# Distributional Impacts of Climate Change I: Building a Custom Initialization Data Product for a Life-cycle OLG Model

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**C**ommunity **I**ntegrated **M**odel
of **E**nergy **A**nd **R**esource **T**rajectories for **H**umankind

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Argonne National Lab &
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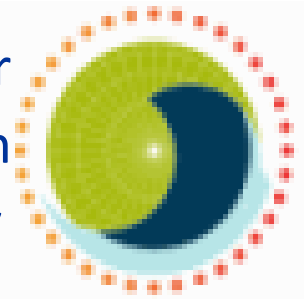
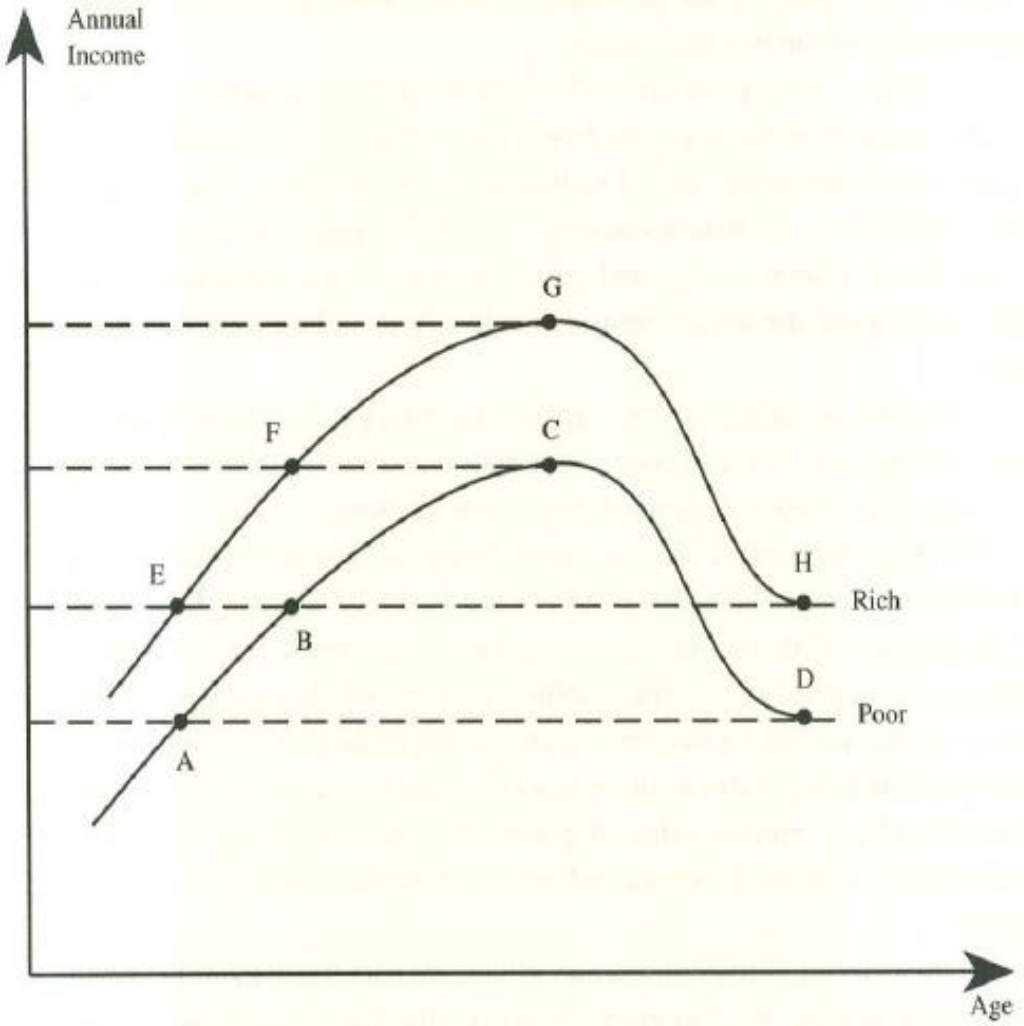
**R**obust **D**ecision-making in
**C**limate and **E**nergy **P**olicy



# Distributional impacts of tax policy by age and income

Figure 1-1. *Two Lifetime Profiles*[a]




- Annual income classes combine groups at very different points in their life-cycle
- Age-based classes combine people of very different wealth
- In both cases, consumer preferences, and thus the relative effects of a policy, vary widely within an aggregate.

# Fullerton and Rogers 1993

- Combines these approaches using lifetime income to define ‘rich’ and ‘poor’ across ages
- Study the incidence and distributional effects of tax policy, primarily that of the tax reform measures of 1986
- Focus on wealth and progressive/regressive tax policy in the context of lifetime wealth, instead of annual income in a snapshot

# Steps for FR OLG model

1. Using the Panel Study of Income Dynamics (PSID), estimate wage rates as a function of age and other demographics and construct a wage profile for each model agent
2. Estimate age profiles for personal income tax and government transfers such as SS, and estimate inheritances for each lifetime income group.
3. Using the Consumer Expenditure Survey (CEX), estimate consumption shares and minimal subsistence levels (in a Stone-Geary consumption system), as a function of age, for each commodity.
4. Build a life-cycle OLG GE model with consumers identified by age and lifetime income. Depending on model time-step, this implies something like 144 – 720 unique consumer agents (for 5 – 1 yr steps).
5. Evaluate the effects of environmental policy and climate impacts in the food and fuel sectors

# A CE project: Life-cycle Distributional Effects of Climate Policy and Impacts

- The modeling goal: reproduce the FR93 framework with modern data: updated PSID, CEX, and global SAMs based on the GTAP expenditure database.
- Computational goal: Apply modern numerical techniques to scale to larger and more complex models (more consumer classes, commodities, etc.)
- Application goal: Apply the model to environmental policy questions around carbon emissions and to climate change mitigation and adaptation questions with distributional characteristics.
- Advanced modeling goals: Develop a framework that transitions from static expectations to perfect foresight by continuously varying the foresight horizon; include rational expectations, precautionary savings, etc.

