Labor Market Implications of Taiwan's Accession to the WTO: A Dynamic Quantitative Analysis

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Introduction

- The trade literature has extensively studied the labor-market and welfare effects of the "China shock" on large economies such as the US (e.g., Caliendo, Dvorkin and Parro, 2019; Adão, Arkolakis and Esposito, 2021; Autor, Dorn and Hanson, 2013, 2021) and their heterogeneous responses across regions and sectors.
- In this paper, we focus on Taiwan to highlight the importance of contexts for the study of labor market adjustments to a large-scale external shock.
- In particular, this paper aims to examine the effects of Taiwan's accession to the WTO in January 2002 on Taiwan's labor market outcomes.
- Because China also entered the WTO around the same time, the two economies became much more open to each other through the WTO platform, and thus the China shock also contributed to the overall effects of Taiwan's accession to the WTO.

Why Taiwan?

Taiwan is an interesting case for several reasons:

- First, it is a small open economy that is geographically close to China. Therefore, it may have experienced much greater impacts of the China shock than distant/large economies.
- Second, during the period studied, Taiwan was more developed than China but less than the US. Along the lines of structural change and product cycles, China's rise may have posed greater and more immediate challenges to the manufacturing industries in Taiwan. How did the Taiwanese economy respond to it?
- Third, Taiwan saw swift changes in its skill compositions during the period of WTO accession, becoming a highly skill-abundant economy relative to China and much of the rest of the world. Related to the second point, how did these changes in skill composition play a part in Taiwan's response to the rise of China?

Overview

- We extend the dynamic hat algebra framework of Caliendo, Dvorkin and Parro (2019) to allow for sector-skill transition.
  - In each period, workers choose endogenously the sector of employment, and whether to upgrade skill (low $\rightarrow$ middle $\rightarrow$ high skill)
  - allows for mortality and new birth (replenish the pool of low-skill workers)
  - The model is calibrated to 60 economies and a residual Rest-of-World, 22 sectors plus non-employment, and three skills
- We use the 2-stage estimation procedure of Artuç and McLaren (2015) to estimate labor market transition parameters.
  - cost of skill upgrading
  - cost of switching sectors
  - labor market transition elasticity
- We assess the quantitative effects of Taiwan's WTO entry on the labor dynamics of the Taiwanese economy.
  - anatomy of the effects due to bilateral tariffs w.r.t. China, and due to the skill-upgrade mechanism, respectively

Taiwan's Accession to the WTO

- Taiwan applied for GATT membership in 1990, and became an observer in 1992.
- Its average tariff was already modest in 1990, at 9.7%, due to a long history of bilateral trade talks with the US since 1959.
- Nevertheless, to become a member of GATT/WTO, Taiwan negotiated with the other member countries, and this induced further reductions of its tariffs, many of which took effect after Taiwan became a formal WTO member.
- Taiwan joined the WTO in January 2002, right after China joined (in December 2001).

Tariff Changes

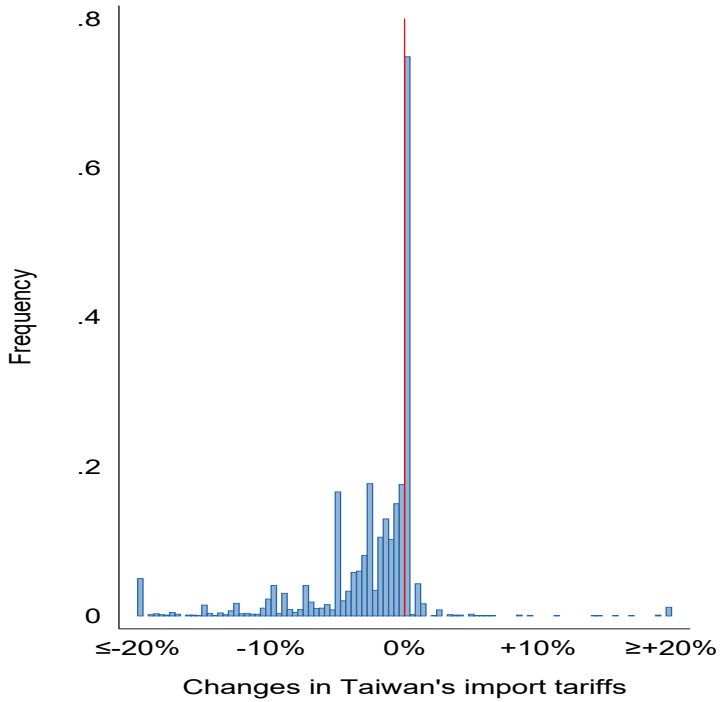
Fact 1(a): Taiwanese import tariffs fell relatively more in the agriculture sector, while foreign tariffs against Taiwanese exports fell relatively more in the manufacturing sectors.

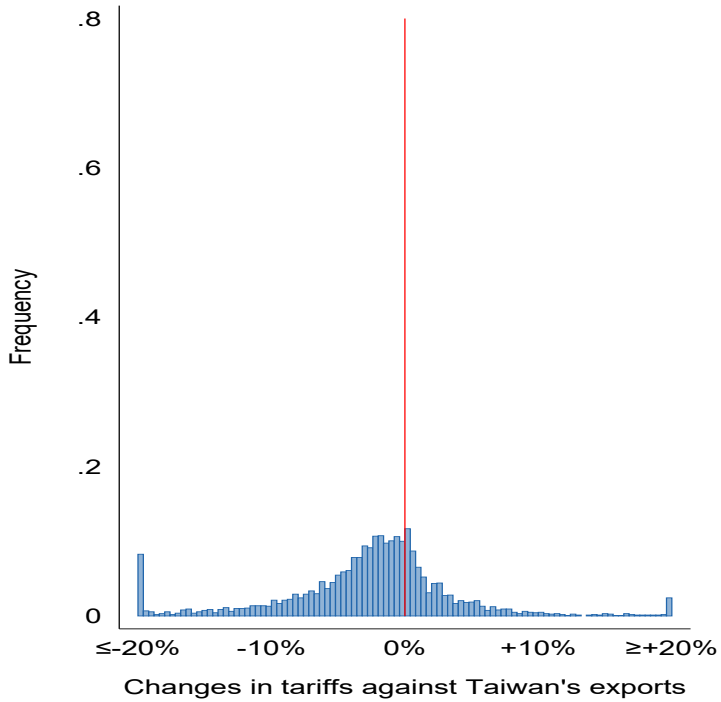
Year	1995–2001		2002–2007	
Sector	Agriculture	Manufacturing	Agriculture	Manufacturing
Foreign Tariffs on Taiwan's Exports	0.07%	−2.54%	−3.10%	−1.75%
Taiwan's Import Tariffs	−0.42%	−1.25%	−4.42%	−1.31%

Notes: The table reports the changes (in percentage points) in average tariffs (across products and trading partners of Taiwan) in agriculture and in manufacturing, before and after its WTO accession. Ad-valorem equivalent tariff rates are obtained from the WITS database. The average tariff rates are computed across 6-digit HS sectors of agriculture and of manufacturing, respectively, weighted by the corresponding WITS trade value. Trading partners include all economies available in the WITS database. The 6-digit HS codes are first concorded to the 2-digit ISIC Rev.3 sectors, and are then aggregated to the agriculture and manufacturing categories. The agricultural sector includes 2-digit ISIC Rev.3 sectors of 01, 02, and 05 (agriculture, forestry, and fishing). The manufacturing includes 2-digit ISIC Rev.3 sectors of 15–37.

Tariff Changes

Fact 1(b): Tariff changes were heterogeneous across disaggregated product lines, with many products that saw tariff reductions of more than 20%.



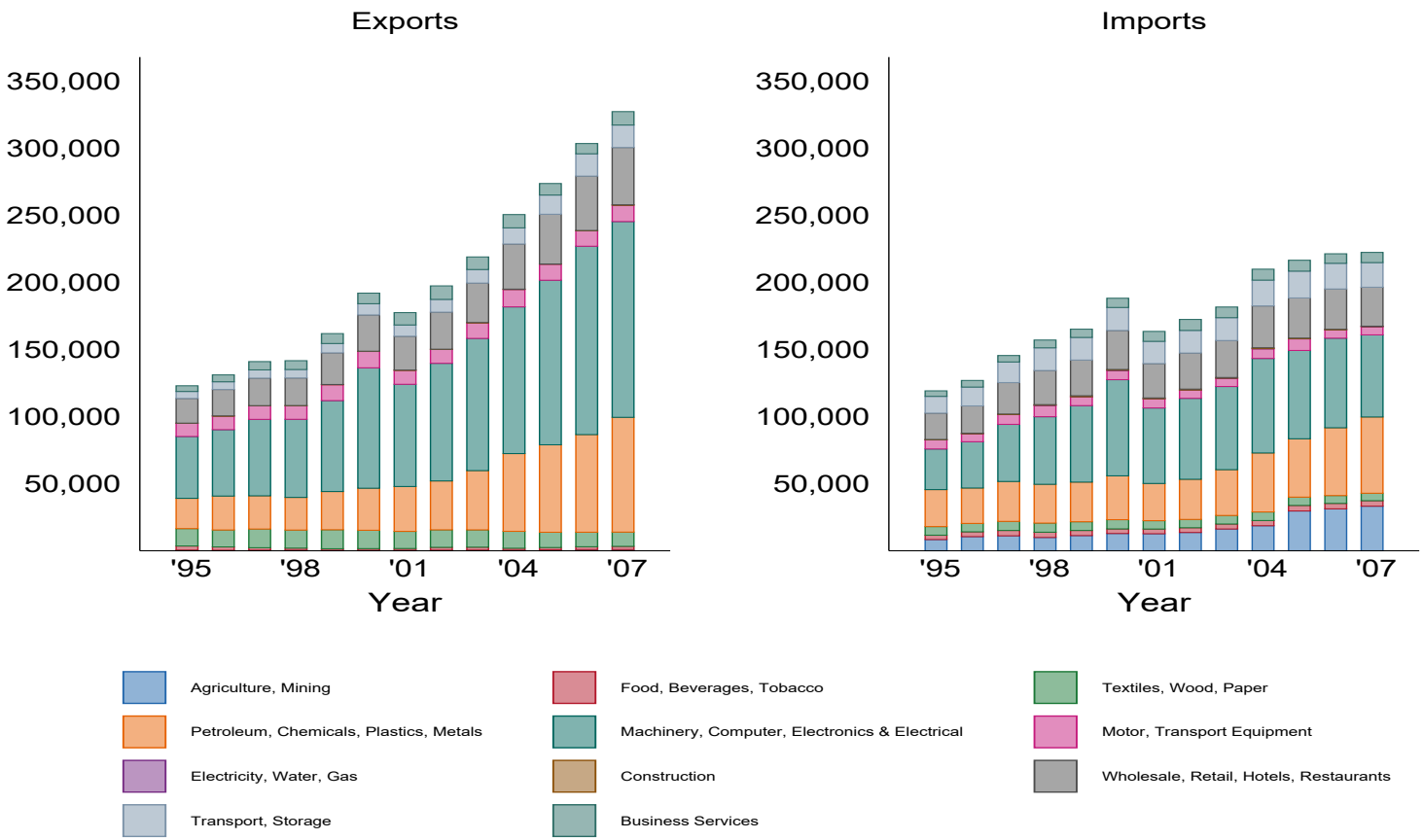


Patterns of Trade

Fact 2(a): China overtook the US and became the leading trading partner of Taiwan.

Patterns of Trade

Fact 2(b): The MCEE and PCPM sectors were the engines of growth of Taiwanese exports.

