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MACROECONOMIC EFFECTS OF AN AGEING POPULATION IN MAURITIUS

JULIA WŁODARCZYK[†,*], INDRANARAIN RAMLALL[‡] AND JAN ACEDAŃSKI[†]

Abstract
The economic literature focuses mostly on faster ageing of population among developed countries; however, many developing countries experience even more dramatic pace of this process. Mauritius, with the median age of population higher than the world average since 1990s, represents a prominent example of such a case. In this paper, we analyse demographic developments in Mauritius and discuss their macroeconomic implications using an open-economy OLG model with demographic shocks. We project that a decline in the Mauritian interest rate and net foreign assets to GDP resulting from ageing will be accompanied by a temporary increase in GDP, consumption and investment.
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1. INTRODUCTION

Imbalances in the population structure can have either a positive or a negative impact on an economy depending on the changes brought to the relative size of the working population. In 1970s, baby boomers started to reinforce the working age population. Today, this demographic dividend has been sapped. According to the estimates of the United Nations (2019), world fertility rate dwindled from approximately five children per woman during 1950s and 1960s to around 2.5 in 2010s with a projected fall below replacement levels by 2070. The rapid pace of demographic changes justifies frequent references to terms such as new "bête noire" of development (Messkoub, 1999) or secular stagnation (Acemoğlu and Restrepo, 2017).

At the present juncture of affairs, ageing population is one of the major challenges already afflicting or expected to strike most of the economies in the world. A burgeoning literature on the economic effects of an ageing population has accumulated over the last two decades. Nevertheless, its research horizon has been tilted mainly towards developed economies with much less attention being paid to developing ones, despite the fact that repercussions of ageing will be far-reaching both for developed and developing countries alike.

This paper attempts to fill in this gap by analysing the impact of ageing on the economy of Mauritius which is an upper-income developing country. To this purpose, we

* Corresponding author: University of Economics in Katowice, Katowice, Poland. E-mail: julia.wlodarczyk@ue.katowice.pl.
† University of Economics in Katowice
‡ University of Mauritius

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resort to an open-economy overlapping-generations (OLG) model with demographic shocks to simulate dynamics of real interest rates, main macroeconomic aggregates and net foreign assets to GDP. In accordance with previous findings, we project a gradual decline in the real interest rate in Mauritius due to ageing. However, the decline is projected to be much sharper than in developed countries.

The choice of Mauritius is justified by the fact that this small open economy has already started to experience adverse demographic developments, which potentially hinder its fiscal discipline, financial stability and relations with the foreign sector. As a matter of fact, since mid-1980s the median age of Mauritian population has been the highest among African countries.

Although Africa is still very young as a continent, there is a significant heterogeneity in demographic processes among African countries. Therefore, results of our simulations can be instructive for policymakers in other ageing African countries such as Tunisia, Morocco or South Africa.

The remainder of this paper is organised as follows. Section 2 summarises the literature on economic effects of ageing, while Section 3 explores characteristics of the ageing process in Mauritius. Section 4 highlights the assumptions underlying the overlapping-generations model applied in simulations and explains the calibration procedure. Section 5 presents baseline and alternative results obtained for Mauritius. Final section concludes.

2. LITERATURE OVERVIEW

There is a snowballing literature which assesses the effects of an ageing population on macroeconomic aggregates such as consumption or savings. Theoretically, ageing population may exert strains on economic growth through undermined levels of consumption and investment (cf. Hansen, 1939; Keynes, 1978). Currently, at the core of the discussion lies the life cycle hypothesis (Modigliani and Brumberg, 1954; Ando and Modigliani, 1963), a concept positing that in order to maximise their utility functions over the life cycle people tend to save during the working phase of their lives to deplete these savings when they retire. However, Danziger *et al.* (1982) find evidence that elderly actually save rather than dissave on the back of blunt human capital level, depleted private pension wealth and uncertainty about health conditions.

Due to the uncertainty the critical role for consumption and savings in the long run is played by the pension system (Bloom *et al.*, 2010). Accordingly, private savings decline in economies with pay-as-you-go pension systems and high replacement rates. Naturally, an ageing population causes high public expenditure and a fall in tax revenue leading to high budget deficits (*e.g.* Lisenkova *et al.*, 2012). Therefore, governments often consider pensions reforms such as increases in statutory retirement age. Their impact on sustainability of public pension systems and their welfare effects were investigated *e.g.* by Díaz-Giménez and Díaz-Saavedra (2009) and Fehr *et al.* (2012). There are also discussions on the choice between the pay-as-you-go (PAYG) and funded pension systems, however, differences between them turn out to be small in economic terms (Barr, 2000; Barr and Diamond, 2006).

In our simulations, we adopt rather standard assumptions concerning the pension system and focus mainly on the dynamics of the domestic real interest rate, GDP, consumption and investment. In the literature this was done *e.g.* by McMillan and Baesel (1990), Lenehan (1996), Miles (1999), Krueger and Ludwig (2007), Ikeda and Saito (2014), Carvalho *et al.* (2016), Gagnon *et al.* (2016), Zhu (2016), Kara and Von Thadden (2016), Eggertsson *et al.* (2017), Acedański and Włodarczyk (2018a) and Aksoy *et al.* (2019). Nevertheless, these studies refer to developed economies only.

With the expansion of research horizons from closed economies and their fiscal situation towards open economies and international capital flows, the economic literature on ageing is likely to pay more attention to developing countries. So far, capital flows between developed and developing countries resulting from demographic trends have been already mentioned by Brooks (2003), Backus *et al.* (2014) and analysed by Bárány *et al.* (2018). In particular, Bárány *et al.* (2018) emphasise the role of global ageing as a potential source of capital flows from developing countries to developed economies. However, apart from Egypt, South Africa and Morocco they do not include other ageing African countries in their sample such as Algeria, Tunisia, Libya nor Mauritius. Besides, in developing countries ageing is likely to make it more difficult to attract foreign direct investment as Davies and Reed (2006) demonstrate that foreign firms usually do not invest in an economy, which is buffeted by ageing population.

In general, the number of empirical works on ageing in developing countries is still very small, with Asian countries dominating the debate (Nagarajan *et al.*, 2017). The literature on economic aspects of ageing in Mauritius is almost non-existent. Only Munozmoreno *et al.* (2014) use OLS and VAR techniques to find a positive impact of lagged savings and GDP growth on current savings in Mauritius, as well as a negative effect of high dependency ratios on saving rates.

Technically, our work is closely related to the paper by Acedański and Włodarczyk (2018a) where an open-economy version of the overlapping-generations model used by Carvalho *et al.* (2016) was developed. We calibrate parameters of this model to match the key features of Mauritian economy and its projected demographic tendencies. Following Williamson (2013), we pay special attention to assumptions concerning interest rates. As in Guest (2006), Kudrna and Woodland (2011), and Acedański and Włodarczyk (2018a) capital is not perfectly mobile and the domestic interest rate is endogenous. More precisely, in the baseline version of the model the domestic interest rate is a linear function of foreign debt measured by net foreign assets to GDP (as in the prevailing literature), while in the alternative specification it takes a nonlinear form.

3. DEMOGRAPHIC PROCESSES IN MAURITIUS

The progression of ageing in Mauritius can be best substantiated via four key metrics. First and foremost, according to United Nations data (2019), the fertility rate underwent a drastic decline from 6.2 in 1960 to hover around 1.4 in 2017. Second, the median age of the Mauritian population exhibited steady increases over the years from 16.7 years in 1960 to reach 35.9 years around 2017. Third, the old-age dependency ratio (measured as a ratio of population aged 65 and above to population aged 15–64) rose from 4.9% in 1960 to stand at 15.5% in 2017. Finally, the life expectancy increased from 58.7 in 1960 to 74.5 in 2017. Projections for the year 2020 for Mauritius and other fast-ageing African countries are presented in Table 1.

When assessing the demographic processes upon three criteria (fertility rate, median age of population and old-age dependency ratio) Mauritius is an undisputed leader in

Table 1. Top 10 African countries/territories in terms of ageing according to demographic statistics (projections for 2020)

Total fertility rate (live births per woman)			**Median age of the total population (years)**			**Old-age dependency ratio (%)**			**Life expectancy at birth (years)**		
Country	**2020**	**<W[1]**	**Country**	**2020**	**>W[1]**	**Country**	**2020**	**>W[1]**	**Country**	**2020**	**>W[1]**
Mauritius	1.39	1965	Mauritius	37.5	1990	Réunion	19.6	2010	Réunion	80.03	1950[3]
Tunisia	2.20	1990	Réunion	35.9	1995	Mauritius	17.7	2015	Mayotte	79.35	1950[3]
Libya	2.25	2000	Seychelles	34.2	2000	Tunisia	13.3	2020	Algeria	76.59	1985
Réunion	2.27	1970	Tunisia	32.8	2010	Seychelles	11.8	.[2]	Tunisia	76.41	1980
Cabo Verde	2.29	2010	Morocco	29.5	.[2]	Morocco	11.6	.[2]	Morocco	76.33	1990
South Africa	2.41	2015	Libya	28.8	.[2]	Algeria	10.8	.[2]	Mauritius	74.76	1950[3]
Western Sahara	2.41	2015	Algeria	28.5	.[2]	Egypt	8.8	.[2]	Seychelles	73.29	1950[3]
Morocco	2.42	2015	Western Sahara	28.4	.[2]	South Africa	8.4	.[2]	Cabo Verde	72.70	1980
Seychelles	2.46	1980	South Africa	27.6	.[2]	Eritrea	8.3	.[2]	Libya	72.70	1970
Djibouti	2.76	.[2]	Cabo Verde	27.6	.[2]	Lesotho	7.9	.[2]	Egypt	71.74	1990
World	*2.47*	.[2]	*World*	*30.9*	.[2]	*World*	*14.3*	.[2]	*World*	*72.28*	.[2]

[1]<W (>W) indicates the year since when a particular country has observed values lower (higher) than the world average.

