The Measurement of Wealth and Inequality: An Application to China

Patrick S. Ward

Purdue University
SHAPE Seminar

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Measuring Well-being

Traditional measures of economic well-being derived from household surveys are monetary in nature

- Can be derived based on canonical household utility maximization model:

\[
\max_x \quad u(x_1, x_2, \ldots x_n) \\
\text{s.t.} \quad p' x \leq y
\]

Measures of well-being can be based off of:

- Budget constraint: Household income \( (y) \)
- Maximized objective function: Money metric utility
  \[
  m(p, x) \equiv e(p, u(x_1^*, x_2^*, \ldots, x_n^*))
  \]
  Money metric utility is often proxied by observed consumption expenditures
Problems with Traditional Measures

- Can be difficult to measure (subject to measurement error).
- Can be subject to systematic reporting biases.
- Income measures can be highly variable from one year to the next, especially in developing countries where much of household income is tied to agricultural production.
  - Highly variable income is inconsistent with the theoretical and practical attractiveness of the Permanent Income Hypothesis
- Expenditure measures fail to take into consideration purchases of durable goods, which have lifespans of several years.
- Both measures fail to adequately control for savings.
- Determining poverty based solely on a pecuniary measure is reductionist: It ignores many other dimensions of household well-being.
Paradigm Shift

Why are these traditional measures of well-being the “gold standard”? Why don’t we use other, multidimensional measures of well-being?
Paradigm Shift

What is well-being?

- “[Monetary] wealth is evidently not the good we are seeking; for it is merely useful and for the sake of something else.” (Aristotle, *Nicomachean Ethics*)
- “We generally have excellent reasons for wanting more income or [monetary] wealth. This is not because income and [monetary] wealth are desirable for their own sake, but because, typically, they are admirable general-purpose means for having more freedom to lead the kind of lives we have reason to value.” (Amartya Sen, *Development as Freedom*)
Capabilities Approach to Measuring Well-Being

- Capabilities approach: focus on what individuals are able to do.
- Multidimensional in nature.
- Capabilities are not judged on the results achieved, but the results achieved are often indicative of the underlying capabilities.

- Assets represent capabilities, but it is the underlying functionings of these capabilities that are true measures of well-being.
- Assets are indicative of an underlying command over social, physical, or human resources.
  - Example: A bicycle.
Objective

Our objectives in this paper are three-fold:

Objective #1

Propose measures of socioeconomic status that are more holistic than traditional, income or expenditure based measures.

Objective #2

Using household survey data from China, we demonstrate both the internal and external consistency of a measure of household well-being based on polychoric principal component analysis on underlying household asset indicator variables.

Objective #3

Examine patterns of wealth and inequality over time and across rural-urban divides.
Economic Reforms in China

- China launched economic reforms at the end of 1978.
- Reforms proceeded “without a blueprint”.
- Chinese model:
  - Gradualist: “Crossing the river by groping the stones”.
  - Economic development concurrent with system transformation.
  - Reform policies judged on the basis of contribution to economic growth, rather than to transition.
- Very different reform model than that of other transitional economies.
Economic Reforms in China

- Reforms began in the organization or rural society:
  - Households were given more autonomy over land and labor allocations.
  - By 1984, grain output was nearly 33% higher than it was in 1978.
  - Output from TVEs increased rapidly as well.
  - Dual-track system—coexistence of plan and market structures:
    - Contracts stabilized some crucial aspects of the economy.
    - Reforms freed up other aspects.
  - Market forces: prices equate supply and demand
- Successes in rural re-organization gave reformers confidence to push forward with reforms in other sectors.
Economic Growth and Poverty Reductions

Ravallion & Chen (2007):

1. Huge reductions in poverty headcount rates:
   - Poverty fell from 53% (1981) to 8% (2001).
   - Progress unevenly distributed over space and time.

