Trade, Growth and Development

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A. Introduction

Conventional macroeconomic models employ aggregate production at national or industrial level, ignoring the interplays between firm dynamics and economic development. The modern literature on international trade and firm distribution, summarized as follows, has generated valuable insight toward understanding international differences in productivities, growth and income distribution.

- **Foundation:**
  - **Jovanovic (1979): firm-specific capital and turnover**
  - **Hopenhayn (1992): firm dynamics: entry and exit**
  - **Mortensen-Pissarides (1994), job creation and job destruction**

- **Firm distribution, productivity and trade:**
  - **Basic theoretic framework: Eaton-Kortum (1999, 2002), Melitz (2003)**
  - **Basic empirical analysis: Bernard-Eaton-Jensen-Kortum (2003)**
  - **Generalization: *Alvareza-Lucas (2007)*, Matsuyama, K. (2007), Atkeson-Burstein (2008), Lucas (2009), Adamopoulos-Restuccia (2014)**

- **Firm distribution, innovation and growth**
  - **Basic theory: Klette-Kortum (2004), Ghironi-Melitz (2005)**
  - **Generalization: *Luttmer (2007)*, Atkeson-Burstein (2009), Burstein & Monge-Naranjo (2009), Impullitti-Licandro (2017), Buera-Oberfield (2020), Cai-Li-Santacreu (2022), Chen-Hsu-Peng-Wang (2023)**
- **Gains from Trade:**
  - **Sufficient statistics: Arkolakis, Costinot & Rodríguez-Clare (2012)**
  - **Generalization: Caliendo-Parro (2015, 2021), Edmond-Midrigan-Xu (2015), Melitz-Redding (2015), Hsieh-Li-Ossa-Yang (2016), Lai-Riezman-Peng-Wang (2022)**
  - **Dynamic gains from trade: Eaton-Kortum-Neiman (2016), Sampson (2016), Ravikumar-Santacreu-Sposi (2019), Alessandria-Choi-Ruhl (2021), Bloom-Romer-Terry-Van Reenen (2021), Caliendo-Opromolla-Parro-Sforza (2021), Hsieh-Klenow-Nath (2021), Perla-Tonetti-Waugh (2021), *Hsu-Riezman-Wang-Yang (2022)***
  - **Dynamic effects of protective tariff policy: Ossa (2014, 2019), Steinberg (2019), Chen-Cheng-Riezman-Peng-Wang (2023)**
- **Trade and inequality: Grossman-Helpman (2014), Antras-de Gortari-Itskhoki (2016), Grossman-Helpman-Kircher (2017), Burstein-Vogel (2017), Waugh (2019).**

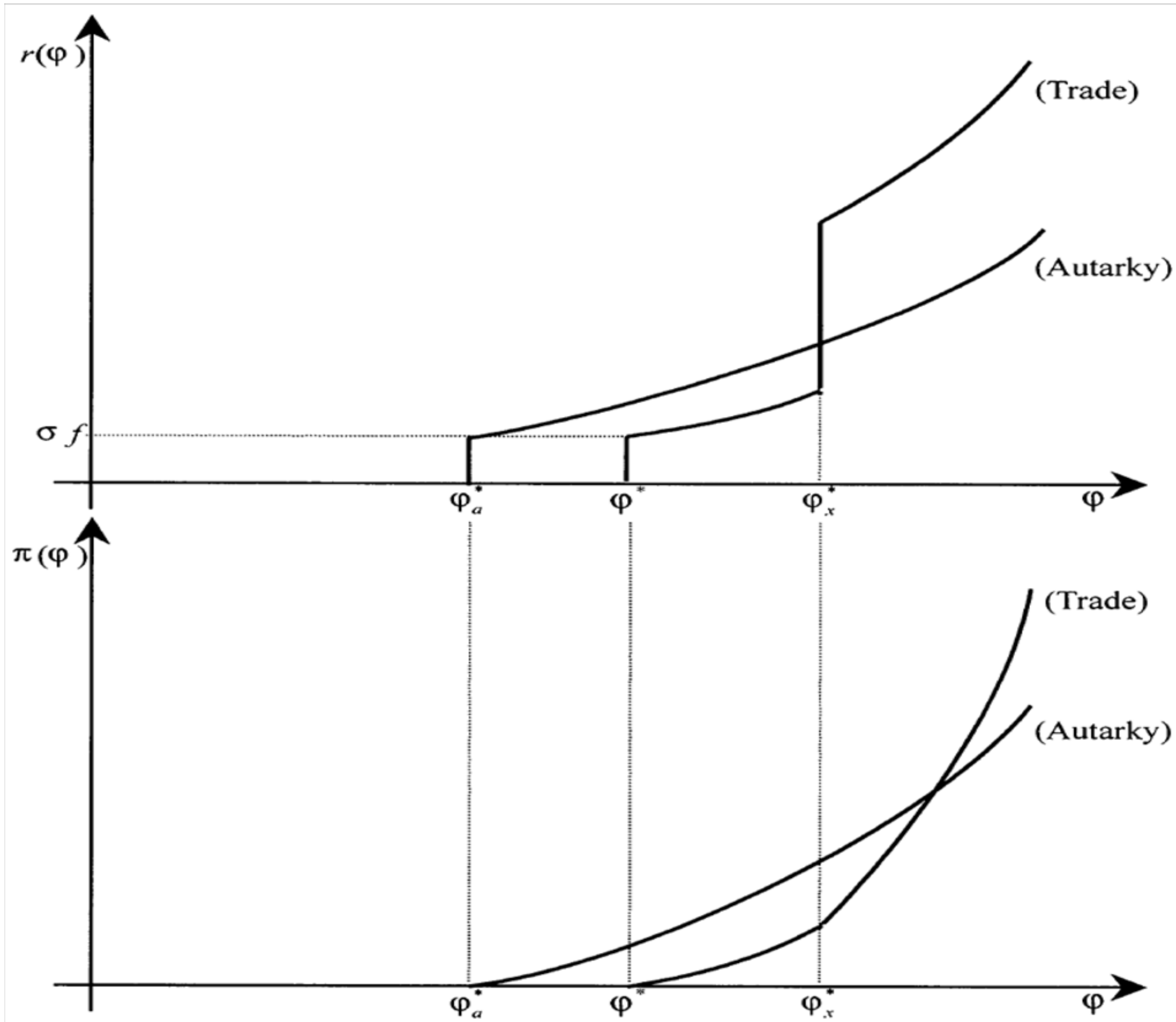
B. Firm Distribution, Productivity and Trade

1. Empirical Regularities: Bernard-Eaton-Jensen-Kortum (2003)

- **large plant productivity dispersion**
- **low export intensity**
- **low earning from exporting**
- **higher productivity among exporters**
- **larger size of exporters (measured by sales)**

2. The Melitz (2003) Model

- **Key: introduce trade to the Hopenhayn (1992) firm entry-exit model under a Spence (1976) and Dixit-Stiglitz (1977) monopolistic competition framework**
- **Effect of trade:**
    - **cutoff φ^* is higher => crowd-out of domestic firms (selection effect)**
    - **total variety rises (variety effect)**
    - **revenue rises among exporting firms**
    - **profit rises for more productive exporters (low earning from export)**



$r(\varphi)$
(Trade)
(Autarky)
σf
φ_a^*
φ^*
φ_x^*
φ
$\pi(\varphi)$
(Trade)
(Autarky)
φ_a^*
φ^*
φ_x^*
φ

C. The Cross-Country Distribution of Trade Volumes: Alvarez-Lucas (2007)

- **Key: a *GE generalization* of the Eaton-Kortum (2002) model**
  - **buyers search over producers in different countries for the lowest price**
  - **trade assigns production of any good to the most efficient producers**
- **Preference for variety:** $q = \left[\int_0^\infty q(x)^{1-1/\eta}\phi(x)\,\mathrm{d}x\right]^{\eta/(\eta-1)}$**, where the inverse of TFP (i.e., unit cost)** $\phi(x)$ **is a common density that is *exponential with parameter λ*:**
  - ***x*** **~ exp(λ) (note: if ω ~ exponential, then exp(ω) ~ Pareto)**
  - **ς*x*** **~ exp(λ/ς) for ς > 0**
  - ***x*** **~ exp(λ_x),** ***y*** **~ exp(λ_y),** ***z*** **= min{*x*,*y*} =>** ***z*** **~ exp($\lambda_x+\lambda_y$), Pr{x≤y} = $\lambda_x/(\lambda_x+\lambda_y)$**
- **Labor allocation to final/intermediate good production:** $s_{\mathrm{f}} + \int_0^\infty s(x)\,\phi(x)\,\mathrm{d}x \leqslant 1$
- **Intermediate good allocation:** $q_{\mathrm{f}} + \int_0^\infty q_{\mathrm{m}}(x)\,\phi(x)\,\mathrm{d}x \leqslant q$
- **Production technologies (α,β ∈ (0,1) and θ > 0):**
  - **final:** $c = s_{\mathrm{f}}^{\alpha} q_{\mathrm{f}}^{1-\alpha}$
  - **intermediate:** $q(x) = x^{-\theta} s(x)^{\beta} q_{\mathrm{m}}(x)^{1-\beta}$**, where** $x^{-\theta}$ **has a Frechet distribution**
    - **higher θ => higher productivity differences**
    - **these cost draws** $\phi(x)$ **are economy-wide, with all producers facing the common stochastic intercept** $x^{-\theta}$ **and having marginal cost pricing**

- **Pricing (based on cost-minimization):**
  - **final:** $p = \alpha^{-\alpha}(1-\alpha)^{-1+\alpha} w^{\alpha} p_{\mathrm{m}}^{1-\alpha}$
  - **intermediate:** $p(x) = Bx^{\theta} w^{\beta} p_{\mathrm{m}}^{1-\beta}$, $B = \beta^{-\beta}(1-\beta)^{-1+\beta}$, $p_{\mathrm{m}} = \left(\lambda \int_0^{\infty} \mathrm{e}^{-\lambda x} p(x)^{1-\eta}\, \mathrm{d}x\right)^{1/1-\eta}$
  - **defining $z = \lambda x$ and A =** $A(\theta,\eta) = \left[\int_0^{\infty} \mathrm{e}^{-z} z^{\theta(1-\eta)}\, \mathrm{d}z\right]^{1/(1-\eta)}$ **(integral of a gamma function $\Gamma(\xi)$, integrable if** $\xi = 1 + \theta(1-\eta)$ **> 0), we have:**
    - $p_{\mathrm{m}} = (AB)^{1/\beta} \lambda^{-\theta/\beta} w$
    - $p(x) = A^{(1-\beta)/\beta} B^{1/\beta} x^{\theta} \lambda^{-\theta(1-\beta)/\beta} w$
    - $p = \alpha^{-\alpha}(1-\alpha)^{-1+\alpha}(AB)^{(1-\alpha)/\beta} \lambda^{-\theta(1-\alpha)/\beta} w$
    - **all prices are multiples of labor cost w and decreases with productivity distribution parameter λ**
- **Open economy in general equilibrium:**
  - **n countries with heterogeneity only in**
    - **labor endowments in efficiency units** $L = (L_1, \ldots, L_n)$
    - **productivity parameters** $\lambda = (\lambda_1, \ldots, \lambda_n)$
    - **wages w =** $(w_1, \ldots, w_n)$
  - **iceberg transport discounting $\kappa_{ij} \gg 0$ & < 1 $\forall$i≠j, κ_{ii} = 1, $\kappa_{ii} = \kappa_{ii}$,** $\kappa_{ij} \geqslant \kappa_{ik}\kappa_{kj}$
  - **joint distribution of independent draws:** $\phi(x) = \left(\prod_{i=1}^{n} \lambda_i\right) \exp\left\{-\sum_{i=1}^{n} \lambda_i x_i\right\}$