[2]indicates countries which have not transgressed the world values.

[3]1950 or earlier (United Nations data go back only to 1950s).

Source: Authors' elaboration based on the United Nations data (2019).

Africa in terms of ageing, followed by Réunion, Tunisia, Seychelles, Morocco and South Africa. Currently, Mauritius is the only African country with fertility below replacement levels. (Tunisia experienced such an episode during the first decade of the twentieth century, but in Mauritius the situation has persisted since mid-1990s).

The pace of ageing in Mauritius and other African countries has attracted little attention of researchers. Da Silva Francisco (2017) analyse demographic developments in African countries and find that over the last seven decades the median age of the population has remained almost constant across the continent and only Mauritius, Morocco and South Africa exhibited signs of ageing (with Mauritius being the most striking exception from the African average). Nevertheless, persistently high fertility rates in the majority of African countries (with almost seven children per woman in Niger or Somalia) and long-term projections that Africa will remain the youngest region in the world effectively crowd out the problems of ageing from the public discourse and policy making (Aboderin, 2012). The focus of national policies is mostly on younger generations and the prevailing high social status of the elderly in traditional African societies has eroded. This state of affairs can be perceived as worrisome at least from the point of view of inclusive growth. Although the relative size of the older population will remain small, the absolute number of the elderly will increase dramatically over the next decades (Pillay and Maharaj, 2013).

Focusing on positive aspects of declining fertility in Nigeria, Karra *et al.* (2017) build a macrosimulation model allowing to analyse the effect of fertility decline on savings and health as well as a feedback from education to fertility. Their model predicts positive effects of fertility decline contributing to faster economic growth, which is also documented in our computations for Mauritius.

There are two main drivers that account for the decline in the fertility rates in Mauritius over the long run. First, the emancipation of women, spurred by industrialisation in Mauritius and development of export-processing zones (associated predominantly with textiles production), led to more and more women entering the labour market. In particular, the male activity rate decreased from 78.8% in 2005 to 73.1% in 2018, while female activity rate increased from 41.6% to 45.5% during the same period (Statistics Mauritius, 2018).

Second, with education playing a preponderant role in moving up the income ladder, declining fertility is also due to postponement of marriage. In Mauritius, the average age at first marriage for women increased from 24.4 years in 1993 to reach 28.0 years in 2018. In the background, gross tertiary enrolment rate among women rose from 16.0% in 2000 to 54.3% in 2017, while the greatest decline in fertility between 1990 and 2018 was observed for women aged 20–24 years (Statistics Mauritius, 2018).

4. MODEL AND CALIBRATION

In our simulations, we use a small open economy version of the OLG model with demographic shocks developed by Gertler (1999) and Carvalho *et al.* (2016) and recently employed by Acedański and Włodarczyk (2018a). The model captures three channels through which demographics affects interest rates in an open economy: decreasing labour supply due to declining population growth rates, increasing expected retirement duration due to increased life expectancy and decreasing global interest rates caused by the global demographic tendencies.

As presented in detail in Appendix A, there are three types of agents in the economy: households (workers and retirees), firms and the government. Workers enter the labour market at the age of 20 without any assets and inelastically supply one unit of labour in each period. Their income consists of their wage and interest on assets (wealth is stored in the form of physical capital and one-period risk-free bonds issued by the government). Income of a retired household consists of a pension and interest on accumulated wealth. Additionally, agents have an access to international financial market: they can borrow capital paying a premium over the world interest rate.

The production sector is perfectly competitive and uses capital and labour to produce a homogeneous final good used for consumption and investment. The production technology is described by the standard Cobb-Douglas function with labour-augmenting technological progress.

The public pension system takes a form of a standard unfunded PAYG scheme. The government levies lump-sum taxes to finance pensions and public consumption that is proportional to output. It also issues one-period risk-free bonds. The amount of government debt is assumed to be constant and proportional to the output.

In order to study the macroeconomic effects of demographic processes, we introduce one-time unexpected shocks for the population growth rate and for the survival probability that generate long-lasting responses in demographic characteristics following the World Population Prospects (United Nations, 2017). A similar shock for the world interest rate is also included.

Importantly, mirroring long-run population projections allows to overcome controversies associated with a relatively common approach to measuring the economic impact of demographic processes in OLG models, which consists in fixing birth and death rates at the beginning of analysis (*e.g.* Braun *et al.*, 2009) or at another time point (*e.g.* Sanchez-Romero, 2013).

All the shocks can be related to the channels through which demographics is linked with interest rates. The population growth rate shock affects labour supply. The surviving probability shock influences expected retirement duration and, naturally, the world's interest rate shock determines the impact of the expected decrease (due to ageing) in global interest rates.

One period in the model corresponds to one year. Following Acedański and Włodarczyk (2018a), we assume that the demographic and interest rate shocks hit the economy in 2000 and the effective retirement age rises gradually from 60 years in 2000 to 68 years in 2100 both in developed countries and in Mauritius. In fact, the Mauritian statutory retirement age has already increased from 60 years in 2008 to 65 years in 2018 with final retirement age equal to 70 years (cf. National Pensions Act, 1976; Soto *et al.*, 2015).

To calibrate the demographic shocks, we use the estimations and projections for the period 2000–2100 (United Nations, 2017). The parameters governing the initial levels of the demographic variables for Mauritius are set to match the values observed in 2000. The parameters of the shock processes are calibrated so that the model-based dynamics of the population growth rate and the retirement-age dependency ratio (defined as the ratio of retired population to the number of workers) are as close as possible to their observed and projected counterparts using the standard squared loss function. The characteristics of the world interest rate shock are taken directly from Acedański and Włodarczyk (2018a). The relationships between the model-based and projected demographic characteristics are depicted in Fig. 1. We also considered some alternative calibration procedures for the demographic characteristics, but we found them inferior to the one presented in the paper. The details are available upon request.

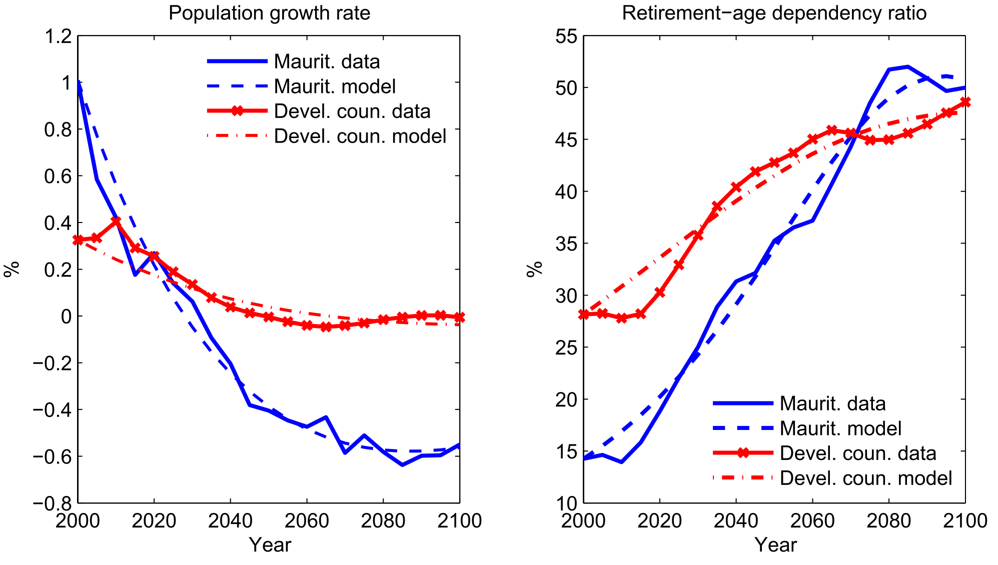

Figure 1. Projected and simulated demographic characteristics for Mauritius and developed countries (Europe, Northern America, Australia, New Zealand, and Japan). Note: Retirement-age dependency ratio is defined as the ratio of retired population to the number of workers and does not depend on the exact age of individuals.
Source: Authors' computations based on the United Nations World Population Prospects 2017 database (medium scenario)

The parameters related to the initial values of macroeconomic characteristics are equal to the averages of the values observed in longer periods around the year 2000. In particular, following Svirydzenka and Petri (2017) the annual technological growth rate in Mauritius is set to 1.2%, while the annual capital depreciation rate is equal to 7%. We also assume that the capital share is equal to 35%. Besides, based on historical data on Mauritian government bond yields, the steady state level of the interest rate in Mauritius is assumed to be 2 p.p. higher than in the developed countries. On the basis of the World Bank data for Mauritius, we set the share of government consumption in GDP at 14%, whereas the ratio of the government debt to GDP amounts to 35%. Following Carvalho *et al.* (2016) in calibrating the aggregate pension transfers to GDP, we get the value of 2%. To calibrate the parameters describing the relationship between domestic and world interest rates, we aim at matching the mean level of the net foreign assets in Mauritius. The values of all the parameters are presented in Table C1 in Appendix C.

