Using Actuarial Methodologies to Analyse Chinese PAYG Pension System

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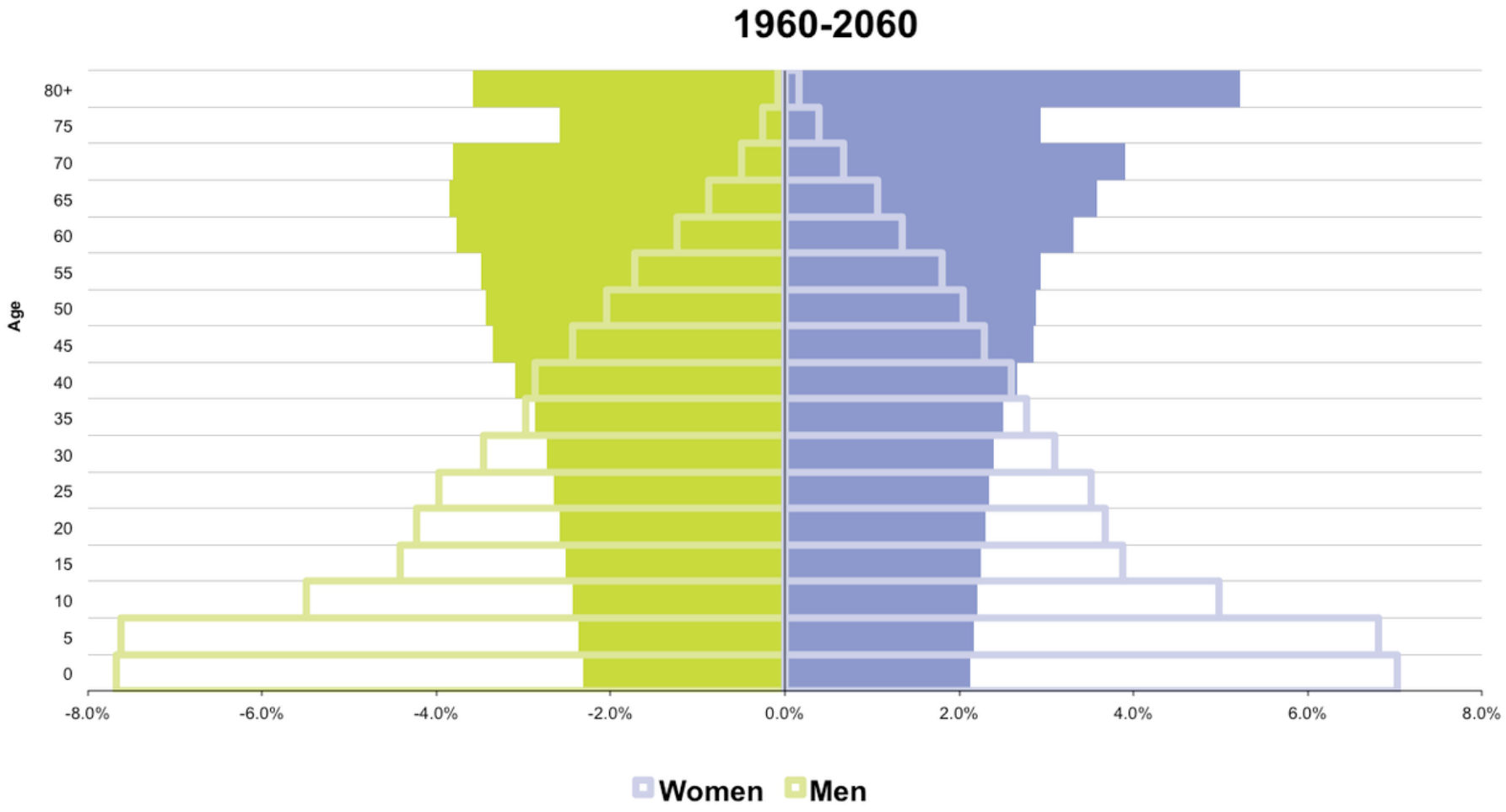
Motivation

