Welfare Costs of Occupational Decline: Counterfactual Approach

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McKinsey (2017): by 2030 3-14% of global workforce lose jobs to automation

Brynjolfsson et al (2018): 9% of workers in the US are at high risk of automation

Large manufacturing job losses (and gains) in 2000’s due to trade and offshoring

Is it a big deal?

Should we have TAA analogue for jobs lost to automation?
Where All the Breaker Boys Have Gone?

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Research Question

- How large would be welfare costs of displaced workers?
- Depends on skill contents and amenities of different jobs
- Problems:
  - We do not know how to classify skills/amenities in the best way
  - Typically no information on workers’ skills and preferences
  - Not least: little historic data for still active occupations
- Solution: structural model of occupational choice with latent skills
- Allows to model heterogeneity of losses between workers and occupations

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Results

- The model with four latent workers characteristics explains 99% of variation in the occupational transitions probabilities.

- Welfare losses vary significantly between occupations:
  - Large losses for broadly classified occupations requiring specific skills/amenities (24% for professionals).
  - Much smaller losses for narrowly defined groups: around 7-12% for most occupations.

- Previous results:
  - Displaced workers lose between 7 to 25% of earnings in the long-run (Jacobson, LaLonde and Sullivan, 1993; Eliason and Storrie, 2006).
Model 1

- Time is discrete $t = 1, 2, \ldots T$

- Continuum of heterogeneous workers chooses between $J$ occupations

- A worker $p$ chooses an occupation $C_{pt}$ maximizing their utility
  $$C_{pt} = i, |U_{pi} \geq U_{pj}, \forall j \in 1, 2 \ldots J$$

- Vector $X_p$ of length $d$ describes worker’s $p$ skills and preferences

- Vectors $A_j^S$ and $A_j^T$ describe job skill sensitivities and amenities respectively

- The cdf $F()$ describes the distribution of workers’ characteristics
Model 2

- Worker’s utility in occupation includes monetary \( W_{pj} \) and non-monetary benefits \( T_{pj} \):

\[
U_{pj} = \alpha W_{pj} + T_{pj}
\]

- Monetary benefits (wage) depends on the match between worker’s characteristics and job skill sensitivities and on the idiosyncratic shock:

\[
W_{pj} = P_{jt} + X_p A_j^S + \eta_{pj}, \eta_{pj} \sim N(0, \sigma^2)
\]

- Non-monetary benefits depend on the match and on the taste shock \( \epsilon_{pj} \):

\[
T_{pj} = X_p A_j^T + \epsilon_{pj}, \epsilon_{pj} \sim EV(1)
\]

- Indirect utility is \( V_{pj} \equiv W_{pj} + X_p A_j^T \)

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Occupations:

<table>
<thead>
<tr>
<th></th>
<th>A</th>
<th>B</th>
<th>C</th>
</tr>
</thead>
<tbody>
<tr>
<td>strength</td>
<td>0</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td>intelligence</td>
<td>4</td>
<td>3.5</td>
<td>0</td>
</tr>
</tbody>
</table>

For a person $X = [0.5, 1]$:

- $V_A = [0.5, 1] \times [0, 4]' = 4$
- $V_B = [0.5, 1] \times [1, 3.5]' = 4$
- $V_C = [0.5, 1] \times [4, 0]' = 2$
Example

Occupations:

\[
\begin{array}{ccc}
\text{A} & \text{B} & \text{C} \\
\text{strength} & 0 & 1 & 4 \\
\text{intelligence} & 4 & 3.5 & 0 \\
\end{array}
\]

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For a person \( X = [0.5, 1] \):

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Occupational transitions:

<table>
<thead>
<tr>
<th></th>
<th>A</th>
<th>B</th>
<th>C</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>0.228</td>
<td>0.095</td>
<td>0.034</td>
</tr>
<tr>
<td>B</td>
<td>0.095</td>
<td>0.061</td>
<td>0.039</td>
</tr>
<tr>
<td>C</td>
<td>0.0343</td>
<td>0.039</td>
<td>0.375</td>
</tr>
</tbody>
</table>

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The probability that a worker \( p \) with characteristics \( X_p \) chooses an occupation \( j \) is:

\[
P_j(X_p, \eta) = \frac{\exp(V_i(X, \eta))}{\sum_k \exp(V_k(X, \eta))}
\]

Proportion of workers choosing occupation \( i \) is:

\[
P_i = E(P_i(X, \eta))
\]

Proportion of workers switching from occupation \( i \) to \( j \) is:

\[
P_{ij} = E(P_i(X, \eta)P(j(X, \eta))
\]
Welfare Analysis

- What is the effect of the decline in occupation $j$ on the welfare of workers?
  - Workers within an occupation $j$ lose jobs
  - Workers in other occupations lose the opportunity to switch to jobs in $j$

