Global Value Chains and Aggregate Income Volatility

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Introduction

- A rise in Globalization Value Chains (GVC) is arguably the biggest change in manufacturing during the last three decades.
- The increased specialization has raised the level of aggregate income.
- There is a concern that GVC might have increased the risk and volatility of aggregate income.

Motivation

- Traditional channels
  - Specialization: price more sensitive to foreign shocks(Newbery and Stiglitz, 1984)
  - Diversification: price less sensitive to domestic shocks (Burgess and Donaldson, 2012; Caselli et al., 2020)

- Network aggregation: GVC may aggregate idiosyncratic "micro" shocks into a "macro" shock (Gabaix, 2011; Acemoglu et al., 2012; Baqaee and Farhi, 2019; Carvalho, 2014)).

Motivation

- A shock in one country propagates to other countries through input-output linkages (Boehm et al., 2019; Kashiwagi et al., 2018).
- Network structure of GVC may aggregate idiosyncratic "micro" shocks into a "macro" shock (Gabaix, 2011; Acemoglu et al., 2012; Baqaee and Farhi, 2019; Carvalho, 2014)).
  - Example: the Oil shock in 1970s

What we do

- Develop a framework to quantify the general equilibrium impact of GVC on the level and volatility of aggregate income of the world and countries.

- Model
  - A multi-country Ricardian model of GVC with input-output linkages
  - Eaton and Kortum (2002); Caliendo and Parro (2015)+ quality differentiation+ final and intermediate goods distinction

- Data
  - Multi-region IO tables: World Input-Output Database
  - Preferential and MFN tariffs: UNCTAD TRAINS
  - 36 countries (88% world GDP), 31 sectors (16 tradable), 14 years (1996-2009)

Main Finding

- GVC impacts

	World	Average Country
Expected Income in 2007	+5.16%	+6.57%
Expected Volatility in 2007	+10.03%	+11.73%

- Impacts are large for initially low income and small countries.

Methodology

- $W_{it}(d, r)$: country i's real income at time t in state (d, r)
  - d: the extent of GVC

$$d = \begin{cases} 1 & \text{with GVC} \\ 0 & \text{without GVC} \end{cases}$$

  - r: a state of idiosyncratic shocks
  - $(d = 1, r = 0)$: actual realization

- Our goal is to estimate

$$\widehat{MW}_{it} = \frac{E_r\left[W_{it}\left(1, r\right)\right]}{E_r\left[W_{it}\left(0, r\right)\right]} \text{ and } \widehat{VW}_{it} = \frac{\sqrt{Var_r\left[W_{it}\left(1, r\right)\right]}}{\sqrt{Var_r\left[W_{it}\left(0, r\right)\right]}}$$

Challenge 1: Productivity/Quality Shocks

- Challenge 1: Idiosyncratic shocks are not observed
- Solution: a structural factor analysis (Foerster, Sarte, and Watson, 2011)
  - Structurally estimate productivity shocks and quality shocks
  - Estimate the stochastic process of shocks by a factor model with global, country, sector level common shocks
  - Simulate 100 samples of shocks

Challenge 2: Endogenous Treatment

- Challenge 2: the most available measures of GVC d is endogenous
- Solution: counterfactual analysis of a Ricardian model
  - Identify exogenous main determinants of GVC
  - Technology vs trade costs vs endowment

Challenge 3: Level Estimation

- Challenge 3: estimation of counterfactual *levels*, $W(d, r)$ is hard
- Solution: estimation of counterfactual *changes*
  - Structural difference-in-difference (Caliendo et al., 2019)

$$\widehat{MW}_{it} = \frac{E_r\left[\hat{W}_{it}(1, r)\right]}{E_r\left[\hat{W}_{it}(0, r)\right]} \text{ and } \widehat{VW}_{it} = \frac{\sqrt{Var_r\left[\hat{W}_{it}(1, r)\right]}}{\sqrt{Var_r\left[\hat{W}_{it}(0, r)\right]}}$$

- Simulate 200 counterfactuals $\{\hat{W}_{it}(1, r), \hat{W}_{it}(0, r)\}_{r=1}^{100}$ and calculate sample analogues of $\widehat{MW}_{it}$ and $\widehat{VW}_{it}$.