5. RESULTS

5.1. Baseline Scenario

Fig. 2 depicts projected dynamics of the interest rates in Mauritius and the developed countries treated as an aggregate. In line with the results presented in the literature, we show a sharp decline in the interest rates in both economies. In Mauritius, the drop is expected to

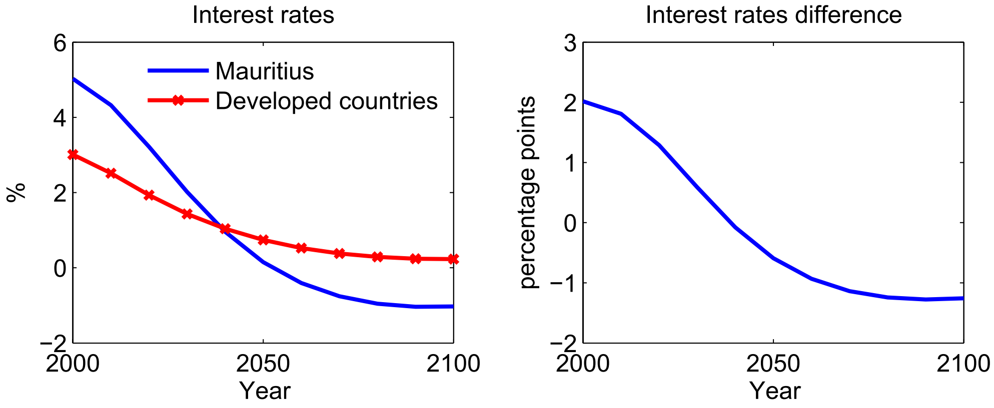

Figure 2. Simulated dynamics of the interest rates (baseline scenario). Note: The interest rate difference is defined as $R_{Mauritius} - R_{World}$

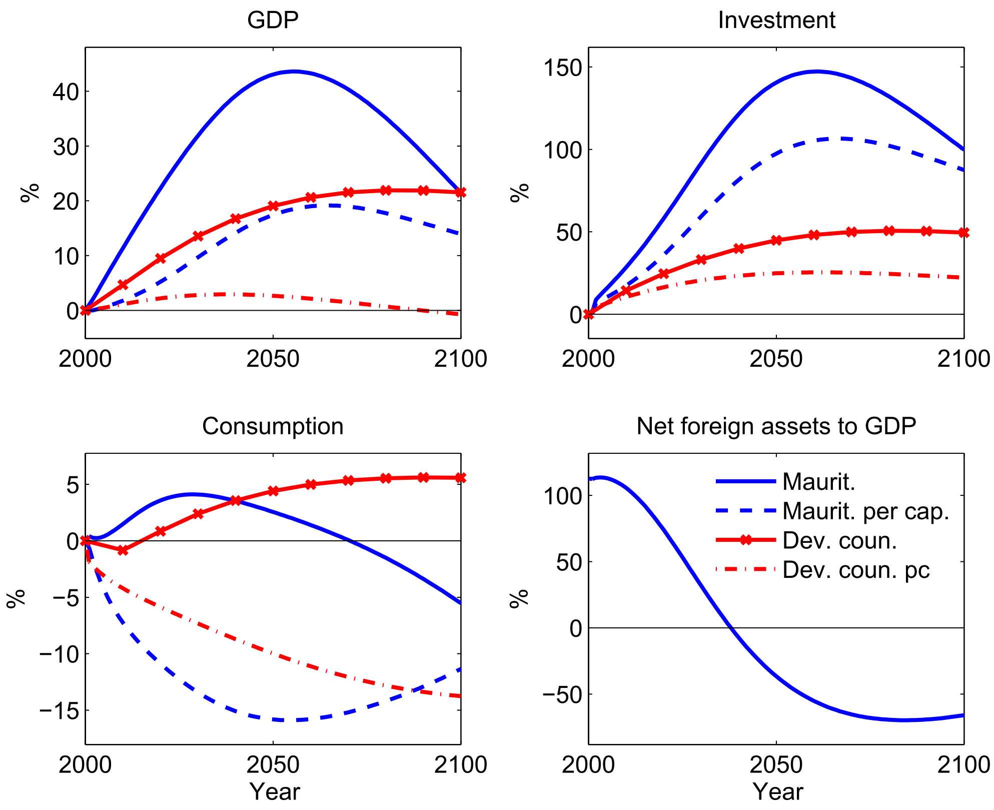

Figure 3. Projected dynamics of the main macro aggregates (baseline scenario). Note: All the variables except net foreign assets to GDP are expressed as percentage deviations from the initial values

be larger than in the developed countries. In the baseline scenario, Mauritian interest rate is projected to fall below the world interest rate in 2040s and below zero in 2050s.

Fig. 3 shows the results for remaining macroeconomic aggregates. In general, demographic changes are likely to bring about much greater effects on Mauritian economy than on developed countries. Declining interest rates are projected to induce greater investment expenditures, which will imply a significant increase in the GDP levels in Mauritius till around 2050.

The second half of the analysed period is projected to exhibit declines in all variables except per capita consumption. Therefore, it can be concluded that the interest rate effect will be crowded out by the effect of declining population.

Declining interest rate is also associated with capital outflow and a decreasing ratio of net foreign assets to GDP, which is expected to fall below zero around 2040 when Mauritius is likely to become capital exporter. This may resemble processes observed in other countries. For instance, in 1980s the Republic of Korea experienced a significant shift from net capital inflow to net capital outflow along with profound demographic changes (Williamson, 2013).

It is worth mentioning that projected developments in interest rates and net foreign assets to GDP resulting from ageing in Mauritius are much more dramatic than results of similar simulations conducted for Poland, which is one of the fast-ageing countries in Europe. In Poland, neither the interest rate nor the ratio of net foreign assets to GDP is expected to fall below zero (Acedański and Włodarczyk, 2018a).

In case of Poland, GDP, investment and consumption per capita are projected to behave similarly to developed countries (with absolute levels of these aggregates exhibiting significant declines due to depopulation), while in Mauritius increases in GDP and investment (both in absolute and per capita terms) will be much greater than in developed countries and only absolute changes in GDP are projected to be similar at the end of the analysed period.

5.2. Alternative Scenario for the Relationship Between the Domestic and World Interest Rates

The baseline scenario stipulates that the Mauritian interest rate will be lower than the world interest rate from 2040s on. Fig. 4 depicts projected dynamics of the interest rates in Mauritius and the developed countries when the decline in the Mauritian interest rate

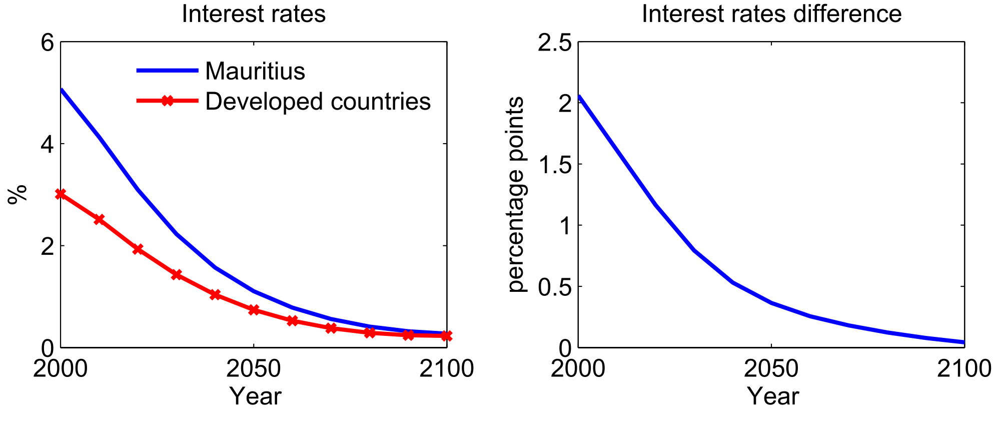

Figure 4. Simulated dynamics of the interest rates (alternative scenario). Note: The interest rate difference is defined as $R_{Mauritius} - R_{World}$

