GLOBAL SOURCING AND DOMESTIC VALUE-ADDED IN EXPORTS

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Preliminary Only.
Downward Trend in Domestic Value Added in Exports across the World

Source: Johnson and Noguera (2014)
China has recently defied the global trend

Misguided Policies?

• “The main drive is for countries to move up the value chain and become more specialised in knowledge-intensive, high value-added activities.” (OECD, 2007)

• “Moving toward a more upstream position in production and raising economic complexity are associated with a growing share of GVC value added captured by countries.” (IMF 2015)
What we do

- What contributes to a country’s domestic content in exports, or its domestic value added ratio in exports (DVAR)?

- Build a multiple-sector Eaton-Kortum model with domestic and global input-output linkages (a la Caliendo-Parro) to quantify the determinants of individual countries’ DVAR.

- Use the calibrated version of our model and the World Input-Output Database (WIOD) over 1995-2008 to fully decompose the changes in a country’s and global DVAR due to (exogenous) changes in
  - Technology ($T$);
  - Trade costs ($\tau$);
  - Other exogenous factors (factor endowments, trade imbalance)
  - (Endogenous) primary factor costs ($w$ and $r$).
Related Literature

• Models of fragmentation
  – Baldwin (2006), Baldwin and Venables (2013); EK (2002); Alvarez and Lucas (2007); Yi (2003; 2010); Antras and Chor (2017)

• The measurement of global value chains.

• Bridging the two literatures
  – Antras and Chor (2017); Antras and de Gortari (2017); Johnson and Noguera (2017); Fally and Hillberry (2018); de Gortari (2018)
Model

- $N$ countries; each country has potentially time-varying labor and capital endowments.
- $J$ sectors. Output used as both final goods and intermediate inputs (with input-output linkages) anywhere.
- All countries have the capability to produce all intermediates and final goods.
- International trade is costly, and is country-pair-sector-pair specific.
- Markets are perfectly competitive.
- Basically Caliendo-Parro (2015) with more flexible trade frictions.
Aggregates of Varieties

- In each country, the representative household aims to maximize the following utility function

\[
U = \prod_{i=1}^{J} \left\{ \left[ \int_{0}^{1} \left( q^i(\omega) \right) \right]^{\frac{\sigma^i}{\sigma^i-1}} d\omega \right\}^{\alpha^i}, \quad \text{with} \quad \sum_{i=1}^{J} \alpha^i = 1.
\]

- \( q^i(\omega) \) stands for consumption of final good \( i \) of variety \( \omega \).

- The production function of variety \( \omega \) of sector \( i \) in country \( n \) is given by

\[
y^i_n(\omega) = z^i_n(\omega) \left[ M^i_n(\omega) \right]^{1-\beta^i} \left[ l^i_n(\omega) \right]^{\mu^i} \left[ k^i_n(\omega) \right]^{(1-\mu^i)}
\]

where \( z^i_n(\omega) \) the efficiency of country \( n \) in producing variety \( \omega \) of sector \( i \).

- Production function of intermediate composite \( M^i_n \) (sector \( i \) and country \( n \)):

\[
M^i_n = \prod_{k=1}^{J} \left\{ \left[ \int_{0}^{1} \left( q^k(\omega) \right) \right]^{\frac{\sigma^k}{\sigma^k-1}} d\omega \right\}^{\gamma^i_n}, \quad \text{with} \quad \sum_{k=1}^{J} \gamma^i_n = 1.
\]
$q^k(\omega)$ is the quantity of sector-$k$ intermediate input variety $\omega$
Prices of Varieties

- Iceberg trade costs: \( \tau_{mn}^{ji} > 1; j = F \) stands for final good trade costs; \( \tau_{mn}^{ji} = 1 \) for all \( i, j \).

- Competitive price of a variety:

\[
p_{nl}^{ji}(\omega) = \frac{\tau_{nl}^{ji}c_l^i}{z_l^i(\omega)} \quad \text{for all } \omega \in [0, 1],
\]

where

\[
c_l^i = \left( \frac{P_l^i}{1 - \beta_l^i} \right)^{1 - \beta_l^i} \left( \frac{w_l}{\beta_l^i \mu_l^i} \right)^{\beta_l^i \mu_l^i} \left( \frac{r_l}{\beta_l^i (1 - \mu_l^i)} \right)^{\beta_l^i (1 - \mu_l^i)}
\]

- \( P_l^i \) = the price index of \( M_l^i \), while \( w_l \) and \( r_l \) are the wage and rental cost of capital.

