Population Aging, Social Security and Fiscal Limits

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Outline

- Population aging and public finances
  - (Dependency ratios)
- Life-cycle model with fiscal limits
  - (Dynamic Laffer effects)
- Threshold Dependency Ratio
  - Definition
  - Competitive equilibrium
  - Level, Distance and Probability
- Quantitative analysis for US and EU14 over 2010-2100
  - Fiscal space
  - Threshold
  - Welfare
  - [Dynamic Laffer effects and life-cycle models]
  - [Tax data]

Related literature

- **Computational life-cycle models**
  - Reforms of the US's tax system, Altig et al. (AER, 2001), Conesa et al (AER, 2009), Guner et al (REStud, 2012), Guner et al (JME, 2016)
  - Sustainability of the US's social security system: Auerbach, Kotlikoff and Skinner (IER, 1983); Auerbach and Kotlikoff (1987), De Nardi et at (REStud, 1999), Fuster et al. (REStud, 2007), Kotlikoff et al (JME, 2007), Heer and Irmen (JECD, 2014), Conesa and Garriga (EER, 2016)
- **Infinitely-lived agent models**
  - Dynamic Laffer effects: Trabandt and Uligh (JME, 2011); D'Erasmo, Mendoza and Zhang (HMac, 2016)
  - Fiscal limits: Davig, Leeper and Walker (JME, 2010); Polito and Wickens (JBF, 2014; EER, 2015).
- **OLG models with dynamic Laffer effects**
  - Progressivity of US' tax system: Holter, Krueger, Stepanchuk (2015) and Guner et al. (JME, 2016)

This talk

- Aging data and trends
- The model
- Quantitative analysis
- Results for the US and EU14 countries

Aging: Variables

- Retirees-to-workers ratio
- United Nations (2015): 1950-2100
  - Old-Age Dependency Ratio 2 (OADR2): [65+/(20-65)]%
  - Old-Age Dependency Ratio 3 (OADR2): [70+/(20-70)]%

Aging: Trends

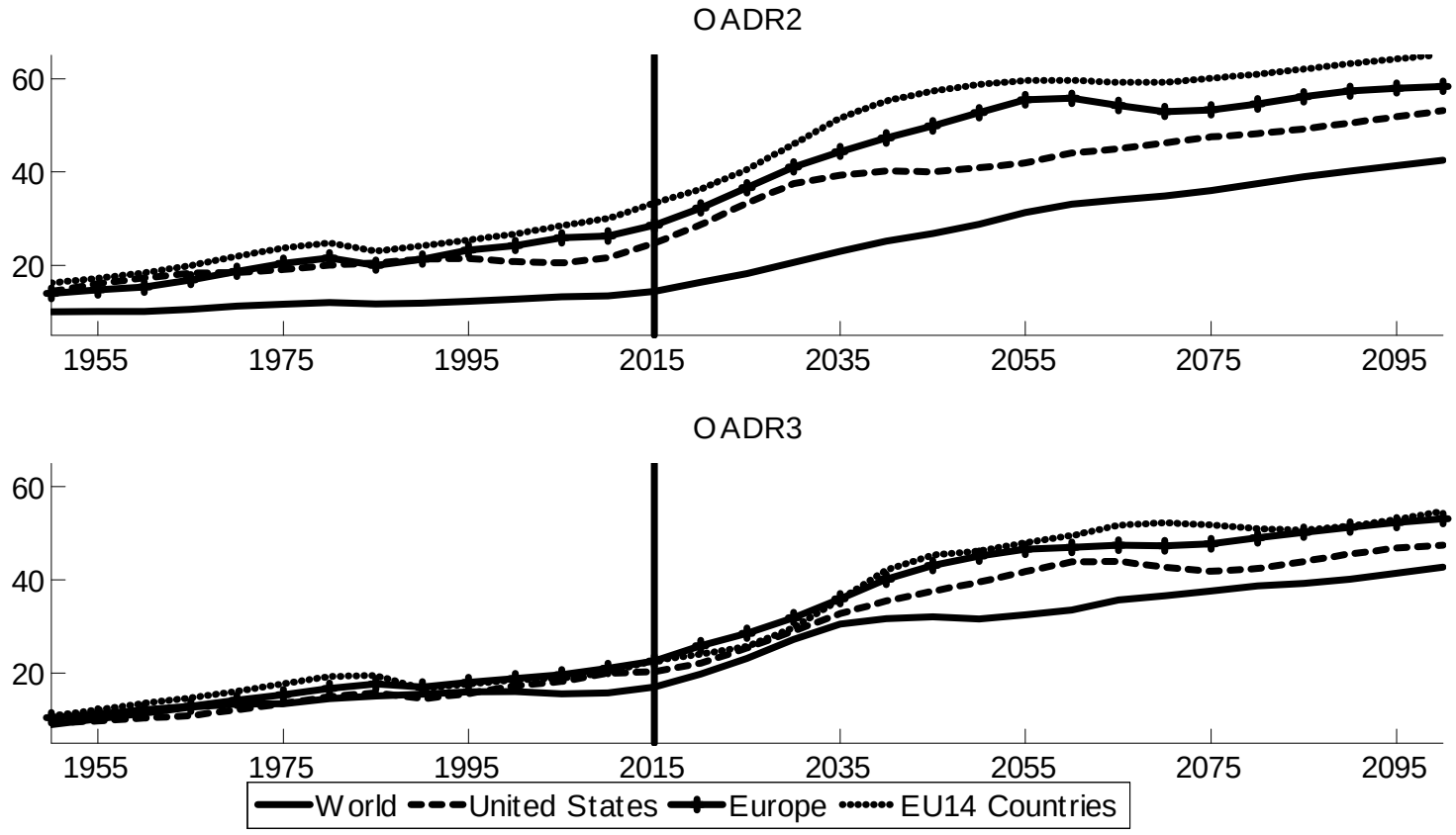

Figure: OADR2 and OADR3 in percentage, selected regions, 1950-2100.
Source: United Nations (2015).

Aging: EU14 countries, 1950-2100

	1950	2010	2050	2100		1950	2010	2050	2100
ESP	13	27	**76**	71	BEL	18	29	**52**	60
ITA	14	34	**74**	72	FRA	20	29	**51**	62
PRT	13	31	**72**	75	IRL	21	18	**50**	59
GRE	13	31	**72**	73	FIN	12	29	**50**	63
GER	16	34	**64**	71	GBR	18	27	**46**	59
AUS	17	29	**60**	67	DNK	16	28	**45**	58
NET	14	25	**53**	63	SWE	17	31	**45**	56

Source: United Nations (2015).

Table: OADR2 in percentage, EU14 countries, selected dates over 1950-2100.

