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

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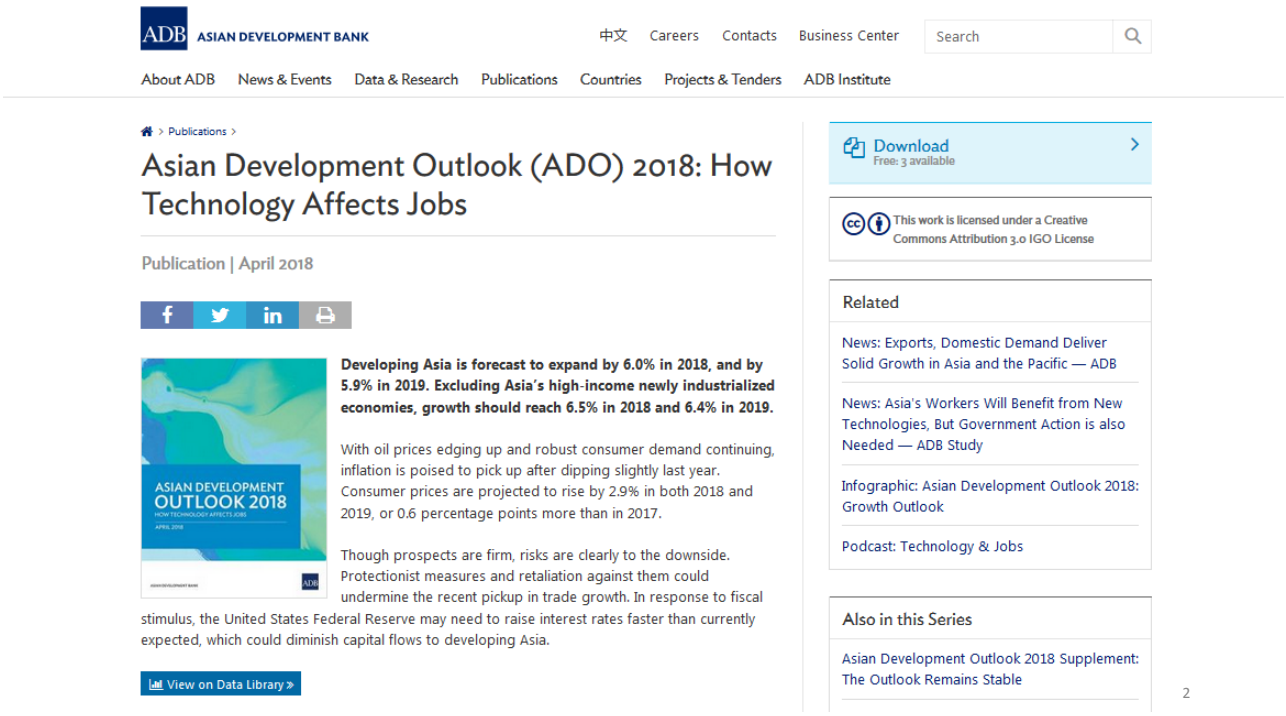

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Asian Development Outlook (ADO) 2018: How Technology Affects Jobs

Publication | April 2018

Developing Asia is forecast to expand by 6.0% in 2018, and by 5.9% in 2019. Excluding Asia's high-income newly industrialized economies, growth should reach 6.5% in 2018 and 6.4% in 2019.

With oil prices edging up and robust consumer demand continuing, inflation is poised to pick up after dipping slightly last year. Consumer prices are projected to rise by 2.9% in both 2018 and 2019, or 0.6 percentage points more than in 2017.

Though prospects are firm, risks are clearly to the downside. Protectionist measures and retaliation against them could undermine the recent pickup in trade growth. In response to fiscal stimulus, the United States Federal Reserve may need to raise interest rates faster than currently expected, which could diminish capital flows to developing 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?

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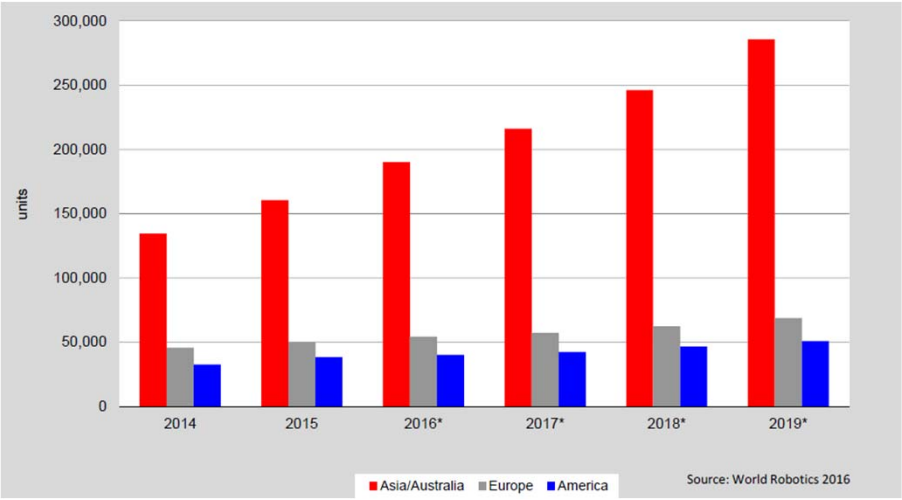
Annual supply of industrial robots 2014-2015 and forecast for 2016-2019



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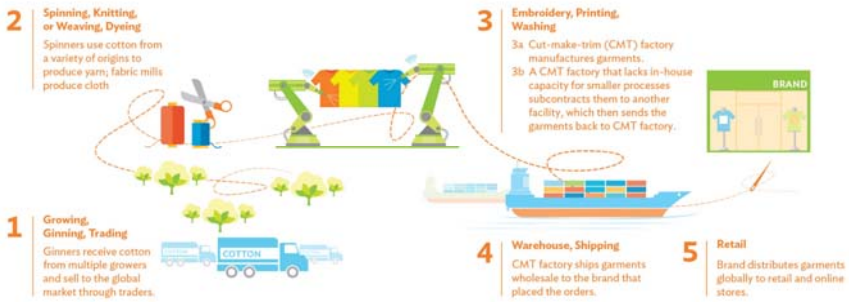
Example: the GVC for garments



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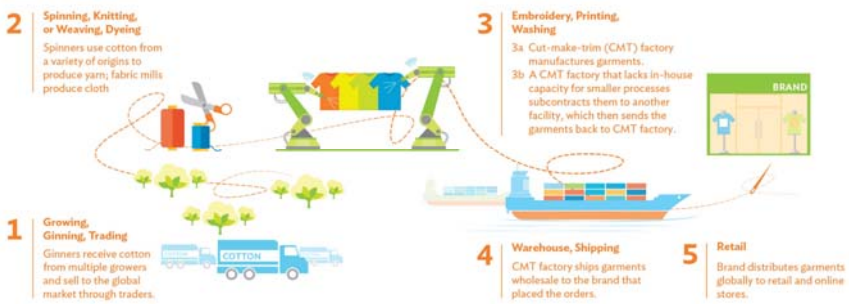
Example: the GVC for garments

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;



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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;

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.

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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.

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Evidence from the literature

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

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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.

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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.

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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).

