Aging Society and Job Polarization

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Preliminary and Incomplete

Question

- How important is population aging in causing job polarization?

- Two channels.
  1. Changing consumption basket over the life cycle.
  2. Lower interest rate makes middle-skill-substituting capital cheaper.

First Channel: Life-Cycle of Consumption Basket

- Households with different stages of life spend on different goods and services.
- Older households spend more on services (healthcare and finance).
- Population aging shifts demand to services.
  - Cravino et al. (2022) – aging and rising importance of service sector.
  - Siliverstovos et al. (2011) – aging and employment shift across sectors.
- Service sectors (healthcare, finance) require more high-skill and low-skill occupations while non-services (manufacturing) require more middle-skill ones.
- Shift of demand to service sectors could induce job polarization.

Second Channel: Middle-Skill-Substituting Capital

- Acemoglu and Autor (2011): *"recent technological developments have enabled information and communication technologies to either directly perform or permit the offshoring of a subset of the core job tasks previously performed by middle skill workers"*
- Assume that one type of capital can substitute middle-skill occupations.
  - Capital-skill complementarity: Krusell et al. (2000).
- When aging increases savings and lowers real interest rate, such middle-skill-substituting capital becomes cheaper, inducing polarization.
  - Aging and lower interest rate: Gagnon et al. (2021), Papetti (2021).

Equilibrium Model with Heterogeneous Consumption Baskets

- Related literature:
  - Hubmer (2023) – income growth and labor share.
  - Comin et al. (2020) – income growth and polarization.
  - Buera et al. (2022) – income growth and skill premium.
  - Aguiar and Bils (2015) – Adjustments to CE and consumption inequality.

- Novel features of our model:
  - Dynamic model with endogenous interest rate.
  - Life cycle.
  - Middle-skill-replacing capital.

Plan

1. Data
2. Data-Based Decomposition
3. Model
4. Calibration
5. Model-Based Experiments

Data: Stage-1 – Building Consumption Basket

- **Input of Stage-1**: Consumption Expenditure Surveys (CE) – 1980, 2000, 2019.
- Convert expenditure categories of the Interview Survey to PCE categories.
- Adjust the CE-based consumption expenditures to match the PCE by BEA.
- **Output of Stage-1**: Consumption basket for different household groups.
  - For now, (age,education).
  - Consistent with aggregate PCE by BEA.

Data: Stage-2 – Convert into Value-Added

- **Input of Stage-2**: Input-Output tables (IO) – 1997, 2000, 2019.
- Convert consumption categories of the PCE to commodity categories.
- Convert final consumption expenditures of the CE into total output
  - Total output includes intermediate inputs.
- Convert total output into value added for each industry/sector.
- Value added consists of compensation, taxes, and gross operating surplus.
- **Output of Stage-2**: How much compensation to each industry/sector is generated by consumption expenditures of different household groups in the CE.

Data: Stage-3 – Compute Skill Shares

- **Input of Stage-3**: CPS-ASEC — 1980, 2000, 2019.
- Follow Acemoglu and Autor (2011) and assign industry/sector and occupational skill level (high, medium, low) to each worker in CPS-ASEC.
- Assign workers to industry/sector and compute employment and wage bill share of three skill levels for each industry/sector.
- **Output of Stage-3**: How much employment and wage bills of three skill levels is generated by consumption expenditure of different household groups in the CE.

Stage-1: Consumption Basket: CE vs PCE in 1980

PCE Categories	CE Share (%)	PCE Share (%)
PCE	100.0	100.0
Goods	65.3	45.7
Durable goods	**14.4**	**12.9**
Motor vehicles and parts	8.1	4.8
Furniture and household equipment	3.3	3.9
Recreational goods and vehicles	2.0	2.7
Other durable goods	1.0	1.6
Nondurable goods	**51.0**	**32.8**
Food and beverages	34.2	13.7
Clothing and footwear	4.4	5.9
Gasoline and other energy goods	9.3	5.8
Other nondurable goods	3.0	7.4
Services	**34.6**	**54.3**
Housing and utilities	**10.1**	**17.8**
Healthcare	**2.5**	**9.8**
Transportation	2.3	3.2
Recreational services	1.7	2.3
Food services and accommodation	6.5	7.0
Financial services and insurance	5.8	5.2
Other services	5.6	7.3
Education services	1.5	1.4

Stage-1: Consumption Basket: CE vs PCE in 1980

PCE Categories	CE Amount (bil$)	BEA Amount (bil$)	CE/BEA
PCE	1,053.8	1,750.7	**60.2**
Goods	688.8	799.8	**86.1**
Durable goods	151.7	226.4	67.0
Motor vehicles and parts	84.9	84.4	100.5
Furniture and household equipment	35.1	67.8	51.7
Recreational goods and vehicles	21.0	46.5	45.1
Other durable goods	10.8	27.6	39.2
Nondurable goods	537.0	573.4	93.7
Food and beverages	360.7	239.2	150.8
Clothing and footwear	46.4	103.0	45.0
Gasoline and other energy goods	98.4	101.9	96.6
Other nondurable goods	31.5	129.3	24.4
Services	365.0	950.9	**38.4**
Housing and utilities	106.1	312.5	**34.0**
Healthcare	26.7	171.7	**15.8**
Transportation	24.7	55.4	44.6
Recreational services	18.2	40.8	44.7
Food services and accommodation	68.6	121.7	56.3
Financial services and insurance	61.5	91.7	67.1
Other services	59.2	127.1	46.6
Education services	15.6	23.7	65.8