Model

- $i, n = 1, ..., N$ countries
- $s = 1, ..., S$ industries of Eaton-Kortum type Ricardian
  - $u \in \{f, m\}$: two usages (final goods and intermediate goods)
  - Each usage u in industry s consists of a continuum of varieties $\omega^{su} \in [0, 1]$.
  - Usages differ only in trade costs and share the same technology
- One factor: Labor
- Perfect competition
- Static model where trade balances are exogenously given

Consumer

- Country n rep consumer utility:

$$U_n = \prod_{s=1}^{S} \left(Q_{nt}^{sf} \right)^{\alpha_n^s}, \; Q_{nt}^{sf} = \left[\int_0^1 \underbrace{q_{nt}^{sf*} \left(\omega^{sf} \right)^{\frac{\sigma^{sf}-1}{\sigma^{sf}}}}_{Quality-adjusted\ Consumption} d\omega^{sf} \right]^{\frac{\sigma^{sf}}{\sigma^{sf}-1}}$$

$$q_{nt}^{sf*} \left(\omega^{sf} \right) = \sum_{i=1}^{n} \underbrace{\kappa_{it}^{s}}_{Quality\ Shock} q_{nit}^{sf} \left(\omega^{sf} \right)$$

- Quality normalization

$$\frac{1}{N} \sum_{i=1}^{N} \ln \kappa_{it}^{s} = 0.$$

Producer

- Production of ω^{su} in industry s in country n

$$y_{nt}\left(\omega^{su}\right) = \underbrace{A_{nt}^{s}}_{TFP\ shock}\ \underbrace{z_n\left(\omega^{su}\right)}_{Frechet}\left(l_{nt}{}^{\beta_n^s}\prod_{k=1}^{S} m_{nt}^{sk\,\beta_n^{sk}}\right),\ \beta_n^s + \sum_{k=1}^{S}\beta_n^{sk} = 1$$

$$m_{nt}^{sk} = \left(\int_0^1 \underbrace{\tilde{m}_{nt}^{*sk}\left(\omega^{km}\right)^{\frac{\sigma^{km}-1}{\sigma^{km}}}}_{Quality-adjusted\ input} d\omega^{km}\right)^{\frac{\sigma^{km}}{\sigma^{km}-1}}$$

$$\tilde{m}_{it}^{*sk}\left(\omega^{km}\right) = \sum_{i=1}^{N}\underbrace{\kappa_i^k}_{Quality\ Shock}\ \tilde{m}_{nit}^{sk}\left(\omega^{km}\right)$$

- β_n: from Input-Output tables
- Combined shocks

$$\Lambda_{it}^{s} \equiv \left(A_{it}^{s}\kappa_{it}^{s}\right)^{\theta^s}$$

θ^s: Frechet parameter.

Parameter Estimation

- Trade elasticities: a gravity model

$$\ln \pi_{nit}^{su} = -\theta^{s} \ln\left(1+\tau_{nit}^{s}\right) + ex_{it}^{s} + im_{nt}^{su} + \sum_{t}\sum_{k} TC_{ni,k} I_{\{Year=t\}} \left(\gamma_{kt}^{f} + I_{\{u=m\}}\gamma_{kt}^{m}\right) + \varepsilon_{nit}^{su}$$

for a sub-sample where bilateral tariff τ_{nit}^{s} are available. $TC_{ni,k}$: gravity controls (e.g. distance).

