The Economic Costs of Low Caloric Intake: Evidence from India

Heather Schofield
University of Pennsylvania

Center for Wellbeing and Child Development Conference

March 18, 2017
Globally, 800 million people are below recommended caloric intake. (WHO 2013)
Calories and Development

Most are in developing countries and are strikingly small and underweight

More than 1/3 of the world’s malnourished children live in India.

Average Indian adult is 5′3″ and weighs only 115 pounds (160cm, 52kg) (DHS 2006)
  • Roughly the same weight as an 11(13) year old in the US(UK) today (NHANES 2011)

Physical impairments from childhood malnutrition are estimated to cost low-income Asian countries roughly 3% of GDP annually.

When the mean amounts of calories are as low as they are in the poor nations of the world, *labor force participation rates and measures of labor productivity are bound to be low, especially when the hours of labor are adjusted for the intensity of labor.*”

– Robert Fogel, 1993 Nobel Lecture
Do Calories Influence Productivity?

The poor can afford sufficient calories:

- Tobacco, alcohol, entertainment ≈15% of expenditures
  (Banerjee and Duflo 2006)

- Additional calories to reach recommended levels, ≈ 5% of income
  (Subramanian and Deaton 1996)

- Alternatively: Less expensive grains → 20-30% ↑ in calories at zero cost
  (Subramanian and Deaton 1996)

Yet, choose not to consume more calories

- “The poor do see themselves as having a significant amount of choice, and choose not to exercise it in the direction of spending more on food” (Banerjee and Duflo 2006)

→ May look “underweight,” but by revealed preference: returns < discount rate
Meaningful productivity gains may be available without liquidity constraints

Empirically, unclear impact of calories on productivity in adulthood

- Mixed results, e.g.
  - Increase: Kraut and Muller (1946), Strauss (1986), and Wolgemuth et al. (1982)

- Identification concerns
  - Endogeneity of caloric intake
  - Magnitude and duration of change in calories (e.g., Keys et al. 1950)
  - Incentives for production (residual claimant)
  - Measurement of productivity and caloric intake

Potential cognitive changes not considered, but may amplify effects
Cognitive Deficits Due to Malnutrition

Evidence from other domains
• Brain consumes 20% of bodies energy at rest, requires blood glucose which is suppressed in malnourished individuals (Fonsec-Azevedo and Herculano-Houzel 2012)
• Soldiers complete half as many cognitive exercises on low rations (US Army 1987)
• Semi-starved individuals exhibit apathy, lack of motivation (Keys 1950)
• Glucose may improve self-control/willpower (Baumeister and Vohs 2007)

Potential implications of cognitive deficits due to malnourishment
1. Influence inframarginal choices as well as productivity on the margin
   → Productivity changes a lower bound on potential benefits
2. Increasing cognitive component to labor
   → Underweight more broadly relevant
3. Impede learning and/or impact discount rates → perpetuate traps
Do Calories Influence Productivity?

→ How does adult caloric intake impact productivity and cognitive function at the levels of intake observed in the developing world today?
Overview – Primary Analyses

Does caloric intake influence productivity?

1. Randomized controlled trial (RCT)
   - 211 cycle rickshaw drivers
   - Additional 700 calories per day
   - 5 weeks
   - Outcomes
     - Labor supply, earnings
     - Laboratory tasks - physical and cognitive

2. Ramadan fasting and agricultural production
   - Decline of 700 calories per day
   - 18 crops, 32 years, 270 districts
   - Differences-in-differences
     - Additional heterogeneity by fraction of Muslims in the district
   - Explore alternative channels

→ Substantial and widespread changes in productivity
Overview – Additional Analyses

What are the returns to caloric intake?

→ Positive returns

Why low caloric intake?

→ Knowledge?
Experimental Design

Participants

• 211 cycle rickshaw drivers in Chennai, India
• BMI ≤ 20
Passenger Cycle Rickshaw
Experimental Design

Participants
- 211 cycle rickshaw drivers in Chennai, India
- BMI ≤ 20

Experimental Conditions
- control (money)
- treatment (food + money)
  - same total value
  - little nutritive value beyond 700 calories (e.g. potato chips)
  - snack foods consumed in office each day between meal hours

Duration
- 5 weeks

Outcome measures
- Daily labor supply (days, hours), earnings
- Lab task earnings - Physical, cognitive
Example Experimental Tasks - Physical
### Example Experimental Tasks - Cognitive