Stage-1: Consumption Basket: CE vs PCE in 2019

PCE Categories	CE Amount (bil$)	BEA Amount (bil$)	CE/BEA
PCE	7,581.6	14,437.5	**52.5**
Goods	2,818.3	4,532.8	**62.2**
Durable goods	1,030.3	1,523.6	67.6
Motor vehicles and parts	748.4	545.0	137.3
Furniture and household equipment	133.3	346.7	38.4
Recreational goods and vehicles	97.2	429.2	22.6
Other durable goods	51.4	202.8	25.4
Nondurable goods	1,788.1	3,009.2	59.4
Food and beverages	1,342.1	1,083.2	123.9
Clothing and footwear	99.5	414.1	24.0
Gasoline and other energy goods	235.6	352.5	66.8
Other nondurable goods	110.8	1,159.3	9.6
Services	4,763.3	9,904.7	**48.1**
Housing and utilities	2,437.3	2,562.0	**95.1**
Healthcare	103.4	2,472.3	**4.2**
Transportation	188.4	486.3	38.7
Recreational services	180.6	597.2	30.2
Food services and accommodation	416.9	1,006.4	41.4
Financial services and insurance	719.7	1,135.0	63.4
Other services	716.9	1,227.8	58.4
Education services	164.7	293.2	56.2

Stage-1: Adjusting CE Consumption Expenditures

- Issues in CE consumption expenditure.
  - Under-reporting of CE in services in general.
  - Under-reporting of CE got worse from 1980 to 2019.
  - Especially severe under-reporting in healthcare services.
  - Large part of education is spent as taxes (public school).
- What others have done so far.
  - Augment expenditures in health and education with external data sources.
- Our approach.
  - Assume that the PCE is the truth, and the CE is misreported.
  - Assume that each CE household misreports by the same factor.
  - Also assumed is that the health insurance coverage is the same for all households.
  - Divide all the reported expenditures by the category-specific under-reporting ratio.
  - We plan to investigate heterogeneity in health insurance coverage (using MEPS).
  - We do not deal with under-reporting of education for now.

Stage-1: Consumption Basket of CE/PCE: 1980 vs 2019

PCE Categories	1980 Share (%)	2019 Share (%)
PCE	100.0	100.0
Goods	45.7	31.4
Durable goods	**12.9**	**10.5**
Motor vehicles and parts	4.8	3.8
Furniture and household equipment	3.9	2.4
Recreational goods and vehicles	2.7	3.0
Other durable goods	1.6	1.4
Nondurable goods	**32.8**	**20.8**
Food and beverages	13.7	7.5
Clothing and footwear	5.9	2.9
Gasoline and other energy goods	5.8	2.4
Other nondurable goods	7.4	8.0
Services	**54.3**	**68.6**
Housing and utilities	17.8	17.7
Healthcare	**9.8**	**17.1**
Transportation	3.2	3.4
Recreational services	2.3	4.1
Food services and accommodation	7.0	7.0
Financial services and insurance	5.2	7.9
Other services	7.3	8.5
Education services	1.4	2.0

Stage-1: CE/PCE Consumption Basket by Age in 1980

PCE Categories	Age 00-65 (%)	Age 66-99 (%)
PCE	100.0	100.0
Goods	46.0	43.9
Durable goods	**13.6**	**8.6**
Motor vehicles and parts	5.1	2.9
Furniture and household equipment	3.9	3.5
Recreational goods and vehicles	2.9	1.0
Other durable goods	1.6	1.5
Nondurable goods	32.5	34.2
Food and beverages	13.4	15.2
Clothing and footwear	6.2	4.0
Gasoline and other energy goods	5.9	5.5
Other nondurable goods	7.2	8.4
Services	53.7	58.3
Housing and utilities	17.5	20.4
Healthcare	**8.1**	**21.3**
Transportation	3.2	2.8
Recreational services	2.4	1.6
Food services and accommodation	7.1	5.8
Financial services and insurance	5.3	5.1
Other services	7.2	7.4
Education services	1.5	0.2

Stage-1: Taking Stock

- 14.3pp shift of PCE from goods (45.7% $\rightarrow$ 31.4%) to services (54.3% $\rightarrow$ 68.6%) over the past four decades.
- Large increase in the healthcare share in PCE (10% $\rightarrow$ 17%).
- Older households allocate their expenditures more on healthcare services (21.3% vs 8.1%) instead of durable goods (8.6% vs 13.6%).

