	468	599	3.2	1.0
China	4.6	3.4	248	477	645	4.4	1.2
Latin America	1.5	1.5	859	1065	1205	1.4	0.5
Middle east and North Africa	1.5	1.7	488	769	870	3.1	0.5
Sub-saharian Africa	1.9	2.0	285	407	438	2.4	0.3
Rest of Asia	2.0	1.9	526	694	765	1.9	0.4
Rest of the World	2.2	1.9	886	1012	918	0.9	-0.4
Total World	1.1	1.5	793	894	931	0.8	0.2

ISO	Country name	Tertiary education (% of working age population)			Secondary education (% of working age population)			Growth of energy productivity (%)		Growth of TFP (%)	
		2010	2025	2050	2010	2025	2050	2010-25	2025-50	2010-25	2025-50
North America		**42.9**	**48.5**	**63.4**	**89.7**	**92.4**	**96.1**	**1.2**	**0.5**	**0.9**	**0.9**
USA	United States	53.0	58.4	72.3	97.6	98.3	99.5	1.2	0.5	0.9	0.9
CAN	Canada	38.7	46.7	65.5	96.7	98.5	99.6	1.5	0.5	1.7	1.3
MEX	Mexico	16.6	22.6	37.7	65.9	74.7	85.4	1.3	0.4	1.7	1.8
Other America		**14.8**	**20.6**	**35.1**	**59.3**	**69.3**	**82.6**	**1.3**	**0.5**	**1.8**	**1.8**
BRA	Brazil	7.7	12.5	26.8	54.6	65.2	80.0	1.6	0.5	1.7	1.8
ARG	Argentina	9.5	10.4	20.3	62.4	72.3	84.7	1.9	0.6	2.0	1.5
COL	Colombia	10.5	17.0	33.2	55.9	67.3	82.8	1.2	0.4	1.2	1.4
VEN	Venezuela, RB	17.0	22.9	38.3	35.5	44.5	62.6	1.1	0.1	1.2	1.3
CHL	Chile	26.5	35.1	50.9	75.0	83.7	92.9	1.2	0.6	2.1	2.0
PHL	Philippines	29.9	37.3	48.9	70.6	80.6	92.0	1.8	0.9	3.1	3.0
PER	Peru	22.0	26.7	39.7	75.5	83.4	92.0	0.2	0.5	2.6	2.2
DOM	Dominican Republic	19.1	29.1	46.9	54.9	64.2	77.2	0.8	0.7	2.9	2.9
GTM	Guatemala	4.2	8.0	20.4	24.6	39.1	61.5	0.6	0.4	1.2	1.7
CRI	Costa Rica	18.4	25.8	41.7	58.8	67.5	80.8	1.3	0.6	2.0	2.1
URY	Uruguay	9.6	13.9	28.1	60.1	69.4	82.5	2.0	0.6	1.8	1.7
PAN	Panama	22.8	29.2	44.8	68.1	76.5	86.7	0.1	0.5	2.7	2.4
TTO	Trinidad and Tobago	4.1	7.0	20.1	77.9	89.0	98.9	4.1	0.9	3.2	2.5
HND	Honduras	8.1	15.0	30.9	42.1	53.7	70.9	2.4	0.8	2.1	2.4
BOL	Bolivia	17.4	25.7	42.7	68.7	78.7	89.1	3.7	0.9	2.4	2.4
PRY	Paraguay	6.0	14.6	32.8	47.8	57.3	72.0	2.4	0.7	1.7	1.8
BHS	Bahamas	12.3	17.5	32.4	57.5	66.6	80.6	2.7	0.6	1.1	1.5
NIC	Nicaragua	17.6	25.7	41.6	45.8	57.6	74.4	3.1	0.9	2.7	2.8
HTI	Haiti	1.3	4.3	15.3	34.6	48.7	67.8	2.4	0.6	1.9	1.8
BRB	Barbados	2.5	4.7	15.2	91.3	95.0	98.6	2.7	0.6	1.7	1.6
SUR	Suriname	12.4	18.2	33.1	58.3	67.8	81.1	2.6	0.8	2.6	2.4
LCA	St. Lucia	12.5	18.0	32.3	59.3	67.8	80.5	2.5	0.6	1.2	1.6
GUY	Guyana	3.7	13.6	32.1	61.6	70.4	83.2	2.3	0.7	2.6	2.3
VCT	St. Vincent and the Grenadines	12.4	18.0	33.0	58.7	67.5	80.9	2.7	0.8	2.6	2.7
Oceania		**31.5**	**43.4**	**66.7**	**78.4**	**82.6**	**90.4**	**1.0**	**0.4**	**1.9**	**1.2**
AUS	Australia	37.1	50.4	73.1	97.3	98.0	99.2	1.0	0.4	1.9	1.1
NZL	New Zealand	50.3	59.3	76.3	78.5	85.7	95.6	1.1	0.4	1.9	1.9
PNG	Papua New Guinea	3.1	15.7	48.4	17.4	36.5	67.0	-0.5	0.4	3.4	3.3
FJI	Fiji	15.5	30.3	60.8	73.2	84.8	95.6	0.7	0.5	1.4	2.2
SLB	Solomon Islands	35.3	47.2	68.0	80.8	86.8	94.0	0.5	0.4	0.4	1.1
VUT	Vanuatu	35.1	47.2	67.8	80.7	86.6	93.8	0.7	0.6	2.0	2.3
European Union		**20.7**	**29.0**	**50.7**	**84.0**	**90.4**	**95.7**	**0.2**	**0.2**	**1.2**	**1.2**
DEU	Germany	19.2	20.8	35.1	87.2	88.3	89.8	0.2	0.2	1.2	1.1
GBR	United Kingdom	27.1	42.1	67.0	76.3	84.6	94.0	0.2	0.2	1.4	1.0
FRA	France	25.5	39.0	62.7	88.2	95.1	98.8	0.2	0.2	1.2	1.0
ITA	Italy	11.2	14.7	31.4	86.5	95.2	98.9	-0.2	0.1	0.8	1.2
ESP	Spain	28.6	39.2	61.0	81.3	91.0	97.1	0.0	0.1	1.6	2.0
NLD	Netherlands	26.8	37.0	59.1	89.2	93.2	97.4	0.6	0.3	1.3	1.0
BEL	Belgium	29.7	40.9	62.2	84.5	91.0	96.7	0.7	0.3	1.0	0.9