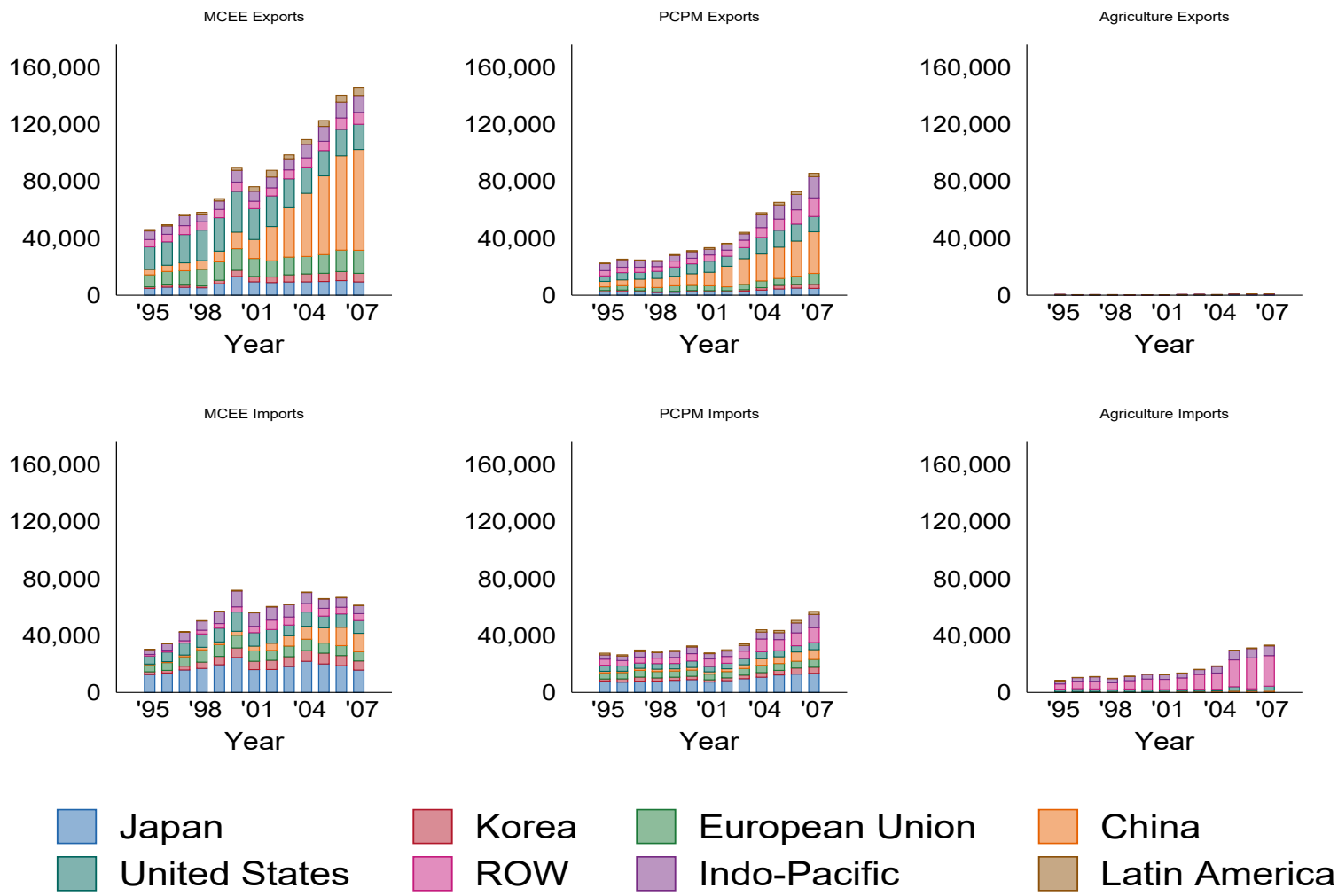


Patterns of Trade

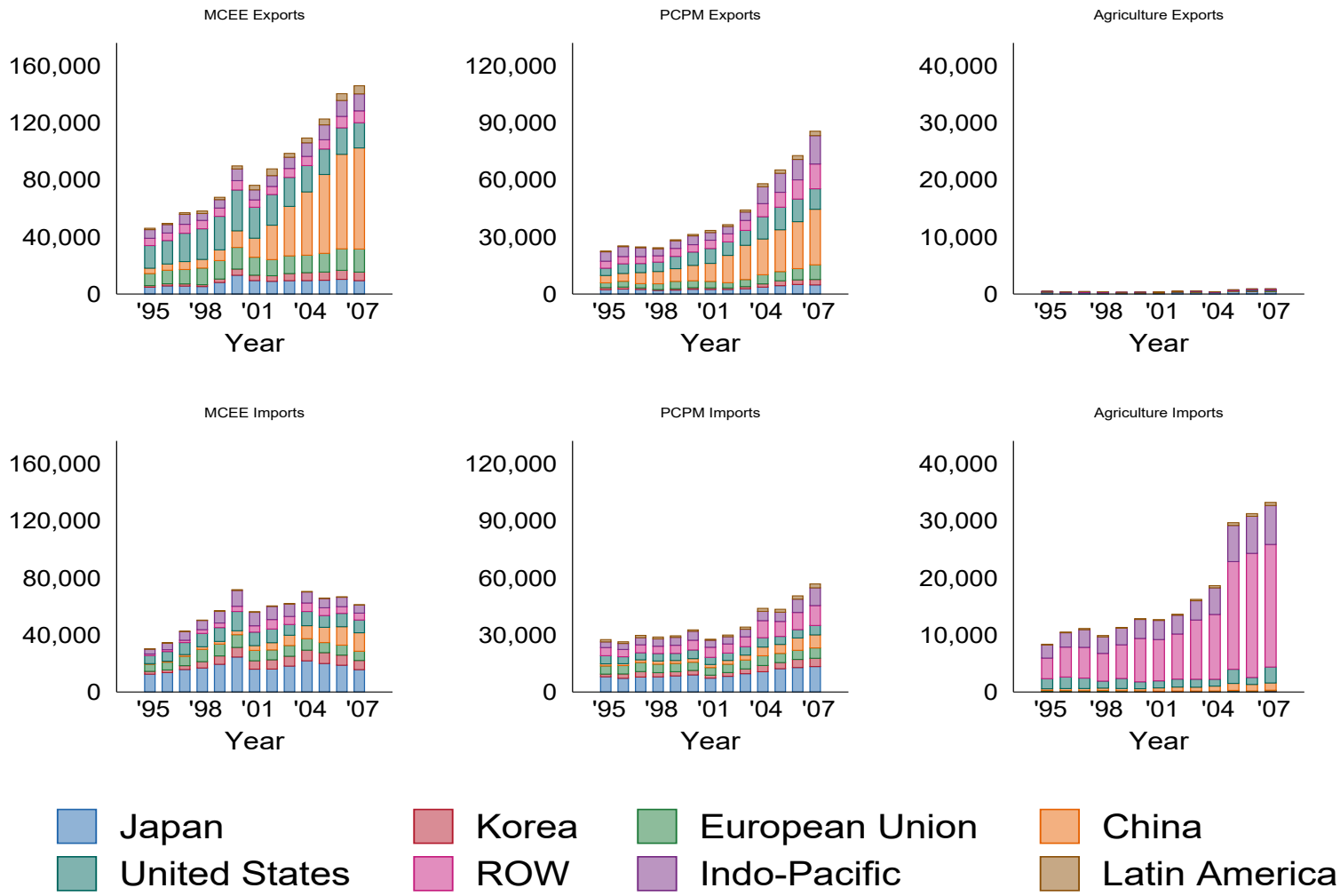
Fact 2(c): MCEE export growth was predominantly driven by exports to China. PCPM export growth could be attributed to a number of destination markets, with China taking a leading role.

Fact 2(d): Agricultural imports rose substantially after 2001.

MCEE, PCPM, and Agriculture



MCEE, PCPM, and Agriculture



Labor Market Transitions during WTO Accession: 1995–2007

Fact 3(a): Labor transitioned out of agriculture and labor-intensive manufacturing sectors and into MCEE and service sectors.

Sectors	From/To	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	School	%95	%07	%Δ
Agriculture, Mining	(1)	85.9	0.4	0.6	0.9	0.3	0.3	0.0	2.4	2.1	0.4	1.5	5.2	7.2	9.2	3.9	−5.3
Food, Beverages, Tobacco	(2)	1.8	77.2	0.7	1.6	1.3	0.3	0.0	0.6	8.5	0.7	1.9	5.4	10.9	1.1	1.1	0.0
Textiles, Wood, Paper	(3)	0.5	0.2	80.7	2.5	1.3	0.8	0.0	0.4	2.9	0.4	2.3	7.9	10.6	5.4	3.4	−1.9
Petroleum, Chemicals, Plastics, Metals	(4)	0.8	0.4	1.7	80.2	4.3	1.6	0.0	1.6	2.5	0.4	1.3	5.2	11.0	6.7	6.9	+0.2
MCEE	(5)	0.2	0.2	0.7	3.8	82.7	1.1	0.0	0.7	3.0	0.2	2.1	5.3	12.5	5.3	8.7	+3.5
Motor, Transport Equipment	(6)	0.8	0.3	1.8	4.8	3.9	75.8	0.0	1.1	3.1	0.7	1.7	5.9	10.9	2.2	2.1	0.0
Electricity, Water, Gas	(7)	0.1	0.0	0.1	0.6	0.5	0.1	92.1	1.9	1.7	0.2	1.8	0.9	13.5	0.3	0.3	−0.1
Construction	(8)	2.2	0.1	0.4	1.9	1.2	0.5	0.1	81.3	2.8	0.7	2.8	6.1	10.0	8.3	6.6	−1.7
Wholesale, Retail, Hotels, Restaurants	(9)	0.7	0.6	0.6	1.0	1.3	0.4	0.0	0.8	84.4	0.5	3.3	6.4	11.2	15.4	18.3	+2.9
Transport, Storage	(10)	0.9	0.2	0.3	1.0	0.6	0.4	0.1	1.0	2.8	86.9	2.6	3.2	11.3	3.2	3.0	−0.2
Business Services	(11)	0.3	0.1	0.5	0.4	0.9	0.2	0.0	0.9	2.8	0.4	88.8	4.7	13.5	17.9	22.5	+4.6
Non-employment	(12)	1.2	0.3	1.2	1.3	1.9	0.4	0.0	1.6	5.4	0.5	5.0	81.3	9.6	24.9	23.1	−1.8

Notes: Statistics are computed based on the *Manpower Utilization Quasi-longitudinal Data* from 1995 to 2007. The numbers reported are time-series-average transition rates in percentage during the period 1995–2007, measuring the proportion of labor transitioning out from a row-origin sector into a column-destination sector during a year. The "School" column measures the average years of schooling in each sector for the period 1995–2007. The columns labeled "%95" and "%07" measure the employment share of each sector in years 1995 and 2007, respectively. The column labeled "%Δ" represents the change in employment share for each sector during the specified time period. The top five destination cells of each row-origin sector are highlighted in color. The cells highlighted in blue are the diagonal cells, which measure the proportions of labor that stay in the same sector. The cells highlighted in yellow are the cells that measure the proportions of labor that transit into a different sector among the top four destinations. Sectors for this table are defined at a more aggregate level than used in the quantitative exercises to reduce dimensionality. We first concord the labor survey data from Taiwanese classifications to 2-digit ISIC Rev.3 sectors. We then aggregate further the 2-digit ISIC Rev.3 sectors to the sectors shown in the table. See Table 87 and its footnote for the sector definitions.

Skill Upgrading

Fact 3(b): The proportion of high-skilled workers increased overall (17.4% in 1995 to 34.7% in 2007), and most significantly in the Business Services and MCEE sectors.

Setup

- N economies, and $J+1$ sectors, with workers of S different skill levels.
  - $n \in \{1, 2, \ldots, N\}$ index economies.
  - $j, k \in \{0, 1, 2, \ldots, J\}$ index sectors.
  - $s, i \in \{1, 2, 3\}$ index skill levels (low-, middle-, and high-skill levels).
  - $j = 0$ corresponds to non-employment (jobless).
- In each economy-sector combination nj:
  - A continuum of intermediate goods varieties produced by perfectly competitive firms.
  - EK-style model with firm-level productivity drawn from a Frechet distribution.
  - Cobb-Douglas production function, using all 3 types of labor, structure, and materials as inputs.
- Each economy-sector-skill combination njs has a perfectly competitive labor market.
- Discrete time: $t = 0, 1, \ldots$

Workers: Consumption

- Each employed worker inelastically supplies one unit of labor, and earns a competitive market wage w_t^{njs}.
- An *njs* worker consumes local final goods from all sectors with a Cobb-Douglas aggregator:

$$C_t^{njs} = \prod_{k=1}^{J} \left(c_t^{njs,k} \right)^{\alpha^k},$$

where $\sum_{k=1}^{J} \alpha^k = 1$.

- Utility per period is defined by the final goods consumed, as: $U\left(C_t^{njs}\right) \equiv \ln C_t^{njs}$.
- Price index is denoted by

$$P_t^n = \prod_{k=1}^{J} \left(\frac{P_t^{nk}}{\alpha^k} \right)^{\alpha^k}.$$

- Jobless workers (of any skill) perform home production, and consume

$$C_t^{n0s} = b^n > 0, \qquad \forall s.$$

Workers: Sector-Skill Choice

- Each worker chooses sector-skill combination for the coming period in a forward-looking manner.
- Cost of transition from sector-skill combination *js* to *ki* is denoted by $\rho^{njs,nki} \geq 0$.
  - $i > s$ indicates skill-upgrading by the worker.
  - Assume that $\rho = \infty$ for $i < s$, i.e., no skill-downgrading.
- Agents observe all economic conditions and the realizations of their own idiosyncratic preference shocks ϵ_t^{ki} (with respect to each *ki* combination) before making decisions.
- Discount rate $\beta \in [0, 1]$.
- In each period, a fraction of workers die, with a survival rate given by δ.

Workers: Utilities

- Bellman equation:

$$v_t^{njs} = \ln C_t^{njs} + \max_{\{k,i\}_{k=0,i=1}^{J,3}} \left\{ \beta\delta V_{t+1}^{nki} - \rho^{njs,nki} + \nu\epsilon_t^{ki} \right\}, \tag{1}$$

  - v_t^{njs} denotes lifetime utility.
  - V_{t+1}^{nki} denotes the expected lifetime utility of an agent with sector-skill combination ki at period $t+1$, with the expectation taken over future realizations of the idiosyncratic shocks.
  - The idiosyncratic shocks ϵ_t^{ki} are assumed to be *i.i.d.* over time, and drawn from a Type-I extreme value distribution with zero mean.
  - ν scales the variance of the idiosyncratic shock.
  - Assume that wages are the only source of income for workers; it follows that consumption is given by:

$$C_t^{njs} = \begin{cases} \frac{w_t^{njs}}{P_t^n} \equiv \omega_t^{njs} & j \neq 0 \\ b^n & j = 0. \end{cases}$$

Workers: Labor Market Transition Probabilities

- Lifetime expected utility V_t^{njs} is given by, given the distribution of ϵ_t^{ki}:

$$V_t^{njs} = \ln C_t^{njs} + \nu \ln \sum_{\mathrm{K}=0}^{J} \sum_{\mathrm{I} \geq s}^{3} e^{\frac{\beta \delta V_{t+1}^{n\mathrm{KI}} - \rho^{njs,n\mathrm{KI}}}{\nu}}. \tag{2}$$

- Probability $\mu_t^{njs,nki}$ of transition from sector-skill *js* to cell *ki* is, given the distribution of ϵ_t^{ki}:

$$\mu_t^{njs,nki} = \frac{e^{\frac{\beta \delta V_{t+1}^{nki} - \rho^{njs,nki}}{\nu}}}{\sum_{\mathrm{K}=0}^{J} \sum_{\mathrm{I} \geq s}^{3} e^{\frac{\beta \delta V_{t+1}^{n\mathrm{KI}} - \rho^{njs,n\mathrm{KI}}}{\nu}}}. \tag{3}$$

Workers: Labor Market Allocations

- Let L_0^{njs} denote the initial mass of labor with sector-skill combination js in economy n, which adds up to the total population:

$$L^n = \sum_{j=0}^{J} \sum_{s=1}^{3} L_0^{njs}.$$

- New workers are born as non-employed low-skilled workers.
- The death rate $(1-\delta)$ equals the birth rate so that the total population size is constant.
- Laws of motion:

$$L_{t+1}^{njs} = \delta \sum_{k=0}^{J} \sum_{i \leq s}^{3} \mu_t^{nki,njs} L_t^{nki}, \; js \neq 01, \tag{4}$$

$$L_{t+1}^{n01} = \delta \sum_{k=0}^{J} \mu_t^{nk1,n01} L_t^{nk1} + (1-\delta) L^n, \tag{5}$$

Production: Technology

- Production function of economy n and sector j:

$$q_t^{nj} = z^{nj}\left(A_t^{nj}\left(h^{nj}\right)^{\xi^n}\left(\left(l_t^{nj1}\right)^{\zeta^{nj1}}\left(l_t^{nj2}\right)^{\zeta^{nj2}}\left(l_t^{nj3}\right)^{\zeta^{nj3}}\right)^{1-\xi^n}\right)^{\gamma^{nj}}\prod_{k=1}^{J}\left(M_t^{nj,nk}\right)^{\gamma^{nj,nk}},$$

- l_t^{njs}: labor input of skill level s; h^{nj}: time-invariant structure input.
- $M_t^{nj,nk}$: material input demanded by a firm in sector j from sector k within economy n.
- A_t^{nj}: time-varying economy-sector specific productivity.
- z^{nj}: firm-specific productivity.
- γ^{nj}: share of value-added, such that $\gamma^{nj} = 1 - \sum_k \gamma^{nj,nk}$.
- ξ^n: share of structures in value-added.
- ζ^{njs}: share of skill-type s in value-added of *labor*.

Production: Input Costs

- Unit price of an input bundle is given by

$$x_t^{nj} = B^{nj} \left(r_t^{nj}\right)^{\xi^n \gamma^{nj}} \prod_{s=1}^{3} \left(w_t^{njs}\right)^{\zeta^{njs}(1-\xi^n)\gamma^{nj}} \prod_{k=1}^{J} \left(P_t^{nk}\right)^{\gamma^{nj,nk}}, \qquad (6)$$

- r_t^{nj} is the rental price of structures and w_t^{njs} the wage rate of skill-type s, in economy-sector nj; B^{nj} is a constant.

- Unit cost of production is:

$$\frac{x_t^{nj}}{z^{nj}\left(A_t^{nj}\right)^{\gamma^{nj}}}.$$

Production: Product Prices

- Exporting goods of sector j from economy o to n incurs iceberg trade cost $d_t^{nj,oj}$ as well as ad valorem tariffs $\tau_t^{nj,oj}$ imposed by economy n:

$$\kappa_t^{nj,oj} \equiv d_t^{nj,oj}\left(1+\tau_t^{nj,oj}\right) \geq 1.$$

- Competitive market implies that the price of a variety in economy-sector nj is given by:

$$p_t^{nj}\left(z^j\right) = \min_o \left\{ \frac{\kappa_t^{nj,oj} x_t^{oj}}{z^{oj}\left(A_t^{oj}\right)^{\gamma^{oj}}} \right\},$$

where the vector $z^j = \left(z^{1j}, ..., z^{Nj}\right)$ represents the productivity draws of the N economies in sector j for a variety.

Production: Local Sectoral Goods

- Intermediate goods demanded by economy n in sector j from all sources, $\widetilde{q}_t^{nj}$, are aggregated into a local sectoral good denoted by:

$$Q_t^{nj} = \left[\int \left(\widetilde{q}_t^{nj} \left(z^j \right) \right)^{1 - \frac{1}{\eta^{nj}}} d\phi^j \left(z^j \right) \right]^{\frac{\eta^{nj}}{\eta^{nj}-1}},$$

where η^{nj} denotes economy n's elasticity of substitution across varieties of sector j.