- **consumption, output and prices:**
  - **consumption/output:** $q_i = \left[\int q_i(x)^{1-1/\eta}\phi(x)\,\mathrm{d}x\right]^{\eta/(\eta-1)}$
  - **intermediate aggregate pricing:** $p_{\mathrm{m}i} = \left[\int p_i(x)^{1-\eta}\phi(x)\,\mathrm{d}x\right]^{1/(1-\eta)}$
  - **buyers search for lowest prices:** $p_i(x) = B\min_j\left[\frac{w_j^{\beta}p_{\mathrm{m}j}^{1-\beta}}{\kappa_{ij}\omega_{ij}}x_j^{\theta}\right]$
  - **applying exponential distribution properties:**
    - $p_{\mathrm{m}i}^{1-\eta} = \int p_i(x)^{1-\eta}\phi(x)\,\mathrm{d}x$
    - $p_i(x)^{1/\theta} = B^{1/\theta}\min_j\left[\frac{w_j^{\beta/\theta}p_{\mathrm{m}j}^{(1-\beta)/\theta}}{(\kappa_{ij}\omega_{ij})^{1/\theta}}x_j\right]$
    - $z_j \equiv w_j^{\beta/\theta}p_{\mathrm{m}j}^{(1-\beta)/\theta}(\kappa_{ij}\omega_{ij})^{-1/\theta}x_j$ **~ exp[ψ_{ij}],** $\psi_{ij} = \left(\frac{w_j^{\beta}p_{\mathrm{m}j}^{1-\beta}}{\kappa_{ij}\omega_{ij}}\right)^{-1/\theta}\lambda_j$
    - $z \equiv \min_j z_j$ **~ exp($\sum_{j=1}^{n}\psi_{ij}$)**
    - $p_i(x)^{1/\theta}$ **~ exp[μ],** $\mu = B^{-1/\theta}\sum_{j=1}^{n}\psi_{ij}$
    - $p_{\mathrm{m}i}(w) = AB\left(\sum_{j=1}^{n}\psi_{ij}\right)^{-\theta} \equiv AB\left(\sum_{j=1}^{n}\left(\frac{w_j^{\beta}p_{\mathrm{m}j}(w)^{1-\beta}}{\kappa_{ij}\omega_{ij}}\right)^{-1/\theta}\lambda_j\right)^{-\theta}$

- **relative spending shares of country i on tradables from country j:**

$$D_{ij} = \Pr\left\{\frac{w_j^{\beta} p_{mj}^{1-\beta}}{\kappa_{ij}\omega_{ij}} x_j^{\theta} \leqslant \min_{k \neq j}\left[\frac{w_k^{\beta} p_{mk}^{1-\beta}}{\kappa_{ik}\omega_{ik}} x_k^{\theta}\right]\right\} = \frac{\psi_{ij}}{\sum_{k=1}^{n} \psi_{ik}} = (AB)^{-1/\theta}\left(\frac{w_j^{\beta} p_{mj}(w)^{1-\beta}}{p_{mi}(w)\kappa_{ij}\omega_{ij}}\right)^{-1/\theta} \lambda_j$$

where ω_{ij} = fraction of purchase by i for good in j received by j: $\omega_{ij} \gg 0$ and $\omega_{ij} < 1$ (due to trade frictions/barriers)

- **trade balance requires:** $L_i p_{mi} q_i \sum_{j=1}^{n} D_{ij}\omega_{ij} = \sum_{j=1}^{n} L_j p_{mj} q_j D_{ji}\omega_{ji}$
  - **in the absence of trade frictions/barriers ($\omega_{ij} = 1$):**
    - **shares of tradables in final good production:** $1 - \alpha = \dfrac{L_i p_{mi} q_{fi}}{L_i w_i}$
    - **share of tradables in production of tradables:** $1 - \beta = \dfrac{L_i p_{mi}(q_i - q_{fi})}{L_i p_{mi} q_i}$
    - **these two shares implies:** $\beta L_i p_{mi} q_i = (1 - \alpha) L_i w_i$
    - **trade balance =>** $L_i p_{mi} q_i = \sum_{j=1}^{n} L_j p_{mj} q_j D_{ji}$**, or,** $L_i w_i = \sum_{j=1}^{n} L_j w_j D_{ji}(w)$
  - **in general, trade balance =>** $L_i w_i (1 - s_{fi}) = \sum_{j=1}^{n} L_j \dfrac{w_j(1 - s_{fj})}{F_j} D_{ji}\omega_{ji}$**, with**
    - **labor share in final production:** $s_{fi} = \dfrac{\alpha[1 - (1 - \beta)F_i]}{(1 - \alpha)\beta F_i + \alpha[1 - (1 - \beta)F_i]}$
    - **fraction of country i spending reaching producers:** $F_i = \sum_{j=1}^{n} D_{ij}\omega_{ij}$

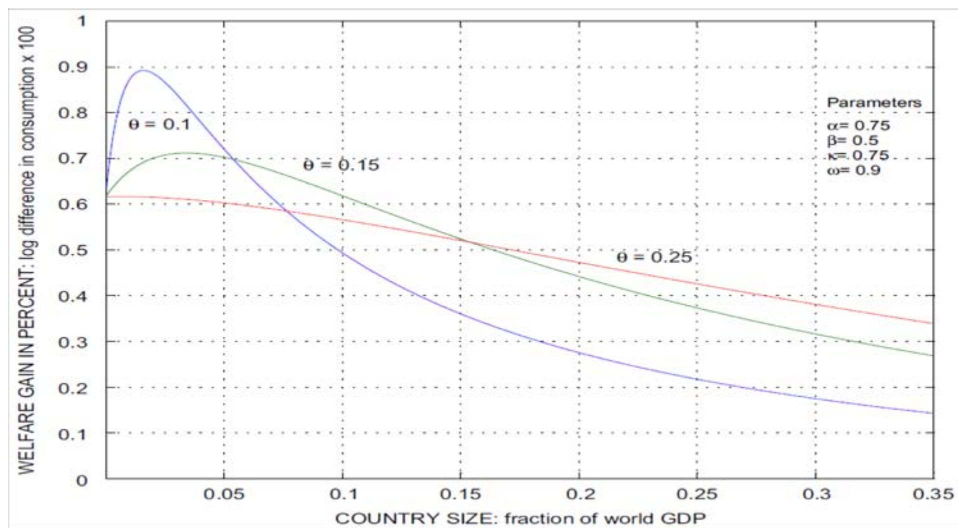
- world equilibrium requires all excess demands be zero: $Z_i(w) = \frac{1}{w_i}\left[\sum_{j=1}^{n} L_j \frac{w_j(1-s_{fj}(w))}{F_j(w)} D_{ji}(w)\omega_{ji} - L_i w_i (1 - s_{fi}(w))\right]$ and $\sum_{i=1}^{n} w_i = 1$
- existence of a unique $p_m(w)$:
  - homogeneous of degree one
  - increasing in each element of w
  - decreasing in κ_{ij} and ω_{ii}
  - bounded below by $\underline{p_m}(w) = (AB)^{1/\beta}\left(\sum_{j=1}^{n} w_j^{-\beta/\theta}\lambda_j\right)^{-\theta/\beta}$ and above by $\underline{p_m}(w)/(\underline{\kappa\omega})^{1/\beta}$
- existence of a world equilibrium, which is unique if
  - $\omega_{ii} = \omega_i$
  - $(\underline{\kappa\omega})^{2/\theta} \geqslant 1 - \beta \geq 1 - \alpha$
  - $\underline{\omega} \geq 1 - [\theta/(\alpha-\beta)]$

- **Calibration of key parameters:**
  - labor share in final production: $\alpha = 0.75$
  - labor share in intermediate production: $\beta = 0.5$
  - productivity amplifier: $\theta = 0.15 \in [0.08, 0.28]$ (Eaton-Kortem)
  - average iceberg transport cost factor: $\kappa = 0.75 \in [0.65, 0.96]$
  - average trade-barrier discounting factor: $\omega = 0.9$

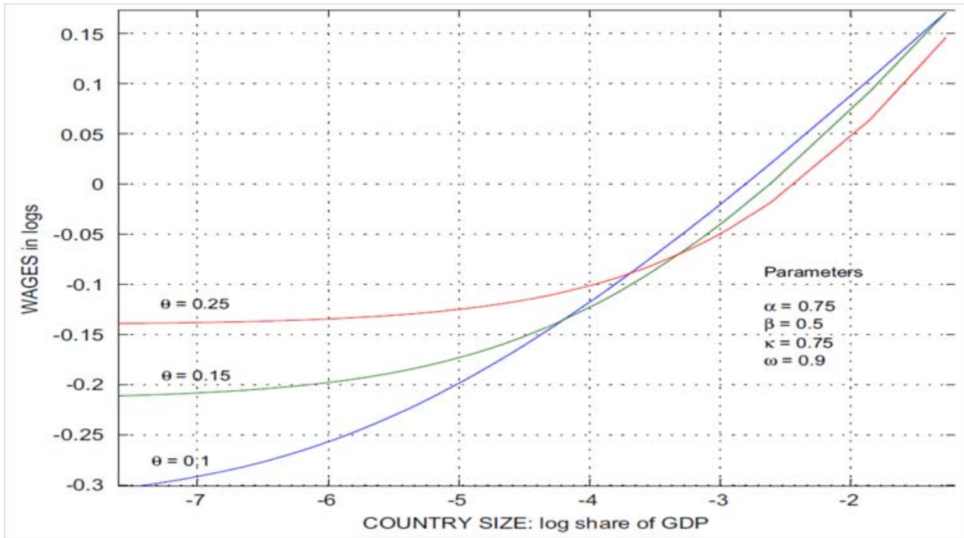
- **Main results:**
  - **1994-2000 data from selected countries: trade barriers harmful for growth**