SWE	Sweden	27.5	38.1	60.2	94.4	98.3	99.5	1.0	0.4	1.2	0.9
POL	Poland	13.8	19.7	42.7	82.8	89.6	95.5	2.7	0.9	2.8	2.6
AUT	Austria	17.1	26.4	50.7	80.5	88.7	97.8	-0.2	0.1	1.3	1.0
DNK	Denmark	20.1	27.8	52.3	62.8	72.6	88.2	0.3	0.2	1.0	0.9
GRC	Greece	26.0	30.9	44.4	76.6	87.8	96.1	0.1	0.2	1.7	2.0
FIN	Finland	26.7	29.0	42.4	74.5	84.5	92.9	1.1	0.5	1.3	0.9
IRL	Ireland	32.2	42.3	62.0	87.3	94.0	98.0	0.5	0.3	0.8	0.9
PRT	Portugal	14.4	24.8	49.8	52.9	68.1	89.8	0.0	0.2	1.1	2.1
CZE	Czech Republic	12.8	22.7	50.8	88.9	95.6	99.1	1.7	0.6	2.4	2.6
ROM	Romania	11.9	17.8	43.3	93.8	96.4	97.8	1.9	0.7	3.1	2.9
HUN	Hungary	14.0	19.4	43.4	97.1	98.3	99.5	1.9	0.7	2.7	2.5
SVK	Slovak Republic	11.6	16.4	39.4	82.3	89.0	95.3	2.0	0.7	3.1	2.8
LUX	Luxembourg	17.5	24.0	45.3	74.5	82.3	92.6	0.4	0.3	1.0	0.9
BGR	Bulgaria	17.3	20.8	42.2	73.6	81.2	92.2	3.0	0.8	3.2	2.8
LTU	Lithuania	24.5	28.4	44.1	95.1	97.0	98.2	2.8	1.0	4.9	3.2
LVA	Latvia	18.4	23.4	47.1	97.1	97.8	98.6	2.4	1.0	4.7	3.8

EST	Estonia	26.9	30.2	50.3	95.7	97.0	98.3	3.4	1.1	4.6	3.1
MLT	Malta	12.3	19.5	36.4	76.2	89.3	94.9	1.7	0.6	2.3	2.3
Former USSR		**45.3**	**48.6**	**61.6**	**96.6**	**97.5**	**98.4**	**3.2**	**0.8**	**4.2**	**3.3**
RUS	Russian Federation	56.0	59.4	70.6	97.8	98.2	98.9	3.1	0.7	4.2	3.2
UKR	Ukraine	39.6	44.2	61.0	97.2	98.0	98.7	4.1	1.2	5.3	4.0
KAZ	Kazakhstan	18.8	27.4	53.9	97.4	98.5	99.3	4.8	0.9	4.3	3.5
BLR	Belarus	32.0	37.1	56.2	93.8	95.9	97.6	3.7	1.2	4.9	4.2
GEO	Georgia	31.5	37.2	55.5	93.7	96.0	97.5	3.3	1.3	5.9	4.5
ARM	Armenia	19.0	22.0	34.9	97.1	98.0	98.7	2.6	1.2	6.1	4.5
MDA	Moldova	31.6	37.4	54.9	93.6	95.9	97.5	3.6	1.2	4.9	3.8
TJK	Tajikistan	6.7	9.3	20.2	91.1	93.8	95.9	3.2	1.1	4.3	3.1
MNG	Mongolia	13.2	20.6	45.9	83.8	89.1	94.8	4.9	1.2	4.6	3.3
KGZ	Kyrgyz Republic	11.5	13.5	25.6	81.1	87.1	93.0	4.0	1.2	4.6	3.5
Other Europe		**19.4**	**24.4**	**42.7**	**81.9**	**86.9**	**93.3**	**-0.2**	**0.0**	**1.0**	**0.9**
CHE	Switzerland	18.1	20.5	37.2	68.8	75.8	87.4	-0.4	0.0	1.0	0.9
NOR	Norway	28.0	33.8	50.1	97.3	98.0	98.4	0.4	0.2	1.0	0.9
ISL	Iceland	30.8	45.9	68.6	69.4	79.8	91.7	2.1	0.7	1.2	0.9
ALB	Albania	8.3	16.2	38.3	91.2	96.6	98.5	0.3	0.6	3.5	3.2
Middle-East and North Africa		**12.3**	**19.0**	**34.7**	**53.5**	**64.8**	**79.8**	**1.7**	**0.5**	**1.4**	**1.5**
TUR	Turkey	10.2	17.3	34.1	45.7	57.9	76.7	1.0	0.4	2.1	2.3
SAU	Saudi Arabia	15.0	23.1	40.3	60.0	72.4	85.4	6.0	0.8	0.6	0.5
IRN	Iran, Islamic Rep.	16.4	23.3	38.7	68.1	77.1	88.5	3.9	0.6	2.2	2.3
SYR	Syrian Arab Republic	4.4	6.7	15.8	26.1	39.2	59.6	0.2	0.1	0.7	1.4
ARE	United Arab Emirates	15.7	19.3	33.5	67.6	71.3	82.5	3.6	0.6	0.6	1.0
ISR	Israel	35.5	40.0	53.9	79.0	86.0	93.9	0.8	0.4	1.3	1.4
EGY	Egypt, Arab Rep.	12.4	21.0	39.3	61.6	74.8	88.1	3.0	0.8	2.5	3.0
DZA	Algeria	10.5	17.2	33.0	52.7	64.6	80.1	2.9	0.5	1.3	1.6
QAT	Qatar	18.1	24.2	40.5	60.8	68.9	81.8	1.8	0.5	2.1	0.9
KWT	Kuwait	7.1	10.8	25.8	50.8	57.6	73.0	3.0	0.4	0.9	0.7
MOR	Morocco	10.5	17.3	32.7	34.6	47.2	67.7	1.4	0.7	2.4	2.5
OMN	Oman	14.5	19.1	34.4	63.3	69.3	82.1	3.4	0.4	1.4	1.6
TUN	Tunisia	10.8	17.2	34.2	49.8	61.3	79.4	1.9	0.7	2.4	2.6
LBN	Lebanon	13.9	19.8	34.1	59.5	69.3	82.1	0.7	0.5	1.5	1.9
YEM	Yemen, Rep.	4.0	10.3	25.6	26.7	42.4	64.3	1.6	0.0	0.6	2.0
BHR	Bahrain	11.1	12.9	24.8	85.2	89.9	95.7	3.9	0.6	1.0	1.3
JOR	Jordan	18.0	26.0	42.1	73.3	82.1	90.0	2.1	0.9	2.4	2.8
Sub-Saharan Africa		**2.9**	**4.0**	**7.4**	**28.9**	**35.7**	**47.8**	**1.8**	**0.1**	**1.4**	**1.4**
ZAF	South Africa	7.1	8.4	13.1	71.9	80.5	88.2	2.9	0.8	1.9	1.7