2. Income inequality has been rising:
   - Inequality is higher in rural areas than in urban areas.


4. Economy-wide policies have had mixed results.
Declining Income Poverty...

Source: Ravallion & Chen (2007)
...Rising Income Inequality

Fig. 5. Income inequality in rural and urban areas and nationally.

Source: Ravallion & Chen (2007)
Do these patterns persist when more holistic measures of household socioeconomic status are considered?
Measures of Well-Being Based on Asset Ownership

- Asset ownership can be a broader, more holistic measure of household well-being.
- Four possible measures of well-being derived from household asset ownership:
  - $W_1$: Subjective household asset valuation.
  - $W_2$: Equal weight household asset index.
  - $W_3$: Household asset index with weights derived using standard PCA.
  - $W_4$: Household asset index with weights derived using polychoric PCA.
The Method of Principal Components

- PCA is a method for reducing the dimensionality of data.
- For a $k$-vector of interrelated random variables $\mathbf{x}$, PCA extracts a series of $k$ orthonormal linear combinations $\alpha' \mathbf{x}$ of the data that contain most of the variance.
- Orthonormal linear combinations $\equiv$ Principal components.
- Mathematical formulation for solving for the first principal component:

$$\max \quad \text{var}(\alpha'_1 \mathbf{x}) = \alpha'_1 \Sigma \alpha_1$$

s.t. \quad \|\alpha_1\| \equiv \alpha'_1 \alpha_1 = 1$

- Lagrangian: $\mathcal{L} = \alpha'_1 \Sigma \alpha_1 - \lambda_1 (\alpha'_1 \alpha_1 - 1)$
- First-Order Condition, $\mathcal{L}_\alpha : \sum \alpha_1 = \lambda_1 \alpha_1$
The Method of Principal Components II

- The FOCs take the form of the *eigenvalue* problem:
  - \( \lambda_1 \): first (largest) eigenvalue associated with the variance-covariance matrix \( \Sigma \).
  - \( \alpha_1 \): eigenvector associated with the first eigenvalue.

- Similar maximizations can be achieved for higher-order principal components.

- The principal components provide intuitive factor loadings interpretable as the relative importance of each variable \( x_1, x_2, \ldots, x_k \) in explaining the underlying latent variable.

- The first principal component is interpretable as the “size” of the underlying latent variable being explained.

- Covariance matrices are not scale-invariant, so in practice the correlation matrix is often used in place of the covariance matrix.
China Health and Nutrition Survey (CHNS)

- Wide geographic coverage (9 provinces).
- Selected communities and survey participants demonstrate a great deal of variation on important variables.
- Multilevel structure:
  - Community level
  - Household level
  - Individual level
- Wide variety of data on various assets and other forms of capital.
Income Poverty in CHNS Data

Foster, Greer & Thorbecke (1984) Poverty Measures:

\[ P_{\alpha,t} = N_t^{-1} \sum_{i=1}^{N_t} \left( 1 - \frac{y_{it}}{z_t} \right)^\alpha I(y_{it} \leq z_t) \]

- Headcount Ratio: \( \alpha = 0 \).
- Poverty Gap Ratio: \( \alpha = 1 \).
- \( I(\cdot) \): Indicator function.
- \( y_{i} \): Real household income for household \( i \).
- \( z \): Poverty line (official poverty line adjusted by community-specific price index).
Income Poverty in CHNS Data

![Graph showing income poverty rates in CHNS Data from 1989 to 2006. The graph demonstrates a decline in poverty rates over time, with a slight stabilization in the late 1990s and early 2000s. The Headcount Ratio and Poverty Gap Ratio are indicated on the graph.](image-url)
Income Inequality in CHNS Data

![Graph showing income inequality over time in CHNS Data](image-url)
Assets in the CHNS

Asset ownership can be decomposed into three primary aggregations:

- Housing Capital
- Physical Non-Productive Capital
  - Transportation Capital
  - Durable Household Goods
- Physical Productive Capital
  - Agricultural Capital
  - Commercial Capital
# Housing Capital

1. Age of the house
2. Number of rooms
3. Drinking water source
4. Lighting source
5. Primary cooking fuel
6. Toilet facilities
7. Roofing material
8. Wall material
9. Flooring material
Physical Non-Productive Capital: Transportation Capital

1. Number of tricycles
2. Number of bicycles
3. Number of motorcycles
4. Number of automobiles
Physical Non-Productive Capital: Durable Goods Capital

1. Number of radios
2. Number of VCRs
3. Number of black & white TVs
4. Number of color TVs
5. Number of washing machines
6. Number of air conditioners
7. Number of non-commercial sewing machines
8. Number of electric fans
9. Number of camera
Physical Productive Capital: Agricultural Capital

1. Number of large tractors
2. Number of small (garden) tractors
3. Number of irrigation units
4. Number of power threshers
5. Number of water pumps
Physical Productive Capital: Commercial Capital

1. Commercial cooking equipment
2. Commercial sewing equipment
3. Commercial carpentry equipment
4. Other commercial equipment
## Wealth Measures Across Survey Waves

<table>
<thead>
<tr>
<th></th>
<th></th>
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<tr>
<td>W₁</td>
<td>127.46</td>
<td>1,600.22</td>
<td>2,096.42</td>
<td>3,608.32</td>
<td>4,027.23</td>
<td>4,714.19</td>
<td>5,594.88</td>
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<td></td>
<td>(310.49)</td>
<td>(1,939.10)</td>
<td>(2,523.58)</td>
<td>(3,894.60)</td>
<td>(4,726.79)</td>
<td>(4,968.67)</td>
<td>(6,361.33)</td>
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<td>W₂</td>
<td>113.494</td>
<td>116.698</td>
<td>123.783</td>
<td>133.044</td>
<td>142.942</td>
<td>153.991</td>
<td>157.832</td>
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<td>(49.69)</td>
<td>(51.37)</td>
<td>(57.77)</td>
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<td>(85.74)</td>
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<td>W₃</td>
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<td>−0.134</td>
<td>−0.128</td>
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<td></td>
<td>(2.11)</td>
<td>(2.10)</td>
<td>(2.07)</td>
<td>(2.08)</td>
<td>(2.06)</td>
<td>(2.02)</td>
<td>(1.96)</td>
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<tr>
<td>W₄</td>
<td>−0.782</td>
<td>−0.682</td>
<td>−0.459</td>
<td>−0.018</td>
<td>0.328</td>
<td>0.868</td>
<td>1.022</td>
</tr>
<tr>
<td></td>
<td>(1.30)</td>
<td>(1.32)</td>
<td>(1.34)</td>
<td>(1.50)</td>
<td>(1.57)</td>
<td>(1.58)</td>
<td>(1.51)</td>
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</table>
## Spearman Rank Correlations: Wealth Measures

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<thead>
<tr>
<th></th>
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<th>$W_3$</th>
<th>$W_4$</th>
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<tr>
<td>$W_1$</td>
<td>1.000</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>$W_2$</td>
<td>0.313</td>
<td>1.000</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$W_3$</td>
<td>0.579</td>
<td>0.336</td>
<td>1.000</td>
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<tr>
<td>$W_4$</td>
<td>0.731</td>
<td>0.375</td>
<td>0.889</td>
<td>1.000</td>
</tr>
</tbody>
</table>

### Calculation of Spearman Rank Correlations

To calculate Spearman's rank correlation, you would use the formula:

$$ r_s = 1 - \frac{6 \sum d_i^2}{n(n^2 - 1)} $$

where $d_i$ is the difference between the ranks of each pair of variables, and $n$ is the number of pairs.

