

# Skill-Based Quality Upgrading and Trade: Country Differences in Innovation Capacity Matter

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- ▶ **Productivity and quality** are two fundamental aspects of firm heterogeneity

- Kugler and Verhoogen 2012, Hottman et al. 2016, Aw-Roberts et al. 2018

## Trade: level vs. distributional effects

- ▶ Trade openness exacerbates firm heterogeneity through
  - ▶ **endogenous markups** (competition)
  - ▶ **endogenous quality choice** (upgrading)

- Aghion et al. 2005, Redding et al 2020, Iacovone 2012, Manova and Zhang 2012, Brambilla and Porto 2016, Antoniadis 2015, Bas and Paunov 2019, Fan et al. 2018, 2020, Verhoogen 2008

## Channels: markups vs. innovation

- ▶ **Country-specific capacity constraints on innovation** shape the trade-off between quality upgrading and expansion of production volumes
  - Feenstra and Romalis 2014, Flach and Unger 2022, Chen and Juvenal 2022

- ▶ Develop a multi-sector multi-country trade model with **variable markups** and **endogenous quality** choice based on **skill intensity**.
- ▶ **Heterogeneous firms** are constrained by the **innovation capacity** of the country where they produce
- ▶ Country-specific innovation capacity consists of two components:
  - ▶ **endogenous skill wage premium**
  - ▶ **exogenous innovation capacity**

## Research goals

- ▶ Assess the effect of trade-induced competition on product quality choice given that firms face **variable demand price elasticity** and **country differences in skill wage premium**;
- ▶ Quantify **sector-specific taste for quality versus variety** and exogenous component of **country-specific innovation capacity** by structurally estimating and simulating the model.

[tbc]

- ▶ Quadratic preferences over a continuum of differentiated varieties  $i \in \Delta_j^h$  of sector specific goods:

$$U^h = \sum_{j \in J} \left[ \alpha_j \int_{i \in \Delta_j^h} q_{ij}^h di + \beta_j \int_{i \in \Delta_j^h} z_{ij} q_{ij}^h di - \frac{1}{2} \gamma_j \int_{i \in \Delta_j^h} (q_{ij}^h)^2 di \right] \quad (1)$$

where  $q_{ij}^h > 0$  is the consumed quantity of good  $i$  produced in sector  $j$  and available in country  $h$ .

- ▶ Each of  $L^h > 0$  individuals in market  $h$  maximises  $U^h$  subject to the budget constraint:

$$\sum_{j \in J} \int_{i \in \Delta_j^h} p_{ij}^h q_{ij}^h di = M^h \quad (2)$$

- ▶ The choke price (driving optimal consumption to zero) in industry  $j$ , country  $h$  for a quality level  $z$  is then given by:

$$\hat{p}_j^h(z) = \frac{\alpha_j + \beta_j z}{\lambda^h} \quad (3)$$

where  $\lambda^h$  is the Lagrange multiplier of the consumer problem in country  $h$ .

- ▶ **Aggregate demand** in country  $h$  for a variety of good in sector  $j$  with quality  $z$  is given by:

$$q_j^{*h}(p, \hat{p}_j^h; z) = L^h \left( \frac{\lambda^h}{\gamma_j} (\hat{p}_j^h - p) + \frac{\beta_j}{\gamma_j} z \right) \quad (4)$$

where  $\beta_j/\gamma_j$  is the sector-specific taste for quality relative to variety.

- ▶ Total cost for a firm producing in country  $h$  sector  $j$ :

$$C_j^h(q, z; c) = w_u^h \left[ (\omega^h)^{\sigma_q^h} c q + (\omega^h)^{\sigma_z^h} \theta^h z^2 \right] \quad (5)$$

- ▶ where  $\omega^h = w_s^h / w_u^h$  is the wage skill premium in country  $h$ .
- ▶  $c > 0$  is a firm idiosyncratic technological coefficient describing the conversion rate of labor in units of output,
- ▶  $\theta^h > 0$  is a country-specific coefficient describing the exogenous cost of gathering new ideas in country  $h$ .