$\rightarrow$ Population aging mechanically shifts expenditure composition from (durable) goods to services (Cravino et al. (2022)).

Stage-2: Consumption Basket (Value Added) by Age in 1980

Line	Sector	00-30	31-40	41-50	51-65	66-99
1	Agriculture	2.4	2.6	2.5	2.5	1.8
2	Mining	2.5	2.6	2.6	2.8	1.9
3	Utilities	2.8	3.3	3.2	3.4	2.6
4	Construction	0.5	0.5	0.5	0.5	0.5
5	Manufacturing	**15.9**	**16.6**	**16.0**	**16.2**	**10.9**
6	Wholesale Trade	7.8	8.0	7.7	7.8	5.1
7	Retail Trade	10.1	10.8	10.1	10.3	6.1
8	Transportation	3.5	3.6	3.6	3.8	2.5
9	Information Services	3.3	2.9	3.0	2.9	1.9
10	Financial Services	6.7	7.1	7.1	7.7	8.5
11	Real Estate	**14.7**	**11.9**	**12.5**	**12.7**	**28.7**
12	Professional Services	4.8	5.0	5.0	5.1	4.4
13	Management Services	1.6	1.6	1.6	1.6	1.2
14	Administrative Services	2.6	2.8	2.8	2.9	2.4
15	Educational Services	1.0	0.8	1.2	0.8	0.2
16	Healthcare Services	**5.5**	**6.0**	**5.9**	**4.8**	**10.6**
17	Entertainment	0.8	0.8	0.9	0.7	0.4
18	Food and Accommodation	4.4	4.1	4.5	4.4	2.7
19	Other Services	4.7	4.5	4.6	4.9	3.5
20	Public Administration	4.4	4.5	4.9	4.3	4.1
21	Total	100.0	100.0	100.0	100.0	100.0

Stage-2: Consumption Basket (Compensation) by Age in 1980

Line	Sector	00-30	31-40	41-50	51-65	66-99
1	Agriculture	1.0	1.1	1.1	1.1	0.9
2	Mining	1.3	1.3	1.3	1.4	1.1
3	Utilities	1.5	1.7	1.7	1.8	1.6
4	Construction	0.7	0.7	0.7	0.7	0.8
5	Manufacturing	**16.5**	**16.7**	**16.1**	**16.5**	**12.7**
6	Wholesale Trade	8.6	8.6	8.3	8.5	6.6
7	Retail Trade	**13.9**	**14.4**	**13.6**	**14.1**	**9.9**
8	Transportation	4.6	4.6	4.6	4.9	3.8
9	Information Services	3.2	2.6	2.7	2.7	2.0
10	Financial Services	**7.1**	**7.3**	**7.3**	**8.0**	**10.2**
11	Real Estate	1.4	1.4	1.4	1.4	1.6
12	Professional Services	6.2	6.2	6.3	6.5	6.5
13	Management Services	2.6	2.5	2.5	2.6	2.3
14	Administrative Services	3.7	3.8	3.8	4.0	4.0
15	Educational Services	1.6	1.3	1.9	1.3	0.4
16	Healthcare Services	**8.6**	**9.1**	**8.9**	**7.3**	**19.6**
17	Entertainment	0.8	0.8	0.9	0.8	0.5
18	Food and Accommodation	5.4	4.8	5.4	5.3	3.9
19	Other Services	5.4	5.1	5.2	5.6	4.8
20	Public Administration	6.0	5.9	6.6	5.7	6.7
21	Total	100.0	100.0	100.0	100.0	100.0

Stage-2: Consumption Basket (Compensation) by Education

		With BA		Without BA	
Line	Sector	00-65	66-99	00-65	66-99
1	Agriculture	0.9	0.9	1.1	0.9
2	Mining	1.1	1.2	1.4	1.1
3	Utilities	1.5	1.6	1.7	1.6
4	Construction	0.6	0.7	0.7	0.8
5	Manufacturing	16.3	**14.0**	16.5	**12.5**
6	Wholesale Trade	8.1	7.2	8.7	6.5
7	Retail Trade	13.6	**11.1**	14.2	**9.7**
8	Transportation	5.1	4.9	4.5	3.7
9	Information Services	3.1	2.3	2.7	1.9
10	Financial Services	6.9	**9.5**	7.6	**10.4**
11	Real Estate	1.3	1.5	1.4	1.6
12	Professional Services	6.2	7.1	6.3	6.4
13	Management Services	2.6	2.5	2.6	2.2
14	Administrative Services	4.1	4.8	3.8	3.9
15	Educational Services	2.2	0.6	1.2	0.4
16	Healthcare Services	7.5	**10.9**	8.8	**20.9**
17	Entertainment	1.0	1.0	0.8	0.4
18	Food and Accommodation	6.2	**6.4**	4.9	**3.6**
19	Other Services	5.5	6.0	5.3	4.7
20	Public Administration	6.3	5.8	5.9	6.8
21	Total	100.0	100.0	100.0	100.0

Stage-2: Taking Stock

- Older households generate more compensation in healthcare and financial sectors, while younger ones generate compensation in manufacturing retail trade sectors.
- Younger (0-65) households with and without BA generate similar compensation across sectors.
- Older households (65-99) without (with) BA generate more compensation in healthcare and financial services (manufacturing, food and accommodation, and retail trade).