NGA	Nigeria	2.9	4.2	8.0	30.4	38.7	52.4	2.4	0.4	2.9	2.4
AGO	Angola	2.9	4.2	8.0	30.7	39.1	52.0	-0.3	-0.8	1.7	1.9
SDN	Sudan	2.9	5.1	10.2	17.1	25.9	41.5	1.7	0.2	0.9	1.7
KEN	Kenya	3.3	5.3	10.4	33.9	43.2	57.9	3.1	0.8	2.4	2.2
ETH	Ethiopia	2.9	4.2	7.8	30.4	38.7	50.8	5.8	1.3	1.8	2.2
TZA	Tanzania	0.6	0.9	2.4	7.8	12.9	26.7	3.6	1.1	3.7	3.3
CMR	Cameroon	2.6	4.4	8.8	33.5	43.7	58.4	2.1	0.6	2.1	2.1
CIV	Cote d'Ivoire	4.8	7.3	13.0	25.9	36.0	51.5	2.5	0.6	1.1	1.7
GHA	Ghana	2.5	2.5	4.8	55.8	61.8	72.0	3.1	0.8	3.1	2.1
UGA	Uganda	3.2	3.9	7.7	15.3	23.2	38.9	3.1	0.9	2.9	2.8
BWA	Botswana	3.8	5.3	9.8	86.2	95.0	98.9	2.2	0.8	2.5	2.0
SEN	Senegal	3.4	4.9	9.2	18.7	26.9	42.1	1.2	0.5	1.8	1.8
GAB	Gabon	12.5	16.6	23.8	51.1	60.2	71.3	2.5	0.0	0.4	0.2
ZMB	Zambia	1.2	1.6	4.1	36.9	48.3	63.7	3.2	0.9	2.9	2.4
MOZ	Mozambique	0.6	1.2	3.4	4.3	8.7	20.5	4.3	1.3	4.1	3.5
COG	Congo, Rep.	2.0	1.7	3.5	50.0	57.5	68.0	0.8	-0.5	0.3	-0.1
MUS	Mauritius	3.0	3.5	5.9	55.4	64.2	76.0	3.6	0.9	2.5	2.0
BFA	Burkina Faso	2.9	4.2	8.0	30.9	38.9	52.5	3.0	1.0	3.1	2.9
MLI	Mali	1.6	2.8	6.4	7.1	12.5	25.7	3.0	0.9	2.6	2.4
TCD	Chad	2.9	4.2	8.0	30.6	39.0	52.4	2.5	-0.2	0.4	0.3
MDG	Madagascar	2.9	4.2	7.9	30.4	38.5	51.9	2.7	0.7	2.0	2.3
BEN	Benin	2.6	3.7	7.5	23.3	31.8	46.9	3.4	0.9	2.4	2.3
MWI	Malawi	0.5	0.6	1.7	15.0	21.6	36.7	2.9	0.9	2.4	2.5
NER	Niger	1.1	2.1	5.4	6.9	12.9	26.8	2.8	0.8	2.6	2.1
GIN	Guinea	2.9	4.2	8.0	30.4	38.7	52.0	2.9	0.9	3.0	2.8
RWA	Rwanda	1.7	2.9	6.7	10.7	17.5	32.1	3.1	1.0	3.7	3.2

SWZ	Swaziland	3.6	5.5	10.2	56.6	67.3	77.9	3.3	0.9	1.4	2.0
TGO	Togo	2.4	4.0	8.1	33.5	41.3	54.4	3.7	0.9	2.4	2.3
MRT	Mauritania	2.6	4.4	9.0	18.1	26.5	41.9	3.0	0.8	2.2	2.1
LSO	Lesotho	1.5	2.8	6.1	29.8	40.4	55.0	3.2	1.0	2.8	2.5
SLE	Sierra Leone	1.5	2.7	6.1	19.1	26.7	40.6	3.3	1.1	5.3	2.5
CAF	Central African Republic	1.8	2.8	6.1	21.7	30.7	45.6	2.8	0.8	1.9	2.0
CPV	Cape Verde	2.9	4.1	7.2	30.6	37.3	48.7	3.6	1.0	2.6	2.2
BLZ	Belize	9.4	15.6	31.0	42.9	50.6	66.7	2.5	0.8	1.8	2.1
MDV	Maldives	1.7	2.6	6.0	39.3	51.3	70.6	3.1	0.8	2.5	2.1
BDI	Burundi	1.0	1.4	3.4	9.3	15.1	28.2	2.6	0.7	1.8	1.9
DJI	Djibouti	2.9	4.2	7.7	30.3	38.0	50.8	3.1	0.6	1.3	1.3
GMB	Gambia, The	1.6	2.4	5.4	32.6	43.0	58.0	3.0	1.0	2.9	2.7
GNB	Guinea-Bissau	2.9	4.2	7.9	30.2	38.6	51.9	2.6	0.6	1.4	1.5
Asia		**8.2**	**11.9**	**21.1**	**56.6**	**66.5**	**79.9**	**-0.8**	**-0.3**	**0.9**	**1.4**
JPN	Japan	42.2	56.6	74.0	89.2	96.0	98.9	0.2	0.2	1.8	1.2
CHN	China	7.3	11.1	21.0	71.4	82.0	93.1	4.4	1.2	4.6	3.4
IND	India	5.9	9.2	18.5	47.4	58.8	75.0	3.2	1.0	3.5	2.9
KOR	Korea, Rep.	41.0	53.4	68.8	92.9	98.3	99.9	1.2	0.5	2.6	1.9
IDN	Indonesia	2.7	3.3	7.2	29.8	41.0	62.8	2.6	0.7	2.0	1.8
HKG	Hong Kong, China	16.2	20.0	27.7	77.7	88.6	97.5	-0.5	0.2	1.6	1.3
THA	Thailand	10.2	15.3	26.9	38.9	52.5	77.2	2.8	0.7	2.2	2.3
MYS	Malaysia	15.5	23.2	37.0	77.4	87.0	94.2	2.9	0.7	2.2	2.1
SGP	Singapore	21.9	32.2	46.0	70.1	83.2	95.6	-0.3	0.3	1.9	1.3
PAK	Pakistan	8.0	13.8	25.7	40.6	50.9	67.2	2.6	0.8	2.1	2.4
BGD	Bangladesh	4.9	7.5	15.1	42.8	52.6	69.1	2.4	0.9	3.2	2.7
VNM	Vietnam	5.5	8.8	18.0	33.6	45.8	70.6	3.8	1.0	3.4	3.2
LKA	Sri Lanka	17.1	22.8	35.1	83.9	89.3	95.2	0.9	0.7	3.3	2.6
NPL	Nepal	3.5	5.6	11.8	34.9	48.4	66.3	3.7	1.1	2.7	2.8
BRN	Brunei Darussalam	10.7	15.7	28.1	64.8	71.5	83.8	2.7	0.2	-1.2	-0.4
KHM	Cambodia	1.0	2.4	7.0	19.8	32.1	56.4	3.1	1.1	3.4	3.2
LAO	Lao PDR	5.1	8.1	15.4	38.2	53.7	74.0	2.7	1.0	3.4	2.9
BTN	Bhutan	8.0	11.5	20.1	55.1	63.9	76.5	3.1	0.9	3.1	2.4

Source: own calculations.

