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Demographic Changes and the Gains from Globalisation: An Analysis of Ageing, Capital Flows, and International Trade

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Marcel Mérette and Patrick Georges

Abstract

This paper develops a multi-country overlapping-generations general equilibrium model to gauge the economic impact of demographic changes in the global economy and its transmission effects on different countries. Although severe demographic pressures contribute to significantly lower real GDP per capita across several regions in the world, globalisation through international trade generates an intertemporal gain from trade and a long-lasting improvement in the terms of trade of older OECD countries, which sustains their real consumption per capita (when goods from different geographical origins are assumed to be imperfectly substitutable), while globalisation through capital flows stimulates capital accumulation and growth in younger countries such as India and various parts of the rest of the world. The paper also illustrates that the very distinct demographic projections for China and India might, *ceteris paribus*, lead to striking divergences in their economic fortune.

KEYWORDS: demographic transition, ageing, globalisation, international trade, intertemporal trade, general equilibrium model

1. Introduction

A country with an aging population is hardly unique – to diverse degrees, all major industrialised countries are observing an increase in their old age dependency ratio (OADR) defined as population 65 year old and older over population aged 15-64. This process which eventually transforms age "pyramids" into "rectangular" or even "inverted" pyramids is the outcome of a demographic transition that started two centuries ago in Europe, then propagated to North America, and is now spreading to most regions in the world. A demographic transition is typically characterised by falling mortality rates (increase in life expectancy), followed subsequently by falling fertility rates (a baby bust). There was, however, a surprising recovery of the fertility rate in most industrialised countries between mid 1940s and mid 1960s (the baby boom), which then reverted back to its downward trend when the baby bust resumed, and which is largely expected to create economic problems and fiscal pressures as baby boomers progressively retire between 2010 and 2030.

Traditionally, ageing has been analysed within the context of the borders of nation states. More recently, globalisation of trade, capital, and labour flows within the OECD countries led some economists to explore the impact of population ageing in a more global context. However, the focus on OECD countries already appears too restrictive at the onset of the 21st century as emerging countries with rapid growth and large population such as China and India are integrating into the world economy through increasing trade and financial flows (e.g., Winters and Yusuf, 2007; Dimaranan et al., 2007; Lane and Schmukler, 2007). Theorising within this truly global perspective is certainly a major priority for understanding the prospective economic and social impacts of population ageing. In this context, the objective of this paper is to quantify the economic impact of ageing within the perspective of an overall ageing world, when globalisation is intensifying international trade and capital flows. The paper shows that globalisation through international trade generates a typical inter-temporal gain from trade and an improvement in the terms of trade of older OECD countries, which would sustain their real consumption per capita (partly alleviating the welfare impact of their ageing problem), while globalisation through capital flows would stimulate capital accumulation and growth in younger countries such as India and various parts of the rest of the world. The paper also illustrates that very different demographic projections for China and India might eventually lead, *ceteris paribus*, to striking divergences in their economic prospects.

Our paper borrows and contributes to several branches of the literature that use large scale overlapping-generations general equilibrium (OLG-GE) simulation models and which originate in the work of Auerbach and Kotlikoff (1987). The

OLG structure based on Samuelson (1958) and Diamond (1965) captures the life cycle assumption that agents have finite lifetimes over which they use capital markets to smooth revenue streams to match expenditure needs, accumulating assets in their peak saving years to use in retirement when income falls. Our paper draws model elements on a first strand of studies that have focused on the economic consequences of population aging in closed economies, often paying attention to the impacts on the social security system (e.g., De Nardi et al., 1999), or the incentives to future generations to invest more in human capital (e.g., Fougère and Mérette, 1999). The literature has also focused on the transition path, of an ageing economy, induced by policy reforms, whether tax reforms (Altig et al., 2001) or social security reforms – such as placing more of the pension responsibility on individuals, converting to defined-contribution approaches, or increasing the length of the working life (e.g., Hviding and Mérette, 1998; De Nardi et al., 2001; Fougère et al., 2009).

Second, our paper borrows and contributes to the literature on open economy OLG models that studies the causes and consequences of international capital flows. A country with a high and rising OADR is eventually subject to a current account deficit as older households eventually dissave by consuming out of wealth. However, if all countries under consideration experience a higher dependency ratio around the same time, they cannot all develop current accounts deficits (Higgins, 1998). Therefore, a general equilibrium framework of the world ageing process is crucial to understand the net foreign asset dynamics of countries during the demographic transition. Feroli (2006) and Domeij and Flodén (2006) use simulation models to provide a demographic explanation of historical capital flows. Börsch-Supan et al. (2001), Fehr et al. (2004, 2005) and Attanasio et al. (2006) construct multi-regions OLG models to study the impact of population ageing on the viability of the social security system and its reform. Krueger and Ludwig (2007) construct a three-region OLG model to quantify the impact of the demographic transition on distributional consequences of changing factor prices.

These multi-region studies typically assume that capital mobility is restricted to OECD countries. As argued by Feroli (2006), one reason for doing this is that the relatively small capital flows between the developing and developed worlds suggest that there exist significant capital market imperfections and capital controls. Furthermore, the political risk hypothesis that Lucas (1990) conjectured might prevent massive amounts of capital from flowing to poor countries from rich countries. On the other hand, Börsch-Supan et al. (2006) introduce scenarios of perfect capital mobility, either within the three largest economies in continental Europe (France, Germany, and Italy), within OECD countries, or across the entire world. In this last case, the non-OECD countries are modeled as an aggregate region representing the rest of the world. Given the increased trade and capital integration of China and India into the world economy,

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as documented in Winters and Yusuf (2007), it might nevertheless be useful to specifically model these two countries, as we do in our analysis, and to analyse the economic impacts of their very different demographic projections. Furthermore, although the political risk hypothesis of Lucas (1990) is well taken, the long-term trend of globalisation suggests that an analysis of ageing in a prospective world of capital mobility between OECD and non-OECD countries is relevant and might shed a new light on the impact of demography on Chinese and U.S. current account balances as they are caught, in the global economy, between relatively older and younger countries. China in the past few years has emerged as a net foreign creditor on the international scene. As mentioned by Dollar and Kraay (2006) and Lane and Schmukler (2007), this is surprising given that China is a relatively poor country with a capital-labour ratio about one-fifth the world average. Our paper contributes to this literature by underlying demography as another distortion that accounts for deviations from what neoclassical models would typically predict.

Finally, our model contributes to the existent literature on the concomitant effects of globalisation and population dynamics by both capturing the life cycle feature included in multi-country OLG models and introducing trade in goods between countries. Typically, other models are either trade-oriented models (e.g., Dimaranan et al., 2007) that lack the life-cycle assumption required for a sound analysis of the impacts of population ageing, or multi-country OLG-GE models (cited above) that do not truly introduce international trade. The Armington (1969) trade structure that we superimpose on our OLG model implies imperfect substitution between goods of different geographical origins, and market power, so that the law of one price does not hold in the form given by the Heckscher-Ohlin model.

The rest of the paper is divided as follows. Section 2 discusses the model. Section 3 presents simulation results and Section 4 concludes and gives extensions for future research.

2. The model

The model economy is made up of seven regions: North-America is disaggregated into U.S. and Canada to distinguish the impacts of ageing on a relatively closed versus an open economy. Europe is aggregated into one region (E.U.-15). Asia is disaggregated into three countries: Japan, as it represents a developed country with an already ageing population, and China and India as they are emergent countries with very different demographic projections. Remaining countries are aggregated into one region – the Rest of the World (ROW), to close the model. This section briefly describes the production sector in an unspecified region, the household sector and pension plans, the government sector, and the market equilibrium conditions.

2.1 Production sector

In each region *j*, a representative firm produces at time *t* a single good using a Cobb-Douglas technology (eq.1)—see Appendix for equations and Table A1 for model variables and parameters. The firm hires effective units of labour and rents physical capital. Both factors are region-specific. Firms are perfectly competitive and factor demands (eq.2 and 3) follow from profit maximization.

2.2 Household behaviour and pension plans

At any given time, and in each region, the household sector is represented by seven overlapping generations of adults. In each period, the oldest generation dies and a new young generation takes its place. Individuals are assumed fully dependent on their parents and play no active role in the model until the age of 15, then enter the labour force, retire (in average) at age 65 and die at the end of their 84^{th} year. All individuals within 10-year age cohorts *gg* (*i.e.*, 15-24, 25-34, …75-84 age groups) are assumed identical. Therefore the model portrays seven representative individuals that characterise the behaviour of the seven cohorts. These individuals are assumed to be forward-looking, endowed with perfect foresight, and to behave in a manner that maximises their lifetime utility.

An individual who begins economic life in region *j* at time *t* chooses a profile of consumption over the life cycle, in order to maximize a CES type inter-temporal utility function (eq.4).[1] The dynamic budget constraint (eq.5) is standard. Labour income is defined by eq.6 where a distinction is made between exogenous supply of physical units of labour (*LS*) and effective labour supply, which takes into account the individual's age-dependent productivity (earnings) profile ($EP_{j,gg}$) itself defined as a quadratic function of age (eq.7) with parametric values chosen to ensure that the maximum is reached between mid-life and retirement. Differentiating eq.4 under the life-time equivalent of eq.5 yields the first-order condition for consumption (eq.8). Finally, trade in goods is introduced in the model by assuming that each region produces one single good which is an imperfect substitute to the good produced in any other regions (the Armington assumption). Therefore, in their next (intra-temporal) optimization step, households allocate consumption expenditures across the seven imperfectly

[1] Each period in the model effectively corresponds to 10 years and a unit increment in the index *k*, *k*=0,...,6, represents both the next period and, for this individual, a shift to the next age group. Note that the household does not leave bequests to its children in this simple framework.

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substitutable regional final goods using CES sub-utilities. Eq.9 gives the consumption demand by household-*gg* of region-*j* for a region-*i* good. The composite consumption price index is consistently defined as a non-linear weighted average of regional prices (eq.10).

Retirees' pension benefits are proportional to their lifetime labour earnings (eq.11) and the fraction is defined by an exogenous pension replacement rate. Pension benefits are financed by contribution rates on labour income (eq.12) where *gj* and *gm* are the (five) working-age and (two) retired generations, and where *CTR* is the endogenous region-specific contribution rate needed to finance the defined-benefit pensions of the pay-as-you-go (PAYG) plan. The population *size* of working-age and retired cohorts, $Pop_{j,t,gi}$ and $Pop_{j,t,gm}$ in eq.12, is what is driving current debates on the sustainability of PAYG pension plans, and is exogenously given by demographic laws of motion (eq.29) discussed shortly.

2.3 Saving instruments, asset returns and investment

Household saving can be "placed" or "invested" in government bonds (issued to finance public debt) and capital shares (issued to finance physical capital formation). Physical capital formation is based on an investment technology characterized by a CES function that combines goods from the seven regions in order to build an aggregate investment good (eq.13) whose composite price index is given by eq.14. The accumulation of each region's capital stock is given by the usual law of motion subject to depreciation (eq.15). In this model we assume perfect substitution between domestic assets (physical assets and governments bonds), and perfect financial capital mobility across countries. Perfect substitution implies that the expected (ex ante) rate of return of owning physical capital and renting it to firms must be equal to the expected rate of return on government bonds (eq.18).[2] Perfect financial capital mobility across countries implies that the expected rate of returns on government bonds of all countries will be equalised *ex ante* leading to a unique world interest rate (eq.19). Finally, eq.20 follows because physical capital has the same *ex ante* return as financial capital.