- Welfare costs of all the workers account for both effect:
  
  $$EC_j = (1/\alpha)(E[U] - E[U_{-j}])$$

- Welfare costs of workers within an occupation $j$ account for the strongest first effect:
  
  $$EC_{ij} = (1/\alpha)(E[U|U_{it} \geq U_{kt}] - E[U_{-j}|U_{it} \geq U_{kt}])$$
Estimation

- Use the simulated method of moments (SMM)

- Draw $S$ random vectors of skills from the normal skill distr. $X \sim N(0, I)$

- Estimate moments $P_{ij} \rightarrow \hat{P}_{ij}$:

$$\hat{P}_{ij} = \frac{1}{S} \sum_{p=1}^{S} \frac{\exp(A_i X'_p) \exp(A_j X'_p)}{(\sum_{k=1}^{J} \exp(A_k X_p))^2}$$

- Matching to the frequencies of occupational transitions observed in the data

- Gradient of the objective function has an analytic form (too cumbersome to write it here)
Identification

- Good news: occupational transitions identify both welfare costs up to scale with $T \to \infty$:

  - Both measures can be written as an infinite sum of data moments:

    $$EC_j = \sum_{n=1}^{\infty} \frac{1}{\alpha n!} E[P_j(X, \eta)^n]$$

    $$EC_{ij} = \sum_{n=1}^{\infty} \frac{1}{\alpha P_i n!} E[P_i(X, \eta)P_j(X, \eta)^n]$$

  - Partial sums are within 10% of value for $T = 2$.

- Bad news: no identification for $A$ (without wage data)

  - Any rotation of $A$ does not affect the moments (occupational transitions matrix).

  - Any permutation of rows of $A$ does not affect the moments.
Monte-Carlo Analysis

1. Does the SMM approach produce consistent estimates of welfare costs?
   - How does the bias and the standard deviation of estimates change with the number of observations $N$?

2. How many simulation draws $S$ is necessary for "good" estimates?

3. How does the error change with the number of occupations $J$?

Algorithm:

1. Pick one random seed
2. Generate data $(X_0, A_0, \epsilon)$ with different $N (S, J)$ observations
3. Simulate $S$ draws of $X$
4. Estimate the model and calculate welfare losses
Monte-Carlo Analysis: Welfare Loss Estimation Error

Monte-Carlo simulation of welfare losses

Monte-Carlo simulation of welfare losses

Monte-Carlo simulation of welfare losses, J=10

Monte-Carlo simulation of welfare losses, J=37

N obs, log scale

Number of occupations, J

N simulation, log scale

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Welfare Costs of Occupational Decline: Counterfactual Approach
Monte-Carlo Analysis: Estimation Example

- Measure welfare losses of workers in each occupation from making an occupation obsolete.

<table>
<thead>
<tr>
<th>Occupation</th>
<th>Actual loss(perc.)</th>
<th>Predicted loss(perc.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>31.36</td>
<td>29.00</td>
</tr>
<tr>
<td>2</td>
<td>38.97</td>
<td>37.75</td>
</tr>
<tr>
<td>3</td>
<td>34.39</td>
<td>31.37</td>
</tr>
<tr>
<td>4</td>
<td>25.67</td>
<td>29.36</td>
</tr>
<tr>
<td>5</td>
<td>28.89</td>
<td>29.94</td>
</tr>
<tr>
<td>6</td>
<td>30.42</td>
<td>31.06</td>
</tr>
<tr>
<td>7</td>
<td>31.76</td>
<td>34.93</td>
</tr>
<tr>
<td>8</td>
<td>25.63</td>
<td>28.43</td>
</tr>
<tr>
<td>9</td>
<td>46.25</td>
<td>37.99</td>
</tr>
<tr>
<td>10</td>
<td>28.49</td>
<td>32.41</td>
</tr>
</tbody>
</table>

- Good approximation of welfare losses: $R^2 = 0.999$ for magnitude, $R^2 = 0.67$ for percentage losses
Data

- Use linked March CPS data 2008-2018, age > 25

  → Each worker is observed for two consecutive years

- Use only the workers employed full-time in both years and workers out of labor force (home sector)

- Use two-digit occupational code and recode rare occupations into more general groups

  → End up with 37 occupations including the home sector

- Calculate the transition frequency for each pair of occupations
Two results:

1. 10-occupations classification, $d = 2$, $S = 10000$
2. 37 occupations classification, $d = 4$, $S = 10000$

Models’ fit:

<table>
<thead>
<tr>
<th>$d$</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>$R^2$</td>
<td>0.78</td>
<td>0.85</td>
<td>0.983</td>
<td>0.993</td>
</tr>
</tbody>
</table>

The model explains 99% of variation in the occupational frequencies for $d = 4$ (overidentification test is rejected)

Next, calculate counterfactual welfare losses by using estimated $\hat{A}$. 

