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Reframing policy responses to population aging in Iran

Stuart Gietel-Basten[1,2*], Guillaume Marois[3,4], Fatemeh Torabi[5] and Kambiz Kabiri[6]

*Correspondence: sgb@ust.hk

[1] The Hong Kong University of Science and Technology, Hong Kong SAR, China
[2] Khalifa University, Abu Dhabi, UAE
[3] Shanghai University, Shanghai, China
[4] International Institute for Applied Systems Analysis, Laxenburg, Austria
[5] Tehran University, Tehran, Iran
[6] Payame Noor University, Tehran, Iran

Abstract

Iran is aging rapidly and is expected to see negative population growth rates later this century. This change is generating significant concern for policymakers, whose response is to seek 'demographic solutions' to these issues: raise the fertility rate, decrease the divorce rate, and promote marriage among young people. Part of these policies has entailed curtailing access to free family planning services. This 'call and response' approach is unlikely to succeed in its stated aim, as it over-simplifies the real challenges of population aging as well as the multiple dimensions of population change. Such policies derive from simple representations of demographic change, most notably using the old-age dependency ratio. Using a microsimulation model, this paper suggests that increasing Iran's currently low female labor force participation and translating educational gains into rising productivity is a more effective means of responding to the challenges of population aging, even under low fertility conditions. The advancement on previous such microsimulation exercises lies in the fact that this study explicitly considers the comparison between raising fertility and increasing female economic empowerment to offset population aging in a setting characterized by an overt pronatalist policy system. In tandem with reforming stressed institutional systems (such as the pension system), releasing the full potential of Iran's existing (and future) human capital—especially of its women—is a far more effective policy direction than fertility-promoting policies.

Keywords: Iran, Policy, Fertility, Projections, Female labor force participation, Human capital

Population aging and pronatalism in Iran

Recent demographic history

The Islamic Republic of Iran (hereafter Iran) is a country of 88 million inhabitants in Western Asia. It is widely known for being home to one of the fastest declines in fertility rates in recorded human history (UNPD, 2023). The sharp decline in the total fertility rate (TFR) can be seen in Fig. 1a. This decline was brought about by a combination of a comprehensive family planning program and higher levels of female education within the broader context of a shift in the political-religious narrative towards reining in population growth and lowering fertility (Abbasi-Shavazi et al., 2009). Figure 1b shows that overall population rates have also sharply declined in Iran. Finally, this transition to low

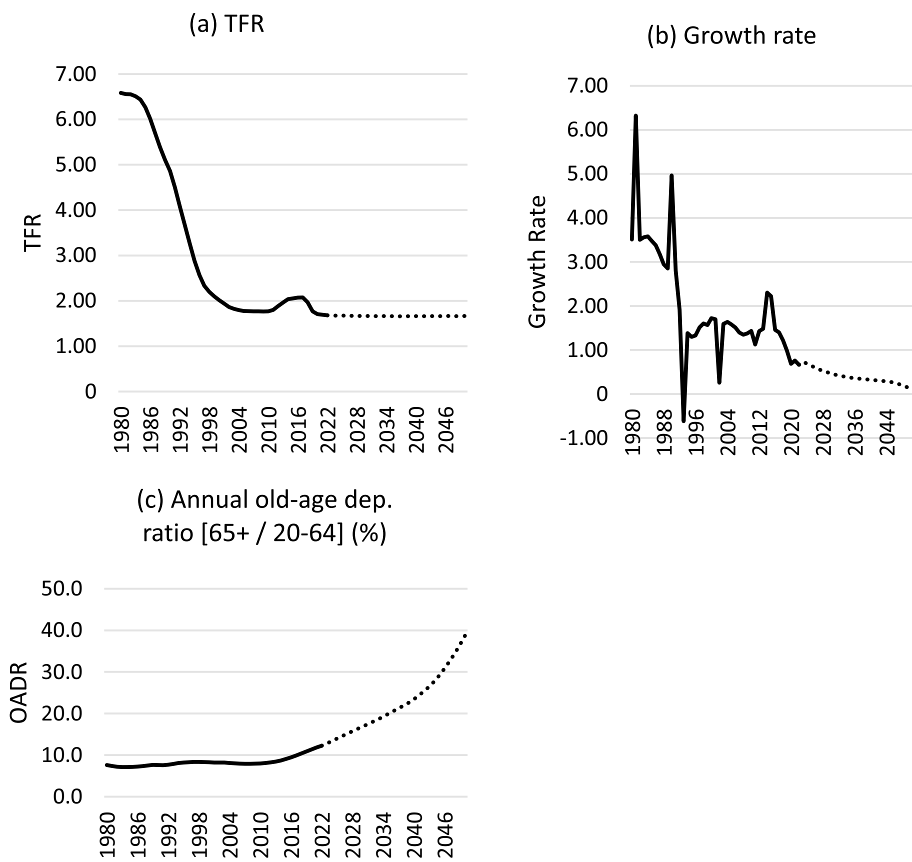


Fig. 1 Demographic change in Iran, 1980–2050. **a** Total fertility rate (TFR). **b** Average annual rate of population change. **c** Old-age dependency ratio (age 65+/age 20–64). . Estimates 1950–2020; medium variant forecasts from 2020 to 2050 Source: (UNPD, 2023)

fertility (coupled with improvements in mortality and relatively low levels of international immigration) has led to a sharp increase in the pace and scale of population aging as measured by traditional measures such as the old-age dependency ratio (OADR). As Fig. 1c shows, this traditional measure of aging is expected to rise even more sharply in the future.

Concerns and responses

In common with other countries worldwide, the Iranian Government has displayed significant concern regarding population aging and stagnation. In response, the government in 2017 implemented the “6th National Economic, Social and Cultural Development Plan of Iran” (2017–2021). The plan covered various policies, including education, employment, empowerment, health, marriage, childbearing, divorce, and housing (IPRCISI, 2017). Specific demographic targets were introduced: reducing the mean age at marriage by 10%, increasing the total fertility rate to at least 2.5 children per woman, and reducing divorce rates by 20%. Access to certain family planning services has also been restricted (Kokabisaghi, 2017). In line with the pronatalist plan of the current Iranian government, a law titled Youthful Population and Family Support was approved by the parliament of Iran in November 2021. The law includes various measures to promote marriage and childbearing among the young and newly married couples to increase fertility in the country and tackle population aging. In other words, there has been an emphasis on responding to the 'demographic problem' of population aging and stagnation by seeking a 'demographic solution' derived from increased fertility. Over this period, however, TFR has not increased (Statistical Centre of Iran 2021); the mean age of marriage has continued to increase (Statistical Centre of Iran, 2017; Torabi et al., 2013), and divorce rates have remained constant (National Organization for Civil Registration, 2019).

Is there an alternative approach?

A growing body of literature has sought to challenge this binary view of a 'demographic solution' (i.e., increasing fertility) to a 'demographic problem' (i.e., aging) (Gietel-Basten 2019). Firstly, it is argued that the threat of low fertility has often been overplayed, significantly where improvements in consumption can offset many of the macroeconomic challenges (Lee et al., 2014). Secondly, it is argued that a consideration of population aging in an abstract form with no reference to prevailing institutional structures (such as the labor market, the nature of the prevailing pension system, or the scope of health and social care provision) provides only a very partial and inaccurate view of the challenges posed by demographic change (Fu, 2009). Focusing on adapting and rendering such institutions sustainable in the face of demographic change will (almost) always be more efficient in the short- to medium term than increasing fertility (Gietel-Basten 2021). Thirdly, it has been argued that attempting to hold constant support ratios through demographic means (e.g., increasing fertility or immigration) is almost impossible (Coleman, 2002). Finally, it is argued that the shift in population size and age structure is but one aspect of the transformation of populations. In what he termed 'demographic metabolism', Lutz argues that aging (and possibly shrinking) populations are also (generally) characterized by improvements in health, education, skills, and individual wealth (Lutz, 2013). Ensuring that these transformations are continually developed, and hence the potential of all human capital is released, is key to mitigating the potential challenges of population aging and stagnation/decline (Gietel-Basten, 2021).