- A firm in sector-\( i \) and country \( l \) draws efficiency \( z_l^i \), distributed Fréchet:

\[
F \left( z_l^i < z \right) = e^{-T_l^i z^{-\theta}},
\]

where \( T_l^i \) stands for country \( l \)’s technology stock for sector \( i \).
Aggregate Prices and Trade Shares

- Perfect competition: firms in country $n$ will purchase the intermediates from the firm that offers the lowest cost across all possible source countries.

- Thanks to Fréchet distribution of $z$, the price index of intermediates in country $n$ and sector $j$

$$P_n^j = \gamma_n^j \prod_{i=1}^J (P_n^{ji})^{\gamma_n^{ji}} = \gamma_n^j \prod_{i=1}^J (\Phi_n^{ji})^{-\frac{\gamma_n^{ji}}{\theta}} ,$$

where $\gamma_n^j = \prod_{i=1}^J (\gamma_n^{ii})^{-\gamma_n^{ii}}$ is a constant and

$$\Phi_n^{ji} = \sum_l T_l^i \left(c_i^l \tau_{nl}^{ji}\right)^{-\theta} .$$

- For sector-$j$ in country $n$, the cost share of intermediates $i$ from country $l$ in total costs spent on intermediates $i$:

$$\pi_{nl}^{ji} = \frac{T_l^i \left(c_i^l \tau_{nl}^{ji}\right)^{-\theta}}{\Phi_n^{ji}}$$
Expressions of DVAR

• Domestic value added (DVA) in sales (domestic or exports) includes

1. DVA from foreign countries embodied in imported intermediates;

2. DVA embodied in domestically-produced intermediates;

3. Primary factors directly employed (direct DVA) — capital and labor.

• Let \( r_{mn}^i = \text{VAR (value-added ratio)} \) of country \( n \) embodied in country \( m \)'s production of sector-\( i \) goods:

\[
r_{nn}^i = \beta_n^i + (1 - \beta_n^i) \sum_{h=1}^{N} \sum_{k=1}^{J} \pi_{nh}^i \gamma_n^i r_{hn}^k
\]

and

\[
r_{mn}^i = (1 - \beta_m^i) \sum_{h=1}^{N} \sum_{k=1}^{J} \pi_{mh}^i \gamma_m^i r_{hn}^k \quad \text{for} \ m \neq n
\]
Expressions of DVAR in Matrix Form

• In matrix form:

\[ \mathbf{r} = \mathbf{r}^i_{mn} = \beta + (\mathbf{I} - \mathbf{B}) \mathbf{G} \mathbf{r} \]

\[ \Rightarrow \mathbf{r} = [\mathbf{I} - (\mathbf{I} - \mathbf{B}) \mathbf{G}]^{-1} \beta \]

where \( \mathbf{r} \) is a \( NJ \times N \) matrix of VAR of country \( n \)

• \( \mathbf{B} \) is the \( NJ \times NJ \) value-added share matrix with the diagonal element being \( \beta^i_n \) \((n = 1, ..., N; \ i = 1, ..., \ J)\), and other elements being zero.

• \( \mathbf{G} = [\pi^{ik}_{nm} \gamma^{ik}_{n}] \) is the \( NJ \times NJ \) global intermediate goods cost share matrix.

• \( \beta = [\beta^i_n I_{mn}] \) is a \( NJ \times N \) matrix (stacking up \( J \) number \( N \times N \) matrixes each with element \( \beta^i_n \) when \( m = n \) and 0 otherwise). \((I_{mn} \) is an indicator function equal 1 when \( m = n \) and 0 otherwise).
Decomposition of DVAR

• Recall that the DVAR matrix \( \mathbf{r} \) satisfies

\[
\mathbf{r} = \beta + (\mathbf{I} - \mathbf{B}) \mathbf{G} \mathbf{r}
\]

• Taking total derivative yields a decomposition of the yearly changes in the DVAR:

\[
d\mathbf{r} = d\beta - (d\mathbf{B}) \mathbf{G} \mathbf{r} + (\mathbf{I} - \mathbf{B}) (d\mathbf{G}) \mathbf{r} + (\mathbf{I} - \mathbf{B}) \mathbf{G} (d\mathbf{r})
\]

\[
\Rightarrow d\mathbf{r} = \left[ \mathbf{I} - (\mathbf{I} - \mathbf{B}) \mathbf{G} \right]^{-1} [d\beta - (d\mathbf{B}) \mathbf{G} \mathbf{r}]
\]

\[
+ \left[ \mathbf{I} - (\mathbf{I} - \mathbf{B}) \mathbf{G} \right]^{-1} (\mathbf{I} - \mathbf{B}) (d\mathbf{G}) \mathbf{r}
\]