Parameter Estimation

WIOD	Industry Description	Theta	Robust SE	n.obs
1	Agriculture, Hunting, Forestry and Fishing	6.26***	(0.54)	36,980
2	Mining and Quarrying	8.05***	(1.60)	33,654
3	Food, Beverages and Tobacco	7.31***	(0.39)	37,101
4	Textile Products, Leather Products and Footwear	6.31***	(0.32)	37,467
6	Wood and Products of Wood and Cork	9.12***	(0.60)	37,133
7	Pulp, Paper, Paper, Printing and Publishing	11.37***	(0.71)	37,394
8	Coke, Refined Petroleum and Nuclear Fuel	6.10***	(0.95)	36,633
9	Chemicals and Chemical Products	6.31***	(0.54)	37,470
10	Rubber and Plastics	6.22***	(0.41)	37,433
11	Other Non-Metallic Mineral	4.78***	(0.47)	37,391
12	Basic Metals and Fabricated Metal	7.78***	(0.54)	37,446
13	Machinery, Nec	7.43***	(0.46)	37,480
14	Electrical and Optical Equipment	9.69***	(0.78)	37,166
15	Transport Equipment	7.13***	(0.40)	36,946
16	Manufacturing, Nec; Recycling	8.01***	(0.52)	37,438

***: 1% significance

Parameter Estimation

- Trade costs: the Head-Ries Index

$$\ln d_{nit}^{su} = \frac{1}{2} \ln \left(\frac{1 + \tilde{\tau}_{nit}^{s}}{1 + \tilde{\tau}_{int}^{s}} \right) + \frac{1}{2\theta^{s}} \ln \frac{\pi_{nnt}^{su} \pi_{iit}^{su}}{\pi_{nit}^{su} \pi_{int}^{su}}$$

where $\tilde{\tau}_{int}^{s}$ is quasi-bilateral tariffs:

$$\tilde{\tau}_{int}^{s} = \begin{cases} 0 & \text{if } i = j \text{ or } i \text{ and } j \text{ sign a FTA/CU at } t \\ \text{MFN tariff} & \text{otherwise} \end{cases}$$

Trade Costs

	Year	Mean	SD	Min	P25	Median	P75	Max	N
Trade Costs (AVE)	1995	1.882	1.673	-0.139	0.939	1.448	2.275	54.981	34,170
	2007	1.561	1.302	-0.58	0.77	1.201	1.893	18.543	34,896
Quasi Tariff Rate	1995	0.076	0.095	0	0.01	0.051	0.106	0.749	17,358
	2007	0.028	0.06	0	0	0	0.033	0.585	17,790
NTB (AVE)	1995	1.673	1.527	-0.139	0.824	1.274	2.007	49.39	34,170
	2007	1.486	1.236	-0.585	0.742	1.142	1.797	16.11	34,896

Productivity and Quality Shocks

- Combined shocks

$$\underbrace{d \ln \Lambda_{it}}_{\text{Productivity/Quality}} = (I - B_i) \underbrace{d \ln S_{it}}_{\substack{\text{competitiveness} \\ \text{(To be estimated)}}} + \underbrace{d \ln W_{it}^{\beta\theta}}_{\text{wage}} + \underbrace{B_i d \ln \pi_{iit}^{m}}_{\text{Intermediates}}.$$

  where B_i: country i's input-output table

- Assumption: producer price index $\tilde{P}_{it}^{s}$ is proportional to marginal costs

$$d \ln \tilde{P}_{it}^{s} = \underbrace{d \ln \frac{c_{it}^{s}}{A_{it}^{s}}}_{\text{Cost Change}}$$

$$\Longrightarrow \underbrace{d \ln S_{it}}_{\text{Competitiveness}} = \underbrace{d \ln \kappa_{it}^{\theta}}_{\text{Quality}} - \underbrace{d \ln \tilde{P}_{it}^{\theta}}_{\text{Cost}}$$