<table>
<thead>
<tr>
<th>$\gamma$</th>
<th>$\psi$</th>
<th>$\varphi$</th>
<th>$\pi$</th>
<th>$\chi$</th>
<th>$\phi$</th>
<th>$\zeta$</th>
<th>$\delta$</th>
<th>$\nu$</th>
<th>$\xi$</th>
<th>$\psi$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\gamma$</td>
<td>$\leq$</td>
<td>$+$</td>
<td>$+$</td>
<td>$\kappa$</td>
<td>$\pi$</td>
<td>$\xi$</td>
<td>$\gamma$</td>
<td>$\leq$</td>
<td>$+$</td>
<td>$\gamma$</td>
</tr>
<tr>
<td>$\delta$</td>
<td>$\leq$</td>
<td>$+$</td>
<td>$\phi$</td>
<td>$\pi$</td>
<td>$\xi$</td>
<td>$\gamma$</td>
<td>$\leq$</td>
<td>$+$</td>
<td>$\kappa$</td>
<td>$\psi$</td>
</tr>
<tr>
<td>$\zeta$</td>
<td>$\leq$</td>
<td>$+$</td>
<td>$\psi$</td>
<td>$\varphi$</td>
<td>$\psi$</td>
<td>$\zeta$</td>
<td>$\leq$</td>
<td>$+$</td>
<td>$\kappa$</td>
<td>$\psi$</td>
</tr>
<tr>
<td>$\chi$</td>
<td>$\leq$</td>
<td>$+$</td>
<td>$\psi$</td>
<td>$\varphi$</td>
<td>$\psi$</td>
<td>$\zeta$</td>
<td>$\leq$</td>
<td>$+$</td>
<td>$\kappa$</td>
<td>$\psi$</td>
</tr>
<tr>
<td>$\kappa$</td>
<td>$\leq$</td>
<td>$+$</td>
<td>$\psi$</td>
<td>$\varphi$</td>
<td>$\psi$</td>
<td>$\zeta$</td>
<td>$\leq$</td>
<td>$+$</td>
<td>$\kappa$</td>
<td>$\psi$</td>
</tr>
<tr>
<td>$\psi$</td>
<td>$\leq$</td>
<td>$+$</td>
<td>$\psi$</td>
<td>$\varphi$</td>
<td>$\psi$</td>
<td>$\zeta$</td>
<td>$\leq$</td>
<td>$+$</td>
<td>$\kappa$</td>
<td>$\psi$</td>
</tr>
<tr>
<td>$\nu$</td>
<td>$\leq$</td>
<td>$+$</td>
<td>$\psi$</td>
<td>$\varphi$</td>
<td>$\psi$</td>
<td>$\zeta$</td>
<td>$\leq$</td>
<td>$+$</td>
<td>$\kappa$</td>
<td>$\psi$</td>
</tr>
</tbody>
</table>
### Characteristics of RCT Participants at Enrollment

<table>
<thead>
<tr>
<th>Experimental Condition</th>
<th>(1) Control</th>
<th>(2) Treatment</th>
<th>(3) Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>BMI</strong></td>
<td>17.87</td>
<td>17.73</td>
<td>-0.14</td>
</tr>
<tr>
<td></td>
<td>[1.41]</td>
<td>[1.39]</td>
<td>[0.19]</td>
</tr>
<tr>
<td><strong>Age</strong></td>
<td>45.63</td>
<td>46.26</td>
<td>0.63</td>
</tr>
<tr>
<td></td>
<td>[10.94]</td>
<td>[9.37]</td>
<td>[1.40]</td>
</tr>
<tr>
<td><strong>Number of household members</strong></td>
<td>3.42</td>
<td>3.40</td>
<td>-0.02</td>
</tr>
<tr>
<td></td>
<td>[2.32]</td>
<td>[2.28]</td>
<td>[0.32]</td>
</tr>
<tr>
<td><strong>Migrant (binary)</strong></td>
<td>0.29</td>
<td>0.22</td>
<td>-0.07</td>
</tr>
<tr>
<td></td>
<td>[0.46]</td>
<td>[0.42]</td>
<td>[0.06]</td>
</tr>
<tr>
<td><strong>Rooms in house</strong></td>
<td>1.41</td>
<td>1.44</td>
<td>0.03</td>
</tr>
<tr>
<td></td>
<td>[0.96]</td>
<td>[1.07]</td>
<td>[0.14]</td>
</tr>
<tr>
<td><strong>Number of small appliances</strong></td>
<td>3.77</td>
<td>4.08</td>
<td>0.31</td>
</tr>
<tr>
<td></td>
<td>[2.16]</td>
<td>[2.54]</td>
<td>[0.33]</td>
</tr>
<tr>
<td><strong>Years as rickshaw driver</strong></td>
<td>20.09</td>
<td>20.64</td>
<td>0.55</td>
</tr>
<tr>
<td></td>
<td>[11.53]</td>
<td>[11.84]</td>
<td>[1.61]</td>
</tr>
<tr>
<td><strong>Earned yesterday</strong></td>
<td>183.28</td>
<td>193.53</td>
<td>10.25</td>
</tr>
<tr>
<td></td>
<td>[145.52]</td>
<td>[160.59]</td>
<td>[21.15]</td>
</tr>
<tr>
<td><strong>Work yesterday</strong></td>
<td>0.77</td>
<td>0.82</td>
<td>0.04</td>
</tr>
<tr>
<td></td>
<td>[0.42]</td>
<td>[0.39]</td>
<td>[0.06]</td>
</tr>
<tr>
<td><strong>Hours, conditional on working yesterday</strong></td>
<td>9.80</td>
<td>9.81</td>
<td>0.01</td>
</tr>
<tr>
<td></td>
<td>[3.61]</td>
<td>[3.40]</td>
<td>[0.56]</td>
</tr>
<tr>
<td><strong>N</strong></td>
<td>102</td>
<td>109</td>
<td>211</td>
</tr>
</tbody>
</table>