E-3: PRODUCTION FACTORS

	Capital stocks (billion constant 2005 USD)			Savings rate (% of GDP)			Investment rate (% of GDP)		
	2010	2025	2050	2010	2025	2050	2010	2025	2050
United States of America	29552	36267	47762	11	14	13	14	16	14
Japan	15897	17447	23292	24	20	22	21	21	20
European Union	36994	43906	56794	16	18	16	15	18	16
Brazil	2092	3437	6613	10	15	12	15	18	16
Russian Federation	2547	3918	9466	14	28	26	16	22	20
India	2580	5599	19402	20	22	21	24	21	19
China	9079	27166	89723	37	34	26	31	33	29
Latin America	7270	10934	21308	13	19	18	14	19	17
Middle east and North Africa	4941	9145	20444	16	25	22	16	21	19
Sub-saharian Africa	1433	2644	8481	13	16	17	15	17	15
Rest of Asia	6430	11948	27447	19	25	22	20	24	21
Rest of the World	5305	7467	14055	20	23	22	18	22	21
Total World	124120	179877	344786	17	21	20	17	21	20

	Labor force (million workers)			Primary energy consumption (billion barrels)			Energy Intensity (barrels per 1000$ of GDP)		
	2010	2025	2050	2010	2025	2050	2010	2025	2050
United States of America	161	174	198	16.4	16.8	21.3	1.2	1.0	0.9
Japan	65	61	52	3.5	4.1	4.9	0.8	0.7	0.6
European Union	241	229	211	12.0	13.4	17.6	0.8	0.8	0.7
Brazil	103	118	119	2.0	2.5	4.0	1.8	1.4	1.2
Russian Federation	77	69	58	4.3	5.3	10.9	4.7	3.0	2.4
India	490	639	785	5.1	8.1	21.4	4.2	2.6	2.0
China	795	811	656	17.9	26.9	56.7	4.8	2.6	1.9
Latin America	177	215	260	5.4	6.7	11.7	1.7	1.3	1.1
Middle east and North Africa	152	194	230	6.6	7.3	13.7	2.8	1.7	1.5
Sub-saharian Africa	310	467	854	3.5	5.0	15.8	4.4	3.0	2.7
Rest of Asia	460	573	670	6.9	9.5	18.9	2.6	1.9	1.7
Rest of the World	71	72	74	3.3	4.1	8.4	1.7	1.4	1.4
Total World	3102	3622	4167	87	110	205	1.7	1.4	1.4

ISO	Country name	Capital stocks (billion 2005 USD)			Labour force (thousands)			Energy Intensity (barrels per '000 USD)			Saving rate (% of GDP)			Investment rate (% of GDP)		
		2010	2025	2050	2010	2025	2050	2010	2025	2050	2010	2025	2050	2010	2025	2050
North America		**34491**	**43322**	**60548**	**229375**	**253503**	**288635**	**1.3**	**1.0**	**0.9**	**11.5**	**14.9**	**14.5**	**13.6**	**16.0**	**14.4**
USA	United States	29552	36267	47762	160791	173587	198482	1.25	1.00	0.86	11.3	14.0	13.3	13.8	15.5	13.8
CAN	Canada	2857	3832	6270	19291	19883	21878	1.59	1.23	1.05	15.1	19.6	20.3	13.6	17.9	16.8
MEX	Mexico	2082	3223	6516	49293	60033	68274	1.43	1.14	0.99	9.9	19.6	18.3	9.9	19.3	16.9
Other America		**4644**	**7826**	**17345**	**249846**	**306057**	**366330**	**1.9**	**1.5**	**1.2**	**12.0**	**16.1**	**14.9**	**16.5**	**18.7**	**17.2**
BRA	Brazil	2092	3437	6613	102846	117945	118621	1.84	1.40	1.18	10.4	14.8	12.4	15.2	17.8	16.1
ARG	Argentina	518	875	1737	19790	22354	25613	2.32	1.69	1.43	14.6	16.7	16.0	17.8	18.6	17.1
COL	Colombia	389	567	998	19343	23248	27891	1.31	1.04	0.92	11.4	13.0	12.1	16.9	17.4	16.0
VEN	Venezuela, RB	445	672	1256	13528	16632	20805	2.18	1.76	1.63	17.8	23.8	23.5	18.8	21.7	20.0
CHL	Chile	304	494	1015	7675	8861	9539	1.70	1.35	1.14	14.3	19.7	17.8	18.8	18.7	17.0
PHL	Philippines	223	514	2224	38297	53458	78249	2.45	1.83	1.44	10.7	15.7	15.8	14.6	20.0	18.6
PER	Peru	229	478	1372	13656	17233	20790	0.97	0.89	0.75	13.1	17.7	16.6	19.5	21.9	20.1
DOM	Dominican Republic	77	167	552	4448	5315	6195	1.29	1.08	0.89	10.2	12.9	13.3	16.4	18.3	17.0
GTM	Guatemala	61	90	241	5672	8784	15795	1.75	1.50	1.30	5.3	6.4	8.3	15.3	14.2	13.5
CRI	Costa Rica	49	89	204	2202	2620	2785	1.52	1.20	1.01	10.1	16.6	13.8	18.3	19.6	17.6
URY	Uruguay	39	64	120	1680	1779	1841	1.62	1.17	0.97	11.9	12.7	12.1	14.5	15.3	14.1
PAN	Panama	39	88	264	1618	2034	2509	0.95	0.87	0.74	22.2	25.3	24.7	18.0	19.4	17.8