Aging: Uncertainty

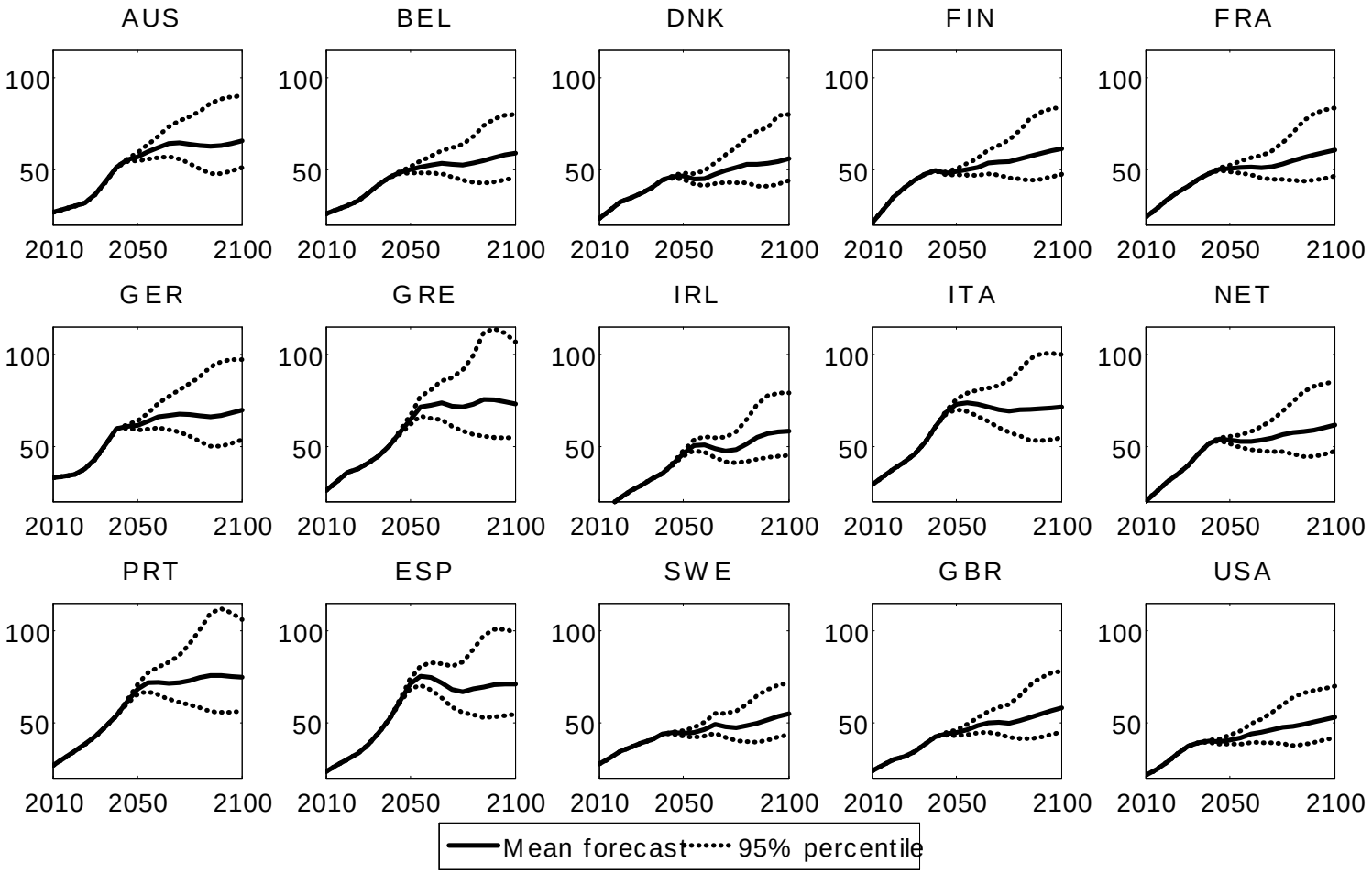

Figure: OADR2 in percentage, EU14 countries and USA, 2010-2100. Source: Alkema et al. (2011), Raftery et al. (2012), Raftery et al. (2013), Gerland et al. (2014) and United Nations (2015).

The model

Stylized life-cycle economy:

- 3 sectors: OLG households (individuals), production, government
- Endogenous labor supply, retirement
- Linear taxes on consumption and income from capital and labor, debt
- Government consumption, transfers and pensions

Demographics

- Time: $t = 0, 1, 2, ...$
- Individuals are born at age $j = 0$ and live for $J + 1$ periods, with $J \geq 1$
- The population grows at the rate $n > -1$
- Retirement age: $j_R \in (2, J)$
- Dependency ratio

$$d = d\left(\left(\mu_j\right)_{j=0}^{J}, n, j_R\right) = \frac{\mu^R}{\mu^W} \tag{1}$$

where $\mu^R = \sum_{j=j_R}^{J} \mu_j$ and $\mu^W = \sum_{j=0}^{j_R-1} \mu_j$ denote the relative shares in the population of retirees and workers

Households

- Preferences

$$U^t = \sum_{j=j_t^0}^{J} \beta^{j-j_t^0} u\left(c_{t,j}, 1 - l_{t,j}\right) \tag{2}$$

- Budget constraints for $j \in \left(j_t^0, J\right)$:

$$q_{t,j} c_{t,j} + a_{t,j+1} = x_{t,j} + tr_{t,j} + \left(1 + r_{t,j}\right) a_{t,j} \tag{3}$$

where

$$x_{t,j} = \begin{cases} w_{t,j} z_j l_{t,j} & \text{for } j \in \left(j_t^0, j_R - 1\right) \\ p_{t,j} & \text{for } j \in \left(j_R, J\right) \end{cases} \tag{4}$$

$$l_{t,j} = 0 \text{ for } j \in \left(j_R, J\right) \tag{5}$$

$$a_{t,J+1} = 0 \tag{6}$$

- $q_{t,j} = 1 + \tau_{t,j}^c$, $w_{t,j} = \left(1 - \tau_{t,j}^l\right) \widehat{w}_{t+j}$ and $r_{t,j} = \left(1 - \tau_{t,j}^k\right) \widehat{r}_{t+j}$

Private Sector (necessary and sufficient conditions)

- Households: individual allocation $\left(c_{t,j}, l_{t,j}, a_{t,j+1}\right)_{j=j_t^0}^{J}$:

$$
\begin{aligned}
u_{c_{t,j}} &= q_{t,j}\lambda_{t,j}, \text{ for } j \in \left(j_t^0, J\right) && (7)\\
u_{1-l_{t,j}} &= \lambda_{t,j} w_{t,j}, \text{ for } j \in \left(j_t^0, j_R - 1\right) && (8)\\
\lambda_{t,j} &= \beta\lambda_{t,j+1}\left(1 + r_{t,j+1}\right), \text{ for } j \in \left(j_t^0, J-1\right) && (9)
\end{aligned}
$$

- Firms: factor prices

$$
\begin{aligned}
\widehat{r}_t &= f_{k_t} - \delta && (10)\\
\widehat{w}_t &= f_{l_t} && (11)
\end{aligned}
$$

Government

- Budget constraints for $t \geq 0$:

$$g_t + tr_t + p_t + (1 + \widehat{r}_t)\, b_t = tax_t + (1 + n)\, b_{t+1} \tag{12}$$

where

$$\begin{aligned} tax_t \quad = \quad & \textstyle\sum_{j=0}^{J} (q_{t-j,j} - 1)\, \mu_j c_{t-j,j} + \\ & \textstyle\sum_{j=0}^{j_R-1} (\widehat{w}_t - w_{t-j,j})\, \mu_j z_j l_{t-j,j} + \\ & \textstyle\sum_{j=0}^{J} (\widehat{r}_t - r_{t-j,j})\, \mu_j a_{t-j,j} \end{aligned} \tag{13}$$

where: $tr_t = \sum_{j=0}^{J} \mu_j tr_{t-j,j}$ and $p_t = \sum_{j=j_R}^{J} \mu_j p_{t-j,j}$

Market-Clearing and Feasibility

- Market clearing

$$
\begin{aligned}
l_t &= \sum_{j=0}^{j_R-1} \mu_j z_j l_{t-j,j} && (14)\\
a_t &= \sum_{j=0}^{J} \mu_j a_{t-j,j} = k_t + b_t && (15)\\
c_t &= \sum_{j=0}^{J} \mu_j c_{t-j,j} && (16)
\end{aligned}
$$

- Feasibility

$$y_t + (1-\delta)\, k_t = c_t + g_t + (1+n)\, k_{t+1} \qquad (17)$$

Competitive Equilibrium

Definition

(**Competitive Equilibrium)** Given an initial aggregate endowment of assets $a_0 = k_0 + b_0$, a competitive equilibrium is a dependency ratio $d = d((\mu_j)_{j=0}^{J}, n, j_R)$, a sequence of government spending, $(g_t, tr_t, p_t)_{t=0}^{\infty}$, tax, $((q_{t,j}, w_{t,j}, r_{t,j})_{j=j_t^0}^{J})_{t=-J}^{\infty}$, and borrowing, $(b_{t+J+1})_{t=-J}^{\infty}$, policies, a sequence of prices $(\widehat{r}_t, \widehat{w}_t)_{t=0}^{\infty}$ and a sequence of individual allocations $((c_{t,j}, l_{t,j}, a_{t,j+1})_{j=j_t^0}^{J})_{t=-J}^{\infty}$ such that:

1. The sequence of individual allocations satisfies (3) - (9), for $t \geq -J$
2. The sequence of prices satisfies (10) and (11), for $t \geq 0$
3. The dependency ratio and the sequence of government spending, tax and borrowing policies satisfy (12) and (13), for $t \geq 0$
4. Feasibility (17) holds, for $t \geq 0$
5. All markets clear, i.e. (14) - (16) hold, for $t \geq 0$