Note: In Columns (1) and (2), results are presented as mean [standard deviation]. Column (3) is presented as mean [standard error].
Fraction of Participants Attending

Day in Study

Daily Attendance

0 .1 .2 .3 .4 .5 .6 .7 .8 .9 .1

0 7 14 21 28 35 36

Treatment  Control
$y_{i,\text{baseline}} = \beta_0 + \beta_1 \text{Treatment}_i + \epsilon_i$

## Selected Attrition – High Earning Treated More Likely To Attrit

<table>
<thead>
<tr>
<th>Dependent Variable</th>
<th>(1) Earn (Rupees)</th>
<th>(2) Work</th>
<th>(3) BMI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Treatment</td>
<td>111.96**</td>
<td>0.33**</td>
<td>0.43</td>
</tr>
<tr>
<td></td>
<td>[52.48]</td>
<td>[0.13]</td>
<td>[0.56]</td>
</tr>
<tr>
<td>Mean of dependent variable</td>
<td>138.20</td>
<td>0.79</td>
<td>17.79</td>
</tr>
<tr>
<td>Observations</td>
<td>38</td>
<td>38</td>
<td>37</td>
</tr>
<tr>
<td>R-squared</td>
<td>0.11</td>
<td>0.16</td>
<td>0.02</td>
</tr>
</tbody>
</table>

**Notes:**
1) Sample consists of individuals with fewer than four days of attendance in the first week.

→ Treated attriters work and earn more
\[ \tilde{y}_{ip} = \beta_0 + \beta_1 \text{Treatment}_i + \beta_2 \text{Second}_p + \beta_3 \text{Treatment}_i \times \text{Second}_p + \alpha X_i + \varepsilon_i \]

<table>
<thead>
<tr>
<th>Dependent variable</th>
<th>(1) Average hours</th>
<th>(2) Average hours if &gt; 0</th>
<th>(3) Fraction of days worked</th>
<th>(4) Average earnings</th>
<th>(5) ln(Average earnings)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Treatment (first half of study)</td>
<td>-0.13 [0.36]</td>
<td>-0.29 [0.32]</td>
<td>0.02 [0.03]</td>
<td>-1.92 [9.16]</td>
<td>0.01 [0.06]</td>
</tr>
<tr>
<td>Second half of study</td>
<td>0.09 [0.23]</td>
<td>-0.35* [0.20]</td>
<td>0.02 [0.02]</td>
<td>3.61 [6.63]</td>
<td>0.00 [0.05]</td>
</tr>
<tr>
<td>Treatment*Second half of study</td>
<td>1.07*** [0.33]</td>
<td>0.73* [0.28]</td>
<td>0.08*** [0.03]</td>
<td>19.61* [10.88]</td>
<td>0.11* [0.06]</td>
</tr>
<tr>
<td>Mean of dependent variable</td>
<td>6.81</td>
<td>8.72</td>
<td>0.77</td>
<td>179.78</td>
<td>5.10</td>
</tr>
<tr>
<td>Observations</td>
<td>370</td>
<td>364</td>
<td>370</td>
<td>383</td>
<td>383</td>
</tr>
<tr>
<td>R-squared</td>
<td>0.19</td>
<td>0.24</td>
<td>0.14</td>
<td>0.15</td>
<td>0.15</td>
</tr>
</tbody>
</table>
\[ \text{Work}_i = \beta_0 + \beta_1 \text{Treated}_i + \beta_N \text{Week}_N + \alpha_N \text{Week}_N \times \text{Treated}_i + \Theta X_i + \epsilon_{id} \]