[2] The expected (ex ante) rate of return on physical capital (purchased at time *t*-1 and rented to firms throughout period *t*) is the real rental price of capital (expressed in terms of the price of the investment good) plus the expected capital gains, net of depreciation cost (eq.16). The expected (ex ante) rate of return on government bonds (issued at end of *t*-1 and held throughout period *t*) is the promised rate of return on a zero-coupon bond plus its expected capital gains due to changes in bond prices (eq.17).

2.4 Government sector

The government budget constraint is standard and given by eq.21 with a budget balance including government spending, debt services (plus the refinancing of the entire stock of one-period debt at current bond prices) and tax revenues from different sources. The model assumes that real government program spending per capita remains constant over time. Thus, population changes imply adjustments in real program spending measures (*Gov*), and governments issue bonds (and therefore let their public debt adjust (left hand side of eq.21)) to finance their overall budget balances. However, the model imposes the condition that governments target a constant debt-to-GDP ratio, which requires that labour taxes must also adjust every period.[3] The government purchases goods from all regions *i* according to eq.22 and the composite government good price index is consistently defined as a non-linear weighted average of regional prices (eq.23).

2.5 Market and aggregation conditions

The model assumes that all markets are perfectly competitive. The equilibrium condition for the goods market is that each regional output must be equal to total demand originating from all regions *i* (eq.24). Labour and physical capital are immobile across regions and a market exists for these two factors in each region (eq.25 and 26). The world capital market must be in equilibrium, that is, the world stock of wealth (*Lend*) accumulated at the end of period *t* must be equal to the value of the world stock of government bonds and stock of physical capital at the end of *t* (eq.27). The current account of region *j* can be derived from this model as the difference between national saving (private saving of all generations and public saving) and domestic investment (eq.28).[4]

2.6 Demography and United Nation population projections

Detailed demographic projections of the UN are the exogenous forcing process of our OLG simulation model. In each country *j*, the size of population of any generation *gg* (= *g*+*k*) in period *t* is given by two laws of motion (eq.29). The first

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[3] We assume that only wage taxes adjust while capital taxes and consumption taxes remain constant throughout.

[4] Alternatively, the current account is either given as the trade balance plus the interest revenues from net foreign asset holdings (eq.28'), or as the difference between nominal GNP (GDP including interest revenues on net foreign assets) and domestic absorption. All three alternative formulations have been coded as an internal check.

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law of motion simply says that the number of young adults (of age group $g+k = g$) at time t is equal to the size of their parents' generation times the (country-specific) per-capita number of children (NN) that this generation had in period t-1. Roughly speaking, if in average any couple has two children, the number of children per capita is $NN = 1$ and the size of the young generation g at time t is equal to the size of their parent generation. The second law gives the size of any other age group ($g+k,\ k \neq 0$) as a function of the age-specific conditional survival rate s ($0 \leq s \leq 1$) and the net migration ratio nm ($nm \geq 0$). We calibrate for the parameters NN, s, and nm in order to simulate a baseline OADR consistent with the UN medium variant demographic projections available for the period 1980–2050 (United Nations Population Division, 2008). The calibration of other parameters is summarized in Table A2 and briefly described in the Appendix.

Figure 1a. Population growth (decade's yearly average)

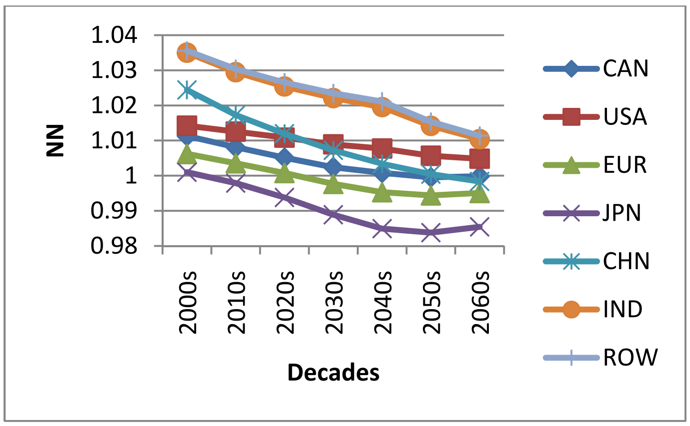
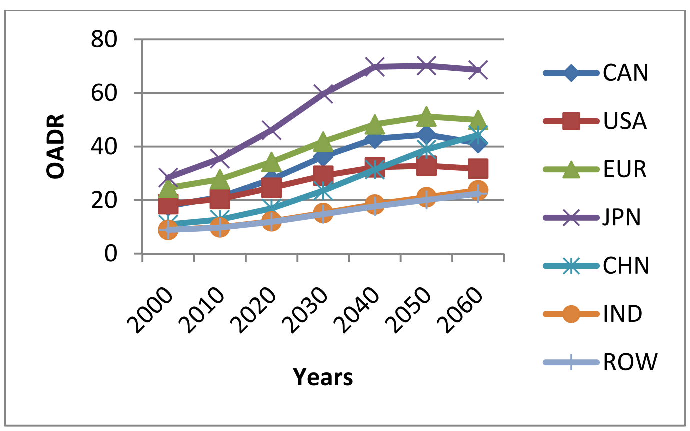
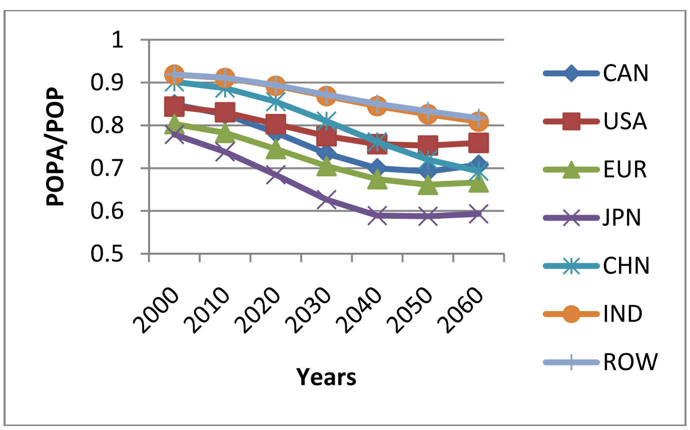


Figure 1b. Old-age dependency ratio



Figures 1a-c (based on our simulation results of parameterised eq.28) illustrate that while demographic changes are occurring in all regions of the world, the extent and timing differ substantially across countries with regard to both the slowing down of population growth, as lower fertility rates progressively catch up low mortality rates, and the population ageing, as OADR increase and ratios of working-age population (of age 15 to 64) to adult population (of age 15 and +) fall. Figure 1a shows the impact of demographic changes on population growth for the period 2000–2060 for the seven regions. During this period, population *growth* is predicted to decline in all regions and will even turn negative in some. Actually, the (*level* of) population of Japan will start declining during the 2010s, eventually followed by Europe (during the 2030s) and China (during the 2060s). The population of USA, India, and the ROW will continue to grow albeit at smaller rates over the 2000-2060 horizon while population of Canada will be essentially stabilised by the 2050s. Figure 1b illustrates that USA is an exception among OECD countries as the increase in its OADR slows down earlier (as early as 2030) while China is an exception among non-OECD countries as its OADR continues to increase significantly over the horizon. The ratio of working age to total adult population in Figure 1c, which will be shown to be a key ratio in the next section, provides similar insights about the particular position of USA and China in terms of demographic dynamics.

Figure 1c. Working-age to adult population



3. Simulated results of the demographic transition

3.1 Working age population, productivity, and real GDP per capita

The decrease of the working age to adult population ratio directly reduces the labour force which reduces overall output and therefore output per capita. Indirect

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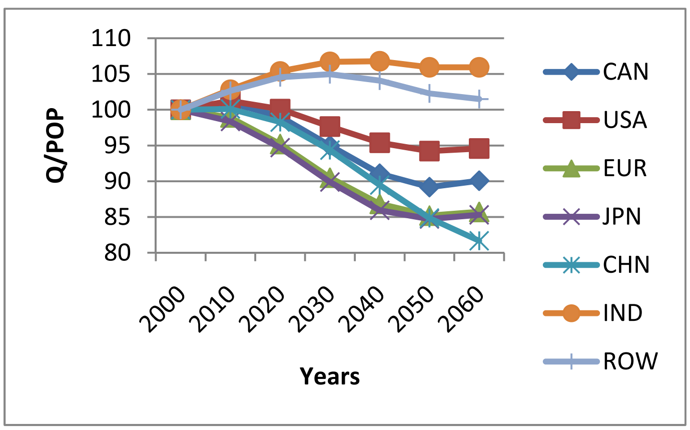
effects might, however, mitigate or accentuate this impact. A mitigating factor is the indirect effect due to an increase in the capital stock per worker (capital deepening) as younger working-age generations will have access to a large (previously accumulated) stock of capital, which should tend to increase their labour productivity and output per capita. Furthermore, the productivity of a worker is not constant across age. Instead, it reaches a peak before eventually decreasing in the later part of the active working life. Hence, variation in the age composition of the labour force may affect overall productivity as the proportion of hours supplied by workers in their peak productivity years increases first but is then eventually followed by an increase in the proportion of hours supplied by older, less effective workers. Quantitative work is needed to measure the relative strengths and the timing of these various effects.[5]

Figure 2 shows the impact of the demographic transition on the *level* of output per capita in the seven regions of the world once technological progress is factored out and therefore not included. For ease of comparison across countries, variables will typically be normalised to 100 in the first period (year 2000). After reaching a peak in 2010, per capita output will start to fall in all OECD countries (this process has started earlier in Japan and Europe), while, excepting China, it will continue to increase in non-OECD countries.

Figure 2. Real GDP per capita



[5] GDP per capita can be conceptually decomposed into 5 ratios – productivity, effort, employment rate, labour force participation, and the ratio of adult (15+) to total population. The literature generally suggests that population ageing might tend to reduce the first four ratios if older workers are less productive, if they chose to work less hours, if there is discrimination against older workers (ageism) on the job market, and finally, if they chose to retire and exit the labour force. Capital deepening might, however, increase productivity and partly offset some of the negative impacts of ageing on output per capita.