- China suffers from more serious ageing problem than other countries due to 'one child' policy which was first conducted in 1980s. This makes the fertility rates fall rapidly.
  - China: 6.11 in 1950s to 1.63 in 2010s
  - EU: 2.67 in 1950s to 1.54 in 2010s.
- China's actions for ageing problem:
  - The replacement rate decreases from 77% to 43% in the last decade.
  - The retirement age increases from 50 (female) and 60 (male) to 65 by year 2030.
- Some political problems such as 'empty accounts' require the transparency of the current Chinese pension system.

Figure 1: Population structure for China



Source: UN World Population Prospects, the 2010 Revision

Aim of this paper

- Analyse the solvency level for Chinese PAYG pension system using the Swedish actuarial balance sheet (ABS) based on verifiable facts.
- Analyse the sustainability of Chinese PAYG pension system following the US actuarial balance indicator based on the projections on demographic and economic changes in the next 75 years.
- Provide some parametric reforms under both methodologies.

Outline

- Introduction.
- Chinese PAYG pension system using Swedish ABS.
- Chinese PAYG pension system using US actuarial balance indicator.
- Conclusions.

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Introduction: Background of China

- The compulsory public pillar for Chinese urban retirement pension system consists of two parts:
  - Individual Accounts (8%): Funded-DC
  - National Accounts (20%): PAYG-DB
- Individual Accounts are suffering from the problem of "empty accounts". Chinese authorities have taken steps to "refill" the Individual Accounts.
- Our research focuses on the PAYG part.

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Actuarial Balance Sheet (ABS)

- Sweden is the first country which compiles an actuarial balance sheet every year from 2001.
- Boado-Penas et al (2008) also compiles the actuarial balance sheet for Spain from 2001 to 2006.
- The actuarial balance sheet can be defined as the financial statement listing the pension system's obligations towards contributors and pensioners at a particular date, with the amount of various assets which back up these commitments.
- We will provide a comparison between the Swedish actuarial balance sheet and the Chinese one.

ABS: Main entries

Table 1: *Main entries on the balance sheet (ABS) of a pay-as-you-go system*

Assets	*Liabilities*
Financial assets	Liability to pensioners
Contribution asset	Liability to contributors
Accumulated deficit	Accumulated surplus
Total assets	**Total liabilities**

ABS: Liabilities

- Liabilities to current pensioners:

$$V_t^r = P_{(x_e+A,t)} \sum_{k=0}^{w-x_e-A-1} N_{(x_e+A+k,t)} \ddot{a}^{\lambda}_{x_e+A+k} \left[\frac{1+\lambda}{1+G}\right]^k$$

where $P_{(x_e+A,t)}$ is the annual pension for an individual aged $x_e + A$ in year t.
$N_{(x_e+A+k,t)}$ is the number of individuals aged $x_e + A + k$ in year t.
$\ddot{a}^{\lambda}_{x_e+A+k}$ is the lifetime annuity growing at real rate λ.
G is the notional rate.
A is the maximum number of generations of contributors that coexist at same time.

- Liabilities to contributors:

$$V_t^c = \overbrace{P_{(x_e+A,t)} N_{(x_e+A,t)} \ddot{a}^{\lambda}_{x_e+A} \sum_{h=1}^{A} \left[\frac{1+G}{1+d}\right]^h}^{\text{Future pensions}} - \underbrace{\theta \sum_{k=0}^{A-1} \sum_{h=0}^{k} N_{(x_e+k,t)} y_{(x_e+k,t)} \left[\frac{1+G}{1+d}\right]^h}_{\text{Future contributions}}$$

where θ is the contribution rate.
$y_{(x_e+k,t)}$ is the average salary for individuals aged $x_e + k$ in year t.