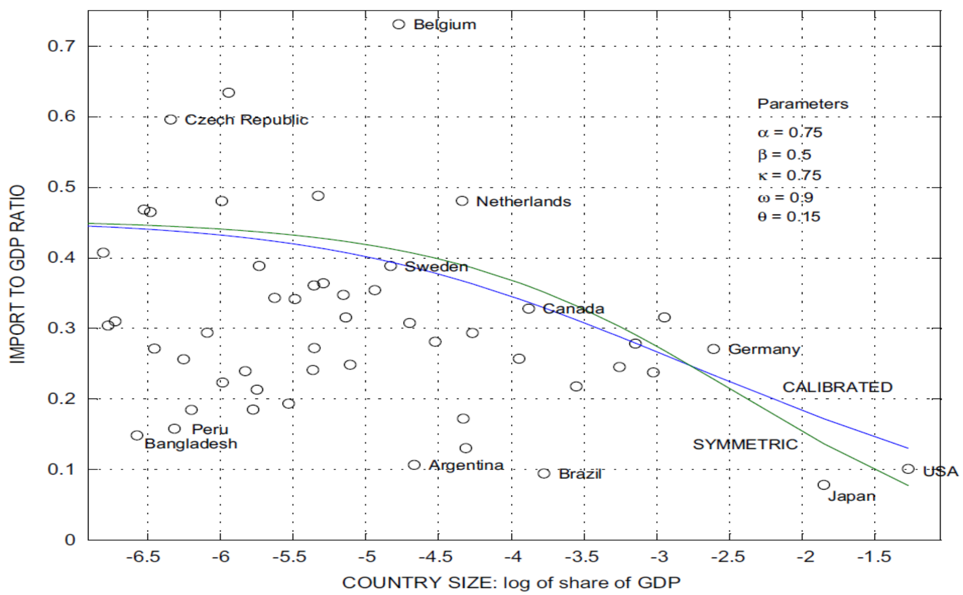
	US	GER	UK	JPN	HKG	SNG	CHN	IND	ARG	BRZ	MEX
GDP/World	**28.0**	**7.4**	**4.3**	**15.7**	**0.52**	**0.29**	**2.9**	**1.3**	**0.94**	**2.3**	**1.4**
Per Capita GDP/U.S.	**1.00**	**0.76**	**0.70**	**0.83**	**0.76**	**0.67**	**0.10**	**0.07**	**0.39**	**0.23**	**0.26**
IM/GDP	**0.10**	**0.27**	**0.28**	**0.08**	**1.39**	**1.62**	**0.22**	**0.13**	**0.11**	**0.09**	**0.29**
Tariff Rate	**5.4**	**5.9**	**5.9**	**5.5**	**0.0**	**0.2**	**18.6**	**33.4**	**12.4**	**13.7**	**14.3**

  - **% welfare gain (in consumption-equivalent) from eliminating a 10% tariff is higher for median-small countries when the productivity amplifier θ is not too large**



- wage vs. size: larger countries are associated with higher wage earning and relative productivity, where the earning-size schedule is steeper if the productivity amplifier θ is not too large
- volumes of trade vs. size: larger countries are associated with lower volumes of trade





- **Extensions:**
  - technology diffusion
  - physical capital accumulation
  - human capital accumulation
  - capital/labor barriers

D. Firm Distribution, Innovation and Growth: Luttmer (2007)

- **Key: extends Klette-Kortum (2004) to explain growth as a result of:**
  - **firm productivity improvements**
  - **selection of successful firms**
  - **imitation by new entrants**
- **Population:** $He^{\eta t}$
- **Expected utility:** $\left(E\left[\int_0^\infty \rho e^{-\rho t}[C_t e^{-\eta t}]^{1-\gamma}\, dt\right]\right)^{1/(1-\gamma)}$ **(in per capita form: Millian)**
  - **Spence-Dixit-Stiglitz consumption aggregator:** $C_t = \left[\int u^{1-\beta} c_t^{\beta}(u,p)\, dM_t(u,p)\right]^{1/\beta}$
    - **u = quality index, p = trading price**
    - **cost-minimization =>** $pc_t(u,p) = P_t(uC_t)^{1-\beta} c_t^{\beta}(u,p)$**, where P is aggregate price:** $P_t = \left[\int up^{-\beta/(1-\beta)}\, dM_t(u,p)\right]^{-(1-\beta)/\beta}$
    - **price elasticity of demand for c(u,p) (in absolute value): 1/(1-β)**
    - **expenditure share of c(u,p):** $u(p/P_t)^{-\beta/(1-\beta)}$
- **Along a balanced growth path (BGP), per capita consumption and real wage both growth at the common rate κ and the real interest rate is** $r = \rho + \gamma\kappa > \kappa$

- **Firm production, revenue and value:**
  - **at age a, a firm set up at t**
    - **employs labor $L_{t,a}$ to produces $z_{t,a}L_{t,a}$ units of good**
    - **pays workers at wage w and sell the output at price $p_{t,a}$**
    - **employs additional labor λ_F (fixed) to stay in business (manager)**
  - **revenue function (RF):** $R_{t.a} = p_{t.a}z_{t.a}L_{t.a}/P_t$ **=** $C_{t+a}^{1-\beta}(Z_{t,a}L_{t,a})^{\beta}$**, where** $Z_{t,a} = (u_{t,a}^{1-\beta}z_{t,a}^{\beta})^{1/\beta}$
  - **productivity evolution (PE):** $Z_{t,a} = Z\ \exp(\theta_E t + \theta_I a + \sigma_Z W_{t,a})$**, depending on an initial condition Z and driven by**
    - **a deterministic trend component (θ_E = productivity growth of new entrants)**
    - **an age trend component (θ_I = productivity growth of incumbents)**
    - **a Brownian motion component $W_{t.a}$ (Wiener process)**
  - **firm value:** $V_t[Z] = \max_{L,\tau} E_t\left[\int_0^{\tau} e^{-ra}(R_{t,a} - w_{t+a}[L_{t,a} + \lambda_F])\, da\right]$ **s.t. (RF) and (PE)**
  - **constant η and λ_F => number of firm grows at rate η =>** $\kappa = \theta_E + \left(\frac{1-\beta}{\beta}\right)\eta$**:**
    - **growth rises with deterministic trend in productivity**
    - **the effect of labor on growth is larger when the price elasticity of variety demand is lower (varieties are less substitutable)**

- **Firm optimization:**
  - **production decision (profit maximization):** $\begin{bmatrix} R_{t,a} \\ w_{t+a}L_{t,a} \end{bmatrix} = \begin{bmatrix} 1 \\ \beta \end{bmatrix} \left(\frac{\beta Z_{t,a}}{w_{t+a}}\right)^{\beta/(1-\beta)} C_{t+a}$
  - **maximized periodic profit: $\Pi_{t,a}$ =** $R_{t,a} - w_{t+a}(L_{t,a} + \lambda_F) = w_{t+a}\lambda_F(e^{s_a} - 1)$**, which is increasing in its size,** $s_a = S[Z] + \frac{\beta}{1-\beta}\left[\ln\left(\frac{Z_{t,a}}{Z_{t,0}}\right) - \theta_E a\right]$**, where**
    - **initial condition:** $e^{S[Z]} = \frac{1-\beta}{\lambda_F}\frac{C}{w}\left(\frac{\beta Z}{w}\right)^{\beta/(1-\beta)}$ **(size relative to fixed cost of new entrants with a detrended initial productivity *Z***
    - **Ito drift-diffusion process:** $ds_a = \mu\, da + \sigma\, dW_{t,a}$**, with** $\begin{bmatrix} \mu \\ \sigma \end{bmatrix} = \frac{\beta}{1-\beta}\begin{bmatrix} \theta_I - \theta_E \\ \sigma_Z \end{bmatrix}$
      - **the process features constant (μ,σ)**
      - **the drift is negative if new entrants grow faster than incumbents**
      - **the variance is amplified when the price elasticity of variety demand is high (varieties are more substitutable)**
  - **finite value: guaranteed by** $\gamma\kappa > \kappa + \mu + \frac{1}{2}\sigma^2$
  - **Bellman:** $rV(s) = \kappa V(s) + \mathscr{A}V(s) + e^s - 1$ **(capital gain = κ, dividend = (e^s -1)/V(*s*))**
    - **flow return to owning a firm: *r*V(*s*)/V(*s*) = capital gain + dividend**
    - **the drift of V(*s*):** $\mathscr{A}V(s) = \mu DV(s) + \sigma^2 D^2 V(s)/2$ **(Ito's Lemma)**
    - **boundary condition: shut down size *b* => V(*b*) = 0, DV(*b*) = 0**
    - **solution:** $V(s) = \frac{1}{r-\kappa}\left(\frac{\xi}{1+\xi}\right)\left(e^{s-b} - 1 - \frac{1 - e^{-\xi(s-b)}}{\xi}\right)$ **=> exit for *s* > *b***

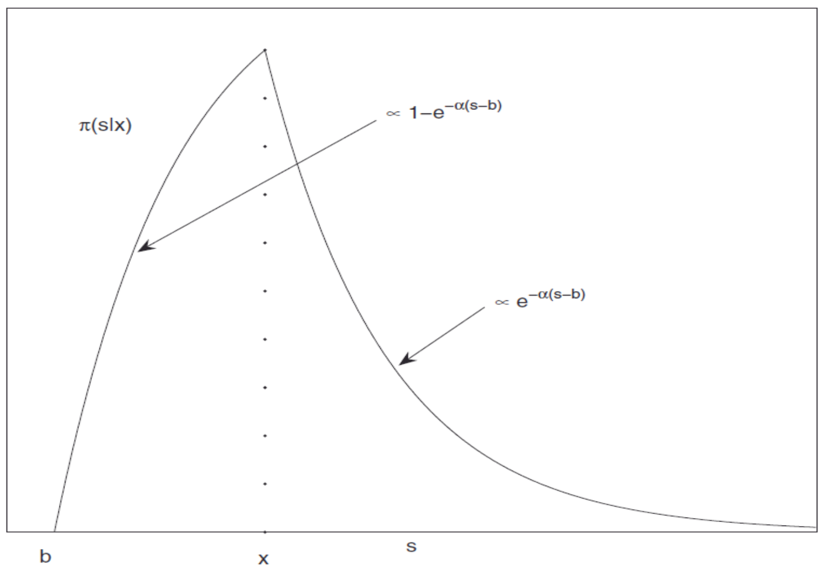
- **entry decision:**
  - **new firms can be start up at cost of λ_E units of labor**
  - **entry results in random draw of productivity Z from distribution J**
    - **initial productivity:** $Ze^{\theta_E t}$
    - **initial size: $S[Z]$**
  - **free entry condition:** $\lambda_E = \lambda_F \int V(S[Z])\, dJ(Z)$
  - **under** $\int Z^{\beta/(1-\beta)}\, dJ(Z) < \infty$**, the equilibrium entry is uniquely determined, featuring an initial size that is increasing in the entry cost λ_E**