Figure 3. Growth rate in real GDP per capita (% point, decade's yearly average)

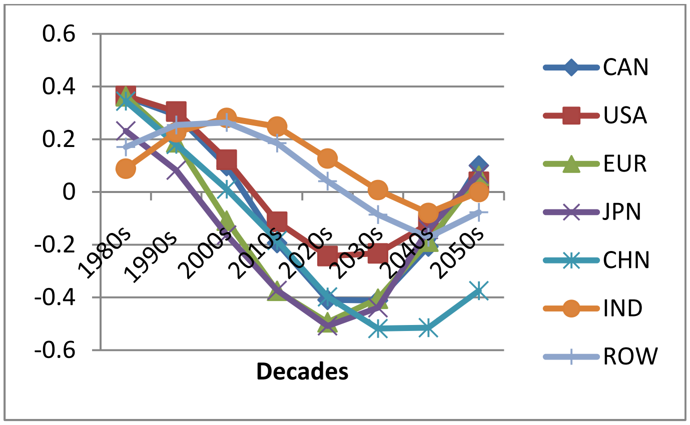


Figure 3 translates this information into impacts on the yearly *growth rate* of output per capita (in percentage points, and averaged over the relevant decade). In order to slightly widen our perspective, this information is reported since the 1980s. It is worth re-emphasizing that projecting the growth rate of output per capita due to technical progress is beyond the scope of this study, so that Figure 3 does not project overall growth rates, but show the expected impact of population ageing on growth rates, *ceteris paribus*. As is clear, the participation of baby-boomers in the job market contributed positively to the overall growth rates of GDP per capita experienced by OECD countries during the 1980s and 1990s. But retirement of baby boomers will start to shave some percentage points off the overall growth rate of GDP per capita in the U.S. and Canada during the 2010s, whereas this phenomenon has already hit Japan and Europe during the 2000s, leaving Canada caught in between Japan and Europe on one side, and the U.S. on the other side. In policy terms, one interpretation of Figure 3 is that it "mirrors" the efforts that OECD countries should pursue in, say, technical progress, if they want to offset the negative impacts of population ageing on economic growth. As for non-OECD countries, Figure 3 shows, on the one hand, that China will experience a negative impact on its growth rate in per capita output that might be stronger and more protracted than for OECD countries as the demographic shock due to its one-child policy starts to kick off during the 2020s. On the other hand, India and many countries from the rest of the world (ROW) will continue to maintain positive growth rates until the 2030s thanks to their demographic dynamics. The population advantage of India will boost its growth rate by roughly a (yearly) 0.5 percentage point differential with respect to China over the next fifty years. This might appear rather small considering the overall growth rates experienced in the recent past by both China, India, and other rapidly developing

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countries. However, the impact of population factors alone, once accumulated over a fifty year period (until the end of the 2050s), can significantly affect the overall position of India and China on the global scene (as shown in Figure 2) if other factors of growth in China do not offset this differential.

To provide a better understanding of what is driving these results, it might be useful to focus on a decomposition of output per capita into four ratios:

$$Q/POP = \underbrace{(Q/Ldem)\times(Ldem/LSup)}_{\text{Productivity}}\times\underbrace{(LSup/POPA)}_{\text{Hours per Worker}}\times\underbrace{POPA/POP}_{\text{Workers per Adult}},$$

where “per capita” means here adult population aged 15 and plus (*POP*), *POPA/POP* is the declining ratio of workers per adult described in Figure 1c, and *LSup/POPA* is the ratio of hours of work per adult worker, which remains constant throughout in our analysis.[6] Therefore, labour productivity (the first two ratios) is the main factor that might dampen or offset the impact of the fall in the ratio of workers per adult on real GDP per capita. Labour productivity is defined as the product of output per unit of effective labour (*Q/Ldem*) and the effective labour supply of each unit (or hour) of work (*Ldem/LSup*). Variation in the age composition of the adult population, as mentioned above, may affect *Ldem/LSup* (eq. 25 and 7). However, productivity gains are mainly driven by the increase in output per effective labour *Q/Ldem* (Figure 4) which will last at least until 2040 for OECD countries. This essentially reflects an increase in the capital–(effective) labour ratio (*Kdem/Ldem*) (and therefore the wage-rental price ratio) as shown in Figure 5 which is projected to increase until 2040 for OECD countries, and then subsequently fall when the (equilibrium) stock of capital eventually falls faster than (effective) labour supply. From profit maximising conditions (eq. 2 and 3) an increase in the capital–labour ratio should push up the marginal productivity of labour and therefore real wages (Figure 4), but lower the marginal productivity of capital, and therefore the real rental price of capital (Figure 6).

[6] In terms of the model described in Section 2 (eq. 25), $LSup = \sum_{gj} Pop_{gj} LS_{gj}$. The total number of hours of work supplied in the economy, *LSup*, is the sum, over all working-age generations, of hours supplied by each generation, of which a representative member supplies a constant number *LS* independently of his/her age (although the effectiveness of each hour will vary with age). Therefore, $LSup = LS\sum_{gj} Pop_{gj} = LS \times POPA$, and the ratio of hours per worker, *LSup/POPA*, remains constant at *LS*.

Figure 4. Output per effective worker (labour productivity and real wages)

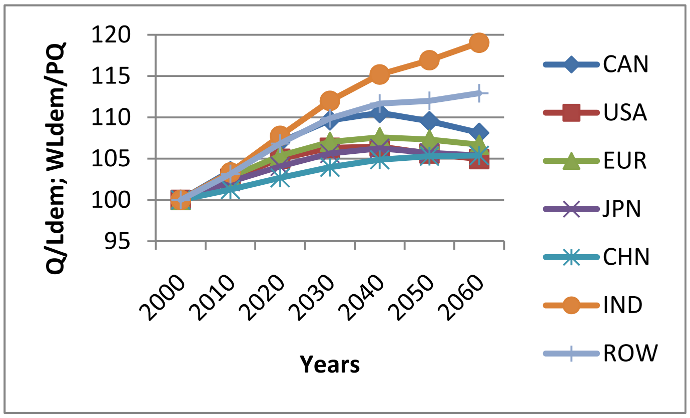


Figure 5. Capital to (effective) labour; wage-rental price ratio

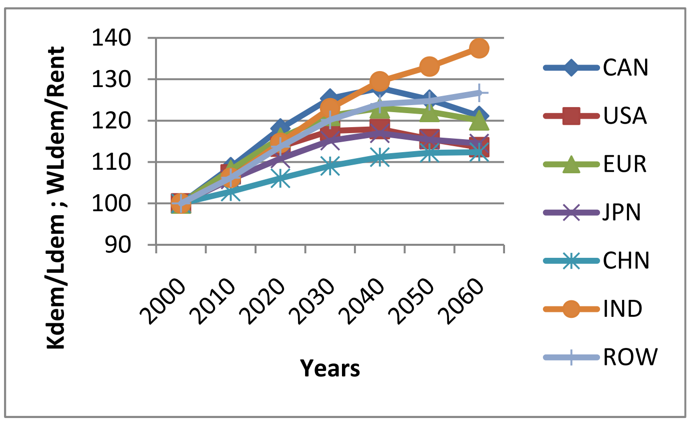
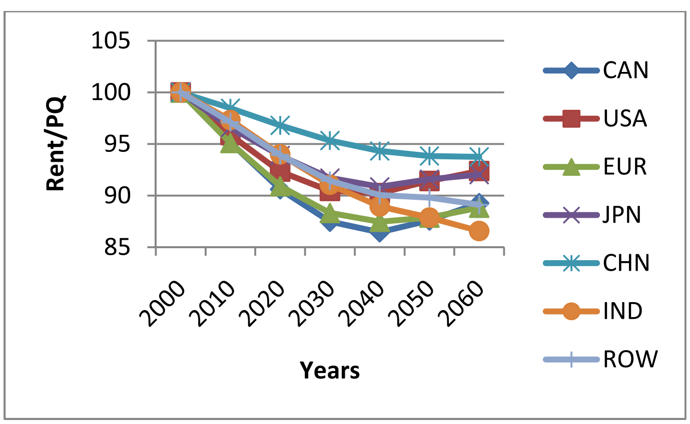


Figure 6. Productivity of capital (real rental price of capital)

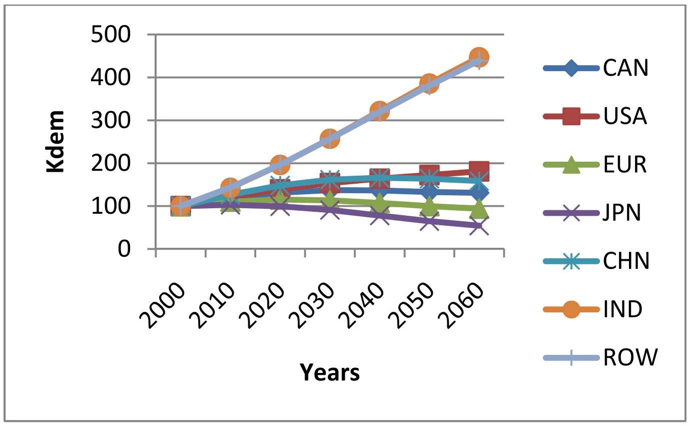


What factors drive the underlying changes in the capital-labour ratio? First, a smaller working age population eventually makes the effective labour supply, as a factor of production, scarcer than capital, potentially increasing the capital-labour ratio through a capital deepening effect. Second, the equilibrium stock of capital will itself be affected through diverse effects. With population ageing, the age composition of the population shifts towards older households and, according to the life-cycle assumptions, after having accumulated saving in anticipation of retirement, older households will eventually dissave by consuming out of wealth. In a partial analysis, a change in saving rates should change equilibrium investment and eventually the stock of capital, possibly increasing and then depressing the capital–labour ratio. However, this partial analysis does not account for several elements. Relative factor price changes since 2000 (as given in Figure 5) will typically affect the inter-temporal budget constraint of individual cohorts through income, substitution, and wealth effects.[7] One possible outcome is that the lower rental price of capital (and therefore lower return on saving) will reduce the incentive of households to save, which might eventually affect the accumulation of capital. Furthermore, the increase in contribution rates needed to finance pension plans should harm capital accumulation. Second, firms might want to use a more capital intensive technique as the relative price of labour increase. But, at the same time, a smaller labour force requires less capital investment for the future – indeed, the previously accumulated stock of capital will exceed the needs of the smaller-size cohorts of younger workers when most baby boomers will have retired by 2030. Third, in an open economy with financial capital mobility, aggregate saving does not need to be equal to aggregate investment because any differential will show up in the current account of the country as a form of net foreign investment. Therefore, excess national saving (over domestic investment) can be placed in a foreign country that needs additional saving to finance its own excess investment. Figure 7 shows the strong increase in the equilibrium stock of capital in India and the ROW. Therefore, the protracted increase in their capital-labour ratio (and wage-rental ratio) in Figure 5 is not so much due to an eventual reduction in effective labour supply but instead to a more than proportional increase in their stock of capital, which further increases the marginal productivity of labour in India and the ROW (Figure 4). In

[7] The substitution and income effects refer to the fraction of lifetime income devoted to present consumption. The wealth effect comes from change in lifetime income. The inter-temporal budget constraint of a typical cohort rotates down due to the fall in capital returns (a fall in the remuneration of saving); this should, through the substitution effect, induce more consumption in the earlier part of life and less in the future (eq. 8), while this should through the income effect lowers consumption in all periods. Higher expected real wages would push up the life-time budget constraint (a positive net wealth effect as long as the life-time increase in real wages more than offset the life-time fall in capital income), which should increase consumption in all period of the life-cycle (eq. 5).

a closed economy, countries such as India and the ROW would have difficulties accumulating so much capital, especially when a large part of their working-age population has not yet reached their prime saving years. The reason why they are able to do this is that they can borrow from other countries. This is shown in Section 3.2.