This formula takes into account the differences in ranking between each pair of variables to determine the strength and direction of the relationship.
**Spearman Rank Correlations: Wealth Measures and Income**

<table>
<thead>
<tr>
<th>Wealth Measure</th>
<th>Correlation</th>
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<tr>
<td>$W_1$</td>
<td>0.4454</td>
</tr>
<tr>
<td>$W_2$</td>
<td>0.2920</td>
</tr>
<tr>
<td>$W_3$</td>
<td>0.4682</td>
</tr>
<tr>
<td>$W_4$</td>
<td>0.4948</td>
</tr>
</tbody>
</table>
External vs. Internal Consistency

We desire a measure of household well-being that is both externally and internally consistent:

**External Consistency**

Rankings are consistent with those generated from traditional, money metric measures of well-being

**Internal Consistency**

Rankings are consistent with the rankings generated from other wealth based measures

- $W_3$ and $W_4$ both display modest degrees of external and internal consistency
- $W_4$ captures more of the variance in latent socioeconomic status than does $W_3$
Scree Plot of Explained Variance

Proportion of Variance Explained

Principal Component

Standard PCA Weights
Polychoric PCA Weights
Distribution of Household Wealth: All China
Variance of Wealth Distribution

What’s wrong with using the variance for distributional comparisons?

- Nothing really, except that...
- Variance measures summarize the dispersion in a particular way, and we may not like the properties it has:
  - Variance is not neutral with respect to a change in the scale of the whole distribution
  - Variance measures do not satisfy the principle of transfers
Inequality Measures

- Gini Coefficient: \( G_t = \frac{N_t + 1}{N_t - 1} - \frac{2}{N_t(N_t - 1) \mu_t} \sum_{i=1}^{N_t} \rho_{it} W_{4,it} \)
  - \( \rho_{it} \): rank of individual \( i \) in the wealth distribution in period \( t \)
  - \( \mu_t \): mean wealth in period \( t \)

- Atkinson Inequality Measure:
  - \( A_t = 1 - \prod_{i=1}^{N_t} \left( \frac{W_{4,it}}{\mu_t} \right)^{1/N_t} \) for \( \epsilon = 1 \)
  - \( A_t = 1 - \left( \frac{1}{N_t} \sum_{i=1}^{N_t} \left( \frac{W_{4,it}}{\mu_t} \right)^{1-\epsilon} \right)^{1/(1-\epsilon)} \) for \( \epsilon \neq 1 \)

  - \( \epsilon \): Degree of “inequality aversion” \( (\epsilon \geq 0) \), the degree to which social welfare trades off mean living standards for equality of the distribution.
  - As \( \epsilon \to \infty \), social preferences are maximin, such that policies aim to maximize the minimum welfare (Rawls, 1971)
Inequality Measures

- **Standard Deviation of Logs:**

\[
SDL_t = \sqrt{\frac{1}{N_t} \sum_{i=1}^{N_t} (\ln W_{4,it} - \ln \mu_t)^2}
\]

- **Coefficient of Variation:**

\[
CV_t = \sqrt{\frac{1}{N_t} \sum_{i=1}^{N_t} (W_{4,it} - \mu_t)^2}
\]
Wealth Inequality in China