$\rightarrow$ Contradictory to the idea that services are more income elastic.

Stage-3: Employment and Wage Bill Shares: 1980

	Sector	Employment Share			Wage Bill Share		
Line	Sector	High	Mid	Low	High	Mid	Low
1	Agriculture	8.6	19.4	72.0	15.3	22.1	62.6
2	Mining	16.2	82.6	1.1	17.3	81.9	0.8
3	Utilities	20.6	77.1	2.3	25.0	73.3	1.8
4	Construction	13.0	86.3	0.7	17.4	82.1	0.5
5	Manufacturing	15.1	83.0	1.9	20.3	78.1	1.6
6	Wholesale Trade	18.0	81.0	1.0	23.2	76.2	0.6
7	Retail Trade	20.6	76.3	3.1	31.2	66.7	2.1
8	Transportation	10.3	86.0	3.6	11.0	86.1	2.9
9	Information Services	33.5	64.6	1.9	37.4	61.5	1.1
10	Financial Services	24.6	73.9	1.5	35.2	63.7	1.0
11	Real Estate	16.8	67.4	15.8	20.8	66.8	12.4
12	Professional Services	53.7	45.6	0.7	66.1	33.5	0.4
13	Management Services	63.4	35.7	0.9	74.3	25.2	0.5
14	Administrative Services	8.8	41.2	50.0	14.5	40.6	44.9
15	Educational Services	63.7	21.6	14.6	77.8	13.7	8.5
16	Healthcare Services	47.2	24.6	28.1	57.1	22.0	20.9
17	Entertainment	31.2	30.1	38.6	36.9	33.1	30,0
18	Food and Accommodation	15.0	11.5	73.5	27.2	12.7	60.1
19	Other Services	21.3	47.9	30.9	29.1	51.4	19.5
20	Public Administration	31.0	42.9	26.1	36.4	36.1	27.5
21	Overall	26.1	60.7	13.1	32.6	59.0	8.4

Stage-3: Employment Shares: 1980 and 2019

Line	Sector	Emp Share in 1980 High	Mid	Low	Emp Share in 2019 High	Mid	Low
1	Agriculture	8.6	19.4	72.0	6.2	18.0	75.8
2	Mining	16.2	82.6	1.1	30.6	68.2	1.2
3	Utilities	20.6	77.1	2.3	27.5	70.3	2.2
4	Construction	13.0	86.3	0.7	17.0	82.3	0.7
5	Manufacturing	15.1	83.0	1.9	30.5	67.4	2.1
6	Wholesale Trade	18.0	81.0	1.0	19.9	77.9	2.2
7	Retail Trade	20.6	76.3	3.1	11.4	84.0	4.6
8	Transportation	10.3	86.0	3.6	12.3	83.4	4.3
9	Information Services	33.5	64.6	1.9	72.9	25.6	1.6
10	Financial Services	24.6	73.9	1.5	53.4	45.4	1.2
11	Real Estate	16.8	67.4	15.8	35.8	54.7	9.5
12	Professional Services	53.7	45.6	0.7	74.0	23.2	2.8
13	Management Services	63.4	35.7	0.9	73.9	22.7	3.4
14	Administrative Services	8.8	41.2	50.0	19.1	21.6	59.3
15	Educational Services	63.7	21.6	14.6	80.4	11.1	8.5
16	Healthcare Services	47.2	24.6	28.1	57.1	15.8	27.0
17	Entertainment	31.2	30.1	38.6	45.0	21.9	33.1
18	Food and Accommodation	15.0	11.5	73.5	18.0	15.7	66.3
19	Other Services	21.3	47.9	30.9	25.5	41.3	33.2
20	Public Administration	31.0	42.9	26.1	44.3	22.0	33.6
21	Overall	**26.1**	**60.7**	**13.1**	**40.0**	**43.1**	**16.9**