Rickshaw Driver Labor Supply By Week

→ 12% net increase in hours worked in fifth week
\[ \text{Earn}_{id} = \beta_0 + \beta_1 \text{Treated}_i + \beta_N \text{Week}_N + \alpha_N \text{Week}_N \ast \text{Treated}_i + \Theta X_i + \varepsilon_{id} \]

Differences in Earnings By Week

Week in Study

Daily Earnings, Ks.
\[ \text{Earn}_{id} = \beta_0 + \beta_1 \text{Treated}_i + \beta_N \text{Week}_N + \alpha_N \text{Week}_N \times \text{Treated}_i + \Theta X_i + \epsilon_{id} \]

**Differences in Earnings by Week**

- **Full Sample**
- **High Attendance**

\[ \rightarrow 9\% \text{ net increase in earnings in fifth week} \]
TaskEarn\textsubscript{id} = \beta_0 + \beta_1 Treated_i + \beta_2 Endline_d + \beta_3 Endline_d * Treated_i + \Theta X_i + \varepsilon_{id}

Increased Task Earnings

Note: Treated participants received additional food at enrollment

→ 9% net increase in total earnings on laboratory tasks
Task$\text{Earn}_{id} = \beta_0 + \beta_1 \text{Treated}_i + \beta_2 \text{Endline}_d + \beta_3 \text{Endline}_d * \text{Treated}_i + \Theta X_i + \varepsilon_{id}$

Increased Task Earnings, By Task Type

Note: Treated participants received additional food at enrollment

→ 7% (12%) net increase in physical (cognitive) performance
Treated individuals discount effort less heavily.
Summary of Randomized Trial Results

Consistent with physiology literature:

- Physical effects are cumulative (e.g., Keys et al. 1950)
- Cognitive effects are immediate (e.g., Gailliot et al. 2007, Danzinger et al. 2011)

In fifth week, treated individuals’ net:

- Labor supply is 12% higher
- Earnings are 9% higher
- Performance on laboratory tasks improves
  - 7% for physical tasks
  - 12% for cognitive tasks
Ramadan Fasting and Agricultural Production

• Ramadan – Muslim holiday, fast from sunrise to sunset for 1 month

• ↓ of 700 calories per person per day in rural Muslim agricultural households [Regression table]

• Primary data sources
  o Indian Agriculture and Climate Dataset (World Bank)
  o Crop calendar
  o University of Delaware Climate Resource Data
  o 1961 Indian Census
  o [Additional Data Sources]

• Identification – DID approach utilizing variation in the extent of overlap between the labor intensive portions of the cropping cycle and fasting
  1. Variation in timing of crop cycles for crops within a district-year
  2. Spatial variation in cropping cycles across districts
  3. Temporal variation comparing crop-district combinations across time
    • Ramadan is a lunar holiday → cycles throughout the calendar year
Diff-in-Diff With Crop-Year-District Variation

\[ q_{cdt} = \beta_0 + \beta_1 S_{cdt} + \beta_2 H_{cdt} + \theta_{cd} + \pi_{dt} + \alpha_{ct} + \lambda X_{cdt} + \varepsilon_{cdt} \]

\[ q_{cdt} = \log \text{production of crop c, in district d, and year t} \]

\[ S_{cdt} = \text{fraction of Ramadan covered by sowing} \]
\[ H_{cdt} = \text{fraction of Ramadan covered by harvest} \]

\[ \theta_{cd}, \pi_{dt}, \alpha_{ct} = \text{crop-district, district-year, and crop-year fixed effects} \]
\[ X_{cdt} = \text{vector of time varying controls for rainfall and temperature} \]
# Overlap Between Ramadan and Cropping Cycles Reduces Output

<table>
<thead>
<tr>
<th>Dependent Variable</th>
<th>(1) (\ln(q)) All</th>
<th>(2) (\ln(\text{value})) All</th>
<th>(3) (\ln(q)) Rice only</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crops</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fraction of Ramadan covered by sowing</td>
<td>-0.017* [0.010]</td>
<td>-0.028*** [0.010]</td>
<td>-0.058*** [0.016]</td>
</tr>
<tr>
<td>Fraction of Ramadan covered by harvest</td>
<td>-0.025*** [0.009]</td>
<td>-0.044*** [0.009]</td>
<td>-0.041*** [0.015]</td>
</tr>
<tr>
<td>Mean of dependent variable</td>
<td>1.517</td>
<td>1.837</td>
<td>3.91</td>
</tr>
<tr>
<td>N</td>
<td>103,104</td>
<td>103,088</td>
<td>7,741</td>
</tr>
</tbody>
</table>