- **The distribution of firms:**
  - **assumption:** $\eta > \mu + \frac{1}{2}\sigma^2$
  - **measure of firm $m(a,s)$ must satisfy:** $D_a m(a,s) = -\eta m(a,s) - \mu D_s m(a,s) + \frac{1}{2}\sigma^2 D_{ss} m(a,s)$ **(Kolmogorov forward equation of Brownian motion)**
  - **boundary condition: $m(a,b) = 0$**
  - **thus,** $m(a,s) = \int_b^\infty e^{-\eta a}\psi(a,s|x)\, dG(x)$**, where**
    - $\psi(a,s|x) = \frac{1}{\sigma\sqrt{a}}\left[\phi\left(\frac{s-x-\mu a}{\sigma\sqrt{a}}\right) - e^{-\mu(x-b)/(\sigma^2/2)}\phi\left(\frac{s+x-2b-\mu a}{\sigma\sqrt{a}}\right)\right]$
    - ϕ **~ N(0,1)**

- conditional prob. density on initial size x: $\pi(a,s|x) = \left(\frac{1-e^{-\alpha_*(x-b)}}{\eta}\right)^{-1} e^{-\eta a}\psi(a,s|x)$,
  - $\alpha = -\frac{\mu}{\sigma^2} + \sqrt{\left(\frac{\mu}{\sigma^2}\right)^2 + \frac{\eta}{\sigma^2/2}}$
  - $\alpha_* = \frac{\mu}{\sigma^2} + \sqrt{\left(\frac{\mu}{\sigma^2}\right)^2 + \frac{\eta}{\sigma^2/2}}$
- solution:

$$m(a,s) = \int_b^\infty \pi(a,s|x)\left(\frac{1-e^{-\alpha_*(x-b)}}{\eta}\right) dG(x)$$

  - weighted sum of conditional probability density
  - weights increasing in x - b, because more productive firms last longer

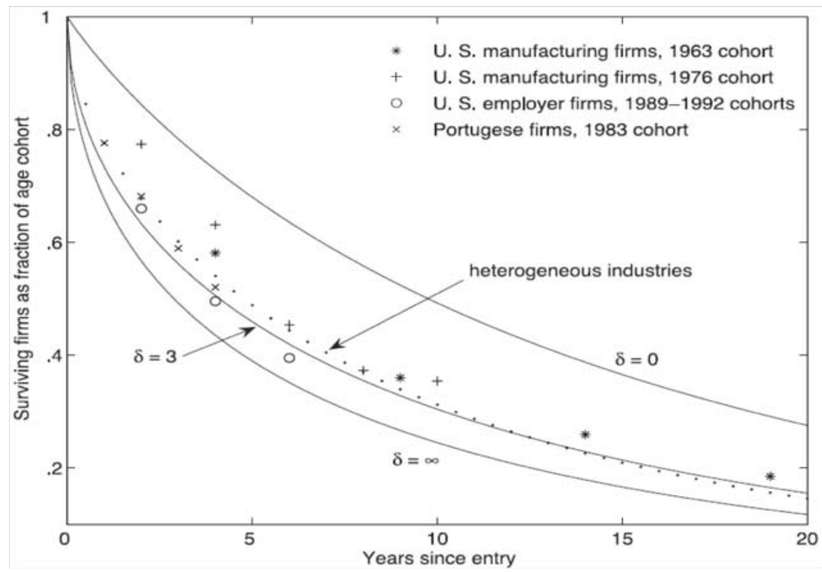


- the case of Pareto density: long right tail (superstar firms)

● Along a BGP, firms enter at constant rate = I => $L_E = I\,\lambda_E$

- thus, $L_F = I\,\lambda_F \int_b^\infty m(s)\,ds$ and $L = I\,\lambda_F\left(\frac{\beta}{1-\beta}\right)\int_b^\infty e^s m(s)\,ds$
- labor market clearing => $L_E + L_F + L = H$
- good market clearing => $C = Y$

- **Main results:**
  - **a BGP exists, satisfying** $\frac{Y}{w} = \frac{\lambda_F I}{1-\beta}\int_b^\infty e^s m(s)\, ds$ **= C/*w* and since zero profit pins down** $(C/w)/w^{\beta/(1-\beta)}$**, the paths of C, *w* and Y are determined accordingly**
  - **along a BGP, a proportional reduction in (λ_E,λ_F) raises output by (1-β)/β**
    - **in the case, zero profit condition does not change**
    - **neither initial size *S*[*Z*] nor size density *m*(*s*) changes**
    - **C/*w* remains unchanged**
    - **since** $S[Z] \propto (1-\lambda_F)(C/w)w^{\beta/(1-\beta)}$**, it must be that *w* grows at rate (1-β)/β, as does Y**
  - **when imitation is difficult (captured by imitation barrier δ facing new entrants), entry becomes tougher:**
    - **firm dynamics features lower survival rates**
    - **in the limit, firm size follows the Zipf's law (i.e., zeta distribution, which is a a discrete counterpart of the Pareto distribution)**



E. Gains from Trade: Arkolakis, Costinot & Rodríguez-Clare (2012)

- **With all the exciting development in modern trade theory and firm distribution, what are the new insights toward assessing the gains from trade?**
- **ACR's seminal contribution produces a *negative* answer: "so far, not much"**
- **Key: Observational Equivalence**
    - **regardless of micro details, the mapping between trade data and welfare is uniform across an important class of models, such as Krugman (1980), Eaton-Kortum (2002), Anderson-van Wincoop (2003), Melitz (2003) and follow-up studies, satisfying: (i) *constant markup*, (ii) *constant import demand elasticity*, and (iii) *bilateral trade balance***
    - **in these models, gains from trade are measured by two aggregate statistics:**
        - **import penetration measured by the share of country j's import from country i:** $\lambda_{ij} \equiv X_{ij} / Y_j$
        - **the trade elasticity ε, based on the gravity model, measuring the extent to which imports response to trade costs**
        - ***Gains from trade* (in income equivalence) =** $\overline{W}_j$ **=** $(\lambda_{jj})^{1/\bar{\varepsilon}} - 1$
- **Such gains are found to be far below 1%**

5. Generalization

- **Trade induced changes in productivity: Melitz-Redding (2015), Chen-Cheng-Peng-Riezman-Wang (2019)**
- **Gains from intermediate trade: Caliendo-Parro (2015), Sampson (2016), Halpern-Koren-Szeidl (2015), Bloom-Romer-Terry-Van Reenen (2021), Caliendo-Opromolla-Parro-Sforza (2021), Hsieh-Klenow-Nath (2021), Perla-Tonetti-Waugh (2021), Lai-Peng-Riezman-Wang (2022)**
- **The role of variable markups: Hsieh-Li-Ossa-Yang (2016), Chen-Cheng-Peng-Riezman-Wang (2023)**
- **Export versus outsourcing: Cheng-Riezman-Wang (2021)**

6. Open Issues

- **Are larger firms more productive and exporting firms larger/more productive?**
- **Is the cost of entry the primary determinant of firm distribution?**
- **What are the dynamic gains from trade with heterogenous firms and endogenous reallocation among firms?**
- **What is the implications of firm heterogeneity for wage inequality?**
- **How to explain large cross-country/industry variations in firm dynamics?**

F. Dynamic Gains from Trade: Hsu-Riezman-Wang-Yang (2022)

- **Literature:**
  - **Sampson (2016), Perla-Tonetti-Waugh (2015): endogenous growth with productivity distribution shifting rightward over time (dynamic gains 3.6%, 13.3%)**
  - **Bloom-Romer-Terry-Van Reenen (2014): trade with factor mobility frictions (dynamic gains without frictions 13-14%)**
  - **Ravikumar-Santacreu-Sposi (2018): trade with capital accumulation (dynamic gains 1.35 times larger than static)**
- **Hsu-Riezman-Wang-Yang (2022): dynamic general equilibrium model of trade featuring:**
  - **endogenous productivity improvement driven by R&D in general purpose technology (GPT) a la Aghion-Howitt (1992; AH)**
  - **endogenous innovation in ideas drawn for producing differentiated varieties**
  - **North-South trade with Bernard-Eaton-Jensen-Kortum (2003; BEJK) trade environment**
  - **occupational choice (innovator vs worker; entrepreneur vs worker)**
  - **endogenous royalty payment**

Basic Structure

- Two countries of size N_i ($i = 1, 2$): 1 = north, 2 = south
- Differentiated goods produced by firms engaging in Bertrand competition as in BEJK and with monopoly GPT as in AH
- Perfectly competitive labor market
- Lifetime utility:

$$U_i = \int_0^\infty U_{it} e^{-\rho t} dt,$$

  with

$$U_{it} = \left(\int_0^1 (q_{it}(\omega))^{\frac{\sigma-1}{\sigma}} d\omega \right)^{\frac{\sigma}{\sigma-1}}$$

- Production of each good ω requires a blueprint of production process and production workers
- Each production process requires use of GPT from the North.

Innovations

- North: the GPT monopolist is selected by a random draw at time ν
- Then at time ν_+ each unit of entrepreneurial labor M_i for each good ω
  - draws an idea from the set of $\gamma^{\nu} T_{i0}$ ideas associated with the current GPT
  - the productivity of that idea is drawn from a Fréchet distribution, $F_i^{\text{draw}}(z) = e^{-z^{-\theta}}$
  - the best ideas prevail in the market
  - the GPT monopoly and each successful entrepreneur engage in Nash bargaining with the bargaining power of the GPT firm = $\beta \in (0, 1)$
- Evolution of total number of ideas: $T_{i\nu} = M_{i\nu} \gamma^{v} T_{i0}$
  - maximum productivity $F_{i,\nu}(z) = e^{-T_{i,\nu} z^{-\theta}}, \quad z \geq 0$
  - joint distribution of top two productivities $F_{i,\nu}(z_1, z_2) = [1 + T_{i,\nu}(z_2^{-\theta} - z_1^{-\theta})] e^{-T_{i,\nu} z_2^{-\theta}}$.