Stage-3: Wage Bill Shares: 1980 and 2019

Line	Sector	Wage Share in 1980			Wage Share in 2019		
	Sector	High	Mid	Low	High	Mid	Low
1	Agriculture	15.3	22.1	62.6	11.1	18.8	70.1
2	Mining	17.3	81.9	0.8	36.7	62.8	0.5
3	Utilities	25.0	73.3	1.8	35.1	63.7	1.3
4	Construction	17.4	82.1	0.5	24.1	75.4	0.5
5	Manufacturing	20.3	78.1	1.6	42.2	56.3	1.5
6	Wholesale Trade	23.2	76.2	0.6	24.6	74.0	1.4
7	Retail Trade	31.2	66.7	2.1	18.3	78.3	3.4
8	Transportation	11.0	86.1	2.9	16.7	79.3	4.1
9	Information Services	37.4	61.5	1.1	80.5	18.6	0.9
10	Financial Services	35.2	63.7	1.0	62.6	36.5	0.9
11	Real Estate	20.8	66.8	12.4	40.7	52.7	6.6
12	Professional Services	66.1	33.5	0.4	81.0	17.3	1.6
13	Management Services	74.3	25.2	0.5	81.7	16.4	2.0
14	Administrative Services	14.5	40.6	44.9	28.3	19.8	51.9
15	Educational Services	77.8	13.7	8.5	86.4	8.6	5.0
16	Healthcare Services	57.1	22.0	20.9	70.1	12.7	17.2
17	Entertainment	36.9	33.1	30,0	54.7	19.3	26.1
18	Food and Accommodation	27.2	12.7	60.1	28.8	14.0	57.2
19	Other Services	29.1	51.4	19.5	34.4	41.5	24.1
20	Public Administration	36.4	36.1	27.5	50.2	16.7	33.1
21	Overall	**32.6**	**59.0**	**8.4**	**50.8**	**37.8**	**11.5**

Stage-3: Taking Stock

- Non-service sectors employ more middle-skill occupations, while services hire more high-skill and low-skill.
- Almost all sectors employ more (less) high-skill (middle-skill) occupations in 2019.
- Shift of employment to service sectors created so-called polarization overall.
  - High-skill employment share: (26.1% $\rightarrow$ 40.0%)
  - Middle-skill employment share: (60.7% $\rightarrow$ 43.1%)
  - Low-skill employment share: (13.1% $\rightarrow$ 16.9%)

Data-Based Decomposition: Framework

Wage bill share of skill-level j in year t is:

$$\frac{WB_{j,t}}{WB_t} = \sum_{s(=sector)} \sum_{g(=age)} \frac{\beta_{s,t}}{\beta_t} \alpha_{j,s,t} \frac{N_{g,t}}{N_t} \frac{va_{g,t}}{va_t} vp_{g,s,t} \tag{1}$$

- $\beta_{s,t}$ is the compensation share of value added in sector s.
- $\alpha_{j,s,t}$ is the j-skill share out of compensation in sector s.
- $N_{g,t}$ is the number of households in age group g.
- $va_{g,t}$ is the value added per household in age group g.
- $vp_{g,s,t}$ is the value-added share of sector s for households in age group g.

We change one component at a time, keeping others at the 1980/2019 values.

Data-Based Decomposition: Results – 1980-2019

Skill Level	High skill	Middle skill	Low skill
Wage Bill Share in 1980 (%)	34.9	52.1	13.0
Wage Bill Share in 2019 (%)	49.8	35.4	14.8
Δ 1980-2019 (pp)	**14.9**	**–16.7**	**1.8**
Δ N – Age Structure	1.2	0.8	0.4
Δ β – Labor Share	–1.9	–1.9	–0.6
Δ α – Skill Share	11.2	–11.6	0.5
Δ va – VA Life Cycle	–1.0	–1.3	–0.4
Δ vp – Consumption Basket	5.5	–2.7	2.0

- Population aging (ΔN) pushes up high- and low-skill wage bill shares, but only about 1/12 (high-skill) and 1/5 (low-skill) of observed changes.
- It also pushes up middle-skill wage share.
- Change in consumption basket for all age groups account for 37%, 16%, and more than 100% of observed changes in high-, middle-, and low-skill wage bill shares.

Model: Overview

- Overlapping generations of stochastic-aging households.
- Steady state analysis.
  - Initial steady state is calibrated to capture the U.S. in 1980.
  - Incorporate changes after 1980 (aging, more college, baby boom, etc)
- Two types of capital:
  - $k = 1$: Regular capital
  - $k = 2$: Middle-skill-substituting capital (computers, etc)

Model: Agents

- Households
  - g (age group): stochastic aging from $g = 1$ (21-25) to $g = 16$ (96-100).
  - i (education): 1 (college), 2 (non-college).
  - a (saving): subject to non-borrowing constraint.
- Consumption Goods Firms
  - $s = 1$ (non-service sector)
  - $s = 2$ (service sector)
- Investment Goods Firms
  - Combine two consumption goods to produce investment goods.
- Government
  - Run the social security program.

