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Demographic Transition and Pension Reforms: Adding Demographics to GIMF

by Benjamin Carton, Emilio Fernandez-Corugedo, Benjamin Hunt and Simon Voigts

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Demographic Transition and Pension Reforms: Adding Demographics to GIMF

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Abstract

The Global Integrated Monetary and Fiscal model (GIMF) is a multi-region, forward-looking, DSGE model developed at the International Monetary Fund for policy analysis and international economic research. This paper documents the incorporation of demographic features into the model. The analysis presented illustrates how these new features enable the model to estimate some of the macroeconomic consequences of changing demographics.

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CONTENTS

I. INTRODUCTION

Given the large demographic changes underway in the global economy, to support its bilateral and multilateral surveillance obligations the IMF needs to have more tools to analyze the global macroeconomic implications of demographic developments. This paper documents the changes made to incorporate demographic features into one of the International Monetary Fund's main workhorse global macroeconomic models, the Global Integrated Monetary and Fiscal model (GIMF).

The original GIMF model, as documented by Kumhof and others (2010) and Anderson and others (2013), and extended by Carton and others (2017) assumes a Blanchard-Yaari overlapping-generation household sector where the two main parameters driving the demographic structure, the population growth rate and the probability to survive, are constant (Yaari, 1965 and Blanchard, 1985). This paper documents the extension of the model that includes introducing time-varying birth and survival rates, the introduction of an age-decreasing hours supply to account for retirement, and the introduction of a pay-as-you-go pension system to more fully capture the fiscal implications of aging.

A fully-fledged demographic structure would track, year-by-year, the growth rate of the total population and the age pyramid, i.e. the repartition by age of the total population. In contrast, this paper introduces a simplified demographic structure allowing the model to capture the impact of dynamics in three demographic variables: the total population growth rate, the average age, and the share of the working-age in the total population. These three variables are key to explaining the growth rate of labor supply, the aggregate saving rate and the fiscal implications of a public pay-as-you-go public pension system. However, this structure does not allow for a precise analysis of inter-generational redistributive effects of macroeconomic shocks or policy reforms. Its parsimonious nature means that analysis can be conducted within a multi-regional framework that will allow for the assessment of the global general equilibrium implications of country and regional differences in demographic trends.

In addition to detailing how these demographic features are introduced into the model, this paper illustrates how these features allow the model to estimate the macroeconomic impact of demographic change. The simulations considered show how changes in population and labor force have important implications for growth, savings and investment, real interest rates, and fiscal policy.

The rest of the paper is organized as follows. Section II presents an overview of GIMF. Section III documents the changes made to the model to incorporate demographic features. Section IV presents some simulations that illustrate the model's adjustment properties to shocks to the key parameters that embody demographic change. Section V concludes. Appendix I provides details of the algebraic derivation associated with the introduction of demographic features into the model.

II. SUMMARY OF THE GLOBAL INTEGRATED MONETARY AND FISCAL MODEL[2]

GIMF is a multicountry DSGE model with optimizing behavior by households and firms, and full intertemporal stock-flow accounting. Frictions in the form of sticky prices and wages, real adjustment costs, liquidity-constrained households, along with finite-planning horizons of households, provide a role for monetary and fiscal policy in economic stabilization.

The assumption of finite horizons separates GIMF from standard monetary DSGE models and allows it to have well-defined steady states where countries can be long-run debtors or creditors. This allows users to study the transition from one steady state to another where fiscal policy and private saving behavior play a critical role in both the dynamics and long-run comparative statics.[3]

The non-Ricardian features of the model provide non-neutrality in both spending-based and revenue-based fiscal measures, which makes the model particularly suitable to analyze fiscal policy questions. Fiscal policy can stimulate the level of economic activity in the short run, but sustained government deficits crowd out private investment and net foreign assets in the long run.[4] Sustained fiscal deficits in large economies can also lead to a higher world real interest rate, which is endogenous.

Asset markets are incomplete in the model. Government debt is only held domestically, as nominal, non-contingent, one-period bonds denominated in domestic currency. The only assets traded internationally are nominal, non-contingent, one-period bonds denominated in U.S. dollars that can be issued by the U.S. government and by private agents in any region. Firms are owned domestically. Equity is not traded in domestic financial markets; instead, households receive lump-sum dividend payments.

Firms employ capital and labor to produce tradable and nontradable intermediate goods. There is a financial sector a la BGG that incorporates a procyclical financial accelerator, with the cost of external finance facing firms rising with their indebtedness.

GIMF is multi-region, encompassing the entire world economy, explicitly modeling all the bilateral trade flows and their relative prices for each region, including exchange rates. The

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[2] For detailed documentation on the structure of the model see Kumhof and others (2010) and Carton and others (2017). For details on the model's properties see Anderson and others (2013) and Carton and others (2017).

[3] See Blanchard (1985) for the basic theoretical building blocks and Kumhof and Laxton (2007, 2009a, 2009b) to understand their fiscal policy implications.

[4] Coenen and others (2010) show that GIMF fiscal multipliers for temporary shocks are similar to standard monetary business cycle models, but more importantly, GIMF can handle a much broader array of permanent shocks that can be used to study transitions from one steady state to another caused by permanent changes in the level of government debt.

version used in this paper comprises 3 regions with different calibrations for ease of exposition. The international linkages in the model allow the analysis of policy spillovers at the regional and global level.

