Characterizing Global Value Chains

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Presentation outline

► Motivations

► Measures of GVC Length, Position and Participation
  ▪ Decompose GDP by industry to identify GVC related and unrelated value-added production activities
  ▪ Intuition behind the derivation of these indexes
  ▪ Are production length measure and production line position the same?

► Estimation Results
  ▪ Has GVC become longer or shorter over time?
  ▪ Why these new GVC Indexes are better?
  ▪ Can these new indexes help to quantify the roles of GVC in the economic shocks of recent global financial crisis

► Conclusion
Motivation

The gross trade accounting framework developed by Koopman, Wang, and Wei (2014) (extended by Wang, Wei and Zhu (2013)) provided measures for cross border production sharing and double counting in gross trade, but their accounting excise does not study the determinants and consequences of production sharing and double counting.

To make such decomposition useful for economic analysis, an important step is to construct various indexes that can measure a country/sector pair’s position and participation in GVCs and econometrically studying the determinates of these indexes over time as guided by economic theory. The GVC production length, position and participation indexes proposed in this paper are part of our efforts in this direction.
Motivations

- Provide a multi dimensional index system that can better characterize GVCs from different perspective and can be used by both theoretical and empirical economists in advancing studies of global supply chain in economics and building bridges between sequential supply chain models based on economic theories and empirical GVC measurement based on accounting excises;

- To better understand what type production and trade activities are closely related to GVC, what are not.
VAX(J&N) = 2 + 3a + 3c =
Production for foreign demand;
DVA(KWW) = 2 + 3 = GDP in exports;
1 + 3b = Production for domestic demand.

Decomposition of GDP by industries

0 border cross

In production of final products to domestic market directly
1-DVA_D

In production of direct value added exports
2-DVA_RT

In production of GVC (indirect) value-added exports
3-DVA_GVC

At least cross border twice

Cross border

Only once

In final product exports
2a-DVA_FIN

In intermediates directly absorbed by direct importers
2b-DVA_INT_RT

In intermediates indirectly absorbed by direct importers
3a-DVA_GVC_r

In intermediates that finally return to home countries
3b-DVA_GVC_s

In intermediates re-exported to third countries
3c-DVA_GVC_t

Deeper cross country production sharing
Different Effects of the Same Economic Shock to Different Value Added Creating Activities

- Pure domestic production activities were least affected.
- GVC production and trade activities were mostly affected.
- GVC production and trade activities had the fastest after-crisis-recovery.

![Bar chart showing growth rates for Pure Domestic, Direct VA, and GVC activities from 2008 to 2011.](image-url)
Decomposition of Output: Based on Leontief Equation

- Decomposition equation

\[
\begin{bmatrix}
X^{ss} & X^{sr} \\
X^{rs} & X^{rr}
\end{bmatrix} =
\begin{bmatrix}
B^{ss} & B^{sr} \\
B^{rs} & B^{rr}
\end{bmatrix}
\begin{bmatrix}
Y^{ss} & Y^{sr} \\
Y^{rs} & Y^{rr}
\end{bmatrix} =
\begin{bmatrix}
B^{ss}Y^{ss} + B^{sr}Y^{rs} & B^{ss}Y^{sr} + B^{sr}Y^{rr} \\
B^{rs}Y^{ss} + B^{rr}Y^{rs} & B^{rs}Y^{sr} + B^{rr}Y^{rr}
\end{bmatrix}
\]

- Row: The output produced by Country s

\[X^s = X^{ss} + X^{sr} = B^{ss}Y^{ss} + B^{sr}Y^{rs} + B^{ss}Y^{sr} + B^{sr}Y^{rr}\]

- Column: The output induced by Country s’ final demand

\[X^{sT} = X^{ss} + X^{rs} = B^{ss}Y^{ss} + B^{sr}Y^{rs} + B^{rs}Y^{ss} + B^{rr}Y^{rs}\]
Start from the row balance condition of ICIO table, we decompose GDP by industry for each country based on forward inter-industry, cross-country linkage:

\[ X^s = B^{ss} Y^{ss} + B^{ss} \sum_{r \neq s}^M Y^{sr} + \sum_{r \neq s}^M B^{sr} Y^{rs} + \sum_{r \neq s}^M B^{sr} \sum_{t \neq s}^M Y^{rt} \]

\[ = L^{ss} Y^{ss} + L^{ss} \sum_{r \neq s}^M Y^{sr} + L^{ss} \sum_{r \neq s}^M A^{sr} \sum_{u}^M B^{ru} \sum_{t}^M Y^{ut} \]

\[ V_a^s = \hat{V}^s X^s = \hat{V}^s L^{ss} Y^{ss} + \hat{V}^s L^{ss} \sum_{r \neq s}^M Y^{sr} + \hat{V}^s L^{ss} \sum_{r \neq s}^M A^{sr} \sum_{u}^M B^{ru} \sum_{t}^M Y^{ut} \]