ABS: Assets

In a pure PAYG system, assets should be equal to liabilities, the assets that we called contribution assets are equal to:

$$CA_t = C_t \cdot TD_t$$

- C_t: the contribution revenue at year t;
- TD_t: turnover duration.

$$TD_t = A_t^r - A_t^c$$

- A_t^r: weighted average age of the pensioners;
- A_t^c: weighted average age of the contributors;

Meaning of TD

TD_t is the time expected to elapse between a monetary unit entering the system as a contribution and leaving in the form of a pension.

ABS: Solvency ratio

Solvency Ratio

$$SR = \frac{Financial\ Assets + Contribution\ Assets)}{Pension\ Liabilities}$$

It is used to measure the financial solvency of the pension system.

- If $SR \geq 1$, the system is solvent.
- If $SR < 1$, the system is partially solvent.

Results: Swedish Balance Sheet 2007-2012

Table 2: *Balance sheet for the Swedish pension system at 31 December each year*

	2007	*2008*	*2009*	*2010*	*2011*	*2012*
Asset (% of GDP)						
Financial asset	28.7	22.1	26.6	26.8	25.1	27.0
Contribution asset	195.6	202.2	204.8	197.0	196.2	194.8
Total assets	224.4	224.2	231.5	223.8	221.2	221.8
Liabilities (% of GDP)						
Liability to pensioners	66.8	70.9	80.8	76.9	74.1	78.2
Liability to contributors	157.0	161.0	161.0	143.7	142.6	145.8
Accumulated surplus	0.6	0.6	-7.8	-9.7	3.0	4.4
Change in net worth	0.0	-8.2	-2.6	12.8	1.6	-6.6
Total liabilities	224.4	224.2	231.5	223.8	221.2	221.8
Funding, solvency and liquidity indicators						
Ratio of (in)solvency (assets/liabilities)	1.00	0.97	0.96	1.01	1.02	0.99
Degree of funding(%) (financial asset/liabilities)	12.84	9.52	11.01	12.15	11.57	12.05
Liabilities to contributors/ liabilities(%)	70.17	69.43	66.59	65.14	65.82	65.10