A. HOUSEHOLD SECTOR

There are two types of households, both of which consume goods and supply labor. First, there are overlapping-generation households (OLG) that optimize their borrowing and saving decisions over a 20-year planning horizon. Second, there are liquidity-constrained households (LIQ), who do not save and have no access to credit. All households pay direct taxes on labor income, indirect taxes on consumption spending, and a lump-sum tax.

OLG households save by acquiring domestic government bonds, international U.S. dollar bonds, and through fixed-term deposits. They maximize their utility subject to their budget constraint. Aggregate consumption for these households is a function of financial wealth and the present discounted value of after-tax wage, pension, and investment income. The consumption of LIQ households is equal to their current net income, so their marginal propensity to consume out of current income is unity. A high proportion of LIQ households in the population would imply large fiscal multipliers from temporary changes to taxes and transfer payments.

For OLG households with finite planning horizons, a tax cut has a short-run positive effect on consumption. When the cuts are matched with a tax increase in the future, to leave government debt unchanged in the long run, the short-run impact remains positive, as the change will tilt the time profile of consumption toward the present. In effect, OLG households discount future tax liabilities at a higher rate than the market rate of interest. Thus, an increase in government debt today represents an increase in their wealth, because a share of the resulting higher taxes in the future is payable beyond their planning horizon. If the increase in government debt is permanent (tax rates are assumed to rise sufficiently in the long run to stabilize the debt-to-GDP ratio by financing the higher interest burden) this will crowd out real private capital by raising real interest rates.

Increases in the interest rate have a negative effect on consumption, mainly through the impact on the value of wealth. The intertemporal substitution effect from interest rate changes is moderate and has been calibrated to be consistent with the empirical evidence. The intertemporal elasticity of substitution determines the magnitude of the long-run crowding-out effects of government debt since it pins down how much real interest rates have to rise to encourage households to provide the required savings.

B. PRODUCTION SECTOR

Firms produce tradable and nontradable intermediate goods. They are managed in accordance with the preferences of their owners, finitely-lived households. Thus, firms also have finite planning horizons. The main substantive implication of this assumption is the presence of a substantial equity premium driven by impatience.[5] Firms are subjected to nominal rigidities in price setting as well as to real adjustment costs in labor hiring and investment. They pay capital income taxes to governments, wages to all households, and dividends to OLG households.

Retained earnings are insufficient to fully finance investment, so firms must borrow from financial intermediaries. If earnings fall below the minimum required to make the contracted interest payments, the financial intermediaries take over the firm's capital stock, less any auditing and bankruptcy costs, and redistribute it back to their depositors (households).

Firms operate in monopolistically competitive markets, and thus goods' prices contain a markup over marginal cost. Exports are priced to the local destination market and imports are subject to quantity adjustment costs. There are also price adjustment costs which lead to sticky prices.

Firms use public infrastructure (which is the government capital stock) as an input, in combination with tradable and nontradable intermediate goods. Thus, government capital adds to the productivity of the economy.

C. FINANCIAL SECTOR

GIMF contains a limited menu of financial assets. Government debt consists of one-period bonds denominated in domestic currency. Banks offer households one-period fixed-term deposits, their source of funds for loans to firms. These financial assets, as well as ownership of firms, are not tradable across borders. OLG households may, however, issue or purchase tradable U.S.-dollar-denominated obligations.

Banks pay a market rate of return on deposits and charge a risk premium on loans. Because of the costs of bankruptcy (capital can only be liquidated at a discount), the lending rate includes an external financing premium, which varies directly with the debt-to-equity (leverage) ratio—the financial accelerator effect. Non-linearities imply steep increases in the risk premium for large negative shocks to net worth.

Uncovered interest parity may not hold, due to the presence of country risk premiums. The premiums can create deviations, both in the short run and the long run, between interest rates in different regions, even after adjustment for expected changes in exchange rates.

D. INTERNATIONAL DIMENSIONS AND SPILLOVERS

All bilateral trade flows are explicitly modeled, as are the relative prices for each region, including exchange rates. These flows include the export and import of intermediate and final goods. They are calibrated in the steady state to match the flows observed in the recent data.

[5] This feature would disappear if equity was assumed to be traded in financial markets. The assumption of myopic firm behavior, and the resulting equity premium, are more plausible.

International linkages are driven by the global saving and investment decisions, a by-product of consumers' finite horizons. This leads to uniquely defined current account balances and net foreign asset positions for each region. Since asset markets are incomplete, net foreign asset positions are represented by nominal non-contingent one-period bonds denominated in U.S. dollars.

Along with uncovered interest parity and long-term movements in the world real interest rate, the magnitude of the international trade linkages is the main determinant of spillover effects from shocks in one region to other regions in the world.

E. FISCAL AND MONETARY POLICY

Fiscal policy is conducted using a variety of expenditure and tax instruments. Government spending may take the form of either consumption or investment expenditure, or lump-sum transfers to either all households or targeted towards LIQ households. Revenue accrue from taxes on labor and corporate income, consumption taxes, and lumpsum taxes. The model also allows for tariffs on imported goods to be a potential source of public revenue. Government investment spending augments public infrastructure, which depreciates at a constant rate over time.