Figure 7. Capital supply



3.2 Saving rates, investment rates, and current accounts

Perfect financial capital mobility implies that the expected rate of return on government bonds will be equalised across countries, leading to a world interest rate (eq. 19), which, as shown in Figure 8 (right scale), is predicted to fall by nearly 100 basis points over the 2000 – 2030 period, and could lose another 40 basis point between 2030 and 2060.[8] This suggests an excess of global saving over global investment, especially until 2030. As discussed in Section 3.1, this reflects the higher saving rates across OECD countries as baby-boomers are saving for their retirement while physical capital is expected to become relatively more abundant and therefore investment less attractive. Between 2030 and 2060, the projected world interest rate continues to decline, but at a slower pace, illustrating two "offsetting" forces. First, baby boomers in OECD countries will eventually retire and start to consume out of wealth, leading to saving rates falling faster than investment rates.[9] Second, younger countries moving towards the

[8] Flodén (2003) reports a decline between 70 and 80 basis point from 2000 to 2030. This is also a magnitude similar to the one reported in Batini et al. (2006).
[9] Furthermore, younger generations are likely to save less because of the higher contribution rates that they will face in order to finance defined benefit pension plans (see Section 3.3).

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center of their population age distribution should experience the reverse, with saving rates progressively catching up the high (but slowing down) investment rates that were previously required in order to provide physical capital in anticipation of a progressively more abundant working age population.

Figure 8. World interest rate and consumption price index

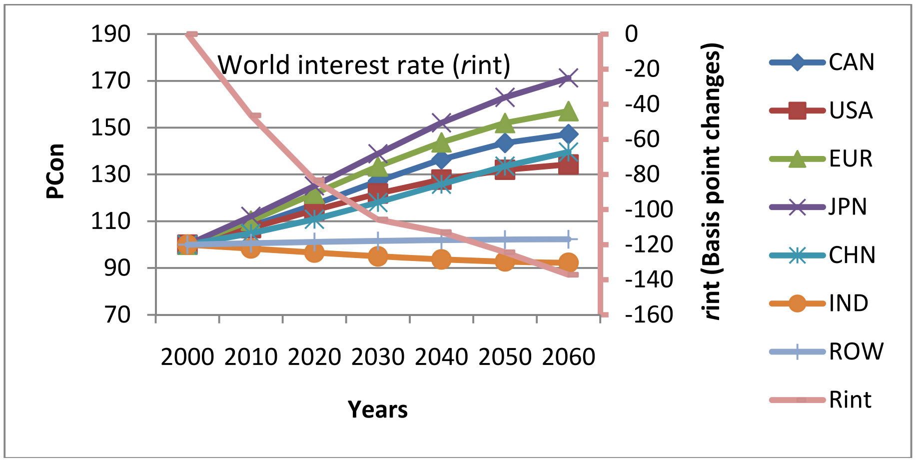

Figure 9. Current account (proportion of GDP)

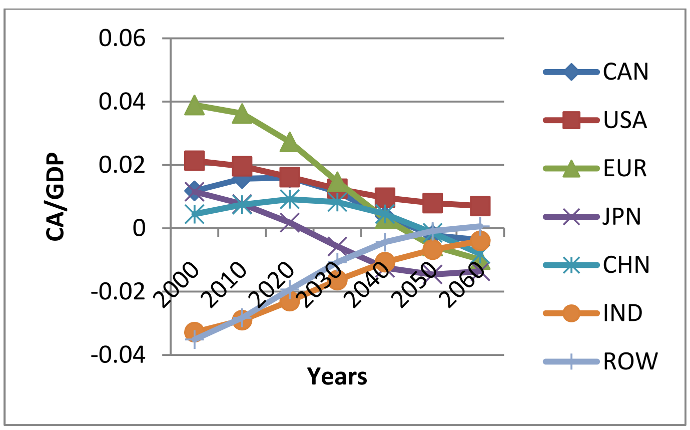

Figure 9 presents the impact of population ageing on the countries' current account (in proportion of GDP) while Table 1 decomposes the current accounts into saving rates and investment rates and provides trade balances and interest revenues on net foreign assets (in proportion of GDP). Japan, E.U., Canada and the U.S. have all larger saving than investment rates at the beginning of the 21st century and therefore have current account surpluses and capital outflows (net investment abroad) for demographic reasons. Japan is at a more advanced stage of ageing and had already low and deteriorating current account surpluses before 2000, with saving rates falling faster than investment rates. Its current account, however, should only turn into a deficit by 2030 for demographic reasons.

Table 1. Impact of population ageing on current account balances (proportion of GDP)

	2000	2010	2020	2030	2040	2050	2060
Current account/GDP							
CAN	0.012	0.016	0.016	0.011	0.004	-0.002	-0.004
USA	0.021	0.020	0.016	0.012	0.010	0.008	0.007
EUR	0.039	0.036	0.027	0.015	0.003	-0.006	-0.010
JPN	0.012	0.008	0.002	-0.006	-0.012	-0.015	-0.014
CHN	0.004	0.007	0.009	0.008	0.005	-0.001	-0.008
IND	-0.033	-0.029	-0.023	-0.016	-0.011	-0.007	-0.004
ROW	-0.035	-0.028	-0.019	-0.011	-0.004	-0.001	0.001
Trade balance/GDP							
CAN	0.018	0.013	0.004	-0.009	-0.021	-0.028	-0.027
USA	-0.025	-0.029	-0.034	-0.038	-0.041	-0.044	-0.045
EUR	-0.020	-0.036	-0.057	-0.078	-0.094	-0.103	-0.104
JPN	-0.006	-0.015	-0.024	-0.031	-0.034	-0.030	-0.020
CHN	0.019	0.016	0.011	0.004	-0.004	-0.012	-0.018
IND	0.015	0.022	0.030	0.037	0.041	0.043	0.043
ROW	0.022	0.030	0.037	0.042	0.043	0.041	0.037
Interest revenue (+) or payments (-) on foreign assets (debts) (as a proportion of GDP)							
CAN	-0.006	0.003	0.012	0.020	0.025	0.026	0.024
USA	0.047	0.049	0.050	0.051	0.051	0.052	0.052
EUR	0.059	0.073	0.084	0.093	0.097	0.098	0.094
JPN	0.018	0.023	0.025	0.025	0.022	0.015	0.006
CHN	-0.015	-0.008	-0.002	0.004	0.008	0.011	0.010
IND	-0.048	-0.051	-0.053	-0.053	-0.051	-0.049	-0.046
ROW	-0.058	-0.058	-0.057	-0.052	-0.047	-0.042	-0.036
National saving/GDP							
CAN	0.085	0.074	0.057	0.036	0.018	0.010	0.009
USA	0.097	0.085	0.068	0.052	0.040	0.033	0.029
EUR	0.083	0.069	0.048	0.023	0.004	-0.007	-0.011
JPN	0.040	0.025	0.005	-0.016	-0.031	-0.036	-0.034
CHN	0.038	0.032	0.026	0.018	0.010	0.001	-0.007
IND	0.147	0.131	0.113	0.096	0.081	0.068	0.056
ROW	0.148	0.136	0.120	0.104	0.089	0.073	0.059
Domestic investment/GDP							
CAN	0.073	0.059	0.041	0.024	0.014	0.012	0.013
USA	0.075	0.065	0.052	0.039	0.030	0.025	0.022
EUR	0.044	0.033	0.020	0.009	0.001	-0.002	-0.001
JPN	0.028	0.017	0.004	-0.010	-0.019	-0.021	-0.020
CHN	0.033	0.024	0.017	0.010	0.006	0.003	0.001
IND	0.180	0.160	0.136	0.112	0.092	0.075	0.060
ROW	0.183	0.164	0.140	0.115	0.093	0.074	0.058

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Cooper (2008) claims that demography is a factor that has received too little attention when trying to explain the current account of several countries, including the current account of the U.S. whose demographics "differ markedly from those of other high-income countries in that birth rates have not fallen nearly so far and immigration, concentrated in young adults, can be expected to continue on a significant scale". This, according to him, is one important factor driving the observed large current account deficit of the U.S. economy. According to our simulations, however, demography suggests that the U.S. should now have a current account surplus (when factors other than demography are controlled), albeit progressively shrinking with the increase in its dependency ratio since the turn of the century. Two reasons explain the difference between Cooper and our analysis. First, while the U.S. is undeniably young with respect to most OECD countries, it is, however, clearly more advanced in its demographic transition than India and other parts of the world, and this should naturally lead to U.S. current account surpluses in a truly global model with perfect financial capital mobility.[10] Second, Cooper eventually rationalises the U.S. deficits by observing that investments with high yields and low risks have driven the world saving into the U.S. economy. He therefore eventually explains the observed U.S. deficits with other factors than demography, which ultimately shows that demography might not, after all, be a dominant explanatory factor of these deficits.

China's relatively younger population with respect to OECD countries might typically lead to current account deficits for demographic reasons. However, as shown in Figure 9, our simulations show that China should have current account surpluses for demographic reasons (which will eventually deteriorate when the pressure on its OADR starts to kick off during the 2020s and 2030s). This can only be understood in a general equilibrium setting, by considering that other countries such as India and other parts of the world are also expected to remain much younger than China. Given the Chinese one-child policy, aggregate saving is large in anticipation of retirement but aggregate investment falls short of saving as the currently "middle-age" working population outnumbers younger generations, which reduces both the need for strong capital accumulation (for future cohorts of workers) and the incentive for domestic investment. Excess national saving should therefore be invested outside China

[10] Flodén (2003) in a model including the U.S., most European countries, and Japan, predicts U.S. current account deficits as the U.S. have a younger population than European countries or Japan. Krueger and Ludwig (2007) also generate the same type of qualitative results. This means that adding younger and emergent regions, like India and the ROW, in a global model with perfect capital mobility, inverses the prediction for the U.S. current account.

through net capital outflows.[11] Incidentally, the accumulation of huge foreign reserves by the Central Bank of China might well be a symptom of this demographic challenge, intertwined with Chinese controls of private capital outflows. As recently stated by Cooper (2006), "China's central bank, the Peoples Bank of China, can be thought of investing abroad on behalf of the public, and against the day in which the currency will be fully convertible (a stated Chinese objective) and net capital outflow may be large". According to this view, private Chinese capital outflows would most likely relay the current official capital outflows in case of full capital control liberalisation, therefore reducing the level of Chinese official reserves, but leaving little credit to the thesis that China could indeed substitute its relatively low interest-bearing official foreign reserve position with more profitable private domestic investment.

India and other parts of the ROW are expected to remain much younger than OECD countries or China. As young workers in India and other regions of the world are expected to continue to enter the labour force they will need capital to work with, implying strong capital accumulation (Figure 7) which, unlike China, transforms these regions into an attractive pole for foreign capital flows.[12] At the start of the 21st century, India and the ROW have lower saving than investment rates and therefore have current account deficits for demographic reasons and associated foreign capital inflows as foreigners invest in these countries. The current account deficits of these regions should, however, slowly shrink through the 21st century as saving and therefore foreign investments, originating from OECD countries, progressively decline as a response to the increase in their own OADR.