- Productivity z^j for each variety follows a joint Frechet distribution, with:

$$\phi^j \left(z^j \right) = e^{-\sum_{o=1}^{N} \left(z^{oj} \right)^{-\theta^j}}.$$

- Free entry and zero profit.

Production: Sectoral Price Index and Trade Shares

- The sectoral price index is equal to:

$$P_t^{nj} = \left[\sum_o \left(\kappa_t^{nj,oj} x_t^{oj}\right)^{-\theta^j} \left(A_t^{oj}\right)^{\gamma^{oj}\theta^j}\right]^{-\frac{1}{\theta^j}} \left(\Gamma^{nj}\left(\frac{1-\eta^{nj}+\theta^j}{\theta^j}\right)\right)^{\frac{1}{1-\eta^j}}, \tag{7}$$

- The share of intermediate varieties in sector j that economy n imports from economy o is:

$$\pi_t^{nj,oj} = \frac{\left(\kappa_t^{nj,oj} x_t^{oj}\right)^{-\theta^j} \left(A_t^{oj}\right)^{\gamma^{oj}\theta^j}}{\sum_{\mathrm{O}} \left(\kappa_t^{nj,\mathrm{O}j} x_t^{\mathrm{O}j}\right)^{-\theta^j} \left(A_t^{\mathrm{O}j}\right)^{\gamma^{\mathrm{O}j}\theta^j}}. \tag{8}$$

Market Clearing: Expenditures

- Local structures are used locally and owned by a mass of local rentiers.
  - Rentiers send their rental income to a global portfolio of total size χ_t, and receive a share ι^n of the portfolio in return:

$$\iota^n \chi_t = \iota^n \sum_{o=1}^{N} \sum_{j=1}^{J} r_t^{oj} H^{oj}.$$

- Let X_t^{nj} denote economy n's total expenditure on sector-j goods. The goods market-clearing condition requires that::

$$\begin{aligned} X_t^{nj} = & \sum_{k=1}^{J} \gamma^{nk,nj} \sum_{o=1}^{N} \frac{\pi_t^{ok,nk} X_t^{ok}}{1+\tau_t^{ok,nk}} \\ & + \alpha^j \left(\sum_{k=1}^{J} \sum_{s=1}^{3} w_t^{nks} L_t^{nks} + \iota^n \chi_t + \sum_{k=1}^{J} \sum_{o=1}^{N} \tau_t^{nk,ok} \frac{\pi_t^{nk,ok} X_t^{nk}}{1+\tau_t^{nk,ok}} \right) \end{aligned} \quad (9)$$

Market Clearing: Factor Markets

- Perfect competition and Cobb-Douglas production function together imply that the market-clearing conditions for labor and structure markets are respectively:

$$L_t^{njs} = \frac{\zeta^{njs}\left(1-\xi^n\right)\gamma^{nj}}{w_t^{njs}} \sum_{o=1}^{N} \frac{\pi_t^{oj,nj} X_t^{oj}}{1+\tau_t^{oj,nj}}, \tag{10}$$

$$H^{nj} = \frac{\xi^n \gamma^{nj}}{r_t^{nj}} \sum_{o=1}^{N} \frac{\pi_t^{oj,nj} X_t^{oj}}{1+\tau_t^{oj,nj}}. \tag{11}$$

- Extensions: Occupation-skill disparity Occupation-Skill Disparity

Parameters

- Time-varying fundamentals $\Theta_t \equiv (A_t, d_t, \tau_t)$: the economy-sector productivities $A_t = \left\{A_t^{nj}\right\}$, the iceberg trade costs $d_t = \left\{d_t^{nj,oj}\right\}$, and the tariff wedges $\tau_t = \left\{\tau_t^{nj,oj}\right\}$.
- Constant fundamentals $\overline{\Theta} \equiv (\rho, H, b)$: the labor transition costs $\rho = \left\{\rho^{njs,nki}\right\}$, the stock of structures $H = \left\{H^{nj}\right\}$, and home production $b = \{b^n\}$.
- The other parameters of the model include:
  - various shares of value-added $\left\{\xi^n, \gamma^{nj}, \gamma^{nj,nk}, \zeta^{njs}\right\}$.
  - survival rate (δ) and discount factor (β).
  - share of receipts from the global portfolio (ι^n).
  - final consumption expenditure share on sector j goods (α^j).
  - trade elasticity (θ^j).
  - scaling factor of the variance of the idiosyncratic shocks (ν).

Solving the Equilibrium

As in CDP, we can solve the dynamic equilibrium in two loops: first in terms of temporary equilibrium (for each period) and then in terms of sequential equilibrium (across periods).

- In each period, given $(L_t, \Theta_t, \overline{\Theta})$, a temporary equilibrium is a vector of wages $w(L_t, \Theta_t, \overline{\Theta})$ that satisfies the equilibrium conditions (6)–(11).

- Given $\left(L_0, \{\Theta_t\}_{t=0}^{\infty}, \overline{\Theta}\right)$, a sequential equilibrium is a sequence of $\left\{L_t, \mu_t, V_t, w(L_t, \Theta_t, \overline{\Theta})\right\}_{t=0}^{\infty}$ that solves equilibrium conditions (2)–(5) and the temporary equilibrium at each t, where $\mu_t = \left\{\mu_t^{njs,nki}\right\}$ and $V_t = \left\{V_t^{njs}\right\}$.

Temporary Equilibrium

Let $\dot{y}_{t+1} \equiv y_{t+1}/y_t$. Given the allocation at t, $\{L_t, \pi_t, X_t\}$, and consider a given change in $\dot{L}_{t+1}$ and $\dot{\Theta}_{t+1}$. The temporary equilibrium at time $t+1$ solves the following equations, and requires no information on the **levels** of fundamentals:

$$\dot{x}_{t+1}^{nj} = \left(\dot{r}_{t+1}^{nj}\right)^{\xi^n \gamma^{nj}} \prod_{s=1}^{3} \left(\dot{w}_{t+1}^{njs}\right)^{\zeta^{njs}\left(1-\xi^n\right)\gamma^{nj}} \prod_{k=1}^{J} \left(\dot{P}_{t+1}^{nk}\right)^{\gamma^{nj,nk}} \tag{12}$$

$$\dot{P}_{t+1}^{nj} = \left[\sum_{o} \pi_t^{nj,oj} \left(\dot{\kappa}_{t+1}^{nj,oj} \dot{x}_{t+1}^{oj}\right)^{-\theta^j} \left(\dot{A}_{t+1}^{oj}\right)^{\gamma^{oj}\theta^j}\right]^{-\frac{1}{\theta^j}} \tag{13}$$

$$\pi_{t+1}^{nj,oj} = \pi_t^{nj,oj} \left(\frac{\dot{\kappa}_{t+1}^{nj,oj} \dot{x}_{t+1}^{oj}}{\dot{P}_{t+1}^{nj}}\right)^{-\theta^j} \left(\dot{A}_{t+1}^{oj}\right)^{\gamma^{oj}\theta^j} \tag{14}$$

Temporary Equilibrium

(... continued)

$$X_{t+1}^{nj} = \sum_{k=1}^{J} \gamma^{nk,nj} \sum_{o=1}^{N} \frac{\pi_{t+1}^{ok,nk} X_{t+1}^{ok}}{1+\tau_{t+1}^{ok,nk}} + \alpha^{j} \left(\sum_{k=1}^{J} \sum_{s=1}^{3} \dot{w}_{t+1}^{nks} \dot{L}_{t+1}^{nks} w_{t}^{nks} L_{t}^{nks} + \iota^{n} \chi_{t+1} + \sum_{k=1}^{J} \sum_{o=1}^{N} \tau_{t+1}^{nk,ok} \frac{\pi_{t+1}^{nk,ok} X_{t+1}^{nk}}{1+\tau_{t+1}^{nk,ok}} \right) \tag{15}$$

$$\dot{w}_{t+1}^{njs} \dot{L}_{t+1}^{njs} w_{t}^{njs} L_{t}^{njs} = \zeta^{njs} \left(1-\xi^{n}\right) \gamma^{nj} \sum_{o=1}^{N} \frac{\pi_{t+1}^{oj,nj} X_{t+1}^{oj}}{1+\tau_{t+1}^{oj,nj}}, \qquad s \in \{1,2,3\} \tag{16}$$

$$\dot{r}_{t+1}^{nj} = \dot{w}_{t+1}^{njs} \dot{L}_{t+1}^{njs}, \qquad s \in \{1,2,3\} \tag{17}$$

Given $\left\{ L_{t}^{njs}, \pi_{t}^{nj}, X_{t}^{nj}, \dot{L}_{t+1}^{njs}, \dot{\Theta}_{t+1} \right\}$ for all $\{n, j, s\}$, one can solve for the change in the allocation of the temporary equilibrium between t and $t+1$, and in the real wages based on $\left\{ \dot{w}_{t+1}^{njs}, \dot{P}_{t+1}^{nj} \right\}$. The next step then characterizes the changes $\dot{L}_{t+1}^{njs}$ that are consistent with the sequential equilibrium in time differences.

Sequential Equilibrium

Define $u_t^{njs} \equiv e^{V_t^{njs}}$. Conditional on an initial allocation of the economy $(L_0, \pi_0, X_0, \mu_{-1})$, given an anticipated convergent sequence of changes in fundamentals $\left\{\dot{\Theta}_t\right\}_{t=1}^{\infty}$, the solution to the sequential equilibrium in time differences satisfies the following equations:

$$\mu_{t+1}^{njs,nki} = \frac{\mu_t^{njs,nki}\left(\dot{u}_{t+2}^{nki}\right)^{\frac{\beta\delta}{\nu}}}{\sum_{\mathrm{K}=0}^{J}\sum_{\mathrm{I}\geq s}^{3}\mu_t^{njs,n\mathrm{KI}}\left(\dot{u}_{t+2}^{n\mathrm{KI}}\right)^{\frac{\beta\delta}{\nu}}} \tag{18}$$

$$\dot{u}_{t+1}^{njs} = \dot{\omega}_{t+1}^{njs}\left[\sum_{\mathrm{K}=0}^{J}\sum_{\mathrm{I}\geq s}^{3}\mu_t^{njs,n\mathrm{KI}}\left(\dot{u}_{t+2}^{n\mathrm{KI}}\right)^{\frac{\beta\delta}{\nu}}\right]^{\nu} \tag{19}$$

$$L_{t+1}^{njs} = \delta\sum_{k=0}^{J}\sum_{i\leq s}^{3}\mu_t^{nki,njs}L_t^{nki},\ js \neq 01 \tag{20}$$

$$L_{t+1}^{n01} = \delta\sum_{k=0}^{J}\mu_t^{nk1,n01}L_t^{nk1} + (1-\delta)L^n \tag{21}$$

where $\left\{\dot{\omega}_t^{njs}\right\}$ is the solution to the temporary equilibrium given $\left\{\dot{L}_t, \dot{\Theta}_t\right\}$.

Dynamic Hat Algebra: Counterfactual

Define $\widehat{y}_{t+1} = \dot{y}'_{t+1}/\dot{y}_{t+1}$. Consider a counterfactual convergent sequence of changes in fundamentals relative to the baseline change $\left\{\widehat{\Theta}_t\right\}_{t=1}^{\infty}$. Given the allocation under the baseline fundamentals $\{L_t, \mu_{t-1}, \pi_t, X_t\}_{t=0}^{\infty}$, the counterfactual sequential allocation $\left\{L'_t, \mu'_{t-1}, \pi'_t, X'_t\right\}_{t=0}^{\infty}$ satisfies the following equations:

$$\mu_{t+1}^{\prime njs,nki} = \frac{\mu_t^{\prime njs,nki}\,\dot{\mu}_{t+1}^{njs,nki}\left(\widehat{u}_{t+2}^{nki}\right)^{\frac{\beta\delta}{\nu}}}{\sum_{\mathrm{K}=0}^{J}\sum_{\mathrm{I}\geq s}^{3}\mu_t^{\prime njs,n\mathrm{KI}}\,\dot{\mu}_{t+1}^{njs,n\mathrm{KI}}\left(\widehat{u}_{t+2}^{n\mathrm{KI}}\right)^{\frac{\beta\delta}{\nu}}} \tag{22}$$

$$\widehat{u}_{t+1}^{njs} = \widehat{\omega}_{t+1}^{njs}\left[\sum_{\mathrm{K}=0}^{J}\sum_{\mathrm{I}\geq s}^{3}\mu_t^{\prime njs,n\mathrm{KI}}\,\dot{\mu}_{t+1}^{njs,n\mathrm{KI}}\left(\widehat{u}_{t+2}^{n\mathrm{KI}}\right)^{\frac{\beta\delta}{\nu}}\right]^{\nu} \tag{23}$$

$$L_{t+1}^{\prime njs} = \delta\sum_{k=0}^{J}\sum_{i\leq s}^{3}\mu_t^{\prime nki,njs}L_t^{\prime nki},\ js\neq 01 \tag{24}$$

$$L_{t+1}^{\prime n01} = \delta\sum_{k=0}^{J}\mu_t^{\prime nk1,n01}L_t^{\prime nk1} + (1-\delta)L^n \tag{25}$$

Dynamic Hat Algebra: Counterfactual

where $\widehat{\omega}_{t+1}^{njs}$ is the solution to the temporary equilibrium given $\left(\widehat{L}_{t+1}, \widehat{\Theta}_{t+1}\right)$ at each t:

$$\widehat{x}_{t+1}^{nj} = \left(\widehat{r}_{t+1}^{nj}\right)^{\xi^n \gamma^{nj}} \prod_{s=1}^{3} \left(\widehat{w}_{t+1}^{njs}\right)^{\zeta^{njs}\left(1-\xi^n\right)\gamma^{nj}} \prod_{k=1}^{J} \left(\widehat{P}_{t+1}^{nk}\right)^{\gamma^{nj,nk}} \tag{26}$$

$$\widehat{P}_{t+1}^{nj} = \left[\sum_{o} \pi_t'^{nj,oj} \dot{\pi}_{t+1}^{nj,oj} \left(\widehat{\kappa}_{t+1}^{nj,oj} \widehat{x}_{t+1}^{oj}\right)^{-\theta^j} \left(\widehat{A}_{t+1}^{oj}\right)^{\gamma^{oj}\theta^j}\right]^{-\frac{1}{\theta^j}} \tag{27}$$

$$\pi_{t+1}'^{nj,oj} = \pi_t'^{nj,oj} \dot{\pi}_{t+1}^{nj,oj} \left(\frac{\widehat{\kappa}_{t+1}^{nj,oj} \widehat{x}_{t+1}^{oj}}{\widehat{P}_{t+1}^{nj}}\right)^{-\theta^j} \left(\widehat{A}_{t+1}^{oj}\right)^{\gamma^{oj}\theta^j} \tag{28}$$

Dynamic Hat Algebra: Counterfactual

(...continued)

$$X'^{nj}_{t+1} = \sum_{k=1}^{J} \gamma^{nk,nj} \sum_{o=1}^{N} \frac{\pi'^{ok,nk}_{t+1} X'^{ok}_{t+1}}{1+\tau'^{ok,nk}_{t+1}} \tag{29}$$

$$+ \alpha^{j} \left(\sum_{k=1}^{J} \sum_{s=1}^{3} \widehat{w}^{nks}_{t+1} \widehat{L}^{nks}_{t+1} w'^{nks}_{t} L'^{nks}_{t} \dot{w}^{nks}_{t+1} \dot{L}^{nks}_{t+1} + \iota^{n} \chi'_{t+1} + \sum_{k=1}^{J} \sum_{o=1}^{N} \tau'^{nk,ok}_{t+1} \frac{\pi'^{nk,ok}_{t+1} X'^{nk}_{t+1}}{1+\tau'^{nk,ok}_{t+1}} \right)$$

$$\widehat{w}^{njs}_{t+1} \widehat{L}^{njs}_{t+1} = \frac{\zeta^{njs}\left(1-\xi^{n}\right)\gamma^{nj}}{w'^{njs}_{t} L'^{njs}_{t} \dot{w}^{njs}_{t+1} \dot{L}^{njs}_{t+1}} \sum_{o=1}^{N} \frac{\pi'^{oj,nj}_{t+1} X'^{oj}_{t+1}}{1+\tau^{oj,nj}_{t+1}}, \qquad s \in \{1,2,3\} \tag{30}$$

$$\widehat{r}^{nj}_{t+1} = \widehat{w}^{njs}_{t+1} \widehat{L}^{njs}_{t+1}, \qquad s \in \{1,2,3\} \tag{31}$$

Data: Trade, Tariffs, and Production Parameters

- For the simulations we include 60 individual economies and a residual Rest-of-World (ROW), 22 sectors (agriculture plus 11 manufacturing sectors and 10 service sectors) and non-employment, and three skill groups (low, middle, and high).
- TiVA ICIO Tables 2016 edition (1995–2011): trade shares ($\pi_t^{nj,oj}$), input-output coefficients ($\gamma^{nj,nk}$), value-added shares (γ^{nj}), final consumption expenditure shares (α^j).
- Karabarbounis and Neiman (2014): labor shares in value added ($1-\xi^n$).
- World Input-Output (WIOD) Database Socioeconomic Account: skill shares in the value-added of labor.
- World Integrated Trade Solution (WITS) database / TRAINS: tariffs ($\tau_t^{nj,oj}$).
- Caliendo and Parro (2015): Trade elasticity (θ^j).