TTO	Trinidad and Tobago	35	71	185	707	681	567	7.73	4.29	3.34	21.0	35.3	33.6	14.9	22.3	20.4
HND	Honduras	31	51	158	2863	4384	6548	2.98	2.05	1.64	12.3	16.2	17.2	23.4	21.4	19.9
BOL	Bolivia	18	34	115	4562	6350	9594	4.50	2.63	2.08	8.5	10.5	11.3	12.0	15.1	14.1
PRY	Paraguay	20	34	87	3098	4165	5850	3.55	2.44	1.99	6.4	11.1	11.6	14.9	18.9	17.6
BHS	Bahamas	22	25	38	196	229	245	3.32	2.20	1.85	3.7	14.5	13.5	20.9	22.4	20.5
NIC	Nicaragua	17	25	72	2370	3109	3871	4.72	2.98	2.32	12.3	16.7	15.9	23.3	22.3	20.5
HTI	Haiti	15	17	31	4488	5965	8109	4.51	3.09	2.57	14.6	15.7	17.4	19.9	17.5	16.5
BRB	Barbados	8	10	14	159	152	128	3.32	2.20	1.84	5.6	13.0	10.5	17.5	18.4	16.6
SUR	Suriname	6	10	25	196	223	235	3.32	2.24	1.80	15.9	18.4	17.0	22.6	23.7	21.7
LCA	St. Lucia	3	4	7	82	96	98	3.32	2.24	1.86	9.6	14.1	12.2	23.6	24.7	22.6
GUY	Guyana	3	4	8	316	384	395	3.32	2.32	1.87	10.7	11.7	10.2	24.5	24.2	22.1
VCT	St. Vincent and the Grenadines	2	3	6	54	55	57	3.32	2.20	1.75	8.7	15.4	14.7	27.3	28.7	26.4
Oceania		**2513**	**3452**	**6361**	**17887**	**20998**	**27100**	**1.3**	**1.0**	**0.9**	**18.1**	**20.2**	**21.4**	**18.1**	**21.1**	**19.9**
AUS	Australia	2140	2991	5462	11850	13121	15458	1.28	1.05	0.91	18.4	20.3	21.2	18.3	21.3	20.0
NZL	New Zealand	305	402	768	2381	2589	2973	1.14	0.93	0.80	15.7	19.0	21.1	16.5	19.3	19.0
PNG	Papua New Guinea	59	45	100	3047	4493	7513	1.06	1.06	0.93	30.8	31.1	34.4	16.9	23.3	22.2
FJI	Fiji	7	9	19	364	416	503	1.19	1.02	0.87	7.9	13.3	12.9	16.2	18.7	17.3
SLB	Solomon Islands	1	1	4	121	190	332	1.19	1.05	0.92	15.0	19.0	19.5	13.8	15.0	14.0
VUT	Vanuatu	1	2	7	124	189	321	1.19	1.02	0.86	10.1	12.4	13.4	20.3	22.4	20.9
European Union		**36994**	**43906**	**56794**	**240787**	**228854**	**211047**	**0.8**	**0.8**	**0.7**	**15.8**	**17.6**	**15.8**	**14.9**	**17.9**	**15.7**
DEU	Germany	7649	8793	9357	42748	36826	30636	0.80	0.73	0.66	17.1	18.1	15.3	13.6	18.1	15.0
GBR	United Kingdom	5209	6438	9291	31936	33520	36026	0.62	0.57	0.51	12.3	14.9	15.0	13.3	15.8	14.6
FRA	France	5673	6596	8537	28814	28721	30637	0.85	0.77	0.70	16.3	16.5	15.9	15.8	16.9	15.2
ITA	Italy	5021	5078	4790	25549	23044	19668	0.70	0.67	0.62	16.5	16.5	12.2	15.3	16.7	12.9
ESP	Spain	3647	4331	6031	23150	22644	20308	0.79	0.74	0.68	15.9	19.6	16.4	18.8	20.7	17.2
NLD	Netherlands	1698	1987	2408	9055	8323	8113	0.83	0.72	0.64	18.4	21.3	20.0	12.6	17.4	15.4
BEL	Belgium	1007	1207	1454	4790	4545	4638	1.05	0.90	0.79	19.1	20.1	18.6	15.4	18.0	15.7
SWE	Sweden	849	1185	1732	5081	5199	5501	0.89	0.74	0.64	20.0	21.7	21.6	13.8	18.0	16.5
POL	Poland	798	1203	2154	17415	16395	13011	1.89	1.25	0.98	14.0	14.9	12.7	15.0	16.7	14.1
AUT	Austria	856	1073	1328	4333	4063	3636	0.70	0.67	0.62	17.9	21.0	19.1	13.9	19.7	17.1
DNK	Denmark	694	822	1006	2972	2923	2917	0.50	0.46	0.41	17.2	20.2	19.4	15.0	18.4	16.5
GRC	Greece	713	883	1445	5196	4982	4345	0.77	0.71	0.65	9.2	10.5	9.9	19.3	20.8	18.8
FIN	Finland	509	665	882	2709	2541	2475	1.17	0.95	0.82	17.6	20.9	20.7	13.6	19.4	17.7
IRL	Ireland	488	731	1148	2227	2368	2651	0.49	0.43	0.39	19.9	28.4	27.2	14.2	22.8	20.2
PRT	Portugal	573	641	802	5658	5333	4210	0.88	0.82	0.75	11.6	12.6	8.2	17.7	20.6	16.4
CZE	Czech Republic	426	547	958	5209	5051	4411	2.07	1.56	1.30	14.9	20.5	18.1	12.9	21.2	18.1
ROM	Romania	326	487	971	9498	9204	7215	2.10	1.54	1.25	5.7	13.5	7.5	19.8	22.5	19.9
HUN	Hungary	308	404	723	4254	3961	3382	1.59	1.16	0.95	13.1	18.5	16.8	12.3	20.6	17.9
SVK	Slovak Republic	176	277	543	2766	2632	2084	1.88	1.36	1.11	11.9	22.0	18.6	14.0	24.4	20.4
LUX	Luxembourg	84	134	215	235	256	272	0.69	0.61	0.55	30.9	38.5	36.8	9.9	20.6	17.9