\[ = \hat{V}^s L^{ss} Y^{ss} + \hat{V}^s L^{ss} \sum_{r \neq s}^M (Y^{sr} + A^{sr} L^{rr} Y^{rr}) + \hat{V}^s L^{ss} \sum_{r \neq s}^M A^{sr} \sum_{u}^M B^{ru} \sum_{t}^M Y^{ut} - \hat{V}^s L^{ss} \sum_{r \neq s}^M A^{sr} L^{rr} Y^{rr} \]

\[ = \hat{V}^s L^{ss} Y^{ss} + \hat{V}^s L^{ss} \sum_{r \neq s}^M (Y^{sr} + A^{sr} L^{rr} Y^{rr}) + \hat{V}^s L^{ss} \sum_{r \neq s}^M A^{sr} \left( \sum_{u}^M B^{ru} Y^{ur} - L^{rr} Y^{rr} \right) \]

\[ + \hat{V}^s L^{ss} \sum_{r \neq s}^M A^{sr} \sum_{u}^M B^{ru} Y^{us} + \hat{V}^s L^{ss} \sum_{r \neq s}^M A^{sr} \sum_{u}^M B^{ru} \sum_{t \neq s, r}^M Y^{ut} \]

\[ (3b-\text{DVA}_GVC_{s=RDV_F}) \quad (3c-\text{DVA}_GVC_{t}) \]
The intuition and derivation of production length in sequential production process

DVA generated in the sequential production process and its length:

first stage: directly embodied in final products that are exported and consumed abroad. Measured as: $\hat{V}^s Y^{sr}$ DPL = 1; FPL = 0.

Second stage: first embodied in its gross output that is used as intermediate input either by country s or other countries (through exports) in the production of final products. Measured as: $\hat{V}^s A^{ss} Y^{sr} + \hat{V}^s A^{sr} \sum_{t} Y^{rt}$ first part: DPL = 2; FPL = 0; second part: DPL = 1; FPL = 1;

Third stage: indirectly embodied in the final products produced from the third stage and consumed in all possible destination counties. Measured as:

$$\hat{V}^s A^{ss} Y^{sr} + \hat{V}^s A^{sr} \sum_{t} Y^{rt} + \hat{V}^s A^{sp} \sum_{u} A^{ru} \sum_{t} Y^{ut}$$

First part: DPL = 3; FPL = 0; second part: DPL = 2; FPL = 1; Third part: DPL = 1; FPL = 2

Multiply DVA with its production length

$X_{vd} = 3\hat{V}^s A^{ss} Y^{sr} + 2\hat{V}^s A^{sr} \sum_{t} Y^{rt} + \hat{V}^s A^{sp} \sum_{u} A^{ru} \sum_{t} Y^{ut}$

$X_{vf} = \hat{V}^s A^{ss} A^{sp} \sum_{t} Y^{rt} + 2\hat{V}^s A^{sr} \sum_{u} A^{ru} \sum_{t} Y^{ut}$
Forward Linkage based production length index system

Average production length of each term is defined as:
Total gross outputs induced by one unit of value added created in the economy
Forward Linkage based GVC participation index

In intermediates indirectly absorbed by direct importers
2b-DVA_INT_RT

GVC participation index = \( \frac{DVA_{-}GVC_{i}^{r}}{GDP_{i}^{r}} \)

\[ 3a : DVA_{-}GVC_{i}^{r} \quad s + 3b : DVA_{-}GVC_{i}^{r} \quad r + 3c : DVA_{-}GVC_{i}^{r} \quad t \]

In intermediates re-exported to third countries
3c-DVA_GVC_t

In intermediates that finally return to home countries
3b.DVA_GVC_s=RDV_F

GDP

A country/sector’s total value-added (GDP by industry)
Decompose final consumption by country/sector

- Consumption of final products by country/sector
  - Domestic VA via domestic market directly
    - 1-FDY_D
  - Trade partner’s VA directly consumed in domestic market
    - 2-FDY_RT
  - Domestic and Foreign VA indirectly consumed in domestic market
    - 3-FDY_GVC
      - In final product imports
        - 2a-FDY_RT_f
      - In intermediate imports
        - 2b-FDY_RT_i
      - Trade partner’s VA in intermediate imports
        - 3a. FDY_GVC_r
      - Domestic VA in intermediates that returns
        - 3b. FDY_GVC_s
      - Other countries’ VA in intermediate imports
        - 3c. FDY_GVC_t
Backward Linkage based production length