# Consumer agents and their assumptions

- At each time step there are 60 consumers of different ages on each of the 12 lifetime income paths (roughly age 20-79).
- At each period, each consumer **makes a new plan** for their remaining years of life (from current age a to 60), based on the following set of assumptions:
  1. Their labor endowment is known throughout their life and depends on which lifetime income group they belong to.
  2. The trajectory of transfer payments made to them from social security and other government programs is known.
  3. Their future preferences (for leisure vs. labor and for the mix of goods within their consumption bundle) are known, as are the subsistence levels, Si, , for each commodity at each stage in the life-cycle.
  4. They assume that the **wage rate will be the same** as it is in period t for all subsequent years.
  5. They assume that the **rate of return on capital will stay the same** as it is in period t.
  6. They assume that **all applicable tax rates will stay the same** as in period t.

# The consumer problem

- The consumer optimization problem for an agent of age ‘a’ at time t.

$$\max_{x_{i,\tau}, I_\tau, l_\tau} \quad U$$

$$\text{s.t.} \quad U \leq \left( \sum_{\tau=a}^{T} \alpha_\tau^{1/\sigma} U_\tau^{\rho} \right)^{1/\rho} \qquad (\text{with} \quad \sigma = 0.5)$$

$$U_\tau \leq \left( \alpha_{c,\tau}^{1/\sigma_l} C_\tau^{\rho_l} + \alpha_{l,\tau}^{1/\sigma_l} l_\tau^{\rho_l} \right)^{1/\rho_l} \qquad \forall \ \tau \geq a \qquad (\text{with} \quad \sigma_l = 0.5)$$

$$C_\tau \leq \left( \sum_i \alpha_{i,\tau}^{1/\sigma_c} \left( x_{i,\tau} - S_{i,\tau} \right)^{\rho_c} \right)^{1/\rho_c} \qquad \forall \ \tau \geq a \qquad (\text{with} \quad \sigma_c = 1.0)$$

$$K_a = K_t = (1 - \delta_k) K_{t-1} + I_{t-1} \qquad \left( \textit{owned capital at start of period } t \right)$$

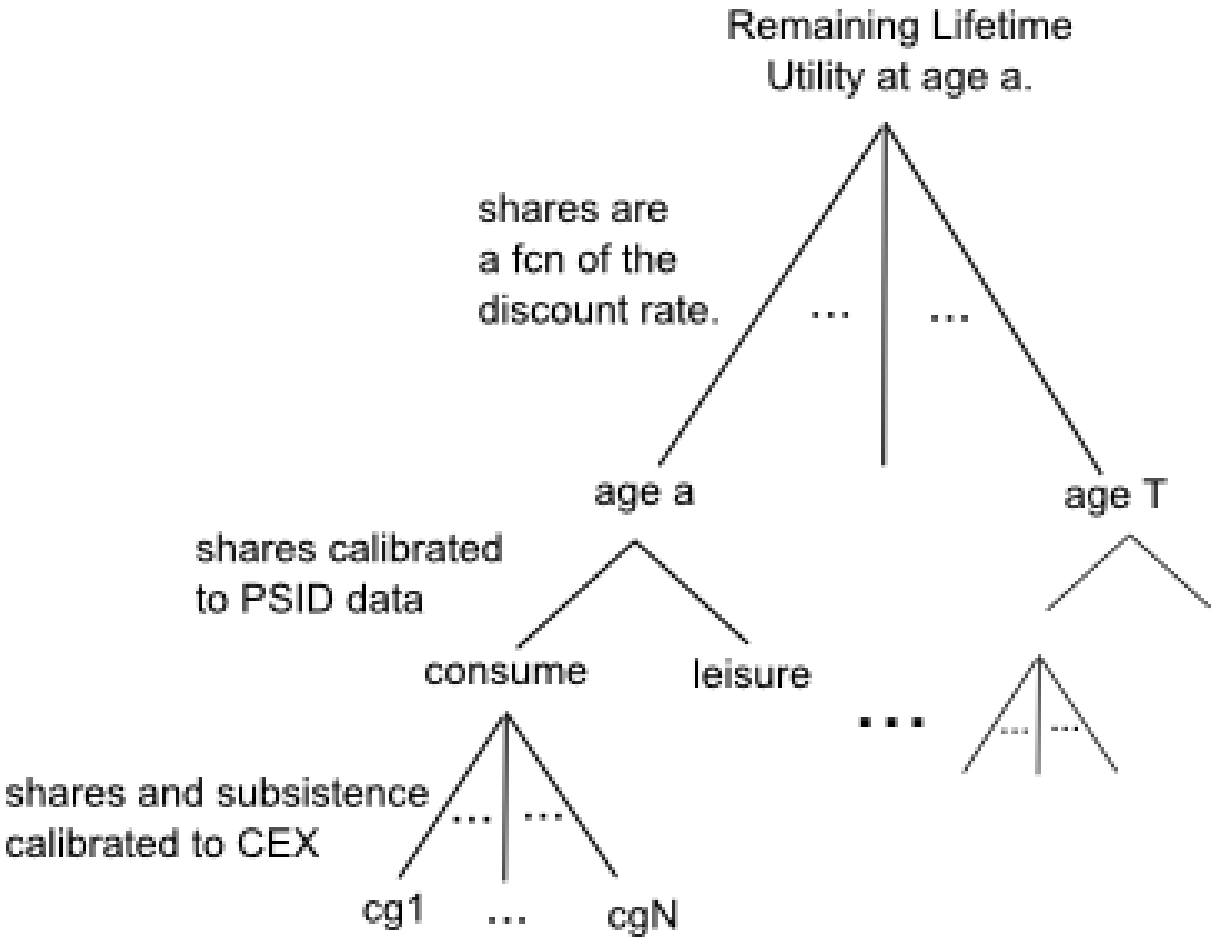
$$K_\tau = (1 - \delta_k) K_{\tau-1} + I_{\tau-1} \qquad \forall \ \tau > a \qquad \left( \textit{owned capital trajectory under savings plan} \right)$$

$$\sum_{\tau=a}^{T} \frac{\sum_i (1 + s_i) p_i x_{i,\tau} + p_K I_\tau}{(1+r)^{\tau-a}} \leq \sum_{\tau=a}^{T} \frac{(1 - s_{L,\tau}) w_L L_\tau + (1 - s_{K,\tau}) r K_\tau + TR_\tau - \text{INT}}{(1+r)^{\tau-a}}$$

$$L_\tau + l_\tau \leq E_{L,\tau} \qquad \forall \tau \qquad \left( \textit{work plus leisure in year } \tau \textit{ equals total labor endowed} \right)$$