• The first term of the RHS captures the pure effect of changing \( \beta^i_n \)

• The second term captures the effect of the changes in intermediate goods shares \( \pi^{ik}_{nm} \) and input-output coefficients \( \gamma^{ik}_n \).
A 2 x 1 x 1 Toy Model

• 2 countries, with technology level $T_i$ and wage $w_i$ for country $i$, and $t = T_1/T_2$; $c = c_1/c_2$. Define $\tau_1 \equiv \tau_{12}$ and $\tau_2 \equiv \tau_{21}$.

• 1 primary factor of production (labor), one sector, and IO linkages.

• Trade Shares

$$\pi_{11} = \frac{tc^{-\theta}}{tc^{-\theta} + \tau_1^{-\theta}}, \pi_{12} = \frac{\tau_1^{-\theta}}{tc^{-\theta} + \tau_1^{-\theta}},$$

$$\pi_{22} = \frac{1}{1 + tc^{-\theta} \tau_2^{-\theta}}, \pi_{21} = \frac{tc^{-\theta} \tau_2^{-\theta}}{1 + tc^{-\theta} \tau_2^{-\theta}}.$$  

• DVAR follows

$$r_{11} = \beta + (1 - \beta) (\pi_{11} r_{11} + \pi_{12} r_{21})$$

$$r_{21} = (1 - \beta) (\pi_{21} r_{11} + \pi_{22} r_{21})$$
Partial Effect on DVAR

• Totally differentiating gives

\[ dr_{11} = (1 - \beta) (\pi_{11} dr_{11} + \pi_{12} dr_{21}) + (1 - \beta) (r_{11} - r_{21}) d\pi_{11} \]
\[ dr_{21} = (1 - \beta) (\pi_{21} dr_{11} + \pi_{22} dr_{21}) - (1 - \beta) (r_{11} - r_{21}) d\pi_{22} \]

which leads to

\[ dr_{11} = A d\pi_{11} - B d\pi_{22} \]

where \( A > B > 0 \).

• Taylor series expansion of \( d\pi_{11} \) and \( d\pi_{22} \) up to the second order derivative gives the decomposition of effects on DVAR, \( r_{11} \), due to different forces
Pure and Interactive Effects

Rearranging the terms and ignoring the second order effects on $c$, the effect on $r_{11}$ can be decomposed into

- Pure effect of technology

\[
(C + D) \frac{dt}{t} - [C\pi_{11} + D\pi_{21}] \left(\frac{dt}{t}\right)^2
\]

where $C, D > 0$.

- Pure effect of trade frictions

\[
-C \left[ \frac{d\left(\tau_{1}^{-\theta}\right)}{\tau_{1}^{-\theta}} - \pi_{12} \left(\frac{d\left(\tau_{1}^{-\theta}\right)}{\tau_{1}^{-\theta}}\right)^2 \right] + D \left[ \frac{d\left(\tau_{2}^{-\theta}\right)}{\tau_{2}^{-\theta}} - \pi_{21} \left(\frac{d\left(\tau_{2}^{-\theta}\right)}{\tau_{2}^{-\theta}}\right)^2 \right]
\]

- Interactive effect of technology and trade frictions

\[
C (\pi_{11} - \pi_{12}) \left(\frac{dt}{t}\right) \left(\frac{d\left(\tau_{1}^{-\theta}\right)}{\tau_{1}^{-\theta}}\right) + D (\pi_{22} - \pi_{21}) \left(\frac{dt}{t}\right) \left(\frac{d\left(\tau_{2}^{-\theta}\right)}{\tau_{2}^{-\theta}}\right)
\]

where $C = A\pi_{11} (1 - \pi_{11})$ and $D = B\pi_{22} (1 - \pi_{22})$
Major Source of Data
Use 2013 edition of the World Input-Output (WIOD) Database

- $J = 40$ countries + ROW
- $S = 35$ industries/sectors
- $T = 14$ years: 1995-2008
- A model to map the yearly changes in the $NJ \times NJ$ (2,059,225) global intermediate goods cost share matrix $G$ due to changes in intermediate goods shares $\pi_{nm}^{ik}$
Taking the Model to Data