Such a multidimensional view of demographic change requires an alternative set of measures. At the macro-level, the National Transfer Accounts Program, for instance, has revolutionized our thinking of intergenerational transfers of financial and time resources and demonstrated how out-of-step traditional measures of aging can be with reality (Lee & Mason, 2012). At a more micro-level, various scholars have demonstrated how chronological measures may misrepresent the reality of aging, given that they do not adequately account for differences in life expectancy over time and between different settings (Fuchs, 1984; Spijker & MacInnes, 2013; Sanderson & Scherbov 2010, 2019). Furthermore, standard aging measures do not consider prevailing institutional frameworks. For example, the most common measure of aging is the 'old-age dependency ratio', often presented as the number of people over 65 divided by the population aged 15–64. The assumption is that the former is 'dependent' on the latter, characterized as the taxpaying, working population. Of course, such a measure relies on not only an institutionally constructed boundary to old age and the notion of redistribution but also assumes that all aged 15–64 are active in the labor force and all aged over 65 are 'dependent' (Gietel-Basten, 2018).

Finally, a holistic view of demographic change must also consider other dimensions in estimates and projections. For instance, the disease burden in society is critical. Various health-related measures have been used to measure and compare aging in a more realistic manner, such as cognitive functioning (Skirbekk et al., 2012). Understanding current and future labor force participation rates is also critical for any appraisal of the intergenerational economy and the true nature of population aging (Backhaus & Loichinger, 2022; Bijak et al., 2007). Various forecasting exercises, furthermore, have appended education attainment to the standard demographic measures of size and structure (Kc et al., 2010; Lutz et al., 2017; WIC, 2018). These forecasts take a scenario-based approach to show the possible pathways to educational attainment changes and how these might affect population growth, size, and structure (Lutz et al., 2017; WIC, 2018).

Recently, some papers have sought to integrate several of these different measures and their institutional context to present a more multidimensional view of the current population in certain settings and a wider range of possible scenarios for the future, often using simulation methods. In turn, these studies often return to multidimensional policy directions. For example, Bijak et al. (2008) analyzed the interrelations of population aging, labor force dynamics and international migration in Europe forecasted population counts and labor force participation rates. They concluded that 'only a combination of policies aimed at increasing fertility and labor force participation, together with reasonable-level immigration, can help meet socioeconomic challenges posed by population aging' (Bijak et al., 2008, 321).

Elsewhere, Marois et al. (2019) used a microsimulation model to explore how improvements in both educational attainment (especially among children with a low educated mother or an immigration background) and labor force participation (especially of women and immigrants) could impact the future labor force in the European Union. They concluded that 'Removing inequalities between subgroups in educational attainment and labor force participation drastically changes the prospective labor force size and labor force dependency ratio (LFDR) in the EU (p. 25). Similar findings have been published for India, showing that female labor force participation is a better driver of shaping dependency ratios than the age structure (Marois et al., 2022).

Elsewhere, Marois and colleagues again used a microsimulation model to build scenarios of future changes in labor force participation, migration volumes, and their educational composition and speed of integration for the 28 EU member states (Marois et al., 2020a). As well as the conventional age dependency ratio (ADR), the authors calculated the labor force dependency ratio (LFDR), and a 'productivity-weighted labor force dependency ratio' (PWLFDR) using 'education as a proxy of productivity, which accounts for the fact that not all individuals are equality productive in society'. The study found that when applying the LFDR and PWLFDR, population aging looks significantly' less daunting' than when using the standard ADR measures. Indeed, they found that lifting labor force participation to the levels found in some countries coupled with education-selective migration with high integration could even see economic dependency *improve*.

In China, as in many other regional settings, the narrative regarding low fertility and population stagnation/aging has become a highly charged political issue (Gietel-Basten, 2019). As in Iran, the Chinese government has changed the narrative towards a more pronatalist stance. At the local level, governments are implementing pronatalist policies such as baby bonuses (Pinghui, 2021). Yet, while fertility is low in China, human capital accumulation has been extremely strong, especially among younger cohorts. Using survey data to link this human capital to productivity gains, the PWLFDR calculated for China shows a much more manageable population aging scale than standard measures such as the ADR. While institutional reforms are certainly needed to respond to immediate challenges of population aging in China, when using alternative measures of aging 'a much more optimistic picture of the economic (and social) future of China can be envisaged'—even under conditions of even lower fertility rates in the future.

Applying a microsimulation model to Iran

In this study, we apply a microsimulation model for Iran as derived from the studies cited above for the countries of the EU and China to produce alternative measures such as the LFDR and PWLFDR as a supplement to the more standard measures of aging. In a sense, it could be argued that this is merely incremental and/or additive. The novelty, however, is that there is a clear empirical difference between the context of Iran (namely, a strongly pronatalist policy within a context of low female labor participation) and Europe and China.

We will begin by presenting a new set of forecasts for Iran, encompassing labor force participation and productivity. By doing so, we hope to demonstrate a more holistic view of aging in Iran which better captures the true nature of demographic change in the country. We will then explore some 'what-if' scenarios relating to fertility, education, and labor force participation to see how such policy trajectories might shape the future of the Iranian population in comparison to standard demographic responses (e.g., attempting to increase the fertility rate).

Materials and methods

Projection model, assumptions and scenarios

Our projections require a multidimensional model allowing us to forecast the population of Iran under five dimensions: age, sex, education, labor force participation and productivity.

The microsimulation model built in this paper uses the framework proposed by Marois and KC (WIC, 2018) using Statistical Analysis System (SAS). The model is time-based, in discrete time, and events occur stochastically with random experiments. The starting population includes 400,000 individuals (agents) and is built synthetically from the population estimates of Iran in 2015 by age, sex, and educational attainment (WIC, 2018), with an over-sampling for smaller population groups. The base population is built from the estimates by age, sex, and education from the WIC. These estimates are built from the National Iranian Census of 2011 with short-run simulations until 2015 using reported components. We used WIC estimates rather than the national direct national estimates because they are already standardized for the education variable and corrected for the undercount. Moreover, assumptions for mortality used in the projection are built from these estimates, so using different sources would bring more inconsistencies. Events are then simulated by a 5-year step until 2070. Risks are recalculated at the end of each step, depending on changes in the characteristics of individuals.

First, prospective survival ratios by age, sex, and education from the SSP2 (medium) scenario of the Wittgenstein Center multistate projections (WIC, 2018) are used to simulate the survival between t and $t+5$. Those assumptions were built by extrapolating past trends, with the input of a poll of experts (WIC, 2018). The increasing trends are still to continue. For the lower educated population, the life expectancy increases from about 72 years and 76 years for males and females in 2015 to about 83 and 88 years in 2070, while for the higher educated one, it passes from 79 years for males and 81 years for females in 2015 to 89 and 92 years old.