BGR	Bulgaria	90	127	218	3535	3004	2137	4.01	2.55	2.02	6.0	9.8	4.9	24.3	21.7	19.2
LTU	Lithuania	86	125	335	1581	1458	1169	2.01	1.32	1.01	3.2	13.8	16.0	18.3	21.1	19.9
LVA	Latvia	55	81	223	1201	1060	904	1.61	1.10	0.85	7.1	14.7	14.2	23.5	25.1	23.2

EST	Estonia	51	80	223	698	637	560	2.46	1.50	1.14	13.3	19.6	24.5	25.3	27.5	26.3
MLT	Malta	8	12	21	175	163	141	1.90	1.44	1.20	6.3	9.1	7.4	18.6	23.3	21.3
Former USSR		**3290**	**5180**	**13550**	**125512**	**116154**	**103065**	**5.2**	**3.2**	**2.5**	**14.3**	**27.0**	**24.5**	**17.5**	**22.3**	**20.4**
RUS	Russian Federation	2547	3918	9466	77006	69325	58220	4.75	3.00	2.43	14.2	28.1	26.0	16.4	21.6	19.7
UKR	Ukraine	342	471	1256	22710	19899	15604	8.68	4.81	3.53	10.3	23.2	17.6	19.8	23.0	20.4
KAZ	Kazakhstan	205	388	1378	8594	9115	10713	7.36	3.75	2.96	17.9	24.4	25.3	20.8	22.9	21.4
BLR	Belarus	108	230	778	4906	4250	3283	4.57	2.66	1.95	17.9	24.3	20.8	25.0	26.4	23.8
GEO	Georgia	29	50	178	2321	2163	1792	2.48	1.53	1.10	16.0	20.5	15.4	24.1	25.8	23.0
ARM	Armenia	20	38	163	1641	1556	1407	3.04	2.04	1.50	9.9	21.9	20.4	27.2	26.8	24.5
MDA	Moldova	12	24	74	1468	1406	1073	5.75	3.41	2.50	12.6	22.8	17.6	29.1	30.8	27.7
TJK	Tajikistan	8	15	66	2919	3641	5052	5.84	3.62	2.73	7.9	11.4	12.0	20.2	22.0	20.5
MNG	Mongolia	10	29	125	1455	1747	2119	7.60	3.83	2.79	14.7	26.8	20.9	31.8	38.6	34.8
KGZ	Kyrgyz Republic	8	16	67	2492	3052	3802	6.74	3.77	2.78	22.4	28.0	25.0	23.5	23.2	20.9
Other Europe		**2065**	**2794**	**3791**	**8729**	**8712**	**8079**	**0.6**	**0.6**	**0.6**	**24.7**	**27.1**	**25.6**	**17.0**	**22.7**	**20.3**
CHE	Switzerland	1196	1428	1548	4376	4129	3526	0.48	0.47	0.45	22.6	24.1	20.7	17.1	20.9	17.3
NOR	Norway	794	1258	2028	2664	2798	2983	0.69	0.61	0.56	28.5	31.5	31.3	16.5	24.8	22.7
ISL	Iceland	47	56	77	195	222	260	2.77	1.99	1.61	9.6	16.2	15.1	15.7	18.9	16.7
ALB	Albania	28	52	137	1495	1563	1310	1.33	1.21	1.00	12.5	14.8	11.7	25.5	24.8	22.4
Middle-East and North Africa		**4941**	**9145**	**20444**	**151828**	**194106**	**229599**	**2.8**	**1.7**	**1.5**	**16.1**	**24.9**	**21.6**	**15.8**	**21.5**	**19.4**
TUR	Turkey	1152	2042	4767	24669	30924	33390	1.32	1.09	0.95	4.9	16.9	15.4	9.7	18.5	16.0
SAU	Saudi Arabia	736	1180	1854	10633	14247	17051	4.28	1.89	1.51	24.6	28.0	28.3	13.1	17.7	16.5
IRN	Iran, Islamic Rep.	642	1247	2899	30160	34973	32677	6.70	3.80	3.20	30.2	35.5	29.7	22.4	27.5	24.5
SYR	Syrian Arab Republic	345	569	1282	6251	8967	12145	0.90	0.82	0.76	18.3	18.3	19.9	16.4	20.0	18.8
ARE	United Arab Emirates	331	585	926	4896	5979	5668	2.88	1.69	1.42	-3.3	28.5	25.1	13.7	21.4	19.3
ISR	Israel	317	612	1423	3085	3692	4969	1.03	0.87	0.75	13.1	15.1	16.8	17.3	22.3	20.9
EGY	Egypt, Arab Rep.	238	495	1846	26979	37504	49050	4.51	2.89	2.30	11.5	14.1	13.3	18.8	20.3	18.6
DZA	Algeria	331	598	1246	15205	18124	20102	2.65	1.72	1.48	30.2	33.1	30.7	22.1	30.2	27.6
QAT	Qatar	173	600	1321	1317	1619	1714	1.94	1.45	1.22	37.0	62.9	57.4	27.5	30.6	27.4
KWT	Kuwait	154	229	331	1365	1739	1983	1.91	1.22	1.07	9.2	22.7	21.8	10.1	13.0	11.9
MOR	Morocco	194	313	772	11990	14710	16929	1.59	1.25	1.03	17.5	18.4	16.7	22.9	20.9	19.0
OMN	Oman	65	133	263	1201	1385	1367	3.31	2.02	1.77	24.5	30.7	28.2	15.5	18.4	16.6
TUN	Tunisia	86	156	403	3843	4416	4570	1.97	1.44	1.19	17.6	21.4	16.9	20.5	23.8	21.3
LBN	Lebanon	64	144	334	1467	1730	1726	1.40	1.19	1.01	27.9	26.8	24.1	24.3	29.7	27.1
YEM	Yemen, Rep.	42	77	269	6225	10717	22295	2.88	2.21	2.09	10.4	11.6	14.4	20.0	20.7	19.6
BHR	Bahrain	32	63	109	706	786	738	4.29	2.46	2.05	7.1	27.7	22.7	16.6	21.5	19.1
