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Sustainable and Equitable Pension Reform for Emerging Economies: an Application to Indonesia

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Abstract

This paper develops a general equilibrium overlapping generation model with heterogenous households to study pension reforms in emerging economies with large informal employment and rapid population ageing. Using Indonesia, a country in which 80% of the labour force works in the informal sector, and which confronts a 5-fold increase in the 65+ share of the population this century, as our exemplar economy, we assess, both separately and in combination, the impact of increasing the pension access age for formal labour and introducing a flat-rate social pension for informal labour.

Households are differentiated by skill and employment type, and confront idiosyncratic labour income and survival shocks. The micro/household behaviours are calibrated with Indonesian Family Life Survey (IFLS) data, along with recent World Bank macro and fiscal data to target some macro moments. The benchmark model assumes tax and pension policy settings applicable solely to formal labour.

We show that in a model incorporating population ageing, the combined reforms would significantly improve aggregate welfare for both groups: flexibility in late life

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work in the formal sector benefits those workers, while informal workers benefit from the social pension, set at 6.5% of per capita GDP. The incremental revenue requirement, taking account of both the reduced formal pension outlays and the cost of the social pension, is calculated to be about 1.5% of GDP.

Keywords: Population Ageing, Informal Labour, Retirement Policies, Social Security, Redistribution, Life Cycle, Stochastic General Equilibrium.

JEL Classification: E26, J1, J21, J26, H55, D15, C68

1 Introduction

It is now generally recognized that population ageing is pervasive in both the developed world and many developing countries. It brings with it a range of policy challenges, especially in emerging economies whose social protection structures are thin. This is typically the case in a range of developing nations in Southeast Asia, which we generically label SEA emerging economies. In these countries, large informal employment sectors, often comprising as much as 80% of the labour force workforce (International Labour Office (ILO), 2018) interact with demographic ageing to generate increasing inequality at older ages. The sharp distinction between the economic welfare of formal and informal workers is exacerbated at older ages, as those in the formal sector enjoy relatively generous pensions while informal workers have no government support, and often very limited assets, to rely upon when their earnings capacity is exhausted. This combines with large scale internal migration to the cities, often leaving older people without access to the care which in the past was available through younger generations, to generate the potential for widespread economic hardship.

Demographic projections from a range of sources indicate that rapid population ageing is underway. Projections for Indonesia show an increase in the old-age dependency ratio of almost 5-fold between 2020 and 2100 (United Nations (UN), 2019). Similar projections exist for Thailand, Vietnam (currently the world's most rapidly ageing nation) and other populous SEA economies.

Pension policy in many of these jurisdictions is largely inadequate. Contributory pensions are available only in the formal sector, with access ages often set to early ages, increasing payroll tax rates and providing a strong incentive for highly productive formal sector workers to leave the workforce earlier than they would otherwise. Non-contributory, or social pensions, are set at levels well below generally accepted poverty lines, and are often not available at all. The situation is compounded by poorly developed private financial governance structures (see Chomik and Piggott (2015), World Bank (2016) and Kudrna, O'Keefe and Piggott (2023)). Demographic change will transform SEA economies within a generation and major social protection policy formulation will be required in coming decades to avoid considerable human suffering.

At the same time, life expectancy, and healthy life expectancy, in these countries has been increasing. This has generated active debate focused on pension access age adjustment. In some countries, for example Indonesia and Vietnam, legislation to progressively increase access age has already been enacted, while in others, for example China, such a policy reform is under active consideration.

This paper develops and applies a general equilibrium overlapping generations (OLG) model, with heterogeneous agents, to analyse reforms geared to these contingencies. The model is calibrated to Indonesia. Households are differentiated by skill and employment type, and in this way the informal sector is explicitly represented. All households confront idiosyncratic labour income and survival shocks. The model includes a production sector and a government sector with taxation and Pay As You Go (PAYG) public pensions.

The model is based on the seminal computable OLG model developed by Auerbach and Kotlikoff (1987). It incorporates many features of the model by Song et al. (2015) applied to China. It is extended here to incorporate formal and informal workers that face stochastic labour productivity and are subject to different policy rules. The benchmark model is calibrated to the Indonesian economy (2000-2019), fitted to Indonesian demographic, household survey, macroeconomic and fiscal data. The model accounts for a detailed representation of Indonesia's labour market, as well as of government tax and pension policies in Indonesia, and a macro specification drawing on national data and international sources.

In the context of demographic ageing, the OLG model is a core construct, and is now routinely used and developed for long-run policy analysis in developed countries. This type of macroeconomic model captures economy-wide interactions, including inter-temporal interactions, which need to be considered in assessing the impacts of alternative social policy paradigms. Importantly, the framework accommodates the life-cycle behaviour of households (now often heterogenous households by skill types, labour productivity and shocks) whose lifespans overlap and a government sector with detailed tax and spending policy settings. Given these properties, the OLG model has become a standard economic tool for studying ageing and public policy issues in advanced economies. See, for example, Nishiyama (2015), McGrattan and Prescott (2017) and Hosseini and Shourideh (2019) for the US; Braun and Joines (2015) and Kitao (2015) for Japan; Kudrna, Tran and Woodland (2015, 2019, 2022) for Australia; and Börsch-Supan and Ludwig (2013) for an example of multi-country OLG model for pension reform in Europe. Fehr (2016) provides a recent review, reporting the major advances in OLG methodology and applications over the past 30 years. The US Congressional Budget Office uses an OLG model for its long run fiscal work (Nishiyama and Reichling 2015), and the Australian Treasury has their Overlapping-Generations for Australia (OLGA) model (Cai et al., 2023).

OLG models to guide social policy have almost exclusively been constructed for developed countries and are almost non-existent in the emerging SEA economies. The development of sophisticated economic modelling in that region, to explicitly incorporate the impact of an ageing demographic and formal-informal labour to assess the impact of alternative age-related social policy initiatives, is long overdue (Lee et al., 2016).

In most cases where OLG modelling has been undertaken in an emerging Asian economy context, interactions with the informal sector are ignored. For example, Widjaja (2008) develops a one sector model for Indonesia, dealing only with the formal sector; and similar studies have been undertaken for China (e.g., Song et al., 2015; Curtis et al., 2015;

Imrohoroglu and Zhao, 2018).[1]

The model developed here may be thought of as an early step towards making OLG structures available to policymakers in emerging economies, taking explicit account of their large informal employment. In the present paper, we account for observed differences in household lifecycle behaviour between formal and informal workers (and uncertain labour productivity and earnings). We rely heavily on the Indonesian Family Life Study (IFLS) to generate a detailed calibration of household and labour force behaviour, distinguishing both between high and low skill, and between informal and formal employment. The IFLS is a rich ongoing longitudinal socio-economic survey representing more than 80% of the population.

It is possible to apply the model reported here to an infinite array of policy proposals. We have examined the policy literature on pensions in our target economies, and chosen the following specific reforms:

- an increase of the access age in the formal sector, which reduces the formal pension revenue requirement, and encourages productive workers to remain in the labour force for longer, thus generating additional income tax revenue and increasing aggregate output.

- The establishment of a (modest, poverty alleviating) social pension, with benefits set at 6.5% of GDP per capita. The additional revenue generated by the access age increase in the contributory pension can be applied to partially offset the cost of the social pension, available to informal workers who do not have access to the contributory pension.

We quantify the impacts of these two policy reforms in combination, and find that not only do all households experience an improvement in welfare, aggregate output also increases. Based on the model simulations, these are our key findings:

[1] There is a limited body of macro-development literature that studies public policy reforms in emerging Latin-American economies, using OLG modelling with formal and informal labour. For example, Jung and Tran (2012) develop their stochastic 2-sector OLG model with an application examining the implications of extending social security to the informal sector in Brazil. There were also more recent papers on social security reforms in Chile, using OLG models with taxed formal labour, untaxed informal labour and home production (e.g., see McKiernan (2021) allowing for labour supply/hours choice across formal and informal sectors). Similarly, Esteban-Pretel and Kitao (2021) develops a structural model of heterogeneous agents with sectoral choice in a dual economy and their applications are to labour market policies in Mexico.

Note that our analysis of the IFLS data (discussed in the next section) indicates that emerging Asian economies (i.e., represented by Indonesia in this paper) are quite different to Latin American countries that typically have a much smaller informal economy (< 50%) – largely due to government policy and regulations (see Levy, 2008). By contrast, in Indonesia the informal labour force is much larger (around 80%) and the IFLS data indicates that only about 10% of informal labour (of prime working age) move to formal employment, while more than half of formal workers move to informal employment around the formal retirement age. As detailed further in the text, our model is closely calibrated to match these micro behaviours specific to emerging Asian economies, using Indonesian data.

Further note that Poonpolkul et al. (2023) use a life-cycle model with features similar to the present OLG structure to investigate the future sustainability of the Thai pension system.

- The extended formal retirement age policy has positive effects on consumption, labour supply and welfare of formal workers (that are no longer forced to retire from formal employment at age 55);
- The introduction of social pensions targeted to informal workers at older age generates large welfare gains for currently living informal elderly;
- The overall pension reform (comprising both the reforms above in combination) leads to higher welfare across the employment-skill distribution of households; and
- Indonesia's population ageing will generate some pronounced fiscal costs, which are shown to be mitigated by the examined changes to PAYG pensions as well as by the means testing of social pensions – with pension reforms generating higher average welfare gains under this demographic transition.

The paper is structured as follows. Because of our reliance on labour force disaggregation to realistically represent the informal sector, we begin in Section 2 by documenting key stylized facts about the labour force in Indonesia, paying particular attention to the distinction between formal and informal labour. Section 3 documents the OLG model; the calibration of the benchmark model to Indonesia is presented in Section 4. Section 5 reports and discusses the economy-wide effects of population ageing and pension reforms, including life cycle, welfare, macroeconomic and fiscal implications in the long run and over the demographic transition path. Section 6 provides the sensitivity analysis of the reform results to several modifications/extensions of the model. Section 7 offers some conclusions.[2]

2 Indonesian labour force

The structure and paramaterization of the model developed here relies heavily on the detailed labour data collected by the IFLS. The salient features of the labour market as revealed by this survey are that the proportion of workers in the informal sector is high and relatively constant, at about 80% of the total labour force; that formal sector workers are much more productive than informal workers; and that there is low transition between the formal and informal sectors through the life cycle, except that a significant proportion of formal sector workers gravitate to the informal sector after pension access age. These observations motivate our decision to remove household choice with respect to whether labour is supplied formally or informally. Note that similar observations for labour force are observed in other emerging Asian countries (of Southeast Asia in particular), such as Vietnam and Thailand (e.g., see ILO (2018), Kudrna, Le and Piggott (2020, 2022)).

[2] The paper is accompanied with several Appendices, with further details on (A) IFLS data work, (B) numerical solution, (C) distributional results (of Section 5) and (D) sensitivity analysis (of Section 6).

We first provide a brief description of the IFLS and then a data analysis of the Indonesian labour force, documenting its composition, labour productivity, hours worked, labour earnings, and also labour transitions.

2.1 Indonesian Family Life Survey

The Indonesian Family Life Survey (IFLS) is an ongoing longitudinal survey in Indonesia, representative of about 83% of the Indonesian population and containing over 30,000 individuals living in 13 of the 27 provinces in the country (see Strauss et al. (2016)).[3] It consists of five waves that were initiated in 1993, 1997, 2000, 2007, and 2014.

These surveys are information-rich socio-economic surveys which collect a wide range of data for studying life cycle behaviour and outcomes for the Indonesian population.[4] Data on employment, labour force participation, education, health, income, expenditure, housing, fixed assets and durable goods are collected by the IFLS.

In this paper, we focus on the labour force data, using the IFLS waves 3 to 5 for years 2000, 2007 and 2014.[5] Further details are provided in Appendix A.

2.2 Composition of labour force

The composition of Indonesia's labour force is presented in Table 1, using all three IFLS waves and also each wave separately, in order to document the recent trends. In the table, we decompose the labour force into four types, defined above as formal-low, formal-high, informal-low and informal-high (skill) types.[6]

[3]Data and documentation can be accessed at https://www.rand.org/well-being/ social-and-behavioral-policy/data/FLS/IFLS.html.

[4]Note that the IFLS covers the whole life cycle, collecting data for household heads aged 18 and over, whereas the Health and Retirement Survey (HRS) in the US and many other HRS-related surveys in other countries cover only older ages - 45 and over.

[5]These last three waves of the IFLS (2000-2007-2014) provide the most updated information and necessary background for the analysis of both labour force in Indonesia. These surveys and their procedures were reviewed and conducted by the RAND corporation, and in Indonesia by the University of Gadjah Mada – the oldest and the largest state university in Indonesia (see https://www.rand.org/well-being/social-and-behavioral-policy/data/FLS/IFLS.html).

[6]For details about employment/ skill definitions see Appendix A.

Table 1: Composition of Indonesian labour force*

Employment type[a]	Skill type[b]	2000	2007	2014	Overall
Formal	Low	6.0%	4.0%	5.6%	5.1%
	High	16.4%	16.5%	20.7%	18.0%
	(Total)	22.4%	20.5%	26.2%	23.1%
Informal	Low	56.1%	50.0%	42.8%	49.1%
	High	21.6%	29.5%	31.0%	27.7%
	(Total)	77.6%	79.5%	73.8%	76.9%
No. of observations[c]		6,784	8,522	9,926	25,232

Notes: *Based on males aged 20-54; [a]Informal employment definition as by ILO, with details in Appndix A; [b]Based on educational attainment, with High depicting those with at least 12 years of schooling; [b]Derived from all three waves - IFLS 2000-2014; [c]Number of observations used in each IFLS wave and all three waves combined under Overall.

First, we focus on the overall sample (in the column "Overall"). The (overall) shares of each type are: 5.1% for formal-low, 18% for formal-high, 49.1% for informal-low, and 27.8% for informal-high – implying about 77% of labour is informal. Note that the informal-low type represents the largest share of the labour force, amounting to almost 50% of working age population (with 25,232 observations across the three IFLS waves). In contrast, most formal workers are high skill (completed high school) representing 18% of the sample, with only about 23% of total employment being formal.

Next, we compare the results from the different IFLS waves. Table 1 indicates that informal employment increased by about 2 p.p. between 2000 and 2007 (to almost 80% of the sample) but overall, there has been a (rather small) decline in informal employment by 3.8 p.p. between 2000 and 2014. This demonstrates the "persistent" property of informal employment. However, the skill composition of the labour force, and particularly of informal workers, has changed significantly in the same period from 2000 to 2014. As shown, the share of the informal-high type has increased by almost 10 p.p. in 2014, compared to 2000. The share of all high skill (in both formal and informal employment) has increased to over 50% of the sample in 2014, from about 38% in 2000. The cohort-specific analysis of the composition of Indonesia's labour force (which is not shown here but can be provided upon request) shows that the increase (of high skills in the population) is particularly significant for young cohorts – who gain education and yet often still remain in informal employment.