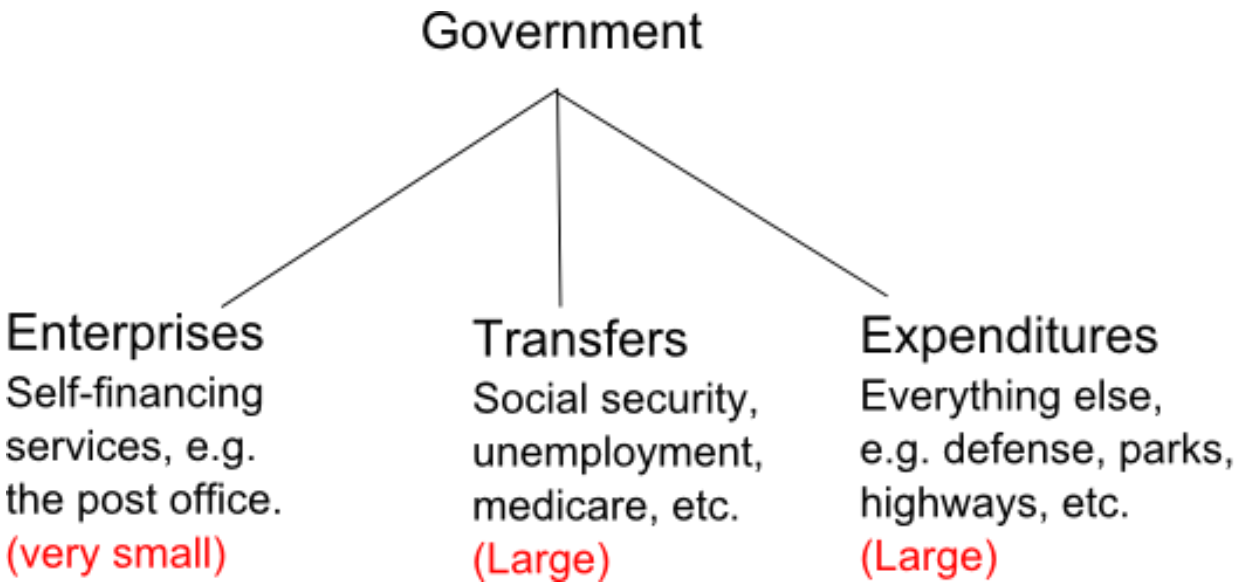
# The consumer problem

- The consumer optimization problem for an agent of age ‘a’ at time t.



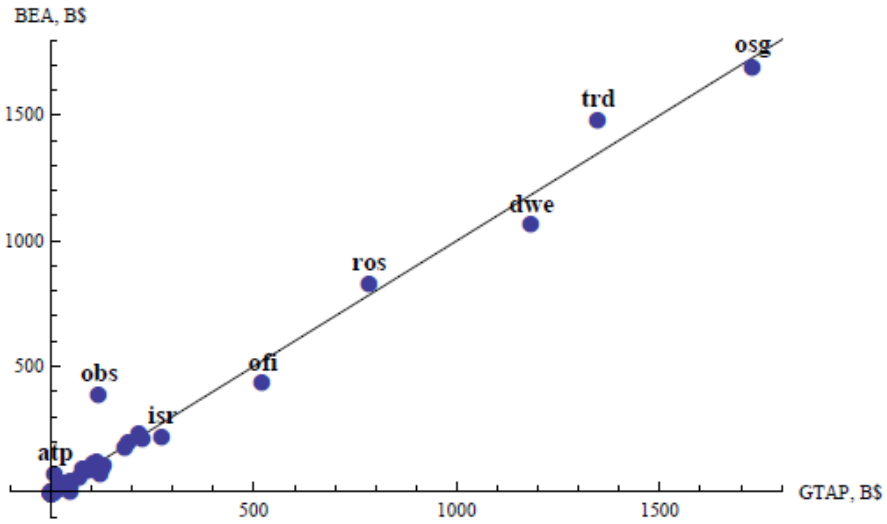
# Some minor modifications to GTAP using the BEA tables

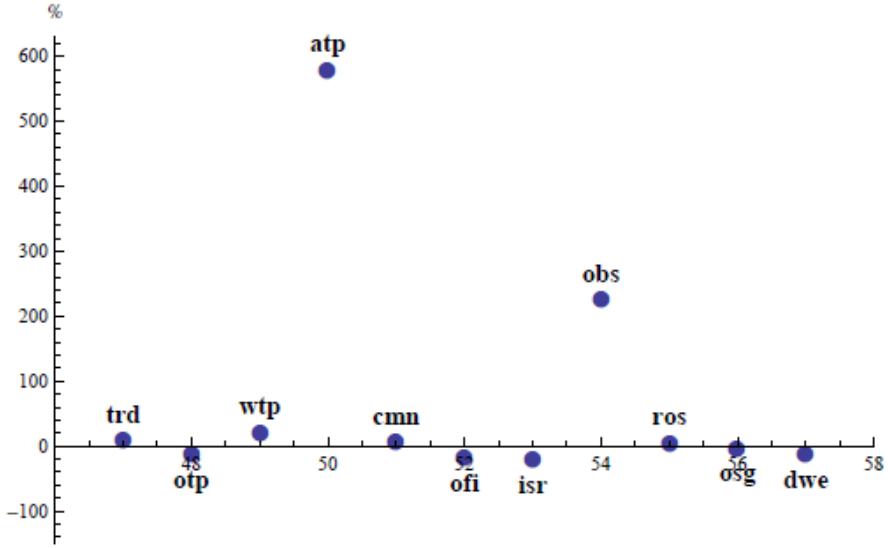
- Because government taxes, transfers , and other revenue distribution play an important part in the story of distributional effects, we have modified the GTAP representation of government to be more flexible in this respect.
- Using the BEA Make/Use tables, we separate out three distinct branches of government:



# Linking producer and consumer goods with the BEA PCE bridge tables

- We want to model consumer demands directly in terms of end-use consumer goods, whereas GTAP is in terms of producer goods.
- The matrix that performs this mapping is called a 'bridge' and is constructed from the BEA PCE bridge tables.




**A comparison of GTAP consumer demands with the BEA PCE bridge:** Considering the potential for conflicting definitions of industries when moving between the NIPA and ISIC classifications, these match up quite well.

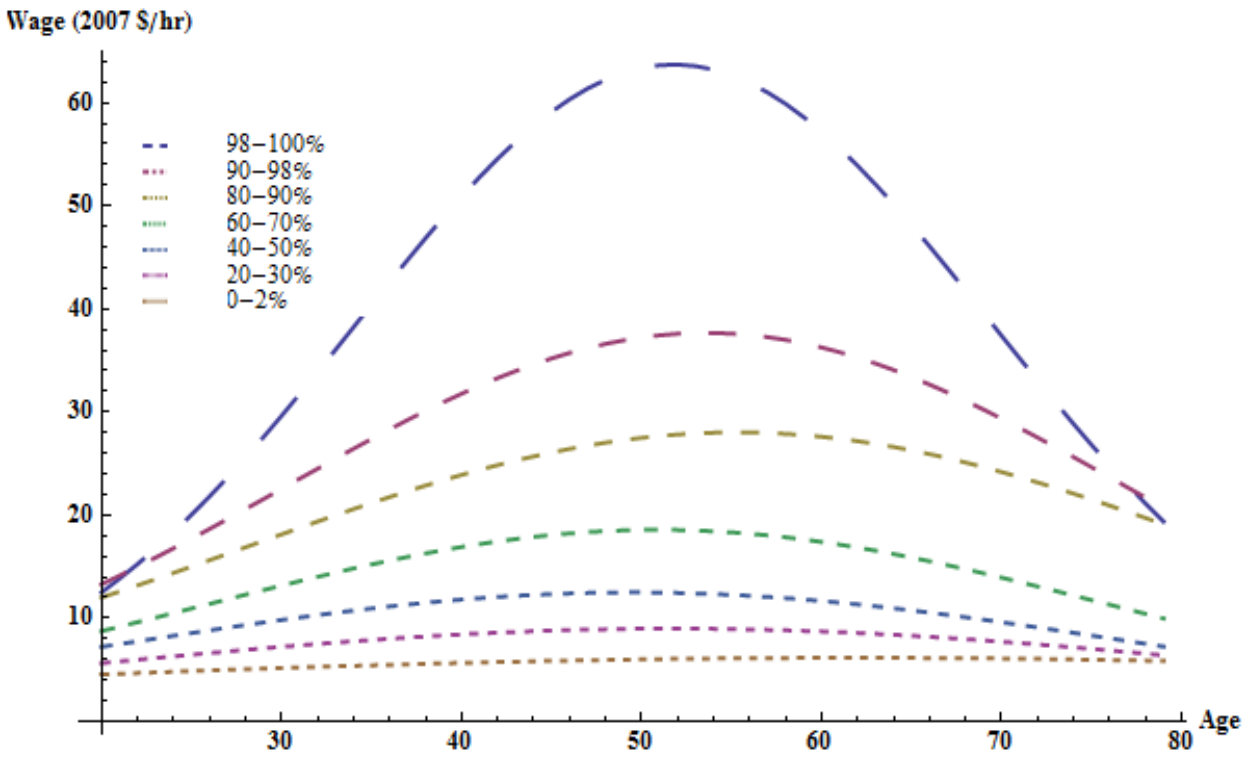
# Consumer expenditures from the CEX and RECS data

- Update FR consumption estimates to modern CEX
- Expand energy sector detail using RECS