3.3 Government and pension plans

As seen in Figure 4, higher labour productivity leads to higher real wage costs for firms (expressed in terms of the producer price index *PQ*). However, wage taxes and pension contributions must be factored in to gauge the impact of population ageing on households' net labour income. Figure 10 reports a wage tax index that reflects the percentage increase in tax rates required to keep government spending on the path assumed in the model. As can be seen, there is actually room for tax cuts in the next decade or so for most countries. However, after 2020 all OECD countries and China will have to raise taxes to meet mounting fiscal pressures. By

[11] Fehr et al. (2005) find that adding China into the framework of their earlier paper (Fehr et al., 2004), might dramatically alter the simulated results because its saving behaviour and fiscal policy are very different from the rest of the world. They argue that China could become the world's saver over the next decades.

[12] Although China attracts more FDI than India, we stress that demographic factors *per se* should favour FDI flows to India instead of China.

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2060 required additional tax rate increases tend to shrink to zero (so that tax rates in 2060 are roughly equal to those observed in 2050), except China's rates that continue to increase. Favourable demographic dynamics in India and the ROW do not require wage tax increases for most of the period.

Figure 10. Wage tax index (percent changes)

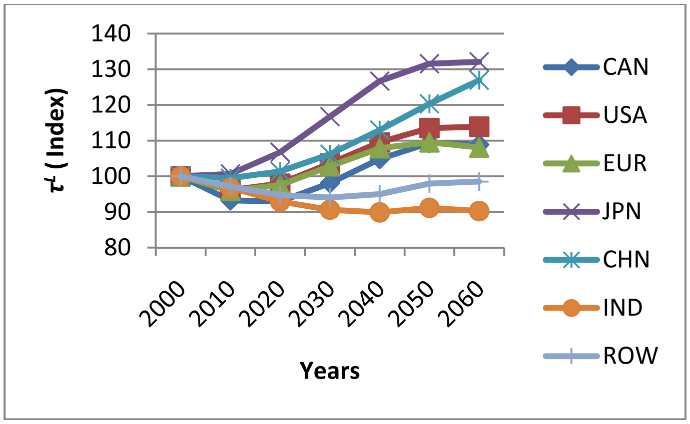
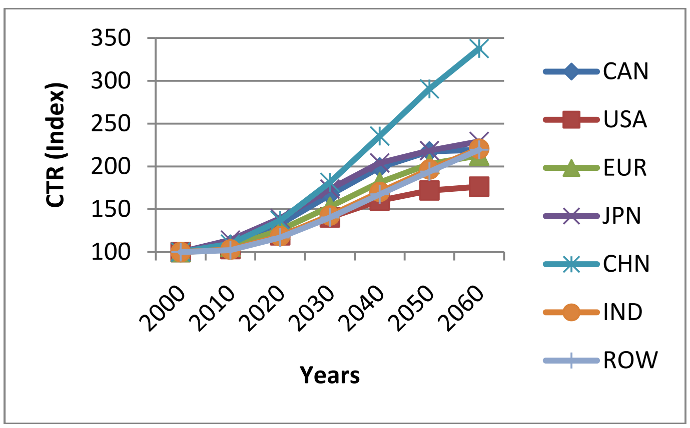


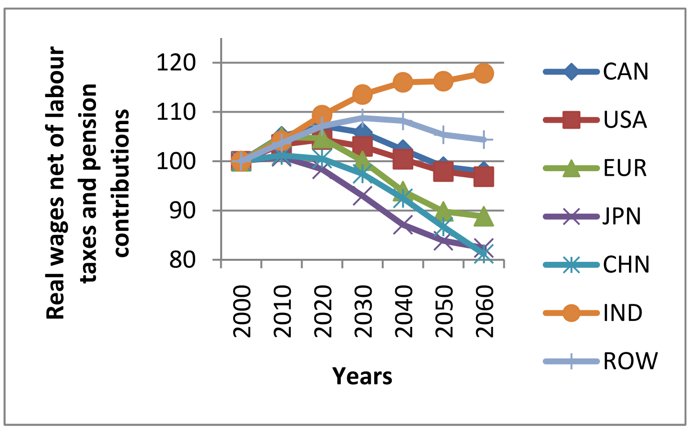
Figure 11. Contribution rate index (percent changes)



The fall in the ratio of workers per adult reduces the basis on which the pension contribution rate is applied, while pension benefit obligations increase with the rise in the OADR. This generates mounting pressures for the defined-benefit PAYG pension systems assumed in the model and requires an endogenous increase in contribution rates as shown by the index in Figure 11 (% increase in contribution rates). Contribution rates should start rising by 2010 in all regions of the world, although at different paces. Among OECD countries, Japan, Europe and Canada will experiment the largest "front-loaded" increases, while the impact on U.S. contribution rates will be much more moderate. Pressures will also mount in non-OECD countries during the 21st century, but in a "back-loaded" fashion. Although it can be argued that there is no official PAYG pension schemes in China (and in some other non-OECD countries), such an arrangement is, however, implicitly organised and expected between parents and children, and the burden of the one-child policy of China on this intergenerational link is again apparent in Figure 11 especially after 2030.

Finally, Figure 12 illustrates the net labour income of households. Wage gains due to capital deepening and labour productivity enhancement (Figure 4) are more than offset by losses due to taxes and contributions to pensions. Net labour incomes across most OECD countries will start to decline around 2010 for Europe and Japan and around 2020 for Canada and the USA, with a marked decrease in Japan, Europe, and China – by 2060, Japan's and China's net labour incomes will be about 18% below their level in 2000. Again, India and China follow diametrically opposite paths on the basis of divergent population dynamics.

Figure 12. Net labour income



3.4 Real consumption per capita and welfare

The economic welfare of a household ultimately depends on real consumption not on income, and although household labour income falls at retirement, consumption may remain relatively high. Therefore, aging-induced declines in output per capita as illustrated in Figure 2 for OECD countries are not necessarily indicative of a corresponding decline in global welfare. Figures 13 and 14 illustrate the level and the (annualised) decade on decade consumption per capita growth rate for all regions in the world. At the aggregate, the level of real consumption per capita will actually continue to increase until about 2020 and be negatively affected in the 2020s and 2030s. Japan will be affected more deeply and sooner, eventually followed by China, while India and the ROW will continue to observe a strong increase in real consumption per capita during the first part of the 21st century. Figure 14 shows that the growth rate in aggregate consumption per capita will turn negative during the 2020s for U.S., Canada, and Europe, by a modest average yearly fall of about 0.1 percentage point.

Figure 13. Consumption per capita

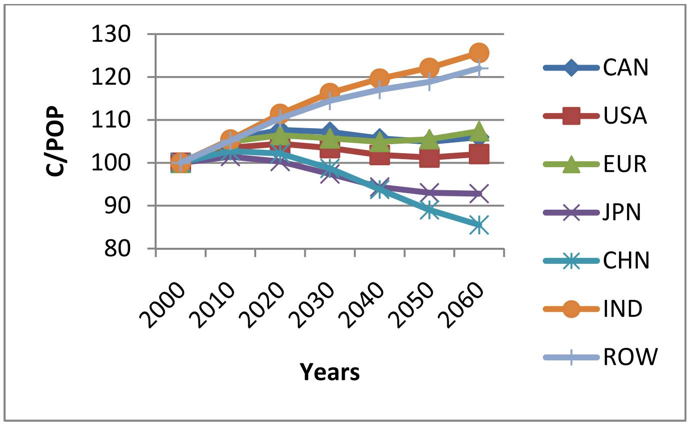
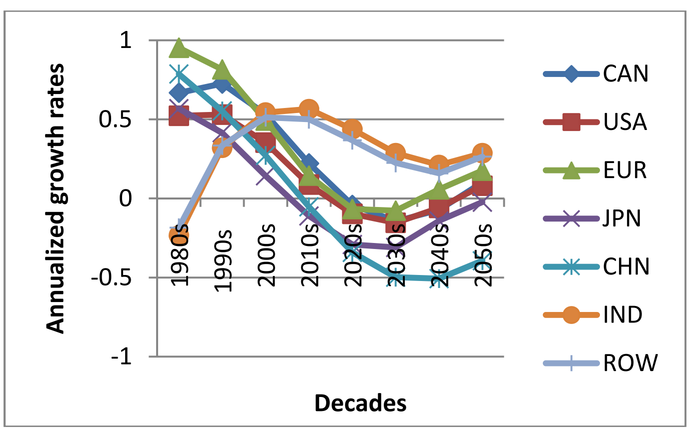
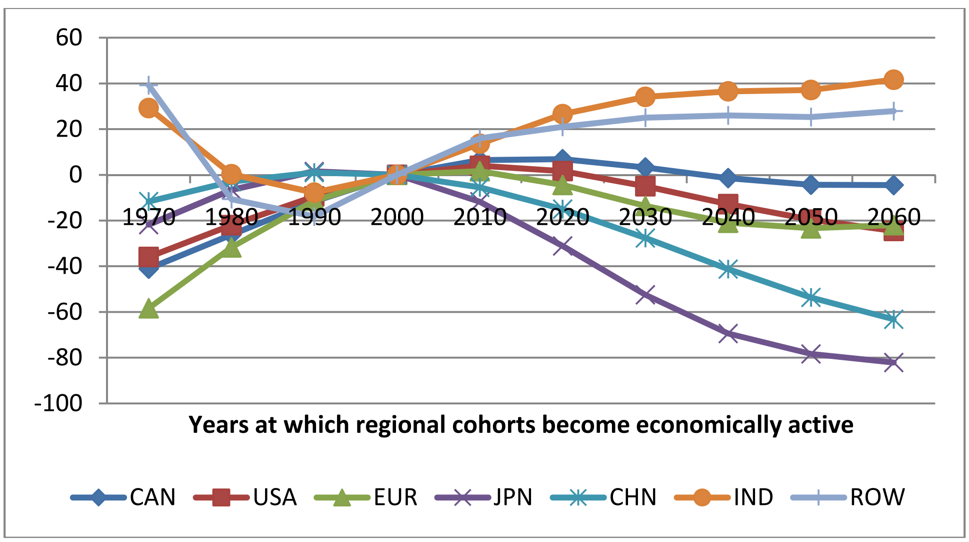


Figure 14. Growth rate in real consumption per capita (% point, decade's yearly average)



On the one hand, this subdued effect shows that population ageing concerns in some OECD countries might be, to a certain extent, biased by an excessive focus on real output (Figures 2 and 3) instead of real consumption. On the other hand, focusing on real aggregate consumption might also be misleading because economic welfare is cohort specific. However, we can compute, for each cohort, an index of economic welfare given by the discounted value of future consumption over life time. Figure 15 presents this welfare index for cohorts in all regions, in percentage deviation from the welfare index reached by the cohort economically born in 2000. In general the 2000 cohort does relatively well with respect to other cohorts as it takes advantage of high real labour incomes in their early working life while tax pressures and contribution rates are still not felt and returns to capital remains high (although declining). Although future cohorts will typically experiment a decline in their economic welfare, the magnitude of this decline is country-specific – Canada will be able to sustain a high level of welfare for future cohorts in contrast to Japan while India will see an increase in the welfare of future cohorts.

