Disentangling the Contemporaneous and Life-Cycle Effects of Body Mass on Earnings

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Outline

1 Motivation
   - HCEO-related questions and the question this paper tackles
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2. Empirical Approach and Data
   - What do we observe, how can we explain it?
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3 Estimation
   - Features of the dynamic empirical model
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   - Features of the dynamic empirical model

4. Results
   - Impacts on wage distribution and over life cycle
The Broad Questions We Might Like to Answer

- How can we empirically capture/model the effect of life-cycle health on productivity?
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- What are the avenues through which health over the life cycle affects productivity? (and vice-versa)
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Health ⇔ Productivity
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What do we mean by health?

- self-reported health
- development of illness (e.g., heart disease, diabetes) or disability
- chronic conditions (e.g., back pain, sleep apnea, obesity)
- mental health (e.g., depression, stress, anxiety)
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- cognitive and non-cognitive skills
- employment (e.g., OLF, unemployed, FT/PT, hours worked)
- wages
- absenteeism, short-term disability, and presenteeism
The Questions We Answer

- How can we empirically capture/model the effect of life-cycle health on productivity?
  - body mass wages

- What are the avenues through which health over the life cycle affects productivity?
  - body mass wages

- Given an estimated empirical model, how can we best quantify/simulate the life-cycle effect of health on productivity?
  - body mass wages
Pros and Cons of the Body Mass Index (BMI)

- A function of weight & height; independent of age & gender

\[
\text{BMI} = \frac{\text{weight (kg)}}{\text{height}^2 (\text{m}^2)} = \frac{\text{weight (lb)} \times 703}{\text{height}^2 (\text{in}^2)}
\]

- A simple means for classifying (sedentary) individuals
  
  \[\begin{align*}
  \text{BMI} < 18.5 : \text{underweight} \\
  18.5 \leq \text{BMI} < 25.0 : \text{ideal weight} \\
  25.0 \leq \text{BMI} < 30.0 : \text{overweight} \\
  \text{BMI} \geq 30.0 : \text{obese}
  \end{align*}\]

- May over/under estimate in those with more/less lean body mass

- May only have self-reported weight & height (subjective measure, rounding issues)

Other measures:

- skinfold, underwater weighing, fat-free mass, body volume/location
Body Mass as Females Age
(using same individuals followed over time from authors’ NLSY79 data)
Distribution of Body Mass over Time
(using repeated cross sections from NHIS data)

Density in black: 1986/1987
Vertical lines: BMI thresholds

- The distribution of BMI is changing over time.
- The mean and median have increased significantly.
- The right tail has thickened (larger percent obese).

Source: DiNardo, Garlick, Stange (2010)
What do we know about body mass and wages?

- Evidence in the economic literature that wages of white women are negatively correlated with BMI. (Cawley, 2004)
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Thus, there is some evidence of wage disparity by body mass... *contemporaneously.*
What might the contemporaneous “wage gap” represent?
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- Unmeasured productivity that is correlated with health
- Unmeasured employer preferences expected health insurance costs that are correlated with employee’s health; expected product demand correlated with employee’s physical appearance; or perhaps taste discrimination by employer or consumers
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Body mass may impact wages *indirectly* through its effects on other wage determinants:
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- **Productivity**: health, marital status, children
  defined by history of health outcomes (and health inputs) each period
  defined by history of marriage outcomes each period
  defined by history of child outcomes each period
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So, what is the life cycle effect of an evolving variable on wages, which depend on these accumulated stocks?
The Big Picture

Body Mass \( t \) → Wages \( t \)

\( t - 1 \) → \( t \) → \( t + 1 \)
The Big Picture

History$_t$ of:

- Schooling
- Employment
- Marriage
- Children

$\text{Body Mass}_t$

$\text{Wages}_t$

$t - 1 \quad t \quad t + 1$
The Big Picture

Info known entering period $t$

History$_t$ of:

- Schooling
- Employment
- Marriage
- Children

Body Mass$_t$

Wages$_t$

$t - 1$  $t$  $t + 1$
The Big Picture

Info known entering period $t$

History$_t$ of:
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- Employment
- Marriage
- Children

Body Mass$_t$

- Employment

Wages$_t$

$t - 1$  $t$  $t + 1$
The Big Picture

Info known entering period $t$

History$_t$ of:
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Body Mass$_t$

Current Decisions$_t$:
- Schooling
- Employment
- Marriage
- Children

Wages$_t$

$t - 1$  $t$  $t + 1$
The Big Picture

Info known entering period $t$

History$_t$ of:

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- Employment
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- Children

Current Decisions$_t$:

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- Employment
- Marriage
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- Wages$_t$

$\text{Body Mass}_t$

$t - 1$ $t$ $t + 1$
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History$_t$ of:
- Schooling
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- Children

Current Decisions$_t$:
- Schooling
- Employment
- Marriage
- Children
- Wages$_t$

Body Mass$_t$

Body Mass$_{t+1}$

$\text{History}_t$ of:
- Schooling
- Employment
- Marriage
- Children

$\text{Current Decisions}_t$:
- Schooling
- Employment
- Marriage
- Children
- Wages$_t$

$\text{Body Mass}_t$

$\text{Body Mass}_{t+1}$

$t - 1$

$t$

$t + 1$
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- Schooling
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Current Decisions$_t$:
- Schooling
- Employment
- Marriage
- Children

$t - 1$  $t$  $t + 1$

Body Mass$_t$

Wages$_t$

Body Mass$_{t+1}$
The Big Picture

Info known entering period $t$

History$_t$ of:
- Schooling
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Current Decisions$_t$:
- Schooling
- Employment
- Marriage
- Children

$Wages_t$

$Caloric Intake_t$

$Caloric Expenditure_t$

$Body\ Mass_{t+1}$

$t - 1$

$t$

$t + 1$
The Big Picture

Info known entering period $t$

History$_{t}$ of:
- Schooling
- Employment
- Marriage
- Children

Current Decisions$_{t}$:
- Schooling
- Employment
- Marriage
- Children

$t - 1$ $t$ $t + 1$

$Wages_{t}$ $Caloric \text{ Intake}_{t}$ $Caloric \text{ Expenditure}_{t}$

$Body \text{ Mass}_{t}$ $Body \text{ Mass}_{t+1}$

Prices$_{t}$

$\text{Contemporaneous}$ $\text{Life-Cycle}$
The Big Picture

History\(_t\) of:
- Schooling
- Employment
- Marriage
- Children

Current Decisions\(_t\):
- Schooling
- Employment
- Marriage
- Children

Body Mass\(_t\)