Production and Trade I

- Unit cost of supplying consumers in country n by the kth most efficient producers located in i:

$$C_{kni}(\omega) = \left(\frac{w_i}{Z_{ki}(\omega)}\right)\tau_{ni},$$

where $\tau_{ni} = 1$ if $n = i$, $\tau_{ni} = \tau$ if $n \neq i$; $Z_{1i}(\omega)$ and $Z_{2i}(\omega)$ follows $F_{i,v}(z_1, z_2)$

- Producer serving n has unit cost $C_{1n}(\omega) = \min_i\{C_{1ni}(\omega)\}$ but, under Bertrand competition, charges $C_{2n}(\omega)$ (markup > 1)
  - with CES utility, markup $\leq$ monopoly markup $\sigma/(\sigma-1)$ for $\sigma > 1$ (for $\sigma \leq 1$, no upper bound)
  - thus, $P_n(\omega) = \min\{C_{2n}(\omega), \frac{\sigma}{\sigma-1}C_{1n}(\omega)\}$.

Production and Trade II

- The probability that country i provides a good at the lowest price in country n is ($\Phi_n \equiv \sum_{k=1}^{2} T_k (w_k \tau_{nk})^{-\theta}$):

$$\pi_{ni} = \frac{T_i (w_i \tau_{ni})^{-\theta}}{\Phi_n}$$

- Denote X_{ni} as the total expenditure of country n on the goods from i and X_n as the total expenditure:

$$X_{ni} = \pi_{ni} Y_n$$

  Y_n on the RHS rather than X_n (BEJK) due to royalty

- Under $\theta + 1 > \sigma$, the price index is

$$P_n = \eta \Phi_n^{-\frac{1}{\theta}}$$

  where $\eta \equiv [\frac{1+\theta-\sigma+(\sigma-1)\left(\frac{\sigma}{\sigma-1}\right)^{-\theta}}{1+\theta-\sigma} \Gamma \left(\frac{\theta+1-\sigma}{\theta}\right)]^{\frac{1}{1-\sigma}}$ depends on a gamma function

- A fraction $\theta/(1+\theta)$ of revenue goes to variable cost.

Labor I

- North: two types of labor with $N_1^M = \psi N_1$ (either entrepreneurs or workers), $N_1^R = (1-\psi)\, N_1$ (either innovators or workers)
- Whether to become a worker depends on occupational choice
- Entreperenuers (also applied to South):
  - ability $a \sim G(a) = 1 - a^{-k}$ (Pareto)
  - expected payoff to become entrepreneurer $av_{iv} = a\frac{1-\beta}{1+\theta}\frac{X_{iv}}{M_{iv}}$, preferred to worker wage w_{iv} for $a \geq \frac{1+\theta}{1-\beta}\frac{M_{iv}}{X_{iv}} w_{iv} \equiv a_{iv}^M$, so

$$M_{iv} = N_i^M \int_{a_{iv}^M}^{\infty} adG\left(a\right) = \left(\frac{kN_i^M}{k-1}\right)^{\frac{1}{k}} \left(\frac{1-\beta}{1+\theta}\frac{X_{iv}}{w_{iv}}\right)^{\frac{k-1}{k}}.$$

Labor II

- Innovators:
  - the GPT winner's total profit is (zero marginal cost): $\Pi^G_{1\nu} = \frac{\beta}{1+\theta}\left(X_{1\nu} + X_{2\nu}\right)$
  - GPT monopoly's value: $V_{\nu+1} = \frac{\Pi^G_{\nu+1}}{r+\lambda(R_1)}$
  - (effective) R&D labor $R_{i,\nu}$ hired for innovating a new GPT (given $V_{\nu+1}$) is by $\max_{R_{1,\nu}} \lambda\left(R_\nu\right) V_{\nu+1} - w^R_\nu R_\nu$
  - occupational choice to become an innovating researcher if $a \geq \frac{(1+\theta)[r+\lambda(R_\nu)]}{\lambda'(R_\nu)\beta(X_{1\nu+1}+X_{2\nu+1})} w_{1\nu} \equiv a^R_{1\nu}$, so $R_\nu = \frac{kN^R_1}{k-1}\left(a^R_{1\nu}\right)^{-k+1}$
  - FOC with $\lambda\left(R\right) = \kappa R^\epsilon$:

$$\kappa\epsilon\left(\frac{kN^R_1}{k-1}\right)^{\frac{1}{k-1}} R_\nu^{\epsilon-1-\frac{1}{k-1}} = \frac{\left(1+\theta\right)\left(r+\kappa R^\epsilon\right)}{\beta\left(X_{1\nu+1}+X_{2\nu+1}\right)} w_{1\nu}.$$

Labor III

- South: no research type labor and hence $N_2^M = N_2$
- Same ability distribution as North
- Similar occupational choice between entrepreneurs and workers
- Labor market clearing implies

$$
\begin{aligned}
\frac{\theta}{1+\theta}\frac{X_{1\nu}}{w_{1\nu}} &= N_1^M G\left(\left(\frac{k}{k\text{-}1}\frac{N_1^M}{M_{1v}}\right)^{\frac{1}{k-1}}\right) + N_1^R G\left(\left(\frac{k}{k\text{-}1}\frac{N_1^R}{R_v}\right)^{\frac{1}{k-1}}\right) \\
\frac{\theta}{1+\theta}\frac{X_{2\nu}}{w_{2\nu}} &= N_2 G\left(\left(\frac{k}{k\text{-}1}\frac{N_2}{M_{2v}}\right)^{\frac{1}{k-1}}\right).
\end{aligned}
$$

Goods Markets

- Goods market clearing:

$$\begin{aligned} Y_{1v} &= X_{1v} + \frac{\beta}{1+\theta} X_{2v} = X_{11,v} + X_{12,v}, \\ Y_{2v} &= X_{2v} - \frac{\beta}{1+\theta} X_{2v} = X_{21,v} + X_{22,v}. \end{aligned}$$

- No balanced trade:

$$\pi_{12} Y_1 = \pi_{21} Y_2 + \frac{\beta}{1+\theta} X_2.$$

- Ratio of total revenues ($t_0 = \frac{T_{10}}{T_{20}}$, $m_v = \frac{M_{1v}}{M_{2v}}$):

$$\frac{X_{1v}}{X_{2v}} = m_v w_v^{-\theta} \left[\frac{m_v t_0 w_v^{-\theta} + \tau^{-\theta}}{m_v t_0 (w_v \tau)^{-\theta} + 1} \frac{1+\theta-\beta}{1+\theta} + \frac{\beta \tau^{\theta}}{1+\theta} \right]$$

- Output growth: $\frac{X_{i,v+1}}{X_{i,v}} = 1 + g = 1 + \lambda (R_v) \ln(\gamma)$.

Welfare

29

- $\chi \equiv N_1/N_2, x \equiv X_1/X_2, m \equiv M_1/M_2, w \equiv w_1/w_2$
- Under constant intertemporal elasticity of substitution, lifetime utility is: $U_n = \int_0^\infty \left[C_{n0}e^{gt}\right]^\xi e^{-\rho t}dt$
- Under bounded utility $\rho > g\xi$, the BGP welfare is measured by $U_n = \frac{1}{\rho - g}\frac{w_{n0}}{P_{n0}}$
- Relative change in welfare with labor in country 1 as numeraire at period zero ($w_{10} = w'_{10} = 1$):

$$\frac{U'_1}{U_1} = \frac{\rho - g}{\rho - \lambda g'}\left[\frac{\frac{T_{10}}{T_{20}} + \left(\frac{\tau}{w}\right)^{-\theta}}{\frac{T_{10}}{T_{20}} + \left(\frac{\tau'}{w'}\right)^{-\theta}}\right]^{-\frac{1}{\theta}} = \underbrace{\frac{\rho - \kappa R^{\epsilon}\ln(\gamma)}{\rho - \kappa R'^{\epsilon}\ln(\gamma)}}\underbrace{\left(\frac{\pi'_{11}}{\pi_{11}}\right)^{-\frac{1}{\theta}}}$$

- Decomposition:

$$1 = \frac{\ln \text{DF}}{\ln(\text{Total Gains})} + \frac{\ln \text{ACR}}{\ln(\text{Total Gains})}.$$

Welfare Gains from Trade

- **Calibration: 2000-2014, 19 North and 33 South,**
  - **presetting**
    - **trade elasticity θ=5.03 (Head-Mayer 2014)**
    - **ladder size γ=1.1017 (Aghion-Bergeaud-Boppart-Klenow-Li 2019)**
  - **jointly calibrating: trade costs, initial technology stocks, bargaining power of GPT firm (β), GPT innovation efficacy (κ) and curvature (ε)**
- **Decomposition of total gains from trade (from autarky to benchmark)**

	Total Gains (%)	GR Gains (%)	IG Gains (%)	ACR Gains (%)
Avg (weighted)	30.62	27.4	0.14	3.07
North Avg (weighted)	32.07	27.4	0.67	3.99
South Avg (weighted)	30.23	27.4	0	2.82
		Share of GR Gains (%)	Share of IG Gains (%)	Share ACR Gains (%)
Avg (weighted)		89.51	0.46	10.03
North Avg (weighted)		85.45	2.1	12.45
South Avg (weighted)		90.66	0	9.34

- **Counterfactual analysis: dynamic versus static gain, with the latter by removing the driver of growth – GPT innovation**

	Total gains (%)	Static gains (%)	Dynamic gains (%)	Dynamic share (%)
Avg (weighted)	30.62	3.35	27.27	89.05
North Avg (weighted)	32.07	5.29	26.78	83.51
South Avg (weighted)	30.23	2.83	27.4	90.63

- **Occupational choice yields a negative labor allocation effect, reducing gains from trade**
- **Intermediate inputs enhance gains from trade**
- **Even with large-scaled sensitivity exercises, total gains remain sizable throughout (all above 10%) whereas the share of dynamic gains continue to be most dominant (all above 2/3),**
  - **total gains higher than 3.6% in Sampson (2016), comparable to 13-14% in Perla-Tonetti-Waugh (2021) and Bloom-Romer-Terry-Van Reenen (2021)**
  - **share of dynamic gains, higher than 57.4% in Ravikumar-Santacreu-Sposi (2019)**