There is a fiscal policy rule that ensures long-run sustainability, while allowing for short-run counter-cyclical policies. Changes in both labor and capital income taxes provide the instrument to put the rule into effect, but this can be replaced with other tax, transfer or spending instruments if that is considered more realistic for a specific region. First, the fiscal rule ensures that in the long run, the government debt-to-GDP ratio—and hence the deficit-to-GDP ratio—eventually converges to its target level. This excludes the possibility of sovereign default, as well as the risk that out-of-control financing requirements of the government will override monetary policy. Second, the rule allows for countercyclical fiscal policy as it embodies automatic stabilizers.

When conducting monetary policy, the central bank uses an inflation forecast-based interest rate rule. The central bank varies the gap between the actual policy rate and the long-run equilibrium rate to achieve a stable target rate of inflation over time.

III. INTRODUCING DEMOGRAPHIC FEATURES

This section presents the key features of the household sector in GIMF and guidelines to calibrate the new demographic structure to actual data.

A. EVOLUTION OF DEMOGRAPHIC VARIABLES

Total population

The evolution of the population is determined by the annual birth rate b_t and the annual survival probability θ_t, which can now both vary over time. With N_{t-1} denoting the total population in the previous year, total population at t is given by:

$$N_t = n_t N_{t-1},$$

where $n_t = b_t + \theta_t$ is the population growth factor accounting for the birth of newcomers and the death of existing households.

Average age

Newborn households are economic agents immediately entering the labor market and making saving and labor supply decisions. The average age evolves according to:

$$A_t n_t = b_t + (A_{t-1} + 1)\theta_t .$$

From t-1 to t, the share θ_t of surviving households age by one year and there is a share b_t of newcomers who now have spent one year in the labor market. The survival probability does not only affect the average age but also the planning horizon of OLG households, as discussed below.

Working-age population share

As explained in detail later on, the impact of a demographic transition on labor supply is modeled by introducing age-dependency of the hours endowment at the level of individual households. New labor-market-entry households initially work full time but gradually reduce working hours as they age. For each household, the total hours endowment – allocated between work and leisure – decays by the time-variant factor $0 < \chi_t^h < 1$, which represents retirement in the model. Introducing retirement as a gradual process instead of a discreet event keeps the model tractable while allowing us to capture the impact of aging on aggregate labor supply. We interpret s_t, the ratio between the total hours endowment at a given time (net of age-dependent decline) divided by a hypothetical hours endowment measure that would hold if all household were newcomers (or if χ_t^h equaled one), as the share of the population that is of working age. The working-age share of the population s_t evolves according to:

$$n_t s_t = b_t + \theta_t \chi_t^h s_{t-1}.$$

B. THE HOUSEHOLD SECTOR

Relative to the original version of GIMF, the household sector is generalized in that we introduce a demographic dimension by including time-varying birth rates, survival rates, and age-dependent decays in the hours endowment. We also introduce public pensions in the form of a pay-as-you-go pension system with (activity-dependent) public transfers.

Lifetime expected utility

The lifetime expected utility of a representative household of age a at time t has the form:

$$E_t \sum_{s=0}^{\infty} \mathrm{B}_t^{t+s} \Theta_{t+1}^{t+s+1} \frac{1}{1-\gamma} \left(\left(c_{a+s,t+s}^{OLG}\right)^{\eta^{OLG}} \left(S_t^L \mathrm{X}_{t-a,t+s}^h - l_{a+s,t+s}^{OLG}\right)^{1-\eta^{OLG}} \right)^{1-\gamma},$$

where $\mathrm{B}_t^{t+s} = \prod_{k=0}^{s-1} \beta_{t+k}$, $\Theta_{t+1}^{t+s+1} = \prod_{k=1}^{s+1} \theta_{t+k}$ and $\mathrm{X}_{t-a,t+s}^h = \prod_{t-a}^{t+s} \chi_t^h$. B_t^{t+s} captures subjective time discounting, and Θ_{t+1}^{t+s+1} adjusts this discounting for the fact that the probability of being alive in the next period is less than one. The latter captures households' anticipation of their expected lifetime, which plays a key role in their saving behavior. The hours endowment of a cohort of age a is given by $S_t^L \mathrm{X}_{t-a,t+s}^h$, where S_t^L is an exogenous shock term and $\mathrm{X}_{t-a,t+s}^h$ summarizes the decay in the cohort's endowment since its birth (representing a growing propensity to retire). This expression replaces Equation (1) p. 7 of the original GIMF working paper (Kumhof and others, 2010).

The budget constraint

The receipt of a public pension is introduced in the modified budget constraint replacing equation (8) on p. 9 of the original GIMF working paper:

$$(P_t^R + P_t^C) c_{a,t}^{OLG} + \cdots = \cdots + \left(1 - \mathrm{X}_{t-a,t}^h\right) W_{a,t}^p .$$

The receipt of a pension is given by the last term and increases in age as the hours endowment in $\left(1 - \mathrm{X}_{t-a,t}^h\right)$ declines. The effective replacement wage W_t^p is based on the nominal net wage at the time the household was born and allows for a varying degree of indexation since. The details of the implementation are derived in Appendix I.