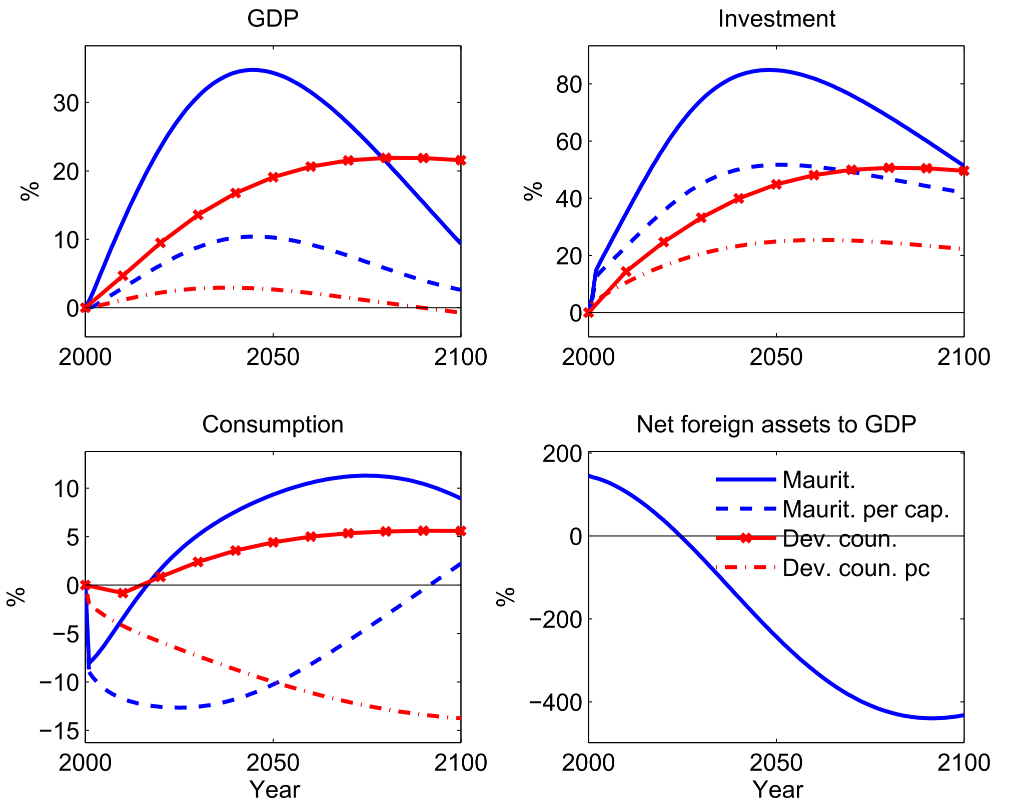

Figure 5. Projected dynamics of the main macro aggregates (alternative scenario). Note: All the variables except net foreign assets to GDP are expressed as percentage deviations from the initial values

is constrained by the developments of interest rates overseas and interest rate difference is assumed not to fall below zero. Fig. 5 shows the results for other macroeconomic aggregates under analysis.

A milder decline in Mauritian interest rate implies not only that increases in investment and GDP will be more moderate, but also that they will last for a shorter period of time (roughly by a decade). However, consumption projection is much more favourable than in the baseline scenario.

In the alternative scenario the ratio of net foreign assets to GDP is expected to exhibit a much more dramatic decline, because within the framework of the adopted model capital outflow can be interpreted as one of the important factors responsible for keeping the Mauritian rate above the world interest rate.

5.3. Alternative Specifications of the Retirement Probability Dynamics

In the baseline case discussed in Section 5.1, we assume a linear relationship between the surviving probability and the retirement probability. In reality, the relationship between mortality decline and retirement age is potentially much more complex and as noted by d'Albis *et al.* (2012) over the twentieth century increasing life expectancy was actually

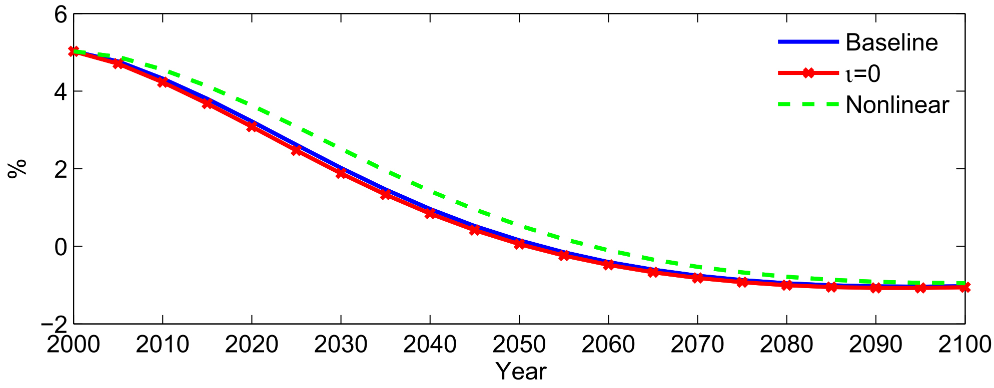

Figure 6. Interest rate projections under alternative specifications of the retirement probability dynamics. Note: ι = 0 refers to the constant retirement probability case, while under Nonlinear scenario retirement probability depends on the surviving probability with the retirement duration extended by 0.25 of the increased life span

accompanied by a declining labour force participation among men aged 65 and over. In our computations, we rely on data from the twenty-first century when this trend reversed in many countries (OECD, 2019).

Therefore, in order to examine the sensitivity of our results to the specification of the relationship between the probability of remaining in the labour force and the surviving probability we have considered two alternative specifications: the constant retirement probability and the nonlinear relationship given by equation (A.100). The former indicates that retirement probability does not depend on the surviving probability, while the latter implies that, on average, a fraction (θ) of the increasing life span is spent on the labour market and the remaining portion extends the retirement duration (similarly to the pension schemes in Finland and Portugal; OECD, 2019:43). We set $\theta = 0.75$.

The expected interest rate dynamics in Mauritius under these alternative specifications is shown in Fig. 6. The differences with the baseline case are rather small and if we consider the same schemes in the model for developed countries, the interest rate differentials (Mauritius vs. the developed countries) will be even closer to the baseline scenario. Therefore, different assumptions concerning the relationship between the surviving probability and the retirement probability do not alter the main conclusions of the study significantly.

6. CONCLUDING REMARKS

Demographic changes in Mauritius will have profound implications for its economy. Our simulations indicate that during forthcoming decades the decline in the Mauritian interest rate due to ageing will temporarily stimulate growth in investment and GDP compared to developed countries. Our results are similar to those already presented in the economic literature with the exception of Goodhart and Pradhan (2017) who argue that ageing will decrease both desired savings and desired investment, but the fall in desired savings will be greater thus raising real interest rates.

Naturally, our analysis is subject to many limitations. First of all, the model abstracts from many factors that are likely to affect the macroeconomic effects of ageing like health, age-related surviving and retirement probabilities or human capital. Taking them into account would definitely make the results more reliable. Unfortunately, it would significantly increase difficulties related to model development, programming and simulating.

As far as health is concerned, a relatively high life expectancy in Mauritius can be attributed to the provision of free health services to all citizens. Even though many authors emphasise differences between developed and developing countries in terms of health, especially concerning the role of infectious diseases (*e.g.* Bloom *et al.*, 2018), we would like to note that Mauritius is already at an advanced stage of epidemiological transition. This transition can be best illustrated with the statistics on the relative burden of noncommunicable diseases. In particular, in 2014, noncommunicable diseases accounted for 85% of all deaths in Mauritius which was only 2 p.p. less than in Belgium, China, France, Luxembourg and Norway (WHO, 2014). Among Sub-Saharan African countries Mauritius was on the top of a ranking of countries listed according to the age-standardised mortality rate due to noncommunicable diseases, followed by Seychelles, Sao Tome and Principe, Cabo Verde, Eritrea and Madagascar (Marquez and Farrington, 2013). Currently, main causes of death in Mauritius comprise cardiovascular diseases, diabetes, influenza and pneumonia, as well as cancer with the effects being more pronounced for men relative to women (WHO, 2018; Simmons, 2019).

Secondly, our assumption concerning the government sector does not allow to capture precisely how Mauritian budget will evolve with higher spending, especially on pensions and healthcare services due to ageing population. Interestingly, increases in the legal retirement age postulated *e.g.* by Bloom *et al.* (2010) or D'Addio *et al.* (2010) may have different implications for developed and developing countries. For instance, compared to the rest of the world African countries are already characterised by the highest labour force participation ratios for the population aged 60 and above, probably due to the lack of sufficiently developed pension systems (Pillay and Maharaj, 2013). However, the case of South Africa demonstrates that despite ageing governments may decide to reduce the eligibility age associated with old age pensions (Muchiri and Garen, 2018).

Moreover, our projections concerning the scale of capital outflow from Mauritius should be interpreted with proper caution as they show only the effect of demographic changes, but do not take into account any policy nor institutional changes affecting capital flows. Besides, the degree of capital mobility in case of developing countries may not be equally high as for developed countries.

Apart from capital flows, we do not include interactions with the foreign sector such as imports or exports of goods and services. Importantly, tourism which is one of the pillars of Mauritian economy may be also adversely affected by ageing due to possible constraints of mobility of elder tourists.