Data: Labor Market Parameters and Sector-Skill Transition

- For Taiwan, the low-, middle-, and high-skilled workers are defined as, respectively, those with highest education attainment:
  - less than or equal to junior high school;
  - equal to senior high school or vocational school diploma;
  - equal to a college degree (bachelor, master or doctorate degree).
- We compile the data on the allocation of labor by sector-skill (L_t^{njs}) during the period 1995–2007 and on the transition statistics ($\mu_t^{njs,nki}$) across sector-skill combinations at annual frequency, based on the *Manpower Utilization Quasi-longitudinal Data* from the Survey Research Data Archive (SRDA) of Academia Sinica, Taiwan.
- For economies other than Taiwan, the dynamics of labor market transition is not explicitly studied, so the skill group definition only matters in the measure of the three skill groups' shares in total labor value added (ζ^{njs}).

Data: Labor Market Parameters and Sector-Skill Transition

- Annual discount factor (β): we set $\beta = 0.97$, à la Artuç and McLaren (2015) and Caliendo, Parro, Opromolla and Sforza (2021).
- Survival rate δ: we set the mortality rate for Taiwan at 0.6% for the period studied, which implies $\delta \backsimeq 0.994$.
  - National Development Council, Taiwan, at `https://pop-proj.ndc.gov.tw/chart.aspx?c=1&uid=61&pid=60`.
- Labor market transition elasticity (here corresponding to $\beta\delta/\nu$): estimated below.

Estimation of $\beta\delta/\nu$

- We estimate the labor market transition elasticity, based on the 2-stage approach proposed by Artuç and McLaren (2015) but adapted for the utility function specified in equation (1).
- Since the labor-market transition dynamics are only studied for the Taiwanese economy, we omit the economy superscript in this section.
- In particular, in the first stage we estimate by PPML the following sector-skill-transition equation:

$$L_t^{js,ki} = \exp\left(\alpha_t^{js} + \lambda_t^{ki} - \rho^{js,ki}/\nu\right) + \xi_t^{js,ki} \tag{32}$$

where $L_t^{js,ki}$ is the flow of workers switching from sector-skill combination js to combination ki, measured by $L_t^{js} \times \mu_t^{js,ki}$.

Estimation of $\beta\delta/\nu$ (continued)

- The transition cost function is empirically implemented in the current study as:

$$\begin{aligned}\rho^{js,ki} &= 0 \text{ if } k=j, i=s; \\ &= \rho_1^{s,i} \text{ if } k=j, i\neq s; \\ &= \rho_2^{j,k} \text{ if } k\neq j, i=s; \\ &= \rho_2^{j,k}+\rho_3^{s,i} \text{ if } k\neq j, i\neq s. \end{aligned} \tag{33}$$

  - $\rho_1^{s,i}$: cost to upgrade skill from s to i (from s=low-skill to i=middle-skill or from s=middle-skill to i=high-skill) in the scenario without sector switching.
  - $\rho_2^{j,k}$: cost to switch from sector j to sector k without skill upgrading.
  - $\rho_3^{s,i}$: cost to upgrade skill from s to i (from s=low-skill to i=middle-skill or from s=middle-skill to i=high-skill) in the scenario with sector switching.

Estimation of $\beta\delta/\nu$ (continued)

- Using the Bellman equation (1) and the transition probability equation (3), we can obtain:

$$\phi_t^{js} = \zeta_t + \frac{\beta\delta}{\nu} \ln w_{t+1}^{js} + \xi_t^{js} \tag{34}$$

  - $\phi_t^{js} \equiv \lambda_t^{js} + \beta\delta\alpha_{t+1}^{js} - \beta\delta \log\left(L_{t+1}^{js}\right)$: imputed given the first-stage estimates of the fixed effects $(\lambda_t^{js}, \alpha_{t+1}^{js})$ and the observed labor allocation L_{t+1}^{js}
  - estimate (34) as an IV regression, using two-period lagged values of the right-hand-side variable ($\ln w_{t+1}^{js}$) as instruments
  - control for extra fixed effects: $\eta_{t+1}^{s} \equiv \eta_1^s + \eta_2^s \times t$, which correspond to the origin-skill fixed effects and origin-skill-specific time trends — Artuç and McLaren (2015) non-pecuniary benefits
  - The utility function in (1) can be modified to include this extra term, without affecting the counterfactual analysis

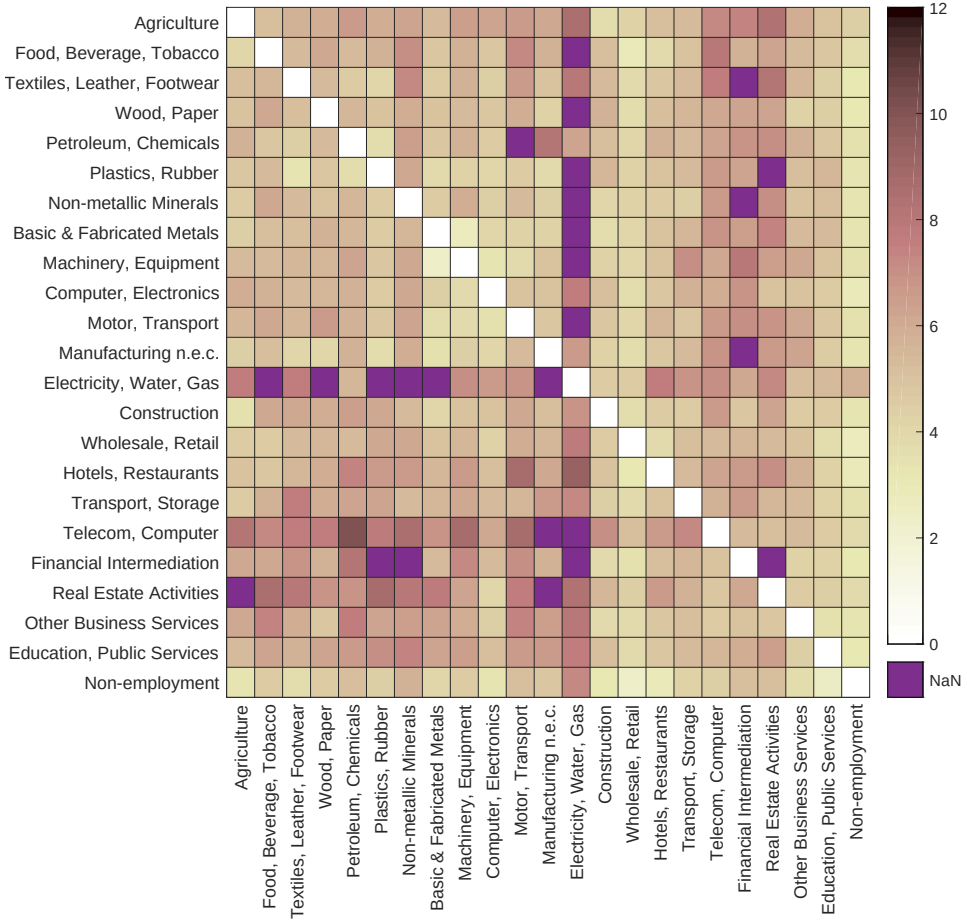
Estimation of Labor Market Transition Elasticity $\beta\delta/\nu$

	(1) Stage 1 Estimation $L_t^{js,ki}$		(2) Stage 2 Estimation ϕ_t^{js}
$\rho_1^{low,mid}$	5.202***	ln w_{t+1}^{js}	**0.806***
	(0.129)		(0.034)
$\rho_1^{mid,high}$	4.301***	$\eta_2^{middle} \times t$	-0.012***
	(0.152)		(0.003)
$\rho_3^{low,mid}$	4.103***	$\eta_2^{high} \times t$	-0.008**
	(0.121)		(0.003)
$\rho_3^{mid,high}$	3.003***		
	(0.136)		
constant	11.01***		
	(0.024)		
Origin-Sector-Skill-Year FE (α_t^{js})	Yes	Year FE (ζ_t)	Yes
Destination-Sector-Skill-Year FE (λ_t^{ki})	Yes	Origin-Skill FE (η_1^s)	Yes
Sector-to-Sector FE	Yes		
No. of Observations	53496	No. of Observations	42540
R^2	0.811	R^2	0.360

Estimation of Labor Market Transition Elasticity $\beta\delta/\nu$

- Elasticity $\beta\delta/\nu$: 0.806 — larger than the implied quarterly elasticity (0.185) of CDP; in the same order of magnitude as the annual elasticity estimate (0.50) of Caliendo, Parro, Opromolla and Sforza (2021)
- Implied ν: 1.196

Estimation of Sector-to-Sector Transition Costs

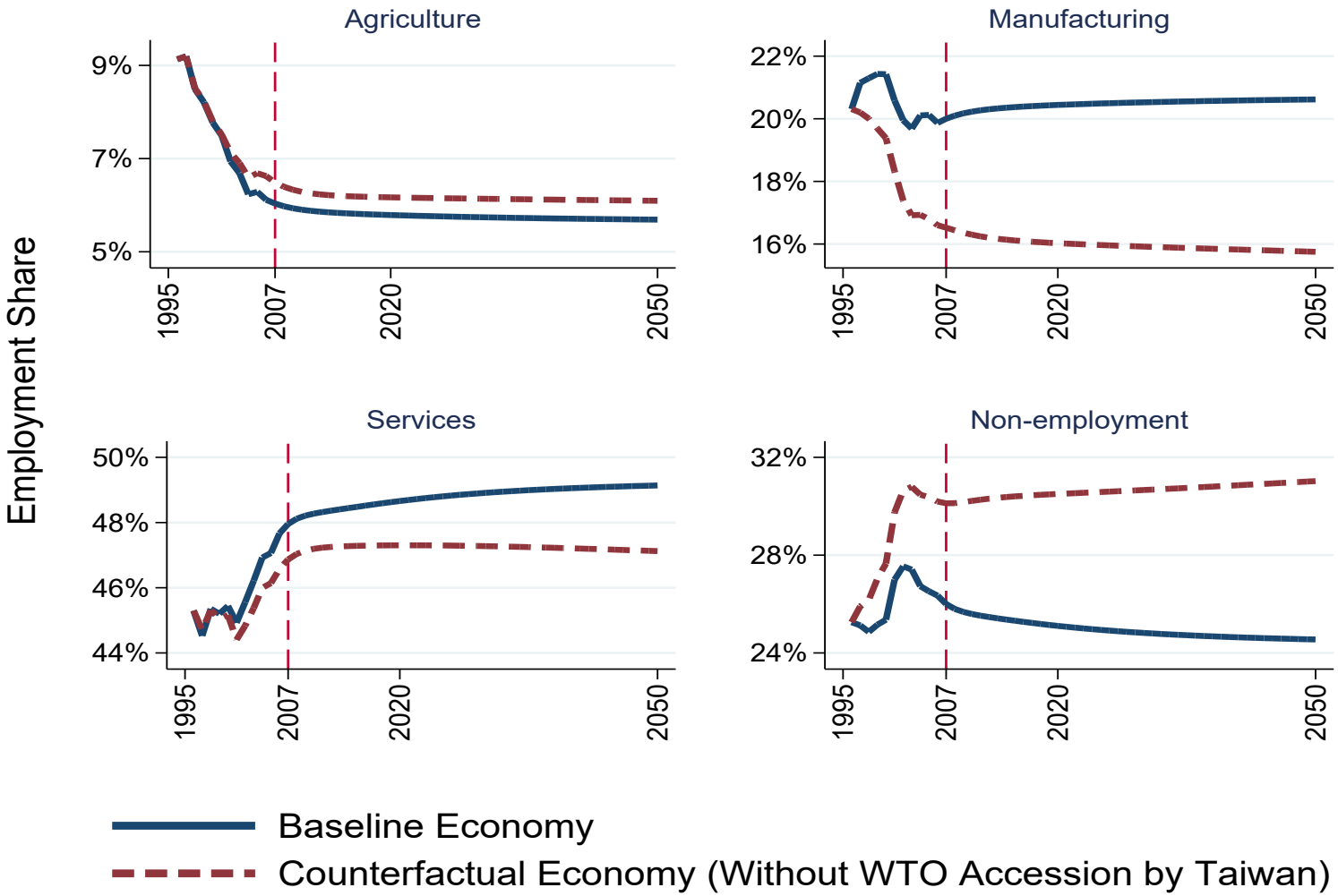


- The origin-sectors in the rows and destination-sectors in the columns.
- the magnitudes reported reflect the sector-switching costs ($\rho_2^{j,k}$) without skill upgrading.
- The switching costs are the largest to switch from service to manufacturing sectors, followed by the costs to switch from manufacturing to service sectors, then the costs to switch across sectors within manufacturing, and the lowest are across sectors within services.