Competitiveness Index

- Competitiveness index for tradable goods

$$d \ln S_{it} = \underbrace{d\hat{ex}_{it} - \frac{1}{N}\sum_{i=1}^{N} d\hat{ex}_{it}}_{\text{Exporter FE in gravity}} - \underbrace{\frac{1}{N}\sum_{i=1}^{N} d \ln S_{it}}_{\text{Mean Competitiveness}}$$

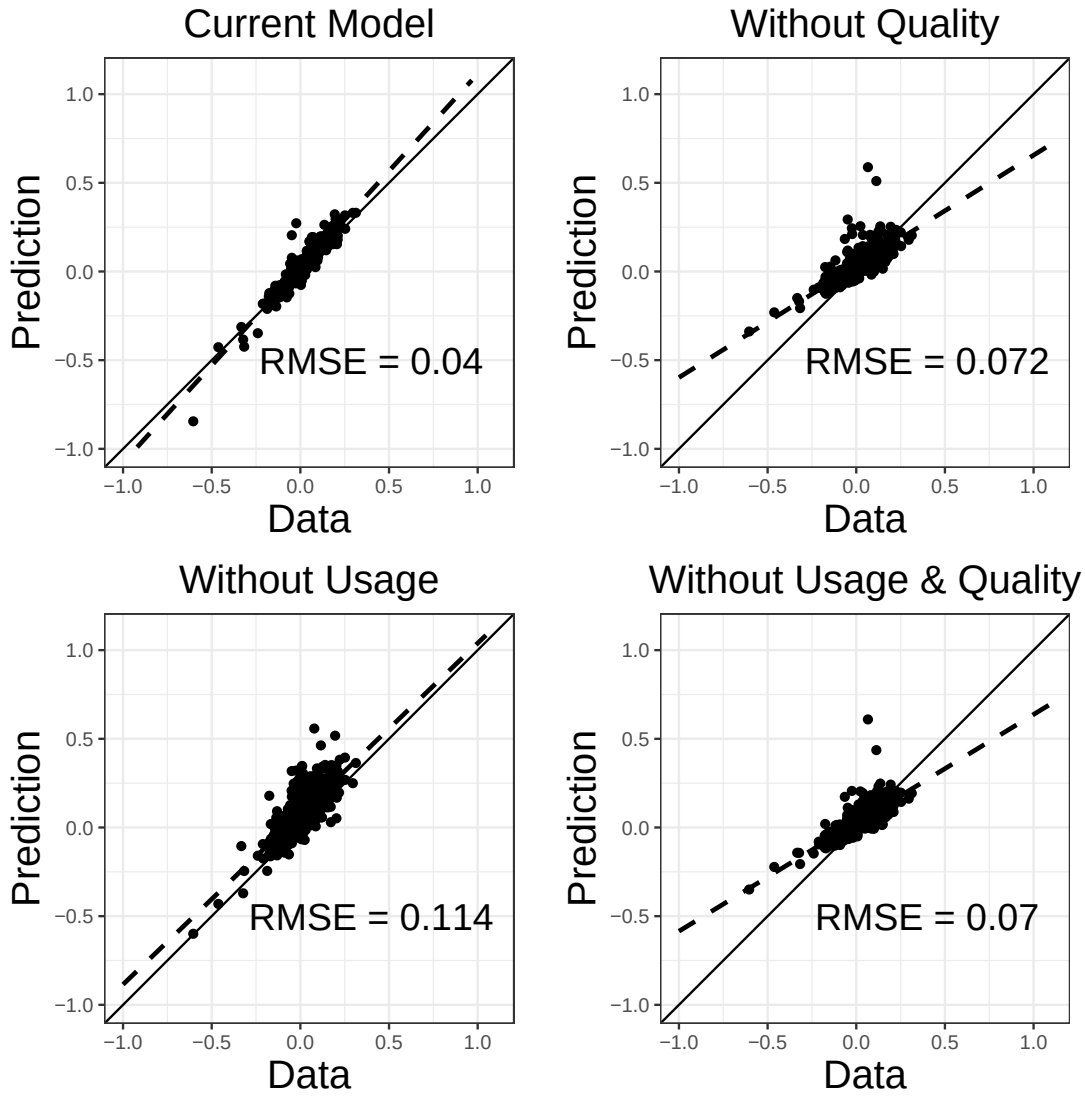
$$\frac{1}{N}\sum_{i=1}^{N} d \ln S_{it} = \underbrace{\frac{1}{N}\sum_{i=1}^{N} d \ln \tilde{P}_{it}^{\theta}}_{\text{Mean Cost Changs}} + \left(\underbrace{\frac{1}{N}\sum_{i=1}^{N} d \ln \kappa_{it}^{\theta}}_{\text{Mean Quality change}} (= 0) \right)$$