Wages\(_t\)

Caloric Intake\(_t\)
Caloric Expenditure\(_t\)

Body Mass\(_{t+1}\)

\(t - 1\) \hspace{2cm} \(t\) \hspace{2cm} \(t + 1\)
The Big Picture

Info known entering period $t$

History$_t$ of:
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- Employment
- Marriage
- Children

Current Decisions$_t$:
- Schooling
- Employment
- Marriage
- Children

Body Mass$_t$

$t - 1$

$t$

$t + 1$

Caloric Intake$_t$
Caloric Expenditure$_t$

Prices$_t$

Body Mass$_{t+1}$
The Big Picture

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History$_t$ of:
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- Employment
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Current Decisions$_t$:
- Schooling
- Employment
- Marriage
- Children

Body Mass$_t$

Contemporaneous

$t - 1$

$t$

$t + 1$

Prices$_t$

Caloric Intake$_t$

Caloric Expenditure$_t$
The Big Picture

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Current Decisions$_t$:
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- Employment
- Marriage
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Body Mass$_t$

Wages$_t$

Prices$_t$

Life Cycle
Contemporaneous

Caloric Intake$_t$
Caloric Expenditure$_t$

$t - 1$
$t$
$t + 1$
Features of our Empirical Model

- **Panel data:**
  - Estimated using 20 years of data on the same individuals
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- **Jointly-estimated, multiple-equation, dynamic model:**
  - Allows BMI to affect wages contemporaneously, but also incorporates the dynamic effects of BMI through other endogenous pathways (e.g., educ, exp, marriage, and kids)
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- **Conditional Density Estimation:**
  - Estimates a distribution-free density (of wages and BMI) conditional on endogenous variables that may have different effects at different levels of the dependent variable
## Data: National Longitudinal Survey of Youth (NLSY79)

<table>
<thead>
<tr>
<th>Year</th>
<th>Sample Size</th>
<th>Attriters</th>
<th>Attrition Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>1983</td>
<td>3,213</td>
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<td>-</td>
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<tr>
<td>1984</td>
<td>3,213</td>
<td>67</td>
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<tr>
<td>1985</td>
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<tr>
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<tr>
<td>2002</td>
<td>1,878</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

Number of person-year observations: 51,884
The Big Picture

Info known entering period $t$

History$_t$ of:
- Schooling
- Employment
- Marriage
- Children

Current Decisions$_t$:
- Schooling
- Employment
- Marriage
- Children

Body Mass$_t$

Body Mass$_{t+1}$

Wages$_t$

Prices$_t$

Caloric Intake$_t$
Caloric Expenditure$_t$

Life Cycle
Contemporaneous

$t - 1$
$t$
$t + 1$
Information entering period $t$

\[ \Omega_t = (B_t, S_t, E_t, M_t, K_t, X_t, P_t) \]

Endogenous variables

- **Body Mass History** $B_t$
  - BMI in $t$
  - Ever overweight ($25 \leq \text{BMI} < 30$) prior to $t$
  - Ever obese ($\text{BMI} \geq 30$) prior to $t$
  - Standardized deviations from mean BMI at $t$ by race

- **Schooling History** $S_t$
  - Enrolled in $t - 1$
  - Years enrolled in school entering $t$
  - Years enrolled $\geq 12$ entering $t$
  - Years enrolled $\geq 16$ entering $t$
  - First year of college in $t$
Information entering period $t$

$$\Omega_t = (B_t, S_t, E_t, M_t, K_t, X_t, P_t)$$

Endogenous variables

- **Employment History** $E_t$
  - Employed in $t - 1$
  - Employed part time in $t - 1$
  - Years employed entering $t$
  - Years part time employed entering $t$

- **Marital History** $M_t$
  - Married in $t - 1$
  - Years married entering $t$ if married in $t - 1$
  - Years single entering $t$ is single in $t - 1$ and ever married

- **Child History** $K_t$
  - Number of children in the household entering $t$
  - Increase in number of children in household from $t - 1$ to $t$
  - Decrease in number of children in household from $t - 1$ to $t$
Information entering period $t$

$$
\Omega_t = (B_t, S_t, E_t, M_t, K_t, X_t, P_t)
$$

- Exogenous Demographics $X_t$
  - Age
  - Race: white, black
  - AFQT score
  - Non-earned income
  - Urbanicity: urban, rural
  - Region of country: northeast, northcentral, west, south
  - Time trend
Information entering period $t$

$$\Omega_t = (B_t, S_t, E_t, M_t, K_t, X_t, P_t)$$

↑ Price and Supply Side Variables $P_t$
that vary at the state and local level

- **Schooling-related $P^s_t$**
  - Two-year college semester tuition (000s)
  - Four-year college semester tuition (000s)
  - Graduate school semester tuition (000s)

- **Employment-related $P^e_t$**
  - Unemployment rate
  - Total employment per capita
  - Ratio of manufacturing employment to total employment
  - Ratio of service employment to total employment
  - Total earnings per employee
  - Ratio of manufacturing earnings to total earnings
  - Ratio of service earnings to total earnings
Information entering period $t$

$$\Omega_t = (B_t, S_t, E_t, M_t, K_t, X_t, P_t)$$

- **Marriage and Children-related** $P^m_t, P^k_t$
  - Total population (000,000s)
  - Gender ratio by race (males, aged 20-60/ females, aged 15-50)
  - Mean Household income (000s)
  - AFDC per month for family of four (00s)

- **Body Mass-related** $P^b_t$
  - Mean price of food
  - Mean price of junk food
  - Mean price of carton of cigarettes
  - Mean price of 6-pack of beer
  - Mean price of bottle of wine
  - Mean price of liter of liquor
  - Ratio of food sales to total retail sales
  - Ratio of restaurant sales to total retail sales

$\uparrow$ Optimization Problem
Jointly-Estimated Set of Equations ... so far...