There is also significant uncertainty concerning the pace and effect of technological progress. Prevailing literature offers mixed evidence: according to Braun *et al.* (2009) and Ikeda and Saito (2014) total factor productivity is likely to play a more important role than ageing, while Acedański and Włodarczyk (2018a) demonstrate that different rates of technological progress have only a minor impact on the evolution of the interest rates. Nevertheless, Acemoğlu and Restrepo (2017) argue that economies subject to ageing of population are more likely to adopt labour-replacing technologies to boost productivity and economic growth. They notice that a shortage of younger and middle-aged workers can be the force responsible for a greater scale of adoption of new automation technologies which can completely neutralise or even reverse the negative effects of labour scarcity. Furthermore, Cai and Stoyanov (2016) show that differences in demographic processes between countries can constitute a source of comparative advantage in international trade. As many skills are age-dependent, ageing populations should develop industries which use age-appreciating skills intensively.

As a consequence, an important extension of conducted considerations would be also to augment our production function with human capital in order to take into account Mauritian focus on knowledge-based growth (Svirydzenka and Petri, 2017). This is justified by the fact that shrinking labour force due to ageing increases the returns to human capital relative to physical capital. This creates more incentives for greater educational effort. To some extent, the government's decision to introduce free higher education in public Tertiary Education Institutions in Mauritius (announced in January 2019) meets these needs of an ageing population. However, in the long run Mauritius may suffer from brain drain, if ageing slows down the economic growth and educated Mauritians migrate abroad to find more opportunities in relatively younger economies. Such an emigration would further impinge on demographic processes in Mauritius.

Although processes of erosion of intergenerational solidarity are rather unlikely to pose economic threat to elder Mauritians who are fully covered by the pension system, in other African countries the proportion of elder population receiving old-age pensions is on average incomparably smaller than in Mauritius, so this process may translate into greater risk of poverty at old age in many African countries.

Finally, a very interesting avenue for future research is associated with the inclusion of the banking sector as declining interest rates (and presumably also declining interest rate spreads) due to ageing are likely to generate important changes to the way banks operate. If the elderly save more, banks will be awash with funds, so that they will need to look for alternative sources of investment in the case that loans do not increase in the same proportion as deposits (*e.g*. long-term instruments issued by the central bank, reverse mortgages or overseas operations in relatively younger populations). Although our projections concerning investment are quite optimistic and make a drastic fall in demand for loans rather unlikely, the openness of Mauritian economy may translate declining interest rates into a greater risk of capital flight.

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REFERENCES

ABODERIN, I. (2012). Ageing Africa. Opportunities for Development. In J. Beard, S. Biggs, D. Bloom, L. Fried, P. Hogan, A. Kalacheand J. Olshansky (eds), Global Ageing: Peril or Promise? Cambridge: World Economic Forum, 69-73.

ACEDAŃSKI, J. and WŁODARCZYK, J. (2018a). Demographics, retirement age, and real interest rates in Poland. *Central European Journal of Economic Modelling and Econometrics*, 10(4): 355-185.

______ (2018b). Demographics and Real Interest Rates in Euro Area Countries. Mimeo.

ACEMOĞLU, D. and RESTREPO, P. (2017). Secular stagnation? The effect of aging on economic growth in the age of automation. *The American Economic Review*, 107(5): 174-179.
AKSOY, Y., BASSO, H. S., SMITH, R. P. and GRASL, T. (2019). Demographic structure and macroeconomic trends. *American Economic Journal: Macroeconomics*, 11(1): 193-222.
ANDO, A. and MODIGLIANI, F. (1963). The "Life-Cycle" hypothesis of saving: Aggregate implications and tests. *The American Economic Review*, 53: 55-84.
BACKUS, D., COOLEY, T. and HENRIKSEN, E. (2014). Demography and low-frequency capital flows. *Journal of International Economics*, 92(1): 94-102.
BÁRÁNY, Z., COEURDACIER, N. and GUIBAUD, S. (2018). Capital Flows in an Aging World. CEPR Discussion Papers No. 13180, Centre for Economic Policy Research.
BARR, N. (2000). Reforming Pensions: Myths, Truths, and Policy Choices. IMF Working Paper No. WP/00/139, International Monetary Fund.
BARR, N. and DIAMOND, P. (2006). The economics of pensions. *Oxford Review of Economic Policy*, 22(1): 15-39.
BLOOM, D. E., CANNING, D. and FINK, G. (2010). Implications of population ageing for economic growth. *Oxford Review of Economic Policy*, 26: 583-612.
BLOOM, D. E., KUHN, M. and PRETTNER, K. (2018) Health and Economic Growth. IZA Discussion Paper No. 11939.
BRAUN, R., IKEDA, D. and JOINES, D. H. (2009). The saving rate in Japan: Why it has fallen and why it will remain low? *International Economic Review*, 50: 291-321.
BROOKS, R. (2003). Population aging and global capital flows in a parallel universe. *IMF Staff Papers*, 50(2): 200-221.
CAI, J. and STOYANOV, A. (2016). Population aging and comparative advantage. *Journal of International Economics*, 102: 1-21.
CARVALHO, C., FERRERO, A. and NECHIO, F. (2016). Demographics and real interest rates: Inspecting the mechanism. *European Economic Review*, 88: 208-226.
D'ADDIO, A. C., KEESE, M. and WHITEHOUSE, E. (2010). Population ageing and labour markets. *Oxford Review of Economic Policy*, 26: 613-635.
D'ALBIS, H., LAU, S.-H. P. and SANCHEZ-ROMERO, M. (2012). Mortality transition and differential incentives for early retirement. *Journal of Economic Theory*, 147(1): 261-283.
DA SILVA FRANCISCO, A. A. (2017). 'Gerontogrowth' and population ageing in Africa and the Global AgeWatch Index. *The Journal of the Economics of Ageing*, 9: 78-89.
DANZIGER, S., VAN DER GAAG, J., SMOLENSKY, E. and TAUSSIG, M. K. (1982). The life-cycle hypothesis and the consumption behavior of the elderly. *Journal of Post Keynesian Economics*, 5: 208-227.
DAVIES, R. and REED, R. R. III. (2006). Population Aging, Foreign Direct Investment, and Tax Competition. Technical Report 1HPWP 07/10, SAID Business School.
DÍAZ-GIMÉNEZ, J. and DÍAZ-SAAVEDRA, J. (2009). Delaying retirement in Spain. *Review of Economic Dynamics*, 12(1): 147-167.
EGGERTSSON, G. B., MEHROTRA, N. R. and ROBBINS, J. A. (2017). A Model of Secular Stagnation: Theory and Quantitative Evaluation. Working Paper No. 23093, National Bureau of Economic Research.
FEHR, H., KALLWEIT, M. and KINDERMANN, F. (2012). Pension reform with variable retirement age: A simulation analysis for Germany. *Journal of Pension Economics and Finance*, 11(3): 389-417.
GAGNON, E., JOHANNSEN, B. K. and LOPEZ-SALIDO, D. (2016). Understanding the New Normal: The Role of Demographics. Working Paper No. 2016–080, Board of Governors of the Federal Reserve System.
GERTLER, M. (1999). Government debt and social security in a life-cycle economy. *Carnegie-Rochester Conference Series on Public Policy*, 50: 61-110.
GOODHART, C. and PRADHAN, M. (2017). Demographics will Reverse Three Multi-Decade Global Trends. BIS Working Papers, 656. Basel: Bank for International Settlements.
GUEST, R. S. (2006). Population ageing, capital mobility and optimal saving. *Journal of Policy Modeling*, 28: 89-102.
HANSEN, A. H. (1939). Economic progress and declining population growth. *The American Economic Review*, 29: 1-15.
IKEDA, D. and SAITO, M. (2014). The effects of demographic changes on the real interest rate in Japan. *Japan and the World Economy*, 32: 37-48.
KARA, E. and VON THADDEN, L. (2016). Interest rate effects of demographic changes in a New Keynesian life-cycle framework. *Macroeconomic Dynamics*, 20: 120-164.
KARRA, M., CANNING, D. and WILDE, J. (2017). The effect of fertility decline on economic growth in Africa: A macrosimulation model. *Population and Development Review*, 43: 237-263.
KEYNES, J. M. (1978). Some economic consequences of a declining population. *Population and Development Review*, 4: 517-523.
KRUEGER, D. and LUDWIG, A. (2007). On the consequences of demographic change for rates of returns to capital, and the distribution of wealth and welfare. *Journal of Monetary Economics*, 54: 49-87.
KUDRNA, G. and WOODLand, A. (2011). Economic effects of population growth and ageing in Australia. In A 'Sustainable' Population? – Key Policy Issues. Canberra: Productivity Commission, 41–56. https://www.pc.gov.au/research/supporting/sustainable-population/sustainable-population-proceedings.pdf
LENEHAN, A. J. (1996). The macroeconomic effects of the postwar baby boom: Evidence from Australia. *Journal of Macroeconomics*, 18: 155-169.