Figure 15. Welfare index of individual cohorts



The economic welfare of future cohorts in North America and Europe never falls below the welfare index for the generation economically born in 1980. These results shed a caveat on the often quite pessimistic views of the economic impact of population ageing. One factor explaining these gloomy views is that, as said above, too much attention is focused on real output per capita and its simple accounting decomposition. Another reason is that ageing is often analysed in a closed economy context. Once we take into account the globalisation of the economy, older OECD countries will benefit from two types of gain from trade. The first is the typical intertemporal gain from trade according to which countries do better running unbalanced current accounts in all periods than to be forced in autarchy – intertemporal trade makes possible to choose an optimal production bundle of consumption and investment goods, pushing economies on their respective highest feasible budget line at world price (interest rates), while at the same time generating a smoother time profile of consumption – with the usual caveat that in an OLG model the gain from trade may not be shared by all generations. Older than average countries will also benefit from a long-lasting terms of trade improvement as shown in Table 2 (TOT), which gives the ratio of the (world) price of a country's exports over an index of trade-weighted foreign producer prices. As well, countries that are ageing faster (Japan, E.U.) will typically experience a negative supply shock and a strong increase in their producer price index (*PQ*) while their consumer price index (*PCon*) will increase less than proportionally as consumers also purchase goods from younger than average countries whose producer price index fall in relative terms. This should, *ceteris paribus*, raise real income and, potentially, real consumption.[13] As shown by Obstfeld (1982), in intertemporal models, the impact of a real income increase on consumption versus saving will depend on the duration of the shock. Saving and therefore the current account will act as a shock absorber to temporary changes in order to smooth consumption. However, in response to a permanent shock consumption would adjust instead of saving, contrarily to the Laursen and Metzler (1950) hypothesis. In a life-cycle model a long-lasting improvement in the terms of trade should prop up real consumption instead of saving (and the current account), reinforcing the gain from trade. Most of the multi-country OLG literature, by focusing on a world with a single homogenous good, cannot capture this effect.[14] Our Armington specification that products are differentiated by country of origin marks a departure from the assumption of perfect substitution that underlies traditional trade theory and changes fundamentally the properties of

[13] Real consumption is defined as real disposable income minus private saving, $\frac{C}{Pop} = \frac{PQ}{PCon} \times \frac{Q}{Pop} - \frac{Saving}{Pop}$, where the basis for calculating real disposable income when taxes are ignored is total value of real production, Q, while the nominal value of this income is (PQ) x Q where PQ is the price of the domestically produced good. To get the real purchasing power of this income we divide by the consumer price index *PCon* defined as an average of the price of the domestically produced good and the foreign produced goods with weights given by the average propensity to spend on each good. An improvement in the terms of trade, or more precisely, a relative increase in *PQ/PCon*, raises the real income.

[14] In these models all countries produce the same perfectly substitutable good so that, although the investment-saving balance will lead to current account deficits or surpluses, the only transaction with other countries takes place in the form of physical capital investment. Other traded goods flowing between countries are not modeled.

a trade model.[15] Assuming that imports and domestic goods are imperfect substitutes in demand has the implication that each country or firm is the sole supplier of its products, leading to some market power – each country faces a downward sloping foreign demand curve for its products (i.e., its price-elasticity is not infinite). Compared to the Heckscher-Ohlin model where small shocks can cause production of goods in a country to appear or disappear through comparative advantage adjustment, here, quantity adjustment by producers to diverse shocks is somewhat muted by the lack of direct competition between regional producers, while terms of trade effects are greater as larger price changes are necessary to clear markets.

Table 2. Terms of trade (TOT) and ratio PQ/PCon (Year 2000 = 100)

	TOT							PQ/PCon					
	2010	**2020**	**2030**	**2040**	**2050**	**2060**		**2010**	**2020**	**2030**	**2040**	**2050**	**2060**
CAN	102.1	105.3	109.5	113.9	117.3	118.9	**CAN**	100.4	101.1	101.9	102.9	103.6	103.9
USA	103.1	106.5	109.6	111.9	113.3	113.9	**USA**	100.3	100.5	100.8	101.0	101.1	101.1
EUR	109.1	119.6	130.5	140.4	148.6	153.7	**EUR**	101.1	102.5	104.0	105.3	106.5	107.2
JPN	109.3	119.1	129.6	139.9	148.3	155.1	**JPN**	100.8	101.6	102.5	103.5	104.3	104.9
CHN	101.4	104.2	108.5	114.0	120.0	125.0	**CHN**	100.1	100.3	100.7	101.2	101.7	102.2
IND	95.1	90.6	86.7	83.8	81.8	80.6	**IND**	99.7	99.5	99.3	99.1	99.0	98.9
ROW	91.7	84.0	77.4	72.3	68.6	66.4	**ROW**	99.4	98.9	98.4	98.1	97.9	97.7

Figure 13 illustrates indirectly that older and more "open" countries might benefit from consuming a larger share of those goods produced by younger than average countries and whose prices do fall relatively. Canada is ageing faster but is a more open economy than the U.S. And while in terms of GDP per capita the U.S. is doing better, Canada is better able to maintain per capita consumption which does not fall below its 2010 level for most of the (first half of the) 21st century, whereas the U.S. will be below its 2010 level starting 2030, and this, for most of the first half of the century. Japan is not a very open economy and therefore cannot take advantage of the terms of trade effect. India gets a strong boost in consumption per capita despite terms of trade deterioration, as they also benefit from capital accumulation, as shown in Figure 5, thanks to foreign capital flows (Figure 9).[16] Therefore, India can achieve a much higher rate of growth and this strongly dominates the negative terms of trade effect. The case of China is

[15] See Lloyd and Zhang (2006), Zhang (2006), and Valenzuela et al. (2008).

[16] By importing foreign goods, India and the ROW "import" the ageing problem of OECD countries through a terms of trade deterioration which requires, *ceteris paribus*, supplying more of their goods on world markets.

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again striking, especially when observing the diametrically opposite directions taken by China and India's real consumption paths from 2000 on (Figure 13). The timing of the one-child policy makes the Chinese economy both a (still) relatively young country with respect to OECD countries but an old one with respect to India and other parts of the world. Being caught between younger and older countries, the Chinese economy does not, initially, benefit from terms of trade improvements unlike older, more open, OECD countries (Table 2), nor does it strongly benefit from capital accumulation (Figure 5) through net foreign capital inflows. Indeed, as shown in Figure 9, unlike India, China develops current account surpluses for demographic reasons and therefore net capital outflows. This implies that in the Asian "catching up" process towards OECD countries, Chinese, more so than Indians, must maintain a higher growth through technical progress if they want to offset the negative economic impact of their specific population demographics.

3.5 Sensitivity analysis on the Armington elasticity of substitution

The standard GTAP Armington elasticities used here are based on econometric estimates by Hertel et al. (2007). In this section we provide a sensitivity analysis on this parameter. The Armington elasticity of substitution between goods of the seven regions of the model is set in the benchmark analysis at 2.5. We now vary the value of this parameter by about ±30% (+1.8; +3.2) and show the impact of this on real consumption and real GDP per capita, and on trade balances for all countries. Intuitively, when the elasticity parameter increases, goods from different geographical origin becomes more substitutable and, for a given change in the relative regional producer prices (*PQ*), consumers will tend to buy more of the product that is cheaper (see eq. 9), that is, consumers will tend to buy more from a single geographical source. In contrast, a low elasticity of substitution makes these goods less substitutable and forces a more regionally-diversified basket of products.

Given that faster ageing countries experience a relatively stronger increase in their domestic producer price, an increase in the Armington elasticity should tend to deteriorate the trade balance of older OECD countries and improve the trade balance of younger countries such as India and the ROW. As shown in Table 3, although this might have a negative effect on the output per capita of older OECD countries as their net imports increase (which deteriorates their trade balance faster than in the benchmark), this will also have a positive effect on their real aggregate consumption because they buy more from younger non-OECD countries, which limits the upward pressure on their consumption price index. This, of course, also sustains the real GDP of non-OECD countries and props up their own aggregate consumption per capita as shown in Table 3.[17] Lower elasticities generate the opposite results: consumers from all countries react less to a given relative change in regional producer prices, and real consumption per capita fall (relative to the benchmark) – the opportunity for OECD countries to alleviate their ageing problem through trade is reduced because goods from different geographical origins are now perceived as mostly complements.

4. Concluding remarks and extensions

This paper develops an overlapping-generations general equilibrium model to gauge the long-term impact of population ageing in a context of globalisation of trade and capital flows among seven regions of the world. With respect to closed-economy models that are still routinely used to analyse population ageing, assuming perfect capital mobility is the opposite end of the spectrum. Actual economies, especially non-OECD economies, are somewhat in the middle of these poles but globalisation pushes countries towards greater openness and capital mobility. Furthermore, the assumption of perfect capital mobility provides, in an ageing world, an upper bound to the prospective gains from more liberalized trade and capital flows across regions.

It is often argued that population ageing *per se* will have large economic and fiscal impacts and the paper gauges these impacts when economic interdependences between countries are taken into account. However, the paper does not offer predictions or forecasts of what economies will look like in the next 50 years. For example, the paper illustrates that the economic impact of ageing will be much more pronounced in China than in India. Of course if differences in technical progress across regions were introduced in a plausible way the results could be very different. The challenge of doing this in a global setting is that technical progress projections for several regions are much less reliable than demographic projections. However, this remains an important next step as it would show that other factors might be more important than demographics when forecasting the economic paths of economies for the 21st century.

[17] As the elasticity of substitution is increased to very high values, paths such as these in Table 3b, quickly converge asymptotically. This reflects an upper bound to the feasibility to substitute goods across countries. As argued by Zhang (2006), the effects of an Armington structure go beyond those of the choice of substitution parameters and increase monopoly power of trading countries for all levels of elasticities of substitution when compared to a non-Armington trade structure. This cannot be removed by changing the elasticities of substitution in any way.