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<thead>
<tr>
<th>Outcome</th>
<th>Estimator</th>
<th>Explanatory Variables</th>
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<td></td>
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<td>Endogenous</td>
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<tr>
<td>Enrolled</td>
<td>$s_t$</td>
<td>logit</td>
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<tr>
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<td>$e_t$</td>
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<tr>
<td>Married</td>
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<td>△ Kids</td>
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<td>$X_t, P^s_t, P^e_t, P^m_t, P^k_t, P^b_t$</td>
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<td>$X_t, P^s_t, P^e_t, P^m_t, P^k_t, P^b_t$</td>
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<td>$X_t, P^s_t, P^e_t, P^m_t, P^k_t, P^b_t$</td>
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<td>$X_t, P^e_t$</td>
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Jointly-Estimated Set of Equations ... so far...

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BMI Equation
Jointly-Estimated Set of Equations ... so far...

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<td>(X_{t} ), (P_{t}^{s} ), (P_{t}^{e} ), (P_{t}^{m} ), (P_{t}^{k} ), (P_{t}^{b} )</td>
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### Initial Observed State Variables

- \(X_1\), \(P_1\), \(Z_1\)

---

**Motivation**

- **Empirical Approach and Data**
- **Estimation**
- **Results**
Unobserved Heterogeneity

(Discrete Factor Random Effects: Heckman and Singer, 1984; Guilkey and Mroz, 1992; Mroz, 1999)

- Permanent: rate of time preference, genetics
- Time-varying: unmodeled stressors, health shocks
Unobserved Heterogeneity

(Discrete Factor Random Effects: Heckman and Singer, 1984; Guilkey and Mroz, 1992; Mroz, 1999)

- Permanent: rate of time preference, genetics
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The unobserved part of equation $e$, $u_t^e$, is decomposed into three components:

$$u_t^e = \rho^e \mu + \omega^e \nu_t + \epsilon_t^e$$
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The unobserved part of equation $e$, $u_t^e$, is decomposed into three components:

$$u_t^e = \rho^e \mu + \omega^e \nu_t + \epsilon_t^e$$

where the first two unobservables are modeled as random effects:

- permanent heterogeneity factor $\mu$ with factor loading $\rho^e$
- time-varying heterogeneity factor $\nu_t$ with factor loading $\omega^e$
- iid component $\epsilon_t^e$

distributed $N(0, \sigma_e^2)$ for continuous equations and Extreme Value for dichotomous/polychotomous outcomes
How should we estimate wages (and body mass index)?

OLS?

- It quantifies how variation in the rhs variables \(Z\) explain variation in the lhs variable \(W\), on average.
- It explains how the mean of \(W\) varies with \(Z\).
- In estimation, we also recover the variance of \(W\).
- The mean and variance of \(W\), and a distributional assumption, describe the distribution of \((\log)\) offered wages.

Using OLS, we obtain the marginal effect of \(Z\) on \(W\), on average.
How should we estimate wages (and body mass index)?

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- In estimation, we also recover the variance of $W$.
- The mean and variance of $W$, and a distributional assumption, describe the distribution of (log) offered wages.

Using OLS, we obtain the marginal effect of $Z$ on $W$, on average.

But what if $Z$ has a different effect on $W$ at different values of $W$?
What do hourly wages (among the employed) look like?
A flexible way to model the density
A flexible way to model the density

\[ p[w_{k-1} \leq W \leq w_k \mid Z] = \int_{w_{k-1}}^{w_k} f(w \mid Z) dw \]
A flexible way to model the density

\[ p[w_{k-1} \leq W \leq w_k | Z] = \int_{w_{k-1}}^{w_k} f(w | Z) dw \]

\[ \lambda(k, Z) = \frac{p[w_{k-1} \leq W \leq w_k | Z, W \geq w_{k-1}]}{\int_{w_0}^{w_{k-1}} f(w | Z) dw} = \frac{\int_{w_{k-1}}^{w_k} f(w | Z) dw}{1 - \int_{w_0}^{w_{k-1}} f(w | Z) dw} \]
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\[ = \frac{\int_{w_{k-1}}^{w_k} f(w | Z) dw}{1 - \int_{w_0}^{w_{k-1}} f(w | Z) dw} \]

\[ p[w_{k-1} \leq W \leq w_k | Z] = \lambda(k, Z) \prod_{j=1}^{k-1} [1 - \lambda(j, Z)] \]

\[ E[W | Z] = \sum_{k=1}^{K} \bar{w}(k | K) \lambda(k, Z) \prod_{j=1}^{k-1} [1 - \lambda(j, Z)] \]
Conditional Density Estimation
(Gilleskie and Mroz, 2004)

- Determine cut points such that $\frac{1}{K}$ of individuals are in each cell.
Conditional Density Estimation
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- Determine cut points such that $\frac{1}{K}$th of individuals are in each cell.
- Then, the probability of being in the kth cell, conditional on not being in a previous cell, is $1 \frac{1}{K-(k-1)}$. 
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- Determine cut points such that $\frac{1}{K}^{th}$ of individuals are in each cell.
- Then, the probability of being in the kth cell, conditional on not being in a previous cell, is $\frac{1}{K - (k - 1)}$.
- Define a cell indicator:
  \[ \gamma_k = -\ln(K - k) \text{ for } k < K, \]
  such that $\text{logit}(\gamma_k) = \frac{e^{\gamma_k}}{1 + e^{\gamma_k}}$. 
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- Replicate each observation $K$ times and create a 0/1 dependent variable indicating into which cell the individual's wage falls.
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Replicated Results (from literature):
Estimated Effects of Body Mass on Wages using OLS model

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<th>Model 2</th>
<th>Model 3</th>
<th>Model 4</th>
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<td>(0.002)</td>
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<tr>
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<tr>
<td></td>
<td>(0.002)</td>
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Method         OLS on lnW  
               clustered std err