Household: Stage-1

- Income of type-(g, i) households are determined in stage-1 of each period.
- Workers ($g < G_R$) draw $z = (z_H, z_M, z_L)$ and choose the skill level which gives the highest labor income.
- Retirees ($g \geq G_R$) receive social security benefits, which is the replacement rate ζ times $\overline{e}_i$ (average labor income of type-i workers).

$$e(g, i, z) = \begin{cases} \max_{j \in \{H,M,L\}} (1 - \tau) z_j \psi_g w_j & \text{if } g < G_R \\ \zeta \overline{e}_i & \text{if } g \geq G_R \end{cases} \tag{2}$$

Household: Stage-2

- A type-(g, i, a, z) Household decides consumption $\{c_s\}_{s=1}^{S}$ and saving a' subject to a budget constraint (4) and a liquidity constraint (5).
- With $\gamma_{g,s} > 0$, the expenditure share of consumption goods s increases as income increases. Buera et al. (2022) set $\gamma_{g,s} > 0$ for services.

$$V(g,i,a,z) = \max_{\{c_s\}_{s=1}^{S}, a'} \phi_g \log \left[\sum_{s=1}^{S} \alpha_{g,s} (c_s + \gamma_{g,s})^{\frac{\epsilon-1}{\epsilon}} \right]^{\frac{\epsilon}{\epsilon-1}} + \beta \mathbb{E} \pi_{g,2} \left[\pi_{g,1} V(g,i,a',z') + (1-\pi_{g,1}) V(g+1,i,a',z') \right] \quad (3)$$

$$\text{s.t.} \sum_{s=1}^{S} p_s c_s + \pi_{g,2} a' = e(g,i,z) + (1+r)a \quad (4)$$

$$a' \geq 0 \quad (5)$$

Consumption Goods Firm

- A type-s representative consumption goods firm decides labor inputs of three skill levels (H_s, M_s, L_s) and capital inputs $(K_{1,s}, K_{2,s})$ each period.

$$\max_{H_s,M_s,L_s,K_{1,s},K_{2,s}} p_s A_s \left[\eta_{s,H} H_s^{\frac{\rho-1}{\rho}} + \eta_{s,M}(M_s + \eta_K K_{2,s})^{\frac{\rho-1}{\rho}} + \eta_{s,L} L_s^{\frac{\rho-1}{\rho}}\right]^{\frac{\rho(1-\theta_s)}{\rho-1}} K_{1,s}^{\theta_s} - w_H H_s - w_M M_s - w_L L_s - (r+\delta_1)K_{1,s} - (r+\delta_2)K_{2,s} \quad (6)$$

First order conditions with respect to M_s and $K_{2,s}$ imply $w_M = \frac{r+\delta_2}{\eta_K}$, meaning that lower interest rate directly lowers w_M and discourages taking middle-skill occupations.

Investment Goods Firm

- A representative investment goods firm combines $s = 1, 2, ..., S$ consumption goods and produce investment goods. This is the numeraire.

$$\max_{\{X_s\}_{s=1}^{S}} \prod_{s=1}^{S} X_s^{\nu_s} - \sum_{s=1}^{S} p_s X_s \tag{7}$$

First order condition associated with consumption goods s is:

$$\nu_s X = p_s X_s \tag{8}$$

Government

- The government runs social security, with period-by-period budget balance.
- $j(g,i,z) \in \{H,M,L\}$ represents the optimal skill choice.
- $m_{g,i,a}$ is the measure of type-(g,i,a) households in a steady state.
- τ is the payroll tax rate to finance social security.
- ζ is the replacement rate of social security benefits.
- $\overline{e}_i$ is average earnings of type-i workers.

$$\sum_{g=1}^{G_R-1} \sum_{i,a} m_{g,i,a} \tau \int_z z_{j(g,i,z)} \psi_g w_{j(g,i,z)} dz = \sum_{g=G_R}^{G} \sum_{i,a} m_{g,i,a} \zeta \overline{e}_i \tag{9}$$

Equilibrium

In a steady-state equilibrium:

- p_s are determined for all s goods to clear the markets.
- w_j are determined for $j = H, M, L$ to clear the three labor markets.
- τ is determined to satisfy the government budget constraint.
- Stationary type distribution of households is consistent with their optimal decision.

Calibration 1/3 – Age-Dependent Parameters

Age	$\pi_{1,g}$	$\pi_{2,g}$	ψ_g	ϕ_g	$\alpha_{2,g}$
21-25	0.8000	0.9987	0.7459	1.3650	0.3700
31-35	0.8000	0.9986	0.9467	1.6983	0.3700
41-45	0.8000	0.9969	1.0956	1.7568	0.3700
51-55	0.8000	0.9922	1.1246	1.6134	0.3700
61-65	0.8000	0.9822	0.9986	1.4011	0.3700
66-70	0.8000	0.9735	0.0000	1.2975	0.5200
76-80	0.8000	0.9413	0.0000	1.1597	0.6767
86-90	0.8000	0.8394	0.0000	1.1429	0.8333
95-100	1.0000	0.6079	0.0000	1.1126	0.9900

- $\pi_{2,g}$ is from Life Tables, 1980.
- ψ_g is from Gourinchas and Parker (2002).
- ϕ_g is based on the average family size in CE, 1980, converted into family equivalence scale (Fernández-Villaverde and Krueger (2007)).
- $\alpha_{2,g}$ is calibrated to match the life cycle of the service share in CE, 1980.