| Category | Age group | | | | | | Age group | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | *20–24* | *25–29* | *30–34* | *35–39* | *40–44* | *45–49* | *50–54* | *55–59* | *60–64* | *65–69* | *70–74* | *75+* |
| 1. Food | 0.12726 | 0.12528 | 0.12082 | 0.14769 | 0.14239 | 0.14193 | 0.11571 | 0.12574 | 0.11228 | 0.12613 | 0.14762 | 0.10120 |
| 2. Alcohol | 0.07362 | 0.03059 | 0.04591 | 0.06275 | 0.02216 | 0.04617 | 0.02642 | 0.03765 | 0.02422 | 0.03722 | 0.03464 | 0.01973 |
| 3. Tobacco | −0.00385 | 0.00255 | 0.00021 | 0.00156 | 0.00157 | −0.00183 | 0.00336 | 0.00328 | −0.00052 | 0.00052 | −0.00064 | −0.00060 |
| 4. Utilities | 0.05167 | 0.03309 | 0.04752 | 0.03776 | 0.04367 | 0.02976 | 0.02738 | 0.02499 | 0.00715 | 0.04044 | 0.04389 | 0.04825 |
| 5. Shelter | 0.21444 | 0.19367 | 0.16491 | 0.16101 | 0.17431 | 0.15868 | 0.13010 | 0.18246 | 0.17556 | 0.15509 | 0.17496 | 0.29508 |
| 6. Furnishings | 0.02047 | 0.03446 | 0.04045 | 0.02573 | 0.04147 | 0.04625 | 0.03816 | 0.04636 | 0.04099 | 0.03459 | 0.03054 | 0.02504 |
| 7. Appliances | 0.01407 | 0.04371 | 0.03731 | 0.02976 | 0.03806 | 0.04154 | 0.03855 | 0.03904 | 0.02932 | 0.03246 | 0.02331 | 0.02452 |
| 8. Apparel | 0.09692 | 0.12375 | 0.12631 | 0.08589 | 0.10763 | 0.10705 | 0.11279 | 0.12476 | 0.10880 | 0.08387 | 0.02047 | 0.03289 |
| 9. Transportation | 0.02502 | 0.02849 | 0.02464 | 0.01982 | 0.02272 | 0.03778 | 0.02121 | 0.02997 | 0.14687 | 0.06406 | 0.01411 | 0.02601 |
| 10. Automobiles | 0.07056 | 0.12342 | 0.10304 | 0.09339 | 0.13097 | 0.13101 | 0.12087 | 0.11889 | 0.09685 | 0.14234 | 0.12254 | 0.10120 |
| 11. Personal services | 0.06550 | 0.10358 | 0.13374 | 0.12758 | 0.11431 | 0.08684 | 0.15743 | 0.09306 | 0.14904 | 0.10819 | 0.21052 | 0.14819 |
| 12. Financial services | 0.03086 | 0.05065 | 0.03023 | 0.03473 | 0.04079 | 0.03810 | 0.06129 | 0.05332 | 0.02668 | 0.07269 | 0.07063 | 0.07684 |
| 13. Recreation | 0.07298 | 0.03919 | 0.06261 | 0.05753 | 0.04767 | 0.05028 | 0.04293 | 0.06349 | 0.03278 | 0.03627 | 0.03494 | 0.01853 |
| 14. Nondurables | 0.01228 | 0.01092 | 0.01472 | 0.00746 | 0.00912 | 0.01643 | 0.01678 | 0.00418 | 0.01089 | 0.00569 | 0.00277 | 0.00681 |
| 15. Fuel | 0.05818 | 0.00722 | 0.02466 | 0.02090 | 0.02516 | 0.03350 | 0.02134 | 0.01546 | 0.01298 | 0.02882 | 0.05661 | 0.02477 |
| 16. Health care | 0.06511 | 0.04946 | 0.01918 | 0.06431 | 0.02044 | 0.02406 | 0.03025 | 0.01744 | 0.02313 | 0.03037 | 0.01215 | 0.04841 |
| 17. Education | 0.00491 | −0.00002 | 0.00375 | 0.02211 | 0.01756 | 0.01244 | 0.03544 | 0.01992 | 0.00297 | 0.00125 | 0.00096 | 0.00314 |

# Wage, tax, and income profiles from the PSID

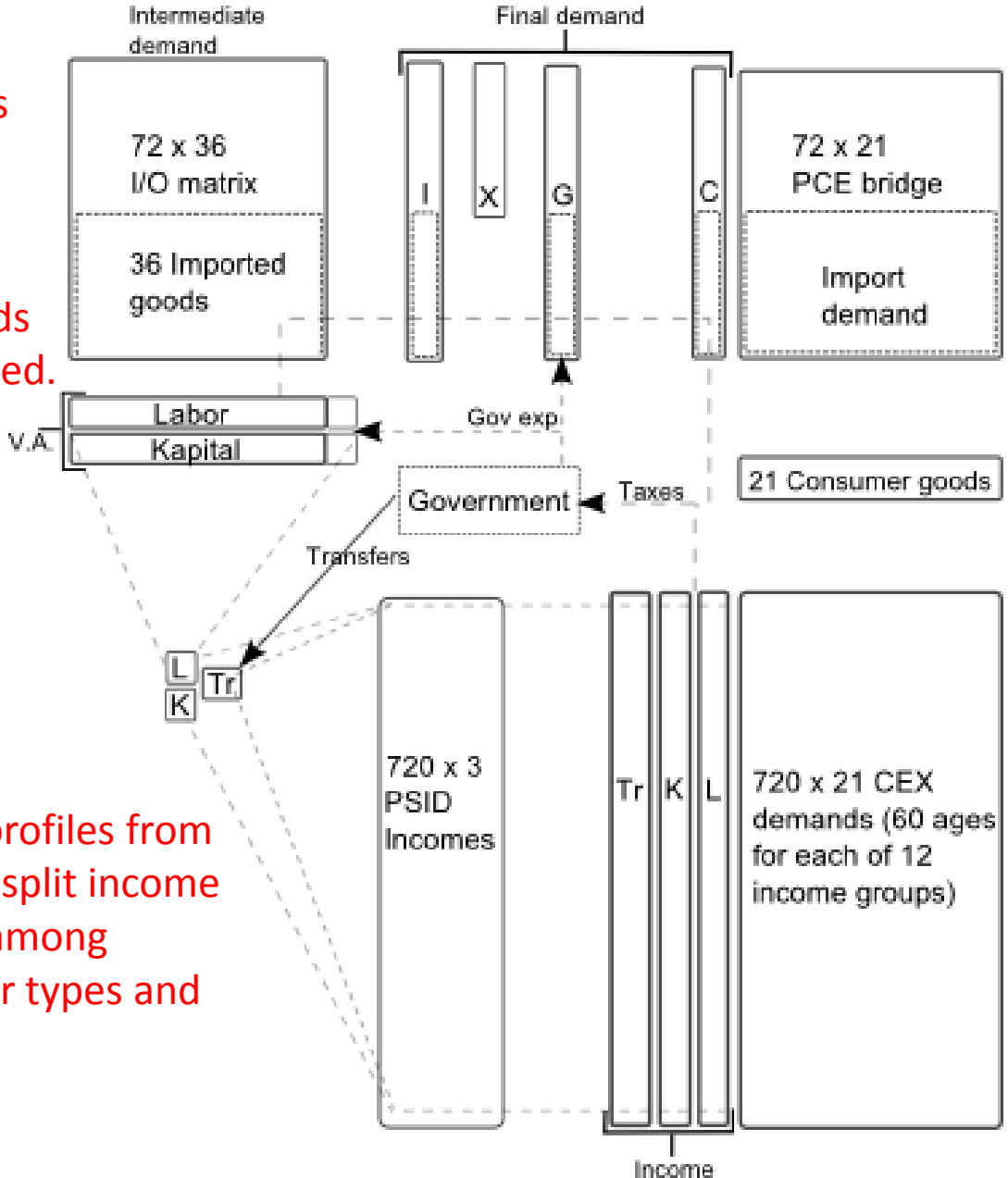
- 4,521 individuals
  - 2,850 heads and 1,677 spouses with positive wages in at least one year.
  - On average we have 20 and 17 years of observations for heads and spouses, respectively.
- Total of 85,367 individual-year observations.