2.3 Earnings, productivity and labour supply

Above, we have shown persistently large informal employment in Indonesia. We now document the labour earnings, hours worked and labour productivity of the (overall) sample over the working life cycle. These lifecycle profiles are plotted in Figure 1 for the four (employment-skill) types of workers, with the mean observations (depicted by markers) and quadratic (in age) estimates (depicted by lines). The labour earnings variable (for each individual in the sample) is constructed as the total of salary (bonus included) from the main job and extra jobs (if any) or the net profit from an own-farm or non-farm business.[7] Labour supply is defined as hours worked per year (normalised by assumed annual time endowment of 5,460 hours per year) and labour productivity as earnings per hour worked.[8]

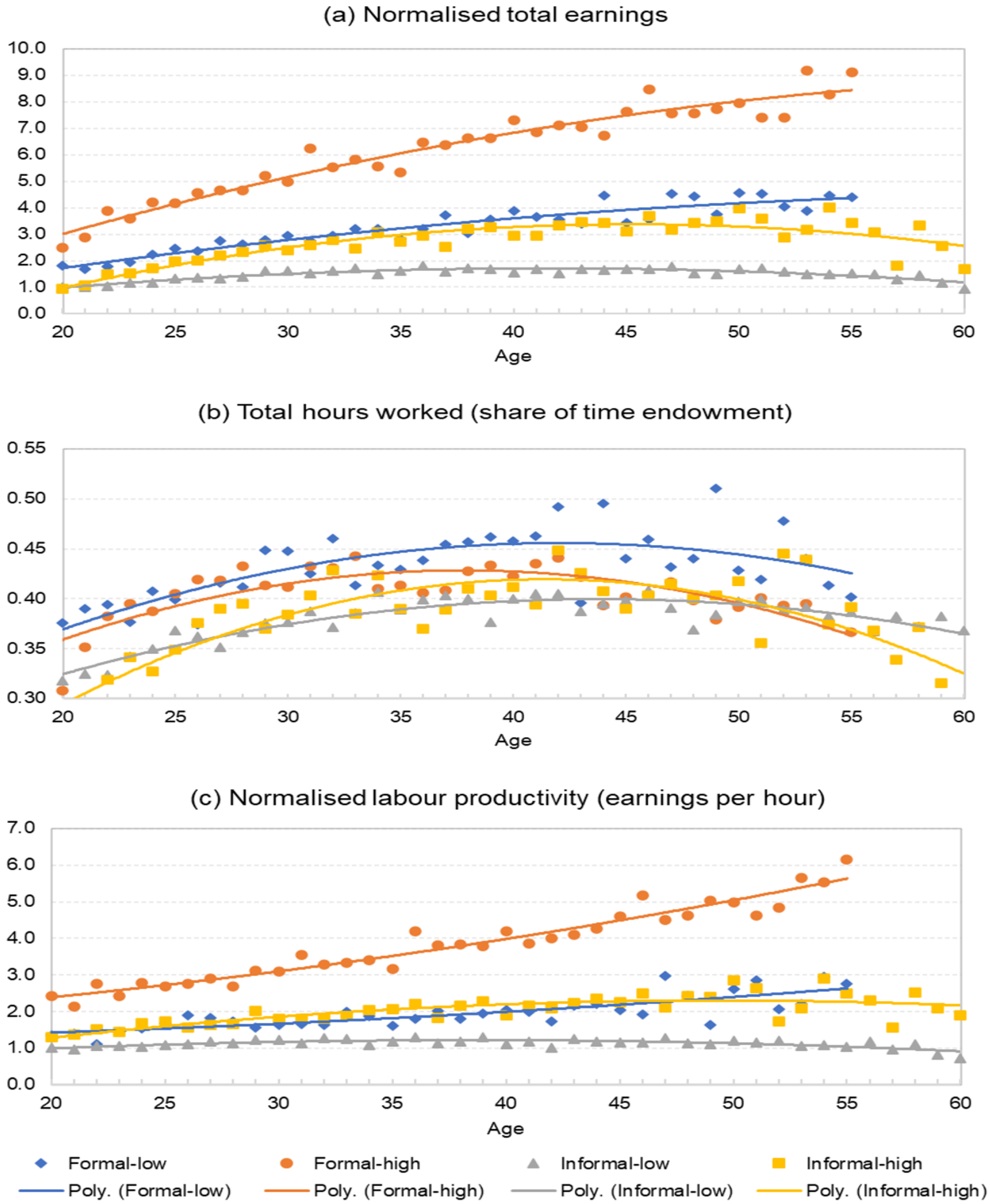
In Figure 1(a), we plot labour earnings (ln of annual male earnings across the three IFLS waves) over the ages of 20-54 for formal types and 20-60 for informal types, with all the profiles normalised by earnings (ln of annual labour earnings) of the informal-low type aged 20 (=15.58). The objective is to compare life cycle earnings across the four types of workers. As shown by the figure, individuals in formal employment have significantly higher earnings compared to those operating in informal employment. The slope of the earnings profile for formal workers is steeper over early working years, increasing more significantly than for informal workers, who, on average, experience gradually declining earnings at older ages. The skill type also matters, as high skill types are shown to earn significantly more than low skill types. For example, Figure 1(a) shows that the formal-high type workers in the age group 50-54 earn on average about eight times more than the informal-low type workers of the same age group.

As indicated by Figure 1(b), one of the reasons for high earnings inequality is lower (average) hours worked by informal workers. We can show that by restricting our data sample (i.e., excluding those with low and irregular hours worked) average hours worked by informal workers increase significantly.[9] This implies that many informal workers work low and irregular hours. The differences in labour supply by employment-skill type worsens earnings inequality. In Figure 1(c), we plot similar hump-shaped profiles of the labour productivity (to life cycle earnings) with the gaps between different household types being somewhat smaller than the gaps in total earnings. Note that we have also calculated the variance of

[7]By nature, a formal worker is mainly a wage worker, while an informal worker is usually self-employed. Note that for an informal worker, it is difficult to distinguish between labour earnings and capital earnings, as they only report the net profit from their business (or their household business). Therefore, we use the net profit in the calculations of their earnings in full. When pooling up data from different survey years, the Consumer Price Index (CPI) obtained from the International Financial Statistics (IFS) is used to construct real annual earnings.

[8]In the model developed in the next section, we use the labour productivity profiles (and the stochastic process) as inputs for calibrating household life cycle decisions but also target the model-generated earnings and hours by age and employment type to data provided in this subsection.

[9]See Kudrna, Le and Piggott (2020) who in their sample, do not include restrictions in relation to hours worked per week (at least 10 hours in this paper) and minimum weeks per year worked (at least 15 weeks here).



Source: IFLS 2000-2014.

Figure 1: Labour earnings, supply and productivity by age and employment-skill type

log productivity by employment type – a measure of labour productivity uncertainty that is estimated to be higher for informal workers.[10]

2.4 Employment transitions

In this subsection, we investigate sectoral (or employment type) transitions for those between waves 2007 and 2014 and their labour earnings observed in 2014. We keep only people who appear in the two consecutive survey years. Table 2 reports the results for selected age groups, using either those in formal or informal employment in 2007 and their employment type observed in 2014. The transitional probabilities are presented as a percentage of those in each category staying in that category or moving to the other category in 2014.[11] Their average annual labour earnings are observed in 2014 and reported in units of 1,000 Indonesian Rupiah (IDR).

Table 2: Employment transitions and earnings*

Employment in 2007	Age group in 2007	Employment in 2014[a]		Labour earnings in 2014[b]	
		Formal	Informal	Formal	Informal
Formal	25-29	61.4%	34.9%	48,418	29,484
	30-34	72.4%	24.1%	52,984	27,418
	35-39	73.6%	25.0%	51,785	34,331
	40-44	68.8%	27.6%	61,314	31,021
	45-49	77.6%	18.7%	69,243	23,654
	50-54	29.8%	56.1%	62,483	29,771
	25-49	69.8%	27.1%	55,540	29,782
Informal	25-29	17.2%	75.0%	33,716	21,644
	30-34	11.5%	80.5%	35,916	19,338
	35-39	10.3%	82.9%	40,163	20,139
	40-44	6.9%	84.5%	32,497	18,123
	45-49	5.6%	86.3%	31,847	17,349
	50-54	3.5%	86.6%	22,692	13,974
	25-49	11.1%	81.1%	35,234	19,526

Notes: *Using IFLS waves in 2007 and 2014 (males in selected working age groups), we calculate (a) transition probabilities (% of those in given employment in 2007 staying in that employment or transitioning to different sector in 2014 (note that remaining percentage are those transitioning to no job category (not displayed)) and (b) their average annual labour earnings (of stayers and movers observed in 2014, expressed in units of 1,000 Indonesian Rupiah (IDR).

[10] Given the 7-year gaps between the IFLS surveys, we use the cross-section data across the IFLS 2000, 2007 and 2014 waves, but here we use main job (MJ) earnings and hours (rather than all job (AJ) earnings and hours used above in Figure 1).

[11] Note that the third category (not reported in Table 2) are all those with no job or low hours worked category (see the data selection in Appendix A), which is also included in the transitional probability matrix. Note that the reported percentages do not add to 100%, with the remaining percentage (to 100%) representing those either in formal or informal in 2007 moving to "no job" category.

Several observations can be drawn from Table 2. First, focusing on those of primary working ages 25-49, we show that only a small fraction of informal workers are moving to the formal sector, with only about 11% of those in informal employment in 2007 switching to formal employment in 2014. However, the proportion of workers moving from formal employment to the informal sector was higher about 27%. Second, the probability of those in either formal or informal employment in 2007 staying in that employment in 2014 increases for older age groups. For example, for formal workers aged 25-29 in 2007, the probability of moving to informal employment increases significantly to over 56%.

Table 2 also shows that the stayers (in formal employment) have significantly higher earnings compared to the movers at every age, and that the gap between their earnings widens by age. However, the movers from informal employment are shown to have higher earnings than the stayers, with the gap between earnings declining significantly at older working ages. The significantly higher earnings in formal employment seem to support the ILO's view that "most people enter (or transition out of formal employment to) the informal economy not by choice, but as a consequence of a lack of opportunities in the formal economy and in the absence of other means of livelihood" in developing countries.[12]

We now turn to the model structure.

3 The model

3.1 Overview

We formulate a dynamic, stochastic general equilibrium model, which consists of overlapping generations of heterogeneous households (by sectoral and educational attainments), profit-maximizing firms, a government sector with taxation and PAYG public pensions applicable to formal labour. The model incorporates population aging and many features of the OLG model by Song et al. (2015) applied to China, but it is extended here to incorporate and distinguish between formal and informal labour facing stochastic labour productivity and different policy rules. The model is calibrated to Indonesia, where around 80% of total employment is informal.

The model comprises a household sector (with formal and informal workers and population ageing), a production sector (that demands labour and capital from all types of workers) and a government sector (with government tax and pension policy).

The household sector is populated by overlapping generations of heterogenous households.[13] Hence, the model accounts for both inter-generational as well as intra-generational

[12] See page 1 (Preamble) of ILO Recommendation R204 (2015), available at: https://www.ilo.org/dyn/normlex/en/f?p=NORMLEXPUB:12100:0::NO::P12100_ILO_CODE:R204

[13] The terms – workers, households, agents and individuals frequently used in this section are interchangeable.

heterogeneity. Specifically, there are multiple overlapping generations in each time period, with each generation consisting of four types of households – formal low-skill, formal high-skill, informal low-skill and informal high-skill types. Individuals are assigned a permanent skill type based on the observed probability distribution and face stochastic labour productivity (differentiated by household type) and survival over the life cycle.[14] Households are assumed to make decisions about their consumption and savings, as well as leisure, labour supply and retirement, by solving their optimization problem – maximizing their expected discounted lifetime utility from consumption and leisure, and bequests (left upon death) subject to their budget and time constraints.

The model incorporates the formal and informal types of households that face different government policy rules.[15] The labour supply (decision) is elastic, both types of workers making labour-leisure and retirement decisions, while only formal workers are subject the formal retirement age (j_R). At $j \geq j_R$, these households can continue working, but their labour productivity is assumed to be reduced to the productivity of the respective skill type in informal employment.[16] In the benchmark model, we assume that only the formal high-skill type ($\approx 18\%$ of the workforce) participates in public PAYG pensions, paying the contributions and collecting public pensions from j_R. All informal workers (and formal low-skill workers only around 5% of the workforce) do not receive any public benefits in the benchmark model, and so they rely on their private resources, including labour earnings and transfers at older age. The government tax policy largely exempts informal workers from the taxation, as indicated below.

The government faces a budget constraint that, on one side, includes revenues from taxing incomes and consumption of largely formal workers and, on the other side, expenditures on government consumption and interest on government debt. The income tax is progressive with the taxable income including labour earnings and pension incomes. The model also features progressive capital income and consumption bases and taxation, each with the given flat tax rate and exemption level. Hence, the price of consumption is lower for most informal workers, with many paying no consumption tax. The government also runs a PAYG public

[14] In this version, we assume perfect labour market frictions in emerging economy and so abstract from the employment choice. As a sensitivity check in Section 6, we allow for observed labour market transitions out of formal employment over the life cycle in the IFLS data.

[15] As indicated in Appendix A, our definition of informal labour (or informal employment) follows the widely used definition by ILO (2018) that classifies all own-account employers and all contributing family members as being in informal employment and for employees to be considered as informal, the employment relationship should not be subject to national labour legislation, income taxation, social protection or entitlement to certain employment benefits. Drawing on the IFLS data, we use any medical spending and health insurance benefits from employers as the policy defining informal employees. Note that this narrower definition underestimates the size of informal employment, but only by about 5 p.p., with recent estimates using a broader definition by ILO (2018) for Indonesia similarly showing a high percentage of the workforce being informal (using the broader definition, i.e., also including social security contributions).

[16] This is to account for the observed transition (out of formal) to informal employment around formal retirement (pension access) age with earning much lower labour income, as reported in Section 2.

pension system with defined benefit pensions based on former earnings applicable only to formal-high skill workers. The benefits are PAYG financed by payroll taxes imposed on the current formal-high skill workers. In the benchmark economy, all other types of workers pay no or low taxes, but also do not receive any public benefits at older age – hence relying on their earnings, asset income and bequest receipts.

The production sector consists of representative (perfectly-competitive) firms demanding labour and capital from both formal and informal workers to produce a single output good, according to the standard Cobb-Douglas production function. Solving the firms' profit maximization problem then determines factor prices – the wage and interest rates. We assume the closed economy market structure with fully endogenous factor prices. And there is a common final consumption good produced that is then consumed by formal and informal household types.[17]

We now proceed to providing the details for the demographic structure, the sectors and the equilibrium of the proposed OLG-EE model.

3.2 Demographics

The model economy is populated by overlapping generations of heterogeneous households with age $j \in \mathcal{J} = \{1, .., J\}$. Upon entering the model at age $j = 1$, each household is assigned a permanent household (employment-skill) type $s \in \mathcal{S} = \{1, .., S\}$ according to the probability distribution ϖ_s.[18] We start from a stationary demographic structure, where the total population growth rate n equals the fertility rate, given by the growth rate of new born cohorts n_1, and where lifespan uncertainty is given by survival probabilities ψ_j (time-invariant) conditional probabilities of surviving from age $j-1$ to age j with $\psi_1 = 1$ and $\psi_{J+1} = 0$. In this stationary demographic environment, the constant population shares can be defined as

$$m_j = \frac{\psi_j m_{j-1}}{1+n} \quad \text{with} \quad m_1 = 1. \tag{1}$$

Over the demographic transition path, we incorporate time index t, and allow for the two growth rates to differ $n_t \neq n_{1,t}$ and with time-variant survival rates $\psi_{j,t}$. The population shares $m_{j,t}$ (of generations at age j and in time period t) are then derived as

$$m_{j,t} = \begin{cases} (1+n_{j,t})m_{j,t-1}, & \text{for} \quad j = 1 \\ \psi_{j,t} m_{j-1,t-1}, & \text{for} \quad j \geq 2 \end{cases}, \tag{2}$$

[17] As a robustness check in Section 6, we consider an alternative approach. Drawing on entrepreneurs models (e.g. Kitao (2008), Fehr and Hofbauer, 2016), we model all informal labour as self-employed working for and investing in their business.

[18] As already indicated, there are 4 types of households in the model – formal-low, formal-high, informal-low and informal-high skill types, with the labour force composition and labour productivity estimated using the IFLS 2000-2014.

where the total population and cohort shares at time t are then calculated as $Pop_t = \sum m_{j,t}$ and $\mu_{j,t} = m_{j,t}/Pop_t$.

3.3 Households

Households make consumption and saving, labour supply and retirement decisions, which depend on the available resources, the existing tax and pension systems, and expected labour productivity shock $\eta_j \in \mathcal{E}$. The workers in both formal and informal employment supply labour, receiving different effective wage rates, with their respective labour productivities estimated from the IFLS data. Formal workers at age j_R are assumed to face significant decline in their productivity, now set to that of informal employment. They can work past j_R but fund their consumption mainly from their savings and pension benefits. Formal workers are subject to government tax and pension policy, while informal workers solely rely on their private resources, including labour income, private assets, and transfers.

Distributional measure of households Households face the following state vector:

$$z = (j, s, a_j, ep_j, \eta_j) \in \mathcal{Z} = \mathcal{J} \times \mathcal{S} \times \mathcal{A} \times P \times \mathcal{E}$$

where $a_j \in \mathcal{A} = [0, \infty]$ denote *current* total assets that are initially zero ($a_1 = 0$) and restricted throughout the whole life cycle to be non-negative, i.e., $a_j \geq 0$. As indicated above, formal workers $j < j_R$ accumulate earnings points $ep_j \in P$, which determine their pension benefits. All workers also receive productivity shock at each age j, which follows a skill-specific, finite-state Markov process.

In each period, the population is fragmented into subgroups $\zeta_t(z)$, according to the initial distribution at age $j = 1$, mortality, population growth, the Markov processes and optimal household decisions. Let $X_t(z)$ be the corresponding cumulated measure to $\zeta_t(z)$. The initial distributional measure of households at age $j = 1$ is

$$\int_{\mathcal{S}\times\mathcal{E}} \mathrm{d}X_t(z) = 1 \qquad \text{with} \quad z_1 = (1, s, 0, 0, \eta). \tag{3}$$

Let $\mathbf{1}_{k=x}$ be an indicator function that returns 1 if $k = x$ and 0 if $k \neq x$. Then, the law of motion for the measure of households follows

$$\zeta_{t+1}(z) = \int_{\mathcal{Z}} \mathbf{1}_{a_{j+1}=a_{j+1}(z,Z_t)} \times \mathbf{1}_{ep_{j+1}=ep_{j+1}(z,Z_t)} \times \\ \times \pi(\eta^+|\eta)\mathrm{d}X_t(z), \tag{4}$$

where $\pi(\cdot)$ denotes the transition probabilities for labour productivity of workers (of each skill type) from one period to the next and $Z_t = (\zeta_t(z), \Psi_t)$ denotes the state of the economy in period t, with Ψ_t being government policy in period t.