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Aggregate Results: Welfare Losses by Occupation

- Top-10 occupations (out of 37) with largest potential welfare losses:

<table>
<thead>
<tr>
<th>Occupation</th>
<th>Welfare loss(perc.)</th>
<th>St. error</th>
<th>Welfare loss</th>
<th>St. error</th>
</tr>
</thead>
<tbody>
<tr>
<td>Home sector</td>
<td>24.70</td>
<td>5.47</td>
<td>-4.99</td>
<td>1.16</td>
</tr>
<tr>
<td>Professionals</td>
<td>23.50</td>
<td>4.63</td>
<td>-3.67</td>
<td>0.79</td>
</tr>
<tr>
<td>Clerical support workers</td>
<td>19.40</td>
<td>4.69</td>
<td>-2.62</td>
<td>1.13</td>
</tr>
<tr>
<td>Service and sales workers</td>
<td>18.27</td>
<td>5.41</td>
<td>-2.89</td>
<td>0.85</td>
</tr>
<tr>
<td>Technicians and associate professionals</td>
<td>18.09</td>
<td>3.36</td>
<td>-2.03</td>
<td>0.57</td>
</tr>
<tr>
<td>Crafts and related trades</td>
<td>17.83</td>
<td>4.05</td>
<td>-2.83</td>
<td>0.89</td>
</tr>
<tr>
<td>Plant and machine operators, assemblers</td>
<td>16.75</td>
<td>4.21</td>
<td>-2.83</td>
<td>1.06</td>
</tr>
<tr>
<td>Managers</td>
<td>15.79</td>
<td>3.69</td>
<td>-1.93</td>
<td>0.32</td>
</tr>
<tr>
<td>Elementary occupations</td>
<td>14.47</td>
<td>3.43</td>
<td>-1.98</td>
<td>0.46</td>
</tr>
<tr>
<td>Skilled agricultural, forestry and fishery</td>
<td>11.84</td>
<td>4.38</td>
<td>-1.25</td>
<td>0.67</td>
</tr>
</tbody>
</table>

- Amenities, education requirement, generality matter
Top-10 occupations with the largest potential welfare losses conditional on becoming obsolete

<table>
<thead>
<tr>
<th>Occupation</th>
<th>Welfare loss(perc.)</th>
<th>Welfare loss</th>
</tr>
</thead>
<tbody>
<tr>
<td>Teachers</td>
<td>21.06</td>
<td>-6.06</td>
</tr>
<tr>
<td>Home sector</td>
<td>19.72</td>
<td>-4.76</td>
</tr>
<tr>
<td>Lawyers</td>
<td>15.69</td>
<td>-3.27</td>
</tr>
<tr>
<td>Office and Administrative Support</td>
<td>15.10</td>
<td>-2.04</td>
</tr>
<tr>
<td>Other healthcare practitioners and technical</td>
<td>14.86</td>
<td>-3.12</td>
</tr>
<tr>
<td>Installation, Maintenance, and Repair</td>
<td>13.82</td>
<td>-3.14</td>
</tr>
<tr>
<td>Construction and Extraction</td>
<td>13.66</td>
<td>-4.01</td>
</tr>
<tr>
<td>Drivers and transportation workers</td>
<td>13.18</td>
<td>-2.87</td>
</tr>
<tr>
<td>Personal Care and Service</td>
<td>11.74</td>
<td>-2.30</td>
</tr>
<tr>
<td>Maintenance occupations</td>
<td>11.39</td>
<td>-2.59</td>
</tr>
</tbody>
</table>
Comparing to Previous Results

- My estimation predicts welfare losses of 5-25%.
- Workers in most occupations lose from 7 to 12%.
- Wide range of estimates of wage losses in the literature due to layoffs (4-50%):
  - Jacobson, LaLonde, Sullivan (1993): displaced workers lose about 25% of wages per year five years after the layoff.
- Layoffs are different from gradual declines:
  - Edin, Evans, Graetz, Hernnas and Michaels (2018): workers in declining industries lose around 5% in earnings.
- Previous estimates do not account for amenities.
Previous Results on Skill Transferability

- No fully structural approach for skills/amenities transferability

- Swithing costs = ad-hoc function of task contents of occupations:

- Switching costs = ad-hoc function of occupational transition probability: Shaw (1984, 1987)

- Contribution: measure transferability for both skills and preferences, no ad-hoc assumptions on skills and their scaling
Develop a new approach to predict welfare cost of occupational decline

Welfare costs > earnings costs in the literature

Losses are highly heterogeneous (between occupations and workers)

Workers in most occupations lose from 6 to 10%

Next: incorporate wage data; contrast estimates with O-NET data