Income profiles for selected groups from the PSID.

# Schematic of the data set

**GTAP** provides final and intermediate demand for producer goods and value added.




**PCE bridge** matches producer and consumer goods.

Income profiles from the **PSID** split income sources among consumer types and ages.

Consumption shares and subsistence levels from the **CEX** then determine the consumer demands of each consumer type at each age.

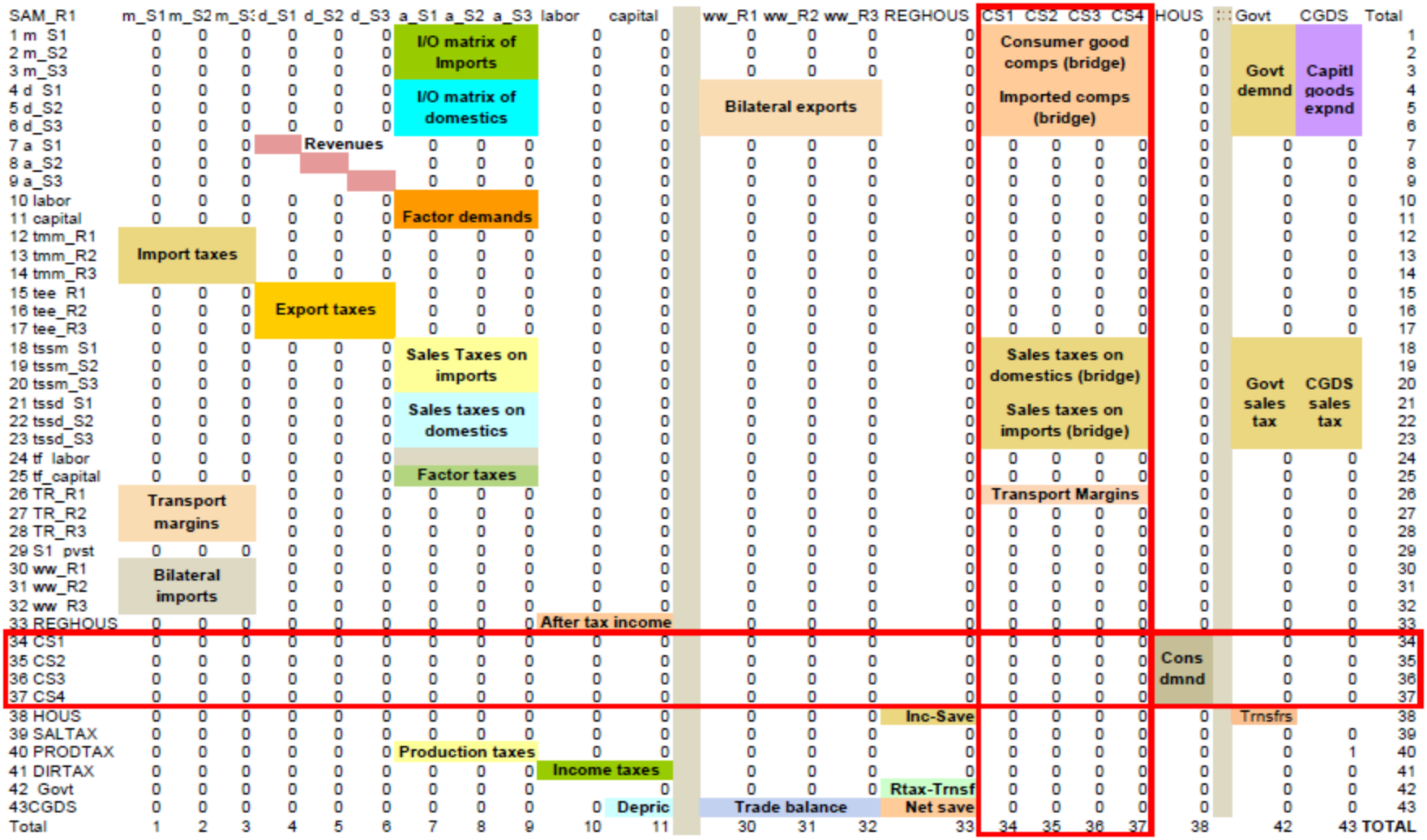
# Stages of the database construction

- SAM format of McDonald and Thierfelder with explicit transfer payments.