Source: Swedish Orange Report 2008-2013 and own source

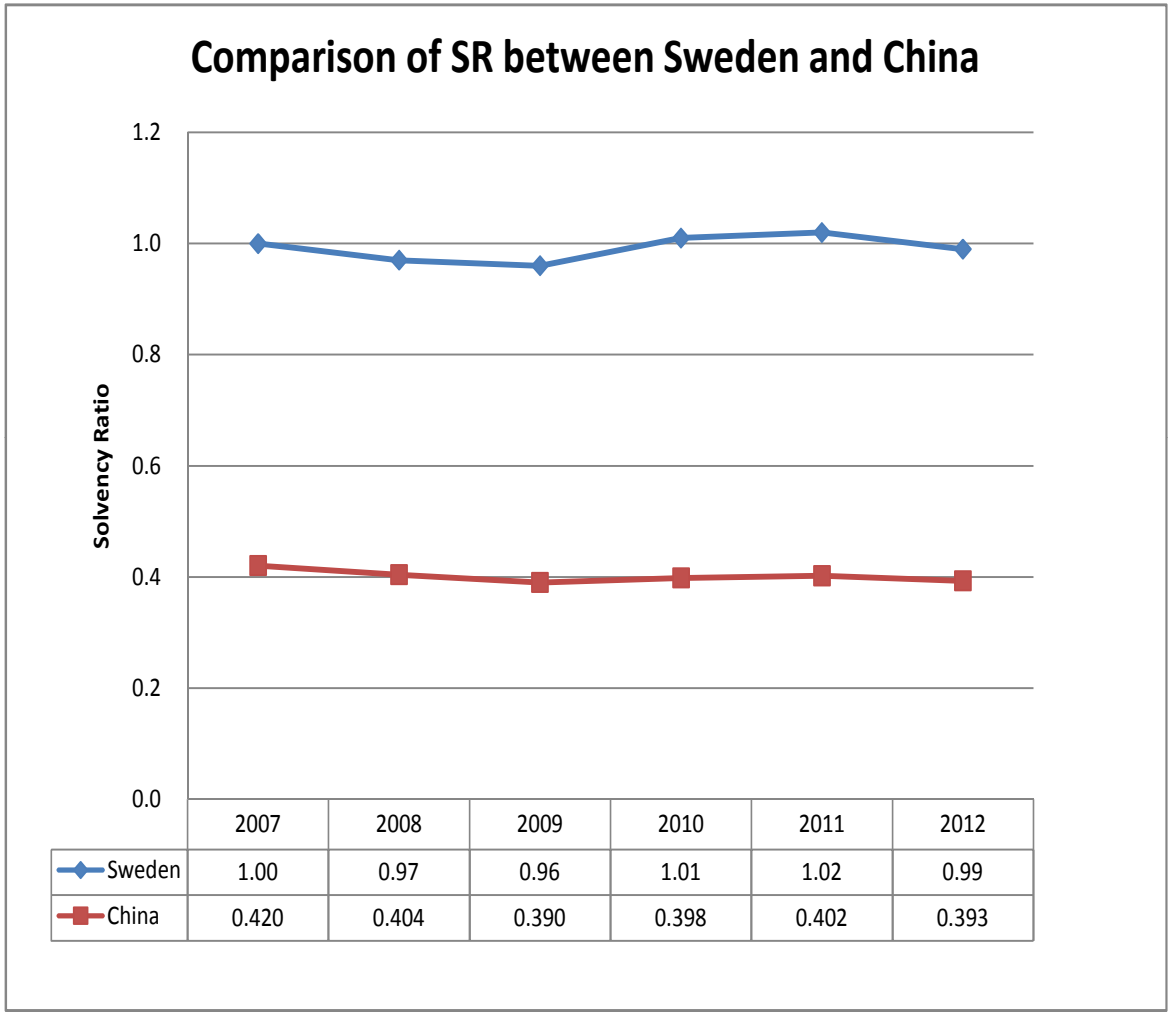
Results: Chinese Balance Sheet 2007-2012

Table 3: *Balance sheet for the Chinese PAYG pension system at 31 December each year*

	2007	*2008*	*2009*	*2010*	*2011*	*2012*
Asset (% of GDP)						
Financial asset	2.30	2.60	3.14	3.49	3.75	4.22
Contribution asset	58.84	61.10	67.91	68.90	72.81	76.73
Accumulated deficit	84.28	84.28	93.96	111.00	109.30	113.79
'Losses for the period'	0.00	9.68	17.04	-1.70	4.49	11.14
Total Assets	145.42	157.66	182.06	181.70	190.35	205.88
Liabilities (% of GDP)						
Liability to pensioners	64.15	69.76	80.67	83.25	84.54	90.63
Liability to contributors	81.27	87.90	101.39	98.44	105.81	115.25
Total liabilities	145.42	157.66	182.06	181.70	190.35	205.88
Funding, solvency and liquidity indicators						
Ratio of (in)solvency (assets/liabilities)	0.420	0.404	0.390	0.398	0.402	0.393
Degree of funding(%) (financial asset/liabilities)	1.58	1.65	1.73	1.92	1.97	2.05
Liabilities to contributors/ liabilities(%)	55.9	55.8	55.7	54.2	55.6	56.0