The per-capita labor endowment

As outline above, the household's hours endowment gradually declines in age. As a further change relative to the original version of GIMF, household productivity is also declining in age, making the economy-wide per-capita labor endowment $\bar{l}_t$ dependent on demographic variables. [6] The productivity and the hours endowments of newcomers are normalized to one. Per-capita labor endowment evolves according to:

$$n_t \bar{l}_t = b_t + \theta_t \chi^a \chi_{t+1}^h \bar{l}_{t-1} .$$

The per-capita labor endowment $\bar{l}_t$ increases in a slower reduction of the individual's age-dependent hours endowment (a decline factor χ^h closer to one), as well as in a slower decline in individual productivity (decline factor χ^a closer to one).

The consumption function

The per-capita consumption function has the same form as in the original version of GIMF. However, the derivation requires more steps as per-capita labor endowment is now time-varying. Instead of having one forward-looking recursive equation for per-capita human wealth, the model now has a forward-looking recursive equation for human wealth per unit of labor endowment, as well as a backward-looking recursive equation for per-capita labor endowment. Per-capita human wealth is then defined as the product of the two.

Human wealth. Each unit of labor endowment pays the after-tax wage of the current period and decays at the rate $\chi^a \chi_{t+1}^h$. Human wealth per unit of labor endowment is thus given by the following recursive equation:

[6] The economy-wide per-capita labor endowment $\bar{l}_t$ is the effective input in the production technology, whereas the term *hours* endowment refers to the actual hours endowment divided between leisure and work.

$$\widetilde{ehw}_t^L = \breve{w}_t(1-\tau_{L,t}) + E_t\left\{\chi^a\chi_{t+1}^h\frac{\theta_{t+1}}{r_t}g_{t+1}\widetilde{ehw}_{t+1}^L\right\}.$$

with $\breve{w}_t(1-\tau_{L,t})$ denoting the net of tax real wage and $\frac{\theta_{t+1}}{r_t}$ the discount factor. Note that the productivity growth factor g_{t+1} accounts for the stationarization of the variable.

Per capita human wealth is the product of the per-capita labor endowment $\bar{l}_t$ and the human wealth per unit of labor endowment:

$$\widetilde{hw}_t^L = \bar{l}_t\widetilde{ehw}_t^L\ ,$$

which replaces equation (23) p.11 of the original paper (written in per-capita terms).

Pension wealth. Pension income received by a household is based on the difference between the hours endowment when the household was a newcomer (entering the labor market) and its current hours endowment. Thus, given that the decline of the labor endowment in age is a gradual process as outlined above, the household receives increasing pension payments throughout its working life. Pension wealth is therefore calculated as the difference between two associated terms, each one coming with a forward-looking and a backward-looking recursive term. The forward-looking terms are given by:

$$\widetilde{epw}_t^1 = \breve{w}_t^p + E_t\left\{\left(\frac{g_{t+1}\breve{w}_{t+1}^p}{\breve{w}_t^p}\right)^{\nu-1}\frac{\theta_{t+1}}{r_t}g_{t+1}\widetilde{epw}_{t+1}^1\right\}, and$$

$$\widetilde{epw}_t^2 = \breve{w}_t^p + E_t\left\{\chi_{t+1}^h\left(\frac{g_{t+1}\breve{w}_{t+1}^p}{\breve{w}_t^p}\right)^{\nu-1}\frac{\theta_{t+1}}{r_t}g_{t+1}\widetilde{epw}_{t+1}^h\right\},$$

where $\breve{w}_t^p$ is the period t policy-driven replacement wage which is a fraction of the current period wage (see Appendix I for details). The backward-looking terms are given by:

$$n_t\bar{p}_t^1 = b_t + \theta_t\left(\frac{g_t\breve{w}_t^p}{\breve{w}_{t-1}^p}\right)^{\nu-1}\bar{p}_{t-1}^1, and$$

$$n_t\bar{p}_t^2 = b_t + \theta_t\chi_t^h\left(\frac{g_t\breve{w}_t^p}{\breve{w}_{t-1}^p}\right)^{\nu-1}\bar{p}_{t-1}^2.$$

Per-capita pension wealth is given by:

$$\widetilde{pw}_t = \bar{p}_t^1\widetilde{epw}_t^1 - \bar{p}_t^2\widetilde{epw}_t^2\ .$$

Equation (20) p. 11, written in per-capita terms, is replaced by:

$$c_t^{OLG}\Theta_t = \widetilde{fw}_t + \widetilde{hw}_t + \widetilde{pw}_t.$$

C. THE GOVERNMENT BUDGET CONSTRAINT

Transfers to households (in a per-capita terms) now include pensions given by

$$\check{t}_t^P = (\bar{p}_t^1 - \bar{p}_t^2)\breve{w}_t^p.$$

In the simulations presented below, lump-sum taxes adjust endogenously to finance pension payments. While this is to reduce complexity and to focus on the immediate impact of changes in demographic variables, GIMF allows for various fiscal instruments to finance the pension system.

D. MULTI-COUNTRY FEATURES

The population growth factor, the planning horizon of households, and the hours endowment decline factor are country/region specific and can be time-varying. The only restrictions are that they stabilize in the long run and, for population growth rates, that they stabilize to a common value in order to ensure the existence of a properly defined final steady state.

In each region/country $r \in R$, the population growth factor is n_t^r and the actual population is N_t^r (we suppress this notation on the other sections). The share swp_t^r of region/country r in the world population is defined by $swp_t^r \equiv N_t^r / N_t$where $N_t = \sum_{r \in R} N_t^r$.