Model Spec     $X_t, B_t$

R-squared      0.28

Marginal Effect of Overweight to Normal (in cents)
White: 0.31
Black: 0.08
### Replicated Results (from literature):
**Estimated Effects of Body Mass on Wages using OLS on lnW model**

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<td>( BMI_t )</td>
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<td>(-0.007) ( ^* ^* ^* )</td>
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<td>R-squared</td>
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<td>Marginal Effect</td>
<td>White: 0.31</td>
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<td>of Overweight</td>
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<td>0.27</td>
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<td>-0.006</td>
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Method
OLS on \(\ln W\)  
clustered std err

Model Spec
\(X_t, B_t\)  
\(X_t, B_t\)  
\(X_t, B_t\)  
\(S_t, E_t, M_t, K_t\)  
\(S_t, E_t, M_t, K_t, P_t^e\)

R-squared
0.28  
0.40  
0.42

Marginal Effect
White: 0.31  
0.27  
0.25
Black: 0.08  
0.12  
0.12
## Replicated Results (from literature):
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<th>Model 2</th>
<th>Model 3</th>
<th>Model 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>$BMI_t$</td>
<td>-0.008 (0.002)</td>
<td>-0.007 (0.002)</td>
<td>-0.006 (0.002)</td>
<td>-0.003 (0.002)</td>
</tr>
<tr>
<td></td>
<td>** * * *</td>
<td>** * * *</td>
<td>** * * *</td>
<td>*</td>
</tr>
<tr>
<td>$BMI_t \times \text{Black}$</td>
<td>0.006 (0.002)</td>
<td>0.003 (0.002)</td>
<td>0.003 (0.002)</td>
<td>0.004 (0.003)</td>
</tr>
</tbody>
</table>

**Method**
- OLS on lnW clustered std err
- OLS on lnW clustered std err
- OLS on lnW clustered std err
- OLS on lnW fixed effects

**Model Spec**
- $X_t, B_t$
- $X_t, B_t$
- $X_t, B_t$
- $X_t, B_t$
- $S_t, E_t, M_t, K_t$
- $S_t, E_t, M_t, K_t, P^e_t$
- $S_t, E_t, M_t, K_t, P^e_t$

**R-squared**
- 0.28
- 0.40
- 0.42
- 0.35

**Marginal Effect**
- **White:** 0.31
- 0.27
- 0.25
- 0.12
- **Black:** 0.08
- 0.12
- 0.12
- -0.02

(in cents)
**Single Equation QR and CDE Results for Females:**
The Role of Body Mass on Wages across the Support of Wages

<table>
<thead>
<tr>
<th>Variable</th>
<th>25th</th>
<th>50th</th>
<th>75th</th>
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<tbody>
<tr>
<td>$BMI_t$</td>
<td>-0.054</td>
<td>-0.068</td>
<td>-0.083</td>
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<tr>
<td></td>
<td>(0.008)</td>
<td>(0.006)</td>
<td>(0.010)</td>
</tr>
<tr>
<td></td>
<td><strong>∗∗∗</strong></td>
<td><strong>∗∗∗</strong></td>
<td><strong>∗∗∗</strong></td>
</tr>
<tr>
<td>$BMI_t \times$ Black</td>
<td>0.028</td>
<td>0.043</td>
<td>0.049</td>
</tr>
<tr>
<td></td>
<td>(0.009)</td>
<td>(0.007)</td>
<td>(0.012)</td>
</tr>
<tr>
<td></td>
<td><strong>∗∗</strong></td>
<td><strong>∗∗∗</strong></td>
<td><strong>∗∗∗</strong></td>
</tr>
</tbody>
</table>

Model Spec

$X_t, B_t$
$S_t, E_t, M_t, K_t, P_e$

Marginal Effect of Improvement from Overweight to Normal Weight (at the point estimates)

<table>
<thead>
<tr>
<th></th>
<th>White</th>
<th>Black</th>
</tr>
</thead>
<tbody>
<tr>
<td>25th</td>
<td>0.19</td>
<td>0.08</td>
</tr>
<tr>
<td>50th</td>
<td>0.24</td>
<td>0.11</td>
</tr>
<tr>
<td>75th</td>
<td>0.28</td>
<td>0.18</td>
</tr>
</tbody>
</table>

QR Average
White: 0.24  Black: 0.10

CDE Average
White: 0.23  Black: 0.12
Comparison of Observed Data to Model Predictions
Comparison of Observed Data to Model Predictions

- Employed full time at age a
- Employed part time at age a
- Body mass at age a
- Hourly wage at age a

Legend:
- Red line: White - observed
- Dashed red line: White - simulated
- Black line: Black - observed
- Dotted black line: Black - simulated
Simulations to determine contemporaneous effect

Consider an improvement in health (i.e., a reduction in body mass)

- Calculate (simple) marginal effect of
  - an x% decrease in BMI,
  - or one unit decrease in BMI,
  - or going from overweight (BMI 27.5) to normal weight (BMI 24)

on wages (i.e., the contemporaneous effect).
Simulations to determine contemporaneous effect

Consider an improvement in health (i.e., a reduction in body mass)

- Calculate (simple) marginal effect of
  - an x% decrease in BMI,
  - or one unit decrease in BMI,
  - or going from overweight (BMI 27.5) to normal weight (BMI 24)

on wages (i.e., the contemporaneous effect).