Second, the education module simulates shifts in education. The education variables count 4 categories, ranging from "no education" to "postsecondary education". This module is applied to the population aged 15–34. At age 15, individuals are classified stochastically according to an education distribution set in inputs. A probability of transition from the current level to the next upper level is applied until the individual reaches the age group 30–34, after which the educational attainment is the highest level reached over the life course. Our projections include two variants for this component. One uses the assumption of the SSP2 (medium) scenario from the Wittgenstein Centre multistate projections (WIC, 2018), which assumes the continuation of past trends (with long-term regional convergence), according to which female education is developing faster than for males. In this variant, the share of postsecondary education passes from 20 and 21% for males and females of the cohort born in 1981–1985 (aged 30–34 in 2015) to 50% and 61% for the cohort born in 2036–2040. The other variant assumes a faster expansion of educational attainment for both genders and uses the assumption of the SSP1 (rapid development) scenario. For males and females, the share of postsecondary education reaches 83% for the cohort born in 2036–2040.

Third, the migration module uses emigration rates by sex and age. Immigrants with a predetermined set of characteristics are then added deterministically to the population. Both emigration and immigration follow assumptions of the SSP2 scenario and have only a marginal impact on the outcome of projections, given their small intensity in Iran.

Fourth, the fertility module simulates the birth of new individuals. Age-specific fertility rates are applied to women aged 15–49, and when the event happens, a new individual is added to the dataset. Our projections test three variants for this component. The first two assume a decline of the total fertility rate (TFR) from 2.1 in 2015 to 1.7 or 1.3 children per woman in 2025 (constant afterward), while the third assumes that the governmental target of above replacement fertility is maintained throughout the projection. The TFR 1.7 scenario represents what might be a 'medium–low' fertility outcome discussed by Lee and Mason Field (2012) as not incompatible with increased consumption, well-being, and economic growth. On the other hand, a TFR of 1.3 has been suggested to be a boundary to 'lowest-low fertility'—a condition often linked to rapid population aging and stagnation and various socioeconomic challenges (Billari, 2008; Billari & Kohler, 2004). In all cases, the fertility schedule follows what is assumed in the SSP2 scenario of the Wittgenstein Center multistate projections (WIC, 2018).

The advancement on previous microsimulation exercises (e.g., Marois et al. 2020a and Marois et al., 2021) lies in the fact that we explicitly consider the comparison between raising fertility and increasing female economic empowerment to offset population aging. As such, fifth, at the end of each step, the labor force participation module identifies stochastically who participates in the labor force. Rates by age, sex, and education are calculated from the 2016 Iranian Census (ages 15–74). Figure 2 shows these labor force participation rates and reveals the strong gender gap for all education levels, for women having no postsecondary education for whom rates constantly are below 20% with any clear age pattern.

Two variants of female labor force participation are built. In the first one, rates by age and education are assumed to stay constant. Indeed, preliminary analyses revealed no significant difference between 2006 and 2016 and no apparent cohort effect. Thus, this assumption continues past trends with a large persistent gender gap. As women's education is expected to increase, women's total labor force participation will also increase moderately by a composition effect. The second variant assumes a gradual tightening of the gender gap that might result from structural changes in the economy and/or labor market, cultural changes and/or government policies encouraging women empowerment and paid work. By 2050, the age and education-specific gap between males and females is assumed to be reduced by two and stays constant afterwards.

Sixth and last, a productivity weight is assigned to those who are in the labor force. This productivity weight is based on the worker's educational attainment and is calculated following the approach proposed by Marois et al. (2020a). The productivity weights are calculated with a Poisson regression model using the salary from the 2016 Expenditure and Income Survey as the dependent variable, controlling for age and gender. A weight of 1 is attributed to workers with secondary education. The model then results in weights of 0.62 for workers with no education, 0.74 for workers with primary education and 1.53 for workers with postsecondary education. Those weights are comparable to those calculated for China and European countries in other studies (Marois et al., 2020a; Marois et al., 2021) and are assumed to stay constant throughout the projection.

From this microsimulation model and this set of assumptions, we built one reference scenario, assuming medium assumption and continuation of past trends, and 4 alternative

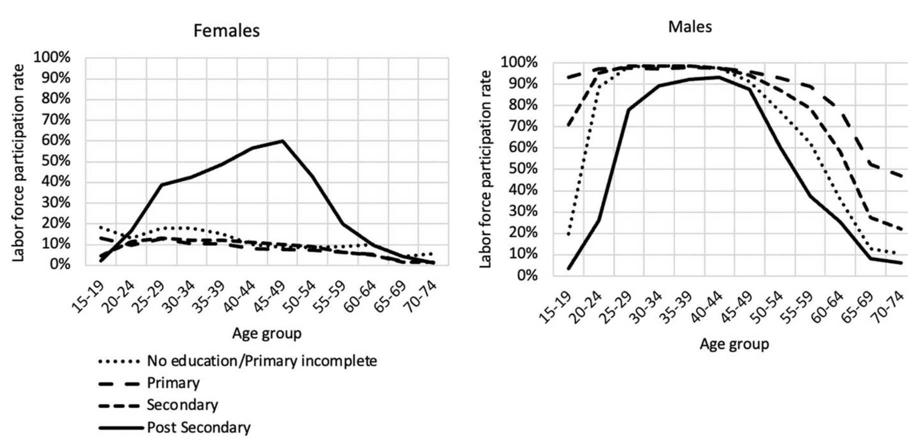


Fig. 2 Labor force participation rates by education, Iran, 2016. Source: Census 2016, authors' calculation

Table 1 Summary of scenarios

Scenario	TFR from 2020	Education	Labor force	Migration	Life expectancy
1-Reference	1.7	SSP2 (medium)	Constant by age, sex, edu	SSP2 (medium)	
2-TFR = 2.1 ('Replacement')	2.1	SSP2 (medium)	Constant by age, sex, edu		
3-TFR = 2.5 (Govt 'target')	2.5	SSP2 (medium)	Constant by age, sex, edu		
4-High Edu	1.7	SSP1 (rapid development)	Constant by age, sex, edu		
5-High FLFP	1.7	SSP2 (medium)	Gap between males and females reduced by 2		
6-Lowest-low fertility	1.3	SSP2 (medium)	Constant by age, sex, edu		

scenarios, each of them isolating the effect of one major change in a component (Table 1). Scenario *2-TFR = 2.1* tests the impact of replacement level fertility. Scenario *3-TFR = 2.5* represents an 'upper limit' of TFR as determined by previous policy statements on targets. Scenario *4-High Edu* tests the impact of faster development in educational attainment (for both males and females), and scenario *5-High FLFP* tests the impact of a policy significantly reducing the gender gap in the labor force participation.

Dependency ratios

Three main projection outcomes are analyzed, either the age dependency ratio, the labor force dependency ratio, and the productivity-weighted labor force dependency ratio.