Threshold Dependency Ratio

- CE is computed in two stages:
  - (1) individual allocation and prices (given fiscal policy and j_R)
  - (2) d and government policy (given private sector and GB constraints)
- One degree of freedom missing in second stage due GBC:
  - Many competitive equilibria
  - d as a residual from the GBC, given tax policy
  - Not uniquely identified d, - either $\left(\mu_j\right)_{j=0}^{J}$ or n fixed
  - The solution is highly nonlinear
- Threshold dependency ratio:
  - Positive correspondence between tax revenue and dependency ratio
  - $d = \overline{d}$ obtained when tax policy maximizes tax revenue
  - No. of retirees per worker the government could sustain through tax policy alone
  - Maximum if there is upper bound on tax revenue (dynamic Laffer effects)
  - $\overline{d}$ not uniquely identified - either $\left(\mu_j\right)_{j=0}^{J}$ or n fixed

Analytic Example

- Two periods, No aggregate saving, No government consumption, log-utility, linear production

$$d = (1+n)^{-1} = \frac{\tau_t^l w_t l_t + \tau_t^c c_{t,0} - tr_t}{p_t - \tau_t^c c_{t,1}}$$

- d: (i) residual from the GBC; (ii) increases with tax revenue; (iii) bounded if tax revenue is bounded
- Labor tax Laffer curve

$$\overline{\tau}_t^l = 1 - \left[\frac{\chi tr_t \left(1+\tau_t^c\right)}{\omega}\right]^{\frac{1}{2}}$$

- Threshold dependency ratio

$$\overline{d} = \frac{\left(1+\tau_t^c\right)\omega - 2\omega\left[\frac{\chi tr_t(1+\tau_t^c)}{\omega}\right]^{\frac{1}{2}} - tr_t}{(1+\chi)\, p_t}$$

Distance and Probability

- Let:

$$d_{t+1} = E_t d_{t+1} + \xi_{t+1}$$

$\xi_{t+1} = \sigma \epsilon_{t+1}$ and $\epsilon_{t+1} \sim i.i.d.\,(0, 1)$

- *Distance from the threshold,* $D\left(\overline{d}, t+h\right)$, the number of standard deviations that the economy is away from the dependency ratio threshold:

$$D\left(\overline{d}, t+h\right) = \frac{E_t d_{t+h} - \overline{d}}{\sigma}$$

- The *Probability* that the h-period ahead dependency ratio exceeds the dependency ratio threshold is

$$\begin{aligned} \Pr\left(\overline{d}, t+h\right) &= \Pr\left[\left(d_{t+h} - \overline{d}\right) \geq 0\right] \\ &= \Pr\left[\frac{E_t d_{t+h} - \overline{d}}{\sigma} \leq u_{t+h}\right] \end{aligned}$$

Quantitative Analysis: Assumptions

Demographics and Timing

- t corresponds to five years
- Newborns have a real-life age of 20-24, retire at age 64 and live up to a maximum age of 94

Households

- Preferences:

$$U^t = \sum_{j=j_t^0}^{J} \beta^{j-j_t^0} \left(\prod_{s=1}^{j} \phi_{t,s} \right) u(\tilde{c}_{t,j}, l_{t,j})$$

where

$$u(\tilde{c}_{t,j}, l_{t,j}) = \frac{1}{1-\eta} \left(\tilde{c}_{t,j}^{1-\eta} \left[1 - \kappa(1-\eta) l_{t,j}^{1+1/\varphi} \right]^{\eta} - 1 \right)$$

$\tilde{c} = c_t / A_t$ is stationary consumption; A_t is the technology level

- Taxes rates and transfers are age-independent
- $(1 - \tau_t^p - \tau_t^w)\, \widehat{w}_t l_t$, for $t \geq 0$
- Individuals assets shares equal to aggregate, $k_t/(k_t + b_t)$

Quantitative Analysis: Assumptions

Production

- Cobb-Douglas function with labour-augmenting technological progress, A_t

Government

- Separate budget for pensions

$$\tau^P w_t l_t = p_t = \sum_{j=j_R}^{J} \mu_j p_{t-j,j}$$

- The government collects all bequests

Stationary Equilibrium

- All individual variables, other than labor, are made stationary by expressing them as a proportion of technological progress

Quantitative Analysis: Calibration

- Country specific
  - Trabandt and Uhlig (2011): $\kappa, \alpha, \delta, g/y, b/y, \tau^l, \tau^k, \tau^c$
  - United Nations, (2015): $n, \phi_{t,s}$
  - OECD (2015): θ
  - Hansen (1993): z_j for USA, 1 otherwise
  - Endogenous: $d, \beta, tr/y, \tau^p$
- Others: $\widehat{r} = 4\%$, $\eta = 2$, $\varphi = 1$and $g_A = 2\%$.
- $\tau^l = \tau^w + \tau^p$

Fiscal Space: USA

	2010		2050	
	Benchmark	Laffer	Benchmark	Laffer
		Total Tax Burden		
Workers	86.6	91.5	81.1	88.6
Retirees	13.4	8.5	18.9	11.4
		Tax Burden on Workers		
Labor Tax	64.0	79.5	60.4	79.8
Capital Tax	24.0	16.4	25.6	16.5
Consumption Tax	12.0	4.1	14.0	3.7
		Tax Burden on Retirees		
Labor Tax	0.0	0.0	0.0	0.0
Capital Tax	73.0	78.2	70.4	79.1
Consumption Tax	27.0	21.8	29.6	20.9

Notes: All numbers in percentage.

Table: Tax burden distribution across workers and retirees, USA, 2010 and 2050.

