The employment effects of technological innovation and participation in global value chains: Evidence from Asia

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Motivation

• Between 1990 and 2010, Asia lifted 786 million people out of poverty, lowering the headcount ratio from 55% to 21% (ADB 2014):
  – Offshoring played a big role in that!

• Two recent developments could potentially threaten the progress made in many ADB developing member countries (DMCs):
  – The acceleration of technological progress;
  – The relocation of one or more production tasks to another country.

• What are the implications for jobs in the region?

Annual supply of industrial robots 2014-2015 and forecast for 2016-2019
Example: the GVC for garments

Task relocation
If the Chinese garments manufacturers decide to outsource some (routine) jobs to Cambodia, then the number of (routine) jobs is unchanged, but fewer workers are employed in China, and more in Thailand;
Example: the GVC for garments

Task relocation
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Technology within GVC
If machines replace workers in some of the production tasks in the supply chain of garments made in China, then this will lower the number of routine jobs in the supply chain.

Challenges

- Technology adoption and task relocation are not independent of each other.
- Their effect on the broader economy depends on the degree of GVC participation.
- Forecasting exercises require heavy assumptions, and the results are quite sensitive to those assumptions.
- Data on ADB DMCs are not as readily available.
Evidence from the literature

- Acemoglu and Restrepo (2017)
- Autor and Salomons (2017)
- Graetz and Michaels (2018)
- Reijnders and de Vries (2017)

Our contribution

1. Structural decomposition analysis (SDA) of the ADB Multiregional Input-Output Tables (MRIOT) based on Reijnders and de Vries (2017):
   - decompose the changes in occupational labor demand associated with technological change, task relocation, income, and other factors.

2. Focus on 2005-2015 period, when a great deal of technological upgrading happened in the region.

3. Econometric analysis of the relation between robot adoption and change in (non)routine employment shares.
Our findings

• Employment levels:
  – Technology within GVC is associated with a decrease in the levels of employment in both routine and nonroutine occupations;
  – Task relocation is smaller and mixed;
  – Increased demand for goods and services is associated with an increase in labor demand that more than compensates for job losses due to technological advances.

• Employment composition:
  – Technology within GVC is associated with an increase in nonroutine employment shares;
  – Task relocation is once again much smaller and mixed.

Advantages and limitations of a demand-based input-output approach

+ Macro-economic analysis of GVCs;
+ Adherence to national account series of gross output and value added (and employment);

- Demand-based, supply effects not modeled;
- Not a fully specified CGE model (with interaction prices and quantities), but we use annual IO tables such that cost shares are not fixed (as in Leontief or Cobb-Douglas type of production).
STRUCTURAL DECOMPOSITION ANALYSIS

Decomposing changes in labor demand
Decomposing changes in labor demand

Change in Employment

Within GVC

Income

Between GVC

Technology
Task relocation
Country-level efficiency

First level
Second level

Decomposing changes in labor demand

Change in Employment

Within GVC

Income

Between GVC

Technology
Task relocation
Country-level efficiency

Own country
Rest of the world

First level
Second level
Data

1. The ADB Multiregional Input-Output Tables (MRIOT):
   - 35 industries and 48 countries; we focus on 12 developing Asian economies: Bangladesh, the PRC, India, Indonesia, South Korea, Malaysia, Mongolia, the Philippines, Sri Lanka, Taipei, China, Thailand, Vietnam;
   - prices deflated to 2000.

2. Labor force surveys (or population censuses):
   - If unavailable for a given year, then occupation-industry shares are interpolated or extrapolated, while ensuring that shares always sum up to 1.

3. The Penn World Tables, release 9.0:
   - We construct a measure of TFP for each country-year.

The Structure of a Multiregional Input-Output Table

<table>
<thead>
<tr>
<th>Intermediate use</th>
<th>Final use</th>
<th>Gross output</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>$y_1$</td>
</tr>
<tr>
<td>2</td>
<td>$z_{11}$</td>
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<tr>
<td>$G$</td>
<td>$z_{G1}$</td>
<td>$z_{G2}$</td>
</tr>
<tr>
<td>...</td>
<td></td>
<td>$z_{GG}$</td>
</tr>
</tbody>
</table>