The age dependency ratio (ADR), widely used in demography for assessing the demographic dividend or the population aging, is based on the age dimension and corresponds to the ratio of the children (0–14) and the elderly (65+) on the working-age population (15–64):

$$\mathrm{ADR} = \frac{\mathrm{Pop}_{0-14} + \mathrm{Pop}_{65+}}{\mathrm{Pop}_{15-64}}. \tag{1}$$

The labor force dependency ratio (LFDR) divides the inactive population (I), whatever is their age, on the active (A) one of any age. Contrary to the ADR, this ratio takes into account that not all the working-age population is actually working, which is particularly true in Iran where labor force participation rates for women are extremely low:

$$\mathrm{LFDR} = \frac{I}{A}. \tag{2}$$

Finally, the productivity-weighted labor force dependency ratio (PWLFDR) multiplies the workers in the denominator by their education-specific (e) productivity weight (W), thus accounting that not all workers are equally productive. Given a weight of 1 is assigned to workers with secondary education, this ratio would thus be the same as the LFDR if all workers were as productive as workers with secondary education:

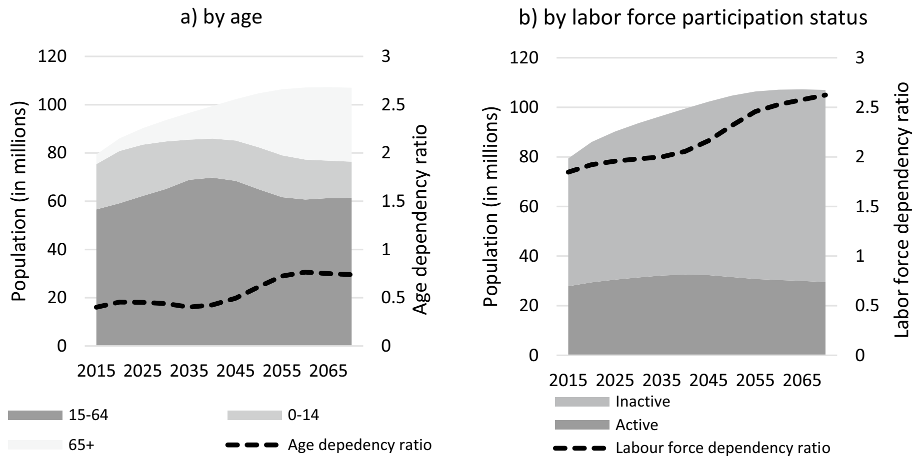


Fig. 3 Projected population by and by labor force participation status, plus age dependency ratio (ADR), labor force dependency ratio (LFDR), reference scenario, Iran 2015–2070

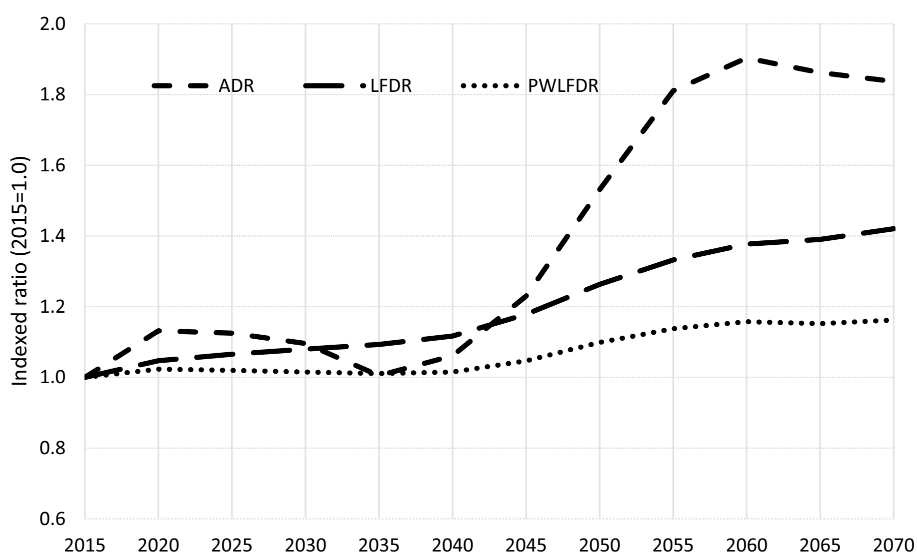


Fig. 4 Projected age dependency ratio (ADR), labor force dependency ratio (LFDR) and productivity-weighted labor force dependency ratio (PWLFDR), reference scenario, Iran 2015–2070

$$\text{PWLFDR} = \frac{I}{\sum_{e=1}^{k} W_e * A_e}. \tag{3}$$

Results

Figure 3 shows Iran's projected population by age and labor force status under the reference scenario. Figure 4, meanwhile, shows the dependency ratios according to the reference scenario indexed to 1 in 2015. It is immediately apparent that the LFDR and PWLFDR demonstrate a much slower increase to 2070 than the ADR, especially after 2045. For example, the changes in the LFDR represent a 40% increase compared to a 90% increase in the ADR. Meanwhile, the PWLFDR increase is even more minor (10%). This is because both the LFDR and the PWLDR started at a much more unfavorable level in 2015 than the ADR. Indeed, while the ADR considers all the working-age population as potential economic support, the LFDR and the PWLFDR explicitly account that a large share of this working-age population, mainly the women with no postsecondary education, are indeed not in the labor force and should not be counted as potential economic support who contribute significantly to the production of wealth and in the fiscal balance of the state. Under this reference scenario that assumes the continuation of this labor force dynamic, the LFDR would never go below 2 in Iran. In comparison, the ratio is about twice as low in the European Union (1.08) and is expected to reach 1.33 in 2060 despite the fast population aging that faces this region (Marois et al., 2020a, Marois et al. 2020b).

Figures 5 and 6 represent the projected changes in LFDR and PWLDFR according to different scenarios. In both indicators, the highest ratios are derived from the higher fertility scenarios. This is because of an increased number of children added to the numerator in terms of 'dependency'. For LFDR, there is relatively little difference between the reference scenario and the scenario that assumes the education trends of SSP1. While the higher education scenario assumes a greater degree of work among women, this is offset by the opposite effect for men, where those with lower levels of education tend to start working earlier and work longer. However, the higher education scenario significantly impacts the PWLFDR as this improved investment in human capital is translated into productivity gains. In both scenarios, however, Scenario 5—where the gap between

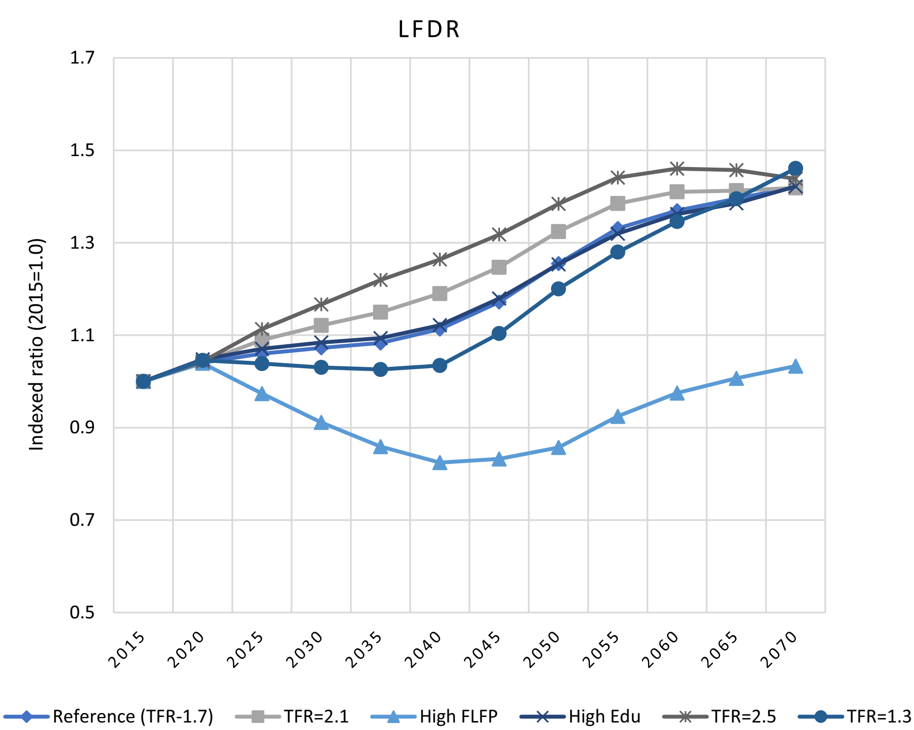


Fig. 5 Labor force dependency ratio (LFDR), alternative scenarios, Iran 2015–2070. See Table 1 for the definition of scenarios