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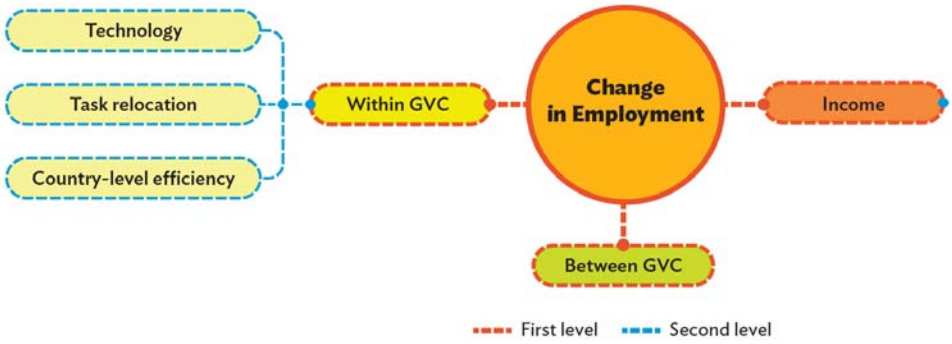
STRUCTURAL DECOMPOSITION ANALYSIS

Decomposing changes in labor demand

Decomposing changes in labor demand



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Decomposing changes in labor demand

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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;
   - available for 2000, 2005, 2008, 2011, and 2015; we focus on the period 2005-2015;
   - 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.

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The Structure of a Multiregional Input-Output Table

	Intermediate use				Final use				Gross output
	1	*2*	...	*G*	*1*	*2*	...	*G*	
1	$\mathbf{Z}^{11}$	$\mathbf{Z}^{12}$	...	$\mathbf{Z}^{1G}$	$\mathbf{F}^{11}$	$\mathbf{F}^{12}$	...	$\mathbf{F}^{1G}$	$\mathbf{y}^{1}$
2	$\mathbf{Z}^{21}$	$\mathbf{Z}^{22}$	...	$\mathbf{Z}^{2G}$	$\mathbf{F}^{21}$	$\mathbf{F}^{22}$	...	$\mathbf{F}^{2G}$	$\mathbf{y}^{2}$
...	...	...	...	...	...	...	...	...	...
G	$\mathbf{Z}^{G1}$	$\mathbf{Z}^{G2}$	...	$\mathbf{Z}^{GG}$	$\mathbf{F}^{G1}$	$\mathbf{F}^{G2}$	...	$\mathbf{F}^{GG}$	$\mathbf{y}^{G}$
Value added	$w^{1\prime}$	$w^{2\prime}$	...	$w^{G\prime}$					
Gross output	$y^{1\prime}$	$y^{2\prime}$	...	$y^{G\prime}$					

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The Structure of a Multiregional Input-Output Table

	Intermediate use				Final use				Gross output
	1	*2*	…	*G*	*1*	*2*	…	*G*	
1	$\mathbf{Z}^{11}$	$\mathbf{Z}^{12}$	…	$\mathbf{Z}^{1G}$	$\mathbf{F}^{11}$	$\mathbf{F}^{12}$	…	$\mathbf{F}^{1G}$	$\mathbf{y}^{1}$
2	$\mathbf{Z}^{21}$	$\mathbf{Z}^{22}$	…	$\mathbf{Z}^{2G}$	$\mathbf{F}^{21}$	$\mathbf{F}^{22}$	…	$\mathbf{F}^{2G}$	$\mathbf{y}^{2}$
…	…	…	…	…	…	…	…	…	…
G	$\mathbf{Z}^{G1}$	$\mathbf{Z}^{G2}$	…	$\mathbf{Z}^{GG}$	$\mathbf{F}^{G1}$	$\mathbf{F}^{G2}$	…	$\mathbf{F}^{GG}$	$\mathbf{y}^{G}$
Value added	$\boldsymbol{w}^{1\prime}$	$\boldsymbol{w}^{2\prime}$	…	$\boldsymbol{w}^{G\prime}$					
Gross output	$\boldsymbol{y}^{1\prime}$	$\boldsymbol{y}^{2\prime}$	…	$\boldsymbol{y}^{G\prime}$					

Rows show how gross output of country-industries are distributed across country-industries worldwide

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The Structure of a Multiregional Input-Output Table

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

	Intermediate use				Final use				Gross output
	1	*2*	…	*G*	*1*	*2*	…	*G*	
1	$\mathbf{Z}^{11}$	$\mathbf{Z}^{12}$	…	$\mathbf{Z}^{1G}$	$\mathbf{F}^{11}$	$\mathbf{F}^{12}$	…	$\mathbf{F}^{1G}$	$\mathbf{y}^{1}$
2	$\mathbf{Z}^{21}$	$\mathbf{Z}^{22}$	…	$\mathbf{Z}^{2G}$	$\mathbf{F}^{21}$	$\mathbf{F}^{22}$	…	$\mathbf{F}^{2G}$	$\mathbf{y}^{2}$
…	…	…	…	…	…	…	…	…	…
G	$\mathbf{Z}^{G1}$	$\mathbf{Z}^{G2}$	…	$\mathbf{Z}^{GG}$	$\mathbf{F}^{G1}$	$\mathbf{F}^{G2}$	…	$\mathbf{F}^{GG}$	$\mathbf{y}^{G}$
Value added	$\boldsymbol{w}^{1\prime}$	$\boldsymbol{w}^{2\prime}$	…	$\boldsymbol{w}^{G\prime}$					
Gross output	$\boldsymbol{y}^{1\prime}$	$\boldsymbol{y}^{2\prime}$	…	$\boldsymbol{y}^{G\prime}$					

Rows show how gross output of country-industries are distributed across country-industries worldwide

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The Structure of a Multiregional Input-Output Table

		Intermediate use				Final use				Gross output
		1	*2*	…	*G*	*1*	*2*	…	*G*	
	1	$\mathbf{Z}^{11}$	$\mathbf{Z}^{12}$	…	$\mathbf{Z}^{1G}$	$\mathbf{F}^{11}$	$\mathbf{F}^{12}$	…	$\mathbf{F}^{1G}$	$\mathbf{y}^{1}$
	2	$\mathbf{Z}^{21}$	$\mathbf{Z}^{22}$	…	$\mathbf{Z}^{2G}$	$\mathbf{F}^{21}$	$\mathbf{F}^{22}$	…	$\mathbf{F}^{2G}$	$\mathbf{y}^{2}$
	…	…	…	…	…	…	…	…	…	…
	G	$\mathbf{Z}^{G1}$	$\mathbf{Z}^{G2}$	…	$\mathbf{Z}^{GG}$	$\mathbf{F}^{G1}$	$\mathbf{F}^{G2}$	…	$\mathbf{F}^{GG}$	$\mathbf{y}^{G}$
Value added		$w^{1\prime}$	$w^{2\prime}$	…	$w^{G\prime}$					
Gross output		$y^{1\prime}$	$y^{2\prime}$	…	$y^{G\prime}$					
Employment		$x^{1\prime}$	$x^{2\prime}$	…	$x^{G\prime}$					

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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

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Methodology

- From the MRIOTs, we can construct the matrix of technical coefficients:

$$\mathbf{A} = \mathbf{Z} * \mathbf{diag}(\mathbf{y})^{-1}$$

- This allows us to write the gross output $\mathbf{y}$ as:

$$\mathbf{y} = \mathbf{A}\mathbf{y} + \mathbf{f}$$

- Rearranging, we obtain:

$$\mathbf{y} = (\mathbf{I} - \mathbf{A})^{-1}\mathbf{f} = \mathbf{B}\mathbf{f}$$

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Methodology

- Let $\mathbf{x}_k$ be the vector containing quantities of employment in occupation k for each country-industry; $\mathbf{l}_k$ the vector of employment in occupation k per unit of gross output.
  - $k \in$ {routine manual, routine cognitive, nonroutine manual, nonroutine cognitive}
- We can express the demand for labor of occupation k as:

$$x_k = \widehat{\mathbf{l}_k}\mathbf{B}\mathbf{f}$$

where $\widehat{\mathbf{l}_k}$ is a diagonal matrix with elements of $\mathbf{l}_k$ in the main diagonal