Value added: $w_{1_1}, w_{2_1}, \ldots, w_{G_1}$

Gross output: $y_{1_1}, y_{2_1}, \ldots, y_{G_1}$
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<tr>
<td></td>
<td>Z^{GG}</td>
<td>F^{GG}</td>
</tr>
<tr>
<td>Value added</td>
<td>w_1'</td>
<td>y_1'</td>
</tr>
<tr>
<td>Gross output</td>
<td>y_1''</td>
<td>y_1''</td>
</tr>
</tbody>
</table>

**Columns** show how gross output of each country-industry is produced.

**Rows** show how gross output of country-industries are distributed across country-industries worldwide.
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<tr>
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<td>$Z^{22}$</td>
<td>...</td>
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<tr>
<td>...</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td>$G$</td>
<td>$Z^{G1}$</td>
<td>$Z^{G2}$</td>
</tr>
</tbody>
</table>

| Value added      | $w^{1'}$  | $w^{2'}$    | ... | $w^{G'}$ |
| Gross output     | $y^{1'}$  | $y^{2'}$    | ... | $y^{G'}$ |
| Employment       | $x^{1'}$  | $x^{2'}$    | ... | $x^{G'}$ |

Model Assumptions

- **Task-based production function**
  - Tasks are perfect complements to production (Leontief type); can be produced by countries worldwide
  - Countries differ in overall productivity levels; but task production functions differ across countries and GVCs
    - Two variants of technology: country-level efficiency and technology within GVCs
  - There is a **one-to-one mapping** between occupation and tasks
Methodology

• From the MRIOTs, we can construct the matrix of technical coefficients:
  \[ A = Z \times \text{diag}(y)^{-1} \]
• This allows us to write the gross output \( y \) as:
  \[ y = Ay + f \]
• Rearranging, we obtain:
  \[ y = (I - A)^{-1}f = Bf \]

Methodology

• Let \( x_k \) be the vector containing quantities of employment in occupation \( k \) for each country-industry; \( l_k \) the vector of employment in occupation \( k \) per unit of gross output.
  \[ k \in \{ \text{routine manual, routine cognitive, nonroutine manual, nonroutine cognitive} \} \]
• We can express the demand for labor of occupation \( k \) as:
  \[ x_k = \hat{l}_kBf \]
  where \( \hat{l}_k \) is a diagonal matrix with elements of \( l_k \) in the main diagonal
Methodology

• To analyze the relative impacts of trade, technology and income on occupational labor demand, we specify:
  – three intertemporal changes in $x_k$ that affect $\hat{I}_k B$ and
  – three intertemporal changes that affect $f$.

$$x_k = \hat{I}_k B \ast f$$

$$x_k = \hat{\pi}^{-1} R_k \hat{I}_k^* [T^*(S^* \cdot \hat{\epsilon})] u$$

Methodology

$$x_k = \hat{\pi}^{-1} R_k \hat{I}_k^* [T^* \circ (S^* \cdot \hat{\epsilon})] u$$

• $\pi$: productivity vector ($G N x 1$)
• $I_k^*$: labor of occupation $k$ (directly and indirectly) generated by final goods production in each country-industry pair (measured in efficiency units) ($1 x G N$)
• $R_k$: matrix containing shares of each of the $G N$ industries in total employment of occupation $k$ per unit of final demand produced by a global value chain ($G N x G N$)
• $T^*$: matrix of final product trade coefficients,
• $S$: matrix of final demand shares
• $c$: matrix of total final demand exerted by countries worldwide
• $u$: summation vector (vector of ones)

Note: It can be shown mathematically that $\hat{I}_k B = \hat{\pi}^{-1} R_k \hat{I}_k^*$ and $f = [T^*(S^* \cdot \hat{\epsilon})] u$
Structural decomposition of change in employment