| SAM_R1 | m_S1 | m_S2 | m_S3 | d_S1 | d_S2 | d_S3 | a_S1 | a_S2 | a_S3 | labor | capital | ww_R1 | ww_R2 | ww_R3 | REGHOUS | HOUS | Govt | CGDS | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 m_S1 | 0 | 0 | 0 | 0 | 0 | 0 | I/O matrix of Imports | | | 0 | 0 | 0 | 0 | 0 | 0 | | | | 1 |
| 2 m_S2 | 0 | 0 | 0 | 0 | 0 | 0 | | | | 0 | 0 | 0 | 0 | 0 | 0 | | | | 2 |
| 3 m_S3 | 0 | 0 | 0 | 0 | 0 | 0 | | | | 0 | 0 | 0 | 0 | 0 | 0 | Cnsmer demnd | Govt demnd | Capitl goods expnd | 3 |
| 4 d_S1 | 0 | 0 | 0 | 0 | 0 | 0 | I/O matrix of domestics | | | 0 | 0 | Bilateral exports | | | 0 | | | | 4 |
| 5 d_S2 | 0 | 0 | 0 | 0 | 0 | 0 | | | | 0 | 0 | | | | 0 | | | | 5 |
| 6 d_S3 | 0 | 0 | 0 | 0 | 0 | 0 | | | | 0 | 0 | | | | 0 | | | | 6 |
| 7 a_S1 | 0 | 0 | 0 | Revenues | | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 7 |
| 8 a_S2 | 0 | 0 | 0 | | | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 8 |
| 9 a_S3 | 0 | 0 | 0 | | | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 9 |
| 10 labor | 0 | 0 | 0 | 0 | 0 | 0 | Factor demands | | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 10 |
| 11 capital | 0 | 0 | 0 | 0 | 0 | 0 | | | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 11 |
| 12 tmm_R1 | Import taxes | | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 12 |
| 13 tmm_R2 | | | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 13 |
| 14 tmm_R3 | | | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 14 |
| 15 tee_R1 | 0 | 0 | 0 | Export taxes | | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 15 |
| 16 tee_R2 | 0 | 0 | 0 | | | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 16 |
| 17 tee_R3 | 0 | 0 | 0 | | | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 17 |
| 18 tssm_S1 | 0 | 0 | 0 | 0 | 0 | 0 | Sales Taxes on imports | | | 0 | 0 | 0 | 0 | 0 | 0 | | | | 18 |
| 19 tssm_S2 | 0 | 0 | 0 | 0 | 0 | 0 | | | | 0 | 0 | 0 | 0 | 0 | 0 | | | | 19 |
| 20 tssm_S3 | 0 | 0 | 0 | 0 | 0 | 0 | | | | 0 | 0 | 0 | 0 | 0 | 0 | Cnsmer sales tax | Govt sales tax | CGDS sales tax | 20 |
| 21 tssd_S1 | 0 | 0 | 0 | 0 | 0 | 0 | Sales taxes on domestics | | | 0 | 0 | 0 | 0 | 0 | 0 | | | | 21 |
| 22 tssd_S2 | 0 | 0 | 0 | 0 | 0 | 0 | | | | 0 | 0 | 0 | 0 | 0 | 0 | | | | 22 |
| 23 tssd_S3 | 0 | 0 | 0 | 0 | 0 | 0 | | | | 0 | 0 | 0 | 0 | 0 | 0 | | | | 23 |
| 24 tf_labor | 0 | 0 | 0 | 0 | 0 | 0 | Factor taxes | | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 24 |
| 25 tf_capital | 0 | 0 | 0 | 0 | 0 | 0 | | | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 25 |
| 26 TR_R1 | Transport margins | | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 26 |
| 27 TR_R2 | | | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 27 |
| 28 TR_R3 | | | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 28 |
| 29 S1_pvst | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 29 |
| 30 ww_R1 | Bilateral imports | | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 30 |
| 31 ww_R2 | | | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 31 |
| 32 ww_R3 | | | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 32 |
| 33 REGHOUS | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | After tax income | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 33 |
| 34 HOUS | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | Inc-Save | 0 | Trnsfrs | 0 | 34 |
| 35 SALTAX | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 35 |
| 36 PRODTAX | 0 | 0 | 0 | 0 | 0 | 0 | Production taxes | | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 36 |
| 37 DIRTAX | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | Income taxes | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 37 |
| 38 Govt | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 0 | 0 | 0 | Rtax-Trans | 0 | 0 | 0 | 38 |
| 39 CGDS | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | Depric | Trade balance | | | Net save | 0 | 0 | 0 | 39 |
| Total | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 30 | 31 | 32 | 33 | 34 | 38 | 39 | TOTAL |