Effects of Taiwan's WTO Entry: Setup

- Baseline Economy:
  - 1995–2007 (data period): with actual changes in fundamentals
  - 2008 onwards: constant fundamentals until year 3000.
- Counterfactual Economy: Taiwan's tariffs on imports and foreign tariffs on Taiwan's exports are set to their levels in 1995.
- Effects: Baseline / Counterfactual

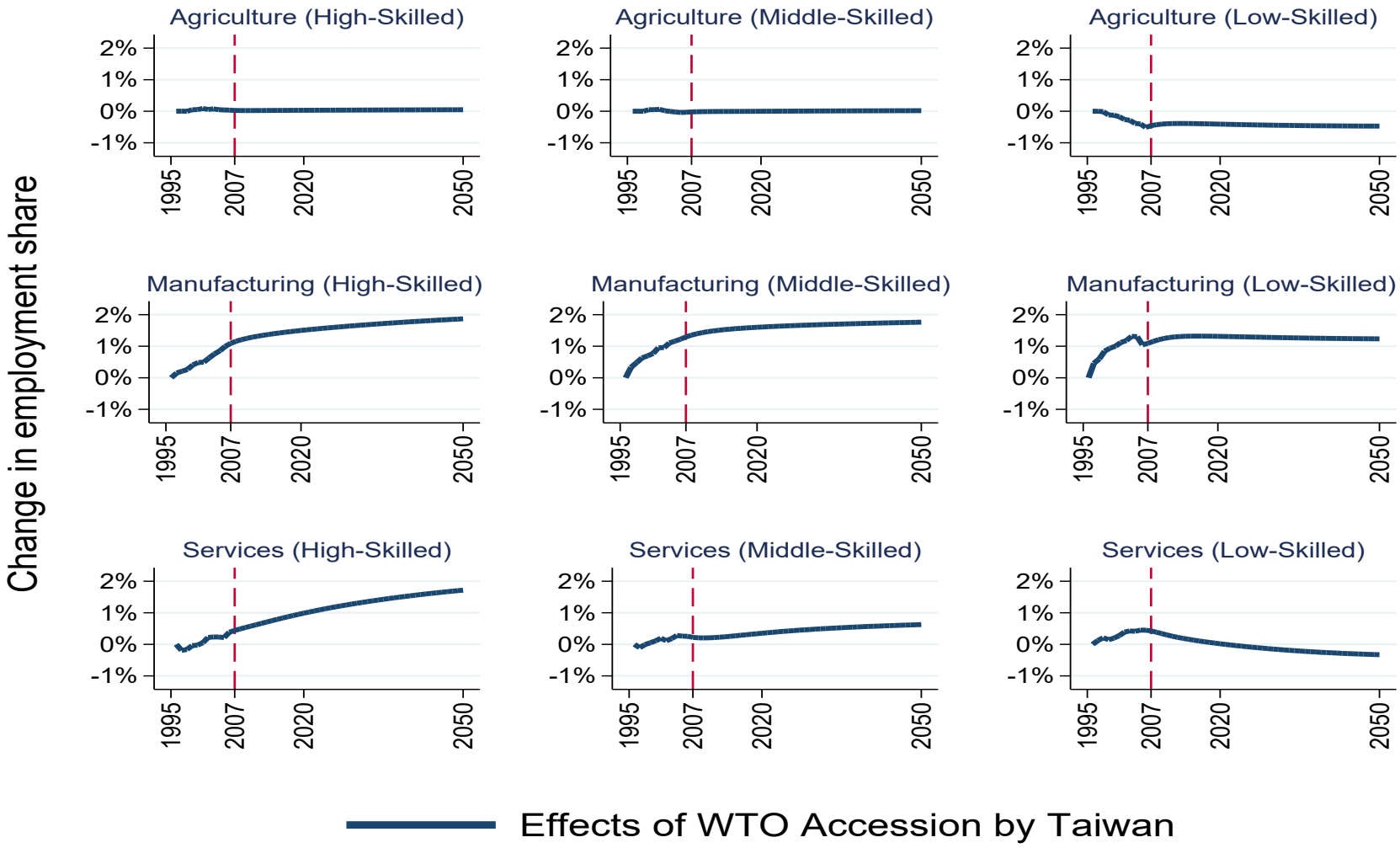
Effects of Taiwan's WTO Entry: Transition dynamics of employment shares



Effects of Taiwan's WTO Entry: Transition dynamics of employment shares

- Manufacturing and service employment shares increased by about 4.4% and 1.3% of the total population (measured as the sum of employed, unemployed, and not-in-labor-force), respectively.
- These effects are quantitatively large, in comparison with the literature such as CDP (around $\pm 0.3\%$).
- In addition, the increase in manufacturing and service employment ($\approx 5.7\%$ all told) is far larger than the decrease in agricultural employment ($\approx 0.37\%$), which suggests that employment increased overall.
- The outflow of farmers from the agricultural sector took place rather quickly and the adjustment was basically completed by the time Taiwan finished all tariff changes.
- However, the gain in manufacturing and service employment was a long and slow-moving process that continued to the present decade.

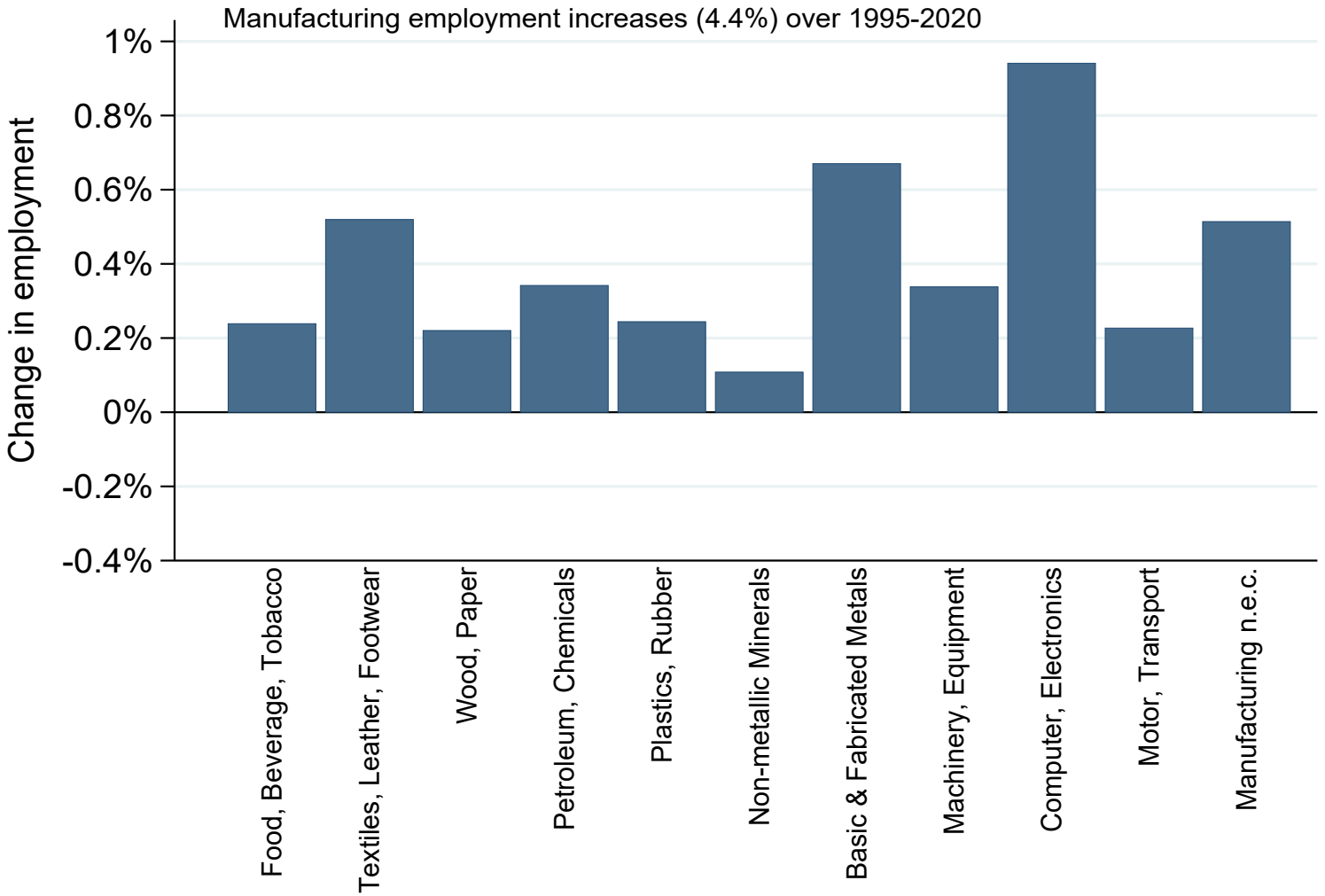
Effects of Taiwan's WTO Entry: Transition dynamics of employment shares by skill groups



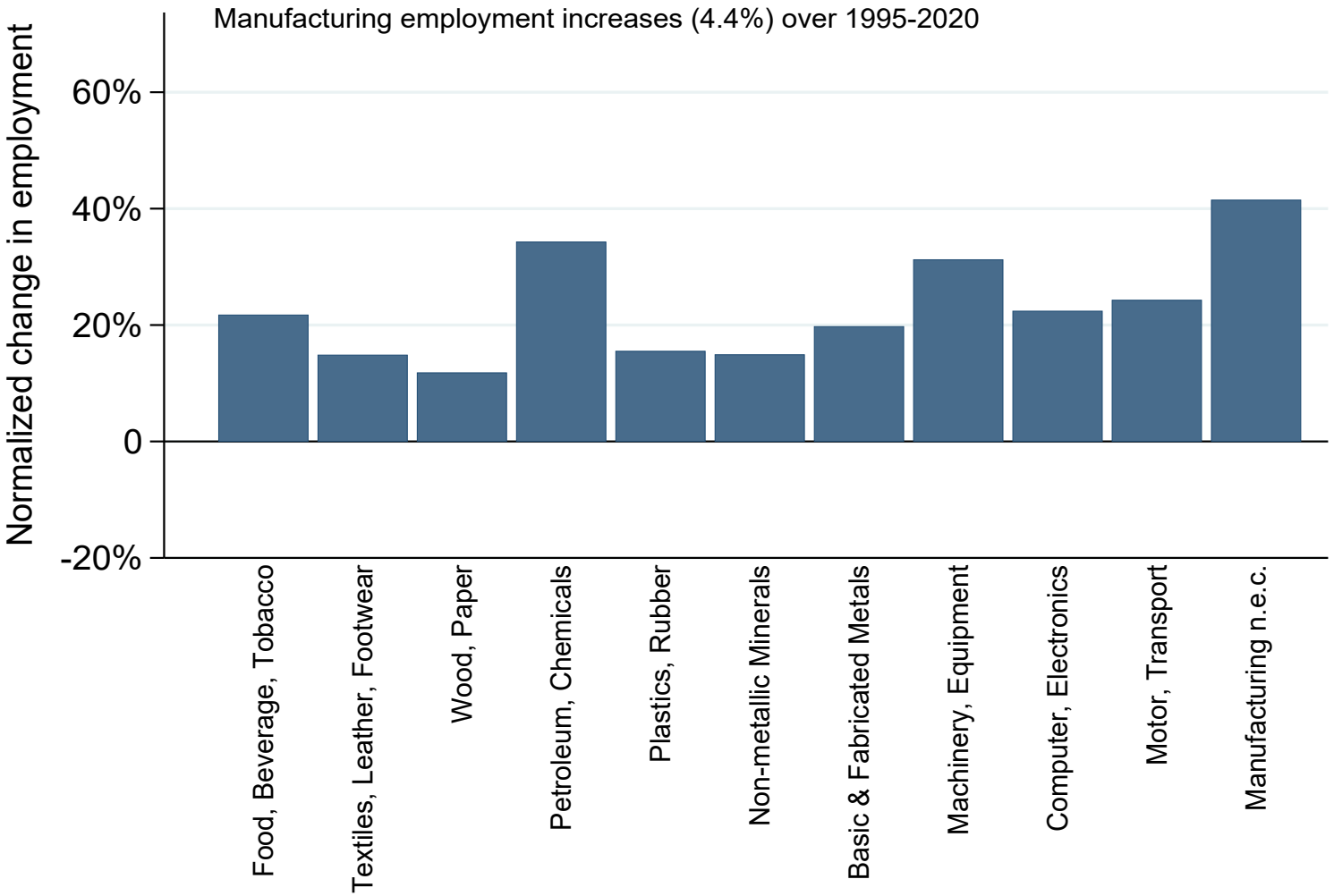
Effects of Taiwan's WTO Entry: Transition dynamics of employment shares by skill groups

- The decrease in agricultural employment was almost entirely driven by the low-skilled workers
- Both the manufacturing and service sectors saw an increase of high-skill employment (by about 1.5% and 0.9%, respectively).
- In comparison, the middle-skill employment increased by more in manufacturing (about 1.6%) than in the service sectors (0.3%).
- While there was a positive inflow of low-skilled workers into manufacturing sectors, the service sectors saw a decline in low-skill employment.
- The manufacturing sectors helped absorb some of the displaced agricultural workers with low skills.

Effects of Taiwan's WTO Entry: Employment Shares in Manufacturing



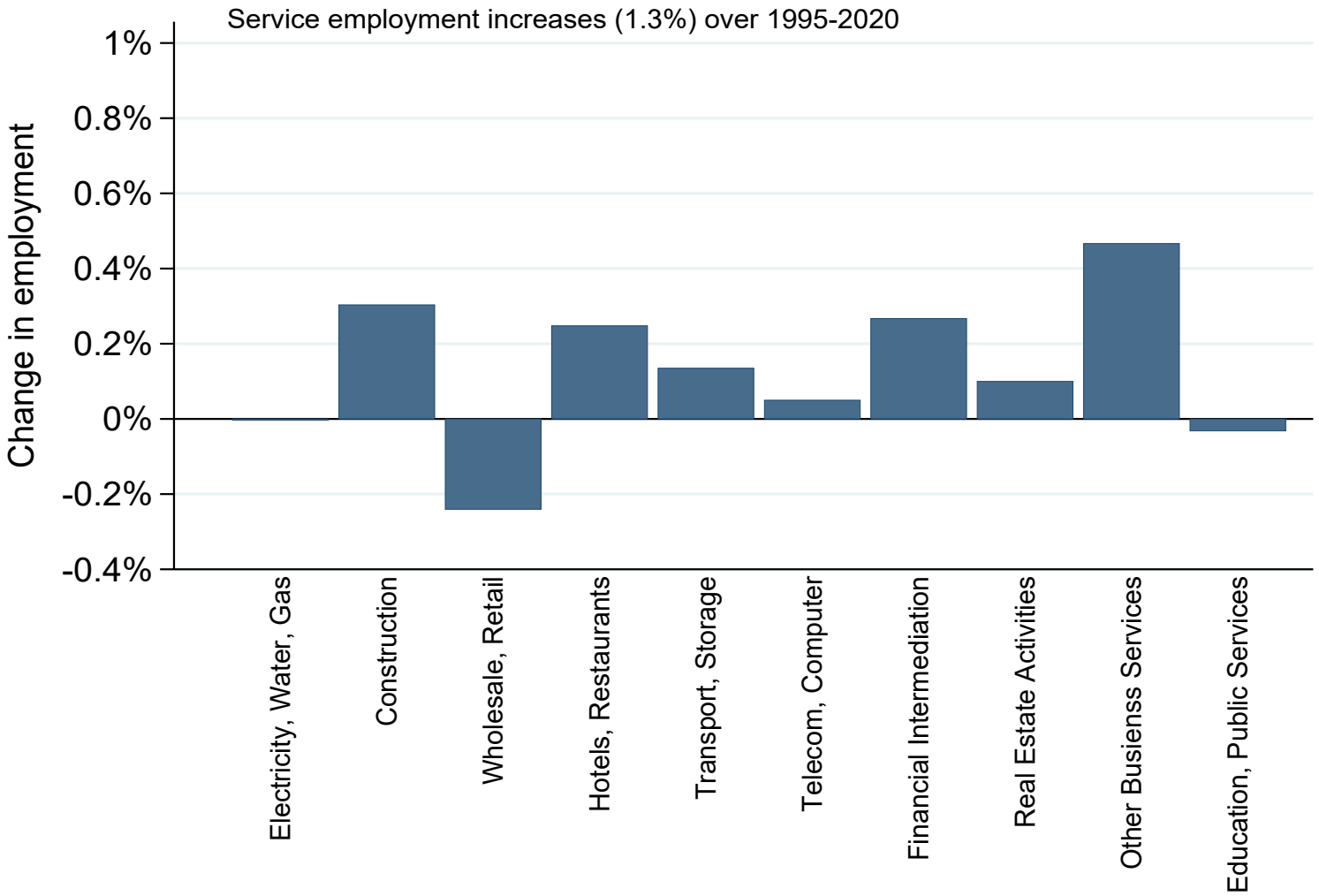
Effects of Taiwan's WTO Entry: Employment Shares in Manufacturing (normalized by sector size)