- Optimal quantity, quality, and price of goods produced and sold domestically by a firm of sector  $j$  with inverse productivity  $c$ , and cost cutoff  $c_{jD}^h$ :

$$q_j^h(c) = \frac{L^h}{2\gamma_j} (\lambda^h + \Omega_j^h) w_u^h(\omega^h)^{\sigma_q^h} (c_{jD}^h - c)$$

$$\beta_j z_j^h(c) = \Omega_j^h w_u^h(\omega^h)^{\sigma_q^h} (c_{jD}^h - c)$$

$$\text{where } \Omega_j^h = \frac{L^h \vartheta_j \lambda^h}{4\lambda^h w_u^h(\omega^h)^{\sigma_z^h} \theta^h - L^h \vartheta_j^2} \text{ and } \vartheta_j = \frac{\beta_j^2}{\gamma_j}$$

$$p_j^h(c) = \frac{1}{2} w_u^h(\omega^h)^{\sigma_q^h} (c_{jD}^h + c) + \frac{1}{2\lambda^h} w_u^h(\omega^h)^{\sigma_q^h} \Omega_j^h (c_{jD}^h - c)$$

$$\hat{p}_j^h = w_u^h(\omega^h)^{\sigma_q^h} c_{jD}^h$$

- ▶ System of  $J \times \{H = 1\}$  **Free Entry conditions** → cost cutoff  $c_{jD}^h$ :

$$f_E^h = \frac{(c_{jD}^h)^2}{\gamma_j} \left( \frac{c_{jD}^h}{\bar{c}_j^h} \right)^{k_j} \left[ \frac{L^h}{4} (\lambda^h + \Omega_j^h) (w_u^h (\omega^h)^{\sigma_q^h})^2 \left( 1 + \frac{k_j}{k_j + 2} - 2 \frac{k_j}{k_j + 1} \right) \right]$$

- ▶  $J \times \{H = 1\}$  **Output Market Clearing conditions** → mass of entrant firms ( $N_j^h$ )
- ▶ **Labor Market Clearing** → wage ( $w_u^h, w_s^h$ )

- Optimal quantity and quality of goods shipped to country  $f$  produced in country  $h$  by a firm of sector  $j$  with inverse productivity  $c$ , and the corresponding cost cutoff in the destination market:

$$q_j^{hf}(c) = \frac{L^f}{2\gamma_j} (\lambda^f + \tilde{\Omega}_j^{hf}) (\omega_q^f c_{jD}^f - \tau_j^{hf} \omega_q^h c) \quad (6)$$

$$z_j^{hf}(c) = \tilde{\Omega}_j^{hf} (\omega_q^f c_{jD}^f - \tau_j^{hf} \omega_q^h c) \quad (7)$$

where  $\tilde{\Omega}_j^{hf} = \frac{L^f \lambda^f \vartheta_j}{4\lambda^f \tau_j^{hf} \omega_z^h \theta^h - L^f \vartheta_j}$  and  $w_u^h (\omega^h)^{\sigma_q^h} = \omega_q^h$ ,  $w_u^h (\omega^h)^{\sigma_z^h} = \omega_z^h$ .

$\rightarrow \tilde{\Omega}_j^{hf}$  shows how rewarding the production of quality is (higher  $\vartheta$ ) as opposed to how costly that is (higher  $\theta$ ).

- Optimal pricing rule for a firm in sector  $j$  selling  $q > 0$  units of quality  $z$  to market  $f$ :

$$p_j^{hf}(c) = \frac{1}{2} (\omega_q^f c_{jD}^f + \tau_j^{hf} \omega_q^h c) + \frac{1}{2\lambda^f} \tilde{\Omega}_j^{hf} (\omega_q^f c_{jD}^f - \tau_j^{hf} \omega_q^h c) \quad (8)$$

- ▶ Among firms producing in country  $h$  sector  $j$  only those endowed with a cost coefficient  $c \leq c_{jX}^{hf}$  will export to market  $f$ , where the export cost cutoff is given by:

$$c_{jX}^{hf} = \frac{1}{\tau_j^{hf}} \left( \frac{\omega^f}{\omega^h} \right)^{\sigma_q^h} c_{jD}^f \quad (9)$$