- Given two time periods \( t_1 \) and \( t_0 \), we can decompose the change in demand for labor of occupation \( k \) in the following manner:

\[
X_{k1} - X_{k0} = \frac{1}{2} \left[ \pi_{1}^{-1} R_{k1} l_{k1} [T_{1}'] = (S_{1}^* \cdot \epsilon_{1}) u - \pi_{2}^{-1} R_{k0} l_{k0} [T_{0}'] = (S_{0}^* \cdot \epsilon_{0}) u \right]
\]

\[
\frac{1}{2} [\pi_{1}^{-1} R_{k1} l_{k1} [T_{1}'] = (S_{1}^* \cdot \epsilon_{1}) u + \pi_{2}^{-1} R_{k0} l_{k0} [T_{0}'] = (S_{0}^* \cdot \epsilon_{0}) u]
\]

\[
\frac{1}{2} [\pi_{1}^{-1} R_{k1} l_{k1} [T_{1}'] = (S_{1}^* \cdot \epsilon_{1}) u + \pi_{2}^{-1} R_{k0} l_{k0} (T_{1}' - T_{0}') = (S_{0}^* \cdot \epsilon_{0}) u]
\]

\[
\frac{1}{2} [\pi_{1}^{-1} R_{k1} l_{k1} (T_{1}' - T_{0}') = (S_{1}^* \cdot \epsilon_{1}) u + \pi_{2}^{-1} R_{k0} l_{k0} (T_{1}' - T_{0}') = (S_{0}^* \cdot \epsilon_{0}) u]
\]

\[
\frac{1}{2} [\pi_{1}^{-1} R_{k1} l_{k1} (T_{1}' - T_{0}') = (S_{1}^* \cdot \epsilon_{1}) u + \pi_{2}^{-1} R_{k0} l_{k0} (T_{1}' - T_{0}') = (S_{0}^* \cdot \epsilon_{0}) u]
\]

The Two-Country Case

- Suppose \( G=2 \) and \( N=2 \):

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<tr>
<td>1</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>( Z^{11} )</td>
<td>( Z^{12} )</td>
<td>( F^{11} )</td>
</tr>
<tr>
<td>2</td>
<td>( Z^{22} )</td>
<td>( F^{22} )</td>
</tr>
</tbody>
</table>

- Value added: \( w^{1'} \), \( w^{2'} \)
- Gross output: \( y^{1'} \), \( y^{2'} \)
- Employment: \( e^{1'} \), \( e^{2'} \)
### The Two-Country Case

- Suppose G=2 and N=2:

  The amount of gross output from industry 1 of country 1 used to satisfy final demand in country 2

  \[
  \mathbf{F}^{12} = \begin{bmatrix}
  f_{11}^{12} \\
  f_{12}^{12}
  \end{bmatrix}
  \]

  The amount of gross output from industry 2 of country 2 used as intermediate input to production by industry 1 of country 2

  \[
  \mathbf{Z}^{22} = \begin{bmatrix}
  z_{11}^{22} & z_{12}^{22} \\
  z_{21}^{22} & z_{22}^{22}
  \end{bmatrix}
  \]

### The Two-Country Case

- An expanded form of two-country MRIO

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<tr>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>1</td>
<td>Z_{11}^{22}</td>
<td>F_{11}^{22}</td>
</tr>
<tr>
<td>2</td>
<td>Z_{21}^{22}</td>
<td>F_{21}^{22}</td>
</tr>
<tr>
<td>1</td>
<td>Z_{12}^{22}</td>
<td>F_{12}^{22}</td>
</tr>
<tr>
<td>2</td>
<td>Z_{22}^{22}</td>
<td>F_{22}^{22}</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Value added</th>
<th>( w_1^1 )</th>
<th>( w_2^1 )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gross output</td>
<td>( y_1^1 )</td>
<td>( y_2^1 )</td>
</tr>
<tr>
<td>Employment of occupation ( k )</td>
<td>( x_k^1 )</td>
<td>( x_k^2 )</td>
</tr>
</tbody>
</table>
The Two-Country Case