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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 $\widehat{\mathbf{l}_k}\mathbf{B}$ and
  - three intertemporal changes that affect $\mathbf{f}$.

$$x_k = \widehat{\mathbf{l}_k}\mathbf{B} * \mathbf{f}$$

$$x_k = \widehat{\boldsymbol{\pi}}^{-1}\mathbf{R_k}\hat{\mathbf{l}}_\mathbf{k}^* \, [\mathbf{T}^{*\circ}(\mathbf{S}^* \cdot \hat{\mathbf{c}})]\mathbf{u}$$

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Methodology

$$x_k = \widehat{\boldsymbol{\pi}}^{-1}\mathbf{R_k}\hat{\mathbf{l}}_\mathbf{k}^* \, [\mathbf{T}^* \circ (\mathbf{S}^* \cdot \hat{\mathbf{c}})]\mathbf{u}$$

- $\boldsymbol{\pi}$: productivity vector (*GNx1*)
- $\mathbf{l}_k^*$: labor of occupation k (directly and indirectly) generated by final goods production in each country-industry pair (measured in efficiency units) (*1xGN*)
- $\mathbf{R}_k$: matrix containing shares of each of the *GN* industries in total employment of occupation k per unit of final demand produced by a global value chain (*GNxGN*)
- $\mathbf{T}^*$**:** matrix of final product trade coefficients,
- $\mathbf{S}$**:** matrix of final demand shares
- $\mathbf{c}$**:** matrix of total final demand exerted by countries worldwide
- $\mathbf{u}$**:** summation vector (vector of ones)

Note: It can be shown mathematically that $\widehat{\mathbf{l}_k}\mathbf{B} = \widehat{\boldsymbol{\pi}}^{-1}\,\mathbf{R}_k\hat{\mathbf{l}}_k^*$ and $\mathbf{f} = [\mathbf{T}^{*\circ}(\mathbf{S}^* \cdot \hat{\mathbf{c}})]\mathbf{u}$

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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:

$$x_{k1} - x_{k0}$$

$$\hat{\pi}_1^{-1} R_{k1} \hat{l}_{k1}^* [T_1^* \circ (S_1^* \cdot \hat{c}_1)]u - \hat{\pi}_0^{-1} R_{k0} \hat{l}_{k0}^* [T_0^* \circ (S_0^* \cdot \hat{c}_0)]u$$

change in employment

$$\frac{1}{2}\{\hat{\pi}_0^{-1} R_{k0} \langle \hat{l}_{k1}^* - \hat{l}_{k0}^* \rangle [T_1^* \circ (S_1^* \cdot \hat{c}_1)]u + \hat{\pi}_1^{-1} R_{k1} \langle \hat{l}_{k1}^* - \hat{l}_{k0}^* \rangle [T_0^* \circ (S_0^* \cdot \hat{c}_0)]u\}$$

technology within GVC

$$\frac{1}{2}\{\hat{\pi}_0^{-1} \langle R_{k1} - R_{k0} \rangle \hat{l}_{k1}^* [T_1^* \circ (S_1^* \cdot \hat{c}_1)]u + \hat{\pi}_1^{-1} \langle R_{k1} - R_{k0} \rangle \hat{l}_{i0}^* [T_0^* \circ (S_0^* \cdot \hat{c}_0)]u\} + \frac{1}{2}\{\hat{\pi}_0^{-1} R_{k0} \hat{l}_{k0}^* [\langle T_1^* - T_0^* \rangle \circ (S_1^* \cdot \hat{c}_1)]u + \hat{\pi}_1^{-1} R_{k1} \hat{l}_{k1}^* [\langle T_1^* - T_0^* \rangle \circ (S_0^* \cdot \hat{c}_0)]u\}$$

task relocation

$$\frac{1}{2}\{\langle \hat{\pi}_1^{-1} - \hat{\pi}_0^{-1} \rangle R_{k1} \hat{l}_{k1}^* [T_1^* \circ (S_1^* \cdot \hat{c}_1)]u + \langle \hat{\pi}_1^{-1} - \hat{\pi}_0^{-1} \rangle R_{k0} \hat{l}_{k0}^* [T_0^* \circ (S_0^* \cdot \hat{c}_0)]u\}$$

country-level efficiency

$$\frac{1}{2}\{\hat{\pi}_0^{-1} R_{k0} \hat{l}_{k0}^* [T_0^* \circ ((S_1^* - S_0^*) \cdot \hat{c}_1)]u + \hat{\pi}_1^{-1} R_{k1} \hat{l}_{k1}^* [T_1^* \circ ((S_1^* - S_0^*) \cdot \hat{c}_0)]u\}$$

between GVC

$$\frac{1}{2}\{\hat{\pi}_0^{-1} R_{k0} \hat{l}_{k0}^* [T_0^* \circ (S_0^* \cdot \langle \hat{c}_1 - \hat{c}_0 \rangle)]u + \hat{\pi}_1^{-1} R_{k1} \hat{l}_{k1}^* [T_1^* \circ (S_0^* \cdot \langle \hat{c}_1 - \hat{c}_0 \rangle)]u\}$$

income

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The Two-Country Case

- Suppose G=2 and N=2:

		Intermediate use		Final use		Gross output
		1	*2*	*1*	*2*	
	1	$\mathbf{Z}^{11}$	$\mathbf{Z}^{12}$	$\mathbf{F}^{11}$	$\mathbf{F}^{12}$	$\mathbf{y}^{1}$
	2	$\mathbf{Z}^{21}$	$\mathbf{Z}^{22}$	$\mathbf{F}^{21}$	$\mathbf{F}^{22}$	$\mathbf{y}^{2}$
Value added		$w^{1\prime}$	$w^{2\prime}$			
Gross output		$y^{1\prime}$	$y^{2\prime}$			
Employment		$e^{1\prime}$	$e^{2\prime}$			

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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**

		Intermediate use		Final use		Gross output
		1	*2*	*1*	*2*	
	1	$\mathbf{Z}^{11}$	$\mathbf{Z}^{12}$	$\mathbf{F}^{11}$	$\mathbf{F}^{12}$	$\mathbf{y}^{1}$
	2	$\mathbf{Z}^{21}$	$\mathbf{Z}^{22}$	$\mathbf{F}^{21}$	$\mathbf{F}^{22}$	$\mathbf{y}^{2}$
Value added		$\boldsymbol{w}^{1\prime}$	$\boldsymbol{w}^{2\prime}$			
Gross output		$\boldsymbol{y}^{1\prime}$	$\boldsymbol{y}^{2\prime}$			
Employment		$\boldsymbol{e}^{1\prime}$	$\boldsymbol{e}^{2\prime}$			