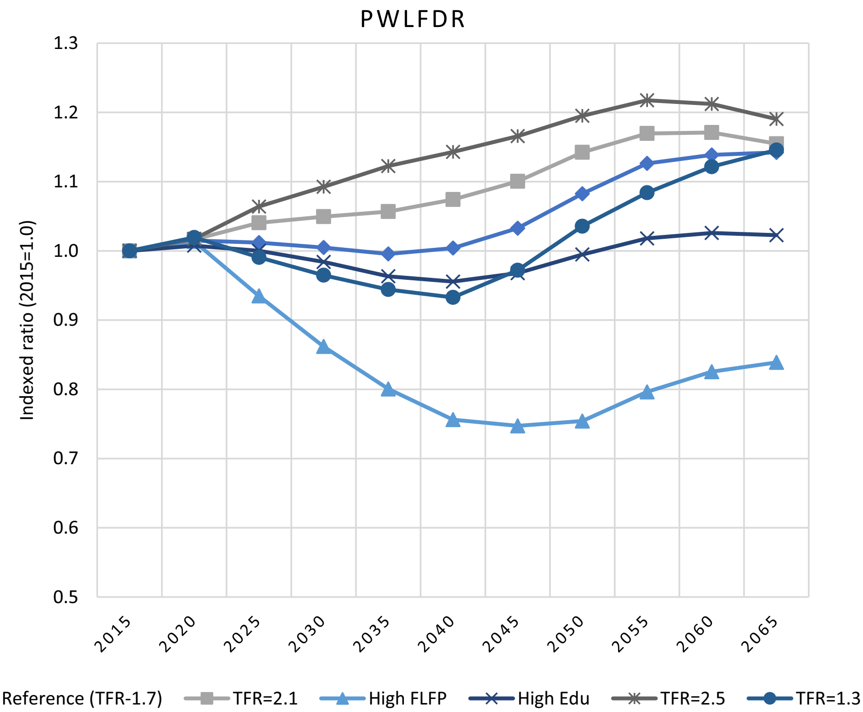


Fig. 6 Productivity-weighted labor force dependency ratio (PWLFDR), alternative scenarios, Iran 2015–2070

female and male labor force participation rates are halved—yields the most positive impact.

It is clear, then, that the LFDR and PWLDFR are anticipated to grow at a much more measured pace than the traditional ADR measure under the reference scenario. This is because, in Iran, education and labor force participation rates are highly correlated for women. Women with a university degree are four times more likely to work than those without. As such, older cohorts who are generally characterized by lower levels of education are increasingly replaced by those with higher educational attainment, the total labor force participation rates among the working-age population are likely to increase. Indeed, according to the model, the labor force participation rate for women aged 15–64 passed from 15% in 2015 to 22% in 2070 precisely because of this change in education. (The main reason the increase is minor in percentage terms is because the initial level of the LFDR is much higher than the ADR.) Once expected gains from education in terms of productivity are factored in, this resulting human capital bonus means that the increase in the PWLFDR is even lower. Despite this, the initial level of the LFDR is still relatively high in Iran and does not fall below 2.0. This is in contrast, for example, to the EU, which is 1.08 and expected to reach 1.33 in 2060 despite having a much older population than Iran. Therefore, the primary reason for this divergence is the very low labor force participation rate among women in Iran. This will lessen the potential economic development anticipated from the demographic dividend.

When turning to the alternative scenarios, the first conclusion is that increasing fertility rates will *increase* dependency ratios because of the added number of children in the 'dependent' population. This is a significant finding given the current pronatalist policies in Iran. Indeed, if this 'target' TFR (2.5) were to be met, then the ensuing dependency ratios would be higher and would not help mitigate the consequences of population aging in the short and medium term.

When turning to the different scenarios, increasing education alone was not enough to impact the LFDR. This is because, under prevailing labor market conditions, males with less education started work earlier and worked for longer. Only after accounting for possible changes in productivity resulting from these human capital gains did the dependency ratio change from the Reference Scenario, which highlights the importance of go beyond the age dimension when assessing the social and economic consequences of population aging.

For both the LFDR and PWLFDR, though, Scenario 5—where the gap between female and male labor force participation rates are halved—has brought the most positive impact. It yielded a LFDR about 40% lower than the reference scenarios and a PWLFDR of around 30%. Indeed, under conditions of improving female labor force participation in Iran, the LFDR and PWLFDR would *decrease* over the next two decades.

The significance of the female labor force participation rate in Iran is made clear in Fig. 7. The 2015 pyramid clearly shows the right pyramid shape for a demographic dividend. However, the very high rates of female inactivity in the labor market prevent this from being fully actualized. By 2070, we see an apparent transformation of the age structure as Iran ages. However, we see a relatively modest difference in the shape of the pyramid when comparing the higher fertility scenario with the reference scenario. If we are primarily interested (in crude terms) in the relative size of the 'green' portion of the pyramid compared to the 'brown' portion, Scenario 5 (high FLFP) looks the most favorable—even though the overall population structure may, indeed, be 'older' than under the higher fertility scenario.

Discussion

Our findings empirically demonstrate that if the stated aim of a population policy is to decrease measures of dependency in Iran, increasing levels of female labor force participation is by far the most effective route to achieve this—even under conditions of what is considered to be 'low' fertility. This finding is especially pertinent given the current policy direction towards increasing fertility, lowering the age of marriage, and lowering divorce rates. Indeed, it is argued in some quarters that increasing female labor force participation would decrease fertility rates. This argument is questionable on comparative grounds (because of limited evidence from elsewhere) and the currently low starting point of female labor force participation in Iran. Despite this, lessons from other parts of the world strongly suggest that policies that can help women (and men) balance labor force engagement with family formation would help.

While increasing female labor force participation is, in theory, the most effective means of lowering dependency ratios in Iran, it is questionable whether such a change can be implemented. Firstly, strong pressures still work against a transformation in attitudes toward female labor force participation. These reflect a (growing) set of conservative values and expectations about gender and the family. Although female labor force participation has been constantly low in Iran, highly educated women participate at much higher rates. So, with increasing education of younger cohorts, we could expect that female labor force participation will grow. For this to happen, cultural barriers to female work outside the home reflected in gender-stratified roles (Torabi, 2020) should be relaxed. In fact, it seems that highly educated spouses are more similar in their role performance (Torabi 2021). A second issue is the extent to which the education system can be appropriately aligned to the needs of the labor market and, in turn, whether the labor market can translate the improved human capital gains of the population into productivity gains. Finally, there is the issue of the capacity of the economy to create decent employment in the first place. Under international sanctions and slow economic growth, the capacity to develop the labor market to the degree where the demand for (female) labor increases sharply is highly constrained.