\[(I - A)^{-1} = \begin{bmatrix}
1 - (x_{11}^1/y_{11}^1) & -x_{12}^1/y_{11}^1 & -x_{11}^2/y_{12}^2 & -x_{12}^2/y_{12}^2 \\
-x_{21}^1/y_{21}^1 & 1 - (x_{21}^1/y_{21}^1) & -x_{22}^1/y_{22}^2 & -x_{22}^2/y_{22}^2 \\
-x_{21}^2/y_{21}^2 & -x_{22}^1/y_{22}^2 & 1 - (x_{22}^1/y_{22}^2) & -x_{22}^2/y_{22}^2 \\
-x_{21}^2/y_{21}^2 & -x_{22}^2/y_{22}^2 & -x_{22}^2/y_{22}^2 & 1 - (x_{22}^2/y_{22}^2)
\end{bmatrix}^{-1} = \begin{bmatrix}
b_{11}^1 & b_{12}^1 & b_{12}^2 & b_{12}^2 \\
b_{21}^1 & b_{21}^1 & b_{21}^2 & b_{21}^2 \\
b_{22}^1 & b_{22}^1 & b_{22}^2 & b_{22}^2 \\
b_{22}^2 & b_{22}^2 & b_{22}^2 & b_{22}^2
\end{bmatrix}
\]

\[l_k = \begin{bmatrix}
x_{1k1}^1/y_{1k1}^1 \\
x_{1k2}^1/y_{2k1}^2 \\
x_{2k1}^1/y_{1k2}^2 \\
x_{2k2}^1/y_{2k2}^2
\end{bmatrix}
\text{ and } \pi = \begin{bmatrix}
\pi_1 \\
\pi_1 \\
\pi_2 \\
\pi_2
\end{bmatrix}
\]

\[x_k = l_k B F = \begin{bmatrix}
x_{1k1}^1/y_{1k1}^1 & 0 & 0 & 0 \\
0 & x_{1k2}^1/y_{2k1}^2 & 0 & 0 \\
0 & 0 & x_{2k1}^1/y_{1k2}^2 & 0 \\
0 & 0 & 0 & x_{2k2}^1/y_{2k2}^2
\end{bmatrix}
\begin{bmatrix}
b_{11}^1 & b_{12}^1 & b_{12}^2 & b_{12}^2 \\
b_{21}^1 & b_{21}^1 & b_{21}^2 & b_{21}^2 \\
b_{22}^1 & b_{22}^1 & b_{22}^2 & b_{22}^2 \\
b_{22}^2 & b_{22}^2 & b_{22}^2 & b_{22}^2
\end{bmatrix}
\begin{bmatrix}
f_{11}^1 + f_{12}^1 \\
f_{21}^1 + f_{22}^1 \\
f_{11}^2 + f_{12}^2 \\
f_{21}^2 + f_{22}^2
\end{bmatrix}
\]

The Two-Country Case

\[x_k = \begin{bmatrix}
x_{1k1}^1 \\
x_{1k2}^1 \\
x_{2k1}^1 \\
x_{2k2}^1
\end{bmatrix} = \begin{bmatrix}
(x_{1k1}^1/y_{1k1}^1)(b_{11}^1(f_1^{11} + f_2^{12}) + b_{12}^1(f_1^{11} + f_2^{12}) + b_{12}^2(f_1^{21} + f_2^{22}) + b_{12}^2(f_1^{21} + f_2^{22})) \\
(x_{1k2}^1/y_{2k1}^2)(b_{11}^1(f_1^{11} + f_2^{12}) + b_{12}^1(f_1^{11} + f_2^{12}) + b_{12}^2(f_1^{21} + f_2^{22}) + b_{12}^2(f_1^{21} + f_2^{22})) \\
(x_{2k1}^1/y_{1k2}^2)(b_{21}^1(f_1^{11} + f_2^{12}) + b_{21}^2(f_1^{21} + f_2^{22}) + b_{22}^2(f_1^{21} + f_2^{22}) + b_{22}^2(f_1^{21} + f_2^{22})) \\
(x_{2k2}^1/y_{2k2}^2)(b_{21}^1(f_1^{11} + f_2^{12}) + b_{21}^2(f_1^{21} + f_2^{22}) + b_{22}^2(f_1^{21} + f_2^{22}) + b_{22}^2(f_1^{21} + f_2^{22}))
\end{bmatrix}
\]

\[x_{k2}^1 = (x_{1k1}^1/y_{1k1}^1)(f_1^{11} + f_2^{12}) + (x_{1k2}^1/y_{2k1}^2)(f_1^{11} + f_2^{12}) + (x_{2k1}^1/y_{1k2}^2)(f_1^{21} + f_2^{22}) + (x_{2k2}^1/y_{2k2}^2)(f_1^{21} + f_2^{22})
\]