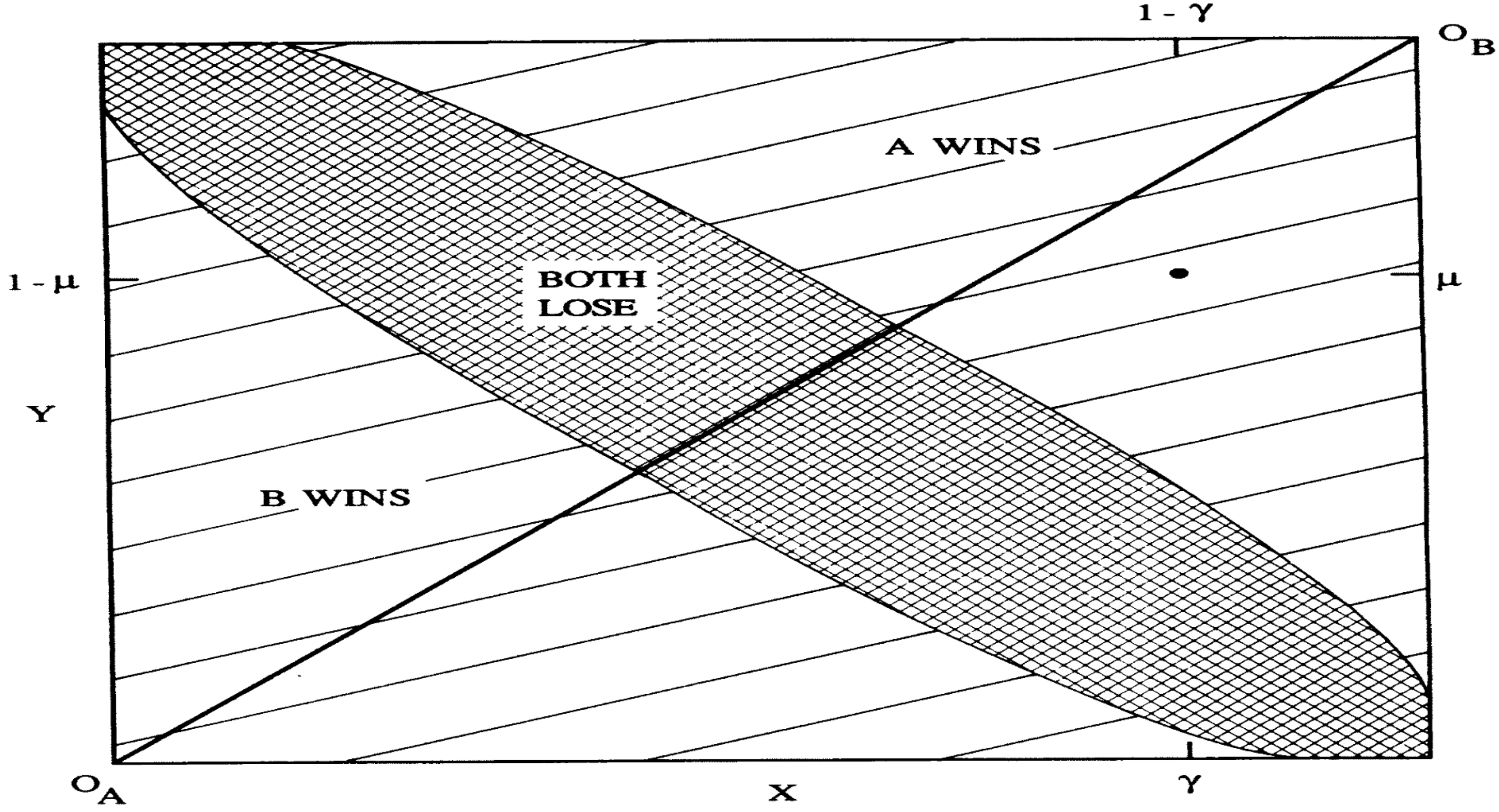
G. Trade War: Cheng-Wang (2022) and Chen-Cheng-Peng-Riezman-Wang (2023)

- **What happened over the past decade?**
  - **Rising trade protectionism since the Great Recession:**
  - **Brexit**
  - **Battled renegotiations of the NAFTA**
  - **Recently exacerbated U.S.-China trade war and chip war**
  - **Ongoing Japan-Korea trade war**
  - **Possible US-EU trade war**

Source: Financial Times

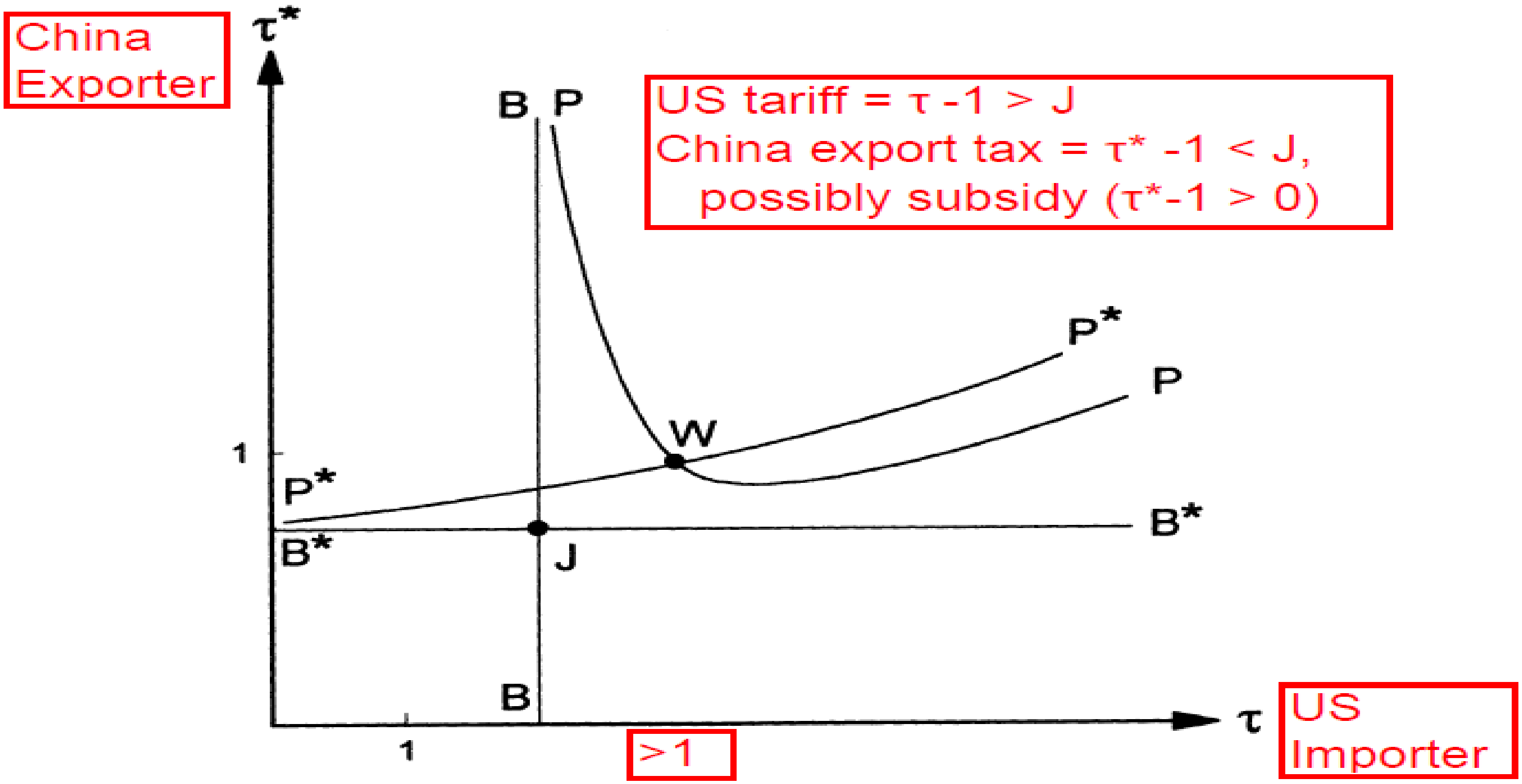
Theory of Trade Wars

- Large & more advanced countries can manipulate international prices and control key upstream supplies => more likely to win the wars (Kennan and Riezman,1988 IER)



Trade Wars in Political Equilibrium

- In political equilibrium, importing country optimally sets higher tariff than the Johnson (1954 REStud) benchmark (J), and lower export tax (possibly subsidy) than J (Grossman-Helpman, 1995 JPE)



Quantitative Analysis of Trade Wars

- Ossa (2014 AER) – a unified dynamic general equilibrium model of trade wars with or without political lobbying:
  - Under Nash tariffs when all countries retaliate optimally, such a trade war would lead to median tariffs at upper 50 percent (58.6, 59.6 and 59.1 percent for China, U.S. and EU)
  - It only generate a modest welfare loss (about 2% in China/U.S. & 2.6% for EU), together with a small profit loss (< 1%) and a wage gain (0.5-6.3%)
- Steinberg (2018 WP) – a dynamic general equilibrium model with policy uncertainty:
  - Brexit leads to an average of 4.5% increase in tariffs for UK and the remaining EU members, with uncertainty of larger scales
  - It only generate a modest welfare cost by Britain households in the range of 0.4-1.2%

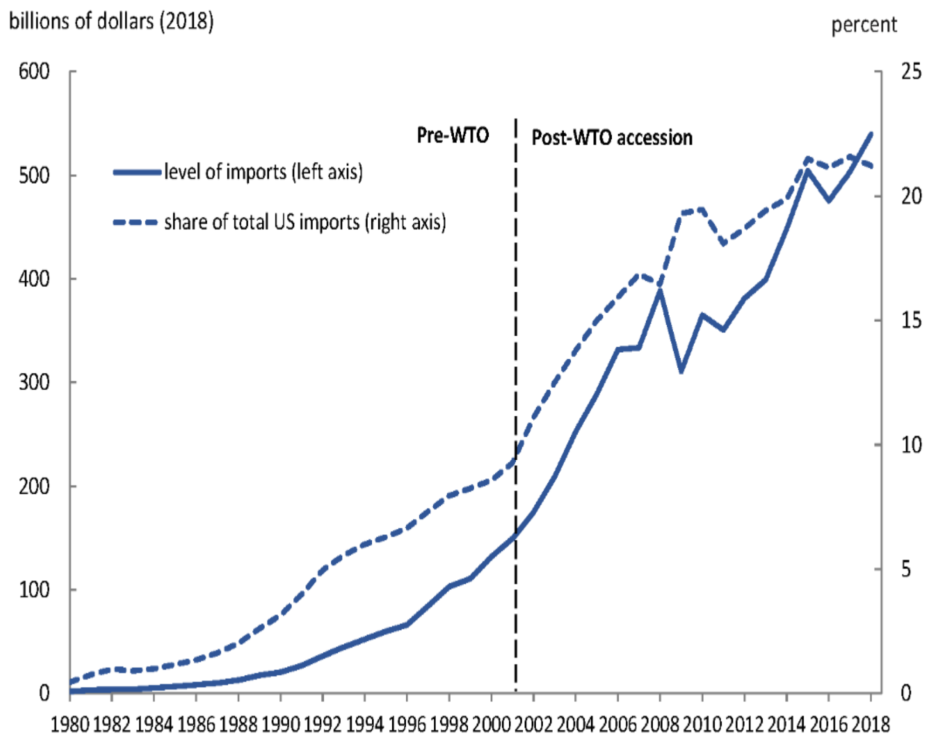
Surprising Phenomena of Recent Trade Wars