Fiscal Space: USA

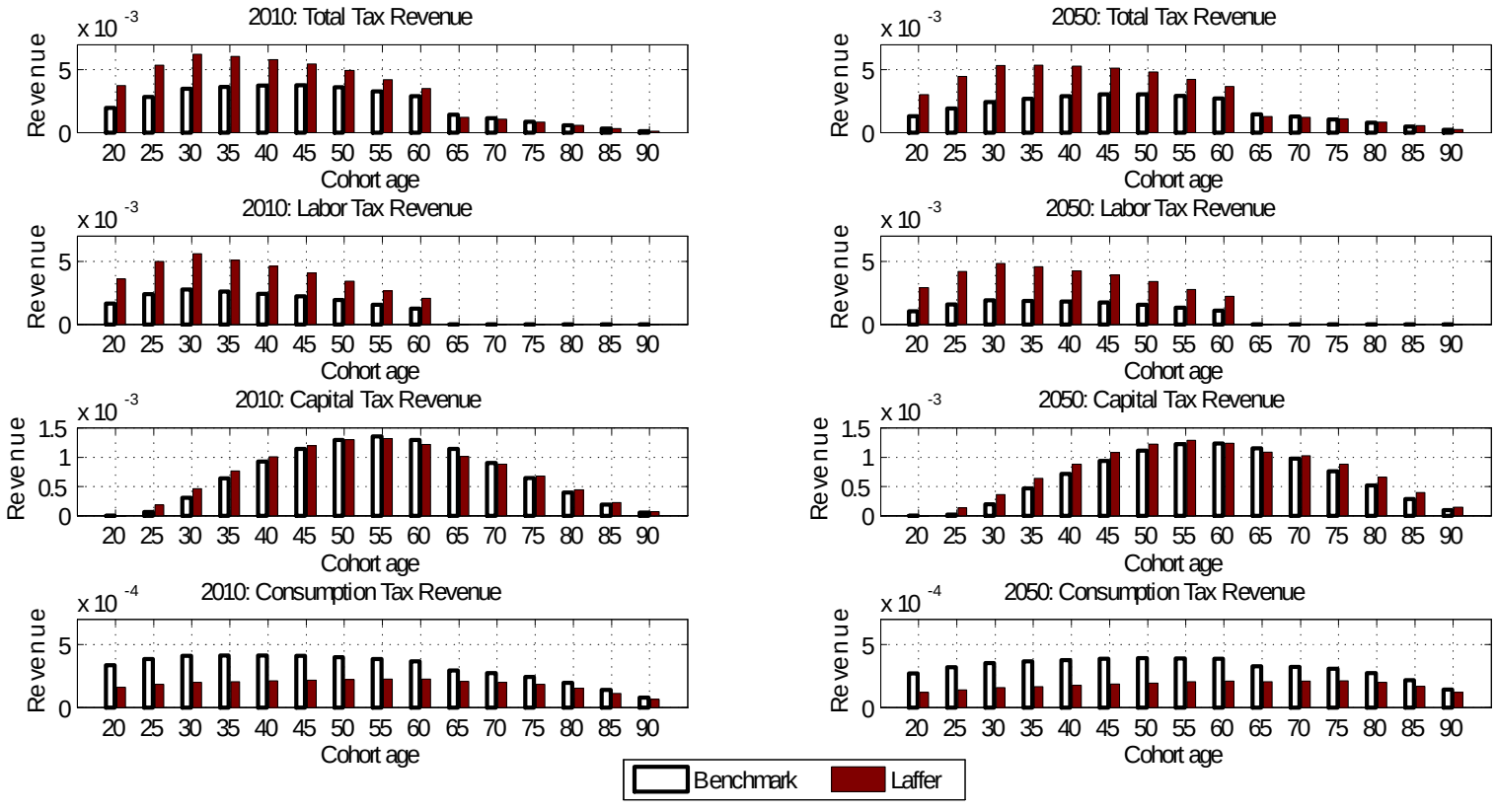

Figure: Tax burden distribution across cohorts under (i) benchmark calibration and at (ii) peak of the Laffer hill, USA, 2010 and 2050.

Fiscal Space: USA

	τ^l	τ^k	τ^p	τ^c	FS
		Benchmark			
	28	36	11	5	-
		Laffer			
Constant θ	63.6	47.3	11	5	46.9
Constant p	60.0	34.5	15.7	5	31.8

Notes: All numbers in percentage.

Table: Tax rates on income from labor, income from capital and Fiscal Space (FS) at the peak of the Laffer hill, USA, 2010.

Fiscal Space: USA

	τ^l	τ^k	τ^p	FS
		Constant θ		
Low	66.7	50.9	17.5	57.9
Medium	65.5	50.3	15.4	64.8
High	64.8	49.1	13.5	70.8
		Constant p		
Low	61.2	33.9	22.4	39.7
Medium	61.2	33.3	20.2	46.9
High	60.6	33.3	18.2	53.2

Notes: All numbers in percentage.

Table: Tax rates on income from labor, income from capital and Fiscal Space (FS) at the peak of the Laffer hill, USA, 2050.

Fiscal Space: USA

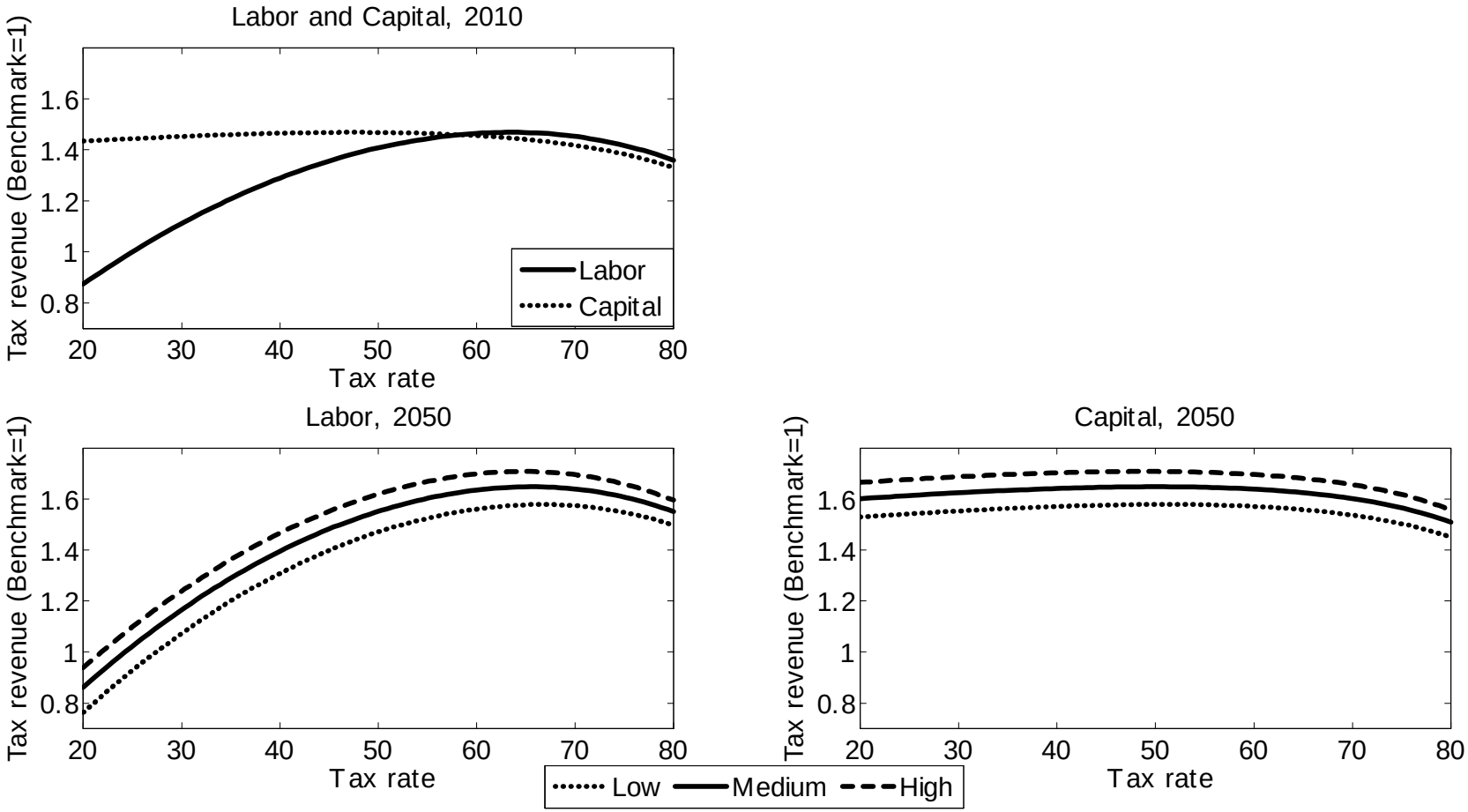

Figure: Laffer curves on income from labor and capital for low-, medium- and high-fertility demographic projections, USA, 2010 and 2050.

Threshold: Policy scenarios

- **S1**: No policy change
- **S2**: Increase tax rate on consumption τ^c by 5 percentage points
- **S3**: Reduce replacement ratio of pensions θ by 10 percentage points
- **S4** Increase retirement age j_R from 65 to 70