JOR	Jordan	38	102	398	1834	2593	3223	3.10	2.22	1.75	21.4	26.9	26.3	25.5	32.0	29.5
Sub-Saharan Africa		**1433**	**2644**	**8481**	**310153**	**466816**	**854445**	**4.4**	**3.0**	**2.7**	**13.5**	**15.7**	**16.6**	**14.8**	**16.9**	**15.4**
ZAF	South Africa	599	949	1964	19315	22039	24938	3.49	2.26	1.83	10.8	15.6	17.0	17.2	18.9	17.7
NGA	Nigeria	206	436	1865	51286	75980	148546	5.40	3.70	3.22	19.3	19.5	20.6	8.1	13.6	12.8
AGO	Angola	57	140	530	8273	13539	24695	1.39	1.35	1.53	16.0	17.6	21.6	7.5	13.3	13.0
SDN	Sudan	53	105	311	13700	20643	36048	2.77	2.09	1.90	8.9	9.7	10.9	14.3	14.8	13.9
KEN	Kenya	46	88	320	19193	29320	53761	5.84	3.69	2.93	7.8	9.8	10.6	18.4	17.7	16.5
ETH	Ethiopia	32	80	325	41526	62164	94845	14.84	6.70	4.80	6.3	7.6	9.5	16.9	17.1	16.2
TZA	Tanzania	33	86	564	21916	35087	76194	7.63	4.52	3.39	5.9	6.7	7.3	16.5	18.9	17.6
CMR	Cameroon	39	66	206	7833	11271	18802	2.79	2.00	1.68	13.7	15.8	17.3	15.2	17.2	16.2
CIV	Cote d'Ivoire	28	46	133	7788	11666	20291	4.62	3.13	2.62	15.0	15.7	17.4	10.6	14.3	13.6
GHA	Ghana	33	53	152	11186	16376	26846	5.25	3.29	2.61	5.9	7.5	7.8	21.0	15.4	14.3
UGA	Uganda	21	44	216	14577	24707	52344	5.32	3.34	2.59	13.9	14.3	16.4	17.3	14.2	13.4
BWA	Botswana	27	66	195	1038	1242	1486	1.48	1.04	0.83	31.5	37.4	40.9	23.5	30.8	29.1
SEN	Senegal	25	32	82	5361	8381	15321	2.15	1.72	1.47	6.9	8.7	10.4	19.8	14.7	13.8
GAB	Gabon	33	50	83	736	1019	1542	1.70	1.15	1.09	38.0	39.4	39.8	22.3	28.6	26.6
ZMB	Zambia	18	38	181	4872	7820	18557	5.90	3.66	2.89	8.9	9.3	9.8	16.1	17.8	16.6
MOZ	Mozambique	15	41	259	11203	16889	29859	7.92	4.27	3.09	6.4	6.6	9.7	17.8	18.5	17.7
COG	Congo, Rep.	20	40	75	1768	2505	4445	1.41	1.19	1.27	38.0	35.9	36.3	24.6	29.1	27.1
MUS	Mauritius	18	33	67	583	607	540	5.32	3.13	2.47	18.2	19.2	15.6	21.1	23.6	21.2
BFA	Burkina Faso	13	29	152	7569	12218	25205	5.32	3.37	2.60	14.0	16.7	17.2	18.2	18.9	17.5
MLI	Mali	14	27	112	4234	6580	13892	5.32	3.39	2.68	7.4	8.7	10.0	18.2	18.9	17.7
TCD	Chad	11	19	41	4308	6840	13603	4.67	3.19	3.18	6.9	8.6	9.3	11.7	16.2	15.1
MDG	Madagascar	14	19	55	10177	16520	31722	5.32	3.51	2.85	11.3	15.5	16.6	22.1	14.2	13.2
BEN	Benin	10	18	69	3609	5536	10615	4.70	2.84	2.23	13.7	15.8	17.0	16.5	17.0	16.0
MWI	Malawi	8	18	86	6189	10110	23626	5.32	3.45	2.72	13.6	13.3	14.3	23.0	19.9	18.5
NER	Niger	7	14	59	4974	8575	21241	5.32	3.46	2.78	12.1	16.3	17.1	13.9	14.2	13.3
GIN	Guinea	6	13	59	4799	7305	13177	5.32	3.42	2.65	10.0	13.4	14.8	12.4	16.3	15.3
RWA	Rwanda	6	12	65	5250	7976	14913	5.32	3.35	2.56	11.8	14.3	15.2	16.7	15.5	14.5

SWZ	Swaziland	5	10	30	468	604	839	5.32	3.28	2.58	14.3	15.3	19.7	15.8	21.3	20.5
TGO	Togo	6	9	29	2715	3911	6153	8.58	5.00	3.89	14.5	16.9	17.8	18.6	18.7	17.5
MRT	Mauritania	6	10	30	1455	2093	3431	5.32	3.38	2.71	11.0	16.2	16.7	20.0	21.3	19.8
LSO	Lesotho	7	14	44	1016	1268	1599	5.32	3.31	2.56	13.8	15.9	19.3	34.0	40.6	38.2
SLE	Sierra Leone	2	7	30	2217	3309	5620	5.32	3.28	2.48	15.9	19.0	21.0	15.1	13.4	12.7
CAF	Central African Republic	2	4	15	2070	2967	4935	5.32	3.46	2.76	13.5	15.7	17.3	11.9	15.2	14.3
CPV	Cape Verde	4	9	25	226	287	327	5.32	3.15	2.44	15.3	20.6	19.4	33.3	31.8	29.2
BLZ	Belize	3	5	14	129	175	240	3.32	2.25	1.82	10.3	14.6	14.9	17.8	21.5	20.0
MDV	Maldives	3	5	12	157	195	215	4.32	2.72	2.15	23.3	31.9	27.5	28.9	25.2	22.6
BDI	Burundi	2	3	7	4654	6417	9365	5.32	3.57	2.90	15.7	17.9	19.1	14.7	13.5	12.7
DJI	Djibouti	2	3	6	401	547	832	5.32	3.37	2.79	17.0	17.0	17.8	23.3	17.3	16.1
GMB	Gambia, The	1	3	12	746	1206	2237	5.32	3.39	2.63	15.6	17.1	18.8	19.1	19.0	17.9
GNB	Guinea-Bissau	1	2	4	634	923	1598	5.32	3.56	2.95	13.4	14.3	15.2	22.6	26.1	24.3