$$\mathbf{F}^{12} = \begin{bmatrix} f_1^{12} \\ f_2^{12} \end{bmatrix}$$

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

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

The Two-Country Case

- An expanded form of two-country MRIO

		Intermediate use				Final use		Gross output
		1		*2*		*1*	*2*	
	1	z_{11}^{11}	z_{12}^{11}	z_{11}^{12}	z_{12}^{12}	f_1^{11}	f_1^{12}	y_1^1
		z_{21}^{11}	z_{22}^{11}	z_{21}^{12}	z_{22}^{12}	f_2^{11}	f_2^{12}	y_2^1
	2	z_{11}^{21}	z_{12}^{21}	z_{11}^{22}	z_{12}^{22}	f_1^{21}	f_1^{22}	y_1^2
		z_{21}^{21}	z_{22}^{21}	z_{21}^{22}	z_{22}^{22}	f_2^{21}	f_2^{22}	y_2^2
Value added		w_1^1	w_2^1	w_1^2	w_2^2			
Gross output		y_1^1	y_2^1	y_1^2	y_2^2			
Employment of occupation *k*		x_{k1}^1	x_{k2}^1	x_{k1}^2	x_{k2}^2			

$$\mathbf{A} = \begin{bmatrix} z_{11}^{11}/y_1^1 & z_{12}^{11}/y_2^1 & z_{11}^{12}/y_1^2 & z_{12}^{12}/y_2^2 \\ z_{21}^{11}/y_1^1 & z_{22}^{11}/y_2^1 & z_{21}^{12}/y_1^2 & z_{22}^{12}/y_2^2 \\ z_{11}^{21}/y_1^1 & z_{12}^{21}/y_2^1 & z_{11}^{22}/y_1^2 & z_{12}^{22}/y_2^2 \\ z_{21}^{21}/y_1^1 & z_{22}^{21}/y_2^1 & z_{21}^{22}/y_1^2 & z_{21}^{22}/y_2^2 \end{bmatrix}$$

The Two-Country Case

$$(\mathbf{I}-\mathbf{A})^{-1}=\begin{bmatrix}1-(z_{11}^{11}/y_1^1) & -z_{12}^{11}/y_2^1 & -z_{11}^{12}/y_1^2 & -z_{12}^{12}/y_2^2\\ -z_{21}^{11}/y_1^1 & 1-(z_{22}^{11}/y_2^1) & -z_{21}^{12}/y_1^2 & -z_{22}^{12}/y_2^2\\ -z_{11}^{21}/y_1^1 & -z_{12}^{21}/y_2^1 & 1-(z_{11}^{22}/y_1^2) & -z_{12}^{22}/y_2^2\\ -z_{21}^{21}/y_1^1 & -z_{22}^{21}/y_2^1 & -z_{21}^{22}/y_1^2 & 1-(z_{21}^{22}/y_2^2)\end{bmatrix}^{-1}=\begin{bmatrix}b_{11}^{11} & b_{12}^{11} & b_{11}^{12} & b_{12}^{12}\\ b_{21}^{11} & b_{22}^{11} & b_{21}^{12} & b_{22}^{12}\\ b_{11}^{21} & b_{12}^{21} & b_{11}^{22} & b_{12}^{22}\\ b_{21}^{21} & b_{22}^{21} & b_{21}^{22} & b_{22}^{22}\end{bmatrix}$$

$$\mathbf{l_k}=\begin{bmatrix}x_{k1}^1/y_1^1\\ x_{k2}^1/y_2^1\\ x_{k1}^2/y_1^2\\ x_{k2}^2/y_2^2\end{bmatrix}\text{ and }\boldsymbol{\pi}=\begin{bmatrix}\pi^1\\ \pi^1\\ \pi^2\\ \pi^2\end{bmatrix}$$

$$\boldsymbol{x_k}=\widehat{\mathbf{l}_k}\mathbf{Bf}=\begin{bmatrix}x_{k1}^1/y_1^1 & 0 & 0 & 0\\ 0 & x_{k2}^1/y_2^1 & 0 & 0\\ 0 & 0 & x_{k1}^2/y_1^2 & 0\\ 0 & 0 & 0 & x_{k2}^2/y_2^2\end{bmatrix}\begin{bmatrix}b_{11}^{11} & b_{12}^{11} & b_{11}^{12} & b_{12}^{12}\\ b_{21}^{11} & b_{22}^{11} & b_{21}^{12} & b_{22}^{12}\\ b_{11}^{21} & b_{12}^{21} & b_{11}^{22} & b_{12}^{22}\\ b_{21}^{21} & b_{22}^{21} & b_{21}^{22} & b_{22}^{22}\end{bmatrix}\begin{bmatrix}f_1^{11}+f_1^{12}\\ f_2^{11}+f_2^{12}\\ f_1^{21}+f_1^{22}\\ f_2^{21}+f_2^{22}\end{bmatrix}$$

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The Two-Country Case

$$\mathbf{x_k}=\begin{bmatrix}x_{k1}^1\\ x_{k2}^1\\ x_{k1}^2\\ x_{k2}^2\end{bmatrix}=\begin{bmatrix}(x_{k1}^1/y_1^1)\{b_{11}^{11}(f_1^{11}+f_1^{12})+b_{12}^{11}(f_2^{11}+f_2^{12})+b_{11}^{12}(f_1^{21}+f_1^{22})+b_{12}^{12}(f_2^{21}+f_2^{22})\}\\ (x_{k2}^1/y_2^1)\{b_{21}^{11}(f_1^{11}+f_1^{12})+b_{22}^{11}(f_2^{11}+f_2^{12})+b_{21}^{12}(f_1^{21}+f_1^{22})+b_{22}^{12}(f_2^{21}+f_2^{22})\}\\ (x_{k1}^2/y_1^2)\{b_{11}^{21}(f_1^{11}+f_1^{12})+b_{12}^{21}(f_2^{11}+f_2^{12})+b_{11}^{22}(f_1^{21}+f_1^{22})+b_{12}^{22}(f_2^{21}+f_2^{22})\}\\ (x_{k2}^2/y_2^2)\{b_{21}^{21}(f_1^{11}+f_1^{12})+b_{22}^{21}(f_2^{11}+f_2^{12})+b_{21}^{22}(f_1^{21}+f_1^{22})+b_{22}^{22}(f_2^{21}+f_2^{22})\}\end{bmatrix}$$

$$x_{k1}^1=(x_{k1}^1/y_1^1)b_{11}^{11}(f_1^{11}+f_1^{12})+(x_{k1}^1/y_1^1)b_{12}^{11}(f_2^{11}+f_2^{12})+(x_{k1}^1/y_1^1)b_{11}^{12}(f_1^{21}+f_1^{22})+(x_{k1}^1/y_1^1)b_{12}^{12}(f_2^{21}+f_2^{22})$$