• We estimate the change in competitiveness (relative to the US) using the following gravity equation, which is derived from the model:

\[
\ln \left( \frac{\pi_{ntl}^{ji}}{\pi_{nmt}^{ji}} \right) = \ln \left( T_{lt}^i (c_{lt}^i)^{-\theta} \right) - \theta e x_{lt}^i - \ln \left( T_{nt}^i (c_{nt}^i)^{-\theta} \right) - \theta v_{nlt}^{ji}
\]

• The estimated asymmetric bilateral trade costs \( \{\tau_{nl}^{ji}\} \) is obtained from the gravity estimation based on

\[
\ln \tau_{nlt}^{ji} = e x_{lt}^i + v_{nlt}^{ji}
\]

• The data are directly obtained from the WIOD table or PWT9.0 (Penn World Table).
Solving for the Equilibrium

• Following Dekle, Eaton, and Kortum (2008), we use hat algebra to characterize the equilibrium changes. \( \hat{x} = x'/x \)

• For each year, use the estimated \( \{\hat{T}_{nl}^i, (\hat{c}_i)^{-\theta}\} \) and \( \{\hat{\tau}_{nl}^{ji}\} \) as initial values. Start with a guess of \( \{\hat{w}_l\} \) and \( \{\hat{r}_l\} \), solve for \( \{\hat{c}_i\} \) and \( \{\hat{P}_i\} \) as follows:

\[
\hat{c}_i = \left( \hat{P}_i \right)^{1-\beta_i} (\hat{w}_l)^{\beta_i\mu_i} (\hat{r}_l)^{\beta_i(1-\mu_i)}
\]

\[
\hat{P}_n = \prod_{i=1}^{J} (\hat{P}_n)^{\gamma_{ji}^{ji}}
\]

\[
\hat{p}_{ji}^{ji} = \left[ \sum_{l=1}^{N} \pi_{nl}^{ji} \hat{T}_l^{ji} \left( \hat{c}_l^{ji} \hat{\tau}_{nl}^{ji} \right)^{-\theta} \right]^{-\frac{1}{\theta}}
\]

• We can thus get the changes in trade shares \( \{\hat{\pi}_{nl}^{ji}\} \), and thus the new trade shares \( \pi_{nl}^{ji'} = \pi_{nl}^{ji} \cdot \hat{\pi}_{nl}^{ji} \) from
\[ \hat{\pi}_{nl}^{ji} = \hat{T}_l^{i} \left( \frac{\hat{C}_l^{ji} \hat{T}_{nl}^{ji}}{\hat{P}_n^{ji}} \right)^{-\theta} \]
Constraints

• The total expenditure on final goods is equal to total output plus trade deficit:

\[ E'_n = w'_n L'_n + r'_n K'_n + D'_n \]

where \( D_n \) is trade deficit.

• Total production of each sector in each country \( \{ (X_n^i)' \} \)

\[ (X_n^i)' = \sum_{k=1}^{J} \sum_{m=1}^{N} (1 - \beta_m^k) \gamma_m^{ki} (\pi_{mn}^k)' (X_m^k)' + \sum_{m=1}^{N} (\pi_{mn}^{Fi})' \alpha_m E'_m \]

• Capital and labor market clearing conditions

\[ r'_n K'_n = \sum_{i=1}^{J} \beta_n^i (1 - \mu_n^i) (X_n^i)' \]
\[ w'_n L'_n = \sum_{i=1}^{J} \beta_n^i \mu_n^i (X_n^i)' \]

• We solve for \( \{ \hat{w}_l \} \) and \( \{ \hat{r}_l \} \).

• Repeat the entire process until \( \{ \hat{w}_l \} \) and \( \{ \hat{r}_l \} \) converge.
• $K'_n$, $L'_n$ and $\mu^i_n$ are directly obtained from the WIOD table of each year and PWT9.0.

• $\{\widehat{c}_l^i\}$, $\{\widehat{P}_l^i\}$, $\{\widehat{w}_l\}$, $\{\widehat{r}_l\}$ and thus $\{\widehat{T}_l^i\}$ are solved from the general equilibrium described previously.
Figure 1: Developed and Developing Countries’ DVAR
Figure 2: Fit of the Calibration.
The vertical axis is our prediction and the horizontal axis is the data. The fit is very good.
Figure 3: The Pure (Stand-alone) Effect of Changes in $\tau$.
The pure (stand-alone) effect of changes in trade costs does not fit the data very well.
Figure 4: Pure Effect of Changes in $T$.
The pure effect of changes in technology stocks also does not fit the data well.
Figure 5: Pure Effects of Changes in Other Factors (i.e. $K$, $L$ and trade balance).