Note that below (to simplify the notation), the state index z is omitted with households distinguished only according to their age j (and for the employment-skill specific parameters by household type s).

Preferences Households (of type s) have preferences over streams of consumption c_j and leisure l_j (where $1 - l_j$ is labour supply with time endowment normalized to one) and also bequests (or transfers) left, if not survive to age $j + 1$.[19] We assume the standard Cobb-Douglas period utility form of

$$u(c, l) = \frac{\left((\frac{c}{\mu_j})^{\gamma_j^s} (l)^{1-\gamma_j^s} \right)^{1-\sigma}}{1 - \sigma},$$

and the bequest function given by

$$\mathcal{B}(\bar{b}) = q_1 \left[1 + \frac{\bar{b}}{q_2} \right]^{1-\sigma_b},$$

where the utility function parameters include the coefficient of relative risk aversion σ, the expenditure share of ordinary consumption γ_j^s (note that this parameter is household type- and age-specific, calibrated to match observed labour supply profiles by household type in the IFLS data), equivalence scale parameter μ_j (that accounts for changing household composition over the life cycle and the number of dependents). Any future annual utility is discounted by the enmployment type-specific discount factor β^s and uncertain survival, with surival probabilities given by ψ_j. The bequest motive function follows De Nardi (2004), with the term q_1 reflecting the parent's concern about leaving bequests, q_2 measuring the extent to which a bequest is a luxury good (i.e., indicating that bequests are less likely to be made by those in informal employment) and σ_b governing the relative risk aversion for the bequest. Bequests (also skill specific) are equal to assets ($\bar{b}_{j+1} = (1 + r)a_{i+1}$) left by those agents who do not survive to $j + 1$.

At the beginning of each period, each worker with assets a_j and bequest transfers $\bar{b}_j$ (and earning points ep_j only for formal workers) realizes the current productivity level η (also skill-specific) and then decides on consumption, savings, labour supply at age j and when to retire. In what follows, we describe the optimization problem of a household.

Households' problem The optimization problem can be expressed as

[19] In this subsection, we will omit the state index z for every variable, and households are only distinguished according to their age j. Since some parameters describing household preferences and in households' optimization problem are also household type specific, we indicate these parameters by including the household type s.

$$V_j = \max_{c_j, l_j, a_{j+1}} \left\{ u(c_j, l_j) + \beta \psi_{j+1} E_j \left[V_{j+1} | \eta \right] + (1 - \psi_{j+1}) \mathcal{B}(\bar{b}_{j+1}) \right\}, \tag{5}$$

subject to the constraint

$$(1+g)a_{j+1} = \begin{cases} (1+r)a_j + \widetilde{y}_j + b_j + p_j - t^y(\widetilde{y}_j) - t^r(\widetilde{a}_j) - (c_j + t^c(\widetilde{c}_j)), & \text{if formal,} \\ (1+r)a_j + y_j + b_j - (c_j + t^c(\widetilde{c}_j)), & \text{if informal,} \end{cases} \tag{6}$$

$$c_j > 0, 0 \leq l_j \leq 1, a_{j+1} \geq 0,$$

and $a_1 = 0$. The expectation operators E_j in equation (5) are with respect to the stochastic processes of η. According to the per-period budget constraint (6) for formal workers, future assets a_{j+1} (adjusted for economic progress growth at the rate g) are derived from current assets (including interest income), gross labour income (net of PAYG pension contributions paid the rate of τ^p up to the contribution ceiling of $3\overline{y}$ – three time average economy-wide labour earnings) $\widetilde{y}_j = y_j - \tau^p \min[y_j; 3\overline{y}]$, bequests b_j and pensions p_j less progressive income taxes $t^y(\cdot)$, capital income taxes $t^r(\cdot)$ and consumption expenditure (including consumption taxes, $t^c(\cdot)$).[20] Note that gross labour income equals $y_j = we_j\eta_j\ (1 - l_j)$, where w is the economy-wide wage rate (normalized to one in the benchmark), age- (as well as household type-) specific labour productivity $e_j\eta_j$ and labour supply $1-l_j$. Labour productivity consists of the deterministic part e_j per time unit and the transitory component η_j that evolves stochastically over time according to an AR(1) process.[21] Consumption and leisure have to be positive, with the latter $(1 - l_j)$ restricted by 20 discrete labour supply points equally spaced between 0 and 1. We do not allow for negative assets, with the borrowing constraint $a_{j+1} \geq 0$ imposed on all households.[22]

3.4 Production sector

The production sector is characterized by an aggregated firm (representing a large number of perfectly-competitive firms) that demands capital K_t and effective labour L_t from both

[20] Taxation and pension benefits are discussed in more detail in the government sub-section below.

[21] Specifically, the transitory component is assumed to have an AR(1) autoregressive structure:

$$\eta_j = \rho \eta_{j-1} + \epsilon_j \quad \text{with} \quad \epsilon_j \sim N\left(0, \sigma_\epsilon^2\right) \quad \text{and } \eta_0 = 0,$$

where ρ is the persistence parameter and ϵ_j is the innovation of the process. The idiosyncratic innovation term ϵ_j is normally distributed with mean zero and variance, σ_ϵ^2. Note that ρ and σ_ϵ^2 are also skill-specific, but to simplify the expression we do not include the state s.

[22] Note that in the quantitative analysis section one of the counterfactuals introduces social pensions sp for informal households aged $j \geq 65$, which means that the budget constraint for informal households would need to include sp, with the aggregate expenditure on social pensions also included on the expenditure side of the government budget discussed in the government sector subsection below.

formal and informal households to produce aggregate output good Y, according to the Cobb-Douglas production technology:

$$Y_t = \kappa_t \left(K_t\right)^{\alpha} \left(L_t\right)^{1-\alpha}, \tag{7}$$

where α denotes the capital shares in production and κ is the productivity variable (assumed to growth at a constant progress rate g). Capital is rented from households at the riskless rate and depreciates at the depreciation rate δ.

The factor prices – wage rate w and interest rate r – are determined competitively by their respective marginal productivity conditions:

$$w_t = (1-\alpha)\kappa \left(\frac{K_t}{L_t}\right)^{\alpha}, \tag{8}$$

$$r_t = \alpha\kappa \left(\frac{L_t}{K_t}\right)^{1-\alpha} - \delta. \tag{9}$$

This approach of the production sector modelling is traditionally applied in developed-country OLG models. However, in our emerging economy model, we account for employment-specific inputs to the production, and as shown in the previous section, these differ significantly by employment type (e.g., formal-high types with much higher labour productivity compared to informal workers).[23]

To capture this, we specify one output (and so one consumption good), but with the model capturing closely life-cycle economic behaviour of households, which is impacted by government policy differentiated by employment type. We argue that this approach approximates heterogeneity in consumption, with informal labour mainly consuming low-price consumption goods, which are not taxed (given the consumption tax exemption defined in the government subsection below).[24]

3.5 Government sector

The government is responsible for collecting revenues from taxing households' labour income, capital income and consumption (all paid mainly by formal workers), in order to pay for its general consumption and interest on government debt. It is also responsible for regulating the PAYG pension system with payroll taxes financing public benefits (in this benchmark model, only applicable to formal-high type workers). The modelling of fiscal and pension

[23] Note that we can calculate the output produced by formal inputs, which, in our benchmark economy, is about 40% of overall output (despite only about 20% of workers being formal). In Loayza and Meza-Cuadra (2018), the share of formal output in Indonesia is even higher, estimated at about 46% in 2019.

[24] There are several possible alternative approaches to modelling the informal production sector in a model such as this: we undertake a preliminary exploration of the implications of adopting such alternatives in our sensitivity analysis (Section 6).

policies is described in more detail below.

PAYG financed pensions We assume a PAYG financed pension system, so that contributions (of those in formal high-skill employment) are directly used to finance benefits of (the formal high-skill) pensioners. The payroll tax rate τ_t^p is levied on labour income of formal high-skill workers, up to the contribution ceiling of $3\overline{y}$.[25] The resulting contributions are used to update the so-called earning points ep (that are used to link pension benefits to former earnings):

$$ep_{j+1} = ep_j + \min\left[\frac{y_j}{\overline{y}}; 3\right] / \left(j_R - 1\right), \tag{10}$$

where $\overline{y}$ is the average economy wide earnings level of the working age population (in our case of those aged 20 to 54). After reaching the retirement age j_R, pension benefit p is computed as the product of the accumulated earning points ep and the so-called pension value with the benefit amount for each individual earning point. For simplicity, we define the pension value as a fraction κ of average income $\bar{y}$, so that the pension benefit (for formal high-skill households only) is given as

$$p = ep \times \kappa \times \bar{y}. \tag{11}$$

This also implies an intra-generationally fair formal pension system, with little redistribution within the cohort.[26]

The total expenditure of this public pension program is given by

$$P_t^A = \textstyle\sum_{j \geq j_R}^{J} \mu_{j,t} \displaystyle\int_{\mathcal{Z}} p(z, Z_t) dX_t(z).$$

Finally, the budget constraint of this pension system (in the benchmark applied to formal high-skill households only) balances aggregate benefits P_t^A by endogenous payroll taxes at the rate τ_t^p in period t levied on the contribution base CB_t, i.e.

$$\tau_t^p CB_t = P_t^A \qquad \text{with} \qquad CB_t = \textstyle\sum_{j=1}^{J_R - 1} \mu_{j,t} \displaystyle\int_{\mathcal{Z}} \min[y(z, Z_t); 3\overline{y}] dX_t(z). \tag{12}$$

Taxes The government collects taxes to finance its spending programs. The model incorporates separate progressive tax policies impacting labour income, capital income, and consumption expenditure (collected mainly from formal workers).

The household's taxable labour income $\tilde{y}$ (includes labour earnings net of payroll tax up to the contribution ceiling) is taxed under the 2017-18 progressive income tax schedule $t^y(\tilde{y})$.

[25] This is based on OECD (2018) data for Indonesia.

[26] Note that this formula can be easily adjusted to allow for more redistribution within the cohort, adopting, for example, the bend points formula calculating old age social security benefits for the US retirees (see Kitao, 2014; Hosseini and Shourideh, 2019).

We assume that the capital income tax is collected on the household size rather than taxing the production sector. In the model, all household types are subject to capital income taxation, but we incorporate savings exemption $\overline{a}$ that is not taxed, effectively removing most informal household types from capital income taxation. The capital income tax function $t^r(\cdot)$ (with the flat capital income tax rate τ^r applied to taxable capital income above $\overline{a}$) can be expressed as:

$$t^r(\cdot) = \begin{cases} 0, & ra(z) \leq \overline{a} \\ \tau^r ra, & ra(z) > \overline{a} \end{cases} . \tag{13}$$

Similarly, consumption taxation is imposed on all household types, but we incorporate consumption floor $\overline{c}$ that is not taxed, effectively removing most informal household types from taxation of their consumption. The consumption tax function $t^c(\cdot)$ (with the flat consumption tax rate τ_t^c applied to taxable consumption above the consumption exemption) is given as:

$$t^c(\cdot) = \begin{cases} 0, & c(z) \leq \overline{c} \\ \tau_t^c c, & c(z) > \overline{c} \end{cases} . \tag{14}$$

The government total tax revenue TR_t in period t consists of revenues from the three different taxation sources: household income tax T_t^Y, capital income tax T_t^R and consumption tax T_t^C, with the tax receipts expressed as

$$\begin{aligned} T_t^Y &= \textstyle\sum_{j=1}^J \mu_{j,t} \int_{\mathcal{Z}} t^y(\tilde{y}(z, Z_t)) \mathrm{d}X_t(z) \\ T_t^R &= \textstyle\sum_{j=1}^J \mu_{j,t} \int_{\mathcal{Z}} t^r(a(z, Z_t)) \mathrm{d}X_t(z) \\ T_t^C &= \textstyle\sum_{j=1}^J \mu_{j,t} \int_{\mathcal{Z}} t^c(c(z, Z_t)) \mathrm{d}X_t(z). \end{aligned} \tag{15}$$

Government budget constraint The government issues new debt and collects taxes, with total tax revenue TR_t given above, in order to finance its general expenditure G_t and interest payments on its debt $r_t B_t^G$, with the government budget constraint given as

$$(1+g)(1+n_{t+1})B_{t+1}^G + TR_t = (1+r_t)B_t^G + G_t, \tag{16}$$

where B_t^G denotes net government debt.[27] We assume that the consumption tax rate τ_t^c adjusts to balance (16).[28]

[27] In the steady state, the budget balance becomes: $TR = G + (r - n - g - gn)B_G$.

[28] As indicated, under the overall pension reform scenario ($S3$) that includes social pensions sp, the total cost (of sp) P_t^S becomes an expenditure in the goverment budget constraint (16).

3.6 Equilibrium

Given the demographic structure (with cohort shares $\mu_{j,t}$) and government policy Ψ_t, a recursive equilibrium is a set of value functions $V(z, Z_t)$, household decision rules $c(z, Z_t), l(z, Z_t), a^+(z, Z_t)$, distribution of bequests $b(z, Z_t)$, and distributional measure of households $\zeta_t(z)$ that the following conditions are satisfied:

1. households make optimal decisions by maximizing value function (5) subject to their respective constraints (6);
2. factor prices are competitive, determined by (8) and (9);
3. the aggregation holds

$$\begin{aligned} L_t &= \sum_{j=1}^{J} \mu_{j,t} \int_{\mathcal{Z}} e\eta(1 - l(z, Z_t))\mathrm{d}X_t(z) \\ C_t &= \sum_{j=1}^{J} \mu_{j,t} \int_{\mathcal{Z}} c(z, Z_t)\mathrm{d}X_t(z) \\ A_t &= \sum_{j=1}^{J} \mu_{j,t} \int_{\mathcal{Z}} a(z, Z_t)\mathrm{d}X_t(z); \end{aligned}$$

4. The laws of motion (3) and (4) for the measure of households hold;
5. bequests satisfy

$$(1 + n_t)(1 + g) \int_{\mathcal{Z}} b(z, Z_{t+1})dX_{t+1}(z) = \int_{\mathcal{Z}} (1 - \psi_{j+1})(1 + r_{t+1})a^+(z, Z_t)\mathrm{d}X_t(z); \quad (17)$$

6. the government budget (16) and PAYG pension budget (12) are balanced by choosing τ_t^c and τ_t^p, respectively;
7. the capital market clears:

$$K_t = A_t - B_t^G; \quad (18)$$

8. the goods market clears:

$$Y_t = C_t + I_t + G_t, \quad (19)$$

with gross investment $I_t = (1 + g)(1 + n_{t+1})K_{t+1} - (1 - \delta)K_t$.[29]

[29] Note that the aggregate variables are presented as per capita in time period t (with population structure impacted by the total population growth rate n and survival rates assumed to vary during demographic transition paths) and de-trended at a constant economic growth rate g.

4 Calibration of the benchmark model economy

The benchmark model economy is assumed to be in an initial steady state equilibrium, which is calibrated to Indonesia – IFLS surveys to calibrate household economic behaviours, World Bank data for the macroeconomic targets, and OECD and IMF data for fiscal and pension policy targets. The parameter values of the benchmark model are presented in Table 3.

Table 3: Values of Main Parameters of Benchmark Model

Description	Value	Source
Demographics		
Population growth rate (% p.a.)	2.92	Calibrated[a]
Conditional survival probabilities	-*	Data[a]
Fraction of households of labour and skill types	-*	Data[b]
Utility function		
Coefficient of relative risk aversion	2	Literature[c]
Consumption weight parameter	-*	Data/Calibrated[b]
Subjective discount factor (p.a.)	[0.995; 0.99]	Calibrated
Household equivalence scale	-*	Data[b]
Bequest function parameters	-*	Literature[d]
Endowment and productivity		
Time endowment (hours p.a.)	5460	Assumed[e]
Labour productivity profiles	-*	Estimated[b]
Stochastic labour productivity process	-*	Estimated[b]
Technological growth rate (% p.a.)	2.05	Data[f]
Technology		
Production constant	1.50	Calibrated
Capital share	0.38	Calibrated
Depreciation rate (% p.a.)	3.7	Calibrated
Policy parameters		
(Formal) Pension benefit (% of ybar)	22.8	Data/Calibrated[g]
Pension access age (J_R)	55-59	Data
Pension contribution (or payroll tax) rate (%)	5.46	Data/Calibrated[g]
Labour earnings tax (progressive tax schedule)	-*	Data/Calibrated[h]
Capital income (corporate) tax rate (%)	20.99	Data/Calibrated[h]
Consumption tax rate (%)	9.49	Data/Calibrated[h]
Government debt to GDP (%)	31.37	Data

Notes: *See the text; [a]Demographic data based on UN (2019) for Indonesia 2020, with population growth rate calibrated to match the current old-age dependency ratio of 10.56%; [b]These values derived/estimated from IFLS 2000-2014. [c]This value is standard in related literature (e.g., see Imrohoroglu and Kitao 2009); [d]Parameterization of bequest function based on DeNardi (2004); [e]This represents 15 non-sleeping hours per day, in the model normalized to one; [f]Matching per capita GDP growth rate for Indonesia (World Bank 2020); [g]Derived from OECD(2018); [h]Derived from IMF(2019).