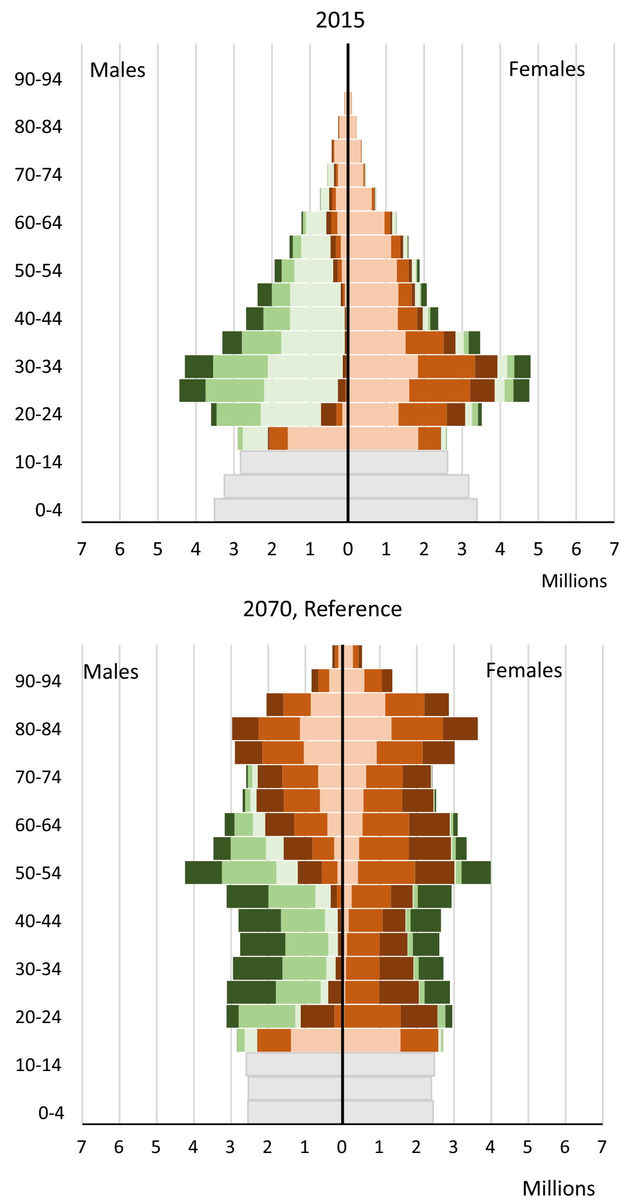
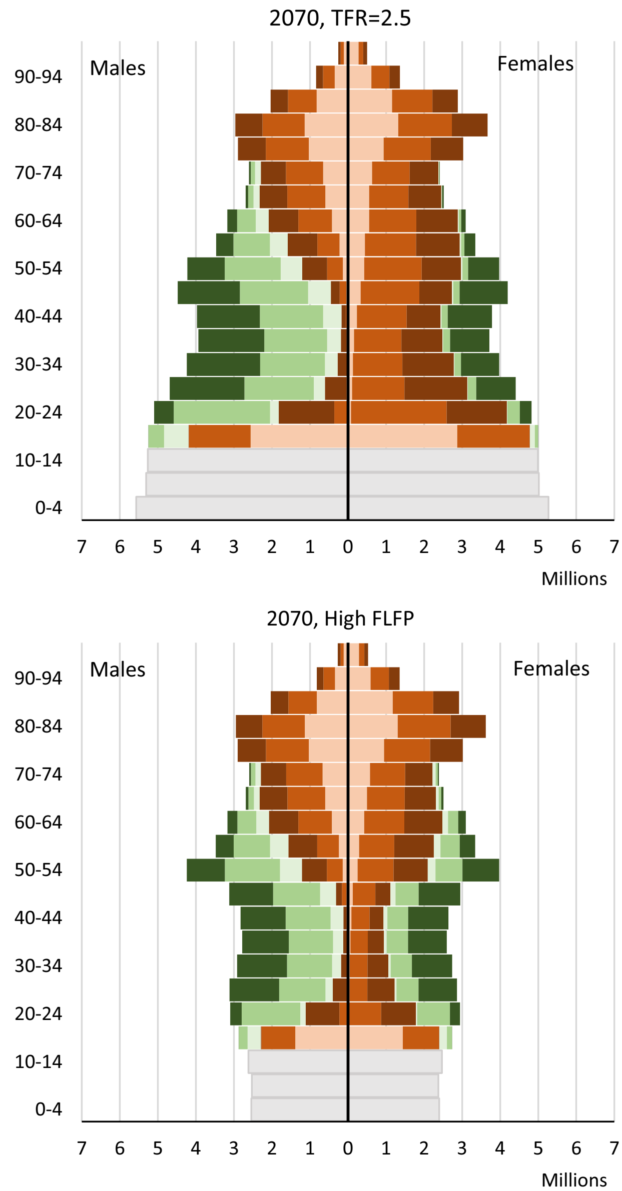


Fig. 7 Population pyramids for Iran by scenario, 2015 and 2070. See Table 1 for definition of scenarios



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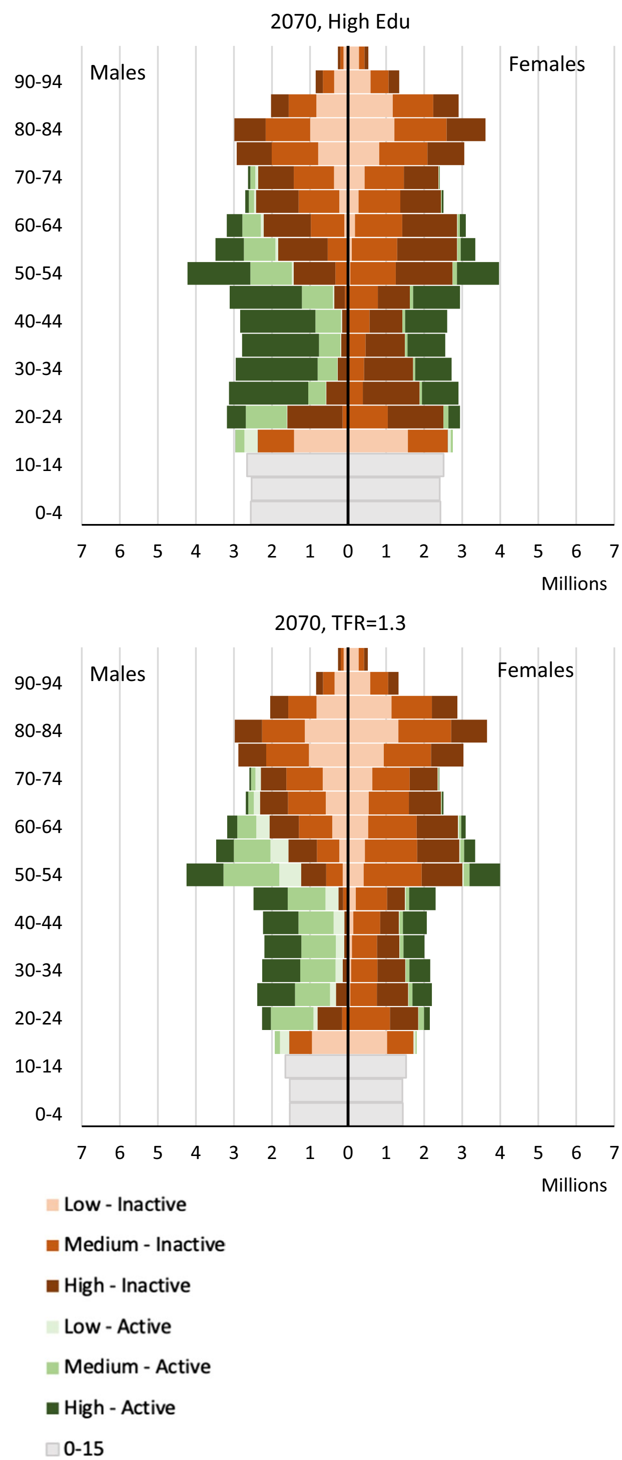

Fig. 7 continued

We should consider some of the limitations of our study. As with all projections, our forecasts rely on assumptions and cannot account for countless unpredictable events that can alter demographic trends. Our scenarios, even the reference one, should, therefore be considered "what if" scenarios and do not have the ambition to predict anything.