Threshold: USA

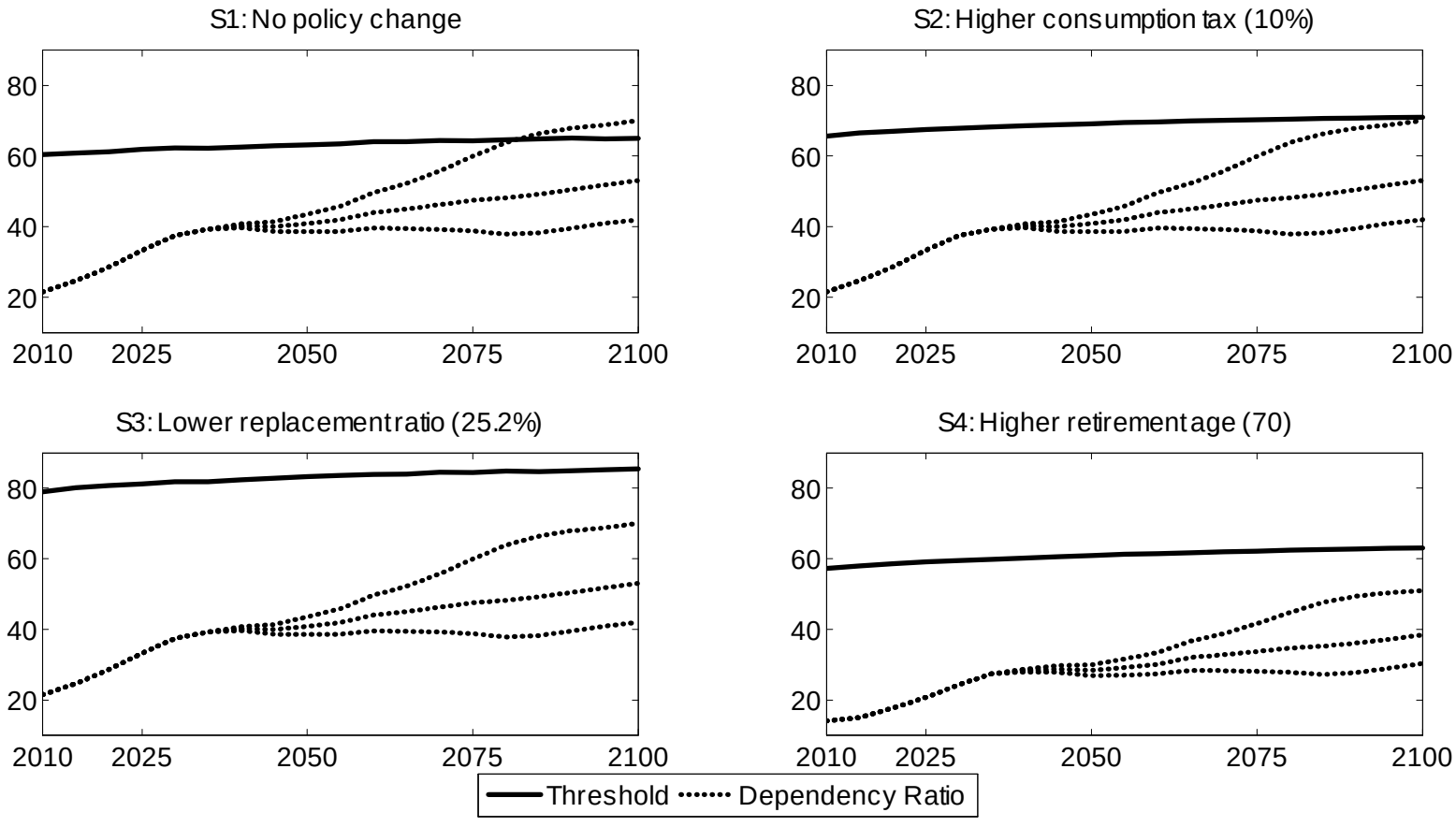

Figure: Threshold dependency ratio, USA, 2010-2100.

Threshold: USA

	Actual/Projected Dependency Ratio (d)		Threshold Dependency Ratio ($\overline{d}$)			
			Policy Scenarios:			
			S1	S2	S3	S4
	65+ / (20-64)	70+ / (20-69)	$\tau^c = 5$ $\theta = 35.2$ $j_R = 65$	$\tau^c = 10$	$\theta = 25.2$	$j_R = 70$
2010	21.6	14.1	60.4	65.7	79.0	57.3
2015	24.7	15.1	60.9	66.6	80.2	58.0
2050	40.9	28.4	63.3	69.2	83.3	60.9
2100	53.1	38.5	65.0	71.0	85.5	63.0

Notes: All numbers are in percentage.

Table: Actual and threshold dependency ratios, USA, selected dates over 2010-2100.

Threshold: USA

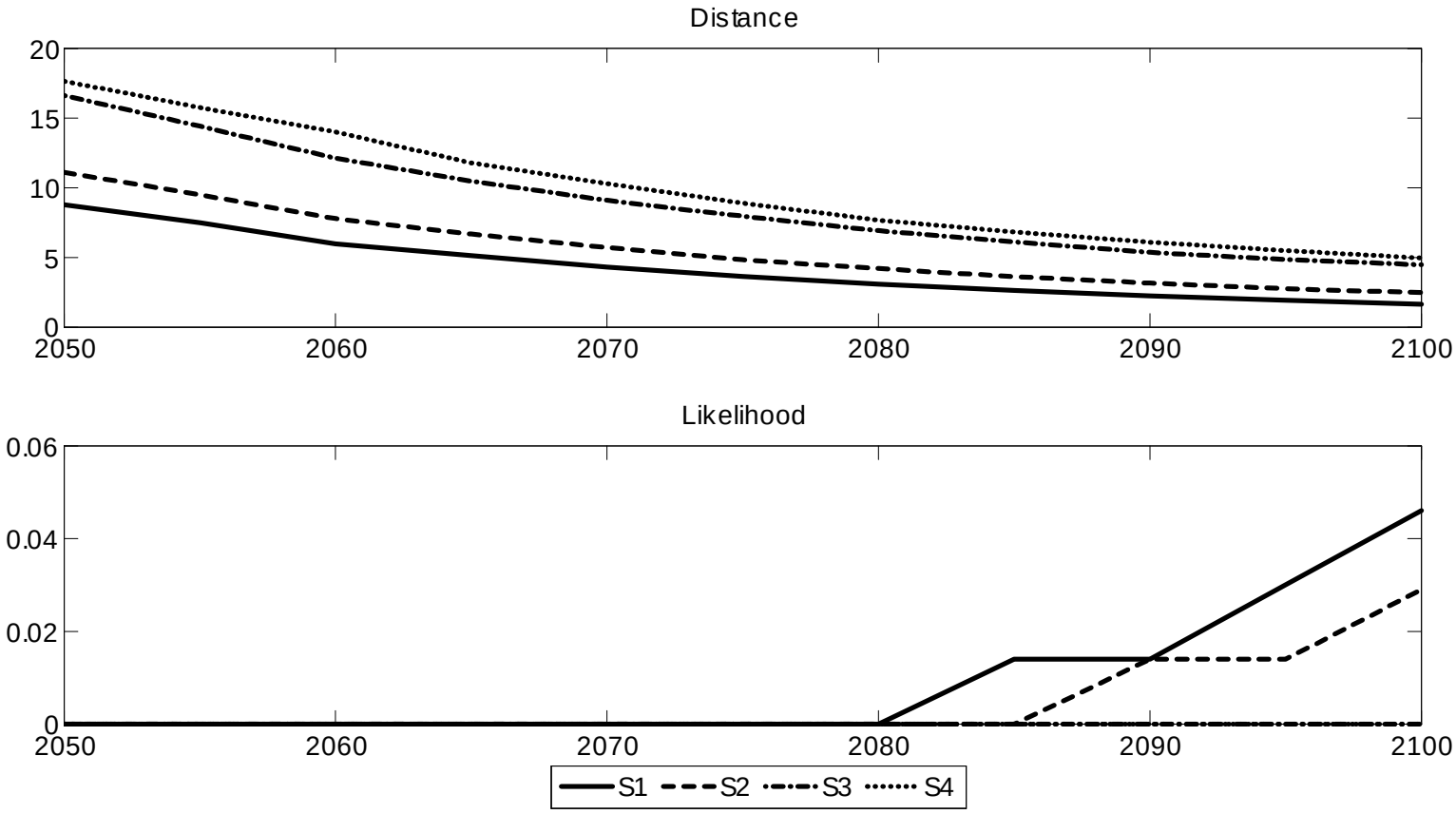

Figure: Distance from the threshold and probability of reaching the threshold, USA, 2050-2100.

Welfare: USA

- **Policy standardization**: Policy change required to achieve same distance at a given period.
- **Target**: 17.66 standard deviations by 2050.
  - **S2(4)**: τ^c =25.4%
  - **S3(4)**: θ =24.1%
  - S4: $j_R = 70$

Welfare: USA

	S2(4)	S3(4)	S4
c	0.095	0.096	0.097
l	0.230	0.233	0.238
τ^l	0.168	0.287	0.298
U	-102.78	-103.55	-107.07
$\Delta(\%)$	$+4.17$	$+3.40$	

Notes: U is steady-state life-time utility; Δ is the onsumption compensations w.r.t. S4.