<table>
<thead>
<tr>
<th>Year</th>
<th>Gini Coefficient</th>
<th>$\epsilon = 0.5$</th>
<th>$\epsilon = 1$</th>
<th>$\epsilon = 2$</th>
<th>Std. Dev. Logs</th>
<th>Coef. of Variation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1989</td>
<td>0.2384</td>
<td>0.0456</td>
<td>0.0919</td>
<td>0.1576</td>
<td>0.4611</td>
<td>0.4327</td>
</tr>
<tr>
<td>1991</td>
<td>0.2228</td>
<td>0.0387</td>
<td>0.0773</td>
<td>0.1375</td>
<td>0.4081</td>
<td>0.3993</td>
</tr>
<tr>
<td>1993</td>
<td>0.2128</td>
<td>0.0351</td>
<td>0.0699</td>
<td>0.1270</td>
<td>0.3855</td>
<td>0.3814</td>
</tr>
<tr>
<td>1997</td>
<td>0.2127</td>
<td>0.0353</td>
<td>0.0711</td>
<td>0.1243</td>
<td>0.3934</td>
<td>0.3768</td>
</tr>
<tr>
<td>2000</td>
<td>0.2049</td>
<td>0.0330</td>
<td>0.0668</td>
<td>0.1151</td>
<td>0.3821</td>
<td>0.3607</td>
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<tr>
<td>2004</td>
<td>0.1800</td>
<td>0.0259</td>
<td>0.0527</td>
<td>0.0915</td>
<td>0.3393</td>
<td>0.3174</td>
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<tr>
<td>2006</td>
<td>0.1670</td>
<td>0.0223</td>
<td>0.0455</td>
<td>0.0794</td>
<td>0.3141</td>
<td>0.2938</td>
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</table>
Lorenze Curves: Wealth Inequality in China
Pen’s Parade: Wealth Inequality in China
Pen’s Parade and Distributional Comparisons

Social Welfare Functions:

- $\mathcal{M}$: class of social welfare functions
- $M = M (W_{4,1}, W_{4,2}, ..., W_{4,n})$ such that:
  - $M$ is increasing: $\partial M / \partial W_{4,i} > 0 \ \forall i$
  - $M$ is symmetric: invariant to permutations in the wealth vector
  - $M$ is replication invariant
Welfare Dominance and Poverty Dominance

First-Order Welfare Dominance (Saposnik, 1981):
- The Parade diagram for the \( j^{th} \) distribution lies everywhere above the diagram for every other \( i < j \) distribution.
- \( M(W_4,j) > M(W_4,i) \quad \forall i < j \) for all \( M \in M \)

Poverty (Headcount, H) Dominance (Foster and Sharrocks, 1988):
- The Parade diagram for the \( j^{th} \) distribution lies to the left of every other \( i < j \) distribution.
- \( H(W_4,j) < H(W_4,i) \quad \forall i < j \) for any common poverty line.
Findings for $W_4$

- Increasing asset wealth over time.
- Externally consistent with real household income rankings.
- Internally consistent with other asset-based measures of household socioeconomic status.
- Declining wealth inequality across China.
- Social welfare is generally increasing over time.
- Asset poverty is generally declining over time.
  - For any arbitrarily defined asset poverty line
Urban-Rural Wealth Divide

Ratio of Urban Wealth to Rural Wealth

<table>
<thead>
<tr>
<th>Year</th>
<th>Unadjusted</th>
<th>COL Adjusted (unweighted)</th>
<th>COL Adjusted (weighted)</th>
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<tbody>
<tr>
<td>1989</td>
<td>1.4875</td>
<td>1.4259</td>
<td>1.4258</td>
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<tr>
<td>1991</td>
<td>1.4165</td>
<td>1.3653</td>
<td>1.3662</td>
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<tr>
<td>1993</td>
<td>1.4066</td>
<td>1.3462</td>
<td>1.3467</td>
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<tr>
<td>1997</td>
<td>1.3751</td>
<td>1.3033</td>
<td>1.3065</td>
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<td>2000</td>
<td>1.3324</td>
<td>1.2421</td>
<td>1.2461</td>
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<td>2004</td>
<td>1.2717</td>
<td>1.1952</td>
<td>1.1988</td>
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<tr>
<td>2006</td>
<td>1.2351</td>
<td>1.1670</td>
<td>1.1705</td>
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Urban-Rural Wealth Divide

- **Introduction**
- **China**
- **Well-Being**
- **Data**
- **Wealth**
- **Inequality**
- **Conclusions**
## Wealth Growth in Urban and Rural Areas