- Quality and productivity

$$\underbrace{d \ln \kappa_{it}^{\theta}}_{\text{Quality}} = \underbrace{d \ln S_{it}}_{\text{Competitiveness}} + \underbrace{d \ln \tilde{P}_{it}^{\theta}}_{\text{Cost}}$$

$$\underbrace{d \ln A_{it}^{\theta}}_{\text{Productivity}} = \underbrace{d \ln \Lambda_{it}}_{\text{Combined}} - \underbrace{d \ln \kappa_{it}^{\theta}}_{\text{Quality}}$$

Model Evaluation: Per Capita Income Growth

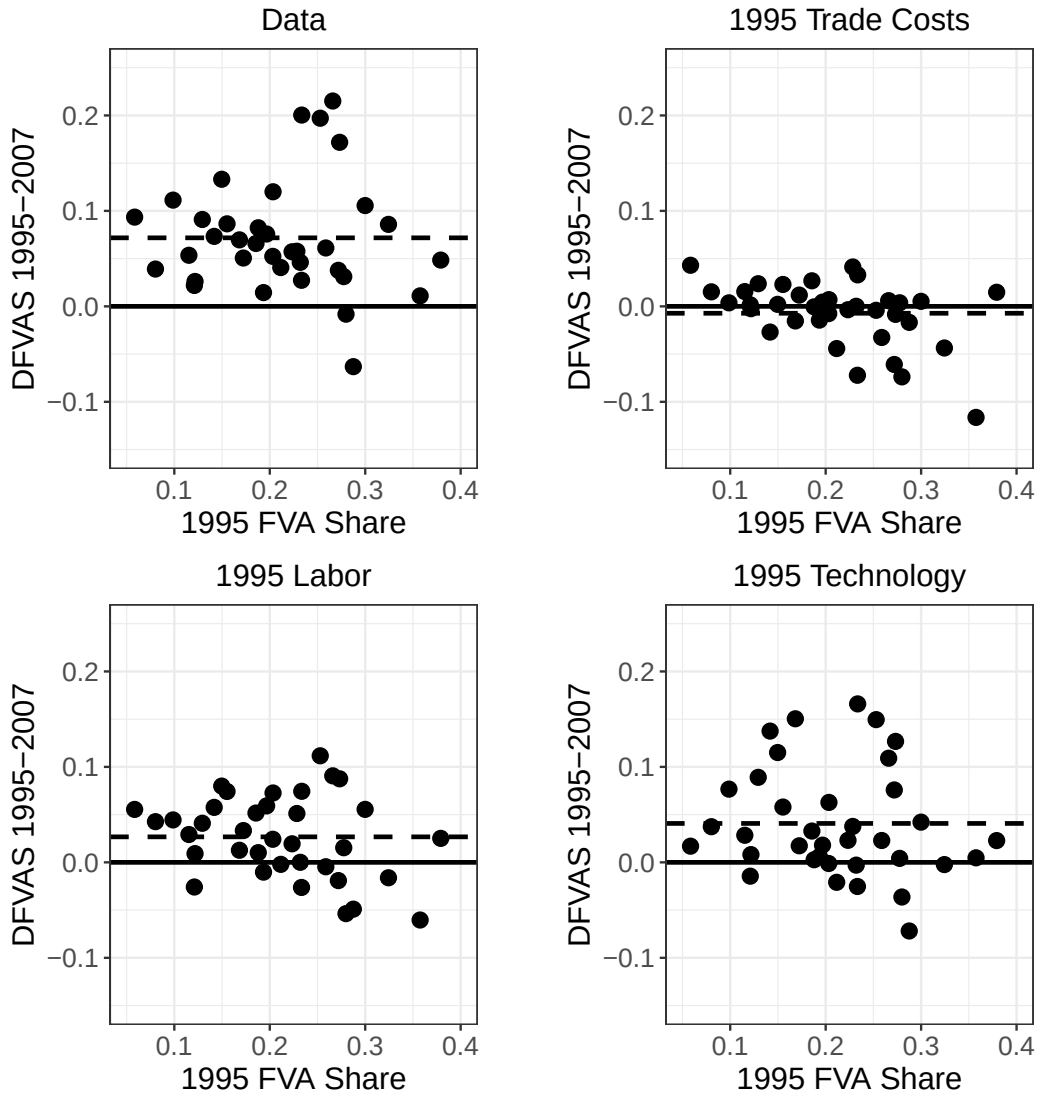


Dashed lines: OLS fits

Identify GVC Drivers

- Measure of GVC integration:
  - FVA share: Foreign value added share in manufacturing value added (Los et al., 2015; Timmer et al., 2014)
- Identification of GVC drivers
  - Counterfactual 2007 FVA share under 1995 technology, endowment and trade costs

Actual and Counterfactual Changes in FVA Shares



Dashed lines: mean changes

Factor Model

- Three level factor model

$$d \ln \tilde{A}^s_{it} = \zeta^{gA}_{is} f^{gA}_t + \zeta^{cA}_{is} f^{cA}_{it} + \zeta^{sA}_{is} f^{sA}_{st} + \varepsilon^{A}_{ist}$$