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

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Two-Country Case

$$\mathbf{l}_{\mathbf{k}}^{*\prime} \equiv \begin{bmatrix} l_{k1}^{1*} \\ l_{k2}^{1*} \\ l_{k1}^{2*} \\ l_{k2}^{2*} \end{bmatrix}' \equiv \left(\begin{bmatrix} \pi^1 \\ \pi^1 \\ \pi^2 \\ \pi^2 \end{bmatrix} \circ \begin{bmatrix} x_{k1}^1/y_1^1 \\ x_{k2}^1/y_2^1 \\ x_{k1}^2/y_1^2 \\ x_{k2}^2/y_2^2 \end{bmatrix} \right)' \begin{bmatrix} b_{11}^{11} & b_{12}^{11} & b_{11}^{12} & b_{12}^{12} \\ b_{21}^{11} & b_{22}^{11} & b_{21}^{12} & b_{22}^{12} \\ b_{11}^{21} & b_{12}^{21} & b_{11}^{22} & b_{12}^{22} \\ b_{21}^{21} & b_{22}^{21} & b_{21}^{22} & b_{22}^{22} \end{bmatrix}$$

$$= \begin{bmatrix} \pi^1(x_{k1}^1/y_1^1)b_{11}^{11} + \pi^1(x_{k2}^1/y_2^1)b_{21}^{11} + \pi^2(x_{k1}^2/y_1^2)b_{11}^{21} + \pi^2(x_{k2}^2/y_2^2)b_{21}^{21} \\ \pi^1(x_{k1}^1/y_1^1)b_{12}^{11} + \pi^1(x_{k2}^1/y_2^1)b_{22}^{11} + \pi^2(x_{k1}^2/y_1^2)b_{12}^{21} + \pi^2(x_{k2}^2/y_2^2)b_{22}^{21} \\ \pi^1(x_{k1}^1/y_1^1)b_{11}^{12} + \pi^1(x_{k2}^1/y_2^1)b_{21}^{12} + \pi^2(x_{k1}^2/y_1^2)b_{11}^{22} + \pi^2(x_{k2}^2/y_2^2)b_{21}^{22} \\ \pi^1(x_{k1}^1/y_1^1)b_{12}^{12} + \pi^1(x_{k2}^1/y_2^1)b_{22}^{12} + \pi^2(x_{k1}^2/y_1^2)b_{12}^{22} + \pi^2(x_{k2}^2/y_2^2)b_{22}^{22} \end{bmatrix}'$$

$$l_{k1}^{1*} = \pi^1(x_{k1}^1/y_1^1)b_{11}^{11} + \pi^1(x_{k2}^1/y_2^1)b_{21}^{11} + \pi^2(x_{k1}^2/y_1^2)b_{11}^{21} + \pi^2(x_{k2}^2/y_2^2)b_{21}^{21}$$

number of jobs of occupation *k* generated in industry 2 of country 1 to satisfy one unit of final demand in industry 1 of country 1.

number of jobs of occupation *k* generated in industry 2 of country 2 to satisfy one unit of final demand in industry 1 of country 1.

Two-Country Case

$$\mathbf{R}_{\mathrm{k}} \equiv \{\hat{\boldsymbol{\pi}}\hat{\mathbf{l}}_{\mathbf{k}}\mathbf{B}\}\hat{\mathbf{l}}_{\mathrm{k}}^{*\,-1} = \begin{bmatrix} \frac{\pi^1 x_{k1}^1 b_{11}^{11}}{y_1^1 l_{k1}^{1*}} & \frac{\pi^1 x_{k1}^1 b_{12}^{11}}{y_1^1 l_{k2}^{1*}} & \frac{\pi^1 x_{k1}^1 b_{11}^{12}}{y_1^1 l_{k1}^{2*}} & \frac{\pi^1 x_{k1}^1 b_{12}^{12}}{y_1^1 l_{k2}^{2*}} \\ \frac{\pi^1 x_{k2}^1 b_{21}^{11}}{y_2^1 l_{k1}^{1*}} & \frac{\pi^1 x_{k2}^1 b_{22}^{11}}{y_2^1 l_{k2}^{1*}} & \frac{\pi^1 x_{k2}^1 b_{21}^{12}}{y_2^1 l_{k1}^{2*}} & \frac{\pi^1 x_{k2}^1 b_{22}^{12}}{y_2^1 l_{k2}^{2*}} \\ \frac{\pi^2 x_{k1}^2 b_{11}^{21}}{y_1^2 l_{k1}^{1*}} & \frac{\pi^2 x_{k1}^2 b_{12}^{21}}{y_1^2 l_{k2}^{1*}} & \frac{\pi^2 x_{k1}^2 b_{11}^{22}}{y_1^2 l_{k1}^{2*}} & \frac{\pi^2 x_{k1}^2 b_{12}^{22}}{y_1^2 l_{k2}^{2*}} \\ \frac{\pi^2 x_{k2}^2 b_{21}^{21}}{y_2^2 l_{k1}^{1*}} & \frac{\pi^2 x_{k2}^2 b_{22}^{21}}{y_2^2 l_{k2}^{1*}} & \frac{\pi^2 x_{k2}^2 b_{21}^{22}}{y_2^2 l_{k1}^{2*}} & \frac{\pi^2 x_{k2}^2 b_{22}^{22}}{y_2^2 l_{k2}^{2*}} \end{bmatrix}$$

share of industry 1 of country 2 to total labor generated in the production of final products by industry 1 country 1

share of industry 2 of country 2 to total labor generated in the production of final products by industry 1 country 2

Two-Country Case

$$\mathbf{c} = [f_1^{11} + f_2^{11} + f_1^{21} + f_2^{21} \quad f_1^{12} + f_2^{12} + f_1^{22} + f_2^{22}]$$

$$\mathbf{S} = \begin{bmatrix} \frac{f_1^{11} + f_1^{21}}{f_1^{11} + f_2^{11} + f_1^{21} + f_2^{21}} & \frac{f_1^{12} + f_1^{22}}{f_1^{12} + f_2^{12} + f_1^{22} + f_2^{22}} \\ \frac{f_2^{11} + f_2^{21}}{f_1^{11} + f_2^{11} + f_1^{21} + f_2^{21}} & \frac{f_2^{12} + f_2^{22}}{f_1^{12} + f_2^{12} + f_1^{22} + f_2^{22}} \end{bmatrix}$$

$$\mathbf{T}^* = \begin{bmatrix} \frac{f_1^{11}}{f_1^{11} + f_1^{21}} & \frac{f_1^{12}}{f_1^{12} + f_1^{22}} \\ \frac{f_2^{11}}{f_2^{11} + f_2^{21}} & \frac{f_2^{12}}{f_2^{12} + f_2^{22}} \\ \frac{f_1^{21}}{f_1^{11} + f_1^{21}} & \frac{f_1^{22}}{f_1^{12} + f_1^{22}} \\ \frac{f_2^{21}}{f_2^{11} + f_2^{21}} & \frac{f_2^{22}}{f_2^{12} + f_2^{22}} \end{bmatrix}$$

- Finally, one can verify that:

$$x_{k1}^1 = \sum_{s=1}^{2} \sum_{j=1}^{2} \left(\frac{1}{\pi^1}\right) \left(\frac{\pi^1 x_{k1}^1 b_{1j}^{1s}}{y_1^1 l_{kj}^{s*}}\right) (l_{kj}^{s*}) \left[\sum_{p=1}^{2} \left(\frac{f_1^{1p}}{\sum_{q=1}^{2} f_1^{qp}}\right) \left(\frac{\sum_{q=1}^{2} f_1^{qp}}{\sum_{q=1}^{2} \sum_{p=1}^{2} f_1^{qp}}\right) \left(\sum_{q=1}^{2} \sum_{p=1}^{2} f_1^{qp}\right)\right]$$