Moreover, our approximation of productivity by educational attainment is based on the salary in 2016. Though various studies (Policardo et al., 2019; Van Biesebroeck, 2011) show that salary is a good proxy of productivity, the association might not be constant as we assumed, as it is influenced by several unaccountable factors such as economic cycles, the supply, and the demand, etc. In addition, our labor force dependency ratios consider all those out of the labor force as economically dependent and do not account for the sizable contribution of these people other than from formal work. Related to this, it is estimated that the informal sector accounts for some 31% of the economy. In some regions, the proportion of females and males working in the informal labor market can be greater than 80 and 90%, respectively (Pilehvar, 2022). Furthermore, unpaid labor in the home and in informal care settings is not accounted for. As such, our exercise underestimates female labor force participation. We also consider only fertility as a main changing demographic factor. Of course, mortality and migration significantly impact the age structure. However, Iran's central demographic policy now focuses on fertility, hence our choice to focus on this variable. Finally, our productivity-weighted labor force dependency ratio does not consider the increasing productivity resulting from sources other than education, such as progress in technologies or organizations.

In short, in focusing on dependency ratios, we take a very functional, simplistic view of the processes of population aging. As we argue in the introduction, the concept of 'dependency' is highly problematic unless grounded in an institutional framework. While we make an improvement on simple age-based dependency measures by incorporating education, labor force, and productivity, the base concept of 'dependency' is still problematic without adequate consideration of health, welfare, pension, and tax systems and modes of redistribution. Indeed, urgent reforms are needed to adopt innovative approaches to offset population aging soon. A life-cycle approach to population aging is among the effective measures that offer a proper investment in the current youth population; ensuring access to adequate skills, decent job opportunities, and income sources as well as access to health and reproductive health services, could significantly mitigate the challenges of population aging. In addition to the development of policies to further increase human capital at all ages, including reducing inequality, closing the digital divide, active aging policies, and developing age-friendly environments as well as community-based approaches to social and health care services would all further improve the prospects for Iran to respond to the challenges of population aging. In only presenting four scenarios, our analysis does not adequately consider other pathways to human capital transformation and changing patterns of 'dependency'. Despite this, on a conceptual level, our findings suggest the importance of considering institutional reforms to offset aging (denoted by one conceptual measure of dependency) over purely a demographic response.

Conclusion

In common with many countries worldwide, Iran is grappling with changing population size and structure. In part because of the success of previous policies designed to reduce fertility, it is home to one of the most rapidly aging populations on earth. Again, in common with several other countries, Iran has instituted a population policy designed to offset some of the challenges associated with these transitions towards an older population characterized by slower growth. This policy goes further than most in setting clearly defined demographic targets related to increasing the fertility rate, lowering the divorce rate, and decreasing the age of marriage. The government has also instituted policies restricting access to free reproductive and family planning services.

Microsimulation models enable scientists to explore multidimensional possible future directions of demographic change and, as Burch puts it, blur the lines between 'theory' and 'model' (Burch, 2017). More importantly, such simulation models can 'provide crucial insights into mechanism(s) at work and a systematic framework for discussion and further research' (Burch, 2017, 25). It is, perhaps, for these reasons that such microsimulation modeling exercises in population have been taken up by statistical offices (e.g., Statistics Canada, 2009) as well as other academic exercises to model the future of not only population (Siripanich & Rashidi, 2020) and its interaction with welfare systems (MicroWELT, 2022), healthcare (Spielauer, 2007) and so on.

Using such a microsimulation model, which incorporates changes in both human capital, labor force participation, and productivity as well as a changing population age structure, our findings here clearly demonstrate that if the stated aim of a population policy is to decrease measures of dependency in Iran, increasing levels of female labor force participation is by far the most effective route to achieve this—even under conditions of what is considered to be 'low' fertility. Indeed, the analysis presented here represents a development on previous such simulations performed on Europe (Marois et al. 2020a) and China (Marois et al., 2021) by explicitly considering a very low female labor force participation context.

Our evidence suggests that the economic empowerment of young people, particularly women, should be a central part of the country's population and development plans. Because children do not work, increasing the fertility rate will only result in higher dependency ratios for several years before having a positive effect. Bringing about these changes in productivity and female labor force participation will, however, require both a major cultural shift as well as a significant reframing of the economy.

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Availability of data and materials
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Declarations

Competing interests
The authors declare that they have no competing interest.

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References

Abbasi-Shavazi, M. J., McDonald, P., & Hosseini-Chavoshi, M. (2009). *The fertility transition in Iran: revolution and reproduction*. Springer.

Backhaus, A., & Loichinger, E. (2022). Female labor force participation in Sub-Saharan Africa: A cohort analysis. *Population and Development Review*. https://doi.org/10.1111/padr.12492

Bijak, J., Kupiszewska, D., Kupiszewski, M., Saczuk, K., & Kicinger, A. (2007). Population and Labour Force Projections for 27 European Countries, 2002-052: Impact of International Migration on Population Ageing: Projections de Population et de Population Active Pour 27 Pays Europ{é}ens 2002-052: Impact de La Migration Internationale. European Journal of Population 23 (1): 1–31.

Bijak, J., Kupiszewska, D., & Kupiszewski, M. (2008). Replacement migration revisited: simulations of the effects of selected population and labor market strategies for the Aging Europe, 2002–2052. *Population Research and Policy Review, 27*(3), 321–342.

Billari, F. C. (2008). Lowest-low fertility in Europe: Exploring the causes and finding some surprises. *Japanese Journal of Population, 6*(1), 2–18.

Billari, F. C., & Kohler, H.-P. (2004). Patterns of low and lowest-low fertility in Europe. *Population Studies, 58*(2), 161–176.

Spijker, J., & MacInnes, J. (2013). Population ageing: The timebomb that isn't? *BMJ Clinical Research Ed, 347*(12), 6598.

Börsch-Supan, A., Ludwig, A., & Winter, J. (2006). Ageing, pension reform and capital flows: A multi-country simulation model. *Economica, 73*(292), 625–58. https://doi.org/10.1111/j.1468-0335.2006.00526.x

Burch TK (2017) Model-based demography. In: Demographic research monographs. Springer, Basel

Coleman, D. A. (2002). Replacement migration, or why everyone is going to have to live in Korea: A fable for our times from the United Nations. *Philosophical Transactions of the Royal Society of London Series B Biological Sciences, 357*(1420), 583–598.

Fu, T.-H., & Hughes, R. (2009). *Ageing in East Asia: Challenges and policies for the twenty-first century*. Routledge.

Fuchs, V. R. (1984). Though much is taken: Reflections on aging, health, and medical care. *The Milbank Memorial Fund Quarterly Health and Society, 62*(2), 142–66.

Gietel-Basten, S. (2018). Reconceptualising ageing for comparative analysis. *Wirtschaftspolitische Blätter, 2018*(1), 65–75.

Gietel-Basten, S.A. (2019). The "Population Problem" in Pacific Asia. International Policy Exchange Series. New York, NY: Oxford University Press.