$$\underbrace{d \ln \tilde{\kappa}^s_{it}}_{\text{Demeaned}} = \zeta^{g\kappa}_{is} \underbrace{f^{g\kappa}_t}_{\text{Global}} + \zeta^{c\kappa}_{is} \underbrace{f^{c\kappa}_{it}}_{\text{Country}} + \zeta^{s\kappa}_{is} \underbrace{f^{s\kappa}_{st}}_{\text{Sector}} + \underbrace{\varepsilon^{\kappa}_{ist}}_{\text{Idiosyncratic}}$$

  - f^{gt}_t: global factor; f^{ct}_{it}: country-level factor;

- Estimation
  - Assume $f^{gx}_t \perp f^{cx}_{it} \perp f^{sx}_{st} \perp \varepsilon^{x}_{ist}$ for $x \in \{A, \kappa\}$
  - Two stage sequential extraction $f^{gx}_t \to f^{cx}_{it} \to f^{sx}_{st} \to \varepsilon^{x}_{ist}$ with initialf^{gx}_t is canonical correlation (Choi, Kim, Kim, and Kwark, 2018)

Factor Model

- Cf. dummy model (Koren and Tenreyro, 2007; Caselli et al., 2020))

$$d \ln \tilde{A}^s_{it} = f^{cA}_{it} + f^{sA}_{st} + \varepsilon^{A}_{ist}$$
$$d \ln \tilde{\kappa}^s_{it} = f^{c\kappa}_{it} + f^{s\kappa}_{st} + \varepsilon^{\kappa}_{ist}$$

  - Special case: $\zeta^{g\kappa}_{is} = 0$ and $\zeta^{c\kappa}_{is} = \zeta^{s\kappa}_{is} = 1$