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Two-Country Case

$$x_{k1}^1 = \sum_{s=1}^{2} \sum_{j=1}^{2} \left(\frac{1}{\pi^1}\right) \left(\frac{\pi^1 x_{k1}^1 b_{1j}^{1s}}{y_1^1 l_{kj}^{s*}}\right) (l_{kj}^{s*}) \left[\sum_{p=1}^{2} \left(\frac{f_1^{1p}}{\sum_{q=1}^{2} f_1^{qp}}\right) \left(\frac{\sum_{q=1}^{2} f_1^{qp}}{\sum_{q=1}^{2} \sum_{p=1}^{2} f_1^{qp}}\right) \left(\sum_{q=1}^{2} \sum_{p=1}^{2} f_1^{qp}\right)\right]$$

country-level efficiency

task relocation: intermediate

technology within GVCs

task relocation: final

between GVCs

income

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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:

$$x_{k1} - x_{k0}$$

$$\hat{\pi}_1^{-1} R_{k1} \hat{l}_{k1}^* [T_1^* \circ (S_1^* \cdot \hat{c}_1)] u - \hat{\pi}_0^{-1} R_{k0} \hat{l}_{k0}^* [T_0^* \circ (S_0^* \cdot \hat{c}_0)] u$$

change in employment

$$\frac{1}{2}\{\hat{\pi}_0^{-1} R_{k0} \langle \hat{l}_{k1}^* - \hat{l}_{k0}^* \rangle [T_1^* \circ (S_1^* \cdot \hat{c}_1)] u + \hat{\pi}_1^{-1} R_{k1} \langle \hat{l}_{k1}^* - \hat{l}_{k0}^* \rangle [T_0^* \circ (S_0^* \cdot \hat{c}_0)] u\}$$

technology within GVC

$$\frac{1}{2}\{\hat{\pi}_0^{-1} \langle R_{k1} - R_{k0} \rangle \hat{l}_{k1}^* [T_1^* \circ (S_1^* \cdot \hat{c}_1)] u + \hat{\pi}_1^{-1} \langle R_{k1} - R_{k0} \rangle \hat{l}_{i0}^* [T_0^* \circ (S_0^* \cdot \hat{c}_0)] u\} + \frac{1}{2}\{\hat{\pi}_0^{-1} R_{k0} \hat{l}_{k0}^* [\langle T_1^* - T_0^* \rangle \circ (S_1^* \cdot \hat{c}_1)] u + \hat{\pi}_1^{-1} R_{k1} \hat{l}_{k1}^* [\langle T_1^* - T_0^* \rangle \circ (S_0^* \cdot \hat{c}_0)] u\}$$

task relocation

$$\frac{1}{2}\{\langle \hat{\pi}_1^{-1} - \hat{\pi}_0^{-1} \rangle R_{k1} \hat{l}_{k1}^* [T_1^* \circ (S_1^* \cdot \hat{c}_1)] u + \langle \hat{\pi}_1^{-1} - \hat{\pi}_0^{-1} \rangle R_{k0} \hat{l}_{k0}^* [T_0^* \circ (S_0^* \cdot \hat{c}_0)] u\}$$

country-level efficiency

$$\frac{1}{2}\{\hat{\pi}_0^{-1} R_{k0} \hat{l}_{k0}^* [T_0^* \circ ((S_1^* - S_0^*) \cdot \hat{c}_1)] u + \hat{\pi}_1^{-1} R_{k1} \hat{l}_{k1}^* [T_1^* \circ ((S_1^* - S_0^*) \cdot \hat{c}_0)] u\}$$

between GVC

$$\frac{1}{2}\{\hat{\pi}_0^{-1} R_{k0} \hat{l}_{k0}^* [T_0^* \circ (S_0^* \cdot \langle \hat{c}_1 - \hat{c}_0 \rangle)] u + \hat{\pi}_1^{-1} R_{k1} \hat{l}_{k1}^* [T_1^* \circ (S_0^* \cdot \langle \hat{c}_1 - \hat{c}_0 \rangle)] u\}$$

income

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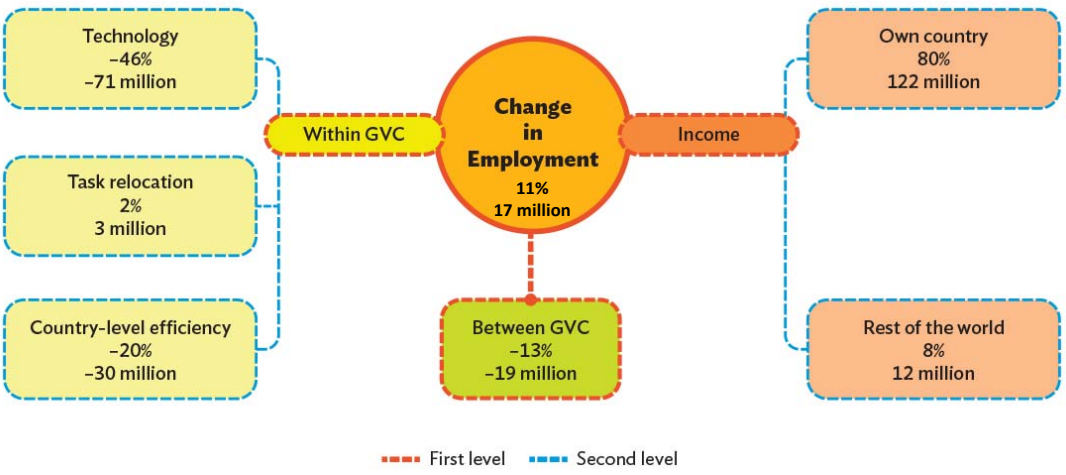
Aggregate results



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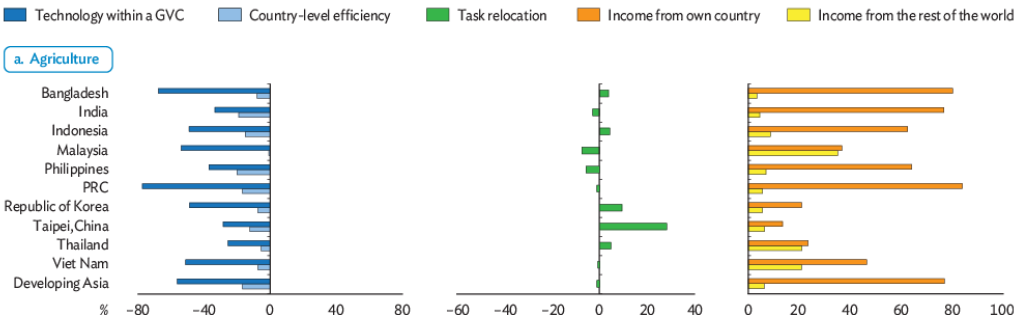
Structural decomposition analysis of changes in employment by sector, 2005-2015



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).

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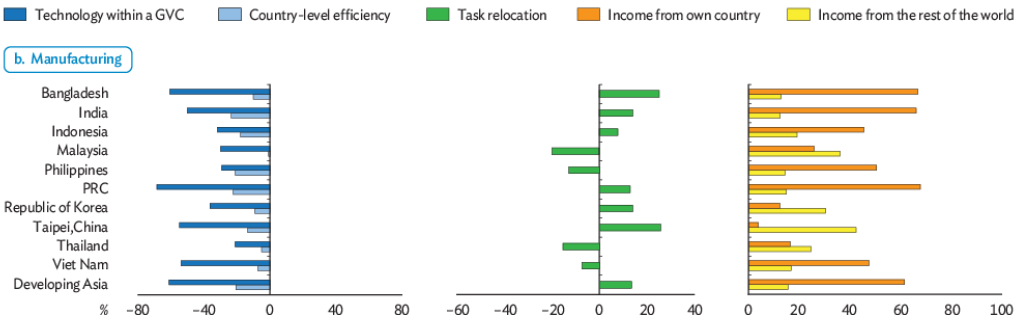
Structural decomposition analysis of changes in employment by sector, 2005-2015