number of jobs of occupation k in industry 1 of country 1 that contribute to final goods production in industry 1 of country 1

number of jobs of occupation k in industry 1 of country 1 that contribute to final goods production in industry 1 of country 2
Two-Country Case

\[ \mathbf{l}_k^k \equiv \begin{bmatrix} l_{k1}^k \\ l_{k2}^k \\ l_{k1}^k \\ l_{k2}^k \end{bmatrix} \equiv \begin{bmatrix} n_1^1 \\ n_2^1 \\ n_1^2 \\ n_2^2 \end{bmatrix} \begin{bmatrix} x_{k1}/y_{11}^k \\ x_{k2}/y_{12}^k \\ x_{k1}/y_{21}^k \\ x_{k2}/y_{22}^k \end{bmatrix} \begin{bmatrix} b_{11}^k \\ b_{12}^k \\ b_{21}^k \\ b_{22}^k \end{bmatrix} \]

\[ \pi^1(x_{k1}/y_{11}^k)b_{11}^k + \pi^1(x_{k2}/y_{12}^k)b_{12}^k + \pi^2(x_{k1}/y_{21}^k)b_{21}^k + \pi^2(x_{k2}/y_{22}^k)b_{22}^k = \pi^1(x_{k1}/y_{11}^k)b_{11}^k + \pi^1(x_{k2}/y_{12}^k)b_{12}^k + \pi^2(x_{k1}/y_{21}^k)b_{21}^k + \pi^2(x_{k2}/y_{22}^k)b_{22}^k \]

\[ l_{k1}^k = \pi^1(x_{k1}/y_{11}^k)b_{11}^k + \pi^1(x_{k2}/y_{12}^k)b_{12}^k + \pi^2(x_{k1}/y_{21}^k)b_{21}^k + \pi^2(x_{k2}/y_{22}^k)b_{22}^k \]

Two-Country Case

\[ \mathbf{R}_k \equiv \{\mathbf{n}_k\mathbf{B}\}^{-1} \equiv \begin{bmatrix} \pi^1x_{11}^1b_{11}^1/y_{11}^1k_1 & \pi^1x_{12}^1b_{12}^1/y_{12}^1k_1 & \pi^1x_{21}^1b_{12}^1/y_{21}^1k_1 & \pi^1x_{22}^1b_{12}^1/y_{22}^1k_1 \\ \pi^1x_{11}^2b_{11}^2/y_{11}^2k_2 & \pi^1x_{12}^2b_{12}^2/y_{12}^2k_2 & \pi^1x_{21}^2b_{12}^2/y_{21}^2k_2 & \pi^1x_{22}^2b_{12}^2/y_{22}^2k_2 \\ \pi^1x_{11}^2b_{11}^2/y_{11}^2k_1 & \pi^1x_{12}^2b_{12}^2/y_{12}^2k_2 & \pi^1x_{21}^2b_{12}^2/y_{21}^2k_2 & \pi^1x_{22}^2b_{12}^2/y_{22}^2k_2 \\ \pi^1x_{11}^2b_{11}^2/y_{11}^2k_1 & \pi^1x_{12}^2b_{12}^2/y_{12}^2k_2 & \pi^1x_{21}^2b_{12}^2/y_{21}^2k_2 & \pi^1x_{22}^2b_{12}^2/y_{22}^2k_2 \end{bmatrix} \]

Share of industry 1 of country 2 to total labor generated in the production of final products by industry 1 country 1
Two-Country Case

\[ c = [f_{11}^{11} + f_{12}^{21} + f_{21}^{21} + f_{22}^{21}, f_{11}^{12} + f_{12}^{12} + f_{21}^{22} + f_{22}^{22}] \]

\[ S = \begin{bmatrix} f_{11}^{11} + f_{12}^{21} & f_{12}^{12} + f_{21}^{22} \\ f_{11}^{11} + f_{12}^{21} & f_{12}^{12} + f_{21}^{22} \end{bmatrix} \]

\[ T^* = \begin{bmatrix} f_{11}^{11} & f_{12}^{12} \\ f_{11}^{11} & f_{12}^{12} \end{bmatrix} \]