Variance Decomposition

		Variance Share of Component			
Variable	Volatility	Global	Country	Sector	Idiosyncratic
	(1)	(2)	(3)	(4)	(5)
Productivity	0.517	0.201	0.372	0.165	0.297
Quality	0.676	0.190	0.453	0.109	0.276

note: volatility is standard deviation; Productivity and Quality are multiplied with theta

Re-sampling Shocks

- Simulate $r = 100$ sets of factors and idiosyncratic shocks from iid Normal:

$$f_t^{gX}(r) \sim N(0, \sigma_X^2)$$
$$f_{it}^{cX}(r) \sim N(0, \sigma_{Xi}^2)$$
$$f_{st}^{sX}(r) \sim N(0, \sigma_{Xs}^2)$$
$$\hat{\varepsilon}_{ist}^{X}(r) \sim N(0, \sigma_{Xis}^2)$$

▸ QQ plot

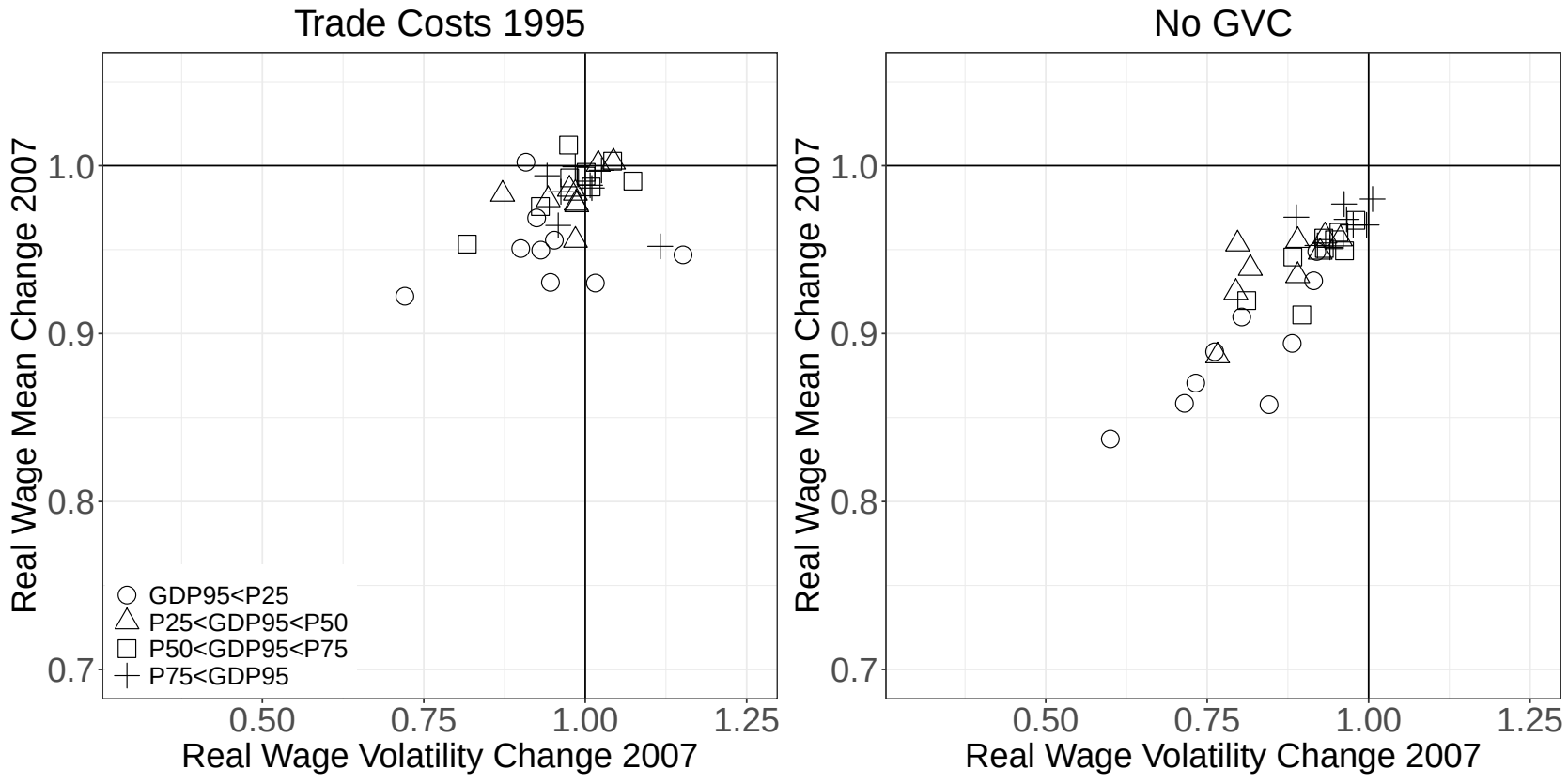
World Income Changes

	Counterfactual Scenarios			
	Trade Costs 1995	No GVC	No Final Trade	Autarky
Mean World Real Wage Change in 2007	-2.93%	-5.16%	-3.21%	-7.88%
World Real Wage Volatility Change in 2007	-2.07%	-10.30%	-4.12%	-19.37%

Country's Income Changes

		Counterfactual Scenarios			
		Trade Costs 1995	No GVC	No Final Trade	Autarky
Mean Real Wage Change in 2007	Mean	-2.36%	-6.57%	-5.95%	-11.71%
	SE	(0.40)	(0.63)	(0.67)	(1.14)
Real Wage Volatility Change in 2007	Mean	-2.64%	-11.73%	-10.22%	-19.22%
	SE	(1.30)	(1.56)	(1.77)	(2.73)
Number of Countries		35	35	33	33

Role of Country Size (1)



Role of Country Size (2)

GDP, Employment, GDP per Capita

	Mean Log Real Wage Change in 2007							
	1995 Trade Costs		No GVC		Autarky		No Final Trade	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