LISENKOVA, K., MERETTE, M. and WRIGHT, R. (2012). The Impact of Population Ageing on the Labour Market: Evidence from Overlapping Generations Computable General Equilibrium (OLG-CGE) Model of Scotland. Technical report, Scottish Institute for Research in Economics (SIRE).
MARQUEZ, P. V. and FARRINGTON, J. L. (2013). The Challenge of Non-Communicable Diseases and Road Traffic Injuries in Sub-Saharan Africa. An Overview. Washington, DC: The World Bank.
MCMILLAN, H. M. and BAESEL, J. B. (1990). The macroeconomic impact of the baby boom generation. *Journal of Macroeconomics*, 12: 167-195.
MESSKOUB, M. (1999). Crisis of ageing in less developed countries: Too much consumption or too little production? *Development and Change*, 30: 217-235.
MILES, D. K. (1999). Modelling the impact of demographic change upon the economy. *Economic Journal*, 109: 1-36.
MODIGLIANI, F. and BRUMBERG, R. H. (1954). Utility analysis and the consumption function: An interpretation of cross-section data. In Kurihara, K. K. (ed), Post-Keynesian Economics. New Brunswick, NJ: Rutgers University Press, 388-436.
MUCHIRI, S. and GAREN, J. (2018). Social transfer benefits and retirement decisions: Evidence from South Africa. *South African Journal of Economics*, 86: 23-52.
MUNOZMORENO, R., TandRAYEN-RAGOOBUR, V., SEETANAH, B. and SANNASSEE, R. V. (2014). Chapter 6 – Demographic Transition and Savings Behavior in Mauritius. In Arouri, M., S. Boubaker and D. Nguyen (eds), Emerging Markets and the Global Economy. San Diego: Academic Press, 115-141.
NAGARAJAN, R., TEIXEIRA, A. A. C. and SILVA, S. (2017). The impact of population ageing on economic growth: A bibliometric survey. *The Singapore Economic Review*, 62: 275-296.
NATIONAL PENSIONS ACT. (1976). Ministry of Social Integration, Social Security and National Solidarity. http://socialsecurity.govmu.org/ (with further amendments).
OECD. (2019). Pensions at a Glance 2019: OECD and G20 Indicators. Paris: OECD Publishing.
PILLAY, N. K. and MAHARAJ, P. (2013). Population ageing in Africa. In P. Maharaj (ed), Aging and Health in Africa. International Perspectives on Aging, Vol. 4. Boston: Springer, 11–51.
SANCHEZ-ROMERO, M. (2013). The role of demography on per capita output growth and saving rates. *Journal of Population Economics*, 26: 1347-1377.
SIMMONS, S. S. (2019). The contributions of the leading causes of death to the life expectancy gap in Mauritius from 2005 to 2015. *International Journal of Medical Research & Health Sciences*, 8(3): 179-187.
SOTO, M., THAKOOR, V. and PETRI, M. (2015). Pension Reforms in Mauritius: Fair and Fast-Balancing Social Protection and Fiscal Sustainability. IMF Working Paper No. 15/126.
STATISTICS MAURITIUS. (2018). Gender Statistics. http://statsmauritius.govmu.org.
SVIRYDZENKA, K. and PETRI, M. (2017). Mauritius: The drivers of growth – Can the past be extended? *Journal of Banking and Financial Economics*, 2: 54-83.
UNITED NATIONS. (2017). World Population Prospects: The 2017 Revision. Department of Economic and Social Affairs, Population Division. https://population.un.org.
______. (2019). World Population Prospects 2019. Department of Economic and Social Affairs, Population Division. https://population.un.org.
WHO. (2014). Noncommunicable Diseases Country Profiles. Geneva: WHO.
______. (2018). Countries: Mauritius. https://www.who.int/countries/mus/en/.
WILLIAMSON, J. G. (2013). Demographic dividends revisited. *Asian Development Review*, 30(2): 1-25.
ZHU, F. (2016). Understanding the Changing Equilibrium Real Interest Rates in Asia-Pacific. Working Paper Series 567, Bank of International Settlements.

APPENDIX A

DERIVATION OF THE MODEL'S EQUATIONS

This appendix contains the detailed description and derivation of the model used in the paper, which is based on Acedański and Włodarczyk (2018a). The model distinguishes the three standard types of economic agents: households (workers and retirees), firms and the government.

A.1 Households

The economy is inhabited by a continuum of households who are either workers (w) or retirees (r). The masses of workers and retirees in period t–1 are denoted by N^w_{t-1} and N^r_{t-1}, respectively. In period t, a worker remains in the labour force with probability ω_t and retires otherwise. The life length of a retiree is stochastic and the probability of surviving from period t–1 to period t is denoted by γ_t. To facilitate aggregation, both probabilities, ω_t and γ_t, are constant across individuals and independent of their age. In every period t, a fraction of $(n_t+\gamma_t)$ working households supplies the labour force and a fraction γ_t retires, which gives the *net* growth rate of the mass of workers equal to n_t:

$$N_t^w = \left(1+n_t\right) N_{t-1}^w. \tag{A.1}$$

The evolution of the number of retirees is given by:

$$N_t^r = \left(1-\omega_t\right) N_{t-1}^w + \gamma_t N_{t-1}^r. \tag{A.2}$$

The demographic structure of the population is represented by the retirement-age dependency ratio defined as the ratio of retired population to the number of workers:

$$\psi_t \equiv \frac{N_t^r}{N_t^w} = \frac{1-\omega_t}{1+n_t} + \frac{\gamma_t}{1+n_t}\psi_{t-1}. \tag{A.3}$$

This measure differs from the old-age dependency ratio discussed in Section 3 of the study (Table 1), because ψ_t is based on the actual status on the labour market, while the old-age dependency ratio refers simply to the age of individuals. Formally, n_t represents the growth rate of the working population. However, in the steady state of the model it also coincides with the growth rate of the total population as shown and discussed in Appendix B.

Following Carvalho *et al.* (2016), we assume that the retirement probability depends on the surviving probability. More specifically:

$$\omega_t = \omega_{init} + \iota\left(\gamma_t/\gamma_{init} - 1\right), \tag{A.4}$$

where ι governs sensitivity of ω_t to changes in γ_t and ω_{init} and γ_{init} denote initial values of ω_t and γ_t. The initial values, which are the starting point of the simulations, coincide with the model's steady state. This specification captures the increase in retirement age implemented lately as a remedy to pension systems imbalances in many developed countries. As the robustness check, we also consider an alternative specification of the following form:

$$\omega_t = 1 - \frac{1}{\frac{\theta}{1-\theta}\left(\frac{1}{1-\gamma_t} - \frac{1}{1-\gamma_{init}}\right) + \frac{1}{1-\omega_{init}}}. \tag{A.100}$$

This specification implies that, on average, a fraction θ of the increasing life span is spent on the labour market and the remaining (1–θ) extends the retirement duration.

Households' preferences are described by a non-expected risk neutral utility function that takes the following recursive form:

$$V_t^z = \begin{cases} \{(C_t^w)^\sigma + \beta\left[\omega_{t+1} V_{t+1}^w + \left(1-\omega_{t+1}\right) V_{t+1}^r\right]^\sigma\}^{\frac{1}{\sigma}} & \text{if}\, z = w, \\ \{(C_t^r)^\sigma + \beta\gamma_{t+1}(V_{t+1}^r)^\sigma\}^{\frac{1}{\sigma}} & \text{if}\, z = r, \end{cases} \tag{A.5}$$

where $z = \{w, r\}$, C_t^z denotes consumption of the group z and V_t^z is the value function. The expression $(1–\sigma)$ is the inverse of elasticity of intertemporal substitution. The difference in the effective discount rates between workers (β) and retirees ($\beta\gamma_{t+1}$) reflects the death probability in the latter group. Retirees cannot return to the workers' group and their expected value part of the equation (A.5) is simpler.

A.1.1. Retirees Income of a retired household consists of a pension and interest on accumulated wealth. The wealth is stored in the form of physical capital K and one-period risk-free bonds B issued by the government. Additionally, agents have access to the international financial market where they can borrow capital paying a premium $P(F)$ over the world interest rate R^*, where F denotes total foreign assets in the economy. It is assumed that at the beginning of each period retirees invest their total wealth into investment funds operating on a perfectly competitive market that pay back a premium over the market return equal to $1/\gamma_t$. This compensates for the probability of death. Wealth of a dead household is collected by the government and spent on public consumption. A slightly more realistic assumption that bequests are distributed equally across workers does not change the main results, as documented by Acedański and Włodarczyk (2018b).