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Table 3. Sensitivity analysis

(a) Benchmark

	2000	2010	2020	2030	2040	2050	2060
			Q/POP (Benchmark)				
CAN	100.0	101.0	99.0	95.0	91.1	89.2	90.1
USA	100.0	101.2	100.1	97.7	95.4	94.2	94.6
EUR	100.0	98.9	95.2	90.5	86.8	85.2	85.7
JPN	100.0	98.4	94.7	89.9	85.9	84.7	85.3
CHN	100.0	100.1	98.3	94.4	89.5	84.9	81.7
IND	100.0	102.8	105.4	106.7	106.8	105.9	105.9
ROW	100.0	102.6	104.5	105.0	104.1	102.3	101.5
			C/POP (Benchmark)				
CAN	100.0	105.3	107.7	107.2	105.7	104.9	106.0
USA	100.0	103.5	104.4	103.4	101.8	101.2	102.0
EUR	100.0	104.9	106.4	105.7	104.9	105.5	107.4
JPN	100.0	101.4	100.3	97.4	94.4	93.0	92.8
CHN	100.0	102.7	102.2	98.7	93.8	89.0	85.5
IND	100.0	105.4	111.4	116.3	119.6	122.1	125.6
ROW	100.0	105.1	110.4	114.4	117.0	118.9	122.0
			Trade balance (as a proportion of GDP) (Benchmark)				
CAN	0.018	0.013	0.004	-0.009	-0.021	-0.028	-0.027
USA	-0.025	-0.029	-0.034	-0.038	-0.041	-0.044	-0.045
EUR	-0.020	-0.036	-0.057	-0.078	-0.094	-0.103	-0.104
JPN	-0.006	-0.015	-0.024	-0.031	-0.034	-0.030	-0.020
CHN	0.019	0.016	0.011	0.004	-0.004	-0.012	-0.018
IND	0.015	0.022	0.030	0.037	0.041	0.043	0.043
ROW	0.022	0.030	0.037	0.042	0.043	0.041	0.037

(b) Higher Armington

	2000	2010	2020	2030	2040	2050	2060
			Q/POP (Higher Armington, 3.2)				
CAN	99.69	100.52	98.39	94.18	90.19	88.31	89.28
USA	99.67	100.84	99.64	97.19	94.92	93.78	94.19
EUR	99.10	97.86	94.05	89.29	85.62	84.00	84.57
JPN	99.29	97.55	93.80	88.93	84.94	83.69	84.25
CHN	100.20	100.24	98.32	94.32	89.34	84.67	81.47
IND	101.64	104.66	107.35	108.73	108.77	107.82	107.72
ROW	101.72	104.58	106.63	107.12	106.21	104.38	103.58
			C/POP (Higher Armington, 3.2)				
CAN	100.14	105.82	108.70	108.85	107.76	107.08	107.82
USA	100.20	103.90	105.03	104.20	102.69	102.06	102.73
EUR	99.46	105.08	107.60	107.87	107.68	108.35	109.44
JPN	100.87	103.05	102.67	100.44	97.91	96.64	96.07
CHN	99.88	102.77	102.57	99.59	95.26	91.00	87.72
IND	100.39	105.83	111.81	116.76	120.25	123.03	126.79
ROW	101.55	107.09	112.83	117.45	120.68	123.26	127.18
			Trade balance (as a proportion of GDP) (Higher Armington, 3.2)				
CAN	0.018	0.010	-0.003	-0.021	-0.039	-0.049	-0.047
USA	-0.028	-0.034	-0.040	-0.046	-0.051	-0.053	-0.053
EUR	-0.026	-0.048	-0.077	-0.106	-0.129	-0.142	-0.139
JPN	-0.015	-0.030	-0.044	-0.058	-0.067	-0.064	-0.053
CHN	0.022	0.018	0.012	0.003	-0.009	-0.021	-0.028
IND	0.019	0.028	0.038	0.046	0.050	0.052	0.051
ROW	0.026	0.035	0.044	0.049	0.050	0.046	0.041

Table 3 *continued*

(c) Lower Armington

	2000	2010	2020	2030	2040	2050	2060
Q/POP (Lower Armington, 1.8)							
CAN	100.37	101.56	99.83	96.01	92.25	90.41	91.25
USA	100.43	101.72	100.63	98.22	95.95	94.78	95.12
EUR	101.48	100.57	96.97	92.30	88.64	86.99	87.47
JPN	101.01	99.52	95.95	91.22	87.35	86.21	86.86
CHN	99.59	99.76	98.01	94.22	89.45	84.95	81.80
IND	97.54	100.02	102.31	103.50	103.52	102.70	102.73
ROW	96.96	99.15	100.70	100.88	99.84	97.97	97.06
C/POP (Lower Armington, 1.8)							
CAN	99.73	104.56	106.16	104.90	102.71	101.71	103.05
USA	99.71	103.01	103.64	102.38	100.66	100.05	100.97
EUR	101.03	104.93	104.95	102.72	100.79	100.87	103.19
JPN	98.95	99.41	97.30	93.44	89.65	87.93	87.75
CHN	99.94	102.42	101.41	97.24	91.53	86.05	82.12
IND	99.35	104.73	110.61	115.32	118.36	120.49	123.55
ROW	97.09	101.41	105.72	108.65	109.94	110.37	111.96
Trade balance (as a proportion of GDP) (Lower Armington, 1.8)							
CAN	0.018	0.016	0.012	0.007	0.001	-0.002	-0.001
USA	-0.021	-0.023	-0.026	-0.028	-0.030	-0.032	-0.033
EUR	-0.010	-0.019	-0.030	-0.040	-0.047	-0.051	-0.052
JPN	0.005	0.003	0.002	0.002	0.006	0.014	0.025
CHN	0.015	0.012	0.010	0.006	0.002	-0.002	-0.004
IND	0.009	0.014	0.019	0.023	0.026	0.027	0.027
ROW	0.016	0.021	0.026	0.029	0.030	0.029	0.028

One of the key features of the model is to superimpose an international trade component on an OLG-GE model. We showed the special role that the Armington trade structure might have on our results. However, several extensions should be considered that would make the link between international trade, OLG, and population ageing even more relevant. First, we plan to increase the number of goods produced in each country. If national economies are characterised by one-sector neoclassical production functions with diminishing returns to capital, a high level of saving in a country should create an incentive to export capital. However, that virtually all of what is saved in a country is also invested in that country has been initially interpreted by Feldstein and Horioka (1980) as evidence of segmented capital markets or low capital mobility – a puzzle in a world of ongoing liberalisation in capital markets that has led to an extended literature. Nonetheless, the incentive to export saving may disappear, even in a world of free capital market, in the presence of multiple sectors with differing capital intensities. In this case, national saving can be absorbed domestically, without a decline in its marginal product, through a shift in the sectoral composition of national production towards capital intensive goods – a variation on the Rybczynski effect as suggested by Debaere and Demiroglu (2008). Second, we plan to introduce different skills levels of workers in the model. Indeed, globalisation and the rise of a huge, but relatively unskilled labour force in China

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and India may have significant implications for incomes in the "North". For example, based on the Heckscher-Ohlin model and the factor price equalization theorem, it has often been argued that trade with China may be one of the factors contributing to the tendency for a distributional shift in rich countries against unskilled workers in favour of the higher skilled, even in the context of immobility of labour across countries. While much of the initial research suggested that trade has played only a small role in raising inequality – as skill-using and unskilled-labour-saving technological change would have the same effect – more recent work focusing on the role of imported intermediate inputs has generated larger estimates of the negative impact of trade on unskilled wages in rich countries (Feenstra, 2000, and Feenstra and Hanson, 2004). Introducing different skills levels in the model would permit to shed a new light on this debate.

Appendix: Equations, variables and parameters, and calibration

A.1 Production sector

(1) $$Q_{j,t} = A_{j,t}\left(Kdem_{j,t}\right)^{\alpha_j}\left(Ldem_{j,t}\right)^{1-\alpha_j}, \quad 0<\alpha_j<1, \quad j \in J = \{\text{CAN}, \text{USA}, ...\}$$

(2) $$\text{Re}nt_{j,t}/PQ_{j,t} = \alpha_j A_{j,t}\left(Kdem_{j,t}/Ldem_{j,t}\right)^{\alpha_j - 1}$$

(3) $$WLdem_{j,t}/PQ_{j,t} = (1-\alpha_j)A_{j,t}\left(Kdem_{j,t}/Ldem_{j,t}\right)^{\alpha_j}$$

A.2 Household behaviour and pension plans

(4) $$U_{j,t} = (1/(1-\gamma_j))\sum_{k=0}^{6}\left\{\left(1/(1+\psi_j)\right)^{k+1}\left((Con_{j,t+k,g+k})^{1-\gamma_j}\right)\right\}, \qquad 0<\gamma_j<1$$

(5) $$\underbrace{Lend_{j,t+1,gg+1} - Lend_{j,t,gg}}_{\text{Asset Accumulation (during period } t)} = \underbrace{\left(1-\tau^L_{j,t} - CTR_{j,t}\right)Y^L_{j,t,gg}}_{\text{Net Labour Income}} + \underbrace{\left(1-\tau^K_{j,t}\right)ret_{j,t}Lend_{j,t,gg}}_{\text{Net Capital Income}}$$

$$+ \underbrace{Pens_{j,t,gg}}_{\text{Pension Benefit}} - \underbrace{\left(1+\tau^C_{j,t}\right)PCon_{j,t}Con_{j,t,gg}}_{\text{Net Consumption Spending}},$$

$$gg \in GG = \{g, g+1, ..., g+6\} = \{g+k; k=0,...,6\}$$

(6) $$Y^L_{j,t,gg} = WLdem_{j,t}EP_{j,gg}LS_{j,gg}$$

(7) $$EP_{j,gg} = \omega + (\xi)(gg) - (\phi)(gg)^2, \quad \omega,\ \xi,\ \phi \geq 0$$

(8) $$Con_{j,t+1,gg+1}/Con_{j,t,gg} =$$

$$\left[\left(\left(1+\left(1-\tau^K_{j,t+1}\right)ret_{j,t+1}\right)/(1+\psi_j)\right)\times\left(PCon_{j,t}(1+\tau^C_{j,t})/PCon_{j,t+1}(1+\tau^C_{j,t+1})\right)\right]^{\frac{1}{\gamma_j}}$$

(9) $$ConI_{i,j,t,gg} = ALCI_{i,j}^{\ SigC_j}\left(PCon_{j,t}/PQ_{i,t}\right)^{SigC_j} Con_{j,t,gg},$$
$$i \in J = \{\text{CAN}, \text{USA}, ...\}$$

(10) $$PCon_{j,t} = \left[\sum_i ALCI_{i,j}^{\ SigC_j}\left(PQ_{i,t}\right)^{(1-SigC_j)}\right]^{\frac{1}{1-SigC_j}}$$

(11) $$Pens_{j,t+5,g+5} = Pens_{j,t+6,g+6} = PensR_{j,t,g}\left((1/5)\sum\nolimits_{k=0}^{4} Y^L_{j,t+k,g+k}\right)$$

(12) $$\sum_{gm} Pop_{j,t,gm} Pens_{j,t,gm} = CTR_{j,t}\sum_{gj} Pop_{j,t,gj} Y^L_{j,t,gj},$$
$$gj \in GJ = \{g+k; k = 0,...,4)\}; \quad gm \in GM = \{g+5, g+6\}$$

A.3 Investment and asset returns

(13) $$InvI_{i,j,t} = ALII_{i,j}^{\ SigI_j}\left(PInv_{j,t}/PQ_{i,t}\right)^{SigI_j} Inv_{j,t}$$

(14) $$PInv_{j,t} = \left[\sum_i ALII_{i,j}^{\ SigI_j}\left(PQ_{i,t}\right)^{(1-SigI_j)}\right]^{\frac{1}{1-SigI_j}}$$