Start from the column balance condition of ICIO table, we can decompose final product consumed by each country:

\[
X^s = B^{ss} Y^{ss} + \sum_{r \neq s} M B^{sr} Y^{rs} + \sum_{r \neq s} M B^{rs} Y^{ss} + \sum_{r \neq s} M B^{rr} Y^{rs} = L^{ss} Y^{ss} + \sum_{r \neq s} M L^{sr} Y^{rs} + \sum_{r \neq s} M L^{rt} \sum_{u \neq r} M A^{ru} \sum_{t} M B^{ut} Y^{ts}
\]  

(3)

\[
Y_i^s = \sum_{r} M V^r X_i^r = V^s L^{ss} Y_i^{ss} + \sum_{r \neq s} M V^r L^{sr} Y_i^{rs} + \sum_{r \neq s} M V^r L^{rt} \sum_{u \neq r} M A^{ru} \sum_{t} M B^{ut} Y_i^{ts}
\]

(4)

Average production length for each term can be defined as:
Total gross outputs induced by one unit of final products consumed
Can production length measure directly infer production line position?

- Production lengths based on forward and backward linkage are equal each other at the global level because the accounting identity of global final demand always sums to global value-added. However, they may not equal each other at the country or country/sector level due to international trade and cross-border production activities.

- What is the relation between production length measure and production line position? Can production length measure be used directly to infer “upstreamness” or “downstreamness” of a country or a country/sector pair? Current literature is not clear on such important questions and often uses production length to infer production line position directly.
Measure of production line position
(work in progress)

- GVC production lines not only have a starting and an ending stage, they usually involve at least one and often many additional middle stages because value-added in GVC cross national borders at least twice.

- Consider a GVC starting from primary input (value-added) at sector $i$ of country $s$, embodied in its intermediate exports used by sector $j$ of country $r$, but finally absorbed by final product of sector $k$ consumed at country $t$, in math term:

$$
\begin{align*}
V_i^s B_{ij}^sr Y_j^r & \quad \text{final exports} \\
V_i^s B_{ij}^sr \sum_{u \neq r} G A_{jr}^ru \sum_{v} G B_{jv}^lv Y_k^vt & \quad \text{intermediate exports}
\end{align*}
$$

\[
\begin{bmatrix}
V_i^s & B_{ij}^sr \\
0 & V_i^s
\end{bmatrix}
= \begin{bmatrix}
\cdot & 0 & 0 \\
0 & v_i^s & 0 \\
0 & 0 & \cdot
\end{bmatrix}
\quad
\begin{bmatrix}
A_{jr}^ru & B_{jv}^lv \\
0 & a_{jr}^ru & \cdots & a_{jr}^nu
\end{bmatrix}
= \begin{bmatrix}
0 & \cdots & 0 \\
0 & a_{jr}^ru & \cdots & a_{jr}^nu
\end{bmatrix}
\quad
\begin{bmatrix}
B_{jr}^rv & B_{jr}^ru \\
0 & b_{jr}^rv & \cdots & b_{jr}^ru
\end{bmatrix}
= \begin{bmatrix}
0 & \cdots & 0 \\
0 & b_{jr}^rv & \cdots & b_{jr}^ru
\end{bmatrix}
\quad
Y_k^vt = \begin{bmatrix}
y_k^vt \\
0
\end{bmatrix}
\]
Cost push gross output:

\[
X_{ik}^{st} - GVC_j = \begin{cases} 
V_i^s \sum_u^G B_{i,u}^s B_{j,u}^r Y_j^t \\
V_i^s \sum_w^G B_{i,w}^s B_{j,w}^r \sum_{t \neq r}^G A_{j,t}^r \sum_v^G B_{k,v}^w Y_{k,v}^t
\end{cases}
\]

Summing over \(s, i, t,\) and \(k\), we can obtain the product of the value-added and production length backward from \((r,j)\) to all \((s,i)\) as:

\[
X_{ij}^{r} = \sum_s^M V_i^s \sum_u^G B_{i,u}^s B_{j,u}^r \sum_{t \neq r}^M Y_j^t + \sum_s^M V_i^s \sum_w^G B_{i,w}^s B_{j,w}^r \sum_{t \neq r}^G A_{j,t}^r \sum_v^G B_{k,v}^w \sum_t^M Y_{k,v}^t
\]

Final demand driven gross output:

\[
X_{ij}^{st} - GVC_j = \begin{cases} 
0 \\
V_i^s B_{i,j}^{sr} \sum_{t \neq r}^G A_{j,t}^r \sum_w^G B_{k,w}^w \sum_v^G B_{k,v}^w Y_{k,v}^t
\end{cases}
\]

Summing over \(s, i, t,\) and \(k\), we can obtain the product of the value-added and production length forward from \((r,j)\) to all \((t,k)\) as:

\[
X_{ij}^{r} = \sum_{s \neq r}^M V_i^s B_{i,j}^{sr} \sum_{t \neq r}^G A_{j,t}^r \sum_w^G B_{k,w}^w \sum_v^G B_{k,v}^w \sum_t^M Y_{k,v}^t
\]
GVC position index
(work in progress)