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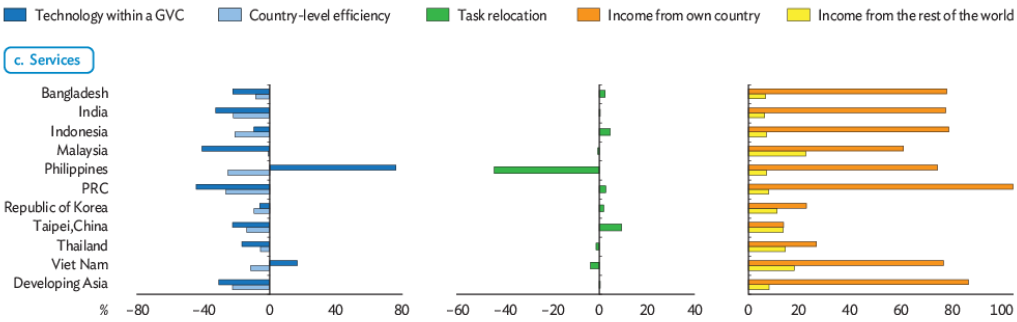
Structural decomposition analysis of changes in employment by sector, 2005-2015



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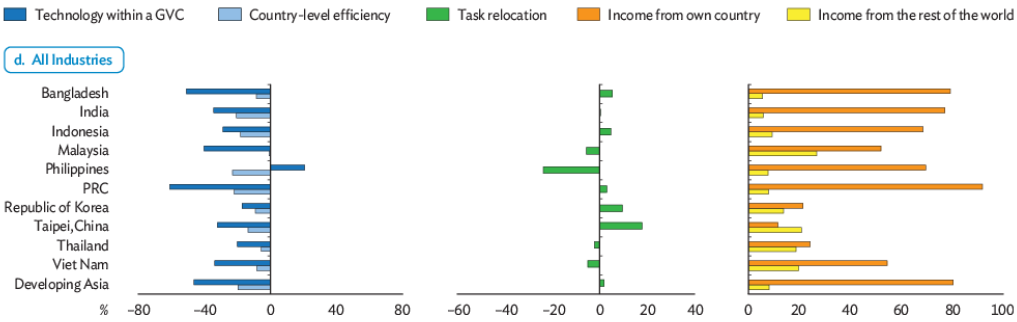
Structural decomposition analysis of changes in employment by sector, 2005-2015



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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.

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Classification of occupations

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

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.

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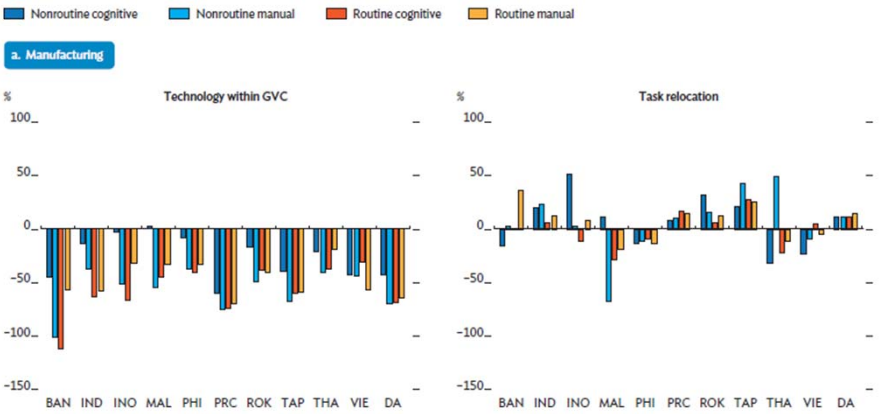
Descriptive Statistics

	Employment (2005)				Employment (2015)				% Change			
	NRC	NRM	RC	RM	NRC	NRM	RC	RM	NRC	NRM	RC	RM
Bangladesh	636	496	124	3,945	988	617	145	6,845	55%	25%	17%	74%
India	9,098	1,541	1,233	42,615	16,631	2,515	1,376	52,111	83%	63%	12%	22%
Indonesia	583	691	526	10,146	1,227	675	334	12,686	110%	-2%	-36%	25%
Malaysia	361	217	185	1,226	716	50	157	1,377	98%	-77%	-15%	12%
Mongolia	9	2	1	34	15	5	2	59	73%	137%	100%	75%
Philippines	596	50	187	2,243	778	53	185	2,193	31%	6%	-1%	-2%
PRC	17,569	7,161	6,092	93,593	21,637	7,618	6,959	104,189	23%	6%	14%	11%
Rep. of Korea	685	194	851	2,504	1,081	197	883	2,685	58%	2%	4%	7%
Sri Lanka	150	35	44	1,031	121	57	38	1,173	-19%	62%	-13%	14%
Taipei,China	819	21	260	1,633	1,005	22	277	1,721	23%	7%	7%	5%
Thailand	1,041	34	387	4,125	852	54	287	4,367	-18%	57%	-26%	6%
Viet Nam	859	225	163	6,195	802	244	230	6,009	-7%	8%	42%	-3%
All Asian DMCs	**32,406**	**10,667**	**10,052**	**169,291**	**45,854**	**12,110**	**10,873**	**195,415**	**41%**	**14%**	**8%**	**15%**

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



BAN = Bangladesh, DA = developing Asia, GVC = global value chain, IND = India, INO = Indonesia, MAL = Malaysia, PRC = People's Republic of China, PHI = Philippines, ROK = Republic of Korea, TAP = Taipei,China, THA = Thailand, VIE = Viet Nam.

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.

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).

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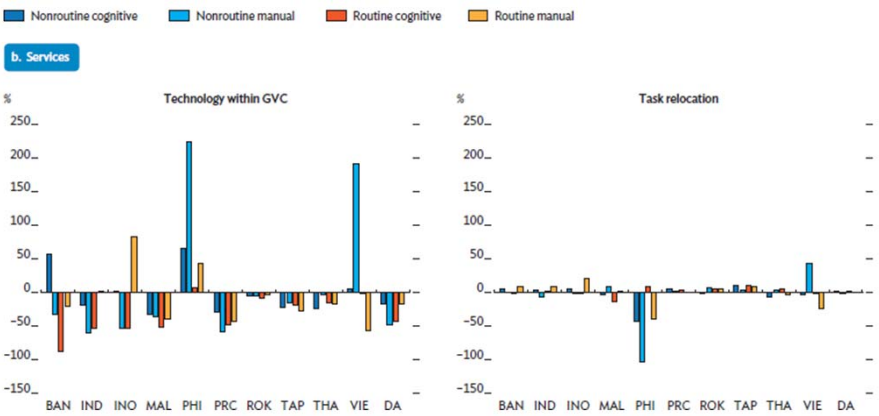
SDA of changes in employment by sector and occupation type, 2005-2015



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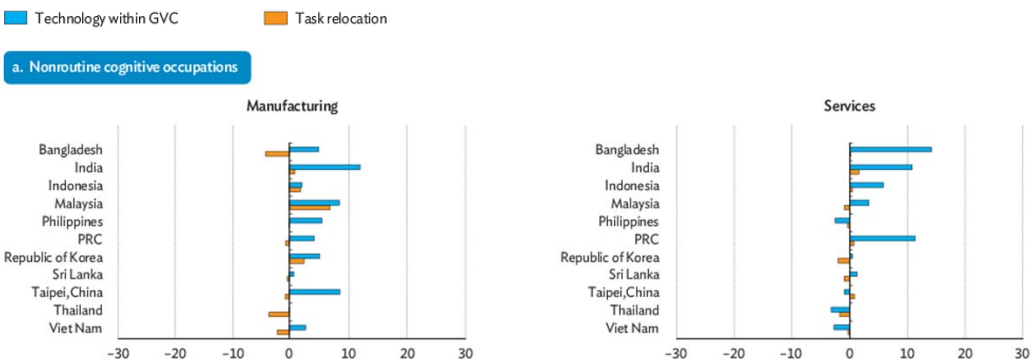
Changes in employment shares by occupation type, 2005-2015