The pure effect of "other factors" provides the poorest fit among the three sets of factors.
Figure 6: Counterfactuals of Shutting Down Other Factors
## Decomposition Results

- **Percentage-point Changes in DVAR (1995-2008)**

<table>
<thead>
<tr>
<th></th>
<th>Global</th>
<th>Developed</th>
<th>Developing</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Total</strong></td>
<td>-4.36</td>
<td>-4.20</td>
<td>-4.58</td>
</tr>
<tr>
<td>due to changes in</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Technology (stand-alone)</td>
<td>-2.78</td>
<td>-3.25</td>
<td>-2.28</td>
</tr>
<tr>
<td>Trade Costs (stand-alone)</td>
<td>-8.03</td>
<td>-5.84</td>
<td>-10.62</td>
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<tr>
<td>Other Factors (stand-alone)</td>
<td>0.94</td>
<td>-0.69</td>
<td>2.75</td>
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<tr>
<td>Tech * Trade Costs</td>
<td>5.79</td>
<td>4.82</td>
<td>6.99</td>
</tr>
<tr>
<td>Tech * Other Factors</td>
<td>-0.72</td>
<td>0.42</td>
<td>-1.98</td>
</tr>
<tr>
<td>Trade Costs * Other Factors</td>
<td>-0.86</td>
<td>0.41</td>
<td>-2.27</td>
</tr>
<tr>
<td><strong>All Three Forces</strong></td>
<td>1.05</td>
<td>-0.14</td>
<td>2.38</td>
</tr>
<tr>
<td><strong>Residual</strong></td>
<td>0.25</td>
<td>0.07</td>
<td>0.45</td>
</tr>
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</table>
## Total Effects

- **Percentage-point Changes in DVAR (1995-2008)**

<table>
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<th></th>
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<th>Developing</th>
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<tr>
<td><strong>Total</strong></td>
<td>-4.36</td>
<td>-4.20</td>
<td>-4.58</td>
</tr>
<tr>
<td><strong>Total effect of</strong></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Technology</td>
<td>3.34</td>
<td>1.84</td>
<td>5.11</td>
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<tr>
<td>Trade Costs</td>
<td>-2.05</td>
<td>-0.74</td>
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<tr>
<td>Other Factors</td>
<td>0.40</td>
<td>0.01</td>
<td>0.88</td>
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Figure 7: Different Pure Effects on Global DVAR
Figure 8: Effects of Interaction Terms on Global DVAR
Figure 9: Total Effects of T, τ, and Other Factors on Global DVAR
Figure 10: Total effects of $T$, $\tau$ and other factors for Developed Countries
Figure 11: Total effects of $T$, $\tau$ and other factors on Developing Countries
Figure 12: Total effects of $T$, $\tau$ and other factors on China
Figure 13: Total effects of $T$, $\tau$ and other factors on the US
Figure 14: Effects of Shutting Down Changes in China’s T on China’s DVAR
Figure 15: Effects of Shutting Down Changes in China’s $\tau$ on China’s DVAR
Figure 16: Effects of Shutting Down Changes in China’s Capital on China’s DVAR
Figure 17: Effects of Shutting Down Changes in China’s Technology on ROW’s DVAR
Figure 18: Effects of Shutting Down Changes in China’s $\tau$ on ROW’s DVAR
Figure 19: Effects of Shutting Down Changes in China’s T on US’s DVAR
Figure 20: Effects of Shutting Down Changes in China’s $\tau$ on US’s DVAR
Conclusion

• Based on a multi-sector EK model with domestic and global input-output linkages, we quantify the contributions of different factors to the changes in individual countries’ and global DVAR (1995-2008)

• In addition to trade frictions, emphasize the importance of the positive effect of technology on countries’ and global DVAR.

• The contribution of other exogenous factors (factor endowment, trade imbalance) are small.

• Fast-growing countries, like China, which experienced a substantial improvement in technology, despite falling trade frictions, could have DVAR increasing over time.
Fast Growing Countries’ DVAR

Developed Countries’ (OECD) DVAR
Graphs by origin_country