As a special node \((j,r)\) in a particular GVC, the closer it is to value-added crossing national borders that it used as input, the smaller the gross output it can induce; in the other hand, the closer it is to these final products that use its value-added as source, the smaller the gross output it is able to push out. Therefore, its average production line position can be defined as:

\[
GVC - P^r_j = \frac{Xy'_j}{Xy'_j + Xv'_j}
\]

This index is bounded by one. The larger the index, the more upstream is the country/pair. Importantly, under our definitions, the upstreamness and downstreamness of a given country sector are really the same thing, thus overcoming the inconsistency of the production position indexes used in the literature.
Two important differences of the new GVC position index from the up- and down-streamness indexes used in literature

- **Relative vs absolute production length as the measure of production line position**: We recognize GVC position index is a relative measure. If a country/sector pair participant GVC in a particular production stage, the more production stages occurring before the stage it engages, the relative more downstream the country/sector pair’s position in the particular GVC. While position indexes used in the literature, such as the N* and D* indexes proposed by Fally (2012) and the Down measure proposed by Atras and Chor (2013), all use absolute production length directly to infer production line position.

- **We consider only cross border production lines, while existing index does not distinguish domestic and cross border productions.**
Estimation Results: Production Length Index (1)
Electrical and optical equipment, China and the US, 2011
Using US as an example, compare the value added flows from US to Canada, Australia, and Russia, the value added imported by East Asian economies (such as China, Korea, and Taiwan) from US has to go through more production stages outside the US to reach the final consumers.

Average Length in the International Portion for Value Added Created by the US Electrical Equipment Sector, 2011

<table>
<thead>
<tr>
<th>Direct Importers</th>
<th>Length in International Production Portion</th>
</tr>
</thead>
<tbody>
<tr>
<td>TWN</td>
<td>2.403</td>
</tr>
<tr>
<td>KOR</td>
<td>2.219</td>
</tr>
<tr>
<td>CHN</td>
<td>1.953</td>
</tr>
<tr>
<td>CAN</td>
<td>0.815</td>
</tr>
<tr>
<td>AUS</td>
<td>0.813</td>
</tr>
<tr>
<td>RUS</td>
<td>0.806</td>
</tr>
</tbody>
</table>
Has the length of Global Value Chains become longer or shorter over time(1)?

- The world average “Total Production Length” shows a clearly upward trend, especially after year 2002 (this trend was temporarily interrupted by the global financial crisis during 2008 to 2009).
- Furthermore, the average production length of GVCs has increased by 0.36 from 2002 to 2011, which is much faster than the direct value-added exports and pure domestic production length.
Which part drives the lengthening of GVC production lines

- The increasing length of GVCs is primarily driven by the rapid growth of its international portion.
Has the length of Global Value Chains become longer or shorter over time (2)?

**Country level results**

The average GVC production length, especially its international portion, has increased considerably for all countries over this period; The same results can be found at the sectoral level.
During 1995–2011, as covered by WIOD data, China is the country closest to the final consumption end all the times, while Russia and Australia is always positioned on the most upstream side.

Both East Asian Economies (JPN, KOR, CHN, TWN, etc) and economies abundant in natural resources (RUS, AUS, FIN, etc.) are involved in relatively longer value chains.

<table>
<thead>
<tr>
<th>Country</th>
<th>Position Index</th>
<th>Average Length of Value Chains that it Engages in</th>
</tr>
</thead>
<tbody>
<tr>
<td>AUS</td>
<td>0.577</td>
<td>4.756</td>
</tr>
<tr>
<td>RUS</td>
<td>0.553</td>
<td>4.369</td>
</tr>
<tr>
<td>TWN</td>
<td>0.411</td>
<td>4.892</td>
</tr>
<tr>
<td>CAN</td>
<td>0.408</td>
<td>3.835</td>
</tr>
<tr>
<td>FIN</td>
<td>0.397</td>
<td>4.325</td>
</tr>
<tr>
<td>USA</td>
<td>0.371</td>
<td>3.648</td>
</tr>
<tr>
<td>JPN</td>
<td>0.363</td>
<td>4.371</td>
</tr>
<tr>
<td>GBR</td>
<td>0.360</td>
<td>3.543</td>
</tr>
<tr>
<td>MEX</td>
<td>0.349</td>
<td>3.618</td>
</tr>
<tr>
<td>KOR</td>
<td>0.344</td>
<td>4.797</td>
</tr>
<tr>
<td>DEU</td>
<td>0.342</td>
<td>3.743</td>
</tr>
<tr>
<td>ITA</td>
<td>0.306</td>
<td>3.795</td>
</tr>
<tr>
<td>FRA</td>
<td>0.298</td>
<td>3.905</td>
</tr>
<tr>
<td>IND</td>
<td>0.291</td>
<td>3.671</td>
</tr>
<tr>
<td>CHN</td>
<td>0.237</td>
<td>4.492</td>
</tr>
</tbody>
</table>
Furthermore, our results show that the GVC position for a certain sector may vary considerably across countries, which reflects the differences in production stages.