That is, hold all other determinants of wage constant
(regardless of how those might have been influenced
by the history of one’s body mass)
Contemporaneous Effect of BMI Reduction on Wages
(without and with unobserved heterogeneity)
Simulations to determine life-cycle effect
Simulations to determine life-cycle effect

- We can impose
  - normal weight (or overweight, obese) throughout the life cycle
Simulations to determine life-cycle effect

- We can impose
  - normal weight (or overweight, obese) throughout the life cycle
  - becoming overweight early (or later) in life cycle
Simulations to determine life-cycle effect

- We can impose
  - normal weight (or overweight, obese) throughout the life cycle
  - becoming overweight early (or later) in life cycle
  - gaining weight steadily over the life cycle
Simulations to determine life-cycle effect

- We can impose
  - normal weight (or overweight, obese) throughout the life cycle
  - becoming overweight early (or later) in life cycle
  - gaining weight steadily over the life cycle
  - normal weight at age 18, and endogenous weight over time

We can impose normal weight (or overweight, obese) throughout the life cycle becoming overweight early (or later) in life cycle gaining weight steadily over the life cycle normal weight at age 18, and endogenous weight over time
Simulations to determine life-cycle effect

- We can impose
  - normal weight (or overweight, obese) throughout the life cycle
  - becoming overweight early (or later) in life cycle
  - gaining weight steadily over the life cycle
  - normal weight at age 18, and endogenous weight over time

- and compare
  - average wages over the life cycle
  - age 40 average wage
  - age 40 distribution of wages?
Simulations to determine life-cycle effect

- We can impose
  - normal weight (or overweight, obese) throughout the life cycle
  - becoming overweight early (or later) in life cycle
  - gaining weight steadily over the life cycle
  - normal weight at age 18, and endogenous weight over time

- and compare
  - average wages over the life cycle
  - age 40 average wage
  - age 40 distribution of wages?

Today’s simulation: the impact of being overweight over the life cycle compared to being normal weight over the life cycle.
Life-Cycle Effect of BMI Reduction on Wages

[Graph showing the hourly wage difference by decile for different wage levels, with lines for white and black individuals, both contemporaneous and life-cycle effects.]
Evidence of Life Cycle Impact...

Life cycle "better health" has an impact... *Why? How?*
Evidence of Life Cycle Impact...

Life cycle "better health" has an impact... Why? How?

- An additional year of education and work experience increase hourly wages (by $1.15 and $0.85 and by $0.27 and $0.30, for white and black females respectively). ▶ Figures
Evidence of Life Cycle Impact...

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- An additional year of education and work experience increase hourly wages (by $1.15 and $0.85 and by $0.27 and $0.30, for white and black females respectively).

- How does life-cycle weight improvement affect investment in human capital?
Evidence of Life Cycle Impact...

Life cycle "better health" has an impact... *Why? How?*

- An additional year of education and work experience increase hourly wages (by $1.15 and $0.85 and by $0.27 and $0.30, for white and black females respectively).  

- How does life-cycle weight improvement affect investment in human capital?  

  - the probability of enrollment increases early but decreases later  
  - the probability of full time employment decreases (by 2 and 4 percentage points); greater reduction for blacks as they age  
  - white females substitute part time employment for full time employment; black females substitute this way also, but are more likely to be non-employed
Evidence of Life Cycle Impact...

Life cycle “better health” has an impact... *Why? How?*

- And, what happens to productivity measures (other than health) that may be impacted by body mass over time? Marital status and Number of children? ▶ Figures
Evidence of Life Cycle Impact...

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  - White females have fewer children in the household. Blacks have fewer earlier.
- Marriage and children histories reduce wages.
Evidence of Life Cycle Impact...

Life cycle “better health” has an impact... *Why? How?*

- And, what happens to productivity measures (other than health) that may be impacted by body mass over time? Marital status and Number of children? 

  - Females are more likely to be married, and to be married longer, when in better health. Whites marry earlier.
  - White females have fewer children in the household. Blacks have fewer earlier.

- Marriage and children histories reduce wages.

- But these also impact schooling and work decisions over time.
Impacts of BMI Reduction on Wages over the Life Cycle

a.) Unconditional on employment

b.) Conditional on being employed
Concluding Remarks...

- The contemporaneous wage penalty attributed to body mass is smaller when unobserved permanent and time-varying heterogeneity is modeled.
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There are sizable effects of body mass on life-cycle behaviors that also impact wages.
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These are wage impacts and not welfare impacts.
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Individual’s Optimization Problem — 1

Let $d_{t}^{semk}$ indicate the schooling ($s$), employment ($e$), marriage ($m$), and kids ($k$) alternative in period $t$.

<table>
<thead>
<tr>
<th></th>
<th>$s = 0, 1$</th>
<th>$e = 0, 1, 2$</th>
<th>$m = 0, 1$</th>
<th>$k = 0, 1, 2$</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(not in school, in school)</td>
<td>(not employed, employed full time</td>
<td>(not married, married)</td>
<td>(no change in # of kids, increase hh size, decrease hh size)</td>
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- $e = 0, 1, 2$ (not employed, employed full time, employed part time)
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- $k = 0, 1, 2$ (no change in # of kids, increase hh size, decrease hh size)

$$V_{semk}(\Omega_t, \epsilon_t | w_t)$$

info entering period
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$$V_{semk}(\Omega_t, \epsilon_t \mid w_t)$$

info entering period

$$\Omega_t = (B_t, S_t, E_t, M_t, K_t, X_t, P_t)$$
Individual’s Optimization Problem — 1

Let $d_t^{semk}$ indicate the schooling $(s)$, employment $(e)$, marriage $(m)$, and kids $(k)$ alternative in period $t$.

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$k = 0, 1, 2$  
(no change in # of kids, increase hh size, decrease hh size)

$$V_{semk}(\Omega_t, \epsilon_t | w_t) = U(\underbrace{C_t, C_t^I}_{consumption}, \underbrace{L_t, L_t^E}_{leisure}, \underbrace{K_t, d_t^{semk}}_{kids & marriage}, \underbrace{B_t, X_t, \epsilon_t^{semk}}_{preference shifters})$$

$$\Omega_t = (B_t, S_t, E_t, M_t, K_t, X_t, P_t)$$
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Let $d_t^{semk}$ indicate the schooling ($s$), employment ($e$), marriage ($m$), and kids ($k$) alternative in period $t$.