- Such trade protection acts have been originated from high income countries (the North) which were major participants in GATT/WTO
- Broad ranges of tariff imposed on intermediate products
  - In the U.S., nearly 90% of intermediate imports from China face increased tariff (cf. Bown 2019)
  - Violation of the Diamond and Mirrlees (1971) Intermediate Goods Principle of Optimal Taxation – taxing intermediate goods creates much larger distortions, more harmful for economic development

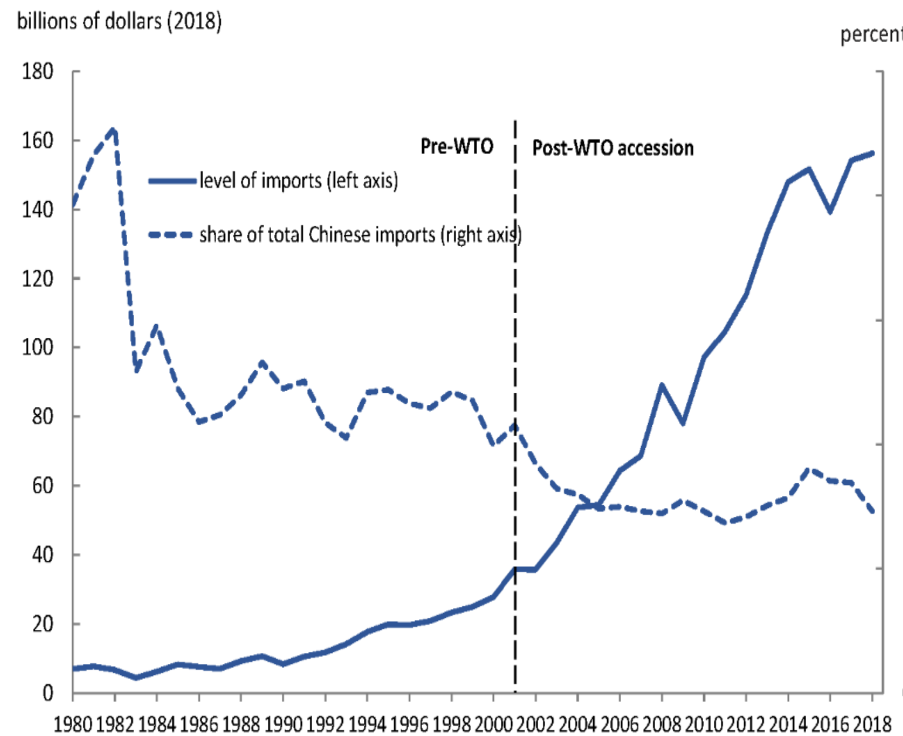
Pre- and Post-WTO U.S.-China Trade

- While value and volume of trade increased, U.S. imports become more China-dependent but China less U.S.-dependent (Bown 2019 WP)

a. US imports from China



b. China's imports from US



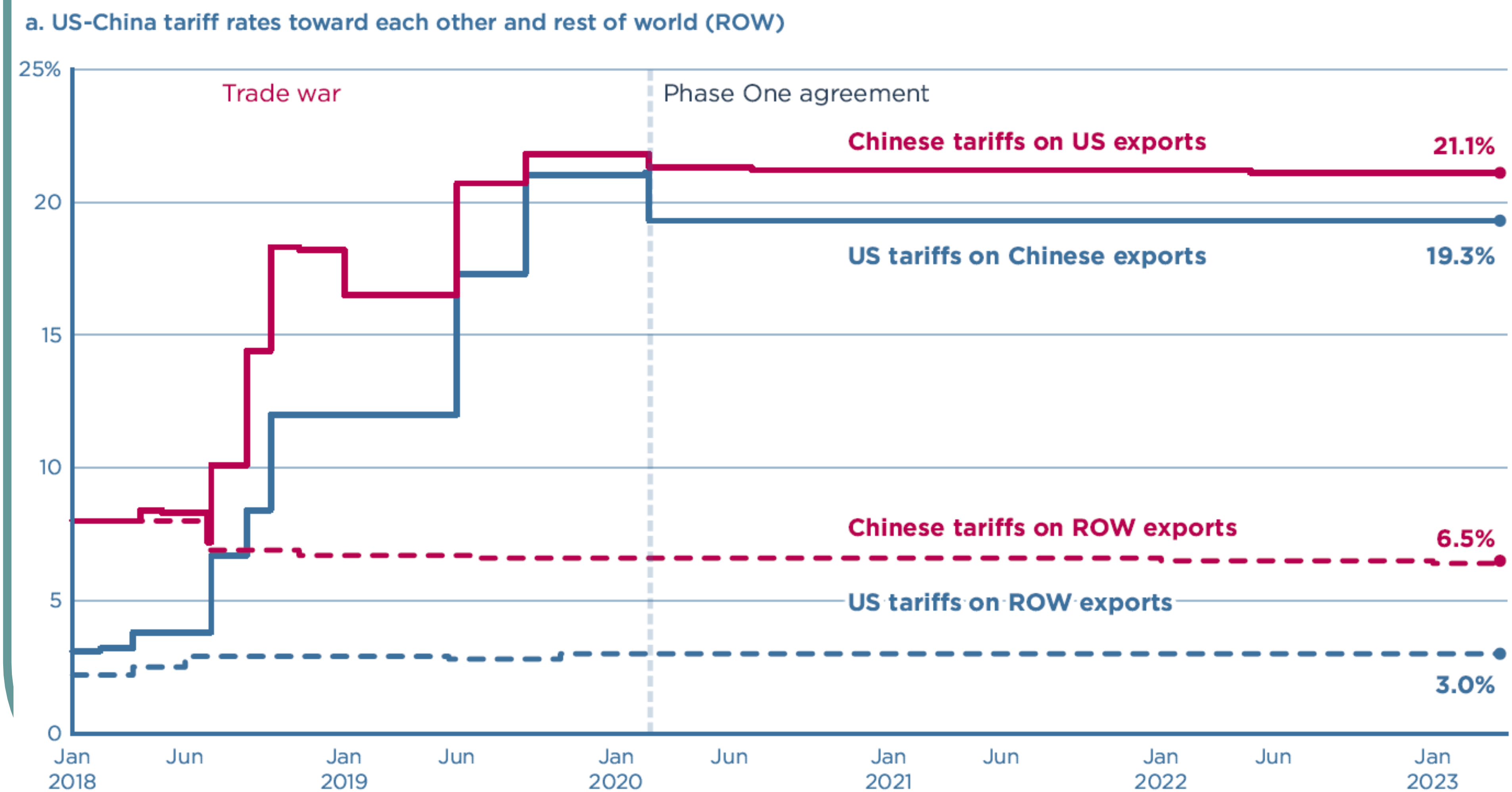
Current U.S.-China Trade War

- Under the current U.S.-China trade war, average tariffs raise from 5% to 12% in the U.S. and from 15% to 20% in China (Bown 2019 WP)

Country	MFN tariffs, 2017		MFN + 2018 special tariffs**		MFN + antidumping duties		MFN + antidumping duties + 2018 special tariffs	
	Simple average	Trade-weighted*	Simple average	Trade-weighted*	Simple average	Trade-weighted*	Simple average	Trade-weighted*
United States	3.4	3.1	12.5	12.4	10.4	13.6	19.5	22.9
China	9.6	8.0	18.1	19.6	9.8	8.5	18.3	20.1

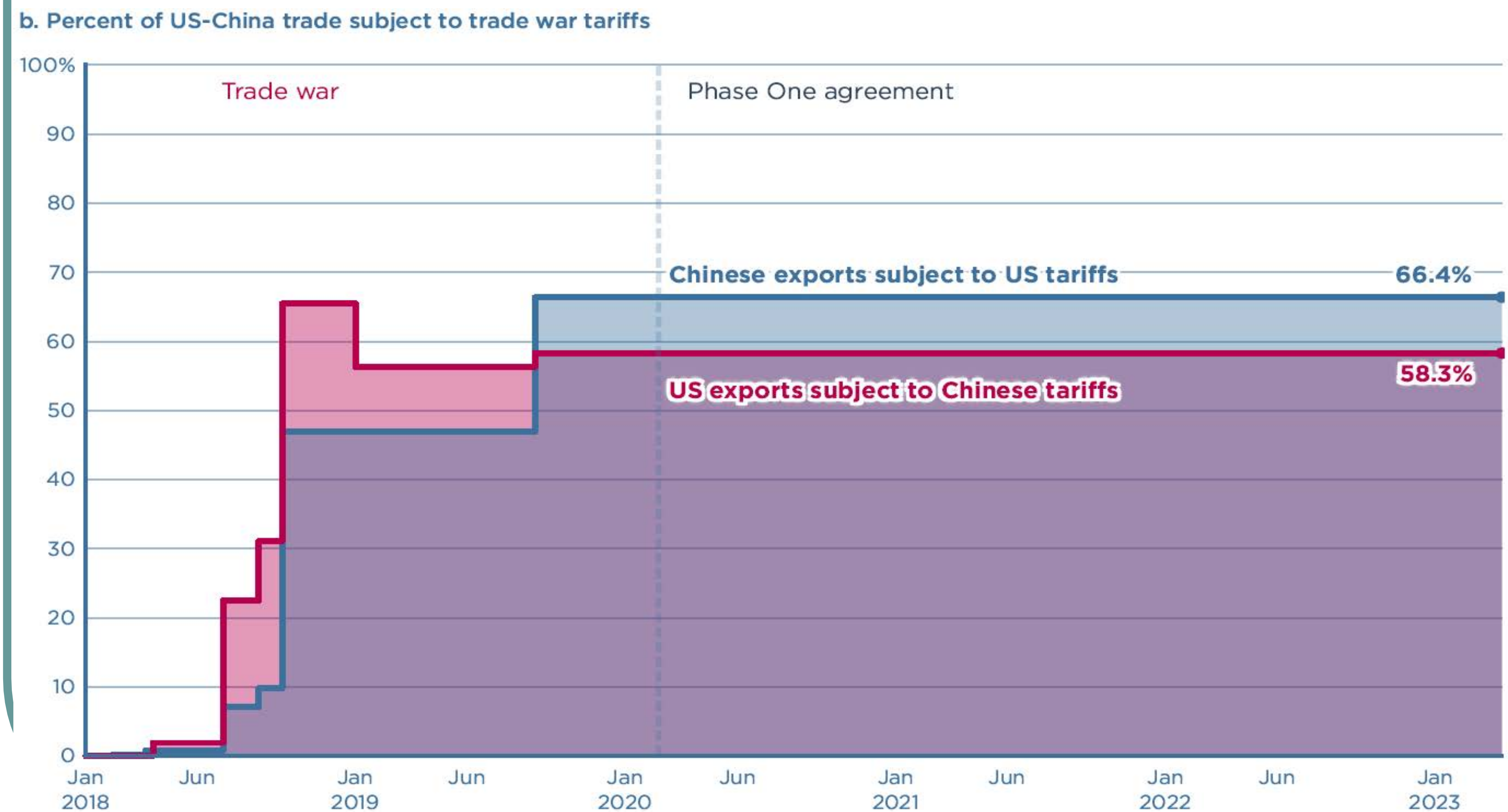
Current U.S.-China Trade War

- The timeline of the tariff war (Bown 2023 Policy Report)