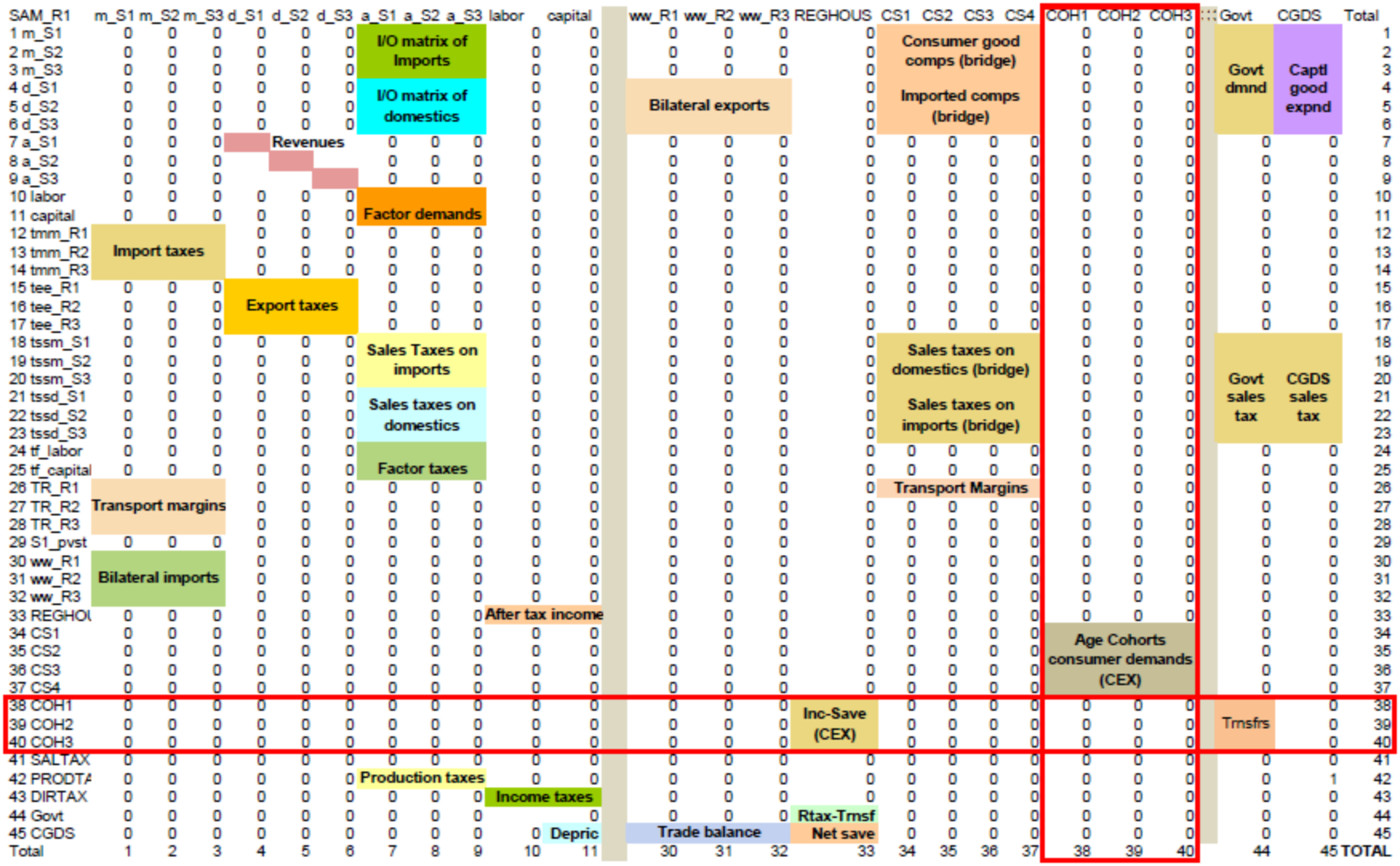
# Stages of the database construction

- Add columns and rows for consumer goods from the PCE bridge



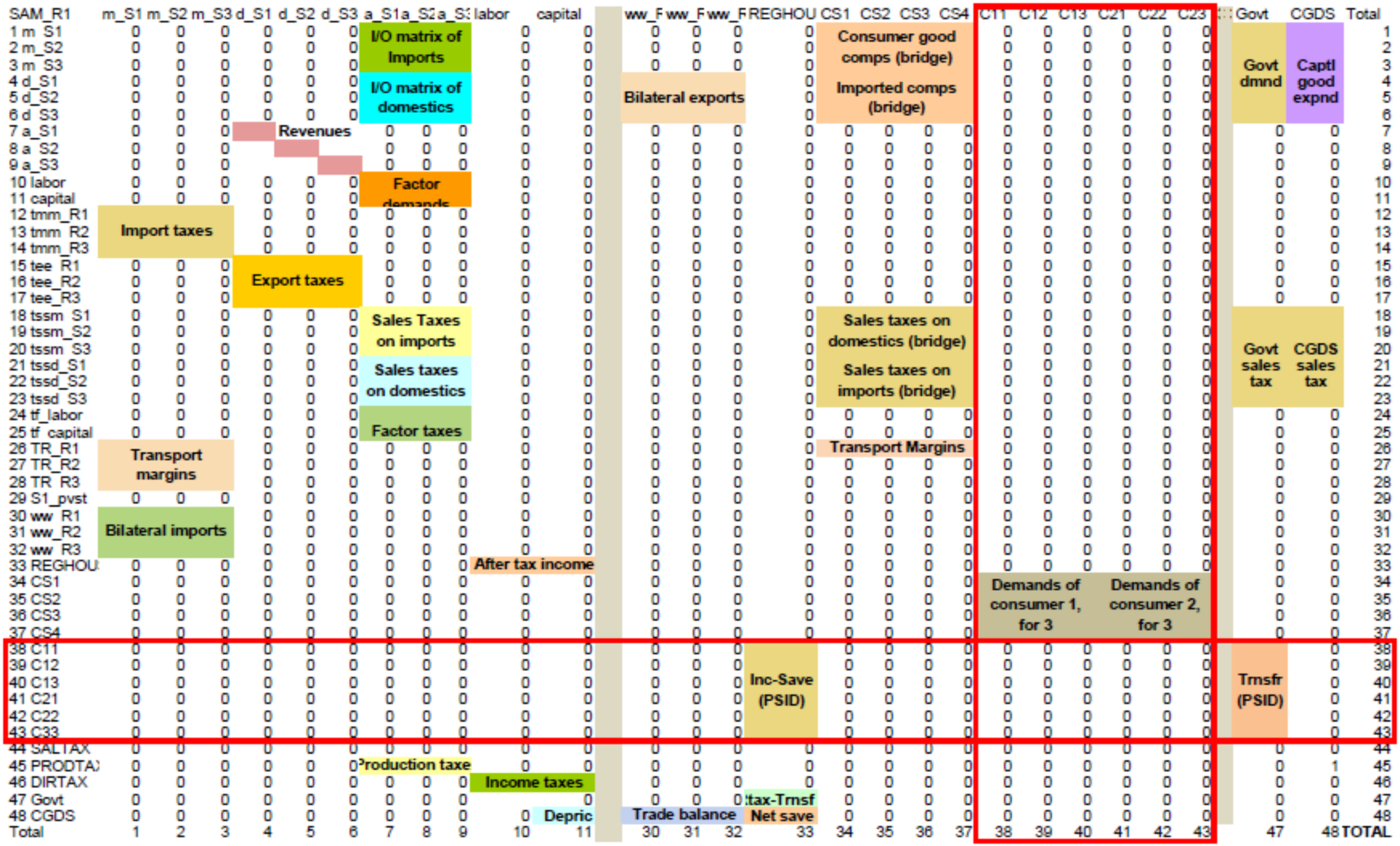
# Stages of the database construction

- Add columns and rows for consumer age cohorts using CEX



# Stages of the database construction

- Add columns and rows for each lifetime income class in each age cohort



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