**Full overlap between Ramadan and sowing or harvesting ↓ production 1.7% to 4.4%**

**But, scale declines by fraction of individuals impacted by the holiday**
- 9.9% of rural population is Muslim

→ **Productivity per individual declines 17 to 44%**
Possible Alternative Channels

Caloric intake ↓ for Muslims during Ramadan, but other behaviors also change
→ Assess other possible channels
  ○ Religious obligations reducing labor supply
  ○ Sleep deprivation
  ○ Dehydration

Omnibus test – Lagged productivity declines
  • Consistent with calories channel
  • Inconsistent with religious obligation, sleep deprivation, dehydration

Religious and social obligations
  • No change in labor supply or earnings

Sleep Deprivation
  • Napping does not interfere with labor supply
  • Little to no impact on physical performance

Dehydration
  • Physical declines begin at >2% body weight (e.g. Sawka et al 2007)
  • Expected losses \( \leq \) this threshold
  • No decline in production with higher evaporative potential
Summary of Productivity Results

Higher caloric intake increases productivity

1. RCT – additional 700 calories/day
   • ≈ 10% increase in labor supply and earnings in final week
   • ≈ 10% gain on cognitive and physical tasks at endline

2. Fasting and agricultural production – decline of 700 calories/day
   • ≈ 20% to 40% decline in productivity

What are the returns?
• Wide range: [-212, 515] for the RCT, and [8,1623] during Ramadan
• Generally positive and relatively large: 75-200%

Low investment with high returns → A puzzle
Why Low Caloric Intake?

In the paper, describe and assess:

- Liquidity
  - Subramanian and Deaton 1996; Behrman and Deolalikar 1987; Bouis and Haddad 1992

- High discount rates
  - Banerjee and Mullainathan 2010
  - Survey evidence

- Structural features of the economy
  - Rickshaw driver BMI

- Disutility of labor
  - RCT experimental tasks
  - Fare offers

- Lack of knowledge
  - Incentivized “nutrition survey” with similar participants
    1. Returns to calories
    2. Caloric density (calories/Rupee)
Lack of Knowledge

1. Returns to calories
5 variants: “Do you think that if an average person like yourself (similar profession, height and weight) ate an additional [Food type] every day for the next [timeframe] they would [Labor outcome] less, the same, or more [Timeframe] from now?”

On average: 20% respond “more”

2. Caloric density (calories/Rupee)
Photographs and verbal description of 10 pairs of foods (commonly consumed, same cost)
  • To scale, label food type and amount, large difference in calories (average ratio = 3.7; average difference = 280 calories)
Asked to indicate which item in pair has more energy. Rs. 1 per correct answer.

A. 200g tomato
B. 100g onion

Below chance (39%) at identifying correct response
Summary of Results

Caloric intake drives changes in productivity
- *RCT*: 12% ↑ in labor supply, 9% ↑ earnings in final week and 12% ↑ cognitive performance and 7% ↑ physical performance
- *Ramadan fasting*: 20% to 40% ↓ in productivity

High returns to caloric intake for underweight adults
- *RCT*: 6-month ROI 75%, excluding cognitive gains
- *Ramadan fasting*: 1-month ROI ≈225%

Yet, caloric intake remains low
- 50% consume less than 1900 calories/day (Deaton and Dreze 2008)

Traditional hypothesis that liquidity limits investment is not supported
- Structural features of the economy, disutility of labor, and high discount rates also do not appear to limit caloric intake

Rather, suggestive evidence that incorrect beliefs may play an important role
- 80% have incorrect beliefs about returns to calories
- Below chance in identifying calorically dense foods
Implications and Future Research

**Economics**

Example (1): Empirical – Can knowledge help people escape a nutrition poverty trap?

Example (2): Theory - Nutrition poverty trap models

**Policy**

India spends \( \approx 1\% \) of GDP on food subsidies (Kumar and Soumya 2010)

Example: Targeting food subsidies – unintended consequences?

- Subsidizing low caloric density foods (e.g. dairy)
  - Substitute rather than supplement current foods
    - caloric intake and productivity ↓

- Disease burden and poor sanitation
  - Decreases the return on investments among adults and children

- Is it possible to make these returns clearer?