The world population growth factor is defined by:

$$n_t \equiv \sum_{r \in R} swp_{t-1}^r n_t^r \ ,$$

and the share in world population evolves according to

$$swp_t^r = \frac{n_t^r}{n_t} swp_{t-1}^r \ .$$

E. CALIBRATING GIMF DEMOGRAPHIC VARIABLES

Total population

The model encompasses only the working-age population and retirees but abstracts from the young population. Total population for a given region /country is therefore defined as the population above a country-specific age threshold (15 or 20 years). Taking this into account, the share in world population and the population growth factor can be calibrated directly.

Panning horizon

In the model, the annual survival probability determines households' average age and the length of their planning horizon. This double role poses a problem for its calibration: Estimates of the wealth effect on consumption suggest a planning horizon below 20 years whereas the average life expectation for people older than 20 years is between 30 and 35 years in developed countries in the early 2000s. Why, despite their life expectancy, do households have saving decisions planned for a maximum 20 years? Households may make saving decisions over a time horizon shorter that their life expectancy either for cognitive reasons (they don't take into account distant future) or because of the risk of idiosyncratic shocks wiping out their savings.

Agnostic about the origin of the difference, the original GIMF sets the survival probability such that the planning horizon in the steady state equals 20 years, informed by estimates of the wealth effect.

Hours endowment decline factor

Once the total population growth factor and planning horizon have been calibrated, the calibration of the hours endowment decline factor is set to reproduce the share of working age population in the data, i.e. the population above the entry-age in the labor market.

IV. THE PROPERTIES OF DEMOGRAPHIC SHOCKS IN THE MODEL

A demographic transition is a multidimensional phenomenon, but our macroeconomic framework simplifies it to only three factors: changes in the growth rate of the population (the birth rate), in the average age (households' survival probability), and in the share of the working age population (speed of decline in the labor endowment). In the model, any transition is represented by the joint impact of changes in all three of these variables. This section builds intuition by discussing three illustrative simulations, each shocking one demographic variable in a three-country version of the model.

The first simulation assumes a decline in the population growth rate by 0.25 percentage points over 10 years. The second simulation analyzes a permanent increase in the annual survival probability by one percentage point, accompanied by a decline in the birth rate such that population growth remains constant. Finally, the third exercise considers a one-percentage-point increase in the speed by which labor supply declines in age.

A. POPULATION GROWTH

The reduction in the population growth rate is induced by a decline in the birth rate of 0.25 percentage points for 10 years. As the shock affects only the home economy, it has to be temporary in order to guarantee the existence of a final steady state (a permanent shock would cause the country's share in world GDP to approach zero). Figure 1 depicts the adjustment path of key macroeconomic aggregates.

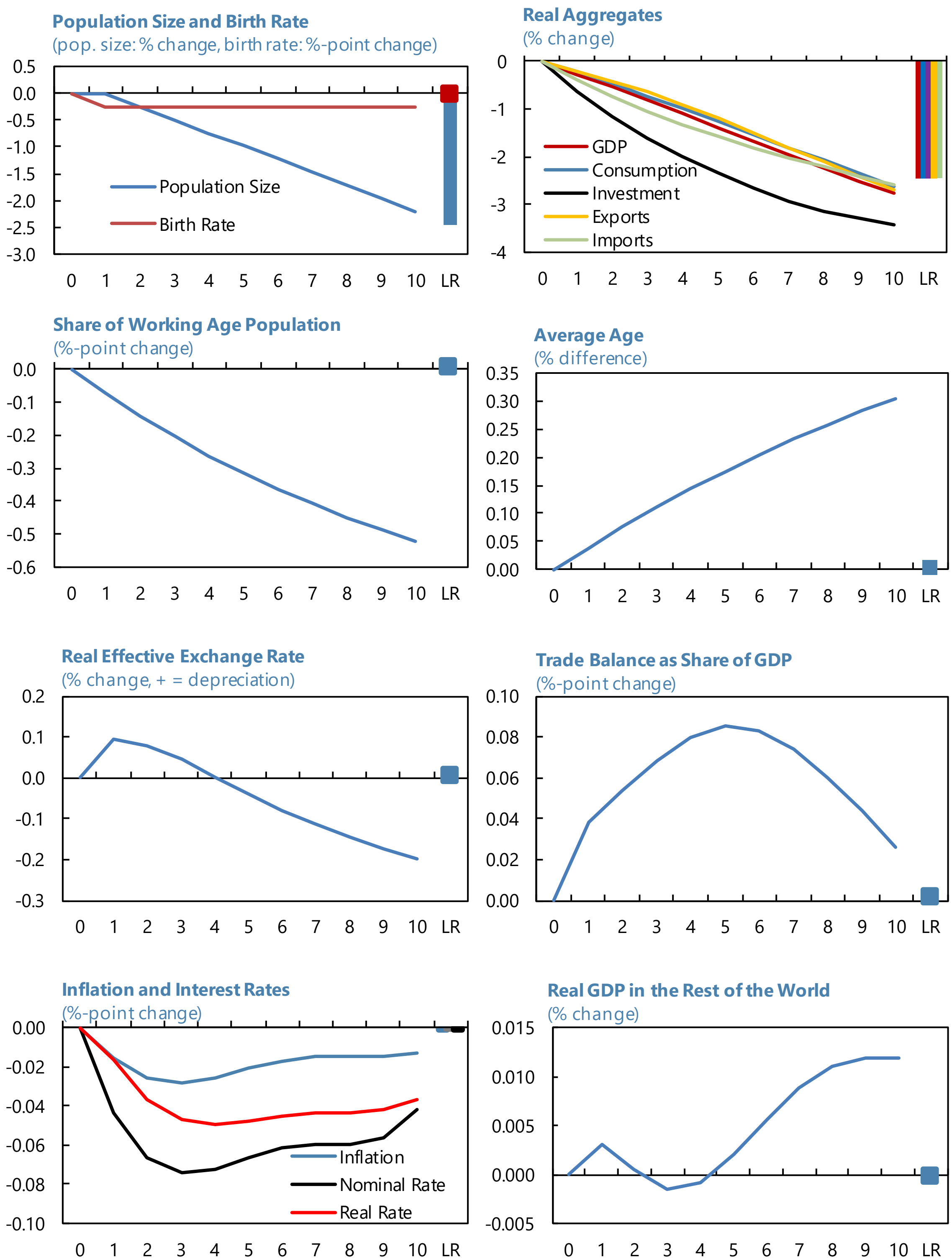
The decline in the population growth rate has no direct impact on the behavior of individual households, but it changes the age structure and population size of the economy. As shown in Figure 1, the temporary drop in the birth rate lowers the population size by about 2½ percent after 10 years, and this reduction in the size of the economy reduces the main macroeconomic aggregates. The reduced labor supply growth rate dampens capital accumulation and investment drops immediately. At the twenty-year horizon, output, consumption, investment, imports and exports have all adjusted downwards by roughly the same amount as the decline in the labor supply.