Below, we provide the details of the benchmark model calibration to demographic, household survey and macroeconomic and fiscal data for Indonesia (with the parameter values in Table 3).[30] In this section, we also present and discuss the main solutions of the benchmark model and provide comparisons with Indonesian data.

4.1 Demographics

Households become economically active at age 20 (representing age group 20-24 or the model age $j = 1$) when they are assigned a household type and face a random survival up to the maximum age of 99 (or age group 95-99) (represented by the maximum model age $J = 16$). Hence, the model consists of 16 overlapping generations (or age cohorts), with each generation containing four types of households based on employment and skill type.

As for the demographics inputs, here we only discuss parameterization of the initial steady state economy, with constant survival rates and population growth rate for Indonesia (with Section 5 also introducing projections for Indonesia's demographic transitions and older populations in the long run, apart from pension reforms). The demographic parameters include the life cycle survival rates, ψ_j, and the population growth, n, that both determine the age structure and size of the population. The survival rates are taken from UN (2019) for Indonesia (for a cohort of both sexes born in 2015-20). Note that they imply the life expectancy at birth of 71.4 years. The population (and steady state cohort) growth rate $n = 2.92\%$ p.a. is then calculated (calibrated) to target the old-age dependency ratio of 10.56% in 2015-20 (i.e., ratio of the population aged 65+ to the population aged 20-64).[31]

As for the household heterogeneity, the model targets the (average) intra-generational shares (by employment-skill type) (denoted by state s in the model description), derived from the IFLS 2000-2014. As reported in Section 2, these shares are: 5.1% for formal-low, 18% for formal-high, 49.1% for informal-low, and 27.8% for informal-high (implying 77% of labour being informal, which compares closely to over 80%, reported in ILO 2018).

4.2 Endowments, preferences and technology

Endowments The model assumes the time endowment of 5460 non-sleeping hours per year (or 15 non-sleeping hours per day), that is normalized to one. Hence the impact on household labour supply discussed later in this section are presented as the fraction or share of time endowment spent working. The model also incorporates technological progress via the

[30] Note that the model comes with the calibration database, which includes the spreadsheets with (and the description of) all the data used in calibrating the benchmark model (and in Section 5, incorporating the demographic transition). This database can be provided upon request from the corresponding author.

[31] Note that $n = 2.92\%$ p.a. is higher than the current growth rate of the Indonesian total population. Since we assume the steady state economy of this benchmark model, one should think of this growth rate averaged over last several decades.

so-called time-augmenting progress with an exogenous growth rate, that (together with the population growth rate) determines the real GDP growth rate (of 5% according to World Bank (2020) data for the growth rate averaged over 2000-2019), with $g = 2.05\%$ in the model.[32]

Labour productivity estimated for each employment-skill type consists of a deterministic, age-specific part and a transitory component, which follows an AR(1) process. The estimates for a quadratic approximation of labour productivity (i.e., wage per hour, based on hours worked in all jobs), based on IFLS 2000-2014, were plotted in Figure 1(c) and discussed in Section 2. Here we provide only a brief summary of the main features. The formal-high types have significantly higher (and steeper) productivity than any other type. The formal-low and informal-high types have very similar labour productivity, while the informal-low type has very low (and almost flat) labour productivity. Those in formal employment face the retirement (from formal employment) age j_R, with their labour productivity assumed to be reduced to the level experienced by their respective skill type in informal employment. For those households in informal employment, we estimate their labour productivity to age 60 after which it is assumed to decline at a constant rate, reaching zero at the maximum age J (representing the age group 95-99). The stochastic component is calibrated to match the observed variance of log labour productivity over the working life cycle of 20-54 years.

Preferences The periodic utility in consumption and leisure is of the standard Cobb-Douglas functional form, with the consumption weight parameter γ (being calibrated for the model to approximate labour supply (hours worked) by age and employment-skill type. Note that we target average and lifecycle hours worked over ages 20-54 years for the four (intra-generational) types of households – formal-low, formal-high, informal-low and informal-high types. Following Imrohoroglu and Kitao (2009), the risk aversion parameter is set to $\sigma = 2$, implying the inter-temporal elasticity of substitution at $1/\sigma = 0.5$. The subjective discount factor β is employment specific, lower for the informal types, which are more time impatient. This parameter (i.e., discount factor for formal types) and the bequest motive parameter $q_1 = 3$ are calibrated for the benchmark model to approximate Indonesia's capital to output ratio of about 3.8 in 2018 (World Bank 2020).[33] The remaining parameters of the bequest function are based on De Nardi (2004).

Similarly to Nishiyama (2015), we also incorporate the household equivalence parameter μ, which is age-specific and derived from the IFLS 2000-2014 data. The objective is to account for a changing household size over the life cycle by incorporating the adjusted consumption (of dependents) in the utility function.

[32]Note that the aggregate variables in the steady state equilibrium of the model then grow at the rate of $(1+g)(1+n)$.

[33]Note that the estimated ratio by Loayza and Meza-Cuadra (2018) for Indonesia in 2020 is $K/Y = 3.56$.

Technology The Cobb-Douglas functional form is also assumed for our production function. In this calibrated version of the model, we assume that there is only one aggregated sector that demands capital and labour from both formal and informal workers. The technology level of the Cobb-Douglas production function set $\kappa = 1.5$ is such that the wage rate is one in the benchmark economy. The income share of capital is set at $\alpha = 0.38$.[34] The depreciation rate of the capital stock is set to $\delta = 0.037$, (which together with the population and technological growth rates determines private gross investment, with the model targeting the private investment to GDP ratio of 0.338 (World Bank (2020) data for Indonesia 2018-19).

4.3 Government policy

Formal PAYG pension As discussed, only the formal-high (skill) types of households are subject to formal pension policy, paying contributions during their working years and collecting pension benefits for $j \geq j_R$.[35] The pension benefits (for the formal sector workers) are set in the benchmark model to target the overall public pension expenditure to GDP at 1% (based on OECD, 2018). Note that we calculate a scalar (adjustment parameter) to match this ratio. The implied pension replacement rate is 22.8% of the average formal sector earnings. The social contribution (or payroll tax) rate (that is imposed on labour earnings up to the ceiling of 3 times average earnings (OECD, 2018)) is determined endogenously to balance the PAYG public pension budget in (12). The resulting pension contribution rate is $\tau^p = 5.2\%$.

Taxes and budget balance In the benchmark model, we target the observed ratio of government debt to GDP ($g_y = 31.37\%$) (based on IMF (2019) Government Finance Statistics for Indonesia). The labour income taxation is subject to Indonesia's progressive income tax schedule. We use the near exact approximation of the schedule in 2017-18. Also, as already discussed, we calculate an income tax scalar (or adjustment parameter) for the benchmark model solution to match the observed personal income tax revenue at 0.85% of GDP in 2018-19 (IMF, 2019). Similar adjustment parameters for the capital income and consumption taxation are used to match the corporate tax revenue at 4% of GDP and the consumption tax revenue at 5% of GDP, respectively. For these revenues, we also use the statutory tax rates and the respective exemptions (of capital income and consumption up to which no tax is made), with the resulting effective capital income and consumption tax rate being $\tau^r = 20.9\%$ and $\tau^c = 9.5\%$. Finally, we adjust government consumption to balance the government budget in (16).

[34] The parameter α is used to target the interest rate r (of about 6% p.a. generated by this benchmark model).

[35] Note that this assumption (of removing formal-low types from the PAYG pension systems) more closely represents the current Indonesian coverage by formal pensions (where only government workers and some private sector workers are covered by the public pension schemes).

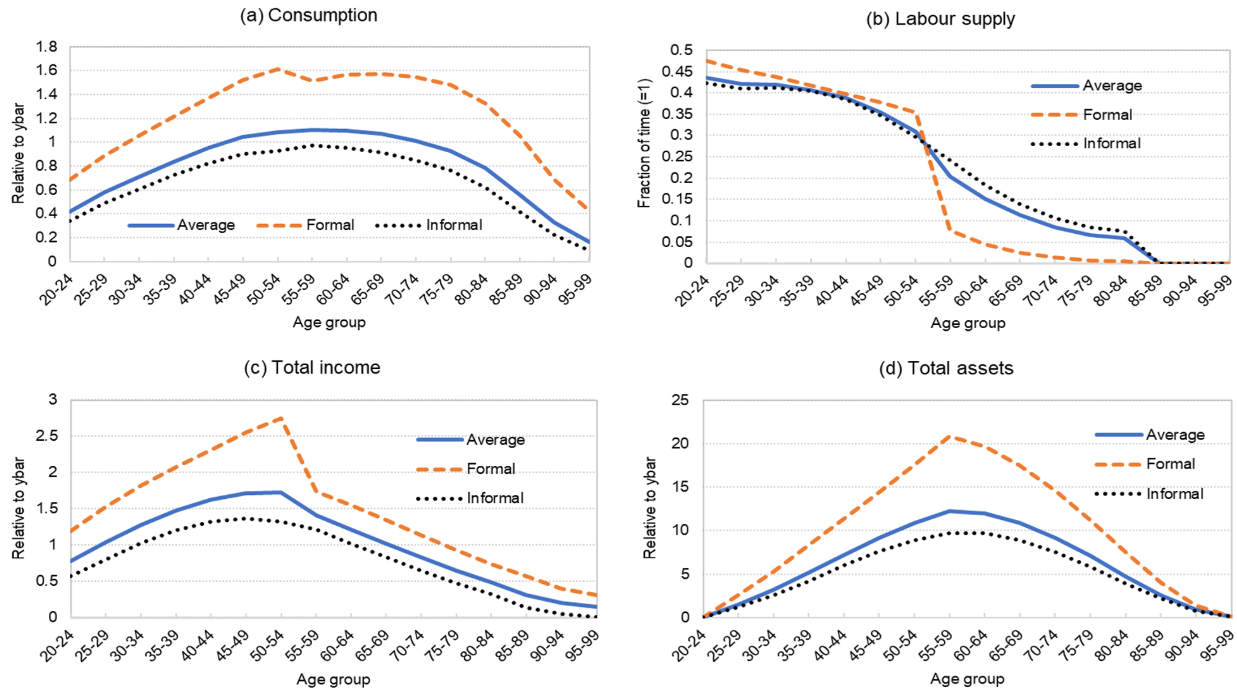
4.4 Benchmark solution and Indonesian data

The benchmark solution is obtained by numerically solving the model for the initial steady state equilibrium, with the parameters and the government policy settings specified above. The model (for both long run steady state as well as transition path solutions) is coded in Fortran, as in Fehr and Kindermann (2018). We use the value function iteration procedure to solve the dynamic programming problem of the households and the Gauss-Seidel iterative method to solve for this benchmark steady state equilibrium (and all the counterfactuals). The Gauss-Seidel algorithm involves choosing initial guesses for some variables and then updating them by iterating between the production, household and government sectors until convergence. For more detials, see the algorithm description in Appendix B.

The main model-generated results at both the household life cycle and aggregate levels (and how they compare to Indonesian data) are presented and discussed below.

Life cycle household profiles Figure 2 depicts the benchmark solutions for selected life cycle household profiles, including (average and employment-specific) profiles of consumption (net consumption expenditure), labour supply (hours worked), total income (sum of labour earnings, asset income, pension income and transfers), and total assets. The consumption, total income and assets are presented relative to the economy-wide average labour income, while the labour supply variable is measured as fraction of annual time endowment (of 5,460) (hence directly comparable to the IFLS targets in Figure 1). In this section, we present "formal" and "informal" values (by accounting for low and high skill type weights and productivity risk in each employment type) and overall "average" values generated by the benchmark model.

The age-profiles in Figure 2 exhibit standard hump-shape. For example, the age-profiles of household consumption in Figure 2(a) are increasing during working ages and then declining, with the shape reflecting the hump-shaped productivity profiles (in Figure 1(b)) (impacting labour earnings), the hump-shaped consumption preference parameter profiles, survival probabilities (that start declining significantly at older ages) and also the (undeveloped) government policy (with the mandatory retirement (from formal employment) age) and the transfers. The same features of the model impact labour supply plotted in Figure 2(b), where we target normalised hours worked during prime working years 20-54 from the IFLS 2000-2014 (presented in Section 2). The formal employment retirement age is set at the age group 55-59 ($j_R = 8$) in the benchmark economy. At $j \geq j_R$, formal households are endowed with much lower productivity (set to informal employment productivity) and they also receive their public pension benefits. In particular, the former assumption has a significant impact on their labour supply, with labour supply (of formal workers) declining sharply at j_R, which



Notes: Benchmark model generated life cycle solutions distinguished by employment type and on average.

Figure 2: Benchmark model solutions over the life cycle

has also been shown in Section 2, documenting the IFLS labour force data. Labour supply of informal workers at older ages is high, on average over 20% of their time endowment. There is significant gap between total income and assets between formal and informal employment types (as indicated in Figures 2(c) and 2(d)), and this gap further increases when comparing formal-high with informal-low skill types.

Aggregated data The selected macroeconomic and fiscal variables and distributional labour supply data (most of which are used as the calibration targets) generated by this benchmark model are presented in Table 4. It also provides comparison with Indonesian data (drawing on World Bank (2020), Loayza and Meza-Cuadra (2018) for macro targets, IFLS 2000-2014 for aggregated labour supply data, IMF (2019) for fiscal data and OECD (2018) for pension policy data).

Table 4: Comparison of Benchmark Solution with Indonesian Data

Variable	Benchmark model	Indonesia 2018-2019*
Expenditures on GDP (% of GDP)		
Private consumption	56.70	57.93
Investment	33.80	33.77
Government consumption	9.50	8.75
Trade balance	0.00	-0.49
Fiscal policy calibration targets (% of GDP)		
Public pension expenditure	1.00	1.00
Labour income tax revenue	0.85	0.85
Corporation tax revenues	4.00	4.00
Consumption tax revenues	5.00	5.01
Government debt	31.37	31.37
Macro calibration targets		
Capital-output ratio	3.76	3.82
Hours (average)	0.401	0.401
Hours (formal-low)	0.442	0.434
Hours (formal-high)	0.409	0.406
Hours (informal-low)	0.379	0.379
Hours (informal-high)	0.388	0.387

Sources: *Aggregate demand data are derived from World Bank (2020) data for Indonesia 2018-19; Pension expenditure is taken from OECD (2018); Fiscal data from IMF (2019); Capital-output ratio is derived from World Bank (2020); Hours worked (average labour supply share of time endowment for those 20-54) are derived from IFLS 2000-2014.

As indicated in Table 4, this calibrated benchmark model replicates the Indonesian economy and fiscal policies very closely, targeting many fiscal policy and macroeconomic data. As discussed, we calibrate the fiscal adjustment tax and pension expenditure parameters to match the composition of Indonesia's government budget (using OECD (2018) and IMF (2019) data), and we calculate government consumption to balance the government budget (with the benchmark model-generated $G = 8\%$ of GDP, that closely compares to 7% of GDP in 2018-19 based on IMF (2019)). The model is fitted to household survey (IFLS 2000-2014) data, matching the observed labour market composition (averaged over the (primary) working ages), and also approximating hours worked and earnings (with hours worked on average and by employment-skill type generated by the model and derived from IFLS 2000-2014, presented at the bottom of Table 4).

5 Quantitative analysis of population ageing and public pension reforms

In this section, we apply the calibrated model to explore the economy-wide implications of population aging and pension policy reforms, including the effects on household lifecycle behaviour, macroeconomic aggregates (including output, capital stock, consumption and labour as well as budget implications) and household welfare.

The calibration reported here is representative of an economy in stationary demographic equilibrium. Indonesia, in common with many countries, is ageing rapidly, even though it is at the moment quite young, and analysis of pension reform into the future must necessarily take account of this demographic transition. We have chosen to represent this by imposing a dynamic demographic age structure, and solving for an "ageing" benchmark (assuming the pension and fiscal policy in the benchmark). The impacts of this are significant and of interest in their own right, and we therefore report them here, rather than as part of the calibration exercise in Section 4. We then turn to the analysis of the impacts of pension policy reforms.