In period t, the decision problem of a retiree born in period j and retired in period τ takes the following form:

$$\max_{C_t^r(j,\tau), K_t^r(j,\tau), B_t^r(j,\tau), F_t^r(j,\tau)} \{(C_t^r\left(j,\tau\right))^\sigma + \beta\gamma_{t+1}[V_{t+1}^r\left(j,\tau\right)]^\sigma\}^{\frac{1}{\sigma}}, \tag{A.6}$$

subject to:

$$C_t^r\left(j,\tau\right) + K_t^r\left(j,\tau\right) + B_t^r\left(j,\tau\right) - F_t^r\left(j,\tau\right) = \frac{\left(1-\delta+R_t^K\right) K_{t-1}^r\left(j,\tau\right) + R_{t-1} B_{t-1}^r\left(j,\tau\right) - \left[R_{t-1}^* + P\left(F_{t-1}\right)\right] F_{t-1}^r\left(j,\tau\right)}{\gamma_t} + E_t^r, \tag{A.7}$$

where C_t^r is consumption, F_t^r – foreign assets, R_t^K and R_t denote the interest rates on capital and bonds, respectively, E_t^r stands for the lump-sum pension transfer and δ is the capital depreciation rate.

The Euler equations for capital, bonds and foreign assets imply that the interest rates on all assets are equal:

$$R_t = R_{t+1}^K + 1 - \delta = R_t^* + P\left(F_t\right). \tag{A.8}$$

From the first order optimality conditions one can derive the consumption function for retirees:

$$C_t^r\left(j,\tau\right)=\xi_t^r\left[\frac{R_{t-1}A_{t-1}^r\left(j,\tau\right)}{\gamma_t}+S_t^r\right], \tag{A.9}$$

where $A_t^r\left(j,\tau\right)=K_t^r\left(j,\tau\right)+B_t^r\left(j,\tau\right)-F_t^r\left(j,\tau\right)$ denotes total assets of the household, S_t^r is the present discounted value of pension transfers:

$$S_t^r=E_t^r+\frac{S_{t+1}^r\gamma_{t+1}}{R_t} \tag{A.10}$$

and ξ_t^r denotes the marginal propensity to consume satisfying the following first-order difference equation:

$$\xi_{t+1}^r\left(\frac{R_tA_t^r\left(j,\tau\right)}{\gamma_{t+1}}+S_{t+1}^r\right)=\left(\beta R_t\right)^\sigma\xi_t^r\left(\frac{R_{t-1}A_{t-1}^r\left(j,\tau\right)}{\gamma_t}+S_t^r\right). \tag{A.11}$$

A.1.2. Workers Workers enter the labour market with no assets and inelastically supply one unit of labour in each period. Their income consists of wage and interest on assets. The decision problem of a worker born in period j expressed in terms of total assets: $A_t^w\left(j\right)\equiv K_t^w\left(j\right)+B_t^w\left(j\right)-F_t^w\left(j\right)$ can be written as:

$$\max_{C_t^w(j),A_t^w(j)}\left\{\left(C_t^w(j)^\sigma+\beta\left[\omega_{t+1}V_{t+1}^w\left(j\right)+\left(1-\omega_{t+1}\right)V_{t+1}^r\left(j,t+1\right)\right]^\sigma\right\}^{\frac{1}{\sigma}}, \tag{A.12}$$

subject to:

$$C_t^w\left(j\right)+A_t^w\left(j\right)=R_{t-1}A_{t-1}^w\left(j\right)+W_t-T_t^w, \tag{A.13}$$

where W_t denotes the wage and T_t^w stands for lump-sum taxes.

From the first order conditions, the consumption function of a worker takes the following form:

$$C_t^w\left(j\right)=\xi_t^w\left[R_{t-1}A_{t-1}^w\left(j\right)+H_t^w+S_t^w\right], \tag{A.14}$$

where ξ_t^w denotes the marginal propensity to consume of a worker whereas H_t^w and S_t^w are the discounted present values of future wages net of taxes and pension benefits, respectively, defined as:

$$H_t^w\equiv W_t-T_t^w+\sum_{v=1}^{\infty}\frac{\left(W_{t+v}-T_{t+v}^w\right)}{\prod_{s=1}^{v}\frac{\Omega_{t+s}R_{t+s-1}}{\omega_{t+s}}}=W_t-T_t^w+\frac{\omega_{t+1}H_{t+1}^w}{\Omega_{t+1}R_t} \tag{A.15}$$

$$S_t^w \equiv \frac{(\Omega_{t+1}-\omega_{t+1})S_{t+1}^r}{\Omega_{t+1}R_t} \sum_{v=1}^{\infty} \frac{\frac{(\Omega_{t+v+1}-\omega_{t+v+1})S_{t+v+1}^r}{\Omega_{t+v+1}R_{t+v}}}{\prod_{s=1}^{v}(\Omega_{t+s}R_{t+s-1})} = \frac{(\Omega_{t+1}-\omega_{t+1})S_{t+1}^r}{\Omega_{t+1}R_t} + \frac{\omega_{t+1}S_{t+1}^w}{\Omega_{t+1}R_t} \quad (A.16)$$

with:

$$\Omega_t \equiv \omega + (1-\omega)\left(\frac{\xi_t^r}{\xi_t^w}\right)^{\frac{1}{1-\sigma}}. \quad (A.17)$$

The marginal propensity to consume evolves according to:

$$\frac{1}{\xi_t^w} = 1 + \beta^\sigma (\Omega_{t+1}R_t)^{\sigma-1}\frac{1}{\xi_{t+1}^w}. \quad (A.18)$$

A.1.3. Aggregation The model's specification described above allows for a straightforward aggregation of households' decision rules. The aggregates are denoted without the indices j and τ. The aggregate consumption of workers (C_t^w) and retirees (C_t^r) takes the same form as the consumption of an individual household of a given type:

$$C_t^w = \xi_t^w \left(R_{t-1}\left(1-\lambda_{t-1}\right)A_{t-1} + H_t + \tilde{S}_t\right), \quad (A.19)$$

$$C_t^r = \xi_t^r \left(R_{t-1}\lambda_{t-1}A_{t-1} + S_t\right), \quad (A.20)$$

where λ_t denotes the share of total assets $A_t = A_t^r + A_t^w$ held by retirees. The share evolves according to:

$$\left[\lambda_t - \left(1-\omega_{t+1}\right)\right]A_t = \omega_{t+1}\left[\left(1-\xi_t^r\right)R_{t-1}\lambda_{t-1}A_{t-1} + E_t - \xi_t^r S_t\right]. \quad (A.21)$$

Dynamics of the aggregate non-financial wealth is described by the following equation:

$$H_t = W_t N_t - T_t + \frac{\omega_{t+1}H_{t+1}}{\Omega_{t+1}R_t}, \quad (A.22)$$

while $\tilde{S}_t$ and S_t represent the aggregate discounted future pension benefits of workers and retirees and satisfy the following set of difference equations:

$$\left(1+n_{t+1}\right)\tilde{S}_t = \frac{\left(\Omega_{t+1}-\omega_{t+1}\right)S_{t+1}/\psi_{t+1}}{\Omega_{t+1}R_t} + \frac{\omega_{t+1}\tilde{S}_{t+1}}{\Omega_{t+1}R_t}, \quad (A.23)$$

$$\left(1+n_{t+1}\right)S_t=\left(1+n_{t+1}\right)E_t+\frac{\psi_t S_{t+1}\gamma_{t+1}}{\psi_{t+1}R_t}. \tag{A.24}$$

Finally, dynamics of the aggregate discounted future wages net of taxes H_t is governed by the following equation:

$$\left(1+n_{t+1}\right)H_t=\left(1+n_{t+1}\right)W_tN_t^w-\left(1+n_{t+1}\right)T_t+\frac{\omega_{t+1}H_{t+1}}{\Omega_{t+1}R_t}. \tag{A.25}$$

A.2 Production Sector

The perfectly competitive production sector uses capital and labour to produce a homogeneous final good. The production technology is described by the standard Cobb-Douglas function with labour-augmenting technological progress:

$$Y_t=K_{t-1}^{\alpha}(X_tN_t^w)^{1-\alpha}, \tag{A.26}$$

where α is the capital share and X_t represents the technological progress with the constant growth rate x:

$$X_t=(1+x)X_{t-1}. \tag{A.27}$$

Factor prices are equal to the marginal productivities of capital and labour:

$$R_t^K=\alpha\frac{Y_t}{K_{t-1}}, \tag{A.28}$$

$$W_t=(1-\alpha)\frac{Y_t}{N_t^w}. \tag{A.29}$$

The final good is used for consumption and investment purposes.

A.3 Government

The public pension system in the model takes a form of the standard unfunded PAYG scheme. The government levies lump-sum taxes T_t to finance pensions E_t and public consumption that is proportional to output $G_t=gY_t$. It also issues one-period bonds. The amount of government debt is assumed to be constant and proportional to the output:

$$B_t=bY_t. \tag{A.30}$$

The government budget takes the following form:

$$T_t+B_t=R_{t-1}B_{t-1}+G_t+E_t. \tag{A.31}$$

A.4 World Interest Rate and the Risk Premium

As already mentioned in the introduction, the domestic interest rate R is endogenous due to imperfect capital mobility. Accordingly,

$$R_t = R_t^* + P\left(F_t\right), \tag{A.32}$$

where the dynamics of the world interest rate R^* is treated as exogenous, while the risk premium $P(F)$ in the baseline version of the model is given by:

$$P\left(F_t\right) \equiv \phi \frac{F_t}{Y_t}, \tag{A.33}$$

where ϕ represents the economy's degree of openness. If $\phi = 0$ there is no premium at all and $R_t = R_t^*$. On the contrary, if $\phi \to \infty$ the economy is autarkic and $F_t \to 0$.