The shock also impacts the composition of the population: With fewer newcomers the population is aging, leading to a decline in the share of the working age population by about half a percent after 10 years. At the same time, aging reduces the average productivity, and both effects contribute to a decline in per-capita GDP by about ½ a percent at its trough.

With both labor supply and capital accumulation declining, potential output declines. However, in the short-run, demand declines more as the increase in average age in the population leads to more national saving as illustrated by the economy running a trade surplus. Weak demand results in inflation declining, and the central bank lowers the nominal interest rate, causing a small and short-lived depreciation in the real exchange rate. Later, the real exchange rate appreciates, as to maintain external balance the domestic economy doesn't need to export as much to pay for its now lower level of imports.

As noted above, the improvement in the trade balance and the resulting accumulation of foreign assets is driven by the change in the age distribution. At an individual level, newborn households start with no asset holdings and accumulate them over the lifecycle. Thus, aging of the population increases average asset holdings by raising the share of older (and therefore comparably asset-rich) households. The transition to higher average asset holdings drives the temporary, albeit small, improvement in the trade balance. The impact on the rest of the world is a balance between two opposite driving forces: on one hand the increase in saving in the domestic economy lowers the global interest rate and stimulates investment; on the other hand, the appreciation of the domestic currency is a negative term-of-trade shock for other countries, which increases the price of investment goods for them, and depresses their investment. In the simulation, the net impact is roughly zero.