Calibration 2/3 – Non-Age-Dependent Parameters

Parameter	Value	Remark	Source
$\overline{m}_{i=1}$	0.1897	Fraction with BA.	CE in 1980.
$\gamma_{g,1} = \gamma_{g,2}$	0.0000	Stone-Geary parameter.	Homothetic preferences.
ϵ	0.4500	Elasticity of substitution.	From Comin et al. (2020).
$\sigma_1 = \sigma_2$	0.8000	S.D. of productivity shocks.	Storesletten et al. (2004).
$\eta_{H,1}$	0.2090	High-skill wage bill share of non-service.	CPS-ASEC in 1980.
$\eta_{M,1}$	0.7650	Middle-skill wage bill share of non-service.	CPS-ASEC in 1980.
$\eta_{L,1}$	0.0260	Low-skill wage bill share of non-service.	CPS-ASEC in 1980.
$\eta_{H,2}$	0.4910	High-skill wage bill share of service.	CPS-ASEC in 1980.
$\eta_{M,2}$	0.3430	Middle-skill wage bill share of service.	CPS-ASEC in 1980.
$\eta_{L,2}$	0.1660	Low-skill wage bill share of service.	CPS-ASEC in 1980.
ρ	1.5000	Elasticity of substitution.	Comin et al. (2020) and Katz and Murphy (1992).
$\theta_1 = \theta_2$	0.2170	Capital share in production.	NIPA, 1980-2019.
δ_1	0.0600	Depreciation rate of regular capital	NIPA, 1971-1980.
δ_2	0.2000	Depreciation rate of labor-replacing capital	NIPA, 1971-1980.
$A_1 = A_2$	1.0000	TFP level.	Normalization.
ν_1	0.4667	Non-service share in production	Non-service expenditure share.
ζ	0.4000	Replacement rate of social security.	Biggs and Springstead (2008).

Calibration 3/3 – Internally Calibrated Parameters

Parameter	Value	Remark	Target
$\mu_{1,H}$	–1.6000	Mean for high-skill without BA.	16.0% choose high-skill occupations.
$\mu_{1,M}$	0.0000	Mean for middle-skill without BA.	Normalization.
$\mu_{1,L}$	–0.3000	Mean for low-skill w/o BA.	15.1% choose low-skill occupations.
$\mu_{2,H}$	–0.4000	Mean for high-skill with BA.	73.1% choose high-skill occupations.
$\mu_{2,M}$	–0.5000	Mean for middle-skill with BA.	College premium is 1.34.
$\mu_{2,L}$	–0.7000	Mean for low-skill with BA.	3.8% choose low-skill occupations.
$\alpha_{2,1}$	0.3700	Service expenditure share of 21-65.	Workers spend 51.7% on services.
α_{2,G_R}	0.5200	Service expenditure share of 66-70.	Retirees spend 62.5% on services.
$\alpha_{2,G}$	0.9900	Service expenditure share of 95-100.	Service share rises with age.
β	0.9560	Time discount factor.	$K/Y = 1.97$.
η_K	0.6587	Type-2 capital intensity in production.	$K_2/Y = 0.13$.

Results: The 1980 Model

Statistic	1980 Data	2019 Data	1980 Model
Employment share: High	26.1	40.0	27.95
Employment share: Middle	60.7	43.1	57.77
Employment share: Low	13.1	16.9	14.28
Wage bill share: High	32.6	50.8	29.39
Wage bill share: Middle	59.0	37.8	60.76
Wage bill share: Low	8.4	11.5	9.86
Wage: High	1.156	1.269	1.051
Wage: Middle	0.978	0.876	1.052
Wage: Low	0.733	0.679	0.690
College premium	1.340	1.540	1.340
Non-service exp share	46.67	31.35	46.74
Service exp share	53.33	68.64	53.26
Real interest rate	6.700	0.840	5.780
Relative price of services	–	–	1.693

- The 1980 model is calibrated such that relevant statistics of the 1980 U.S. economy are replicated.

Experiment: Population Aging

Model	20s	30s	40s	50s	60s	70s	80s+
Baseline (%)	18.5	18.2	17.7	16.4	13.9	9.8	5.5
2019 Mortality (%)	17.1	16.9	16.5	15.7	14.1	11.3	8.5
2019 + Baby boomer (%)	14.4	14.2	13.9	17.5	19.8	13.0	7.2

- In the first counterfactual, we replace the mortality rate from 1980 to 2019.
- In the second counterfactual, we add baby boomers (age 56-75 in 2019), using the fact that the birth rate was 67% higher for baby boomers.