- Finally, one can verify that:

\[ x_{k_1}^1 = \sum_{s=1}^{2} \sum_{j=1}^{2} \left( \frac{1}{n} \right) \left( \frac{\pi_1 x_{k_1}^{1 \ast} b_{ij}^{1 \ast}}{y_{i_1 k_1}^{1 \ast}} \right) (i_1^k) \left[ \sum_{p=1}^{2} \left( \frac{f_{11}^{1p}}{\sum_{q=1}^{2} f_{1q}^{1p}} \right) \left( \frac{\sum_{q=1}^{2} f_{1q}^{1p}}{\sum_{p=1}^{2} f_{1q}^{1p}} \right) \right] \]

Two-Country Case

\[ x_{k_1}^1 = \sum_{s=1}^{2} \sum_{j=1}^{2} \left( \frac{1}{n} \right) \left( \frac{\pi_1 x_{k_1}^{1 \ast} b_{ij}^{1 \ast}}{y_{i_1 k_1}^{1 \ast}} \right) (i_1^k) \left[ \sum_{p=1}^{2} \left( \frac{f_{11}^{1p}}{\sum_{q=1}^{2} f_{1q}^{1p}} \right) \left( \frac{\sum_{q=1}^{2} f_{1q}^{1p}}{\sum_{p=1}^{2} f_{1q}^{1p}} \right) \right] \]
Structural decomposition of change in employment

- Given two time periods $t_1$ and $t_0$, we can decompose the change in demand for labor of occupation $k$ in the following manner:

$$X_{k1} - X_{k0}$$

- Aggregate results

- Technology -46% -71 million
- Task relocation 3% 3 million
- Country-level efficiency -20% -30 million

Within GVC

Change in Employment 11% 17 million

- Between GVC -13% -19 million
- Own country 80% 122 million
- Rest of the world 8% 12 million
Structural decomposition analysis of changes in employment by sector, 2005-2015

### 1. Agriculture

<table>
<thead>
<tr>
<th>Country</th>
<th>Technology within a GVC</th>
<th>Country-level efficiency</th>
<th>Task relocation</th>
<th>Income from own country</th>
<th>Income from the rest of the world</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bangladesh</td>
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<tr>
<td>Developing Asia</td>
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</tbody>
</table>

GVC = global value chain, PRC = People’s Republic of China.

Note: Because manufacturing excludes the industry subsectors electricity, gas, and water supply and construction, “all sectors” is larger than the sum of agriculture, manufacturing, and services. Developing Asia in the decomposition analysis includes Bangladesh, India, Indonesia, Malaysia, Mongolia, the People’s Republic of China, the Philippines, the Republic of Korea, Sri Lanka, Taipei, China, Thailand, and Viet Nam.

Source: ADB estimates using the ADB Multiregional Input-Output Database (accessed 20 November 2017); labor force surveys; various countries; World Input-Output Database—Socioeconomic Accounts (Timmer et al. 2015).

### 2. Manufacturing

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Structural decomposition analysis of changes in employment by sector, 2005-2015

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Source: ADB estimates using the ADB Multi-Regional Input-Output Database (accessed 20 November 2017); labor force surveys, various countries; World Input-Output Database—Socioeconomic Accounts (Timmer et al. 2015).
Routine vs. nonroutine occupations

- We use the International Standard Classification of Occupations (ISCO), version 2008 (ISCO-08), at the two-digit level;

- We classify occupations into routine manual, routine cognitive, nonroutine manual, and nonroutine cognitive based on Autor, Levy, and Murnane (2003);
  - This classification is not possible for occupations in agriculture.

Classification of occupations

<table>
<thead>
<tr>
<th>Routine</th>
<th>Non-routine</th>
</tr>
</thead>
<tbody>
<tr>
<td>Manual</td>
<td></td>
</tr>
<tr>
<td>Craft and related trade workers [71-75]</td>
<td>Services and sales workers [51-54]</td>
</tr>
<tr>
<td>Plant and machine operators and assemblers [81-83]</td>
<td></td>
</tr>
<tr>
<td>Elementary occupations [91-96]*</td>
<td></td>
</tr>
<tr>
<td>Cognitive</td>
<td></td>
</tr>
<tr>
<td>Clerical support workers [41-44]</td>
<td>Managers [11-14]</td>
</tr>
<tr>
<td></td>
<td>Professionals [21-26]</td>
</tr>
<tr>
<td></td>
<td>Technicians and associate professionals [31-35]</td>
</tr>
</tbody>
</table>

The numbers in brackets refer to ISCO-08 codes, excluding Agriculture [61-63] and Armed forces [01-03]. The grouping of occupations in four categories (routine manual, routine cognitive, non-routine manual, non-routine cognitive) is based on Autor et al. (2003), see Reijnders and de Vries (2017).