Own source

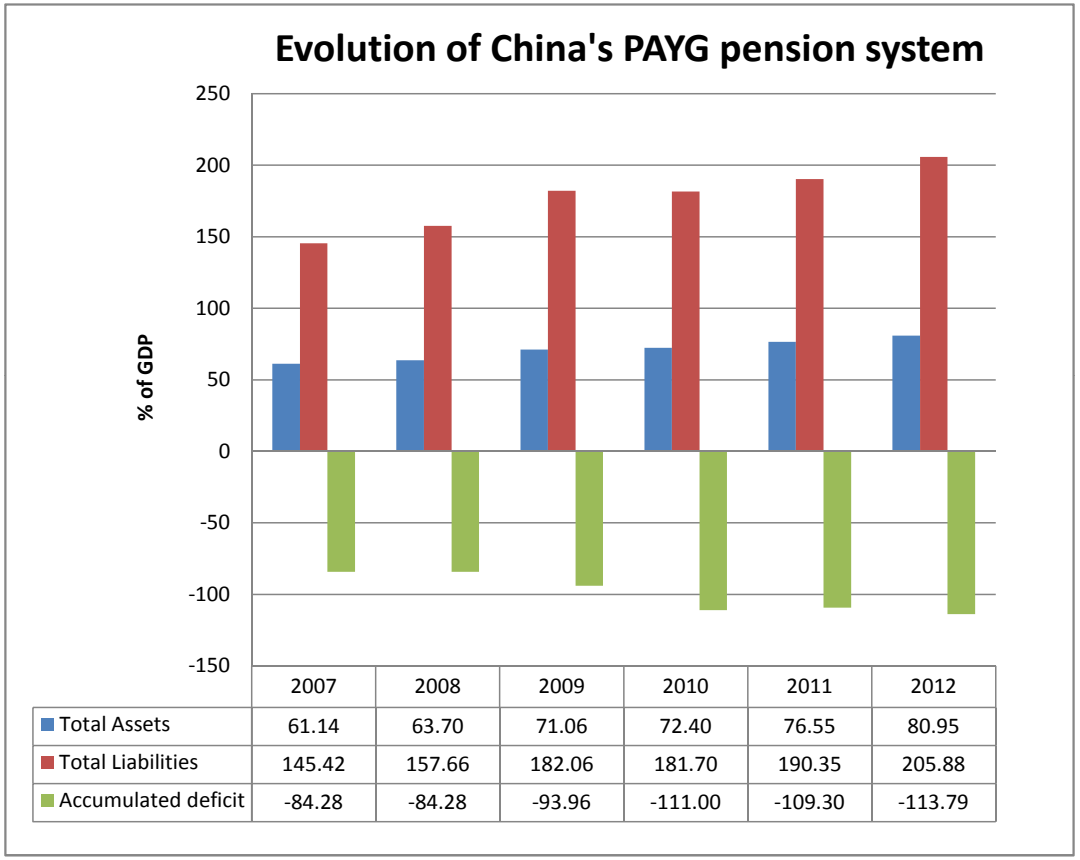
Figure 2: Comparison of Solvency Ratio for China and Sweden 2007-2012



	2007	2008	2009	2010	2011	2012
Sweden	1.00	0.97	0.96	1.01	1.02	0.99
China	0.420	0.404	0.390	0.398	0.402	0.393

Own source

Figure 3: Evolution of the total assets, liabilities and accumulated deficit of the Chinese PAYG pension system



	2007	2008	2009	2010	2011	2012
Total Assets	61.14	63.70	71.06	72.40	76.55	80.95
Total Liabilities	145.42	157.66	182.06	181.70	190.35	205.88
Accumulated deficit	-84.28	-84.28	-93.96	-111.00	-109.30	-113.79

Own source

Parametric solutions of Chinese ABS

Table 4: Parametric solutions of Two measures function together

Item		RR			λ			Retirement Age		
		31%	22%	18%	0%	-10%	-20%	53	60	63
CR	=	0.393	0.539	0.649	0.393	0.455	0.539	0.393	0.613	0.790
	5%	0.533	0.758	0.938	0.533	0.626	0.758	0.533	0.946	1.372
	10%	0.703	1.046	1.346	0.703	0.841	1.046	0.703	1.497	2.742
	15%	0.914	1.444	1.963	0.914	1.119	1.444	0.914	2.590	9.869
RR	31%				0.393	0.455	0.539	0.393	0.613	0.790
	22%					0.633	0.766	0.539	0.913	1.265
	18%					0.770	0.948	0.649	1.175	1.744
λ	0%							0.393	0.613	0.790
	-10%							0.455	0.747	1.007
	-20%							0.539	0.956	1.386