(15) $$Kstock_{j,t+1} = Inv_{j,t} + (1-\delta_j)Kstock_{j,t}$$

(16) $$ret_{j,t} =$$
$$\underbrace{\mathrm{Re}nt_{j,t}/PInv_{j,t-1}}_{\substack{\text{Rental Price of Capital} \\ \text{(in terms of the investment good)}}} + \underbrace{(PInv_{j,t} - PInv_{j,t-1})/PInv_{j,t-1}}_{\text{Expected Capital Gains}} - \underbrace{\delta_j PInv_{j,t}/PInv_{j,t-1}}_{\text{Depreciation Cost}}$$

(17) $$\underbrace{ri_{j,t-1}}_{\substack{\text{Promised Rate of Return} \\ \text{on Government Bonds}}} + \underbrace{(PGov_{j,t} - PGov_{j,t-1})/PGov_{j,t-1}}_{\text{Expected Capital Gains on Bonds}}$$

(18) $$ret_{j,t} = ri_{j,t-1} + (PGov_{j,t} - PGov_{j,t-1})/PGov_{j,t-1}$$

(19) $$r\,\text{int}_t = ri_{j,t-1} + (PGov_{j,t} - PGov_{j,t-1})/PGov_{j,t-1}, \ \forall\ j$$

(20) $$r\,\text{int}_t = ret_{j,t}, \ \forall\ j$$

A.4 Government sector

(21) $$PGov_{j,t}Bond_{j,t+1} - PGov_{j,t-1}Bond_{j,t} =$$
$$PGov_{j,t}Gov_{j,t} + \left(ri_{j,t-1} + (PGov_{j,t} - PGov_{j,t-1})/PGov_{j,t-1}\right)PGov_{j,t-1}Bond_{j,t}$$
$$-\sum_{gg} POP_{j,t,gg}\left\{\tau^L_{j,t}\left(Y^L_{j,t,gg}\right) + \tau^C_{j,t}\left(Pcon_{j,t}Con_{j,t,gg}\right) + \tau^K_{j,t}\left(ret_{j,t}Lend_{j,t,gg}\right)\right\}$$

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(22) $$GovI_{i,j,t} = ALGI_{i,j}^{\ SigG_j}\left(PGov_{j,t}/PQ_{i,t}\right)^{SigG_j} Gov_{j,t}$$

(23) $$PGov_{j,t} = \left[\sum_i ALGI_{i,j}^{\ SigG_j}\left(PQ_{i,t}\right)^{(1-SigG_j)}\right]^{\frac{1}{1-SigG_j}}$$

A.5 Market and aggregation conditions

(24) $$Q_{j,t} = \sum_i E_{j,i,t} = \sum_i \left[\left(\sum_{gg} Pop_{i,t,gg} ConI_{j,i,t,gg}\right) + InvI_{j,i,t} + GovI_{j,i,t}\right]$$

(25) $$Ldem_{j,t} = \sum_{gj} Pop_{j,t,gj} LS_{j,gj} EP_{j,gj}$$

(26) $$Kdem_{j,t} = Kstock_{j,t}$$

(27) $$\sum_i \sum_{gg} Pop_{i,t+1,gg} Lend_{i,t+1,gg} = \sum_i PGov_{i,t} Bond_{i,t+1} + \sum_i PInv_{i,t} Kstock_{i,t+1}$$

(28) $$CA_{j,t} = \underbrace{\left(\sum_{gg} Pop_{j,t+1,gg} Lend_{j,t+1,gg} - \sum_{gg} Pop_{j,t,gg} Lend_{j,t,gg}\right)}_{\text{Private Saving}} -$$

$$\underbrace{\left(PGov_{j,t}\ Bond_{j,t+1} - PGov_{j,t-1}\ Bond_{j,t}\right)}_{\text{Public Dissaving}} - \underbrace{\left(PInv_{j,t}\ Kstock_{j,t+1} - PInv_{j,t-1}\ Kstock_{j,t}\right)}_{\text{Domestic Investment}}$$

(28') $$CA_{j,t} = \underbrace{\left(\sum_{i,i\neq j} PQ_{j,t} E_{j,i,t} - PQ_{i,j} E_{i,j,t}\right)}_{\text{Trade Balance}} +$$

$$r\,\text{int}_t \left(\underbrace{\sum_{gg} Pop_{j,t,gg} Lend_{j,t,gg}}_{\text{Wealth of Country } j} - \underbrace{\left(PGov_{j,t-1}\ Bond_{j,t} + PInv_{j,t-1}\ Kstock_{j,t}\right)}_{\text{Assets issed by Country } j}\right)$$

A.6 Demography

(29) $$Pop_{j,t,g+k} = \begin{cases} Pop_{j,t-1,g+k} NN_{j,t-1} & \text{for } k = 0 \\ Pop_{j,t-1,g+k-1}\left(s_{j,t-1,g+k-1} + nm_{j,t-1,g+k-1}\right) & \text{for } k = (1,\ldots,6) \end{cases}$$

Table A1. Model variables and parameters

Variables	***Description***
$Q_{j,t}$	region-*j* output
$PQ_{j,t}$	region-*j* output price (producer price index)
$Kdem_{j,t}$	physical capital
$Ldem_{j,t}$	effective units of labour
$Rent_{j,t}$	rental rate of capital
$WLdem_{j,t}$	wages for effective units of labour
$Con_{j,t,gg}$	consumption demand of household of generation *gg* at time *t*
$C_{j,t}$	$=\Sigma_{gg}Con_{j,t,gg}$ = aggregate consumption in region *j* at time *t*
$ConI_{i,j,t,gg}$	household-*gg* of region-*j*'s consumption demand for a region-*i* good
$PCon_{j,t}$	composite consumption price index
$Lend_{j,t,gg}$	stock of wealth accumulated by household-*gg* at the end of period *t*-1
$Kstock_{j,t}$	region-*j* capital stock
$Inv_{j,t}$	investment in region-*j*
$InvI_{i,j,t}$	region-*j*'s investment demand for a region-*i* (investment) good
$PInv_{j,t}$	composite investment good price index
$ret_{j,t}$	expected rate of return on physical capital purchased at end of *t*-1 and rented throughout *t*
$ri_{j,t-1}$	promised coupon rate of interest on country-*j* government bonds issued at end of *t*-1
$rint_t$	world interest rate, expected as of the end of period *t*-1 for period *t*
$Gov_{j,t}$	region-*j* real public expenditures
$GovI_{i,j,t}$	real public expenditures of government-*j* on goods from region *i*
$PGov_{j,t}$	composite government spending price index (price of bonds issued by region-*j* government)
$E_{j,i,t}$	real bilateral export of country *j* to county *i*
$CA_{j,t}$	country-*j* current account
$Pens_{j,t,gm}$	pension benefit to retired generations (*gm*)
$Y^L_{j,t,gg}$	labour income of household-*gg*
$LS_{j,gg}$	supply of physical units of labour by household-*gg* (exogenous)
$EP_{j,gg}$	household age-dependent productivity (earnings) profile
$Pop_{j,t,gi}$	population size of working-age cohorts *gi*
$Pop_{j,t,gm}$	population size of retired cohorts *gm*
Parameters	***Description***
$A_{j,t}$	scaling factor of Cobb-Douglas production function (TFP)
α_j	share of physical capital in Cobb-Douglas production function
ψ_j	pure rate of time preference
γ_j	inverse of the constant inter-temporal elasticity of substitution
$\tau^L_{j,t}$	effective tax rate on labour income (endogenous)
$\tau^K_{j,t}$	effective tax rate on capital income
$\tau^C_{j,t}$	consumption tax rate
$CTR_{j,t}$	contribution to the public pension system (endogenous)
$PensR_{j,t,gg}$	pension replacement rate (exogenous)
δ_j	depreciation rate of capital
$ALCI_{i,j}$	country-*i* share of country- *j* consumption-good demand
$ALII_{i,j}$	country-*i* share of country- *j* investment-good demand
$ALGI_{i,j}$	country-*i* share of country- *j* government consumption demand
$SigC_j$	Armington substitution elasticities in consumption goods
$SigI_j$	Armington substitution elasticities in investment goods
$SigG_j$	Armington substitution elasticities in government consumption
$NN_{j,t}$	country-specific per-capita number of children
$nm_{j,t,gg}$	net migration ratio
$s_{j,t,gg}$	conditional survival rate

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A.7 Calibration

The wage income tax rates, capital income tax rates and consumption tax rates for Canada, U.S., E.U. and Japan are directly based on Carey and Rabesona (2002), while the pension benefit rates are taken from OECD (2005) – see Table A2. However, for China, India and ROW, it is extremely difficult to set these rates with precision since there is little reliable data available. In this paper, we assume lower pension benefit rates for them compared to the developed regions. Considering that the tax collecting system and social security programs of India may not be as advanced as in developed regions, we have set relatively lower tax rates and pension benefit rate compared to other regions. Correspondingly, it is also reasonable to set moderate tax rates for ROW. Moreover, because of the heavy presence of state-owned enterprises in China's economic structure, its wage and capital income tax rates are assumed to be relatively higher compared to other economies in order to incorporate the crowding out effects. Meanwhile, the consumption tax rate of China is set to be lower to ensure that its overall tax levels are consistent with other regions. According to the definition of economically active population, we assume workers retire at age 65 with the exception of workers in E.U. and Japan who are assumed to retire at age 60 and 70 respectively, reflecting their different working culture. The intertemporal elasticity of substitution ($1/\gamma$) is set to 1.5 for all countries, which is in the standard range of 1–4. The (10-year) rate of time preference is solved endogenously in the calibration procedure in order to generate realistic country specific consumption profiles and capital ownership profiles *per age group* for which no data are easily available.[18] A higher rate of time preference reflects a bias towards current versus future consumption and the values generated endogenously are consistent with the priors that, say, Indians are more patient than Americans or Japanese. Finally, the remaining parameters in the model are calibrated on the GTAP-6 database (Dimaranan and McDougall, 2005). This also includes the Armington elasticity of substitution between goods of different countries, which is set uniformly equal to 2.5 across countries for private consumption, investment and government consumption.

[18] The rate of time preference and the intertemporal elasticity of substitution determine together the slope of the consumption profiles *across age groups* in the calibration of the model (where population is assumed stable) and this is also the slope of the consumption profile of an individual *across his lifetime* in the simulated model in absence of demographic shocks.

Table A2. Calibration parameters

Country/Region	CAN	USA	EUR	JPN	CHN	IND	ROW
Intertemporal elast. of substitution, $1/\gamma_j$	1.5	1.5	1.5	1.5	1.5	1.5	1.5
Armington trade elasticity, Sig_j	2.5	2.5	2.5	2.5	2.5	2.5	2.5
Rate of time preference (10-year), ψ_j	0.22	0.28	0.27	0.28	0.25	0.21	0.17
Wage income tax rate, $\tau^{L}_{j,t}$	0.296	0.234	0.38	0.241	0.45	0.20	0.26
Capital income tax rate, $\tau^{K}_{j,t}$	0.368	0.273	0.287	0.279	0.50	0.25	0.30
Consumption tax rate, $\tau^{C}_{j,t}$	0.139	0.064	0.178	0.064	0.05	0.15	0.15
Effective retirement age	65	65	60	70	65	65	65
Pension benefit rate, $PensR_{j,t,gg}$	0.425	0.386	0.536	0.503	0.30	0.20	0.35

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