The second simulation is to gradually increase the formal pension access age, from the benchmark age of 55 to age 65 (by 2040) – increasing formal retirement age policy, with the demographic transition as under the first simulation. The third simulation is also a composite, combining the second simulation with newly introduced social pensions targeted to all informal labour and all those with no formal pensions – overall pension reform with social pensions.

We start with the first scenario for population ageing with the current pension and fiscal policy (baseline case), presenting its macroeconomic and fiscal implications. We then discuss the economic effects of the pension policy reforms under population ageing – for increasing formal retirement age and overall pension reforms – in the long run with ageing population and over the demographic transition.

5.1 Demographic transition and population ageing

Similarly to Song et al. (2015), our approach is first to simulate the demographic transition to an older society with lower population growth and higher longevity, assuming the benchmark equilibrating policy instruments with the payroll tax rate and consumption tax rate balancing the formal pension and fiscal budgets – baseline ageing results. We outline the demographic transition and long run ageing population incorporated into the model (approximating population ageing projections for Indonesia) and present key macroeconomic effects over this demographic transition.

Demographics The model is calibrated to demographic projections derived for Indonesia 2020-2100 from United Nations (2019) (under their medium fertility scenario). Specifically, we use the observed and projected age-specific survival rates, derived from UN (2019), with implied life expectancies at age 20 and 65 then reported in Table 5. This table also presents other demographic statistics such as the total population growth rate and old age dependency

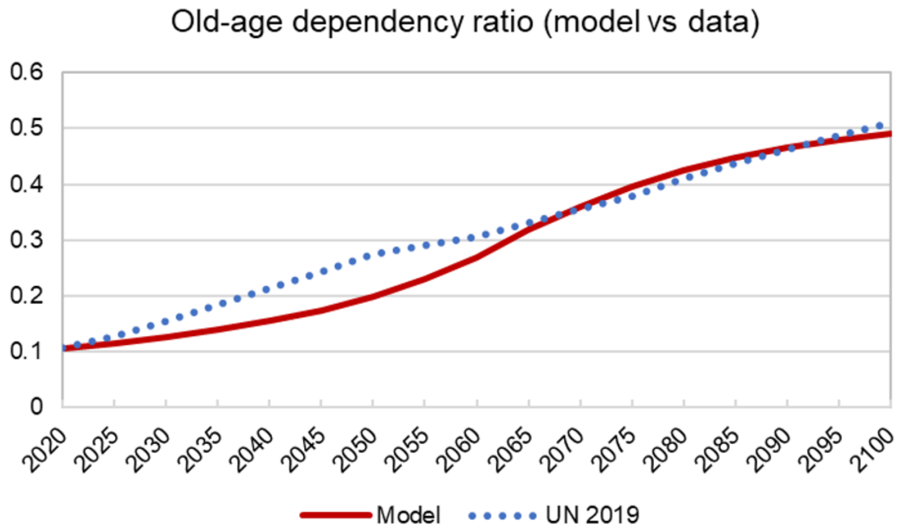


Figure 3: Old age dependency ratio

ratio built into our economic model, while Figure 3 provides comparison with the model-approximated and UN (2019) old age dependency ratio over the transition path.[36]

Table 5: Demographic statistics over the ageing transition path*

Variable	Benchmark economy	Ageing transition path			Long-run economy
		2025	2050	2100	
Life expectancy at 20 (years)	53.22	55.71	58.63	64.78	64.78
Life expectancy at 65 (years)	13.26	15.19	17.27	21.78	21.78
Population growth rate (%) p.a.	2.92	2.60	1.25	0.18	0.00
Aged dependency ratio (65+/20-64)	0.11	0.11	0.20	0.49	0.51
Working-age population (20-64)[a]	90.42	89.70	83.42	67.05	66.27
Elderly population (65+)[a]	9.58	10.30	16.58	32.95	33.73

Notes: *Used in the OLG model, derived from UN (2019) population estimates and projections; [a]% of adult population (aged 20+).

The model developments in demographic variables in Table 5 show increasing life expectancies, old-age dependency and elderly cohort share measures over time, while the total population growth rate gradually declines, converging to the assumed zero rate in the long run. Note that compared to developed countries, these demographic changes reported for Indonesia (and other Southeast Asian countries) are much more pronounced, e.g. the old age

[36] As indicated, the benchmark economy is assumed to be in the steady state equilibrium with a stationary demographic structure (derived using averaged population growth and survival rates over the last 4 decades. As discussed below, in order to more closely match the observed population growth rate, the demographic transition assumes a fertility bust scenario with gradually increasing survival rates, as in Kudrna Tran and Woodland (2022).

dependency ratio projected to increase nearly 5-fold between 2020-2100. The model-built-in population structure underestimates population ageing, compared to UN (2019) data for Indonesia (which is projected to face even negative growth rates). This is because of our assumption of the benchmark steady state economy with stationary demographics, and the assumed fertility bust transition path (with growth rate n_1 of new born generations set to zero in $t = 1$), which reduces the total population growth rate only gradually over time.[37] The model old-age dependency ratio is lower than in UN (2019) data initially but over time, it converges to the targeted long run ratio (UN data for 2100).[38]

Macroeconomic and fiscal effects The demographic projections discussed above are exogenous in the model. We assume the same fiscal policy rules as in the benchmark economy, with the PAYG contribution (payroll tax) rate and the consumption tax rate adjusting to balance the PAYG pension and the government budget constraints, respectively. The government consumption and debt are also assumed to be constant in *per capita* terms under this demographic transition. Households learn about this demographic transition (lower growth rates and gradually increasing survival rates) and adjust their economic behaviour over time. Factor prices also change over this ageing transition.

The macroeconomic and fiscal effects of the demographic transition are reported in Table 6, with the results (for per capita variables) presented as % changes relative to the benchmark steady state solution. Recall that the benchmark solution assumes a demographic structure with the survival rates and the population growth rate for Indonesia averaged over the last 40 years – 1980-2020). The model converges to a new steady state only very slowly. The long run steady state is approximated by year 2200 in Table 6.[39]

[37] We could vary $n_{1,t}$ over time (gradually falling) or even set it to negative rates during transition path (to better match lower total population growth rates in the data), with the requirement of the long run rate being $n_1 \geq 0$.

[38] There are alternative ways of accounting for demographic transitions in OLG models. For example, Kudrna, Tran and Woodland (2015, 2019) use exact cohort shares derived from Australian data and demographic projections. In such framework, first the so-called "artificial" steady state is calibrated to the benchmark data. The issue with this solution (with non-stationary demographics) is that market clearing conditions (e.g. for the goods market) would not be fully satisfied. Since the focus of this paper is on the long run effects of pension reforms with population ageing, we assume the benchmark steady state equilibrium with stationary demographics and model the demographic transition path from it, assuming a fertility bust and gradual improvements in survival rates, as in Kudrna, Tran and Woodland (2022).

[39] Since the old-age dependency ratio increases over 50% by 2100, the differences in economic effects in 2100 and 2200 are rather small.

On the other hand, the effects reported in Table 6 for 2025, which in our 5-year model represents the impact effect of the assumed demographic transition, are quite different from those in the long run.

Table 6: Economic effects along ageing transition path (Scenario S1)*

Variable	Time period				
	2025	2035	2055	2100	2200
Effective labour	1.60	1.68	-2.83	-14.71	-15.58
Hours worked[a]	-0.20	-0.03	0.34	0.85	0.80
Wage rate	-0.04	3.82	11.61	18.88	18.76
Output (GDP)	1.58	5.61	8.56	1.53	0.39
Private consumption	-1.54	5.29	13.42	10.35	9.42
Gross investment	6.17	6.40	1.29	-15.12	-17.36
Capital stock	1.55	12.37	30.07	34.92	33.21
Household wealth	0.17	10.35	26.75	30.47	28.79
Interest rate (p.p.)	0.01	-0.48	-1.35	-2.05	-2.04
Consumption tax rate (p.p.)[b]	0.25	-0.60	-1.10	1.12	1.45
Pension cont. rate (p.p.)[c]	0.15	0.82	4.70	12.63	14.07

Notes: *% change in per capita variables relative to benchmark solution (if not stated otherwise); [a]Average hours for those aged 20-54; [b]Percentage point (p.p.) change in consumption tax rate balancing government budget; [c]P.p. change in payroll tax rate balancing PAYG pension budget.

As shown in Table 6, effective labour supply (total labour input to production measured as average working hours adjusted for labour efficiency) initially increases (because of the demographic dividend), but over the transition it declines significantly. In the long run, the effective labour falls by over 15%. Average hours worked increase over the transition as households are expected to live longer (and so work more to finance retirement consumption) and also get paid a higher wage rate (because of falling working age population shares). Household assets increase significantly, by almost 30% in the long run. This is partly a cohort effect, with the median age of the population shifting to older cohorts with larger asset holdings; and partly a behavioural effect, with rational households responding to their increased life expectancy by increasing savings.

Population ageing is shown to generate capital deepening (increasing the capital labour ratio), associated with a higher wage rate and a lower interest rate. Although the size of the government is relatively small (with tax revenues of only around 10% of GDP), there are some pronounced fiscal costs due to population ageing. Specifically, the consumption tax rate and the payroll tax (PAYG contribution) rate would need to increase by 1.45 p.p. and 14 p.p. in the long run, respectively, to retain budget balance Under this baseline ageing (no reform) scenario, high skilled households in the formal sector would face a payroll tax rate of nearly 20%.

5.2 Pension reforms

We apply now our model to an analysis of two specific pension reforms. We consider them cumulatively. First, we increase the retirement age for the high-skilled formal household group by 10 years, over a 20 year period. This has two impacts: it reduces the revenue requirement, and therefore the payroll tax rate, as benefits are payable for fewer years. Second, these households are able to provide high productivity labour for much longer as retirement age has now increased. This has a significant impact on output.

Our second reform focuses on the informal sector. Comprising some 80% of the labour force, this group receives no government-sponsored retirement support. We simulate the introduction of a non-contributory social pension set at 6.5% of GDP per capita, the international poverty line for Indonesia (World Bank 2021), available to informal workers aged 65. The focus here is on the closed economy simulations with general equilibrium effects through endogenous factor prices. The calibrated fiscal policy variables and/or parameters (i.e., the earnings and corporation tax rates, government consumption and debt, and the formal sector pension replacement rate) are kept at their benchmark values under this pension policy counterfactual. The government budget constraint and the PAYG formal sector pension constraint are balanced by adjusting τ^c and τ^p, respectively.

We first present and discuss the long run steady state implications and then we then provide the transition path implications of the pension reforms under population ageing transition.

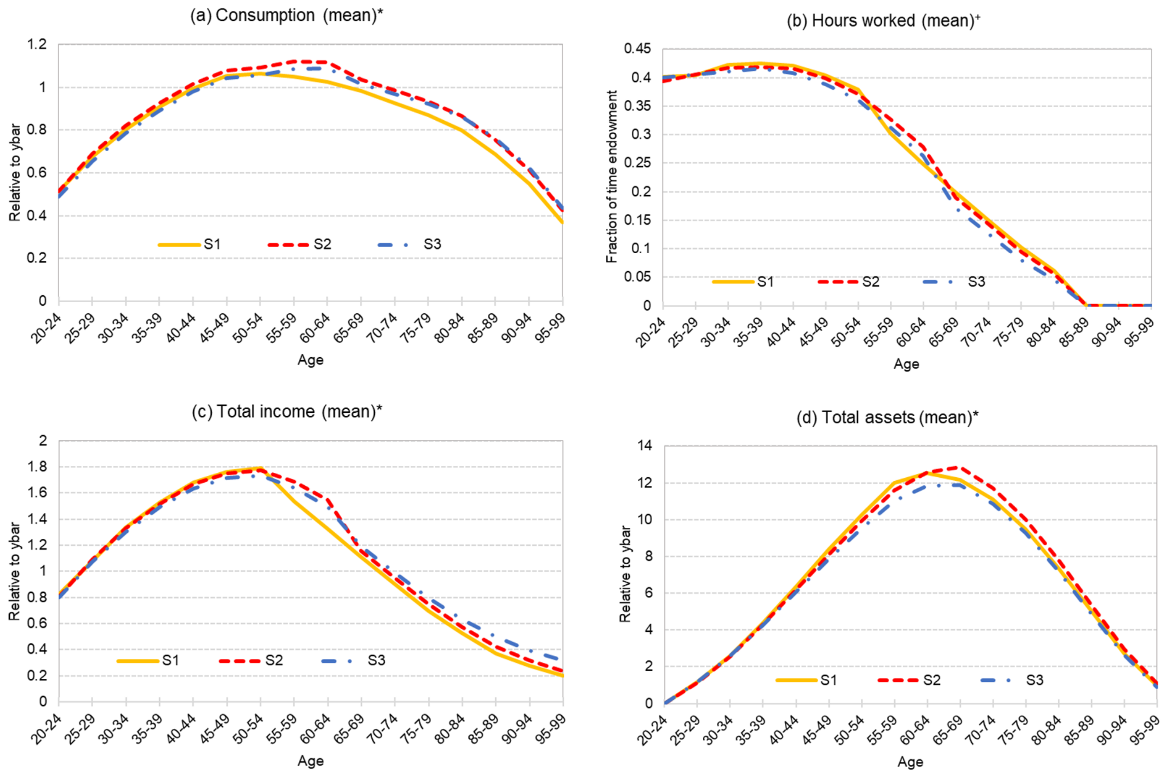
5.2.1 Long run steady state implications

We now present the steady state implications of the two pension reforms. We first discussthe main behavioural implications over the life cycle and then present aggregated solutions for the macroeconomic and welfare effects in the long run.

Household economic behaviour over life cycle The life cycle implications are plotted in Figure 4 for consumption, labour supply, total income and total assets (mean values) under the three counterfactual scenarios in the long run (i.e., $S1$ – baseline ageing results, $S2$ – ageing + formal retirement age policy and $S3$ – overall reform with $S2$ + social pensions to all 65+ with no formal pension).[40]

The **formal retirement age policy** under $S2$ has a significant impact on the lifecycle decisions of formal high-skill workers. Consumption increases over the entire life cycle, and

[40] In Appendix C, we present distributional impacts on life-cycle decisions by formal and informal labour, plotted in Figure 6 to which we briefly refer in the description below.



Notes: *Relative to ybar = benchmark average earnings; +Fraction of annual time endowment (5460 hours p.a.).

Figure 4: Long run life cycle solutions under different scenarios

particularly at older ages. These workers are also shown to reduce their labour supply for most of their working years but in this new (steady state) economy with the increased retirement (from formal employment) age, older workers work significantly more and accumulate more assets. This policy is to be particularly beneficial in the Asian emerging economy context, where retirement ages are low (Kudrna, O'Keefe and Piggott 2023).

The **overall reform** under $S3$ adds the introduction of social pensions targeting informal workers, financed by consumption taxation. This new social pension program generates consumption smoothing for informal workers. In the long run, their consumption declines somewhat during the working years (partly due to an increase in the consumption tax rate, as discussed below), but it increases at older age. As for the labour supply effects, the social pension generates an income effect, lowering hours worked over the life cycle. However, the income effect is small because of a very modest social pension benefit. The overall reform has a negative impact on labour supply (both for formal and informal workers) during the prime working ages, but the higher retirement age policy increases average labour supply for age group 55-64 (due to increased hours by formal workers).

Macroeconomic and welfare implications We now discuss the macroeconomic, fiscal and welfare implications of the three counterfactuals in the long run. First, the macroeconomic and fiscal effects are reported in Table 7. These are obtained by aggregating the values for the household economic decisions over the life cycle, weighted by cohort sizes and adjusted to account for the population and economic growth rates. The results for aggregated variables are reported as a % change relative the benchmark(no ageing) economy for ageing equilibrium ($S1$) or for pensioon reforms ($S2$ and $S3$) relative to baseline ageing equilibrium ($S1$) while the reported rates (e.g., payroll tax rate) are simply expressed as a percentage.

Table 7: Macroeconomic effects of ageing and pension reforms in long run

Variable	Benchmark (no ageing)	S1[i] (ageing)*	S2[ii] (+reform 1)#	S3[iii] (+reform 2)#
Effective labour	100.00	-16.38	4.20	3.09
Wage rate	100.00	18.97	-1.36	-2.95
Output (GDP)	100.00	-0.53	2.82	0.05
Private consumption	100.00	9.43	4.72	1.91
Gross investment	100.00	-18.24	0.60	-4.71
Capital stock	100.00	32.02	0.60	-4.71
Household assets	100.00	29.40	1.17	-4.40
Interest rate p.a. (%)	5.93	3.87	4.02	4.19
PAYG pension cost[a]	1.00	3.08	2.73	2.69
Social pension cost[a]	0.00	0.00	0.00	1.80
PAYG contribution rate (%)[b]	5.46	19.53	13.75	13.75
Consumption tax rate (%)[c]	9.50	11.03	9.64	12.97

Notes: *% change relative to benchmark equilibrium (=100), if not stated otherwise; #% change relative to ageing equilibrium S1, if not stated otherwise; [i]Scenario S1 = Ageing equilibrium with changes in budget balancing payroll and consumption tax rates; [ii]Scenario S2 = S1 + increased retirement/pension access age for formal high skill; [iii]Scenario S3 = S2 + new social pensions; [a]% of benchmark GDP; [b]Balancing PAYG pension budget; [c]Balancing govt. budget.