Asia		**33743**	**61599**	**157448**	**1767697**	**2026556**	**2078186**	**2.7**	**2.0**	**1.7**	**26.7**	**27.1**	**23.9**	**24.3**	**26.6**	**24.7**
JPN	Japan	15897	17447	23292	64706	61390	51835	0.75	0.68	0.62	23.6	19.9	21.8	21.3	20.8	20.1
CHN	China	9079	27166	89723	794926	811012	655552	4.85	2.58	1.89	37.3	33.5	25.8	31.5	32.7	29.0
IND	India	2580	5599	19402	490318	639117	784517	4.19	2.62	2.01	20.2	22.3	20.9	23.5	20.9	19.1
KOR	Korea, Rep.	2812	5071	10471	24449	26155	24245	1.73	1.39	1.19	20.6	26.6	25.9	19.2	26.4	24.0
IDN	Indonesia	845	1501	3172	120734	147979	167404	4.18	2.82	2.32	24.4	24.8	21.2	21.1	20.9	18.8
HKG	Hong Kong, China	497	856	1420	3735	3768	3742	0.50	0.50	0.45	16.0	24.0	21.5	17.0	23.2	21.1
THA	Thailand	554	922	1849	39743	42915	39707	4.18	2.74	2.22	16.3	23.8	19.2	21.9	25.3	22.6
MYS	Malaysia	396	776	2141	12234	15890	20386	3.37	2.19	1.79	24.0	31.7	31.7	18.9	23.7	22.0
SGP	Singapore	384	864	1698	2787	3027	2812	0.74	0.71	0.63	21.8	35.8	33.5	22.7	30.7	28.0
PAK	Pakistan	232	455	1483	60410	82599	117344	4.48	3.00	2.39	10.8	14.6	15.6	16.2	17.6	16.5
BGD	Bangladesh	150	272	798	71701	92281	103417	2.96	2.03	1.60	13.7	17.3	14.4	17.6	16.4	14.7
VNM	Vietnam	177	406	1236	48507	56543	53111	6.42	3.69	2.86	20.6	23.5	15.8	27.0	26.3	23.1
LKA	Sri Lanka	71	138	353	8441	9200	9200	1.97	1.64	1.35	12.3	12.4	8.4	20.1	20.5	18.3
NPL	Nepal	20	38	137	13679	19651	26839	7.62	4.46	3.38	10.8	14.5	14.9	17.0	18.1	16.9
BRN	Brunei Darussalam	24	27	27	199	232	263	3.24	2.14	1.93	27.2	28.4	28.8	13.0	18.2	16.9
KHM	Cambodia	12	34	148	7631	9967	12077	4.35	2.73	2.05	19.1	27.8	27.6	16.9	19.2	17.7
LAO	Lao PDR	9	19	66	3172	4431	5288	3.15	2.10	1.62	7.9	11.7	12.1	23.7	20.8	19.3
BTN	Bhutan	4	11	33	325	399	447	4.32	2.71	2.11	26.0	30.7	27.3	37.8	41.6	38.0

APPENDIX F: COUNTRY GROUPING

Zone code and name	Countries
BRA - Brazil	Brazil
CHN - China	China
EU27 – European Union	Austria, Belgium, Bulgaria, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Poland, Portugal, Romania, Slovak Republic, Spain, Sweden, United Kingdom
IND - India	India
JPN - Japan	Japan
MENA – Middle-east and North Africa	Algeria, Bahrain, Egypt, Arab Rep., Iran, Islamic Rep., Israel, Jordan, Kuwait, Lebanon, Morocco, Oman, Qatar, Saudi Arabia, Syrian Arab Republic, Tunisia, Turkey, United Arab Emirates, Yemen, Rep.
RUS - Russia	Russian Federation
SAM – Rest of America	Argentina, Bahamas, The, Barbados, Belize, Bolivia, Canada, Chile, Colombia, Costa Rica, Dominican Republic, Guatemala, Guyana, Haiti, Honduras, Mexico, Nicaragua, Panama, Paraguay, Peru, St. Lucia, St. Vincent and the Grenadines, Suriname, Trinidad and Tobago, Uruguay, Venezuela, RB
SSA – Sub-Saharan Africa	Angola, Benin, Botswana, Burkina Faso, Burundi, Cameroon, Cape Verde, Central African Republic, Chad, Congo, Rep., Cote d'Ivoire, Djibouti, Ethiopia, Gabon, Gambia, The, Ghana, Guinea, Guinea-Bissau, Kenya, Lesotho, Madagascar, Malawi, Mali, Mauritania, Mauritius, Mozambique, Niger, Nigeria, Rwanda, Senegal, Sierra Leone, South Africa, Sudan, Swaziland, Tanzania, Togo, Uganda, Zambia
USA – United-States	United-States
ROAS – Rest of Asia	Bhutan, Brunei Darussalam, Cambodia, Hong Kong, China, Indonesia, Korea, Rep., Kyrgyz Republic, Lao PDR, Malaysia, Mongolia, Nepal, Pakistan, Philippines, Singapore, Sri Lanka, Thailand, Vietnam
ROW – Rest of the World	Albania, Armenia, Australia, Belarus, Fiji, Georgia, Iceland, Kazakhstan, Maldives, Moldova, New Zealand, Norway, Papua New Guinea, Solomon Islands, Switzerland, Tajikistan, Ukraine, Vanuatu

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