ln GDP 1995	-0.014***		-0.020***		-0.037***		-0.017***	
	(0.003)		(0.003)		(0.005)		(0.003)	
ln per capita		-0.012***		-0.020***		-0.039***		-0.020***
GDP 1995		(0.003)		(0.004)		(0.005)		(0.003)
ln Employment		-0.018***		-0.019***		-0.032***		-0.013***
1995		(0.004)		(0.005)		(0.007)		(0.004)
Constant	0.210***	0.205***	0.324***	0.324***	0.598***	0.605***	0.283***	0.289***
	(0.031)	(0.031)	(0.038)	(0.039)	(0.057)	(0.058)	(0.034)	(0.034)
Observations	35	35	35	35	33	33	33	33
R2	0.479	0.506	0.549	0.549	0.67	0.68	0.562	0.592

*p<0.10, **p<0.05, ***p<0.01

GDP, Employment, GDP per Capita

	Real Wage Volatility Change in 2007							
	1995 Trade Costs		No GVC		Autarky		No Final Trade	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
ln GDP 1995	0.009		0.035***		0.055***		0.038***	
	(0.008)		(0.007)		(0.012)		(0.008)	
ln Per capita		0.004		0.036***		0.059***		0.031**
GDP 1995		(0.011)		(0.010)		(0.018)		(0.011)
ln Employment		0.011		0.034***		0.054***		0.040***
1995		(0.009)		(0.008)		(0.014)		(0.009)
Constant	0.866***	0.860***	0.458***	0.460***	0.130	0.135	0.439***	0.432***
	(0.093)	(0.095)	(0.086)	(0.088)	(0.151)	(0.154)	(0.094)	(0.095)
Observations	35	35	35	35	33	33	33	33
R2	0.21	0.23	0.29	0.29	0.35	0.36	0.41	0.41

*p<0.10, **p<0.05, ***p<0.01

Summary

- This paper has developed a framework to quantify the GE impact of GVC on income level and volatility
- GVC increased income levels and volatility especially for small and low income countries