Own source

If 3 parametric measures were taken simultaneously securing a RR of 50%, it would be needed a retirement age of 60, an increase of the CR of 6%, and at the same time a decrease in the indexation of pensions by 10%.

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Actuarial Balance Indicator (US)

- In US, the annual pension report presents an actuarial balance indicator every year by taking into account of next 75 years' demographic and economic projections.

- This indicator measures the difference between the present value of income from contributions and spending on pensions, expressed as a percentage of the present value of the contribution base for that time horizon.

Actuarial Balance Indicator

$$AB = \underbrace{\left[\frac{TF_0 + \overbrace{y_0 \cdot \sum_{t=0}^{74} \theta_t \cdot N_t \cdot \prod_{h=1}^{t} \frac{(1+g_h)}{(1+r_h)}}^{Present\ value\ of\ Contributions}}{\underbrace{y_0 \cdot \sum_{t=0}^{74} N_t \cdot \prod_{h=1}^{t} \frac{(1+g_h)}{(1+r_h)}}_{Present\ value\ of\ payrolls}} \right]}_{Summarized\ Income\ Rate} - \underbrace{\left[\frac{\overbrace{B_0 \cdot \sum_{t=0}^{74} R_t \cdot \prod_{h=1}^{t} \frac{(1+\lambda_h)}{(1+r_h)}}^{Present\ value\ of\ benefits} + \prod_{h=1}^{74} \frac{(TF_{74})}{(1+r_h)}}{\underbrace{y_0 \cdot \sum_{t=0}^{74} N_t \cdot \prod_{h=1}^{t} \frac{(1+g_h)}{(1+r_h)}}_{Present\ value\ of\ payrolls}} \right]}_{Summarized\ Cost\ Rate}$$

- TF_0: Value of assets in the trust fund at the beginning of the period.
- θ_t: Contribution rate at t.
- y_0: Contribution base at year 0.
- N_t: Number of contributors at year t.
- g: Annual real wage growth rate.
- r: Projected yield rate on trust fund assets.
- B_0: Average pension at year 0.
- R_t: Number of pensioners at year t.
- λ: Annual real benefit growth rate.

Results: Actuarial balance indicator for China and US

Table 5: *Elements of the 75-year actuarial balance 2012-2086. Present value at January 2012.*

	Items	China (RMB in billions)	US (Dollar in billions)
1	Income from contributions	717977	45198
2	Spending on pensions	2027633	56477
3=1-2	Initial deficit	-1309656	-11278
4	Trust fund assets at start of period	2190	2678
5=3+4	Open group unfunded obligation	-1307466	-8601
6	Ending target trust fund	95982	501
7=5-6	Results for the period	-1403448	-9101
8	Aggregate contribution bases	3589883	341465
9=(1+4)/8	Summarized income rate	20.06%	14.02%
10=(2+6)/8	Summarized cost rate	59.16%	16.69%
11=9-10	Actuarial Balance (AB)	-39.09%	-2.67%
12	Year of first deficit	2025	2012
13	Reserve fund exhausted(year)	2034	2033