*Elementary occupations involve the performance of simple and routine tasks which may require the use of hand-held tools and considerable physical effort.
## Descriptive Statistics

<table>
<thead>
<tr>
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<tbody>
<tr>
<td></td>
<td>NRC</td>
<td>NRM</td>
<td>RC</td>
</tr>
<tr>
<td>Bangladesh</td>
<td>636</td>
<td>496</td>
<td>124</td>
</tr>
<tr>
<td>India</td>
<td>9,098</td>
<td>1,541</td>
<td>1,233</td>
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<tr>
<td>Indonesia</td>
<td>583</td>
<td>691</td>
<td>526</td>
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<td>Malaysia</td>
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<td>217</td>
<td>185</td>
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<td>Mongolia</td>
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<tr>
<td>Philippines</td>
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<td>7,161</td>
<td>6,092</td>
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<tr>
<td>Rep. of Korea</td>
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<td>194</td>
<td>851</td>
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<tr>
<td>Sri Lanka</td>
<td>150</td>
<td>35</td>
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<tr>
<td>Taipei, China</td>
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<td>260</td>
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<tr>
<td>Thailand</td>
<td>1,041</td>
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<tr>
<td>Viet Nam</td>
<td>859</td>
<td>225</td>
<td>163</td>
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<tr>
<td><strong>All Asian DMCs</strong></td>
<td><strong>32,406</strong></td>
<td><strong>10,667</strong></td>
<td><strong>10,052</strong></td>
</tr>
</tbody>
</table>

### SDA of changes in employment by sector and occupation type, 2005-2015

- **Nonroutine cognitive**
- **Nonroutine manual**
- **Routine cognitive**
- **Routine manual**

![Diagram](image)
SDA of changes in employment by sector and occupation type, 2005-2015

Changes in employment shares by occupation type, 2005-2015

GVC = global value chain, PRC = People’s Republic of China.

Note: Developing Asia in the decomposition analysis includes Bangladesh, India, Indonesia, Malaysia, Mongolia, the People’s Republic of China, the Philippines, the Republic of Korea, Sri Lanka, Taipei, China, Thailand, and Viet Nam.

Sources: ADB estimates using the ADB Multiregional Input-Output Database (accessed 20 November 2017); Labor force surveys, various countries; World Input–Output Database—Socioeconomic Accounts (Timmer et al. 2015).
Changes in employment shares by occupation type, 2005-2015

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Changes in employment shares by occupation type, 2005-2015

ECONOMETRIC ANALYSIS

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Sources: ADB estimates using the ADB Multiregional Input-Output Database (accessed 20 November 2017); Labor force surveys, various countries; World Input-Output Database—Socioeconomic Accounts (Timmer et al. 2015).
Motivation

- We now use robot adoption to analyze the relationship between technology and jobs in a regression analysis framework.

- Robots’ capacity for autonomous movement and their ability to perform an expanding set of tasks set them apart from earlier waves of automation and more conventional ICT, in which 3-D activities could only be done by humans.

Our contribution

- We use information on occupational employment within industries:
  - we examine the effects of robot adoption on routine and non-routine task-intensive occupations;

- We distinguish between the effects of robot adoption on jobs in developed versus developing countries:
  - factor price differences suggest different substitution elasticities between robots and jobs in developed versus developing countries.
Data

- Investment in industrial robots by country-industry is provided by the International Federation of Robotics (IFR), in ISIC rev. 4 classification;
- ADB MRIOTs (and occupations) use the ISIC rev. 3.1;
- We are able to match 19 industries, including all manufacturing, agriculture, mining, utilities, construction, and education.
- Our results are based on 40 (developed and developing) countries and 19 industries in the period 2005-2015.