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<th>Rural</th>
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<td></td>
<td>Annual</td>
<td>Cumulative</td>
<td>Annual</td>
<td>Cumulative</td>
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<tr>
<td></td>
<td>Growth (%)</td>
<td>Growth (%)</td>
<td>Growth (%)</td>
<td>Growth (%)</td>
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<tr>
<td>1991</td>
<td>6.27%</td>
<td>6.27%</td>
<td>11.60%</td>
<td>11.60%</td>
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<tr>
<td>1993</td>
<td>7.00%</td>
<td>13.71%</td>
<td>7.75%</td>
<td>20.25%</td>
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<tr>
<td>1997</td>
<td>10.25%</td>
<td>25.36%</td>
<td>12.78%</td>
<td>35.62%</td>
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<tr>
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<td>7.29%</td>
<td>34.50%</td>
<td>10.72%</td>
<td>50.15%</td>
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<td>2004</td>
<td>8.35%</td>
<td>45.73%</td>
<td>13.52%</td>
<td>70.46%</td>
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<tr>
<td>2006</td>
<td>1.70%</td>
<td>48.21%</td>
<td>4.71%</td>
<td>78.50%</td>
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Distribution of Household Wealth: Urban Areas
Distribution of Household Wealth: Rural Areas
# Wealth Inequality Within Urban Areas

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<tr>
<th>Year</th>
<th>Gini Coefficient</th>
<th>$\epsilon = 0.5$</th>
<th>$\epsilon = 1$</th>
<th>$\epsilon = 2$</th>
<th>Std. Dev. Logs</th>
<th>Coef. of Variation</th>
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<tbody>
<tr>
<td>1989</td>
<td>0.2056</td>
<td>0.0346</td>
<td>0.0715</td>
<td>0.1142</td>
<td>0.4056</td>
<td>0.3592</td>
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<tr>
<td>1991</td>
<td>0.1890</td>
<td>0.0283</td>
<td>0.0576</td>
<td>0.0974</td>
<td>0.3555</td>
<td>0.3286</td>
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<td>1993</td>
<td>0.1823</td>
<td>0.0269</td>
<td>0.0553</td>
<td>0.0915</td>
<td>0.3507</td>
<td>0.3175</td>
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<td>1997</td>
<td>0.1792</td>
<td>0.0278</td>
<td>0.0581</td>
<td>0.0908</td>
<td>0.3669</td>
<td>0.3162</td>
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<tr>
<td>2000</td>
<td>0.1663</td>
<td>0.0245</td>
<td>0.0517</td>
<td>0.0794</td>
<td>0.3479</td>
<td>0.2939</td>
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<tr>
<td>2004</td>
<td>0.1543</td>
<td>0.0205</td>
<td>0.0429</td>
<td>0.0687</td>
<td>0.3128</td>
<td>0.2719</td>
</tr>
<tr>
<td>2006</td>
<td>0.1429</td>
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<td>0.0368</td>
<td>0.0601</td>
<td>0.2881</td>
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# Wealth Inequality Within Rural Areas

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<th>Gini Coefficient</th>
<th>Atkinson Measures $\epsilon = 0.5$</th>
<th>$\epsilon = 1$</th>
<th>$\epsilon = 2$</th>
<th>Std. Dev. Logs</th>
<th>Coef. of Variation</th>
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<tbody>
<tr>
<td>1989</td>
<td>0.2165</td>
<td>0.0390</td>
<td>0.0789</td>
<td>0.1377</td>
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Findings for $W_4$ Delimited Over Rural and Urban Settings

- The ratio of urban-rural wealth has been decreasing over time.
  - This result is more pronounced when we consider differences in the cost of living.
- Wealth growth in rural areas has outpaced that in urban areas.
- Wealth inequality has fallen in both urban and rural areas.
  - Wealth inequality is higher in rural areas than in urban areas.
Concluding Remarks