The long run welfare effects of the two pension reforms are reported in Table 8 (for average welfare and welfare by employment and skill types) – as a percentage change in lifetime utilities (at age 20 and at age 65) under the pension reform scenario ($S2$ and $S3$) relative to the baseline ageing solution ($S1$). For the new-born households, the welfare effects represent Hicksian equivalent variation (HEV) – a percentage change in consumption and leisure over their life cycle (which is equivalent to a change in initial wealth) that would make them as well-off under the benchmark ageing case as under the pension policy reform. Hence, the positive (negative) sign implies a welfare gain (loss).

Table 8: Welfare effects of pension reforms in long run*

Variable	Reform scenario	
	S2[i] (+ reform 1)	S3[ii] (+ reform 2)
Welfare of newborn cohort (20+)		
- Average	1.35	1.04
- Formal	4.86	4.06
- Informal	0.39	0.21
- Formal-low	0.67	0.53
- Formal-high	6.11	5.12
- Informal-low	0.41	0.51
- Informal-high	0.36	-0.31
Welfare at age 65 (65+)		
- Average	0.80	4.54
- Formal	1.35	1.57
- Informal	0.64	5.42
- Formal-low	0.92	3.96
- Formal-high	1.46	0.93
- Informal-low	0.66	6.70
- Informal-high	0.59	3.24

Notes: *% change in utility levels (sum of discounted values over the life cycle of 20+ and 65+) relative to Scenario S1 (baseline ageing); [i]Scenario S2 = S1 + increased retirement/pension access age for formal high skill; [ii]Scenario S3 = S2 + new social pensions to all 65+ not receiving formal pension.

Table 7 shows that the **formal retirement age policy** – i.e., retirement age extension for all formal workers (under $S2$) has positive impacts on effective labour supply and consumption per capita – compared to baseline ageing results ($S1$), that are higher by over 4.2% and 4.7%, respectively. The effects on household assets and capital stock are also positive. These positive effects are driven by the retirement age extension from formal employment. The fiscal outcomes of this policy reform show lower total formal pension spending (by over 11% relative to the $S1$ economy), and reductions in both the payroll tax rate and consumption tax rate by 5.8 p.p. and 1.4 p.p., respectively, relative to the $S1$ results. Importantly, as seen in Table 8, households would experience a long run "average" welfare gain of 1.35%, no with the largest gain of 6.1% attained by future born generations of formal-high types of households (benefiting from increased labour productivity at older ages). There are some positive indirect effects of this policy on the welfare of informal households, but the effects are small compared to directly affected formal households.

The macroeconomic outcomes for the **overall reform with social pensions** (the results in the last column of Table 7 for $S3$) show increased effective labour supply (up by 3.09% in the long run) and per capita consumption (by 1.9%), but lower average household assets, capital stock and output per capita (due to a negative impact of social pensions on incentives). The formal retirement/access age increase generates a 5.78 p.p. reduction in the PAYG contribution or payroll tax rate, while the overall costs of social pensions in this ageing economy would amount to 1.8% of GDP, causing a long run increase in the consumption tax rate of 1.9 p.p., compared to the S1 economy.

The overall pension reform generates significant welfare gains, as shown in the second column of Table 8. The long run welfare effect, on average, for the newborn at age 20 is 1.04% (equivalent to an increase of their benchmark resources). Formal new-born households would gain more (with a gain of 4.06%), compared to informal new-born households (with the welfare gain of 0.21%). In the long run, the welfare gains (calculated at age 20) are largely driven by the retirement (from formal employment) age policy impacting formal workers rather than social pensions targeted at informal workers. However, based on the welfare effects at age 65 (comparing discounted lifetime utilities at age 65), these are more positive for informal labour, benefiting from newly introduced social pensions directed to them (and all those without contributory formal pensions).[41]

5.2.2 Transition path implications

In this subsection, we present and discuss the macroeconomic and welfare implications of the two pension reforms over the transition path.

Macroeconomic effects The macroeconomic implications of the pension access age policy (under $S2$) and the overall pension reform with newly introduced social pensions (under $S3$) (and how these compare to $S1$) over the transition path for selected macroeconomic variables are depicted in Figure 5. The results are presented relative to the benchmark economy as a percentage change for macro variables or percentage point (p.p.) change for fiscal adjustments or percent of benchmark GDP for the social pension expenditure (under $S3$). The results for the period 2025 (2021-25) provide the impact effects (in the first period of the announcement of the reform or $t = 1$ in the model), while the effects for 2145 approximate the long run steady state effects.

As shown in Figure 5, there are some important differences in the short run results, compared to the long run effects. Under the overall reform ($S3$), effective aggregate labour is initially lower but increases after 2040 (for period 2041-45 when second increase in the

[41] Note that we can also show that isolating the introduction of social pensions from the increased retirement age policy component of the overall reform would generate an income effect on labour supply and saving disincentive, negatively impacting most macroeconomic variables (labour supply and household wealth) in the long run. However, this policy would have positive effects on welfare of informal labour (receiving poverty alleviating income at older age) with some negative effects on welfare of formal labour (financing this expenditure) and so making the overall pension system more equitable.

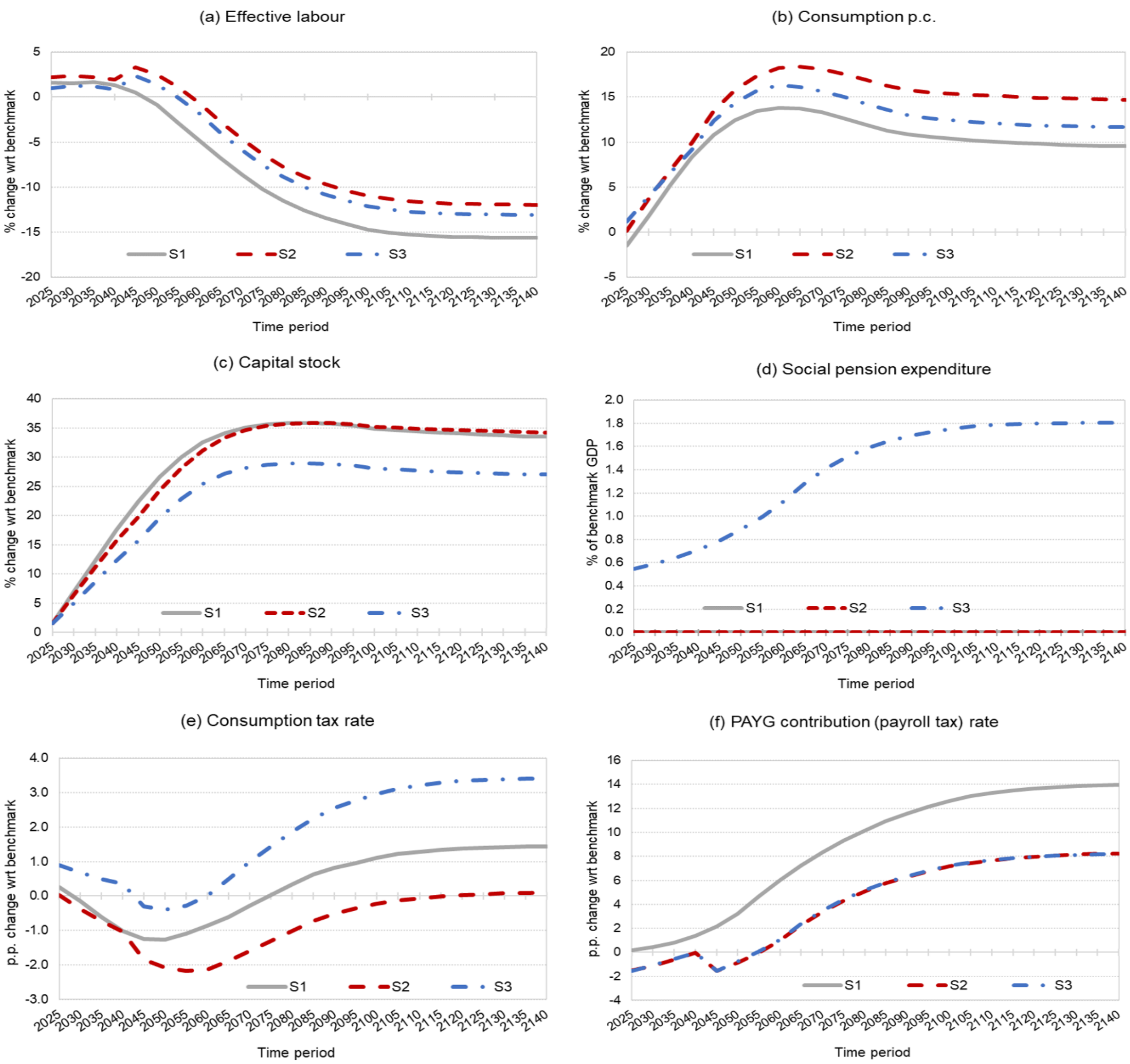


Figure 5: Macroeconomic and fiscal effects over transition path

formal retirement age is adopted). In the long run, it is higher by over 3% (compared to the $S1$ case). This increased effective labour is due to the policy of increasing the formal retirement age (under $S2$). As discussed for the long run effects, the labour input increase is largely due to higher productivity of formal workers at the increased retirement ages, allowing them to smooth their consumption and labour supply (hours) over the life cycle. This positive productivity effect outweighs lower average hours worked (by formal workers but also informal workers facing the pure income effect of social pensions on their labour supply, as shown by comparing $S3$ with $S2$). The increased effective labour supply causes consumption per capita to increase, as shown under $S3$, more significantly in the short run (due to social pensions targeting informal elderly households) than in the succeeding years and the long run (with consumption gains to formal workers).

As for the fiscal effects, the social pension expenditure increases gradually from just over 0.5% of GDP in $t = 1$ to over 1.8% of GDP in the long run, because of gradual increases in the old age dependency ratio over the demographic transition path. Note that although we assume a modest poverty alleviating social pension benefit, over 80% of the population aged 65+ is assumed to receive it. And because of this assumed way of social pension targeting coupled with pronounced population ageing, the overall cost see more than a 3-fold increase – which is still below 2% of benchmark GDP in the long run).[42] Under the overall reform ($S3$), the PAYG contribution or payroll tax rate is lower, and the consumption tax rate higher compared the $S1$ baseline ageing results. The former is due to formal pension access age increases and the latter finances social pensions (with the expenditure being included in the government budget).

Intergenerational welfare effects In this sub-section, we present the distributional welfare effects of pension reforms under $S2$ and $S3$ over the demographic transition. As discussed above, we use Hicksian equivalent variation (HEV) to measure the welfare effects. But note that the welfare effects can only be studied under the same preferences, and since population ageing alters the discount factor in the household utility, and under the same demographic transition. Hence, all the results in this subsection are expressed relative to the baseline (no reform) ageing scenario $S1$.

In Table 9, we present the welfare effects of the two reforms for selected cohorts of different ages in 2021-25, on average (last column) and by employment (and skill) type. The current economically active cohorts are aged 20 years and older (here in Table 9, selected cohorts aged 95, 80, 60, 40, 20), while all younger and future born cohorts enter the model during the transition path (depicted by 0, -20, -80), with the effects on the generation aged -80 closely approximating the long run welfare effects.

[42] As a sensitivity check in the next section, we consider means testing rules based on the Australian age pension policy to improve the social pension targeting and to lower its fiscal cost under population ageing.

Table 9: Intergenerational welfare effects of pension reforms under population ageing*

Reform Scenario	Age in 2021-25	Formal workers Low-skill	Formal workers High-skill	Formal workers Average	Informal workers Low-skill	Informal workers High-skill	Informal workers Average	All workers Average
S2 - Higher formal retirement age	95	0.06	0.06	0.06	0.08	0.06	0.07	0.07
	80	0.11	0.10	0.10	0.11	0.10	0.10	0.10
	60	0.37	0.43	0.42	0.29	0.25	0.28	0.31
	40	0.71	3.74	3.07	0.49	0.36	0.44	1.04
	20	0.62	4.49	3.46	0.38	0.21	0.32	1.07
	0	0.58	5.30	4.05	0.31	0.21	0.28	1.19
	-20	0.65	5.72	4.39	0.38	0.31	0.36	1.34
	-80	0.68	6.13	4.71	0.42	0.39	0.41	1.46
S3 - Overall reform with social pensions	95	15.08	-0.01	3.26	24.26	12.66	20.05	16.10
	80	3.89	-0.05	0.81	7.24	3.72	5.96	4.76
	60	2.70	0.22	0.76	4.38	2.31	3.63	2.97
	40	1.88	3.49	3.13	2.36	1.16	1.92	2.20
	20	1.19	4.10	3.33	1.28	0.34	0.98	1.55
	0	0.81	4.62	3.62	0.82	-0.04	0.55	1.29
	-20	0.65	4.86	3.76	0.64	-0.19	0.38	1.20
	-80	0.52	5.11	3.92	0.51	-0.26	0.27	1.17

Note: *Equivalent variation measure (for selected cohorts of different ages in 2021-25) - HEV in % of remaining (initial) resources (for new-born generations).

As shown in the last column of Table 9, on average, all cohorts of households would gain in welfare, with the gains larger for current generations (about 3% for those aged 60 under $S3$) due to social pensions while the gains to future generations (over 1% in the long run under $S3$) are driven by the higher formal retirement age policy (when compared to $S2$). Note that the (short term) welfare impacts of $S3$ on current elderly generations of informal workers, particularly of the low skill type, are very significant – the flat-rate social pension payment at 65+ have a large and positive impact on their consumption and welfare. In contrast, the formal pension access age policy under $S2$ shows increasing welfare gains over time, since there is no direct impact (of this policy) on current older cohorts (already retired from formal employment), and also due to the gradual implementation of this policy and its gradual changes (reductions) in the payroll tax rate. Interestingly, only some older cohorts of the high-skill type would experience a welfare loss, which compared to average welfare gains (gains to all other types and future themselves), is negligible.

Our findings indicate that the combination of these two reforms generate substantial gains to all household types in the Indonesian economy, and that these gains accrue in the short term as well as in long run equilibrium. The net revenue cost, at 1.2% of GDP, comprising changes to both consumption and payroll tax, is a low figure because, at this stage, revenue savings are being generated by changes to the contributory pension system. Social pension reform will eventually be required, but if delayed, will entail a higher net revenue requirement.

6 Sensitivity analysis and model extension

In this section, we test the sensitivity of our results across a range of variations in model structure, calibration, and policy parameters, focusing on long run simulations. We first calculate what the impact of our combined policy change would be if (I) population ageing were absent (*No ageing environment*). We next examine the impact of (II) means testing the social pension (Alternative II – *Mean tested social pension*); (III) alternative behavioural assumptions in the informal sector (*Model with self-employed*) and finally (the impact of) (IV) labour transition probabilities (for exits from formal labour) over working life (*Model with exit rate*). The focus of this section is to compare the long-run macroeconomic and welfare effects (of the overall reform $S3$) presented in Section 5 with these four alternatives. These results are reported in Table 10.

Table 10: Sensitivity of long run effects of S3 reform to model's alternatives*

Variable	Baseline results[x]	Modifications/ extensions			
		I[i]	II[ii]	III[iii]	IV[iv]
Effective labour	3.09	1.30	2.87	7.78	7.04
Wage rate	-2.95	-2.55	-3.41	-6.73	-3.38
Output (GDP)	0.05	-1.28	-0.61	4.99	3.77
Private consumption	1.91	0.89	2.20	9.03	6.55
Gross investment	-4.71	-5.34	-6.04	-3.54	-1.34
Capital stock	-4.71	-5.34	-6.04	-3.54	-1.34
Household wealth	-4.40	-4.89	-5.54	-3.13	0.78
Interest rate (p.p.)	0.33	0.34	0.38	0.72	0.38
PAYG pension cost (% of GDP)	2.69	0.59	2.66	2.69	2.72
Social pension cost (% of GDP)	1.80	0.51	1.19	1.80	1.62
PAYG contribution rate (p.p.)[a]	-5.78	-2.43	-5.77	-4.59	-4.75
Consumption tax rate (p.p.)[a]	1.93	0.80	1.05	-0.12	0.75
Welfare effects[b]					
- Average (20+)	1.04	0.82	1.28	2.44	1.46
- Formal (20+)	4.06	2.54	4.72	5.32	3.33
- Informal (20+)	0.21	0.31	0.34	1.61	0.53
- Average (65+)	4.54	3.82	4.63	6.25	4.72
- Formal (65+)	1.57	1.19	1.80	2.65	2.48
- Informal (65+)	5.42	4.60	5.48	7.33	5.87

Notes: *% or p.p change due to overall reform S3, relative to ageing equilibrium S1, with pension costs as % of benchmark GDP; [x]Baseline results presented in Section 5 for S3; [i]I assumes no ageing with population structure as in benchmark model; [ii]II assumes social pensions to be means tested (conditional on private resources at older age); [iii]III assumes all informal behave as self-employed (or entrepreneurs); [iv]IV assumes exit rates (over working life) from formal to informal employment; [a]Changes in payroll tax and consumption tax balancing govt budgets; [b]% change in lifetime utility at 20 or 65 under overall reform S3, relative to S1.