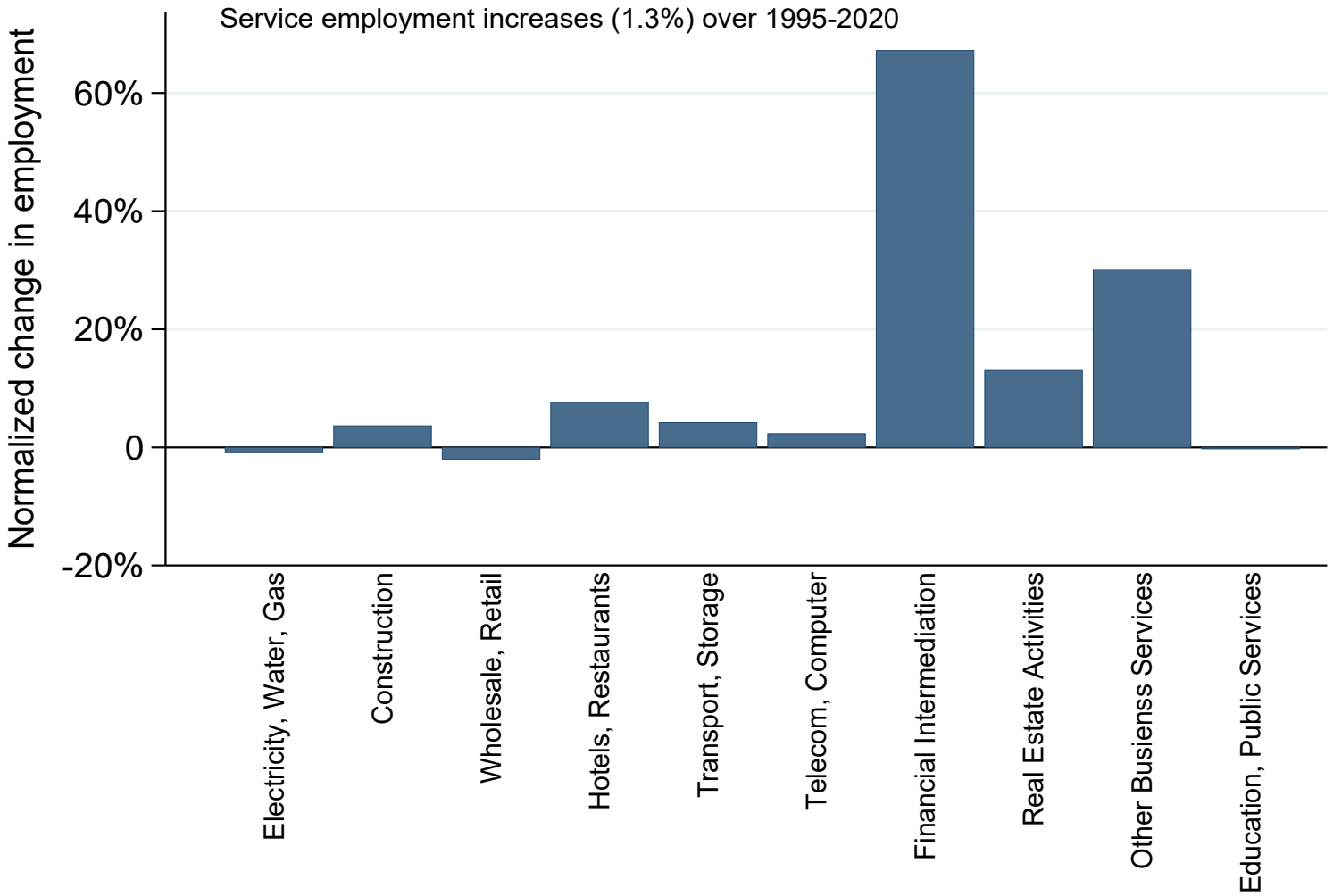
Effects of Taiwan's WTO Entry: Employment Shares in Manufacturing

- Among manufacturing sectors, the positive effect on employment due to Taiwan's WTO entry was mainly driven by the MCEE (Machinery, Computer, Electronics & Electrical) sectors, whose employment increased by about 1.3% of the total population (cf. 4.4% across all manufacturing sectors).
- This was followed by "Basic & Fabricated Metals" (0.67%) and "Textiles, Leather, Footwear" (0.5%).
- When these changes are normalized relative to the initial employment share of the sector in 1995 (of the total population), the importance of MCEE sectors and the sectors of "Petroleum, Chemicals, Plastics, Metals" continued to stand out and that of "Textiles, Leather, Footwear" reduced.

Effects of Taiwan's WTO Entry: Employment Shares in Service



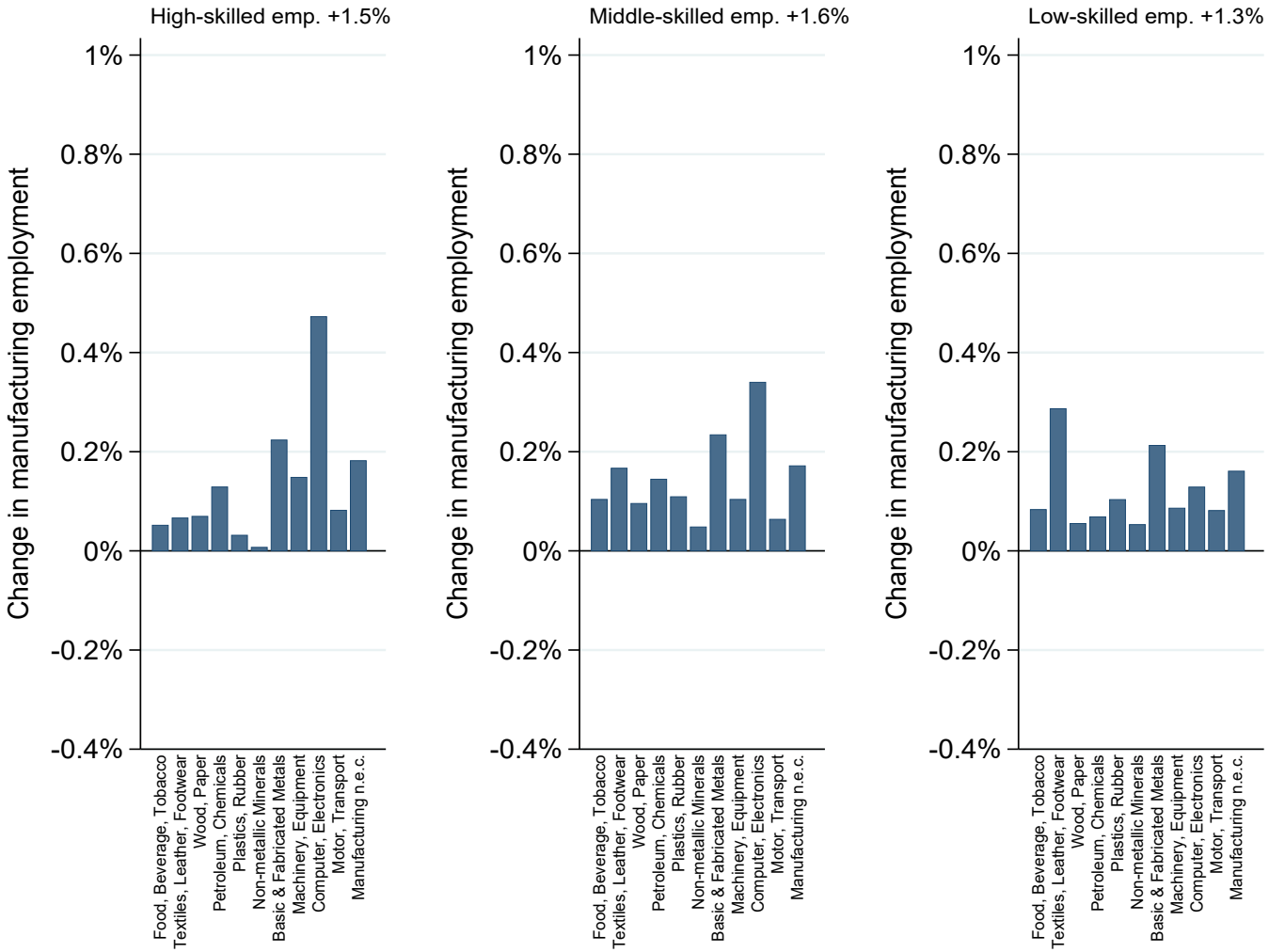
Effects of Taiwan's WTO Entry: Employment Shares in Service (normalized by sector size)



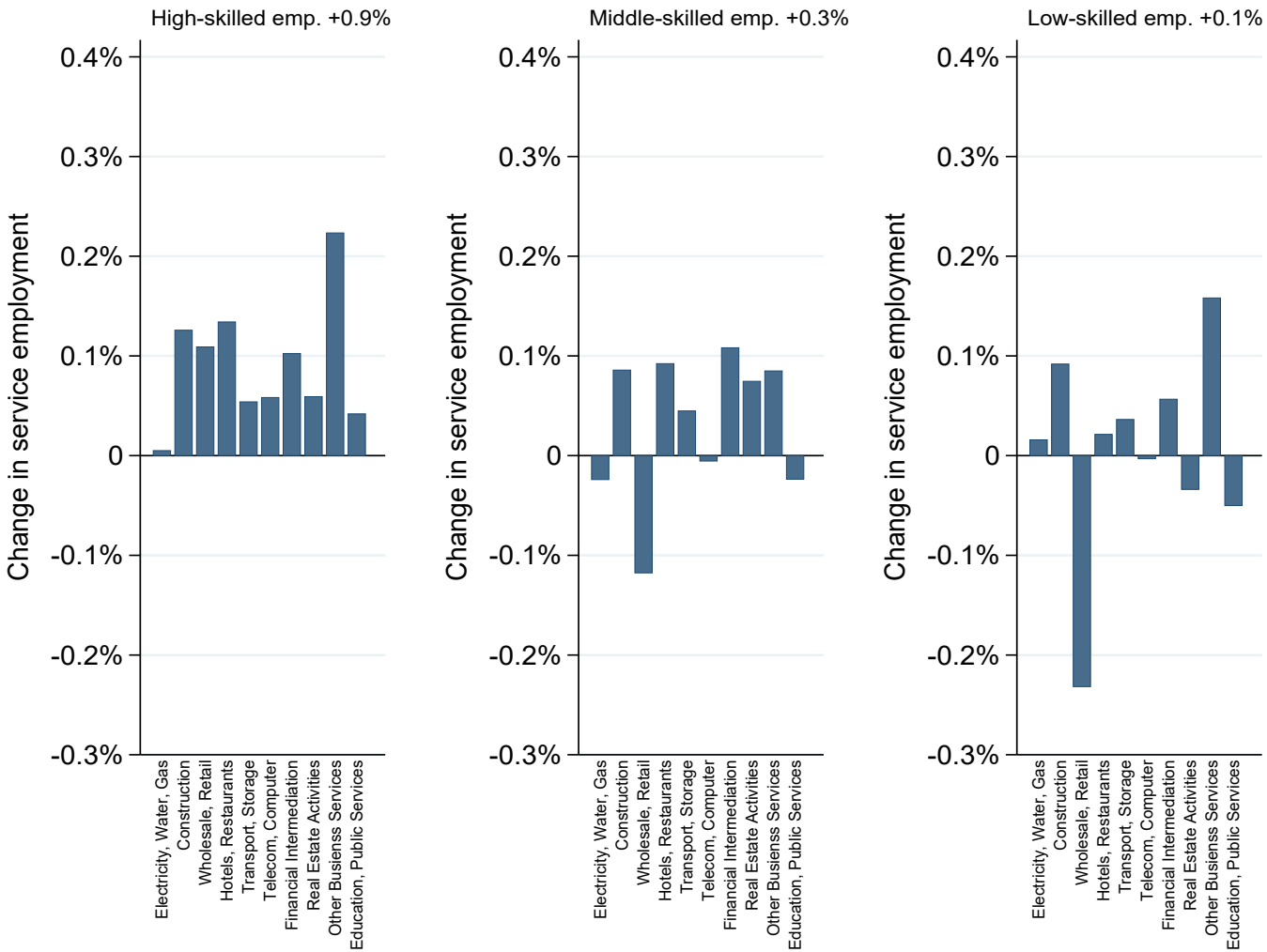
Effects of Taiwan's WTO Entry: Employment Shares in Service

- Employment in the "Other Business Services" sector (including activities such as R&D, law, accounting, business consulting, architecture, engineering, advertising and other business activities) increased the most by more than 0.5% of the total population.
- followed by "Construction", "Financial Intermediation", and "Hotels, Restaurants" (by about 0.3% each).
- The rates of expansion were especially pronounced in "Financial Intermediation" and "Other Business Services", when normalized by the initial employment size.
- Our interpretations are that these two sectors benefitted through input-output linkages from expansion of skill-intensive manufacturing sectors.

Effects of Taiwan's WTO Entry: Employment Shares in Manufacturing by Skill Groups



Effects of Taiwan's WTO Entry: Employment Shares in Service by Skill Groups



Effects of Taiwan's WTO Entry: Employment Shares in Manufacturing/Service by Skill Groups

- The employment shares of high-skilled and middle-skilled workers grew the most in the MCEE sectors among other manufacturing sectors, and that of high-skilled workers mostly in the "Other Business Services" sector among services.
- These sectors also had the largest overall employment gains, as discussed above, which suggests that when these sectors expanded due to export shock and input-output linkages, they tended to hire more skilled workers.
- The "Textiles, Leather, Footwear" sector experienced the largest gain of low-skilled workers among manufacturing sectors. The "Other Business Services" sector, which expanded its employment of high-skilled workers, also increased its employment of low-skilled workers, albeit less proportionally.

Effects of Taiwan's WTO Entry: Welfare of Workers

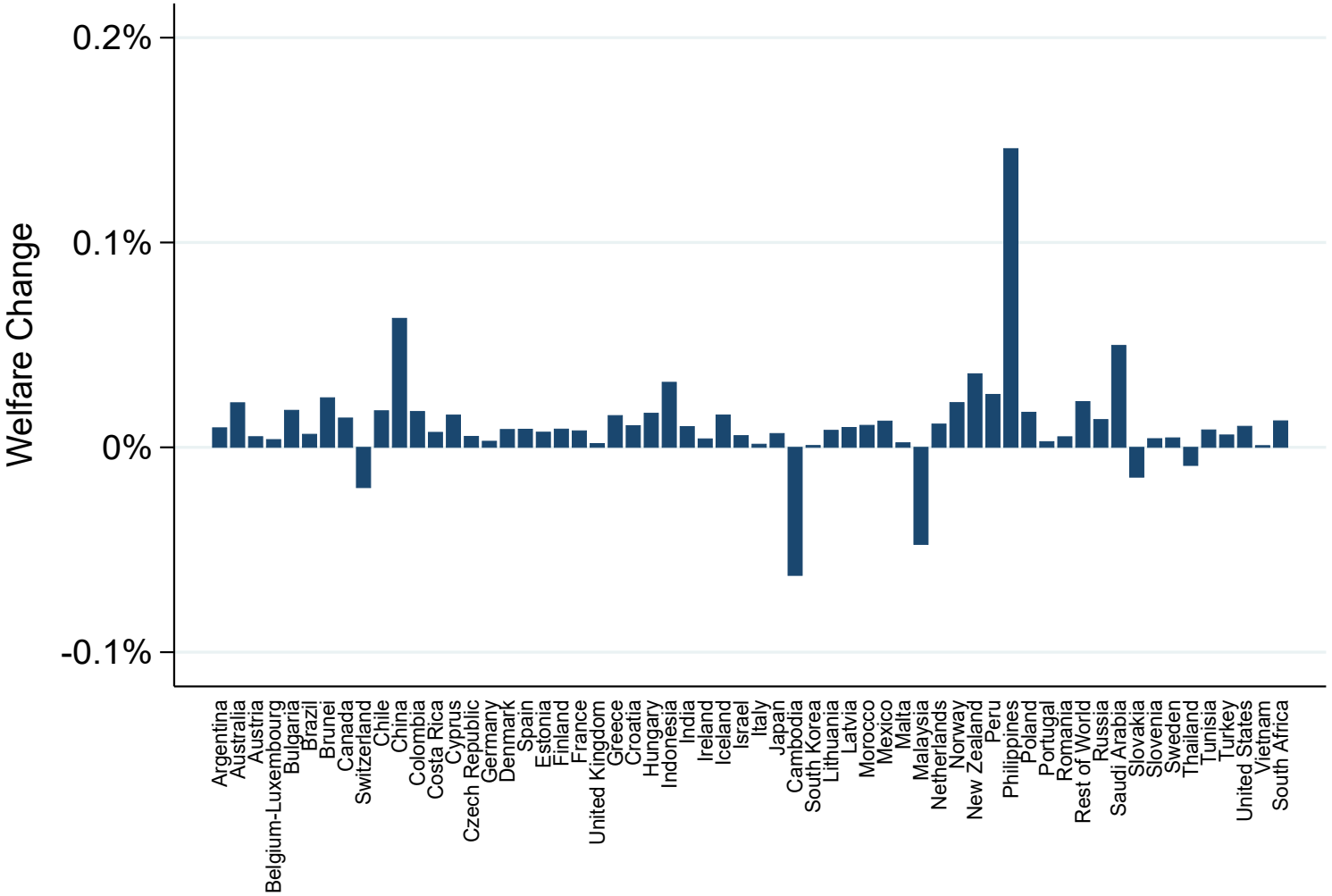
$$\widehat{W}^{njs} = \sum_{t=1995}^{2020} (\beta\delta)^{t-1995} \ln\left(\frac{\widehat{\omega}_t^{njs}}{\left(\widehat{\mu}_t^{njs,njs}\right)^{\nu}}\right) \tag{35}$$

Aggregate	Low-skilled workers	Middle-skilled workers	High-skilled workers
2.396%	2.139%	2.591%	2.685%

Agriculture	Manufacturing	Services
1.764%	3.073%	2.217%

- The welfare effect is large in comparison with the findings of the literature.
- The high-skilled workers experienced the largest welfare gains.
- Consistent with the effects on employment shares discussed above, Taiwan's WTO entry led to the largest welfare gains for workers in manufacturing sectors.