Gietel-Basten, S.A. (2021). Adopting an Adaptation-mitigation-resilience Framework to Ageing. *Age and Ageing*. https://doi.org/10.1093/ageing/afaa282.

Gietel-Basten, S., & Scherbov, S. (2019). Is half the world's population really below 'Replacement-Rate'? *PLoS ONE, 14*(12), e0224985. https://doi.org/10.1371/journal.pone.0224985

Gietel-Basten, S., Scherbov, S., & Sanderson, W. (2015). Remeasuring ageing in Southeast Asia. *Asian Population Studies, 11*(2), 191–210. https://doi.org/10.1080/17441730.2015.1052201

IPRCISI. (2017). Law of the 6th National Economic, Social and Cultural Development Plan of Iran (2017–2021). Islamic Parliament Research Centre of the Islamic Republic of Iran. https://rc.majlis.ir/fa/law/show/1014547.

Kc, S., Barakat, B., Goujon, A., Skirbekk, V., & Lutz, W. (2010). Projection of populations by level of educational attainment, age, and sex for 120 countries for 2005–2050. *Demographic Research, 22*(March), 383–472. https://doi.org/10.4054/DemRes.2010.22.15

Kokabisaghi, F. (2017). Right to sexual and reproductive health in new population policies of Iran. *Journal of Public Health Policy, 38*(2), 240–256. https://doi.org/10.1057/s41271-017-0068-x

Lee, R. D., & Mason, A. (2012). *Population aging and the generational economy: A global perspective*. Edward Elgar.

Lee, R., Mason, A., Members of the NTA Network. (2014). Is low fertility really a problem? Population aging, dependency, and consumption. *Science, 346*(6206), 229–234.

Lutz, W. (2013). Demographic metabolism: A predictive theory of socioeconomic change. *Population and Development Review, 38*(s1), 283–301. https://doi.org/10.1111/j.1728-4457.2013.00564.x

Lutz, W., Butz, W. P., & Kc, S. (2014). *World population and human capital in the twenty-first century*. Oxford: Oxford University Press.

Lutz, W., Butz, W. P., & Samir, K. C. (2017). *World population & human capital in the twenty-first century: an overview*. Oxford: Oxford University Press.

Marois, G., Bélanger, A., & Lutz, W. (2020a). Population aging, migration, and productivity in Europe. *Proceedings of the National Academy of Sciences of the United States of America, 117*(14), 7690–7695. https://doi.org/10.1073/pnas.1918988117

Marois, G., Gietel-Basten, S., & Lutz, W. (2021). China's low fertility may not hinder future prosperity. *Proceedings of the National Academy of Sciences of the United States of America, 118*(40), e2108900118. https://doi.org/10.1073/pnas.2108900118

Marois, G., Sabourin, P., & Bélanger, A. (2019). How reducing differentials in education and labor force participation could lessen workforce decline in the EU-28. *Demographic Research, 41*(July), 125–160. https://doi.org/10.4054/demres.2019.41.6

Marois, G., Sabourin, P., & Bélanger, A. (2020b). Implementing dynamics of immigration integration in labor force participation projection in EU28. *Population Research and Policy Review, 39*(2), 339–363. https://doi.org/10.1007/s11113-019-09537-y

Marois, G., Zhelenkova, E., & Ali, B. (2022). Labour force projections in India until 2060 and implications for the demographic dividend. *Social Indicators Research*. https://doi.org/10.1007/s11205-022-02968-9

MicroWELT. (2022). "Welcome to MicroWELT!— MicroWELT Documentation." MicroWELT. 2022. https://www.microwelt.eu/.

National Organization for Civil Registration. (2019). 2019 Yearbook of Population Statistics. Available From. https://www.sabteahval.ir.

Pilehvar, A. A. (2022). Investigating the relationship between informal economy and competitiveness in Iran's metropolises. *Journal of the Knowledge Economy, March*. https://doi.org/10.1007/s13132-022-00965-4

Pinghui, Z. (2021). China Offers Baby Bonuses, with Births on Track for New Low in 2021. South China Morning Post. July 21, 2021. https://www.scmp.com/news/china/politics/article/3141978/china-offers-baby-bonuses-births-track-new-low-2021

Policardo, L., Punzo, L. F., & Sanchez Carrera, E. J. (2019). On the wage-productivity causal relationship. *Empirical Economics, 57*(1), 329–343. https://doi.org/10.1007/s00181-018-1428-5
Sanderson, W. C., & Scherbov, S. (2010). Remeasuring aging. *Science, 329*, 1287–1288.
Sanderson, W. C., & Scherbov, S. (2015). Are we overly dependent on conventional dependency ratios? *Population and Development Review, 41*(4), 687–708. https://doi.org/10.1111/j.1728-4457.2015.00091.x
Sanderson, W. C., & Scherbov, S. (2019). *Prospective longevity: A new vision of population aging*. Harvard University Press. https://play.google.com/store/books/details?id=gfuwDwAAQBAJ
Scherbov, S., Sanderson, W. C., & Gietel-Basten, S. (2016). Better way to measure ageing in east Asia that takes life expectancy into account. *Australasian Journal on Ageing, 35*(2), 139–142. https://doi.org/10.1111/ajag.12267
Skirbekk, V., Loichinger, E., & Weber, D. (2012). Variation in cognitive functioning as a refined approach to comparing aging across countries. *Proceedings of the National Academy of Sciences of the United States of America, 109*(3), 770–774.
Siripanich, A, & Rashidi, T. (2020). A demographic microsimulation model with an integrated household alignment method. *ArXiv [Econ.GN]*. arXiv. http://arxiv.org/abs/2006.09474
Spielauer, M. (2007). Dynamic microsimulation of health care demand, health care finance and the economic impact of health behaviours: Survey and review. *International Journal of Microsimulation, 1*(1), 35–53.
Statistics Canada. (2009). "Demosim." Statistics Canada. September 30, 2009. https://www.statcan.gc.ca/en/microsimulation/demosim/demosim.
Statistical Centre of Iran. (2017). Changes in mean age at first marriage in Iran, focusing on 2016 census results. Statistical Centre of Iran. 2017. https://www.amar.org.ir.
Statistical Centre of Iran. (2021). Calculating Total Fertility Rate by Provinces of Iran: 2016–2020 [Persian]. Statistical Centre of Iran. 2021. https://www.amar.org.ir/news/ID/15755/categoryId.
Torabi, F. (2020). Spouses' division of household labour in urban areas of Iran. *Asian Population Studies, 16*(3), 248–263. https://doi.org/10.1080/17441730.2020.1763018
Torabi, F. (2021). Education and time investment in domestic and parental activities in urban areas of Iran. *Journal of Population Research (Canberra, A.C.T.), 38*(1), 25–51. https://doi.org/10.1007/s12546-020-09251-z
Torabi, F., Baschieri, A., Clarke, L., & Abbasi-Shavazi, M. J. (2013). Marriage postponement in Iran: Accounting for socioeconomic and cultural change in time and space. *Population, Space and Place, 19*(3), 258–274. https://doi.org/10.1002/psp.1710
UNPD. (2023). World Population Prospects: The 2019 Revision. World Population Prospects 2019. 2019. https://population.un.org/wpp/Download/Standard/.
Van Biesebroeck, J. (2011). Wages equal productivity. Fact or fiction? Evidence from Sub Saharan Africa. *World Development, 39*(8), 1333–46. https://doi.org/10.1016/j.worlddev.2010.12.002
WIC. (2018). Wittgenstein Centre Data Explorer Version 2.0. http://www.wittgensteincentre.org/dataexplorer.

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