Figure 1: TRANSITIONAL DYNAMICS TO LOWER POPULATION GROWTH



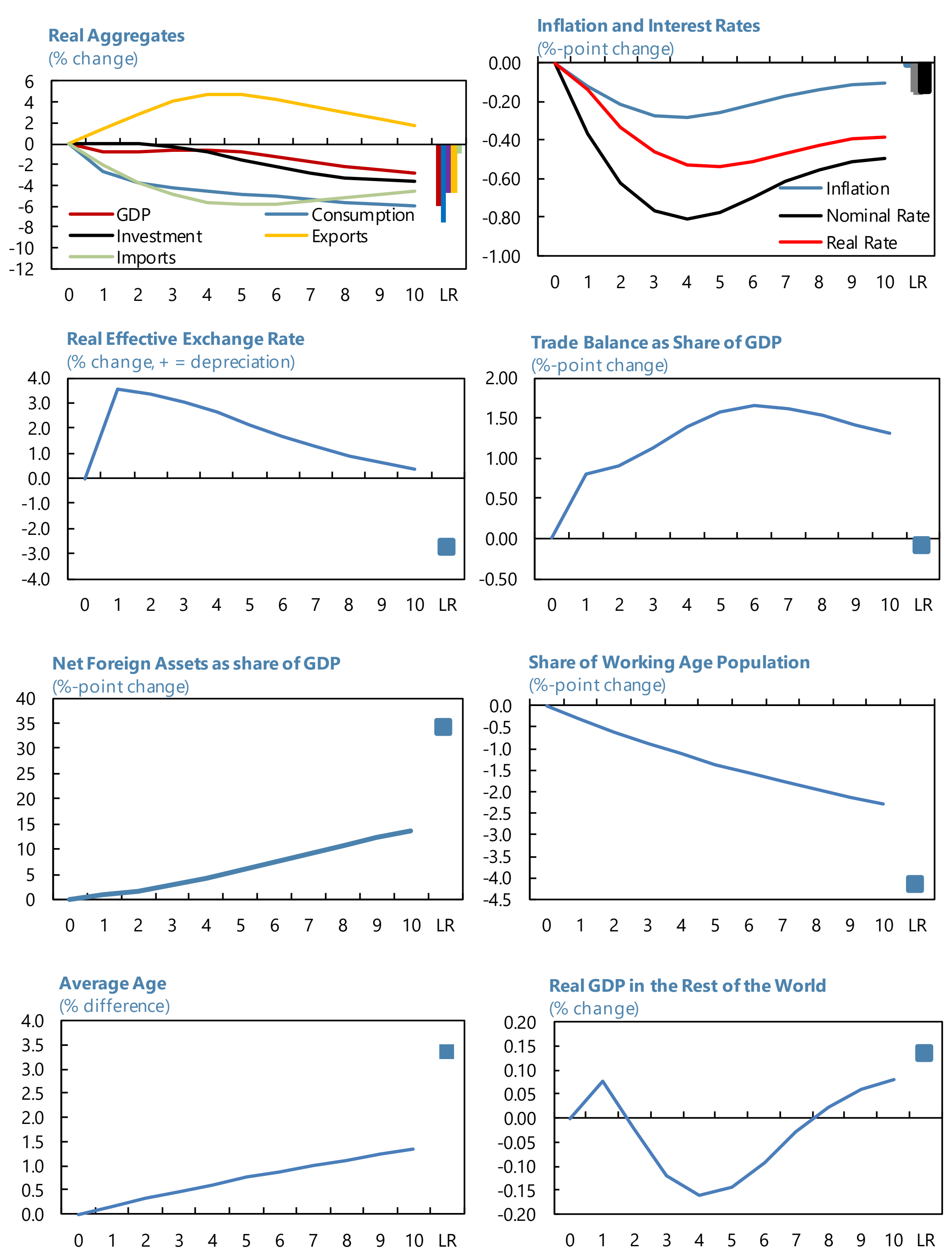
B. INCREASED LIFE EXPECTANCY

This shock permanently increases households' survival probability by one percentage point and thereby raises life expectancy. It simultaneously reduces the birth rate such that the population growth rate remains unchanged. While constant population growth sets this exercise apart from the previously presented shock to the birth rate, both shocks cause the population to age. Here, aging occurs not only because of the diminishing share of newborn households, but also because individual households live longer. Since the retirement age is maintained unchanged, this brings about a significant reduction in the share of the working age population that stabilizes at about 4 percent below its initial level.

As shown in Figure 2, the overall implication of an aging economy is a gradual decline in labor supply as older households work less: output declines by about 6 percent in the long run. Similar to the population growth shock, demand declines more than supply, but more dramatically this time. Not only does the age-distribution shifts to older, asset-rich, households, but also each individual household accumulates more assets during their life-cycle. Indeed, they expect to spend more time in retirement and thus save more during working age to keep the same standard of living during retirement. The transition to an older population goes along with a strong improvement in the trade balance which peaks at almost 2 percent after about 7 years. In the short run, lower domestic demand reduces inflation, the nominal interest rate declines, and, via uncovered interest rate parity, the real exchange rate depreciates. In the long run, the currency appreciates due to two factors. First, with a larger stock of net foreign assets earning income, fewer goods need to be exported to maintain desired wealth holdings. Second, imports decline along with output, again reducing the quantity of goods that need to be exported to maintain external balance.

Comparing to the population growth shock, spillover effects to the rest of the world are larger and positive in the long run and driven by the same two factors. Although there is a mild appreciation of the domestic exchange rate in the long run, this negative terms-of-trade shock is more than offset by the decline in the global real interest rate driven by the increase in domestic saving.