The specification given by equation (A.33) allows the domestic interest rate to fall below the world's one which seems unlikely to happen. Therefore, we also try an alternative specification that always keeps the domestic rate above the world's one:

$$P_{alt}\left(F_t\right) \equiv \phi_1 \exp\left(\phi_2 \frac{F_t}{Y_t}\right), \tag{A.34}$$

where the parameters ϕ_1 and ϕ_2 govern sensitivity and speed of the domestic rate adjustment.

A.5 Equilibrium

Given the demographic processes represented by n_t, ω_t, γ_t and ψ_t as well as the technological growth rate of the economy x and the world interest rate R^*, a competitive equilibrium for this economy is a sequence of quantities $\{C_t^r, C_t^w, A_t, \lambda_t, H_t, Y_t, K_t, I_t, B_t, T_t, F_t\}$, marginal propensities to consume $\{\xi_t^r, \xi_t^w, \Omega_t\}$ and prices $\{R_t, R_t^K, W_t\}$ such that:

1. Taking the prices as given, households maximise lifetime utility subject to their budget constraints.
2. Firms maximise profits subject to their technology.
3. The government chooses taxes to satisfy its budget constraint.
4. The markets clear and the resource constraint is satisfied:

$$Y_t = C_t + I_t + G_t + \left[R_{t-1}^* + P\left(F_{t-1}\right)\right] F_{t-1} - F_t, \tag{A.35}$$

where:

$$I_t = K_t - (1-\delta) K_{t-1}. \tag{A.36}$$

To find the time-invariant solution of the model, stationary variables $s_t \equiv S_t / \left(X_t N_t^w\right)$ are introduced where necessary.

A.6. Exogenous Shocks

It should be noted that there is no aggregate uncertainty in the model presented so far and the equilibrium discussed above can be viewed as a perfect foresight one. In order to study the effects of the changes in demographic characteristics, we consider a single unexpected shock for n_t and γ_t that generates a long-lasting hump-shaped response in these characteristics. To capture the impact of the decreasing world interest rate, a similar shock for R_t^* is introduced. More specifically, it is assumed that the stochastic processes can be characterised by:

$$n_t = \left(1 + n_{init}\right) \exp\left(u_{nt} - v_{nt}\right) - 1, \tag{A.37}$$

$$\gamma_t = \gamma_{init} \exp\left(u_{\gamma t} - v_{\gamma t}\right), \tag{A.38}$$

$$R_t^* = R_{init}^* \exp\left(u_{R^* t} - v_{R^* t}\right), \tag{A.39}$$

where n_{init}, γ_{init} and R_{init}^* stand for the initial levels of the these characteristics and:

$$u_{it} = \rho_{ui} u_{it-1} + \varepsilon_{it}, \left|\rho_{ui}\right| < 1, \tag{A.40}$$

$$v_{it} = \rho_{vi} v_{it-1} + \varepsilon_{it}, \left|\rho_{vi}\right| < 1, \tag{A.41}$$

where:

$$\varepsilon_{it} = \begin{cases} e_{i0} & \text{if } t = 0, \\ 0 & \text{otherwise} \end{cases} \tag{A.42}$$

for $i = \{n, \gamma, R^*\}$.

The three shocks can be related to the channels through which demography is linked with interest rates. The population growth rate shock affects labour supply. The surviving probability shock impacts expected retirement duration and, obviously, the world's interest rate shocks determines global interest rates.

A.7 Simulations of the Model

The model consists of the following equations: (A.3, A.4), (A.8), (A.11), (A.17–A.21), (A.23–A.26), (A.28–A.33), and (A.35–A.42). Conditional on the realisations of the shocks, it forms the set of deterministic, nonlinear difference equations. The steady state of the model is defined as the fixed point of the model in the case of no stochastic shocks: $e_{it} = 0$. In this case, all stationary variables are constant: $s_t = s_{t+1} = \bar{s}$. Steady state can be found by solving numerically the static (time-invariant) version of the model.

We assume that the economy starts in the steady state. In the initial period, it is hit by the demographic shocks e_{i0}. We simulate the trajectories of the model variables for the next 1000 periods by solving a large set of equations that consists of the model equations for all periods together. The long horizon of the simulations ensures that eventually the model reverts to the steady state. However, we show the results for the first 100 periods which coincide with the horizon of the population projection. The simulations are performed in Dynare package for Matlab (see https://www.dynare.org/).

APPENDIX B

THE RELATIONSHIP BETWEEN THE TOTAL AND THE WORKING POPULATION GROWTH RATES IN THE MODEL

In this Appendix, we show that in the steady state, when the demographic parameters are constant, the working population growth rate coincides with the total population growth rate.

Using the definition of the retirement-age dependency ratio given by equation (A.3) and assuming $\omega_t = \omega$, $n_t = n$ and $\gamma_t = \gamma$, for all t, we get:

$$\psi_t \equiv \frac{N_t^r}{N_t^w} = \frac{1-\omega}{1+n} + \frac{\gamma}{1+n}\psi_{t-1} = \frac{1-\omega}{1+n}\sum_{i=0}^{t-1}\left(\frac{\gamma}{1+n}\right)^i + \left(\frac{\gamma}{1+n}\right)^t \psi_0. \tag{B.1}$$

The growth rate of the total population g_t can be expressed as:

$$g_t \equiv \frac{N_t^w + N_t^r}{N_{t-1}^w + N_{t-1}^r} = \frac{\frac{N_t^w}{N_t^w} + \frac{N_t^r}{N_t^w}}{\frac{N_{t-1}^w}{N_t^w} + \frac{N_{t-1}^r}{N_t^w}} = \frac{1+\psi_t}{\frac{1}{1+n} + \frac{1}{(1+n)}\psi_{t-1}} = (1+n)\frac{1+\psi_t}{1+\psi_{t-1}}, \tag{B.2}$$

where we use equation (A.1) for the dynamics of the number of workers N_t^w. Since $0 < \frac{\gamma}{1+n} < 1$ and:

$$\lim_{t\to\infty}\psi_t = \frac{1-\omega}{1+n}\lim_{t\to\infty}\sum_{i=0}^{t-1}\left(\frac{\gamma}{1+n}\right)^i = \frac{1-\omega}{1+n}\cdot\frac{1+n}{1+n-\gamma} = \frac{1-\omega}{1+n-\gamma} < \infty, \tag{B.3}$$

then:

$$\lim_{t\to\infty} g_t = (1+n)\frac{1+\lim_{t\to\infty}\psi_t}{1+\lim_{t\to\infty}\psi_{t-1}} = 1+n. \tag{B.4}$$

This result suggests that the parameters governing the population growth rate n_{init}, u_{nt} and $v_{nt}v_{nt}$ should be calibrated using the total population data.

APPENDIX C

CALIBRATION OF THE MODEL PARAMETERS

In this Appendix, we present the values of parameters described in Appendix A used in the simulations for Mauritius (Table C1). Corresponding values for developed countries are presented in Acedański and Włodarczyk (2018a).

Table C1. Calibration of the model

Symbol	Description	Values for Mauritius
Demographic characteristics		
$1-\omega_{init}$	Initial retirement probability	0.0250
n_{init}	Initial growth rate of the working population	0.0100
γ_{init}	Initial survival probability	0.8345
ρ_{un}	Autocorrelation of the u_{nt} process	0.9873
ρ_{vn}	Autocorrelation of the v_{nt} process	0.9898
$\rho_{u\gamma}$	Autocorrelation of the $u_{\gamma t}$ process	0.9885
$\rho_{v\gamma}$	Autocorrelation of the $v_{\gamma t}$ process	0.9906
e_{n0}	Realisation of the ε_{n0} shock	0.1957
$e_{\gamma 0}$	Realisation of the $\varepsilon_{\gamma 0}$ shock	−1.7412
ι	Sensitivity of ω_t to γ_t	0.0293
Preferences and technology		
β	Discount factor	1.0320
$1-\sigma$	Inverse of elasticity of intertemporal substitution	0.5
α	Capital share	0.350
δ	Capital depreciation rate	0.07
x	Technology growth rate	0.012
Government characteristics		
g	Share of government consumption in GDP	0.14
b	Government debt to GDP	0.35
E	Aggregate pension transfers to GDP	0.0200
World interest rate		
ρ_{uR^*}	Autocorrelation of the u_{R^*t} process	0.9916
ρ_{vR^*}	Autocorrelation of the v_{R^*t} process	0.9909
e_{R^*0}	Realisation of the ε_{R^*0} shock	−0.9177
Risk premium		
ϕ	Degree of economy openness (baseline scenario)	0.018
ϕ_1	Degree of economy openness (alternative scenario)	0.01
ϕ_2	Degree of economy openness (alternative scenario)	0.50

Source: Authors' elaboration.