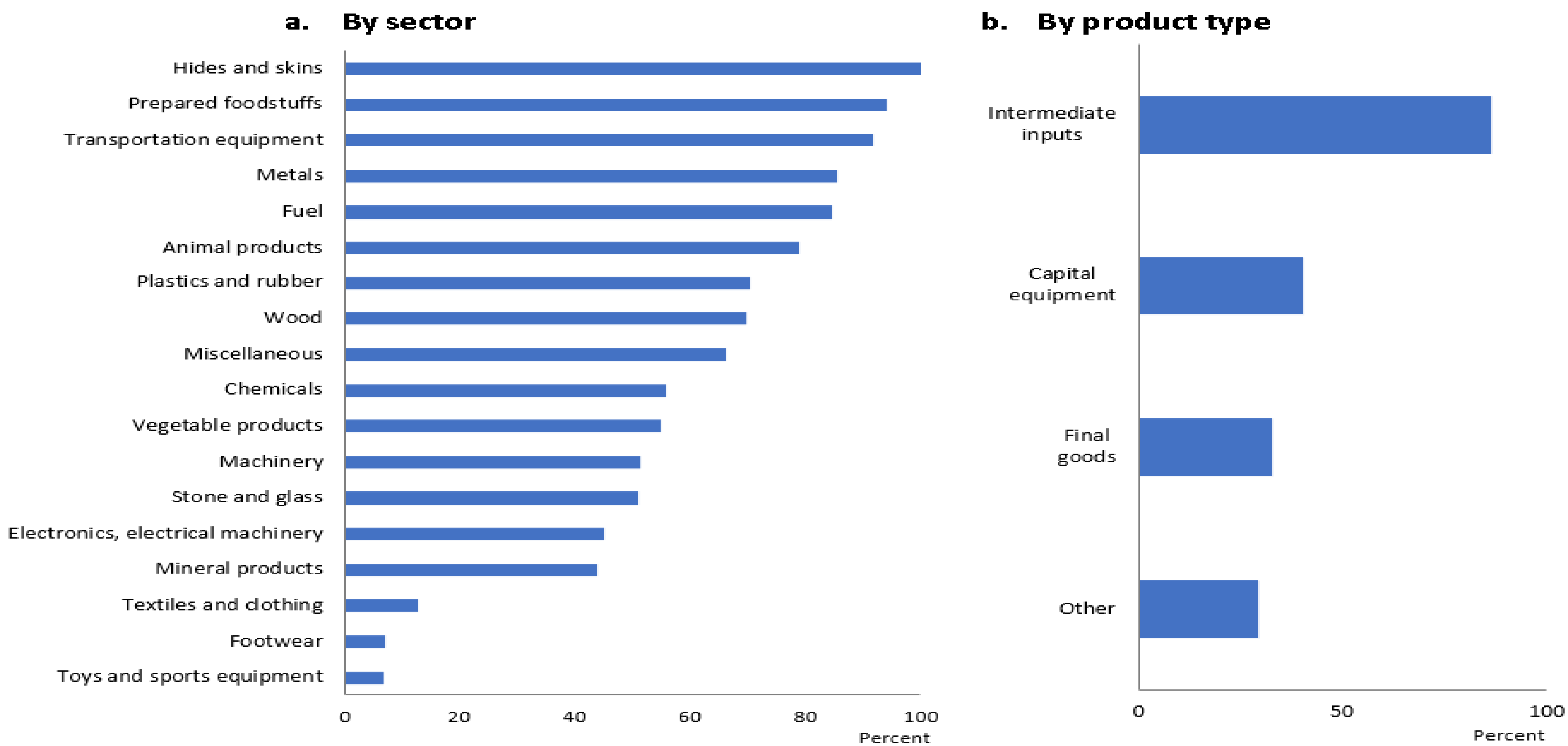
Current U.S.-China Trade War

- The timeline of the tariff war (Bown 2023 Policy Report)



Current U.S.-China Trade War

- About 90% of intermediate goods imports from China are covered by the 2018 special tariff, with > 70% of animal/food/transport/metal/petro/plastic/wood covered



Source: Bown (2019 WP)

China's contribution to U.S. demand: Cheng-Wang (2022)

- China's contribution to U.S. demand (FDR/IDR %):
  - To U.S. final demand (FDR)
  - To U.S. intermediate demand (IDR)

Food	Textiles	Wood	Paper	Printing
0.8/0.2	**29.5**/4.9	7.2/1.9	2.4/1.4	0.9/0.4
Petroleum	Chemicals	Pharmaceutical	Plastic	Minerals
0.2/0.6	1.1/3.8	2.1/0.8	8.4/2.7	9.8/3.4
Basic Metals	Metal Products	ICT	Electrical	Machinery
26.0/1.1	**10.9**/2.4	**26.1/13.6**	**26.0/11.7**	6.7/7.3
Motor	Transport	Furniture	Machinery Repair/Installation	
0.9/3.6	1.5/1.1	**11.6**/2.6	0.0/0.0	

Decomposing U.S. final demand:
Cheng-Wang (2022)

- Impact Intensity (million US$): U.S. final demand for China's products
  - Assume constant I-O coefficients based on the 2016 WIOD and complete passthrough (Amiti-Redding-Weinstein 2019)
  - Exposure rate of country s to country d's tariff increase:
    $ER^{s}_{dj} = FDR^{d}_{sj}$ * country d's tariff coverage rate in sector j TCR^{d}_{j} * 9.3%
  - Trade war impact intensity facing country s to country d's tariff increase:
    $II^{s}_{dj} = ER^{s}_{dj}$ * trade elasticity of country d's sector j TE^{s}_{dj} * US final demand for sector j

Food	Textiles	Wood	Paper	Printing
-986	**-3733**	**-614**	0	0
Petroleum	Chemicals	Pharmaceutical	Plastic	Minerals
-2781	-398	-261	-438	-154
Basic Metals	Metal Products	ICT	Electrical	Machinery
-744	**-3323**	**-12085**	**-10560**	**-1138**
Motor	Transport	Furniture	Machinery Repair/Installation	
-667	-328	**-15950**	0	

Sectoral impact of trade war (mil$): Cheng-Wang (2022)

WIOD Sector	DWL	Leakage Rate (0.2) * Tariff	Total Loss = DWL + Tariff Leakage
A01-03: Primary	11.62	27.09	38.71
C10-12: Food	39.51	331.15	370.67
C13:15: Textile	16.00	431.60	447.60
C16: Wood	26.02	51.02	77.04
C17: Paper	45.30	51.88	97.18
C18: Printing and Media	3.04	3.48	6.52
C19: Petroleum	46.12	0.79	46.91
C20: Chemicals	46.56	561.64	608.21
C21: Pharmaceutical	8.77	105.74	114.51
C22: Plastic and Rubber	21.37	394.79	416.17
C23: Non-metallic Mineral	6.26	117.05	123.30
C24: Basic Metals	52.14	378.19	430.33
C25: Metal Products	169.38	497.33	666.72
C26: Electronic and Optical	522.47	2,575.14	3,097.61
C27: Electrical Equipment	206.16	612.25	818.42
C28: Machinery	35.12	1,033.87	1,068.99
C29: Motor Vehicles	60.08	761.87	821.94
C30: Other Transport	3.56	225.38	228.94
C31-32: Furniture and Other	135.94	1,044.79	1,180.73
C33: Repair and Installation	0.00	0.00	0.00
Total	1,455.42	9,205.06	10,660.48

Global value chain revisited

- Final goods are produced with intermediate goods along an internationally fragmented production line
- Intermediate goods are embodied with differentiated technologies
  - The North owns more advanced technology
  - The South is less advanced, but can upgrade along the value chain through
    - intermediate imports (Chen-Cheng-Peng-Riezman-Wang 2023)
    - global sourcing, joint venture or multinational (Cheng-Riezman-Wang 2019, 2023)
    - investment in own technologies (unrewarding if inferior ones)

Impact of trade war revisited: Chen-Cheng-Peng-Riezman-Wang (2023)

- With the South responding to a trade war by advancing in technologies via the composition of intermediate trade even if it cannot manipulate international prices, the South need not lose:
  - The South final goods producers can counter a trade war by adjusting the mix of intermediate goods, importing those embodied with superior technologies and lengthening & moving up along the value chain, an extensive margin effect
  - This entails a scale-scope trade-off in response to protectionism

Impact of trade war revisited: Chen-Cheng-Peng-Riezman-Wang (2023)

- Dynamic general equilibrium effects of a trade war on the South based on the size of the current U.S.-China war (without/with technology restrictions)

	Production Line	Volume of Export	Value of Export	Volume of Import	Value of Import
% change	35%/17%	121%/-17%	103%/-22%	-50%/-39%	-56%/-42%
	Export Range	**Import Range**	**Average Technology**	**Average Profit Markup**	**Domestic Intermediate Production Ratio**
% change	65%/-6%	-53%/-27%	11%/5%	15%/4%	17%/4%

Impact of Trade War Revisited: Chen-Cheng-Peng-Riezman-Wang (2023)

- Thus, the South need not lose if it adjusts the mix of intermediate goods by importing those embodied with superior technologies and lengthening & moving up along the value chain
- Trade war does reduce the volume and the value of trade (exports and imports) substantially
- As a result of the scale-scope trade-off induced by technology-embodied intermediate goods trade
  - Average technologies both rise
  - Average productivity is higher
  - Average profit markup is larger
  - The value-added and consumption ratios both increase
  - But all such changes are modest quantitatively