Each of these alternatives is discussed below.[43]

[43]Further details are at Appendix D.

6.1 No ageing environment

Setup Here we abstract from population ageing, and so, when we simulate the results for the overall reform under $S3$, we assume the same demographic structure as in the benchmark model. Note that the macroeconomic and welfare effects presented in the second column of Table 10 are expressed relative to the benchmark economy (with no ageing).

Results The macroeconomic and welfare effects of the overall reform $S3$ under this demographic alternative in the second column of Table 10 are shown to be qualitatively (in terms of the sign of a change) in line with the main results but they are shown to be less pronounced.

Starting with the fiscal effects on pension costs, costs are significantly lower compared to the population ageing environment considered in Section 5, in line with expectations. For example, the long run cost of social pension (to all households aged 65+ with no formal pension) would amount only to 0.5% of GDP, barely one third of the cost under our standard population ageing scenario in the long run. Accordingly, the increase in the consumption tax rate balancing the government budget (with social pensions) is smaller, and the reduction in payroll tax or PAYG contribution rate is also smaller. Similarly, less pronounced effects for other macroeconomic and welfare variable are derived for the overall reform under this demographic alternative.

To summarise, population ageing amplifies the (mainly positive) macroeconomic and welfare effects of the examined overall pension reform.

6.2 Means tested social pension

Setup In our standard setup reported in Section 5, we assume that social pensions are paid to all those aged 65 years and over who do not have formal pensions. Here, we incorporate a simple form of means testing social pensions, drawing on Kudrna, Tran and Woodland (2022). The means test (income test) that we consider includes the following three parameters, to determine the social pension benefit sp: the maximum social pension benefit that we set to 6.5% of GDP p.c. (i.e., the same level of sp as in Section 5); the income threshold or disregard up to which the maximum benefit is paid; and the taper rate θ imposed on the excess income – assessable income above the disregard that determines the reduction of sp. As for the parameterization of the disregard and the taper rate, they are calibrated, in the no ageing environment, to target the distribution of the elderly population based on social pension payments, (similar to the Australian age pension example) with about 25% not receiving any benefit, 45% receiving the maximum benefit, and remaining 30% paid a reduced benefit. The calibrated values of the income disregard and the taper are 12% of average earnings and 0.4, respectively. Note that this parameterization is similar to the Australian age pension income test, while the maximum benefit (here absolute poverty alleviating) is significantly lower. We assume that the assessable income of all households 65+ includes returns on savings and formal pensions.[44]

Results The long run effects are provided in column 3 of Table 10. Social pension cost is 1.19% of GDP when social pensions are means tested, which represents a significant reduction, compared to 1.8% of GDP under the baseline results. Under population ageing, the overall reform with means tested pensions (and the means test parameterisation given above) increases the fraction of elderly population receiving no social pension to 35%, which drives down the social pension cost to the government and allows for a lower consumption tax rate, relative to the standard model (i.e., baseline results reported in column 1). In the long run, this generates higher per capita consumption and average welfare of newborn households, increasing by 2.2% and 1.28%, respectively (compared to 1.91% and 1.04% for the baseline results). However, the means test also introduces some disincentive effects on labour supply and savings, as seen when comparing the results for effective labour supply and household wealth.

Overall, adding a means test as specified here would lower the costs of proposed social pensions by about a third of the cost reported in the main result section, and it would also generate higher consumption and welfare in the long run. These results are supported by Kudrna, Tran and Woodland (2022) who studied pension means testing under population ageing with applications to Australia and the US.

6.3 Model with self-employed

Setup The benchmark model assumed that all informal labour or workers are hired by the corporate sector, earning wages at their "lower" labour productivities (also distinguished by the skill type), but they are largely exempt from any taxation and current pensions. In this modification, we assume informal labour and production to be based on OLG models with entrepreneurs (as, e.g., in Kitao (2008) and Fehr and Hofbauer (2016)). More specifically, we assume that all informal workers are treated as self-employed, with (*i*) their full income earned from labour and capital included in their budget constraint (6); (*ii*) a separate output good produced (i.e. total output now consists of an output from the formal sector production and an informal output produced by self-employed;[45] and (*iii*) an investment choice – informal labour now can invest in their business and/or formal sector capital stock (as

[44] Further details are provided in Appendix D.1.

[45] Self-employed have their own production function that is calibrated to target the shares of the formal vs. informal outputs in total production. As opposed to the benchmark model (and baseline reform results), self-employed are assumed to supply labour inelastically, and therefore, the pension reform has no impact on their hours worked. Note that to make the two models comparable, we assume that self-employed in this model work the same hours as informal workers in the benchmark model.

typically assumed in entrepreneur-type OLG models).[46] The tax and pension policy in this modified framework with self-employed is the same as in the benchmark model.[47]

Results The results for this modification are reported in column 4 of Table 10. They show qualitatively the same effects as using the benchmark model's assumptions about informal labour. The pension costs are nearly the same as in the benchmark model (e.g., social pension to GDP ratio at 0.018) but, in this model with self-employed, the long run effects of the overall reform on macroeconomic aggregates and welfare are more pronounced. These more pronounced effects are largely due to inelastic hours worked by self-employed assumed in this model (hence here social pensions generate no impact on hours decisions by the informal self-employed). It is interesting that in this model, the overall reform with the newly introduced social pension is self-financed, in fact allowing for a minor reduction in the consumption tax rate that is assumed to balance the government budget (which includes the social pension expenditure under $S3$).[48] This is the main cause of more pronounced welfare effects on average and across all skill types.

This structural modification does not change the long run effects qualitatively, and under our assumptions (and based on the long-run welfare effects), it strengthens the support for the overall reform $S3$.

6.4 Model with exit rate

Setup Under this scenario, we allow transition probabilities between employment types over the working life and the resulting changes in earnings as presented in Table 2 of Section 2. From Table 2, we observe the net exit rate from formal to informal employment averages about 16% over prime working ages 25-50, with an average decline in earnings of about 50% (of earnings of those who stay in formal employment). While we observe a decline in net exit rates by age (about 18% for those aged 20-30 to 14% for those aged 40-50), the earning reductions for the movers increase by age from 40% for 20-30 year olds to about 65% for 45-50 year olds. This extension of the model captures these transitions and earnings (labour productivities) of the movers.

This scenario makes the model more difficult to solve. We need to extend the state vector of households to include a state that indicates whether formal workers stay in or

[46] As in the benchmark model, we assume perfect labour market frictions and abstract from sectoral/employment choices.

[47] Further details on this model with self-employed, including some algebra and changes to the benchmark model (needed to accommodate self-employment) are provided in Appendix $D.2$.

[48] Note that the assumption about composite consumption good (consumed by both formal and informal labour) is kept unchanged in this model with self-employed. And although they are not subject to any income tax, they are subject to the consumption tax (which at a constant rate applies from the certain consumption exemption level). In this model, the increased consumption tax base finances social pensions (without the need to increase the tax rate).

move out of formal employment. If the agents exit, they do not pay any future contributions (or payroll taxes), do not accumulate future formal pension rights, but they preserve their current accumulated formal pension rights that are paid as formal pensions at retirement (and that are larger for those exiting formal employment at older working ages).[49] Further modelling details about this extension of the model are provided in Appendix $D.3$).

Results The macroeconomic and welfare effects of the pension reform $S3$ taking account for the exit rates – or transition probabilities out of formal to informal employment (under population ageing and in the long run) are presented in the last column of Table 10. As shown, similarly to other modifications discussed above, here the effects are qualitatively the same as in the baseline results. However, as in the case of the previous modification with self-employed, modelling the exit rate makes the long run effects for both macroeconomic aggregates and average welfare more pronounced, compared to the baseline results.

The effects of the overall pension reform on pension costs are similar to those in the main result section (in Table 10 reported as baseline results). The differences in pension costs are mainly due to different benchmark steady states – here and that used in the main result section. Note that the level of social pension is set to 6.5% of benchmark GDP (which is different in the two models). As expected, the decline in the PAYG payroll tax rate is smaller here (as some formal workers transition to informal employment before the retirement age increase) than under the baseline results. It seems that macroeconomic changes in effective labour, consumption and household wealth allow for an increase in the budget-balancing consumption tax rate that is less than half of the increase under the baseline results. This yields higher average welfare in the long run, even though formal workers gain less in welfare since the movers are not impacted by the retirement age increase. Importantly, the long run effects of the overall reform are shown to be robust also to this extension of our OLG model.

This range of extensions and variations shows that while the numerical results of our paper are sensitive to these changes, the broad thrust of our findings, that our combined reforms overwhelmingly increase welfare across both formal and informal households, at least in the long run.

7 Concluding remarks

This paper reports results from an OLG model of the Indonesian economy which examine alternative pension reforms. We consider two reforms: an increase in the access age for

[49] As in the benchmark model, we assume that at the formal retirement age, labour productivity of formal workers declines to that of informal workers. The calibrated labour shares (employment-skill type in the prime age workforce) are assumed to be also the same as in the benchmark model. And we make the same assumptions for the overall pension reform as in the previous section, with the retirement age increase applied to formal high skill workers and social pensions paid to all aged 65+ with no formal pension.

the formal pension, already legislated; and the introduction of a social pension, to provide support to the 80% of the labour force working in the informal sector.

Our results indicate that these two measures in combination generate improved economic welfare to the overwhelming majority of the Indonesian population, whether long run or transitional calculations are considered. Two mechanisms are involved. Increasing the formal sector PAYG access age generates increased output stemming from the greater labour force participation of high productivity workers. The introduction of the social pension, modest in scope, generates improved welfare to the majority of workers, who are likely to have limited resources beyond family support once their earnings capacity is exhausted. Combining the two reforms reduces the increase in the overall revenue requirement, relative to considering the introduction of a social pensions on its own. This suggests that it is timely to given consideration to the development of a social pension now.

We have also examined the economy-wide effects of pension policy extensions to both formal and informal workers, reporting on a range of model simulation outcomes, including the implications for household economic behaviour over the life cycle, macroeconomic implications and distributional welfare effects.

The results we present are illustrative of the potential power and flexibility of this model in providing quantitative analysis of policy proposals in a consistent economic framework. Aggregate economic impacts, price and quantity adjustments, and distributional effects are all reported. It provides the foundation for many elaborations to be developed by the authors in consultation with both the World Bank and Indonesian partners, including Bappenas. It will also provide the basis for model calibration and development in other emerging Asian economies.

Future extensions may include sectoral choice by households (subject to labour market frictions), alternative and more detailed modelling of the production sector and intergenerational transfers, and modelling of individual ages and years (rather than age groups and time periods). These will enrich and increase the relevance of the policy outcomes from the model, and we plan to account for these extensions in future research.

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Appendices

In these appendices, we provide more details for: (A) IFLS empirical analysis (Section 2); (B) Numerical solution (Sections 3 and 4); (C) Distributional results (Section 5); and (D) Sensitivity and model extensions (Section 6).

Appendix A. IFLS empirical analysis

Data selection In documenting labour force in Indonesia that we carried out in Section 2, we used the Indonesian Family Life Survey (IFLS), specifically the last 3 waves in 2000, 2007 and 2014. The focus was on the working age population, reporting (i) labour force composition (Table 1); (ii) life cycle earnings, productivity and labour supply (Figure 1); and (iii) employment transitions (and labour earnings of stayers and movers for (iii), comparing waves 2007 and 2014 (Table 2)). In our sample, we make the following restrictions:

- We use data for male workers only. The main reason for this restriction is that the labour market participation in developing countries is such that women are less likely to have a continuous job compared to men.[50]
- We restrict the age of formal workers to a range from 20 to 54 years (based on the formal retirement age of 55 years during the period covered by the selected IFLS data[51]), utilising data at the individual level for age, education, employment status, labour earnings and transition probabilities.[52]
- We retain farmers and the self-employed in the sample, since they are very populous groups in developing countries.
- People with no jobs (6.6% of total interviews across the IFLS 2000, 2007 and 2014) and people who report themselves as "unpaid family workers" (3.6%) are excluded.
- We also remove those with hours worked $<$ 10 hours per week (and outliers with hours $>$ 99 hours per week) (about 10% of the sample).[53]
- People are defined as "high" skill only if they completed high school (i.e., 12 years of schooling).[54]

[50] Note that Kudrna, Tran and Piggott (2020) also provide some labour force analysis for females.

[51] Note that the retirement age (normal pension age) was increased to 56 in 2012 for employees in the private sector. Currently, the retirement age is 57 years and it has been legislated to gradually increase to age 65 by 2043 (OECD 2018).

[52] For informal workers, we report their earnings and productivity up to age 60, as shown in Figure 1.

[53] This is typically assumed by related empirical literature (e.g., see Freestone 2018).

[54] This definition differs to that commonly used for OECD countries where those defined as high skill have some tertiary education (OECD 2020). Further note that according to World Bank (2020), the median year of schooling for Indonesian males aged 25+ equates to less than ten in 2018. However, we use 12 years of schooling as a cut-off, since this is now a mandated minimum school attendance in Indonesia.

- All observations with missing information are also removed from the constructed sample.[55]

Definition of informal employment We closely follow the international statistical definition of informal employment established by the International Labour Organization (ILO 2018, p.9). According to their definition, informal employment consists of (*i*) "employees if their employment relationship is not subject to national labour legislation, income taxation, social protection or entitlement to certain employment benefits", and (*ii*) others, with non-fixed premises and a size of five employees or less.

In this paper, we use medical benefits from employers in the form of health insurance and/or any other medical expenditure as the indicator of formality for employees. Specifically, if individuals in the IFLS report that they have received neither health insurance nor any medical benefits from their employers, we code them as informal workers.[56] For all those who report that they are self-employed, we also code them as informal labour. Note that most of them are working in agriculture as farmers or for small and unregistered household businesses. The same assumption has been used by, for example, Cuevas et al. (2009) to determine the informality for self-employment in Indonesia.[57]

Appendix B. Numerical solution

In this appendix, we provide more details for the numerical solution of the benchmark equilibrium, outlined in Section 4.4.

The solution method is solved numerically in Fortran by discretizing individual states to simplify the nonlinear dynamic programming problem. Macroeconomic solutions are solved with a Gauss-Seidel and individual policy functions are solved backwards with a value function iteration approach using a minimization routine and interpolation algorithms.[58] In our paper, the algorithm for solving stationary equilibrium includes the following steps:

1. Set demographic parameters, initialize parameters/variables and discretize state space;

2. Calculate factor prices according to (8) and (9);[59]

[55] As reported in Table 1, we end up with 25232 observations across the three waves. The summary statistics for this overall sample (combining IFLS 2000, 2007 and 2014) can be provided upon request.

[56] Given the availability of relevant information in the IFLS, this method of identifying informal workers is in line with ILO (2018), which utilizes the "entitlement to and benefit from paid sick leave" as an indicator to determine informal employment for an employee.

[57] There is also the legal-status-of-firm definition of (in)formality, i.e., whether enterprises are registered (UU Ketenagakerjaan No. 13 of 2003 by the Ministry of Manpower and Transmigration). This definition has been used, for example, by Rothenberg et al. (2016), also documenting a large and persistent informal sector in Indonesia, using firm-level data.

[58] For similar descriptions, see Kudrna and Woodland (2011) (solving deterministic model using Gauss-Seidel iterative method) and more recently, Fehr and Kindermann (2018) for solving stochastic OLG models.

[59] Note that here, we refer to Section 3 for the equation numbering and algebraic description of the model.

3. Use a value function iteration approach and interpolation algorithm to solve for optimal household decisions that maximize value function (5) subject to their respective constraints (6);
4. Use policy functions $a(z, Z_t)$ together with the accumulation of pension earning points (only for formal workers) and the transition probability of labour productivity shocks to solve for individual distributions over state space according to the laws of motion (3) and (4);
5. Calculate age-specific variables and aggregate variables consistent with policy functions and individual distributions over state space;
6. Calculate τ_t^c to balance the government budget according to (16);
7. Calculate PAYG social security benefits according to (10) and adjust payroll tax rate τ_t^p to balance (12);
8. Calculate bequests according to (17) by employment and educational types;
9. Update factor prices and iterate from step 2 until all markets clear (we iterate over goods market clearance (19)).