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(e = 0, 1, 2  
$m = 0, 1$  
$k = 0, 1, 2$

(not in school, in school)  
(not employed, employed full time  
(not married, married)  
(increase hh size, decrease hh size)

$$V_{semk} \left( \Omega_t, \epsilon_t \middle| w_t \right) = U(\underbrace{C_t, C_t^l \star, L_t, L_t^E \star, K_t, d_t^{semk}, B_t, X_t, \epsilon_t^{semk}}_{\text{consumption}, \text{leisure}, \text{kids & marriage}}, \underbrace{B_t, X_t, \epsilon_t^{semk}}_{\text{info entering period, preference shifters}})$$

$$+ \beta \int_B \int_W \int_\epsilon [\max_{(semk)'} V_{(semk)'} \left( \Omega_{t+1}, w_{t+1}, \epsilon_{t+1} \right) | d_{t+1}^{semk}=1] f_B(B) f_W(W) f(\epsilon) dB dW d\epsilon$$

$$\Omega_t = (B_t, S_t, E_t, M_t, K_t, X_t, P_t)$$
Individual’s Optimization Problem — 2

\[ V_{semk}(\Omega_t, \epsilon_t | w_t) = U(C_t, C_t^*, L_t, L_t^E, K_t, d_t^{semk}; B_t, X_t, \epsilon_{semk}^t) \]

\[ + \beta \int_B \int_W \int_\epsilon \left[ \max_{(semk)} V_{(semk)}'(\Omega_{t+1}, w_{t+1}, \epsilon_{t+1}) | d_t^{semk} = 1 \right] f_b(B) f_w(W) f(\epsilon) dB dW d\epsilon \]
Individual’s Optimization Problem — 2

\[ V_{semk}(\Omega_t, \epsilon_t | w_t) = U(C_t, C_t^*, L_t, L_t^E, K_t, d_t^{semk}; B_t, X_t, \epsilon_t^{semk}) \]

\[ + \beta \int_B \int_W \int_\epsilon \left[ \max_{(semk)'} V_{(semk)'}((\Omega_{t+1}, w_{t+1}, \epsilon_{t+1}) | d_t^{semk} = 1) \right] f_b(B) f_w(W) f(\epsilon) d_B d_W d_\epsilon \]

\[ C_t + P^b_t \cdot C_t^* \]

optimal caloric intake
Individual’s Optimization Problem — 2

\[ V_{semk}(\Omega_t, \epsilon_t | w_t) = U(C_t, C_t^*, L_t, L_t^E, K_t, d_t^{semk}; B_t, X_t, \epsilon_t^{semk}) \]

\[ + \beta \int_B \int_W \int_\epsilon \left[ \max_{(semk)'} V_{(semk)'}(\Omega_{t+1}, w_{t+1}, \epsilon_{t+1}) | d_t^{semk} = 1 \right] f_B(B) f_W(W) f(\epsilon) d_B d_W d_\epsilon \]

\[ C_t + P_t^b \cdot C_t^* = w_t \cdot 1000 \cdot e \cdot (1 - d_t^{s0mk}) + Y_t \cdot d_t^{se1k} + N_t \]

earned income

non-earned income

optimal caloric intake
Individual’s Optimization Problem — 2

\[ V_{semk}(\Omega_t, \epsilon_t | w_t) = U(C_t, C_t^*, L_t, L_t^{E*}, K_t, d_t^{semk}; B_t, X_t, \epsilon_t^{semk}) \]

\[ + \beta \int_B \int_W \int_\epsilon [\max_{(semk)} V_{(semk)}(\Omega_{t+1}, w_{t+1}, \epsilon_{t+1})|d_t^{semk}=1] f_b(B) f_w(W) f(\epsilon) dB dW d\epsilon \]

\[ C_t + P_t^b \cdot C_t^* = \begin{cases} \text{earned income} \hspace{1cm} \text{non-earned income} \\ \text{optimal caloric intake} \end{cases} \]

\[ = w_t \cdot 1000 \cdot e \cdot (1 - d_t^{s0mk}) + Y_t \cdot d_t^{se1k} + N_t \]

\[ - P_t^s \cdot d_t^{1emk} - P_t^k \cdot (K_t + d_t^{sem1} - d_t^{sem2} + d_t^{se1k}) \]

\[ \text{earned income} \hspace{1cm} \text{non-earned income} \]

\[ \text{optimal caloric intake} \]

\[ \text{earned income} \hspace{1cm} \text{non-earned income} \]

\[ \text{optimal caloric intake} \]

\[ \text{earned income} \hspace{1cm} \text{non-earned income} \]

\[ \text{optimal caloric intake} \]
Individual’s Optimization Problem — 2

\[ V_{semk}(\Omega_t, \epsilon_t | w_t) = U(C_t, C_t^*, L_t, L_t^E^*, K_t, d_t^{semk}; B_t, X_t, \epsilon_t^{semk}) \]

\[ + \beta \int_B \int_W \int_\epsilon \left[ \max_{(semk)} V_{(semk)}(\Omega_{t+1}, w_{t+1}, \epsilon_{t+1}) \right] d_t^{semk} = 1 \] \[ f_b(B) f_w(W) f(\epsilon) d_B d_W d_\epsilon \]

\[ C_t + P_t^b \cdot C_t^* = \underbrace{w_t \cdot 1000 \cdot e \cdot (1 - d_t^{s0mk})}_{\text{earned income}} + \underbrace{Y_t \cdot d_t^{se1k} + N_t}_{\text{non-earned income}} \]

\[ = \underbrace{w_t \cdot 1000 \cdot e \cdot (1 - d_t^{s0mk})}_{\text{optimal caloric intake}} \]

\[ - P_t^s \cdot d_t^{1emk} - P_t^k \cdot (K_t + d_t^{sem1} - d_t^{sem2} + d_t^{se1k}) \]

\[ L_t + L_t^E^* \]

\[ = \underbrace{w_t \cdot 1000 \cdot e \cdot (1 - d_t^{s0mk})}_{\text{optimal caloric expenditure}} \]

\[ tuition \]

\[ family\ consumption \]
Individual’s Optimization Problem — 2

\[ V_{semk}(\Omega_t, \epsilon_t | w_t) = U(C_t, C_t^{l*}, L_t, L_t^{E*}, K_t, d_t^{semk}; B_t, X_t, \epsilon_t^{semk}) \]

\[ + \beta \int_B \int_W \int_\epsilon \left[ \max_{(semk)}(\Omega_{t+1}, w_{t+1}, \epsilon_{t+1}) | d_t^{semk} = 1 \right] f_B(B) f_W(W) f(\epsilon) d_B d_W d_\epsilon \]