Table: Steady-state welfare of newborn generations under S2(4), S3(4) and S4, USA, 2050

Welfare: United States

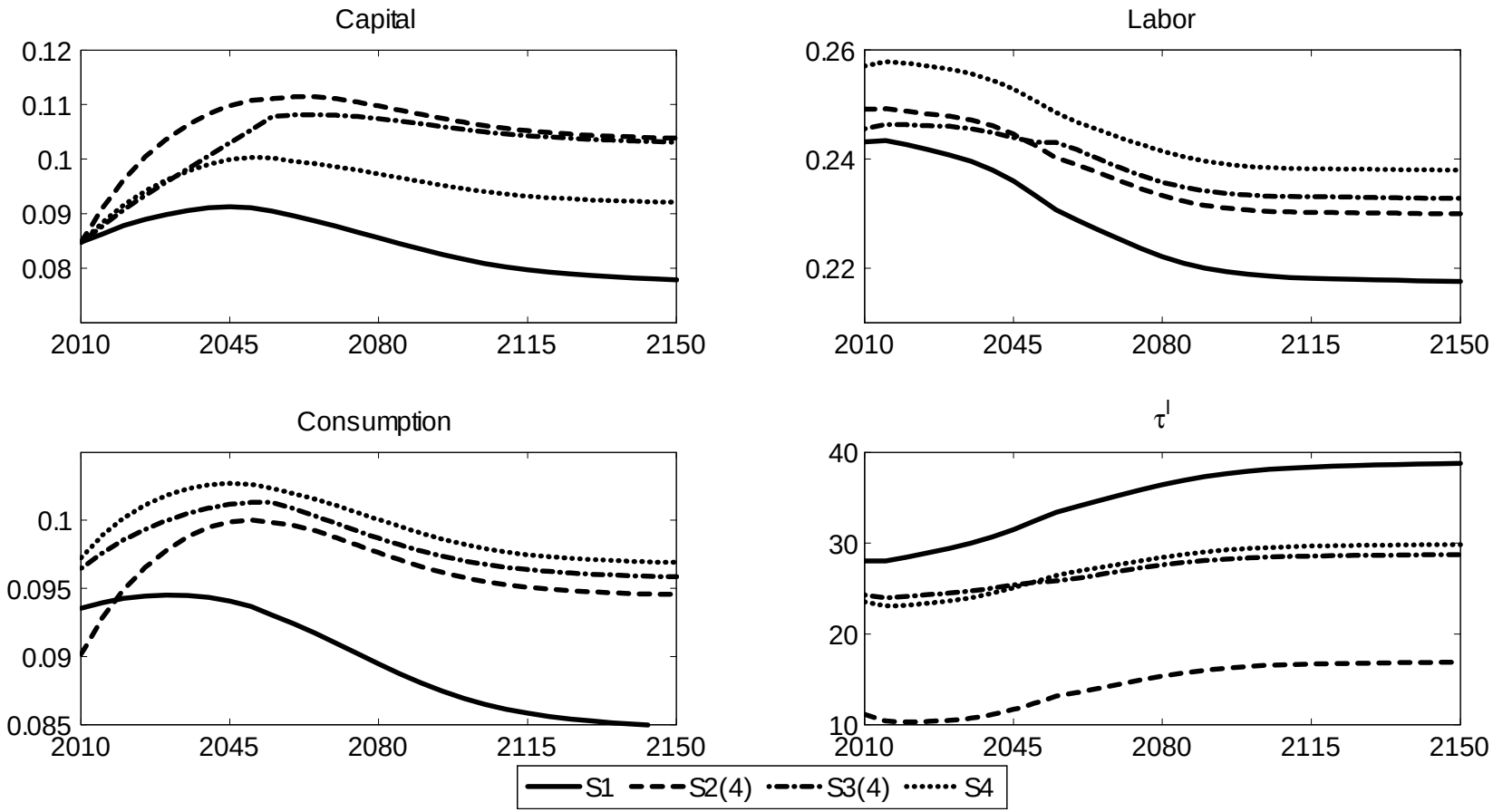

Figure: Transition dynamics, USA, 2010-2150.

Welfare: United States

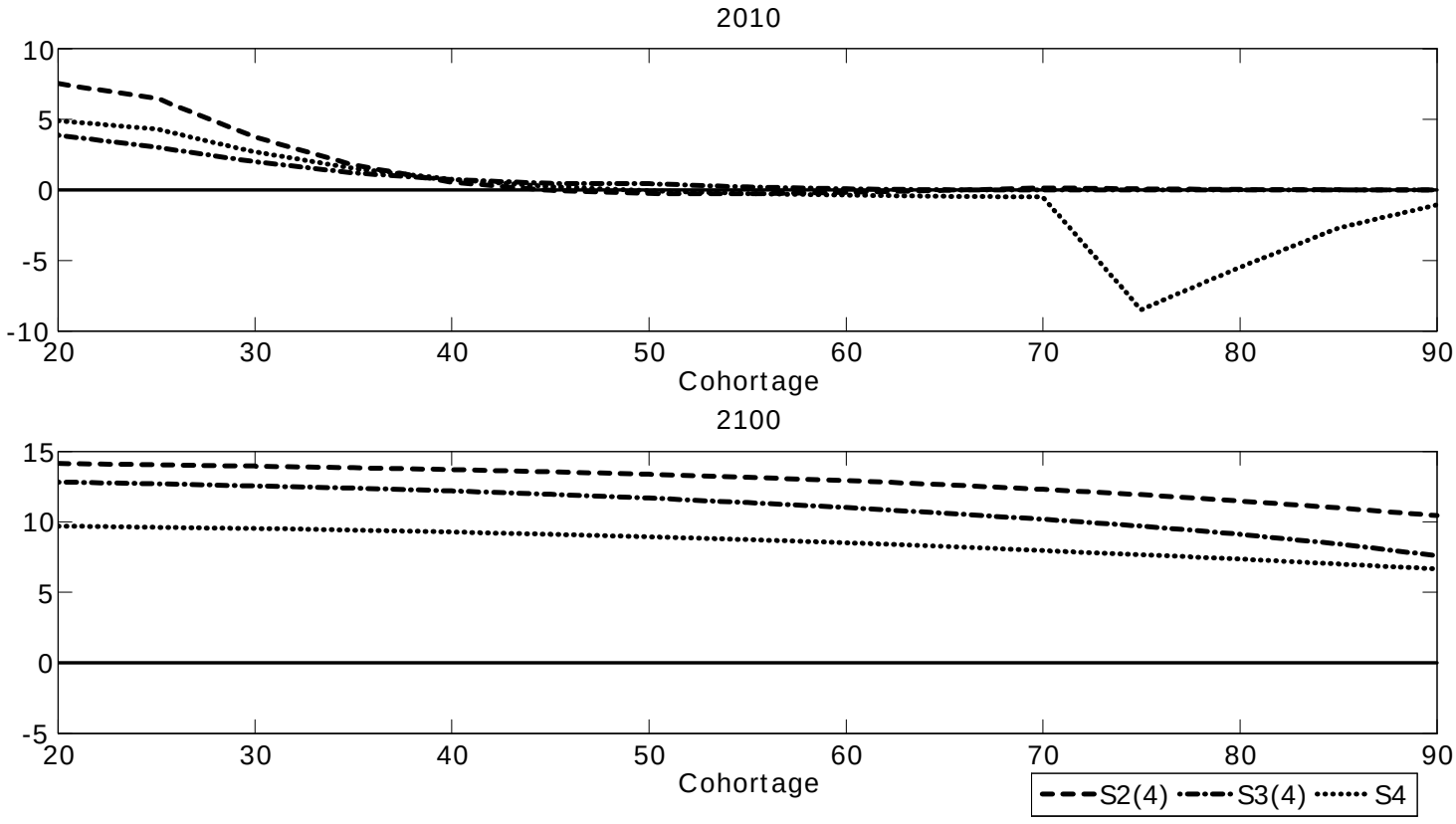

Figure: Welfare effects of policy reforms across cohorts, USA, 2010 and 2100.

Laffer peacks: EU14 countries

	Constant θ			Constant p			
	τ^l	τ^k	FS	τ^l	τ^k	τ^p	FS
AUS	62	52	12.4	52	29	30	0.2
BEL	59	47	3.1	53	**34**	16	0.3
DNK	57	**46**	1.5	49	**27**	20	2.3
FIN	60	45	4.6	53	**26**	21	0.3
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮
ITA	64	51	14.3	53	**30**	36	0.9
NET	69	53	31.5	59	**26**	38	6
PRT	67	50	68.9	61	25	40	28.9
ESP	64	53	44	55	**29**	35	1
SWE	60	50	1	**50**	**37**	18	1.2
GBR	57	**43**	15.7	54	**36**	9	11.2
EU14	61	49	20	53	30	25	6

Notes: All numbers in percentage.