<table>
<thead>
<tr>
<th>Electrical Equipment</th>
<th>Transport Equipment</th>
<th>Business Service</th>
<th>Textiles Products</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Country</strong></td>
<td><strong>Position</strong></td>
<td><strong>Country</strong></td>
<td><strong>Position</strong></td>
</tr>
<tr>
<td>USA</td>
<td>0.439</td>
<td>AUS</td>
<td>0.339</td>
</tr>
<tr>
<td>TWN</td>
<td>0.425</td>
<td>RUS</td>
<td>0.334</td>
</tr>
<tr>
<td>JPN</td>
<td>0.381</td>
<td>TWN</td>
<td>0.301</td>
</tr>
<tr>
<td>RUS</td>
<td>0.378</td>
<td>IND</td>
<td>0.263</td>
</tr>
<tr>
<td>FIN</td>
<td>0.375</td>
<td>FIN</td>
<td>0.260</td>
</tr>
<tr>
<td>KOR</td>
<td>0.365</td>
<td>GBR</td>
<td>0.244</td>
</tr>
<tr>
<td>DEU</td>
<td>0.359</td>
<td>ITA</td>
<td>0.243</td>
</tr>
<tr>
<td>ITA</td>
<td>0.339</td>
<td>USA</td>
<td>0.240</td>
</tr>
<tr>
<td>GBR</td>
<td>0.332</td>
<td>CHN</td>
<td>0.226</td>
</tr>
<tr>
<td>FRA</td>
<td>0.320</td>
<td>DEU</td>
<td>0.225</td>
</tr>
<tr>
<td>AUS</td>
<td>0.320</td>
<td>FRA</td>
<td>0.222</td>
</tr>
<tr>
<td>CAN</td>
<td>0.293</td>
<td>JPN</td>
<td>0.217</td>
</tr>
<tr>
<td>IND</td>
<td>0.285</td>
<td>MEX</td>
<td>0.197</td>
</tr>
<tr>
<td>MEX</td>
<td>0.248</td>
<td>KOR</td>
<td>0.188</td>
</tr>
<tr>
<td>CHN</td>
<td>0.227</td>
<td>CAN</td>
<td>0.148</td>
</tr>
</tbody>
</table>
Time Trend of GVC Position Index
Textiles Products
Time Trend of GVC Position Index

Electrical and Optical Equipment

[Graph showing the time trend of GVC Position Index for different countries over the years 1994 to 2012. The countries are USA, TWN, IND, and CHN, with trends indicated by different colored lines.]
There are three major shortcomings in those indexes:

- Using gross exports as the denominator. The ratio might be very high just because some sectors have very little direct exports (e.g., Mining and Service).
- Only consider export related activities, production related to domestic demand is totally excluded.
- Not able to distinguish deep and shallow participations
The GVC participation index developed in this paper has overcome the above-mentioned shortcomings and is able to better measure the degree of GVC participation as the share of total value-added production at the bilateral/sector level and can be further decomposed into three parts according to where the value added is absorbed. Such detailed GVC participation measure provide better indexes that are needed to conduct GVC related empirical analysis.

**Country Level:** Forward/Backward Linkage based Participation Indexes, 1995 to 2011
Estimation results: GVC Participation Index (2)

### Sectoral Level:

- **Agriculture sector in Finland**: the forward linkage based participation ratio is significantly higher than in other countries: Forestry is the dominant industry in Finland.

- **Russia** is the giant in energy, its mining sector’s forward linkage based participation ratio is as high as 33.8%, in significant contrast to the backward linkage based participation ratio (of only 1.7%).

- **Germany** is the global manufacturing power, so its forward and backward linkage based participation ratios for “electrical and optical equipment” and “transportation equipment” sectors are both higher than that of other countries.