Constructing the explanatory variable

- We define ‘robot density’ as the number of robots per thousand persons employed. We refer to changes in robot density over time as ‘robot adoption.’
- Following Graetz and Michaels (2017):
  - we use the robot investment data and the perpetual inventory method to construct a measure of robot stocks, assuming a depreciation rate of 10 percent;
  - we look at percentiles of changes in robot density (based on within-country weighted distributions of changes).
Relation between routine jobs and Robots, 2005-2015

Notes: Observations are country-industry cells. The size of each circle corresponds to an industry’s 2005 within-country employment share. Fitted regression lines are shown. Measures of robot adoption are net of country trends.

Empirical strategy

\[ \Delta Y_{ci} = \beta_1 + \beta_2 R_{ci} + \beta_3 Controls + \epsilon_{ci} \]

- Change in the outcome of interest in country \( c \), industry \( i \) from 2005 to 2015
- Change in the use of robots relative to labor input
- Country fixed effects and changes in other inputs
Change in robot inputs and impact on employment, 2005-2015 (OLS estimates)

### a. Overall employment

<table>
<thead>
<tr>
<th></th>
<th>Change in employment</th>
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<td>(1)</td>
<td>(2)</td>
<td>(3)</td>
<td>(4)</td>
<td>(5)</td>
<td>(6)</td>
<td>(7)</td>
</tr>
<tr>
<td>Robot adoption</td>
<td>-0.212 (0.37)</td>
<td>-0.212 (0.73)</td>
<td>-0.663 (0.61)</td>
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<tr>
<td>Country trends</td>
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<tr>
<td>Clustered standard errors</td>
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<td>Yes</td>
<td>Yes</td>
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<tr>
<td>Observations</td>
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<td>757</td>
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</table>

### b. Routine employment

<table>
<thead>
<tr>
<th></th>
<th>Change in routine employment share</th>
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<td>(4)</td>
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<tr>
<td>Robot adoption</td>
<td>-0.048*** (0.01)</td>
<td>-0.048*** (0.01)</td>
<td>-0.048*** (0.01)</td>
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<tr>
<td>Country trends</td>
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<tr>
<td>Observations</td>
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</table>

* * p < 0.01, ** p < 0.05, *** p < 0.01.

Note: Robot adoption is the percentile in the weighted distribution of changes in robot density. Controls include real changes in gross fixed capital formation share in value added and changes in value added. Robust standard errors in parenthesis. Regressions are weighted by 2005 within-country employment shares.

Change in robot inputs and impact on employment, 2005-2015 (OLS estimates)

### c. Occupational employment shares

<table>
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<tr>
<th></th>
<th>Change in employment share of</th>
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</tr>
<tr>
<td>Routine manual</td>
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<td>Nonroutine cognitive</td>
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<tr>
<td>Robot adoption</td>
<td>-0.055*** (0.02)</td>
<td>-0.002 (0.00)</td>
<td>-0.004 (0.01)</td>
<td>0.061*** (0.01)</td>
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### d. Developed versus developing countries

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<tr>
<td>Robot adoption</td>
<td>-0.056*** (0.01)</td>
<td>-0.056*** (0.02)</td>
<td>-0.056*** (0.02)</td>
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<tr>
<td>Developing country x robot adoption (Interaction term)</td>
<td>0.038 (0.03)</td>
<td>0.038** (0.02)</td>
<td>0.036*** (0.02)</td>
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</tr>
</tbody>
</table>

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CONCLUSION AND DISCUSSION

Conclusion

• In the 2005-2015 period, the implementation of technology along the GVCs has been associated with a decrease in both routine and nonroutine employment *levels*, and an increase in nonroutine (cognitive) employment *shares*;

• Demand for goods and services from a new Asian middle class has been associated with an increase in both routine and nonroutine employment levels that more than offsets the negative impacts of technology.
Policy implications

• Technological advances are likely to aggravate skills mismatches in developing Asia:
  – Skilling / reskilling of the labor force;
  – Labor regulations and social protection;
  – Tax and expenditure policies;
• Technology, which has created ‘the problem,’ can also be the solution: embrace it!
  – Provide the necessary support infrastructure;
  – Create an environment conducive to innovation.