- In this paper, we have noted some of the problematic features of traditional, money metric measures of socioeconomic status.
- We have proposed four measures of household socioeconomic status that are more holistic and multidimensional in nature.
  - These measures are based on household asset ownership.
  - These measures are more consistent with Sen’s *capabilities* approach.
  - Two of these measures are wealth indices, whose factor loadings are generated using PCA.
- We have demonstrated both internal and external consistency for a measure of household wealth based on polychoric PCA on binary, count, and ordinal asset and capital ownership indicators.
Concluding Remarks

- We have shown that this index ($W_4$) demonstrates:
  - Increasing wealth over time
  - Decreasing wealth inequality over time
  - Increasing social welfare
  - Decreasing asset poverty over time (for arbitrarily defined asset poverty lines)
- Rural wealth has grown considerably faster than urban wealth
- Inequality in both urban and rural areas is declining over time
  - Inequality in rural areas remains higher than in urban areas
Thank you!

pward@purdue.edu
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<tr>
<th>Introduction</th>
<th>China</th>
<th>Well-Being</th>
<th>Data</th>
<th>Wealth</th>
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CHNS Provinces
Subjective Household Asset Valuation

A direct way to measure household asset wealth is to simply take the sum of the market values for all household assets:

\[ W_{1,it}^* = \sum_{j=1}^{N} p_{jt}x_{ijt} \]  

(1)

where \( p_{jt} \) is the price of asset \( j \) in period \( t \) and \( x_{ijt} \) is household \( i \)'s holding of asset \( j \) in period \( t \).

- Price data can be difficult to obtain
- Assumes product homogeneity

An alternative measure sums household’s subjective asset valuations:

\[ W_{1,it} = \sum_{j=1}^{N} v_{ijt} \]  

(2)
Equal Weight Household Asset Index

An indirect way to measure household asset wealth is to create an asset index. Constructing an asset index requires answering the nontrivial question: How do we assign index weights?

- One solution: Equal weights

\[ W_{2,it} = \sum_{j=1}^{N} x_{ijt} \]  

(3)

where, \( x_{ijt} \) is household \( i \)'s holding of asset or capital form \( j \) in period \( t \).
Household Asset Index: Weights Determined by Standard PCA

Principal Component Analysis (PCA) can be used to determine component loadings (index scores)

- Standard PCA must usually be performed on data that are multivariate normal
- Asset indicators (binary, count, ordinal) can have very skewed distributions
- Approach: Normalize the data

\[
W_{3, it} = \sum_{j=1}^{N} \alpha_j \left( \frac{x_{ijt} - \bar{x}_{jt}}{s_{jt}} \right)
\]

(4)

where \( \bar{x}_{jt} \) is the sample mean ownership, \( s_{jt} \) is the sample standard deviation, and \( \alpha_j \) is the factor loading for \( j \) associated with the first principal component.
Household Asset Index: Weights Determined by Polychoric PCA

Polychoric PCA allows for factor weights to be determined on non-normal data

- Allows for varying weights to be assigned to different levels of ownership
- Sometimes non-ownership may be more informative about wealth than ownership
- Perform PCA on polychoric/polyserial correlation matrix

\[
W_{4,it} = \sum_{j=1}^{N} \sum_{k=1}^{K_j} \alpha_{jk} x_{ijkt} \tag{5}
\]

where \( \alpha_{jk} \) is a factor loading associated with owning \( k \in K_j \) of asset category \( j \).
Calculating Spearman Rank Correlations

Spearman Rank Correlations are defined as the Pearson Correlation between the ranked variables:

\[ \rho = \frac{\sum_{i=1}^{N} (x_i - \bar{x})(y_i - \bar{y})}{\sqrt{\sum_{i=1}^{N} (x_i - \bar{x})^2 \sum_{i=1}^{N} (y_i - \bar{y})^2}} \]

For example:
- \( x_i \): rank of \( W_{1,i} \)
- \( y_i \): rank of \( W_{2,i} \)