Appendix C. Distributional effects

In this appendix. we provide additional distributional results for the pension reforms in the long run and over the transition path.

Figure 6 plots life cycle profiles of consumption, hours worked and assets for formal and informal workers in the long run (comparing the three scenarios – baseline ageing (no reform) case $S1$, higher retirement age policy under $S2$, and the overall reform with social pensions under $S3$. It complements the average life cycle profiles for these household variables depicted in Figure 4 (of Section 5).

As discussed in Section 5.1, the left-hand side graphs show significant impacts of $S2$ on formal workers in the long run, increasing their consumption at older ages and their labour supply at ages (of the increased retirement age) and shifting peak in their assets to an older age. One the other hand, social pensions under $S3$ have more significant impacts on informal workers, since they become recipients of these newly introduced benefits at older ages (65+). As indicated in the graphs on the right-hand side of Figure 6 shows, social pensions generate some distortions to labour supply and savings of informal workers.

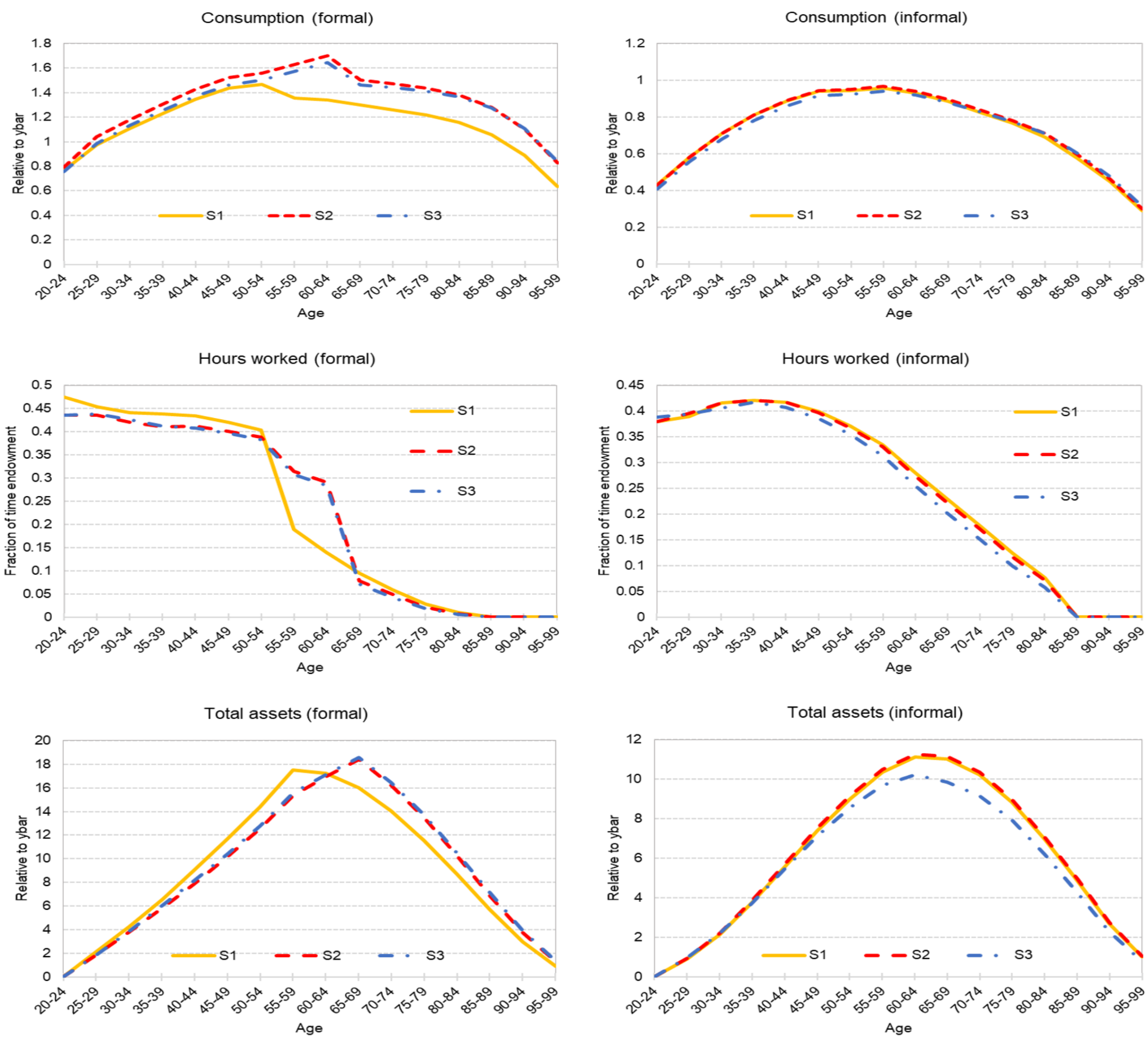

Figure 6: Distributional life cycle effects in long run

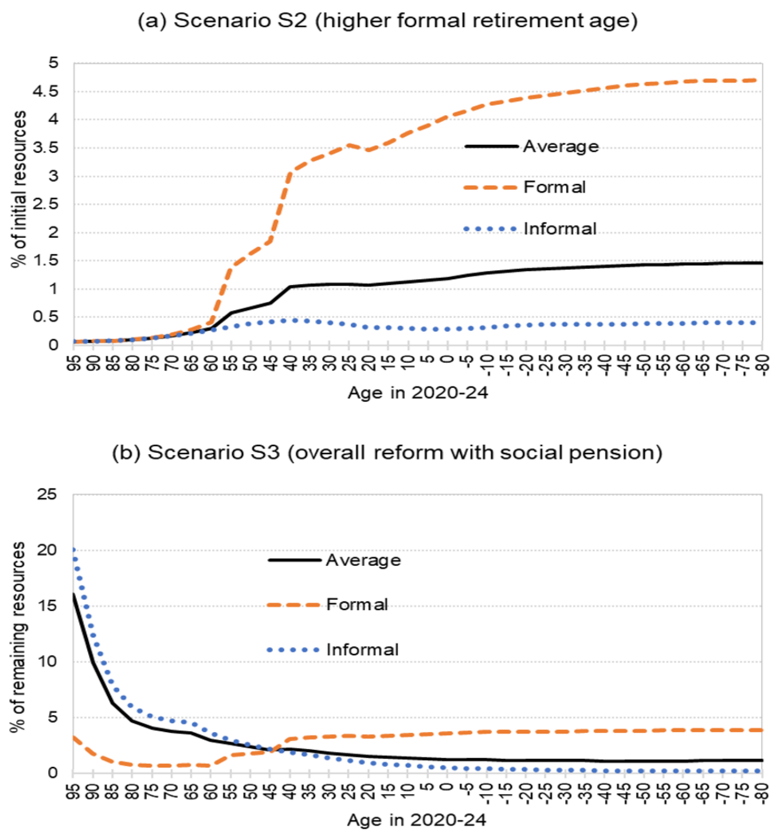

Figure 7: Distributional welfare effects along transition path

The distributional welfare effects over the ageing transition path (for different generations and sectoral types) are displayed by Figure 7. As the intergenrational welfare effects of the two reforms reported in Table 9, the HEV welfare measure is used in Figure 7 (so the welfare results plotted in Figure 7 here and Table 9 of the main text are comparable).

Briefly, three main observations can be drawn from this figure. First, both reforms generate welfare gains for the current generations (at the time of the reform), in the succeeding transition path years and in the long run. Second, welfare gains to future born generations (on x-axis of Figure 7, those aged < 20 at the time of the reform) are due to the $S2$ reform with gains to directly impacted formal workers, while social pensions under $S3$ generate welfare gains for the current generations of informal households at older ages 60+. Third, welfare gains for the $S2$ reform – retirement age increase for formal workers increase over time, while the welfare gains from the social pension introduction under the $S3$ reform fall over time.

Appendix D. Sensitivity and model extension

D.1 Means tested social pension

We consider (a simple form) of means testing social pensions, drawing on Kudrna and Woodland (2011), and Kudrna, Tran and Woodland (2022). We modify the overall reform $S3$ by assuming that the social pension benefit sp_j (with the same age eligibility as in the main result section, i.e. older households aged 65 and over) is subject to the following income test:

$$sp_j = \max\left\{\min\left\{sp^{\max}, sp^{\max} - \theta\left(\widehat{y}_j - \widehat{y}_{\min}\right)\right\}, 0\right\}, \tag{20}$$

where $sp^{\max}$ is the maximum social pension benefit (at the same 6.5% of GDP p.c., as in the main section), $\widehat{y}_{\min}$ is the income disregard (for age-eligible households to be paid the maximum benefit $sp^{\max}$), $\widehat{y}_j$ $(= ra_j + p_j)$ is the assessable income (that is assumed to include interest earnings ra_j and formal PAYG pensions p_j) and θ is the taper rate, at which $sp^{\max}$ is withdrawn for every IDR of $\widehat{y} > \widehat{y}_{\min}$ until $sp = 0$).

We calibrate the social pension means test parameters to approximate the distribution of elderly population in terms of social pension receipts. In terms of that distribution, we draw on the Australian experience with means tested age pensions. Specifically, we simulate the steady state equilibrium with the means tested social pension given in (20), assuming the stationary demographic environment (as in the benchmark model), to calibrate $\widehat{y}_{\min} = 0.12\overline{y}$ (12% of average earnings) and $\theta = 0.4$, which gives the share of those aged 65+ who are paid zero social pension ($\approx 25\%$) and who are paid the maximum rate ($\approx 45\%$). We also assume only a proportion of assets to be included in the means test $ra_j\varphi$, with $\widehat{y}_j = ra_j\varphi + p_j$ and $\varphi = 0.3$.[60]

For the long run results of the $S3$ reform with means tested social pensions, see Section 6.2.

D.2 Model with self-employed

In this modification or model extensions, we assume informal labour to behave as self-employed in OLG models with entrepreneurs (as, e.g., in Kitao (2008) and Fehr and Hofbauer (2016)). More specifically, we assume that all informal labour solves the following optimization problem:

$$V_j = \max_{c_j, k_j, a_{j+1}} \left\{u(c_j, \bar{l}_j) + \beta\psi_{j+1}E_j\left[V_{j+1}|\eta\right] + (1-\psi_{j+1})\mathcal{B}(\bar{b}_{j+1})\right\} \tag{21}$$

[60] In Kudrna et al. (2022), this parameter is set to match share of owner-occupied housing in total assets that is not subject the means test. Here, in the case of Indonesia with a large informal sector, the observed fraction of assets (that can be means-tested) is smaller. However, note that this parameter could provide policy makers with an additional policy instrument to further strengthen the social pension means test over time.

subject to

$$
\begin{aligned}
(1+g)a_{j+1} &= a_j + r\max(a_j - k_j; 0) + y_j + b_j - (c_j + t^c(\widetilde{c}_j)) \qquad (22)\\
y_j &= \kappa^I \left[(k_j)^{\alpha^I}\left(e_j\eta_j(1-\bar{l}_j)\right)^{1-\alpha^I}\right]^{\nu} - \delta k_j - r\max(k_j - a_j; 0)\\
c_j &> 0, \quad 0 \leq k_j \leq (1+d)a_j, \quad a_{j+1} \geq 0.
\end{aligned}
$$

The problem is like the worker's problem in Section 3, but there are three main differences. First, while effective labour supply is assumed to be inelastic $e_j\eta_j(1-\bar{l}_j)$, the self-employed agents make investment decisions k_j (i.e., how much to invest in their business, which is subject to borrowing constraint $k_j \leq (1+d)a_j$, with remaining savings $a_j - k_j$ invested in the capital market). Second, their income y_j is now the profit from their business. Third, they have their own production function given by $y^I = \kappa^I \left[(k)^{\alpha^I}\left(e\eta(1-\bar{l})\right)^{1-\alpha^I}\right]^{\nu}$, where $\nu = 0.88$ reflects the degree of returns to scale of self-employed (taken from Kitao (2008)).

In this economy, there are two output goods – produced by the formal firm and informal self-employed ($Y = Y^F + Y^I$), with the latter expressed as

$$
Y^I = \textstyle\sum_{j=1}^{J}\mu_j \displaystyle\int_{\mathcal{Z}} y^I(z)\mathrm{d}X(z),
$$

where household state vector z is the same as in Section 3.2.

All these features are typically assumed in the related literature that also assumes occupational choice. Our model abstracts from occupational choice, with all informal labour being assigned the informal self-employment state when entering the model. Instead, we calibrate the production function parameters of informal self-employed (with $\kappa^I < \kappa^F$ and $\alpha^I < \alpha^F$) to target the shares of formal vs. informal outputs in the total production (derived from Loayza and Meza-Cuadra (2018) for Indonesia). Note that we also abstract from any borrowing (by self-employed), with $d = 0$. Finally, the government tax and pension policy rules are the same as in the benchmark model or under the $S3$ reform.

The long run results of the $S3$ reform within this self-employed model are presented and discussed in Section 6.3.

D.3 Model with exit rate

As outlined in Section 6.4 in this final structural modification/extension of the model, we account for the so-called exit rates approximating transition probabilities between employment types and the resulting changes in labour productivity presented in Table 2 of Section 2. Note that these net exit rates derived from Table 2 are averaging at around 16% and are age-specific (declining from about 18% for those aged 20-30 to 14% for those aged 40-50). Those (formal workers) who transition have their labour productivity reduced, with the earning reduction for the movers increasing by age from 40% for 20-30 year olds to about

65% for 45-50 year olds. The government tax and pension policy settings are the same as in the benchmark.

To account for this extension in the model description (in Section 3.2), first we need to modify the state vector of households z to include an additional state o that indicates whether formal workers stay in ($o = 0$) or move out of formal employment($o = 1$):

$$z = (j, s, a, ep, \eta, o) \ \in \ \mathcal{Z} = \mathcal{J} \times \mathcal{S} \times \mathcal{A} \times P \times \mathcal{E} \times \mathcal{O}$$

As indicated above, this extension of the model incorporates the exit rate (or transition probabilities of formal workers moving to informal employment), that is, $\pi^o_j(o^+|o)$.

Given these extensions, the distributional measure of households needs to be augmented. Specifically, the initial distributional measure of households at age $j = 1$ becomes

$$\int_{\mathcal{S}\times\mathcal{E}} \mathrm{d}X(z) = 1 \qquad \text{with} \quad z_1 = (1, s, 0, 0, \eta, 0). \tag{23}$$

Let $\mathbf{1}_{k=x}$ be an indicator function that returns 1 if $k = x$ and 0 if $k \neq x$. Then, the law of motion for the measure of households follows

$$\begin{aligned} \zeta(z) = \int_{\mathcal{Z}} \mathbf{1}_{a_{j+1}=a_{j+1}(z,Z)} \times \mathbf{1}_{ep_{j+1}=ep_{j+1}(z,Z)} \times \\ \times \pi(\eta^+|\eta)\pi^o(o^+|o)\mathrm{d}X(z), \end{aligned} \tag{24}$$

where $\pi(\cdot)$ and $\pi^o(\cdot)$ denote the transition probabilities for labour productivity and the exit rates (from formal employment) from one period to the next (denoted $^+$).

If formal workers exit, they do not pay any future contributions (or payroll taxes), do not accumulate future formal pension rights, but they preserve their current accumulated formal pension rights that are paid as formal pensions at retirement (and that are larger for those exiting formal employment at older working ages). For the movers, we scale their deterministic component of their labour productivity by $\lambda_j < 1$ ($= \lambda_j e_j$), derived from Table 2. The optimization problem of an inidividual in the formal sector becomes:

$$\begin{aligned} V_j = \max_{c_j, l_j, a_{j+1}} \{ & u(c_j, l_j) + \beta\psi_{j+1} \left(\pi^o_j E_j \left[V_{j+1}|\eta\right] + (1 - \pi^o_j) E_j \left[V_{j+1}|\eta\right]\right) \\ & + (1 - \psi_{j+1})\mathcal{B}(\bar{b}_{j+1})\}, \end{aligned} \tag{25}$$

subject to the constraint

$$(1+g)a_{j+1} = \begin{cases} (1+r)a_j + \widetilde{y}_j + b_j + p_j - t^y(\widetilde{y}_j) - t^r(\widetilde{a}_j) - (c_j + t^c(\widetilde{c}_j)), & \text{if formal,} \\ (1+r)a_j + \lambda_j \widetilde{y}_j + b_j - (c_j + t^c(\widetilde{c}_j)), & \text{if informal,} \end{cases} \tag{26}$$

$$c_j > 0, 0 \leq l_j \leq 1, a_{j+1} \geq 0,$$

The long run results for the $S3$ pension reform from this model with exit rate are discussed in Section 6.4.