### Table: Forward Linkage Based Participation Index

<table>
<thead>
<tr>
<th></th>
<th>Agriculture</th>
<th>Mining</th>
<th>Electrical Equipment</th>
<th>Transport Equipment</th>
</tr>
</thead>
<tbody>
<tr>
<td>BRA</td>
<td>6.0%</td>
<td>15.1%</td>
<td>5.0%</td>
<td>2.8%</td>
</tr>
<tr>
<td>CHN</td>
<td>2.3%</td>
<td>6.5%</td>
<td>12.1%</td>
<td>4.9%</td>
</tr>
<tr>
<td>DEU</td>
<td>7.3%</td>
<td>22.1%</td>
<td>20.3%</td>
<td>14.5%</td>
</tr>
<tr>
<td>FIN</td>
<td><strong>10.7%</strong></td>
<td>20.9%</td>
<td>18.6%</td>
<td>11.8%</td>
</tr>
<tr>
<td>IND</td>
<td>2.7%</td>
<td>21.5%</td>
<td>6.6%</td>
<td>2.8%</td>
</tr>
<tr>
<td>IDN</td>
<td>1.6%</td>
<td>9.9%</td>
<td>9.5%</td>
<td>4.2%</td>
</tr>
<tr>
<td>RUS</td>
<td>1.8%</td>
<td><strong>33.8%</strong></td>
<td>6.4%</td>
<td>4.3%</td>
</tr>
<tr>
<td>USA</td>
<td>3.4%</td>
<td>5.5%</td>
<td>12.9%</td>
<td>7.2%</td>
</tr>
</tbody>
</table>

### Table: Backward Linkage Based Participation Index

<table>
<thead>
<tr>
<th></th>
<th>Agriculture</th>
<th>Mining</th>
<th>Electrical Equipment</th>
<th>Transport Equipment</th>
</tr>
</thead>
<tbody>
<tr>
<td>BRA</td>
<td>2.4%</td>
<td>2.1%</td>
<td>8.1%</td>
<td>8.0%</td>
</tr>
<tr>
<td>CHN</td>
<td>1.7%</td>
<td>4.0%</td>
<td>21.3%</td>
<td>8.0%</td>
</tr>
<tr>
<td>DEU</td>
<td>7.9%</td>
<td>5.1%</td>
<td>24.7%</td>
<td>28.1%</td>
</tr>
<tr>
<td>FIN</td>
<td>4.4%</td>
<td>7.5%</td>
<td>28.6%</td>
<td>21.9%</td>
</tr>
<tr>
<td>IDN</td>
<td>1.4%</td>
<td>0.7%</td>
<td>13.0%</td>
<td>6.4%</td>
</tr>
<tr>
<td>IND</td>
<td>0.7%</td>
<td>1.2%</td>
<td>10.1%</td>
<td>7.7%</td>
</tr>
<tr>
<td>RUS</td>
<td>2.5%</td>
<td><strong>1.7%</strong></td>
<td>4.5%</td>
<td>11.3%</td>
</tr>
<tr>
<td>USA</td>
<td>4.1%</td>
<td>2.3%</td>
<td>6.7%</td>
<td>14.4%</td>
</tr>
</tbody>
</table>
Why do we need the new GVC Participation Index?

1). To eliminate the sectoral level bias in traditional indexes

For comparison, we use both gross exports and sector GDP as the denominator to estimate the forward linkage participation index.

- The overall level of the index value is higher when using gross exports as the denominator.
- The participation ratios for seven sectors (marked with gray background color) are substantially larger than 100%.
- These sectors have one thing in common: A great proportion of their value added is exported indirectly, which is embodied in other sectors’ exports.
## Forward Linkage Participation Index for US sectors, 2011

### Comparison between *Traditional* and *New Measures*

<table>
<thead>
<tr>
<th>Sector</th>
<th>Denominator: Exports</th>
<th>Denominator: GDP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Agriculture</td>
<td>10.92%</td>
<td>3.36%</td>
</tr>
<tr>
<td>Mining</td>
<td>47.87%</td>
<td>5.46%</td>
</tr>
<tr>
<td>Textiles Products</td>
<td>12.54%</td>
<td>7.64%</td>
</tr>
<tr>
<td>Refined Petroleum</td>
<td>9.19%</td>
<td>5.19%</td>
</tr>
<tr>
<td>Machinery</td>
<td>9.04%</td>
<td>7.95%</td>
</tr>
<tr>
<td>Electrical Equipment</td>
<td>20.74%</td>
<td>12.87%</td>
</tr>
<tr>
<td>Transport Equipment</td>
<td>5.08%</td>
<td>7.16%</td>
</tr>
<tr>
<td>Electricity, Gas and Water</td>
<td>553.49%</td>
<td>1.61%</td>
</tr>
<tr>
<td>Construction</td>
<td>2318.11%</td>
<td>0.37%</td>
</tr>
<tr>
<td>Sale of Vehicles and Fuel</td>
<td>743.56%</td>
<td>0.40%</td>
</tr>
<tr>
<td>Wholesale Trade</td>
<td>27.46%</td>
<td>4.54%</td>
</tr>
<tr>
<td>Retail Trade</td>
<td>2874.46%</td>
<td>0.26%</td>
</tr>
<tr>
<td>Hotels and Restaurants</td>
<td>276.53%</td>
<td>0.62%</td>
</tr>
<tr>
<td>Financial Intermediation</td>
<td>29.14%</td>
<td>3.32%</td>
</tr>
<tr>
<td>Real Estate</td>
<td>662.26%</td>
<td>0.41%</td>
</tr>
<tr>
<td>Business Activities</td>
<td>50.65%</td>
<td>3.72%</td>
</tr>
<tr>
<td>Private Households</td>
<td>1111.34%</td>
<td>0.40%</td>
</tr>
</tbody>
</table>
The overestimation problem is **more pronounced for energy and service sectors**, as a large proportion of their value added is exported indirectly.