\[ C_t + P_t^b \cdot C_t^{l*} = \underbrace{w_t \cdot 1000 \cdot e \cdot (1 - d_t^{s0mk})}_{\text{earned income}} + Y_t \cdot d_t^{se1k} + N_t \]

\[ L_t + L_t^{E*} = T_t - 1000 \cdot e \cdot (1 - d_t^{s0mk}) - P_t^s \cdot d_t^{1emk} \]

\[ \text{optimal caloric intake} \]

\[ - P_t^s \cdot d_t^{1emk} - P_t^k \cdot (K_t + d_t^{sem1} - d_t^{sem2} + d_t^{se1k}) \]

\[ \text{tuition} \quad \text{family consumption} \]

\[ \text{optimal caloric expenditure} \]

\[ \text{time working} \quad \text{time in school} \]
Individual’s Optimization Problem — 2

\[ V_{semk}(\Omega_t, \epsilon_t|w_t) = U(C_t, C_t^{'*}, L_t, L_t^{'*}, K_t, d_t^{semk}; B_t, X_t, \epsilon_t^{semk}) \]

\[ + \beta \int_B \int_W \int_{\epsilon} \left[ \max_{(semk)'} V_{(semk)'}(\Omega_{t+1}, w_{t+1}, \epsilon_{t+1}) | d_t^{semk} = 1 \right] f_B(B) f_W(W) f(\epsilon) d_B d_W d_\epsilon \]

\[ C_t + P_t^b \cdot C_t^{'*} = w_t \cdot 1000 \cdot e \cdot (1 - d_t^{s0mk}) + Y_t \cdot d_t^{se1k} + N_t \]

- **earned income**
  - optimal caloric intake
    - tuition
    - family consumption
  - time working
  - time in school
  - time with family
Individual’s Optimization Problem — 3

lifetime value of alternative semk at period $t$

$$V_{semk}(\Omega_t, \epsilon_t | w_t) = U(C_t, C_t^*, L_t, L_t^{E*}, K_t, d_t^{semk}; B_t, X_t, \epsilon_{t\, semk})$$

$$+ \beta \int_B \int_W \int_\epsilon \left[ \max_{(semk)'} V_{(semk)'}(\Omega_{t+1}, w_{t+1}, \epsilon_{t+1}) | d_{t\, semk} = 1 \right] f_B(B) f_W(W) f(\epsilon) dB dW d\epsilon$$

budget constraint

$$C_t + P_b \cdot C_t^* = w_t \cdot 1000 \cdot e \cdot (1 - d_t^{s0mk}) + Y_t \cdot d_t^{selk} + N_t - P_s \cdot d_t^{lemk} - P_k \cdot (K_t + d_t^{sem1} - d_t^{sem2} + d_t^{selk})$$

time constraint

$$L_t + L_t^{E*} = T_t - 1000 \cdot e \cdot (1 - d_t^{s0mk}) - P_s \cdot d_t^{lemk} - P_k \cdot (K_t + d_t^{sem1} - d_t^{sem2} + d_t^{selk})$$
Individual's Optimization Problem — 3

lifetime value of alternative $semk$ at period $t$

$$V_{semk}(\Omega_t, \epsilon_t | w_t) = U(C_t, C_{t^*}, L_t, L^E_{t^*}, K_t, d_{t|semk}^t; B_t, X_t, \epsilon_{t|semk}^t)$$

$$+ \beta \int_B \int_W \int_{\epsilon} \left[ \max_{(semk)} V_{(semk)}((\Omega_{t+1}, w_{t+1}, \epsilon_{t+1}) | d_{t|semk}^t = 1) \right] f_B(B) f_W(W) f(\epsilon) dB dW d\epsilon$$

budget constraint

$$C_t + P^b_t \cdot C_{t^*} = w_t \cdot 1000 \cdot e \cdot (1 - d_t^{s0mk}) + Y_t \cdot d_{t|semk}^t + N_t - P^s_t \cdot d_{t|1emk}^t - P^k_t \cdot (K_t + d_{t|sem1}^t - d_{t|sem2}^t + d_{t|se1k}^t)$$

time constraint

$$L_t + L^E_{t^*} = T_t - 1000 \cdot e \cdot (1 - d_t^{s0mk}) - P^s_t \cdot d_{t|1emk}^t - P^k_t \cdot (K_t + d_{t|sem1}^t - d_{t|sem2}^t + d_{t|se1k}^t)$$

body mass distribution

$$B_{t+1} \sim F_b(B_t, C_{t^*}, L^E_{t^*}; X_t, \epsilon_{t|b}^t)$$
Individual’s Optimization Problem — 3

lifetime value of alternative $sem_k$ at period $t$

$$V_{sem_k}(\Omega_t, \epsilon_t | w_t) = U(C_t, C_{t^*}, L_t, L_{t^*}, K_t, d_{t}^{sem_k}; B_t, X_t, \epsilon_{t}^{sem_k})$$

$$+ \beta \int_B \int_W \int_\epsilon [\max_{(sem_k)} V_{(sem_k)}'(\Omega_{t+1}, w_{t+1}, \epsilon_{t+1}) | d_{t}^{sem_k} = 1] f_b(B) f_w(W) f(\epsilon) dB dW d\epsilon$$

budget constraint

$$C_t + P_b \cdot C_{t^*} = w_t \cdot 1000 \cdot e \cdot (1 - d_t^{s0mk}) + Y_t \cdot d_t^{se1k} + N_t - P_s \cdot d_t^{lemk} - P_k \cdot (K_t + d_t^{sem1} - d_t^{sem2} + d_t^{se1k})$$

time constraint

$$L_t + L_{t^*} = T_t - 1000 \cdot e \cdot (1 - d_t^{s0mk}) - P_s \cdot d_t^{lemk} - P_k \cdot (K_t + d_t^{sem1} - d_t^{sem2} + d_t^{se1k})$$

body mass distribution

$$B_t + 1 \sim F_b(B_t, C_{t^*}, L_{t^*}; X_t, \epsilon_{t}^{b})$$

wage distribution

$$w_{t+1} \sim F_w(S_{t+1}, E_{t+1}, M_{t+1}, K_{t+1}, B_{t+1}, X_{t+1}, P_{t+1}^{e}, \epsilon_{t+1}^{w})$$
(An) Empirical Model of Wages