Effects of Taiwan's WTO Entry: Welfare of Workers in ROW

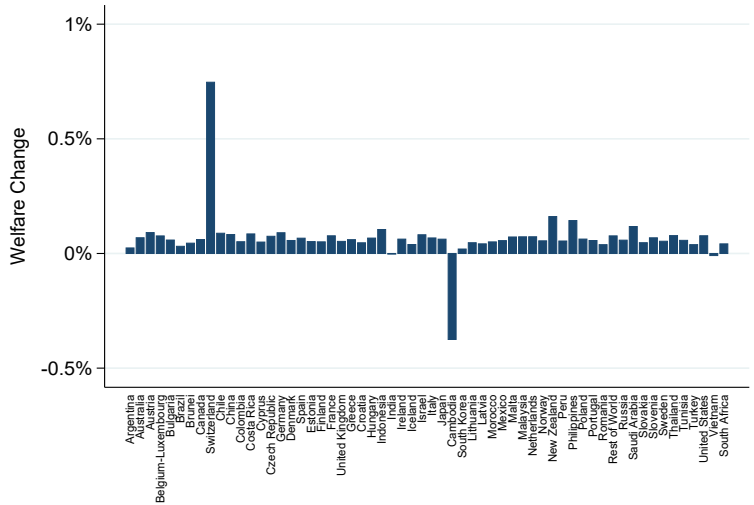


Effects of Taiwan's WTO Entry: Welfare of Workers in ROW

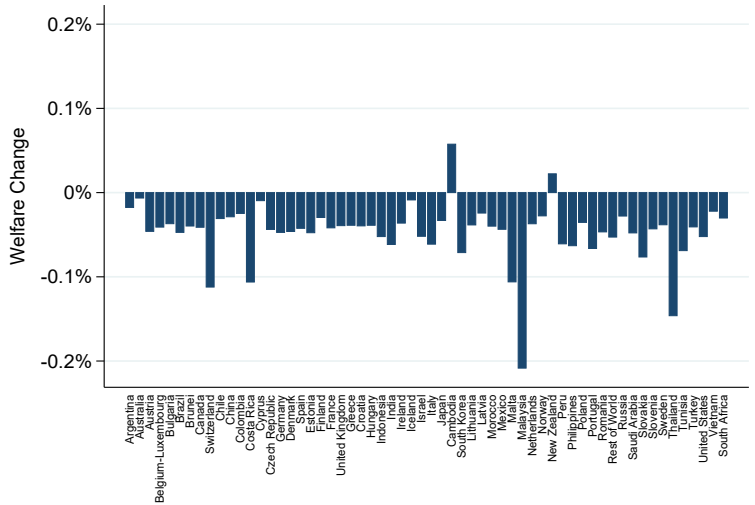
- Taiwan's WTO accession led to general welfare gains across the 60 other economies (with the exception of six economies).
- The magnitudes of welfare changes are between -0.06% and 0.15%.
- Among the economies that experienced welfare gains, they were either closely linked to the Taiwanese economy in terms of geographical proximity (China and Philippines) or via the global value chain (Saudi Arabia, a major material supplier for the Petro-Chemicals industry).
- On the other hand, Southeast Asian economies tended to experience welfare losses: e.g., Cambodia, Malaysia, Thailand, and Vietnam.

Effects of Taiwan's WTO Entry: Welfare of Workers in ROW (distribution)

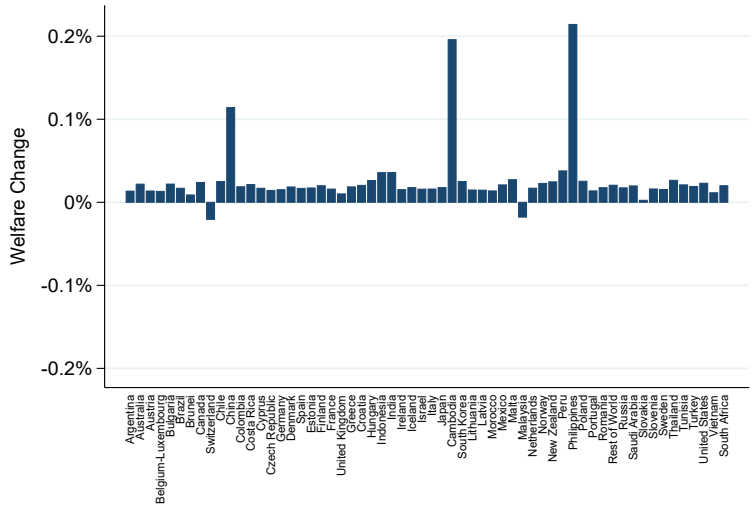
Agriculture



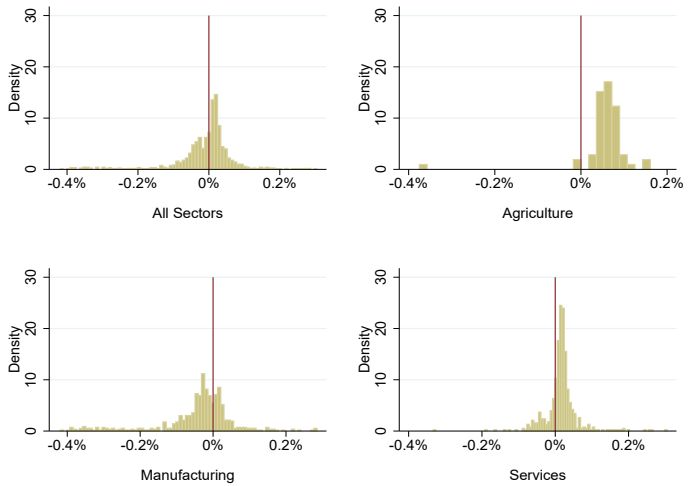
Manufacturing



Service



Distribution



Effects of Taiwan's WTO Entry: Welfare of Workers in ROW (by sectors)

- Taiwan's WTO accession led to: (1) welfare gains in the agricultural sector; (2) welfare losses in the manufacturing sectors; and (3) welfare gains in the service sectors, across almost all the other economies.
- This is consistent with the previous discussion that Taiwan opened its agricultural market in exchange for foreign tariff reductions on its manufacturing exports.
- Hence, faced with increased competition from Taiwanese exports, the workers in the manufacturing sectors of the other economies experienced welfare losses.
- In contrast, workers in the service sectors in the other economies did not face direct competition from Taiwanese exports (recall that there was no labor reallocation in the other economies), and thus tended to experience welfare gains given the lower general price index (as a result of increased market competition in the manufacturing sectors).

Effects of Taiwan's WTO Entry: Welfare of Workers in ROW (distribution)

- The welfare effects across all labor markets (22 sectors in 60 other economies) are heterogeneous, and range from -0.4% to 0.3% across individual labor markets.
- In general, the distribution is skewed towards the positive range, although there are substantial numbers of labor markets that experienced welfare losses.
- Even though previously we observed almost uniform welfare losses for the aggregate manufacturing sectors, a non-negligible number of economy-sector pairs in manufacturing still benefitted.
- This suggests that competition from Taiwanese exports might have been concentrated in certain sectors such as MCEE and PCPM sectors. Hence, it is mainly workers in these sectors in the other economies that tended to suffer the most and experience welfare loss.
- For services, the distribution is skewed to the positive range.

The Role of China

We analyze three more counterfactual scenarios to assess the interaction of the Chinese economy with Taiwan in international markets.

(2) China's WTO accession: in the counterfactual, China's import tariffs and foreign tariffs on China's exports are rolled back to their levels in 1995.

(3) WTO accession by both Taiwan and China: in the counterfactual, both Taiwan's and China's import tariffs and foreign tariffs on Taiwan's and China's exports are set to their levels in 1995.

(4) Tariff concessions between Taiwan and China: in the counterfactual, only the bilateral tariff concessions between the two economies are rescinded and set to their levels in 1995.

Effects on the employment shares: Alternative scenarios of tariff concessions

	(1) WTO accession by Taiwan	(2) WTO accession by China	(3) WTO accession by both	(4) Bilateral tariff concessions only
		Panel A. Aggregate sector		
Agriculture	−0.37%	0.08%	−0.27%	−0.00%
Manufacturing	4.36%	3.68%	4.24%	3.82%
Services	1.29%	1.13%	1.25%	1.16%
		Panel C. Skill type		
Low-skilled workers	−4.36%	−4.05%	−4.30%	−4.10%
Middle-skilled workers	1.37%	1.25%	1.35%	1.27%
High-skilled workers	2.99%	2.80%	2.95%	2.83%

Effects on the employment shares: Scenarios (1) vs (4)

(1) $>$ (4):

- Additional tariff concessions offered by Taiwan to the other economies and its additional access to the other economies' markets beyond China heightened the import competition in the agricultural sector, but increased its exports to the rest of the world in the manufacturing sector, which in turn benefitted the service sectors via the domestic input-output linkages.
- Similarly, (2) $<$ (3).
- Bilateral tariff concessions with China (4) accounted for the bulk of the effects of Taiwan's WTO accession (1).

Effects on the employment shares: Scenarios (2) vs (4)

(2) $<$ (4):

- Additional tariff concessions between China and the other economies in the scenario of WTO accession by China (relative to bilateral tariff concessions) increased the market competition that Taiwanese exports faced in the Chinese market from the other economies, and in the foreign markets from China, hence the smaller positive push to the manufacturing/service sectors in Taiwan.
- Similarly, (1) $>$ (3).
- The ranking of the quantitative effects across scenarios remains the same as highlighted above, when disaggregated by skill types.

Welfare effects on Taiwanese workers: Alternative scenarios of tariff concessions

Scenario	Aggregate	Low-skilled workers	Middle-skilled workers	High-skilled workers
WTO accession by Taiwan	2.396%	2.139%	2.591%	2.685%
WTO accession by China	2.223%	2.072%	2.355%	2.367%
WTO accession by both	2.362%	2.127%	2.543%	2.621%
Bilateral tariff concessions only	2.266%	2.095%	2.409%	2.436%

	Agriculture	Manufacturing	Services
WTO accession by Taiwan	1.764%	3.073%	2.217%
WTO accession by China	1.694%	2.895%	2.026%
WTO accession by both	1.767%	3.039%	2.175%
Bilateral tariff concessions only	1.714%	2.938%	2.073%

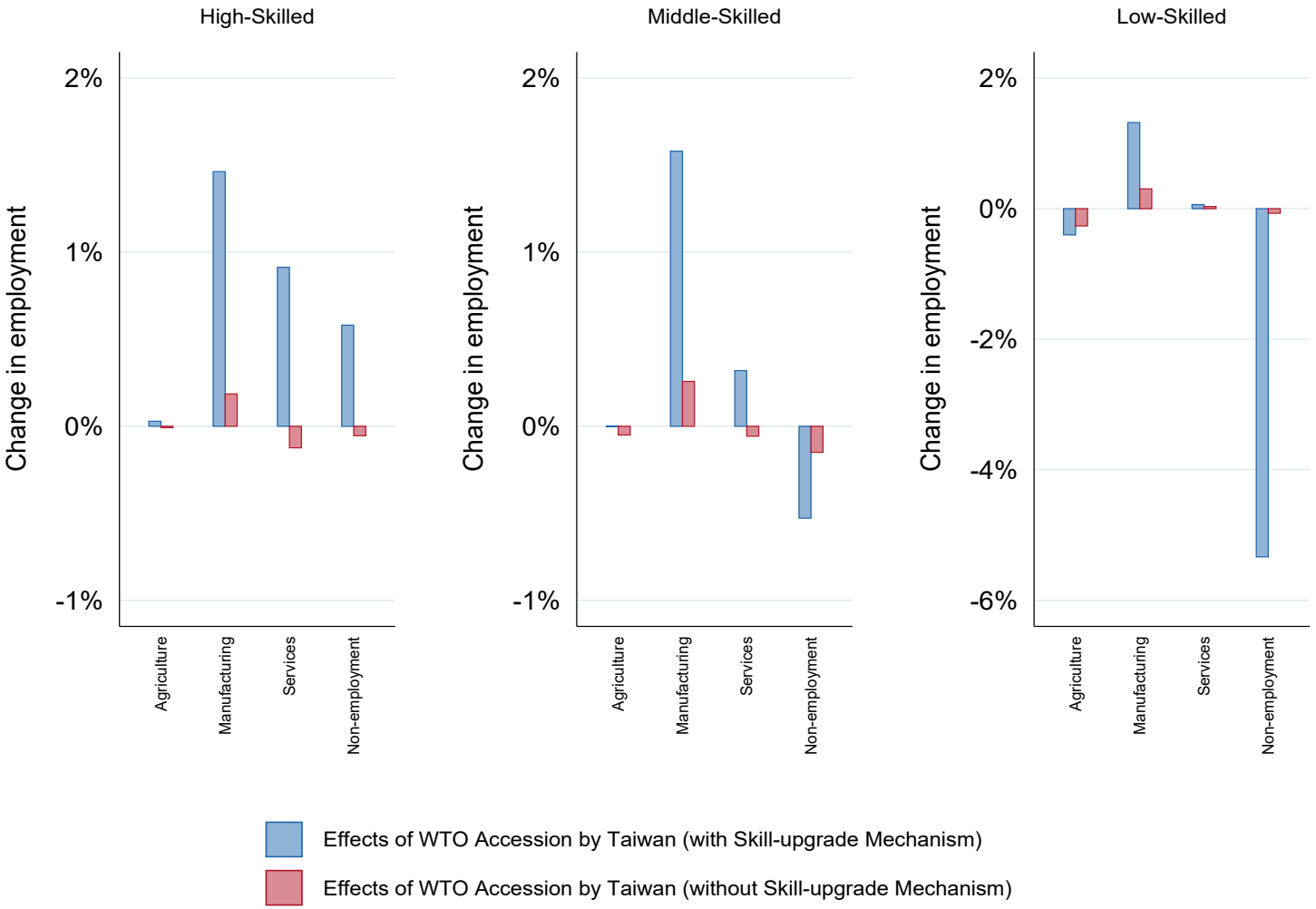
Welfare effects on Taiwanese workers: Alternative scenarios of tariff concessions

- The pattern of the welfare effects largely reflects the ranking of the employment effects across sectors and skill types discussed above.
- Across skill types and aggregate sectors, the effects are most pronounced (and positive) in the scenario of WTO accession by Taiwan, followed by WTO accession by both, and then by accession of China alone.
- Similarly, the positive effects are stronger with WTO accession by Taiwan than its bilateral concessions with China, and further stronger than WTO accession by China alone.
- The exception is the agricultural sector, where workers could potentially benefit from China's further trade liberalization with the rest of the world.