<table>
<thead>
<tr>
<th>Denominator:</th>
<th>Electricity, Gas and Water</th>
<th>Retail Trade</th>
<th>Leather and Footwear</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Exports</td>
<td>GDP</td>
<td>Exports</td>
</tr>
<tr>
<td>CAN</td>
<td>51.5%</td>
<td>5.9%</td>
<td>115.5%</td>
</tr>
<tr>
<td>CHN</td>
<td>625.9%</td>
<td>5.5%</td>
<td>27.4%</td>
</tr>
<tr>
<td>DEU</td>
<td>50.5%</td>
<td>8.9%</td>
<td>769.2%</td>
</tr>
<tr>
<td>FRA</td>
<td>67.4%</td>
<td>5.2%</td>
<td>$2 \times 10^7%$</td>
</tr>
<tr>
<td>GBR</td>
<td>276.0%</td>
<td>4.0%</td>
<td>337.9%</td>
</tr>
<tr>
<td>IND</td>
<td>9944.8%</td>
<td>3.0%</td>
<td>893.5%</td>
</tr>
<tr>
<td>ITA</td>
<td>300.7%</td>
<td>4.8%</td>
<td>38.4%</td>
</tr>
<tr>
<td>JPN</td>
<td>619.9%</td>
<td>3.1%</td>
<td>58.2%</td>
</tr>
<tr>
<td>KOR</td>
<td>1729.8%</td>
<td>8.0%</td>
<td>56.8%</td>
</tr>
<tr>
<td>MEX</td>
<td>341.7%</td>
<td>2.9%</td>
<td>39.0%</td>
</tr>
<tr>
<td>RUS</td>
<td>264.6%</td>
<td>11.8%</td>
<td>35.0%</td>
</tr>
<tr>
<td>USA</td>
<td>553.5%</td>
<td>1.6%</td>
<td>2874.5%</td>
</tr>
</tbody>
</table>
2). To differentiate between deep and shallow cross country production sharing activities

- Crossing the national border only once – direct value-added trade, representing the type of cross border specialization that is relatively shallow, which is excluded from the newly defined participation measures.
- Two or more border crossings – GVC related trade, representing the type of cross border specialization that is deeper.

The relative importance of “Domestic value added in traditional intermediates exports” (direct VA trade) is diminishing over time for all sample countries.
Similarly, from the perspective of backward linkages, foreign value added embodied in “direct value-added trade” is also excluded.

- There is no multinational production activity involved in direct value-added trade.
- The relative importance of “Foreign value added in traditional intermediates imports” is also declining over time.

FVA in “Traditional Intermediates Imports” as a share of FVA in all Intermediate Imports.
3) To provide more detailed data for GVC related empirical analysis

The relative sizes of parts A, B, and C in in GVC Related Exports may reflect the differences of roles in the GVCs for different countries.

For example, part B, “re-imported and absorbed domestically,” accounts for a large proportion in the US, as the US is controlling both ends (design and sales) of the value chain. In contrast, Part B is relatively smaller for Mexico, which is more specialized in processing and assembly activities.
In the aftermath of the Global Financial Crisis, world trade grew by 6.2% in 2011, 2.8% in 2012, and 3.0% in 2013.

- This growth in trade volumes is **substantially lower than the pre-crisis** average of 7.1% (1987–2007), and is **slightly below the growth rate of world GDP in real terms**.

*Source: IMF World Economic Outlook*
The Effects of Financial Crisis to Different Value Added Creating Activities, Sectoral Level, 2009/2008