Results: Population Aging + Baby Boomers

Statistic	1980 Data	2019 Data	1980 Model	2019 Mort	+Boomers
Employment share: High	26.1	40.0	27.95	28.58	28.76
Employment share: Middle	60.7	43.1	57.77	56.78	56.45
Employment share: Low	13.1	16.9	14.28	14.64	14.79
Wage bill share: High	32.6	50.8	29.39	30.29	30.58
Wage bill share: Middle	59.0	37.8	60.76	59.49	59.08
Wage bill share: Low	8.4	11.5	9.86	10.21	10.33
Wage: High	1.156	1.269	1.051	1.060	1.063
Wage: Middle	0.978	0.876	1.052	1.048	1.047
Wage: Low	0.733	0.679	0.690	0.697	0.699
College premium	1.340	1.540	1.340	1.369	1.375
Non-service exp share	46.67	31.35	46.74	45.79	45.65
Service exp share	53.33	68.64	53.26	54.21	54.35
Real interest rate	6.700	0.840	5.780	5.589	5.513
Relative price of services	–	–	1.693	1.712	1.720

- Aging induces polarization in terms of both employment and wage bills.
- However, in the current model, the channel from aging to polarization is weak.
- Aging also induces a higher college premium and a higher service share.

Results: Increase in College Graduates

Statistic	1980 Data	2019 Data	1980 Model	More BA
Employment share: High	26.1	40.0	27.95	33.31
Employment share: Middle	60.7	43.1	57.77	51.47
Employment share: Low	13.1	16.9	14.28	15.22
Wage bill share: High	32.6	50.8	29.39	36.46
Wage bill share: Middle	59.0	37.8	60.76	52.74
Wage bill share: Low	8.4	11.5	9.86	10.80
Wage: High	1.156	1.269	1.051	1.095
Wage: Middle	0.978	0.876	1.052	1.025
Wage: Low	0.733	0.679	0.690	0.709
College premium	1.340	1.540	1.340	1.203
Non-service exp share	46.67	31.35	46.74	46.93
Service exp share	53.33	68.64	53.26	53.07
Real interest rate	6.700	0.840	5.780	6.568
Relative price of services	–	–	1.693	1.642

- Higher share (19% $\rightarrow$ 36%) of college graduates generate some polarization.
- However, abundance in high-skill workers generates lower college premium, higher interest rate, cheaper services, and lower expenditure share of services.

Results: Change in Consumption Basket

Statistic	1980 Data	2019 Data	1980 Model	2019 Basket
Employment share: High	26.1	40.0	27.95	29.85
Employment share: Middle	60.7	43.1	57.77	54.29
Employment share: Low	13.1	16.9	14.28	15.86
Wage bill share: High	32.6	50.8	29.39	32.29
Wage bill share: Middle	59.0	37.8	60.76	56.33
Wage bill share: Low	8.4	11.5	9.86	11.38
Wage: High	1.156	1.269	1.051	1.082
Wage: Middle	0.978	0.876	1.052	1.037
Wage: Low	0.733	0.679	0.690	0.718
College premium	1.340	1.540	1.340	1.424
Non-service exp share	46.67	31.35	46.74	31.55
Service exp share	53.33	68.64	53.26	68.45
Real interest rate	6.700	0.840	5.780	5.556
Relative price of services	–	–	1.693	1.685

- Adjust $\alpha_{2,g}$ to match the service expenditure shares in 2019.
- Income-elastic services (Comin et al. (2020)) or rising service prices.
- Causes moderate polarization and rising college premium.

Results: Change in Skill-Mix in Production Technology

Statistic	1980 Data	2019 Data	1980 Model	2019 Tech
Employment share: High	26.1	40.0	27.95	35.87
Employment share: Middle	60.7	43.1	57.77	49.63
Employment share: Low	13.1	16.9	14.28	14.49
Wage bill share: High	32.6	50.8	29.39	40.67
Wage bill share: Middle	59.0	37.8	60.76	49.33
Wage bill share: Low	8.4	11.5	9.86	10.00
Wage: High	1.156	1.269	1.051	1.134
Wage: Middle	0.978	0.876	1.052	0.994
Wage: Low	0.733	0.679	0.690	0.690
College premium	1.340	1.540	1.340	1.652
Non-service exp share	46.67	31.35	46.74	46.86
Service exp share	53.33	68.64	53.26	53.14
Real interest rate	6.700	0.840	5.780	7.660
Relative price of services	–	–	1.693	1.685

- Demand for high-skill occupations go up, so does high-skill wage.
- College premium shoots up.
- Polarization is induced.
- No change in service expenditure share.

To-Do List

- Other dimensions of household types (single and married, with and w/o children).
- Use MEPS to adjust CE healthcare expenditures with age-dependent factor.
  - Health insurance coverage ratio might be higher for retirees with Medicare.
- More careful modeling of aging.
  - The size of decline in the real interest rate due to aging is too small.
- More careful modeling of healthcare and other expenditures for the elderly.
  - Consumption expenditures of the elderly are too small in the model.
- Non-homothetic preferences (income-sensitive service?).
  - Endogenize changes in the expenditure shares of non-service and service.

Concluding Remarks

- Population aging can generate polarization, but so far the model implies limited strength.
- Long to-do list, which could change this tentative main finding.
- The model allows us to study many changes, in addition to polarization.
  - Aging and relative price of service and non-services.
  - Aging and college premium.

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