## Firm Behaviour in Open Economy

- ▶ Recall that  $\tilde{\Omega}_j^{hf} = \frac{L^f \lambda^f \vartheta_j}{4\lambda^f \tau_j^{hf} \omega_2^h \theta^h - L^f \vartheta_j}$ .
- ▶ Then, we can express all optimal values in terms of cost, scope for innovation, and skill premia:

$$q_j^{*hf}(c) = \frac{L^f}{2\gamma_j} \tau_j^{hf} (\lambda^f + \tilde{\Omega}_j^{hf}) \omega_q^h (c_{jX}^{hf} - c) \quad (10)$$

$$z_j^{*hf}(c) = \tau_j^{hf} \tilde{\Omega}_j^{hf} \omega_q^h (c_{jX}^{hf} - c) \quad (11)$$

$$p_j^{*hf}(c) = \frac{1}{2} \tau_j^{hf} \omega_q^h (c_{jX}^{hf} + c) + \frac{1}{2\lambda^f} \tau_j^{hf} \tilde{\Omega}_j^{hf} \omega_q^h (c_{jX}^{hf} - c) \quad (12)$$

$$\Pi_j^{*hf}(c) = \frac{L^f}{4\gamma_j} (\lambda^f + \tilde{\Omega}_j^{hf}) \left[ \tau_j^{hf} \omega_q^h (c_{jX}^{hf} - c) \right]^2 \quad (13)$$

System of equations defining equilibrium state in open economy:

- ▶  $J \times H$  country-sector specific cost cutoffs ( $c_{jD}^f$ ) - **Free Entry conditions:**

$$\sum_{f=1}^H \mathbb{L}_j^f \left[ \lambda^f + \tilde{\Omega}_j^{hf} \right] (\tau_j^{hf})^{-k_j} (c_{jD}^f)^{k+2} = f_E^h (\omega_q^h \bar{c}_j^h)^{k_j} \quad (14)$$

- ▶  $J \times H$  country-sector specific masses of entrant firms ( $N_j^h$ ) - **Output Market Clearing conditions**
- ▶  $2 \times H - 1$  country-specific wages ( $w_u^h, w_s^h$ ) - **Labor Market Clearing conditions**
- ▶  $\tilde{\Omega}_j^{hf}$  adds to the role of trade cost (pro-competitive effect due to quality), and given wages:

$$\tilde{\Omega}_j^{hf} = f(\underbrace{\theta^h}_{\ominus}, \underbrace{\vartheta_j}_{\oplus}, \underbrace{\tau_j^{hf}}_{\ominus}, \underbrace{\lambda^f}_{\ominus}, \underbrace{L^f}_{\oplus}) \quad (15)$$

*Key distinctive implications from the model to be tested in the data*

The scope for quality upgrading  $\tilde{\Omega}_j^{hf}$ :

- ▶ decreases in country of origin cost for innovation ( $\theta^h$ ),
- ▶ increases in destination market size ( $L^f$ ),
- ▶ increases in sector- specific taste for quality versus variety ( $\vartheta_j$ ), and
- ▶ decreases with trade costs  $\tau_j^{hf}$

- ▶ Dispersion of Pareto distribution ( $k_j$ ) - **CompNet\***
- ▶ Trade cost ( $\tau_j^{hf}$ ): Bilateral trade flows - **UN Comtrade†**
- ▶ Average sales ( $\bar{R}_j^{hf}$ ): Total revenue and total export sales per sector (NACE 2D) and country – **EU KLEMS‡**
- ▶ Wages ( $w_u^h, w_s^h$ ), level of workers' education, input cost shares ( $\sigma_q^h, \sigma_z^h$ ) - **Eurostat, National Statistical Institutes§ ¶**
- ▶ Exogenous innovation capacity ( $\theta^h$ ) - **OECD||**
- ▶ Fixed entry costs ( $f_E^h$ ) - **World Bank WDI, DB\*\***

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\*The Competitiveness Research Network, 8th Vintage Dataset, European Central Bank

†United Nations Commodity Trade Statistics Database, 2023

‡European Union analysis of capital, labor, energy, material, and service inputs, European Commission