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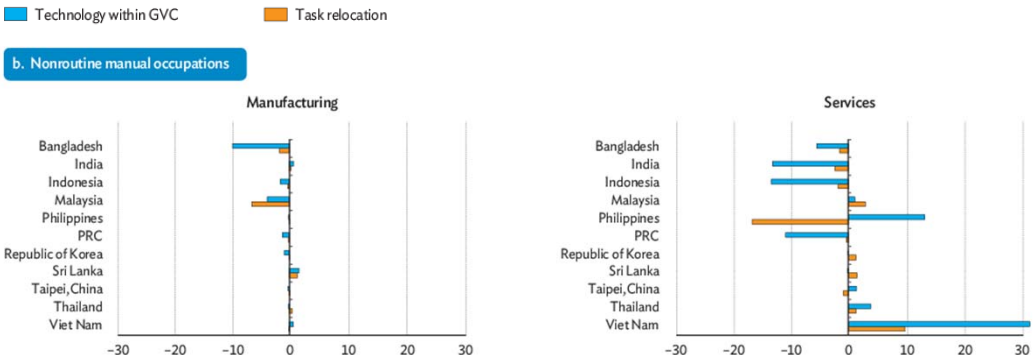
Changes in employment shares by occupation type, 2005-2015



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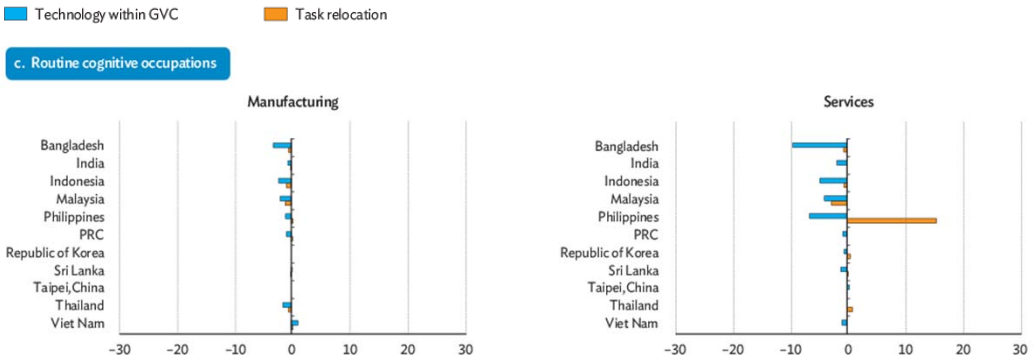
Changes in employment shares by occupation type, 2005-2015



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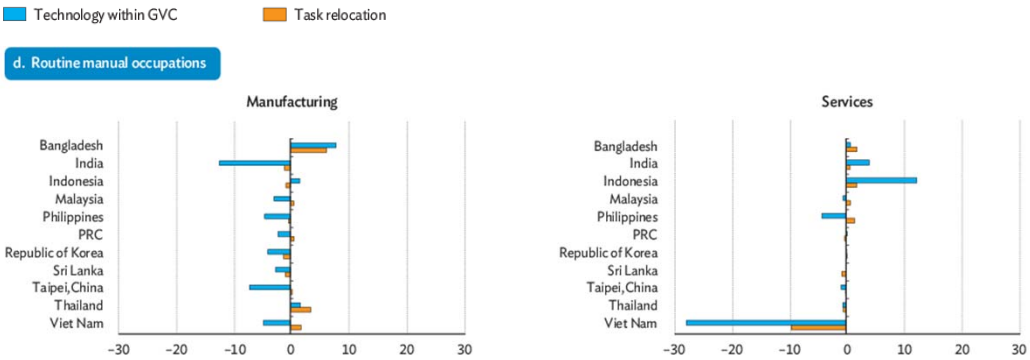
Changes in employment shares by occupation type, 2005-2015



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ECONOMETRIC ANALYSIS

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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.

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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.

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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.

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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).

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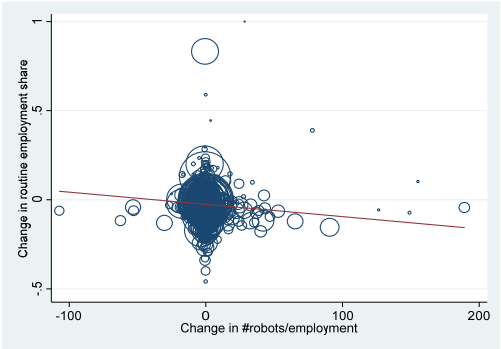
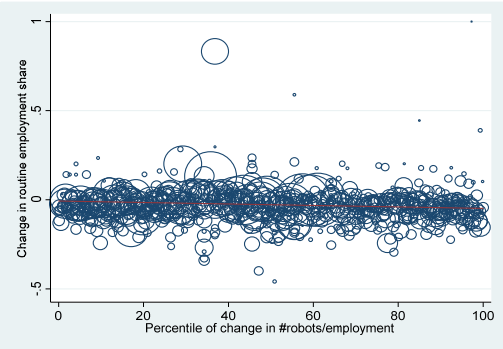
Relation between routine jobs and Robots, 2005-2015





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.

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Empirical strategy

$$\Delta Y_{ci} = \beta_1 + \beta_2 R_{ci} + \beta_3 Controls + \varepsilon_{ci}$$

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

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

a. Overall employment

	Change in employment		
	(1)	(2)	(3)
Robot adoption	−0.212 (0.37)	−0.212 (0.73)	−0.663 (0.61)
Country trends	Yes	Yes	Yes
Controls			Yes
Clustered standard errors		Yes	Yes
Observations	758	758	757

b. Routine employment

	Change in routine employment share		
	(1)	(2)	(3)
Robot adoption	-0.048*** (0.01)	-0.048*** (0.01)	-0.048*** (0.01)
Country trends	Yes	Yes	Yes
Controls			Yes
Clustered standard errors		Yes	Yes
Observations	777	777	776

* = p<0.1, ** = 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.

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

c. Occupational employment shares

	Change in employment share of			
	(1) Routine manual	(2) Routine cognitive	(3) Nonroutine manual	(4) Nonroutine cognitive
Robot adoption	−0.055*** (0.02)	−0.002 (0.00)	−0.004 (0.01)	0.061*** (0.01)
Country trends	Yes	Yes	Yes	Yes
Controls	Yes	Yes	Yes	Yes
Clustered standard errors	Yes	Yes	Yes	Yes
Observations	776	776	776	776

d. Developed versus developing countries

	Change in routine employment share		
	(1)	(2)	(3)
Robot adoption	−0.056*** (0.01)	−0.056*** (0.02)	−0.056*** (0.02)
Developing country x robot adoption (Interaction term)	0.038 (0.03)	0.038** (0.02)	0.036** (0.02)
Country trends	Yes	Yes	Yes
Controls			Yes
Clustered standard errors		Yes	Yes
Observations	777	777	776

* = p<0.1, ** = 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.

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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.

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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.

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THE END

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