\[ \ln(w_t)|e_t \neq 0 = \]
(An) Empirical Model of Wages

\[ \ln(w_t) | e_t \neq 0 = \alpha_0 + \alpha_1 S_t \quad \text{schooling (entering } t) \]
(An) Empirical Model of Wages

\[ \ln(w_t) | e_t \neq 0 = \alpha_0 + \alpha_1 S_t \]  \hspace{1cm} \text{schooling (entering } t) \\
\[ \text{work experience and} \]  \hspace{1cm} \[ + \alpha_2 E_t + \alpha_3 1[\text{parttime}] \]  \\
\[ \text{part time indicator} \]
(An) Empirical Model of Wages

\[ \ln(w_t) | e_t \neq 0 = \alpha_0 + \alpha_1 S_t \]

\[ + \alpha_2 E_t + \alpha_3 1[\text{parttime}] \]

\[ + \alpha_4 B_t \]

schooling (entering \( t \))

work experience and part time indicator

productivity
(An) Empirical Model of Wages

\[ \ln(w_t)|e_t \neq 0 = \alpha_0 + \alpha_1 S_t \quad \text{schooling (entering } t) \]

work experience and part time indicator

\[ + \alpha_2 E_t + \alpha_3 1[\text{parttime}] \]

productivity

\[ + \alpha_4 B_t + \alpha_5 M_t + \alpha_6 K_t \]
(An) Empirical Model of Wages

\[ \ln(w_t) | e_t \neq 0 = \alpha_0 + \alpha_1 S_t \quad \text{schooling (entering } t \text{)} \]

- work experience and part time indicator
  \[ + \alpha_2 E_t + \alpha_3 1[\text{parttime}] \]
- productivity
  \[ + \alpha_4 B_t + \alpha_5 M_t + \alpha_6 K_t \]
- interactions
  \[ + \alpha_7'[S_t, E_t, M_t, K_t, B_t] \times 1[\text{black}] \]
(An) Empirical Model of Wages

\[ \ln(w_t) | e_t \neq 0 = \alpha_0 + \alpha_1 S_t \]

- work experience and part time indicator: \( +\alpha_2 E_t + \alpha_3 1[\text{parttime}] \)
- productivity: \( +\alpha_4 B_t + \alpha_5 M_t + \alpha_6 K_t \)
- interactions: \( +\alpha'_7 [S_t, E_t, M_t, K_t, B_t] \times 1[\text{black}] \)
- exogenous determinants and skill prices: \( +\alpha_8 X_t + \alpha_9 P^e_t + \alpha_{10} t \)
(An) Empirical Model of Wages

$$\ln(w_t)|e_t \neq 0 = \alpha_0 + \alpha_1 S_t$$  \hspace{2cm} \text{schooling (entering } t\text{)}

- work experience and part time indicator: $$+\alpha_2 E_t + \alpha_3 1[\text{parttime}]$$
- productivity: $$+\alpha_4 B_t + \alpha_5 M_t + \alpha_6 K_t$$
- interactions: $$+\alpha'_7 [S_t, E_t, M_t, K_t, B_t] \times 1[\text{black}]$$
- exogenous determinants and skill prices: $$+\alpha_8 X_t + \alpha_9 P_t^e + \alpha_9 t$$
- unobserved heterogeneity: $$+\epsilon_t^w$$
(An) Empirical Model of Body Mass Transition

$$B_{t+1} = b(B_t, C_t^*, L_t^E*; X_t, \epsilon_t^b)$$

biological production function
(An) Empirical Model of Body Mass Transition

\[ B_{t+1} = b(B_t, C_t^*, L_t^E*, X_t, \epsilon^b_t) \]

\[ B_{t+1} = \delta_0 + \delta_1 B_t \]

biological production function
(An) Empirical Model of Body Mass Transition

\[ B_{t+1} = b(B_t, C_t^*, L_t^{E*}; X_t, \epsilon_t^b) \]  

\[ B_{t+1} = \delta_0 + \delta_1 B_t \] 

biological production function

replace with the determinants of these demand functions where decision is made after \( s_t, e_t, m_t, k_t \) decisions
(An) Empirical Model of Body Mass Transition

\[ B_{t+1} = \delta_0 + \delta_1 B_t \]

\[ + \delta_2 S_{t+1} + \delta_3 E_{t+1} + \delta_4 M_{t+1} + \delta_5 K_{t+1} \]

biological production function

replace with the determinants of these demand functions

where decision is made after \( s_t, e_t, m_t, k_t \) decisions
(An) Empirical Model of Body Mass Transition

\[ B_{t+1} = b(B_t, C_t^l, L_t^E, X_t, \epsilon_t^b) \]

replace with the determinants of these demand functions where decision is made after \( s_t, e_t, m_t, k_t \) decisions

\[ B_{t+1} = \delta_0 + \delta_1 B_t \]

\[ + \delta_2 S_{t+1} + \delta_3 E_{t+1} + \delta_4 M_{t+1} + \delta_5 K_{t+1} \]

\[ + \delta_6 X_t + \delta_7 P_t^b + \delta_8 w_t \]
(An) Empirical Model of Body Mass Transition

\[ B_{t+1} = b(B_t, C_t^l, L_t^E, X_t, \epsilon_t^b) \]

--- biological production function

replace with the determinants of these demand functions where decision is made after \( s_t, e_t, m_t, k_t \) decisions

\[ B_{t+1} = \delta_0 + \delta_1 B_t \]

\[ + \delta_2 S_{t+1} + \delta_3 E_{t+1} + \delta_4 M_{t+1} + \delta_5 K_{t+1} \]

\[ + \delta_6 X_t + \delta_7 P_t^b + \delta_8 w_t \]

\[ + \epsilon_t^b \]
Wage Impacts of Education and Experience

a.) Impact of one additional year of schooling

b.) Impact of one additional year of full-time work experience
Education and Employment Impacts
(of BMI improvement from overweight to normal weight)
Marriage and Children Impacts
(of BMI improvement from overweight to normal weight)