Own source

Parametric reforms based on Chinese actuarial balance indicator

Table 6: Parametric solutions of Two measures function together

Item		RR			λ			Retirement Age		
		31%	25%	20%	0%	-1%	-2%	62	64	66
CR	=	-39.0%	-27.7%	-18.1%	-39.0%	-15.3%	-1.4%	-5.3%	-3.0%	1.3%
	10%	-29.1%	-17.7%	-8.1%	-29.1%	-5.3%	8.6%	4.8%	7.0%	11.3%
	15%	-24.1%	-12.7%	-3.1%	-24.1%	-0.3%	13.6%	9.8%	12.0%	16.3%
	20%	-19.1%	-7.7%	1.9%	-19.1%	4.7%	18.6%	14.8%	17.0%	21.3%
RR	31%				-39.0%	-15.3%	-1.4%	-5.3%	-3.0%	1.3%
	25%				-27.7%	-8.4%	2.7%	-0.4%	1.5%	4.9%
	20%				-18.1%	-2.7%	6.2%	3.7%	5.2%	7.9%
λ	0%							-5.3%	-3.0%	1.3%
	-1%							5.0%	6.4%	8.9%
	-2%							11.0%	11.8%	13.3%

Own source

If 3 parametric measures were taken simultaneosly securing a RR of 50%, it would be needed a retirement age of 62, an increase of the CR of 2%, and at the same time a decrease in the indexation of pensions by -1%.

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Conclusions

- The solvency and sustainability levels of Chinese PAYG pension system are quite low.
- Total liabilities are more than double of the total assets in the PAYG system based on the actuarial balance sheet. And the solvency ratio is decreasing over the past few years. Some parametric pension reforms should be taken to ensure the financial solvency. e.g. $Retirement\ Age = 63$, and $\lambda = -10\%$.
- Under the actuarial balance indicator, the Chinese PAYG pension system is quite unsustainable compared to the US. However, we can take some parametric reforms to make the system solvent in the next 75 years. e.g. $CR = +10\%$ and $\lambda = -1\%$.

References

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Thank You!

Takk!

Model: Assets

$$A_t^r = \frac{\sum_{k=0}^{w-1-x_e-A}(x_e + A + k)P_{(x_e+A+k,t)}N_{(x_e+A+k,t)}}{\sum_{k=0}^{w-1-x_e-A} P_{(x_e+A+k,t)}N_{(x_e+A+k,t)}}$$

$$A_t^c = \frac{\sum_{k=0}^{A-1}(x_e + k)y_{(x_e+k,t)}N_{(x_e+k,t)}}{\sum_{k=0}^{A-1} y_{(x_e+k,t)}N_{(x_e+k,t)}}$$

- w: highest age at which there are no survivors;
- x_e: age of entry into the system;
- A: number of years of contributions;
- $P_{(x_e+A+k,t)}$: annual pension for people aged $(x_e + A + k)$ in year t;
- $N_{(x_e+A+k,t)}$: number of pensioners for people aged $(x_e + A + k)$ in year t;
- $y_{(x_e+k,t)}$: average wage for people aged $(x_e + k)$ in year t ;
- $N_{(x_e+k,t)}$: number of contributors for people aged $(x_e + k)$ in year t.

Model: Formulae for China

The formula to calculate the initial pension of Chinese PAYG National Accounts:

$$P_{(x_e+A,t)} = \frac{1 + WI_{(x_e+A)}}{2} \cdot Y_{(t-1)} \cdot A \cdot 1\%$$

where $WI_{(x_e+A)}$ is the wage index for people at age $x_e + A$:

$$WI_{(x_e+A)} = \sum_{k=1}^{A} \frac{y_{(x_e+A,t-k)}}{Y_{(t-k)} \cdot A}$$

- $y_{(x_e+A,t)}$: average wage of people who retires at age $x_e + A$ in year t;
- $Y_{(t-1)}$: average wage of total current workers at year $t - 1$.

Differences between Swedish and US methodologies

Table 7: *Comparison between Sweden and U.S actuarial balances*

Sweden	US
Based on verifiable facts	Projections for next 75-years
Assumptions in a steady state	Projections on pension variables
Structure of accounting balance sheet	More a financial profile
Solvency Ratio	Actuarial Balance Indicator