Table: Tax rates on income from labor, income from capital, and Fiscal Space (FS) at the peak of the Laffer hill, EU14 countries, 2010.

Fiscal Space: EU14 countries

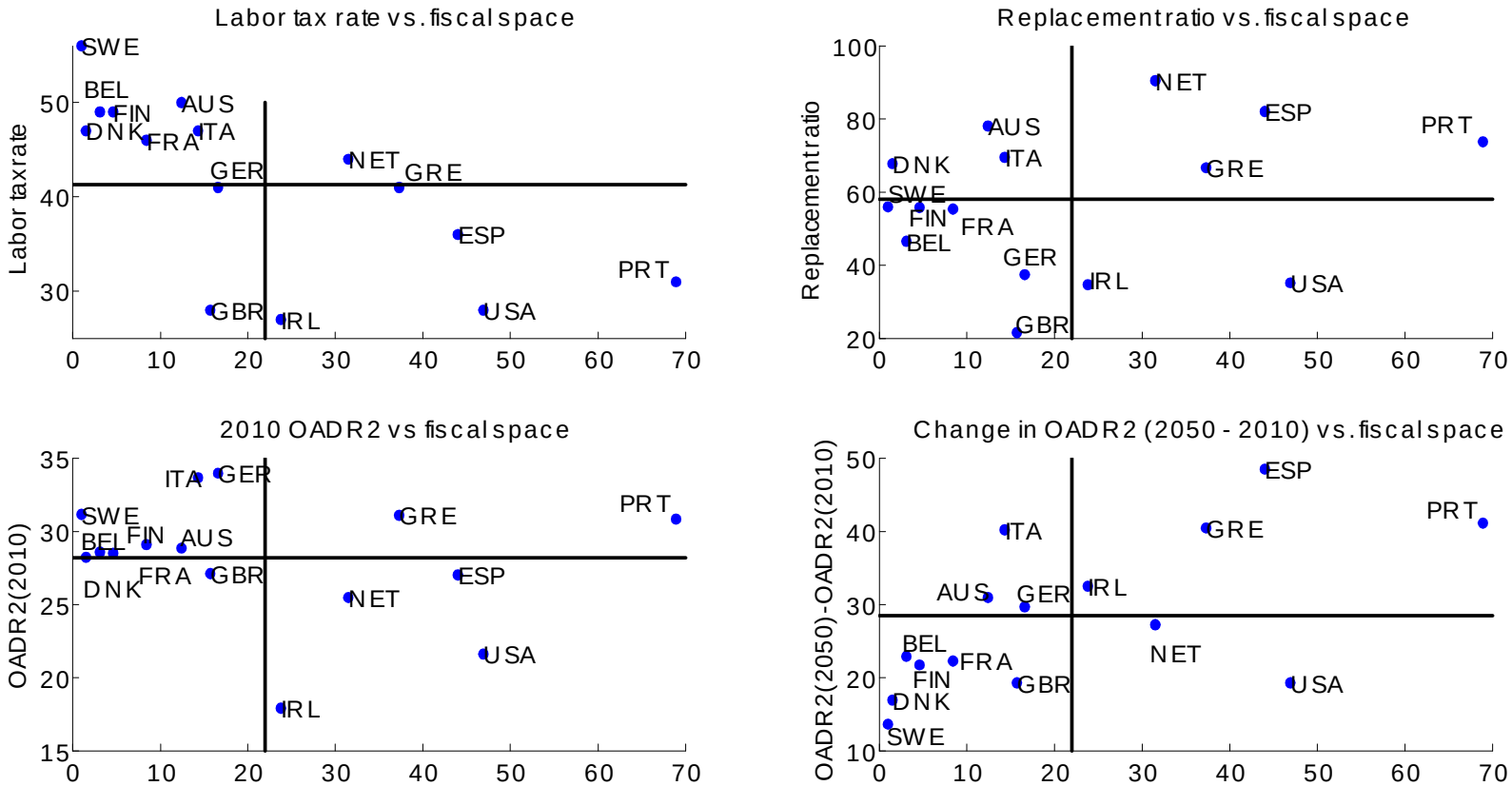

Figure: Fiscal space (horizontal axis) in 2010 (constant replacement ratio) relative to (i) labor income tax rate, (ii) pension replacement ratio, (iii) 2010 OADR2 and (iv) change in the OADR2 over 2010-2050, EU14 countries.

Threshold: EU14 countries

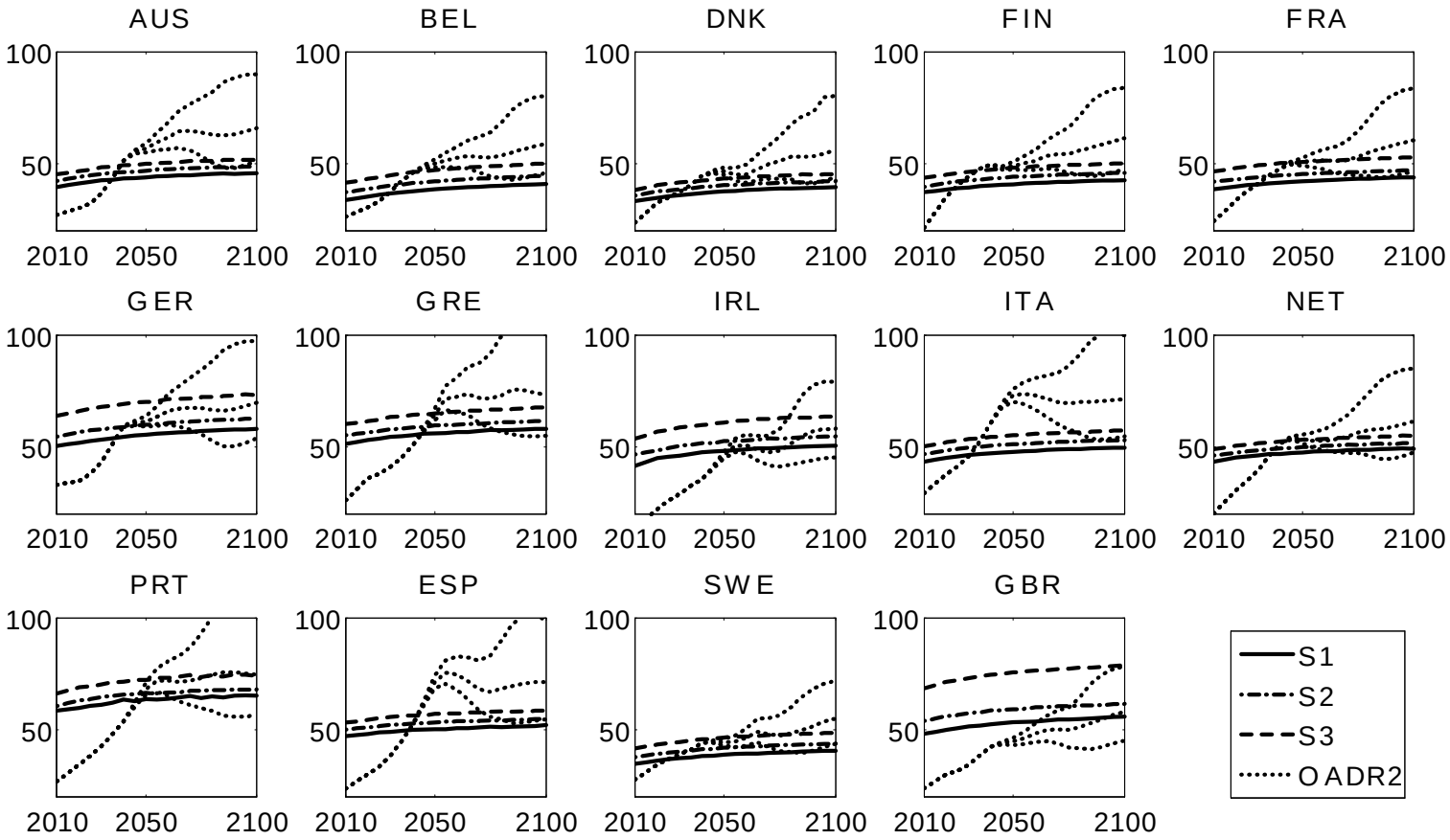

Figure: Thereshold dependency ratios under S1, S2 and S3, EU14 countries, 2010-2100.