Relevance of the Skill-Upgrade Mechanism

- We generalize the model introduced above to allow for time-varying sector-skill transition costs.
- With this extension, we conduct a counterfactual exercise where the cost of skill upgrading (from low to middle or from middle to high) is raised to a prohibitive level from 1996 onwards relative to 1995.
- We then use the equilibrium path of changes from this exercise as the baseline. Conditional on this baseline, we roll back Taiwan's tariffs on imports and foreign tariffs on Taiwan's exports to their levels in 1995.
- Hence, we obtain a baseline where skill upgrading is absent, but WTO accession is present; and a counterfactual economy where both skill upgrading and WTO accession are eliminated.
- The difference between the two simulations then measures the quantitative effect of WTO accession by Taiwan in an environment where skill upgrading is prohibitive.

Effects of Taiwan's WTO entry on the employment shares in Taiwan



Effects of Taiwan's WTO entry on the employment shares in Taiwan

- The employment effects of WTO accession in the presence of skill upgrading are in general much more pronounced than the scenario where skill upgrading is absent.
- This suggests the existence of strong complementarity between skill upgrading and tariff concessions by Taiwan during the period studied.
- The difference between the two scenarios is quantitatively large, thus highlighting the importance of the supply-side adjustment mechanism.

Effects of Taiwan's WTO entry on the employment shares in Taiwan

- Furthermore, the inclusion of the skill-upgrade mechanism is also pivotal to the qualitative findings of employment effects across sectors.
- In particular, WTO accession by Taiwan tends to increase high-/middle-skilled employment in both manufacturing and service sectors when the skill-upgrade mechanism is present.
- In contrast, when skill upgrading is prohibitive, WTO accession increases the employment of high-/middle-skilled workers only in the manufacturing sector and decreases skilled employment in the service sector.

Effects of Taiwan's WTO entry on the employment shares in Taiwan

- To understand these findings, note that when skill upgrading is an option, workers upgrade their skills in response to the larger demand for skills from the manufacturing sector as a result of WTO accession.
- In the process, the service sector also benefits from the input-output linkages and the larger pool of skilled labor.
- In contrast, when skill upgrading is prohibitive, the supply-side adjustment is eliminated, which rules out inflows of new skilled workers.
- As a result, WTO accession results in reallocation of skilled workers from the agriculature/service sectors (and non-employment) toward the expanding manufacturing sectors.

Conclusion I

- This paper studies the evolution of the Taiwanese labor markets (disaggregated by sectors and skills) during 1995–2007, a time when the Taiwanese import tariffs and other economies' tariffs against Taiwanese exports fell significantly due to Taiwan's accession to the GATT/WTO.
- We document a rich set of stylized facts on changes in tariffs, trade flows, and labor market dynamics of Taiwan during this period.
- We extend the CDP framework to allow for skill-upgrade mechanisms, and conduct quantitative analyses to examine the dynamic adjustments of Taiwanese workers' sector-skill choices in this period, due to Taiwan's WTO accession.
- First and foremost, we find that Taiwan's accession to the WTO explains much of the observed patterns of Taiwan's trade and labor-market outcomes during this period.

Conclusion II

- In turn, much of the impacts can be attributed to the bilateral tariff concessions extended by Taiwan and China toward each other.
- China's accession to the WTO (relative to bilateral concessions) or combined accession (relative to Taiwan's accession alone) introduced additional competition in third countries and in China's local market for Taiwanese exports, and moderated the impacts downward.
- At the sector-skill level, the "star" manufacturing sectors (the MCEE in particular) basically drove the changes in trade and labor market patterns, and the effects spilled over to service sectors (mainly financial intermediation and other business services) through input-output linkages.
- The expanding sectors, the MCEE and service sectors, also were the sectors that propelled the skill upgrading seen in both the data and counterfactual analyses.

Conclusion III

- As a result, the high-skilled workers and the star manufacturing/service sectors enjoyed the most welfare gains from Taiwan's trade liberalization during 1995–2007.
- We also evaluate the WTO accession effect in a counterfactual baseline economy where the skill-upgrade mechanism is eliminated.
- Without the skill-upgrade mechanism, the quantitative magnitudes of the employment effects and changes in the production/trade volumes would have been substantially muted.
- In sum, skill upgrading on the supply side helped complement the pull factor for skilled labor on the demand side due to Taiwan's WTO accession and moderated the increased costs of skilled workers.
- The increased supply of skilled labor spilled over into the service industries and other manufacturing industries, and allowed the welfare gains to spill over to a broader spectrum of the economy.

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Population Growth

- Relax the assumption by introducing birth rate g.
  - Each type of worker survives by the survival rate δ.
  - Newborns join the labor market as jobless low-skilled workers every period.

$$L_{t+1}^{n01} = \delta \sum_{k=0}^{J} \mu_t^{nk1,n01} L_t^{nk1} + g L_t^n \tag{36}$$

  - $g > 1 - \delta$ indicates net population growth.
- Population changes over time:

$$L_t^n = \sum_{j=0}^{J} \sum_{s=1}^{3} L_t^{njs}. \tag{37}$$

- Other equilibrium conditions remain to hold.

Occupation-Skill Disparity

- Assumed perfect assignment between skill and jobs, hence no distinction between number of workers and job openings for a given skill level s.
- **Generalization**: allowing workers of higher skill levels to take on jobs with lower skill requirements.
- Denote njs by the economy-sector-occupation combination, where s represents the **skill-requirement** of a job.
- Consider a worker with a skill attainment a_t:
  - chooses a job of skill requirement i for the next period.
  - is said to experience skill-upgrading from a_t to $a_{t+1} = i$ if the skill requirement is higher $a_t < i$, hence $a_{t+1} = \max\{a_t, i\}$.
- In each period, a worker's skill attainment a_t is weakly **higher** than the skill requirement of the current job s.

Occupation-Skill Disparity

- Transition cost from *njs* to *nki* given skill attainment a_t:

$$\begin{aligned} \rho^{njs,nki;a_t \geq s} &= \rho_{job}^{njs,nki;a_t \geq s} + \rho^{a_t,i} \\ \rho^{a_t,i} &= 0 \text{ if } a_t \geq i. \end{aligned}$$

  - $\rho_{job}^{njs,nki;a_t \geq s}$ reflects how difficult it is to move between sector-occupation with different skill requirements given the worker's skill attainment.
  - $\rho^{a_t,i}$ reflects the cost of skill-upgrading, and equals 0 if the worker has high enough skill attainment.
  - Benchmark model is such that $\rho_{job}^{njs,nki;a_t \geq s} = \infty$ for $s \neq a_t$ and $i < s$.

Occupation-Skill Disparity

- Assume that $U(C) = \ln C$, the Bellman equation becomes:

$$v_t^{njs;a_t \geq s} = \ln C_t^{njs;a_t \geq s} + \max_{\{k,i\}_{k=0,i=1}^{J,3}} \left\{ \beta \delta V_{t+1}^{nki;a_{t+1}=\max\{a_t,i\}} - \rho^{njs,nki;a_t \geq s} + \nu \epsilon_t^{ki} \right\}.$$

- Transition probability and lifetime expected utility are obtained similarly as:

$$\mu_t^{njs,nki;a_t \geq s} = \frac{e^{\frac{\beta \delta V_{t+1}^{nki;a_{t+1}=\max\{a_t,i\}} - \rho^{njs,nki;a_t \geq s}}{\nu}}}{\sum_{\mathrm{K}=0}^{J} \sum_{\mathrm{I}=1}^{3} e^{\frac{\beta \delta V_{t+1}^{n\mathrm{KI};a_{t+1}=\max\{a_t,\mathrm{I}\}} - \rho^{njs,n\mathrm{KI};a_t \geq s}}{\nu}}} \tag{38}$$

$$V_t^{njs;a_t \geq s} = \ln C_t^{njs;a_t \geq s} + \nu \ln \sum_{\mathrm{K}=0}^{J} \sum_{\mathrm{I}=1}^{3} e^{\frac{\beta \delta V_{t+1}^{n\mathrm{KI};a_{t+1}=\max\{a_t,\mathrm{I}\}} - \rho^{njs,n\mathrm{KI};a_t \geq s}}{\nu}}. \tag{39}$$

Occupation-Skill Disparity

- Dynamic of workers taking jobs with skill requirement s with skill attainment a_{t+1} in the next period:

$$L_{t+1}^{njs;a_{t+1}>s} = \delta \sum_{k=0}^{J} \sum_{i=1}^{i<a_t} \mu_t^{nki,njs;a_t>i}|_{s<a_t} L_t^{nki;a_t>i} + \delta \sum_{k=0}^{J} \mu_t^{nki,njs;a_t=i}|_{s<a_t} L_t^{nki;a_t=i} \tag{40}$$

$$L_{t+1}^{njs;a_{t+1}=s} = \delta \sum_{k=0}^{J} \sum_{i=1}^{i<a_t} \mu_t^{nki,njs;a_t>i}|_{s\geq a_t} L_t^{nki;a_t>i} + \delta \sum_{k=0}^{J} \mu_t^{nki,njs;a_t=i}|_{s\geq a_t} L_t^{nki;a_t=i} \tag{41}$$

$$L_{t+1}^{n01;a_{t+1}=1} = \delta \sum_{k=0}^{J} \mu_t^{nk1,n01;a_t=1} L_t^{nk1;a_t=1} + (1-\delta) L^n \tag{42}$$

$$L_{t+1}^{njs} = \sum_{a_{t+1}>s}^{3} L_{t+1}^{njs;a_{t+1}>s} + L_{t+1}^{njs;a_{t+1}=s}. \tag{43}$$

Occupation-Skill Disparity

- $L_{t+1}^{njs;a_{t+1}>s}$: workers with higher skill attainment taking jobs requiring lower skill levels.
- $L_{t+1}^{njs;a_{t+1}=s}$: workers that perfectly match with jobs (either with exact skill attainment, or as a result of skill upgrading).
- $L_{t+1}^{n01;a_{t+1}=1}$: number of jobless workers with minimum skill attainment.
  - Composed of existing jobless workers of $a_t = 1$ and newborns.
- L_{t+1}^{njs}: number of workers taking jobs with a skill requirement s.
  - Also equals quantity demanded of the job by labor market clearing.

Occupation-Skill Disparity

- Equilibrium conditions remain the same.
- Can further trace the dynamic of workers with skill attainment $a = s$:

$$
\begin{aligned}
M_{t+1}^{nj;a_{t+1}=s} \quad = \quad & \delta \left[\sum_{k=0}^{J} \mu_t^{nki,njs;a_t=i} |_{s>a_t} L_t^{nki;a_t=i} + \sum_{k=0}^{J} \sum_{i=1}^{i<a_t} \mu_t^{nki,njs;a_t>i} |_{s>a_t} L_t^{nki;a_t>i} \right] \\
& + \delta \left[\sum_{k=0}^{J} \sum_{i=1}^{i<a_t} \mu_t^{nki,njs;a_t>i} |_{s=a_t} L_t^{nki;a_t>i} + \sum_{k=0}^{J} \sum_{i=1}^{i<a_t} \mu_t^{nki,njh;a_t>i} |_{h<s=a_t} L_t^{nki;a_t>i} \right] \\
& + \delta \left[\sum_{k=0}^{J} \mu_t^{nks,njs;a_t=s} |_{s=a_t} L_t^{nks;a_t=s} + \sum_{k=0}^{J} \mu_t^{nks,njh;a_t=s} |_{h<s=a_t} L_t^{nks;a_t=s} \right] .
\end{aligned}
\tag{44}
$$

ISIC Rev 3	ISIC Rev 3 Descriptions	ROC SIC 5 (1995–1996)	ROC SIC 6 (1997–2001)	ROC SIC 7 (2002–2006)	ROC SIC 8 (2007)
c01t05	Agriculture, hunting, forestry and fishing	01–03	01–03	01–03	01–03
c10t14	Mining and quarrying	05–09	05–09	04–06	05–07
c15t16	Food products, beverages and tobacco	11–12	11–12	08–09	08–10
c17t19	Textiles, textile products, leather and footwear	13–15	13–15	10–12	11–13
c20	Wood and products of wood and cork	16	16	13	14
c21t22	Pulp, paper, paper products, printing and publishing	18–19, 83	18–19, 83	15–16, 84	15– 16, 58
c23	Coke, refined petroleum products and nuclear fuel	23	23	19	17
c24	Chemicals and chemical products	21–22	21–22	17–18	18–20
c25	Rubber and plastics products	24–25	24–25	20–21	21–22
c26	Other non-metallic mineral products	26	26	22	23
c27t28	Basic metals and fabricated metal products	27–28	27–28	23–24	24–25
c29	Machinery and equipment, nec	29	29	25	29, 34
c30t33	Computing, electrical and optical equipment	31, 33	31, 33	26–28, 30	26–28
c34t35	Transport equipment	32	32	29	30–31
c36t37	Manufacturing nec; recycling	17, 39	17, 39	14, 31	32–33
c40t41	Electricity, gas and water supply	41–44	41–44	33–36	35–36
c45	Construction	45–49	45–49	38–42	41–43, 81
c50t52	Wholesale and retail trade; repairs	51–57	51–56	44–48, 95	45–48
c55	Hotels and restaurants	58, 88	57, 88	50–51	55–56
c60t63	Transport and storage	61–62	61–62	53–58	49–53, 79
c64 and c72	Post and telecommunications; Computer and related activities	63, 75	63, 75	59–60, 72– 73	54, 61–63
c65t67	Financial intermediation	65–67	65–67	62–64	64–66
c70	Real estate activities	68	68	66	67–68
c71	Renting of machinery and equipment	78	78	67	77
c73t74	R&D and other business activities	71–74, 76, 77, 79	71–74, 76, 77, 79	69–71, 74–77, 92	69–76, 78, 80, 82
c75t95	Community, social and personal services	Else	Else	Else	Else

Notes: In the quantitative simulation analysis, we combine: c01t05 and c10t14; c20 and c21t22; c23 and c24; and c71 and c73t74. In presenting the stylized facts, we group sectors further to reduce the dimensionality. The 12 aggregate sectors in the stylized facts are as follows: "Agriculture, Mining" includes c01t05 and c10t14. "Food, Beverages, Tobacco" includes c15t16. "Textiles, Wood, Paper" includes c17t19, c20 and c21t22. "Petroleum, Chemicals, Plastics, Metals" includes c23, c24, c25, c26, and c27t28. "Machinery, Computer, Electronics & Electrical" includes c29 and c30t33. "Motor, Transport Equipment" includes c34t35 and c36t37. "Electricity, Water, Gas" includes c40t41. Construction includes c45. "Wholesale, Retail, Hotels, Restaurants" includes c50t52 and c55. "Transport, Storage" includes c60t63. "Business Services" includes c64, c65t67, c70, c71, c72, c73t74, and c75t95. "Non-employment" includes unemployment and not-in-labor-force.