Figure 2: TRANSITIONAL DYNAMICS TO INCREASED LIFE EXPECTANCY

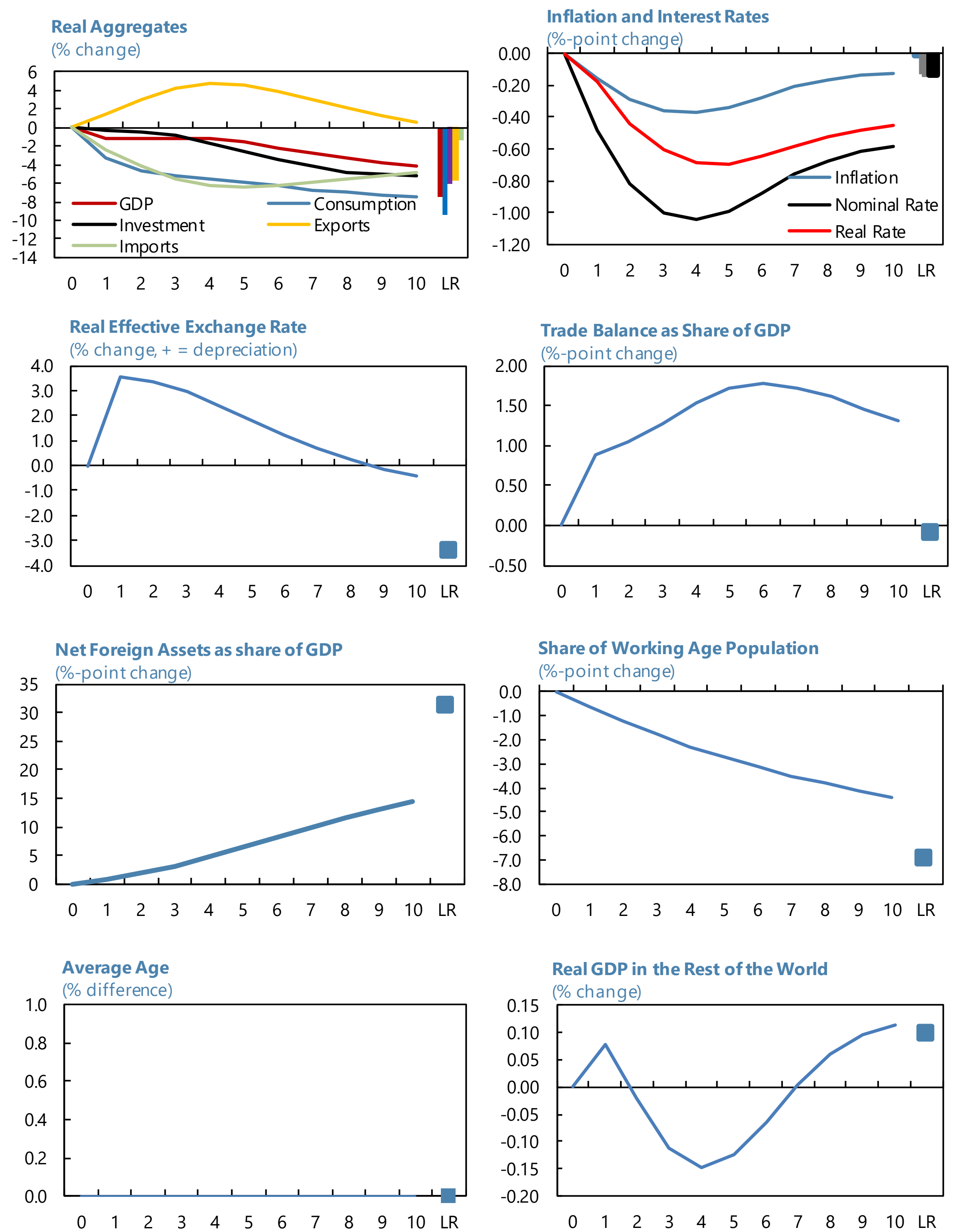


C. EARLIER RETIREMENT

The shock described in this section permanently raises the rate by which the labor endowment decays in age by one percentage point. As the decline in the labor endowment also triggers the receipt of pensions, the shock is interpreted as earlier retirement.

As shown in Figure 3, the adjustment of the economy under earlier retirement closely resembles the adjustment to a higher life expectancy (combined with a reduced birth rate) presented in the previous experiment. With regards to per-capita labor endowment, accelerating its decline in age for a constant age structure (this shock) as akin to increasing the average age (raising the survival rate). A reduction in the pension entry age also strengthens the incentive to accumulate assets, as it increases the length of time expected to be spent in retirement.

Figure 3: TRANSITIONAL DYNAMICS TO EARLIER RETIREMENT



V. CONCLUSIONS

This paper has documented the incorporation of demographic features into GIMF that will allow the model to be used to examine the macroeconomic and fiscal implications of demographic change. The explicit changes that have been made to the model code are detailed and the model's adjustment properties to changes in the three key levers that describe demographic change are illustrated. This version of the GIMF model has already been used for multilateral surveillance, as e.g. by Fernandez-Corugedo and Colacelli (2018) who apply the model to study the demographic transition in Japan as well as policies to offset demographic headwinds.

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APPENDIX I: DETAILS ON THE PENSION SYSTEM

The pay-as-you-go public pension received by a household depends on its characteristic (age), market developments (wage), and on policy variables (replacement rates, indexation on CPI or wage inflation). Let t be the current period (year) and a the age of the households (periods since he was a newcomer). We use the following notation:

- W_{t-a} is the wage level when the household was a newcomer;
- $\overline{h}$ is the hours endowment of a newcomer;
- $\overline{h}_{a,t}$ is the hours endowment of the same household at period t;
- $\overline{h} - \overline{h}_{a,t}$ is "hours in retirement".

The level of pensions $P_{a,t}$ depends on

- the wage level when the household was a newcomer W_{t-a};
- the cohort-specific replacement rate, decided when the household was a newcomer $\tau^{p}_{s\ t-a}$;
- the current replacement rate (apply to all retirees) $\tau^{p}_{h\ t}$;
- the replacement wage growth factor due to indexation π^{p}_{t} is a geometric average of CPI and wage inflation with a policy-determined weight χ_t:

$$\log(\pi^{p}_{t}) = (1-\chi_t)\log(\pi^{c}_{t}) + \chi_t \log(\pi^{w}_{t})$$

The level of pensions is given by

$$P_{a,t} = \tau^{p}_{h\ t}\tau^{p}_{s\ t-a}(\overline{h}_{t-a} - \overline{h}_{a,t})\left(\prod_{k=0}^{a-1} \pi^{p}_{t-k}\right)W_{t-a}$$

Full wage indexation case

Under full wage indexation $\pi^{p}_{t} = \pi^{w}_{t}$,the level of pensions simplifies to

$$P_{a,t} = \tau^{p}_{h\ t}\tau^{p}_{s\ t-a}(\overline{h}_{t-a} - \overline{h}_{a,t})W_t$$

The two policy variables (current replacement rate and cohort-specific replacement rate) allow us to differentiate between pensions reforms that affect all households the same way and pension reforms with grandfathering (only affecting new generations).