Threshold: EU14 countries

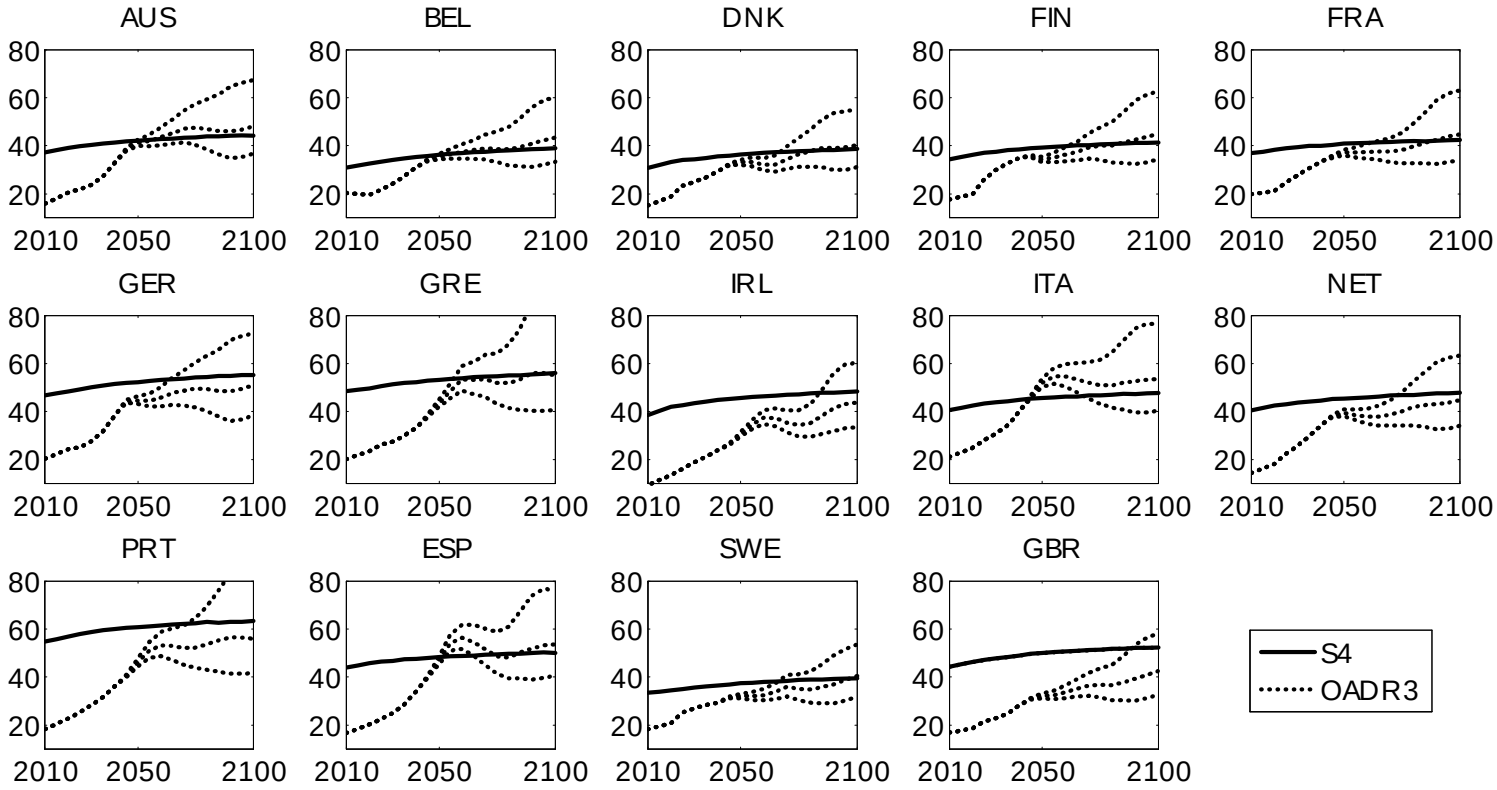

Figure: Thereshold dependency ratios under S4, EU14 countries, 2010-2100.

Threshold: EU14 countries

	S1	S2	S3	S4
AUS	2034	2036	2038	2056
BEL	2029	2033	2040	2056
DNK	2026	2032	2037	2080
FIN	2023	2027	2033	2082
FRA	2029	2034	2070	2087
GER	2036	2039	-	-
GRE	2043	2046	2050	-
IRL	2077	2083	-	-
ITA	2030	2033	2035	2044
NET	2035	2037	2067	-
PRT	2046	2048	2078	-
ESP	2038	2040	2042	2083
SWE	2024	2033	2077	2096
GBR	2091	-	-	-

Table: Years when the projected dependency ratios are estimated to reach the thresholds under S1, S2, S3 and S4, EU14 countries.

Distance and Probability: EU14 countries

	S1		S2		S3		S4	
	D	*P*	*D*	*P*	*D*	*P*	*D*	*P*
EU14	-3.25	91.0	-1.97	82.7	0.09	56.9	2.09	19.0
USA	8.78	0	11.12	0	16.61	0	17.7	0

Notes: All numbers are in percentage. Source: Authors' calculations.

Table: Distance from the threshold and Probability of reaching the threshold, EU14 countries, 2050.

Welfare: EU14 countries

	S4		S2(4)	S3(4)		S4		S2(4)	S3(4)
	D	P	τ^c	θ					
AUS	0.13	1.7	46	56	ITA	-2.86	99.9	41	49
BEL	0.01	47.5	34	33	NET	3.1	0	48	71
DNK	1.56	5.4	55	51	PRT	3.03	0	55	57
FIN	2.08	2.3	50	39	ESP	-1.99	98.1	44	60
FRA	1.72	5.5	39	41	SWE	3.02	0.2	40	42
GER	2.66	0.9	36	25	GBR	8.82	0	28	15
GRE	1.76	4.8	46	47	EU12	2.09	19.0	43	44
IRL	6.17	0	45	23	USA	17.7	0	25	25

Table: Required policy changes to achieve same distance from the threshold under S4, S2(4) and S3(4), EU14 countries, 2050.

Welfare: EU14 countries

	Δ_1	Δ_2		Δ_1	Δ_2
AUS	1.49	1.78	ITA		
BEL	-0.23	2.42	NET	-4.45	-8.01
DNK	-8.79	-4.15	PRT	1.52	-3.36
FIN	-1.36	2.66	ESP		
FRA	-0.36	-1.18	SWE	24.2	-1.45
GER	3.27	4.49	GBR	0.40	1.77
GRE	13.43	7.97	EU12	2.53	0.35
IRL	1.23	1.20	USA	4.17	3.40

Notes: Δ_1 = consumption compensation S2(4) w.r.t. S4;
Δ_2 = consumption compensation S3(4) w.r.t. S4.

Table: Consumption compensations for steady-state lifetime utility under S2(4) and S3(4) required to achieve same lifetime utility as under S4, EU14 countries, 2050.

Conclusion

- Threshold dependency ratio (Level, distance, probability)
- Multi-country Quantitative analysis
- Dynamic Laffer effects in life-cycle models
  - cross-section distribution of the tax burden
  - measurement of the fiscal space depends on how tax revenue is shared among retirees
  - aging impact on the position and the shape of the Laffer curves
  - demographic uncertainty and dynamic Laffer effects
- USA and EU14:
  - GRE, ITA, ESP: old, aging fast, generous pensions
  - GER, FRA: old, aging fast, small FS
  - BEL: and Scandinavian: small FS
  - PRT: old and aging fast, but large FS
  - AUS: generous pensions, small FS and aging fast
  - NET: generous pensions, young and large FS
  - USA, GBR: young, pay low pensions, large FS, not aging fast
- Welfare: No single policy works for all.