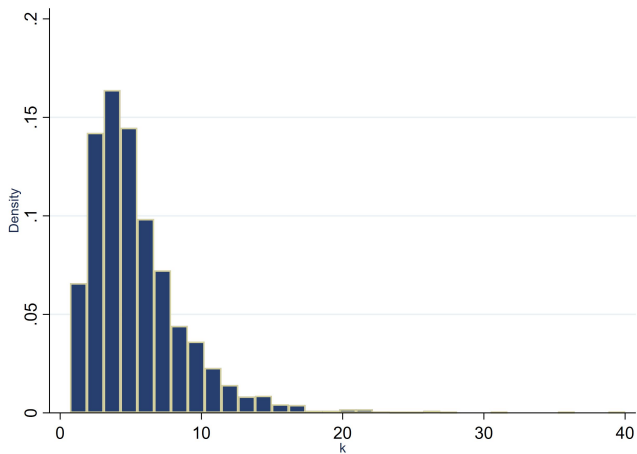
§Structure of Earnings Survey (SES), ISCED, NAD

¶European Union Statistical Office

||Organisation for Economic Co-operation and Development, Business innovation statistics and indicators; STAN

\*\*World Development Indicators, Doing Business Report; World Bank Group

- ▶ Dispersion parameter of the Pareto distribution  $k$  (productivity concentration)



# Calibration Overview

COUNTRY			
<b>Technology</b>			
$\theta^h$	Innovation capacity	Own computation (OECD)	$\theta^h \in (0, 1)$
$L_s^h$	Skilled labor force	Observed (Eurostat)	$L_s^h \in [354.6, 11512.4]$
$L_u^h$	Unskilled labor force	Observed (Eurostat)	$L_u^h \in [583.7, 27473.6]$
$l_s^h$	Skilled labor force in $Q$	Own computation (Eurostat)	$l_s^h \in [347.7, 11071.8]$
$l_u^h$	Unskilled labor force in $Q$	Own computation (Eurostat)	$l_u^h \in [579.8, 11512.4]$
$\ell_s^h$	Skilled labor force in $Z$	Own computation (Eurostat)	$\ell_s^h \in [6.9, 471.2]$
$\ell_u^h$	Unskilled labor force in $Z$	Own computation (Eurostat)	$\ell_u^h \in [8.6, 1193.8]$
$w_s^h$	Skilled wage (med. hourly)	Observed (Eurostat)	$w_s^h \in [5.95, 43.25]$
$w_u^h$	Unskilled wage (med. hourly)	Observed (Eurostat)	$w_u^h \in [3.09, 28.8]$
$\sigma_q^h \in [0.3, 0.6]$	Share of skilled labor	Own computation (Eurostat)	$\sigma_q^h = \frac{w_s^h l_s^h}{w_s^h l_s^h + w_u^h l_u^h}$
$\bar{\sigma}_q^h = 0.45$	in $Q$ prod. cost		
$\sigma_z^h \in [0.4, 0.85]$	Share of skilled labor	Own computation (Eurostat)	$\sigma_z^h = \frac{w_s^h \ell_s^h}{w_s^h \ell_s^h + w_u^h \ell_u^h}$
$\bar{\sigma}_z^h = 0.6$	in $Z$ prod. cost		
$f_E^h$	Fixed entry cost	Own computation (Eurostat)	$f_E^h \in [1.4, 1.7]$
SECTOR			
<b>Preferences</b>			
$\vartheta_j$	Taste for quality versus variety	Own estimation (domestic sales)	$\vartheta_j = \frac{\beta_j^2}{\gamma_j}$
<b>Productivity</b>			
$k_j$	Pareto distribution disp.	Own computation (CompNet)	$k_j = \frac{\ln(p_j)}{\ln(1 - \frac{\sqrt{r_{pj}}}{\sqrt{r_{99j}}})}$
COUNTRY-SECTOR			
<b>Trade cost</b>			
$\tau_j^{hf}$	Bilateral trade cost	Own estimation (UN Comtrade)	Gravity
<b>(Inv.) Productivity</b>			
$\bar{c}_j^h$	Upper bnd of cost distr.	Own estimation	Gravity

- ▶ We identify the interplay between consumers' preferences for quality vs variety ( $\beta_j/\gamma_j$ ) and country-specific characteristics that favor quality upgrading ( $\theta^h$ ) in the firm endogenous quality choice.
- ▶ Skill intensity is a first order determinant of quality upgrading, together with taste of the destination market and innovative environment where production takes place.
- ▶ Observing skill wage premium at the country level and trade flows at the country-pair-sector level, we can use this model to quantify the effect of trade integration on the production of quality.