<table>
<thead>
<tr>
<th>Sector</th>
<th>China</th>
<th>USA</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Domestic</td>
<td>Direct VA</td>
</tr>
<tr>
<td>Agriculture</td>
<td>8.6%</td>
<td>-4.9%</td>
</tr>
<tr>
<td>Mining</td>
<td>16.5%</td>
<td>-16.2%</td>
</tr>
<tr>
<td>Food</td>
<td>7.6%</td>
<td>-5.7%</td>
</tr>
<tr>
<td>Textiles Products</td>
<td>21.3%</td>
<td>-6.1%</td>
</tr>
<tr>
<td>Leather and Footwear</td>
<td>16.8%</td>
<td>-6.7%</td>
</tr>
<tr>
<td>Wood Products</td>
<td>14.3%</td>
<td>-17.0%</td>
</tr>
<tr>
<td>Paper and Printing</td>
<td>12.7%</td>
<td>-10.7%</td>
</tr>
<tr>
<td>Refined Petroleum</td>
<td>15.2%</td>
<td>-18.1%</td>
</tr>
<tr>
<td>Chemical Products</td>
<td>16.5%</td>
<td>-10.5%</td>
</tr>
<tr>
<td>Rubber and Plastics</td>
<td>18.5%</td>
<td>-8.4%</td>
</tr>
<tr>
<td>Other Non-Metal</td>
<td>9.9%</td>
<td>-19.5%</td>
</tr>
<tr>
<td>Basic Metals</td>
<td>20.5%</td>
<td>-17.8%</td>
</tr>
<tr>
<td>Machinery</td>
<td>18.4%</td>
<td>-20.4%</td>
</tr>
<tr>
<td>Electrical Equipment</td>
<td>25.1%</td>
<td>-7.8%</td>
</tr>
<tr>
<td>Transport Equipment</td>
<td>13.1%</td>
<td>-15.4%</td>
</tr>
</tbody>
</table>
Are length and position of GVC related to the degree of effects of financial crisis?

To formally test this, we estimate the following regression:

$$\Delta GVCP_{ic} = \beta_0 + \beta_1 \times \text{Position}_{ic} + \beta_2 \times T\_Length_{ic} + \beta_3 \times GPL\_F\_Portion_{ic} + \beta_4 \times W_{ic} + \beta_5 \times Z_c + \gamma_i + u_i$$

- $\Delta GVCP_{ic}$ equals to $GVCP_{ic}(2009)$ minus $GVCP_{ic}(2008)$, which quantifies the degree of effects on this industry according to the variance of the forward linkage based GVC participation ratio during the financial crisis;
- $\text{Position}_{ic}$: GVC Position Index;
- $T\_Length_{ic}$ is the average length of value chains that country $c$, sector $i$ engages in;
- $GPL\_F\_Portion_{ic}$ is the share of International production length as a portion of (forward linkage based) GVC production length;
- $W_{ic}$: country-sector level control variables, including the logarithm of real capital stock per capita, and hours worked by high-skilled workers (share in total hours);
- $Z_c$: country level control variables, including a dummy variable to indicate whether this is an Asian country ($=1$) and the logarithm of GDP per capita;
- We also control for the sector fixed effects.
The further is the position from the final consumption end, the less affected the node would be by the financial crisis.

The negative impact of financial crisis is magnified with the lengthening of value chains.

The influences of financial crisis tend to be more severe for countries with a longer international portion of the chain.

Capital intensive and high-technology intensive sectors are less affected.

The effects of the financial crisis are significantly higher on Asian countries than on Europe and America.

<table>
<thead>
<tr>
<th>Position Index</th>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>10.54*</td>
<td>17.27**</td>
<td>13.55*</td>
</tr>
<tr>
<td></td>
<td>(5.97)</td>
<td>(7.37)</td>
<td>(7.26)</td>
</tr>
<tr>
<td>T_Length</td>
<td>-5.55***</td>
<td>-8.23***</td>
<td>-6.88***</td>
</tr>
<tr>
<td></td>
<td>(1.38)</td>
<td>(1.69)</td>
<td>(1.66)</td>
</tr>
<tr>
<td>GPL_F_Portion</td>
<td>-18.06*</td>
<td>33.57***</td>
<td>48.35***</td>
</tr>
<tr>
<td></td>
<td>(9.87)</td>
<td>(12.08)</td>
<td>(12.63)</td>
</tr>
<tr>
<td>ln(K/L)</td>
<td>1.19**</td>
<td>1.62***</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.54)</td>
<td>(0.54)</td>
<td></td>
</tr>
<tr>
<td>High Skill</td>
<td>13.96***</td>
<td>15.91***</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(4.34)</td>
<td>(4.33)</td>
<td></td>
</tr>
<tr>
<td>ln(GDP per Capita)</td>
<td>-0.33</td>
<td>-1.79*</td>
<td></td>
</tr>
<tr>
<td>Asia</td>
<td></td>
<td></td>
<td>-6.40***</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(1.52)</td>
</tr>
<tr>
<td>Constant</td>
<td>23.99***</td>
<td>41.40***</td>
<td>62.39***</td>
</tr>
<tr>
<td></td>
<td>(7.07)</td>
<td>(11.92)</td>
<td>(13.40)</td>
</tr>
<tr>
<td>Sector Fixed Effects</td>
<td>YES</td>
<td>YES</td>
<td>YES</td>
</tr>
<tr>
<td>Observations</td>
<td>1,325</td>
<td>741</td>
<td>741</td>
</tr>
<tr>
<td>R-squared</td>
<td>0.23</td>
<td>0.25</td>
<td>0.27</td>
</tr>
</tbody>
</table>
Conclusion Remarks

We have developed a GVC index system that includes three types of indexes:

- a production length index for the average number of production stages and complexity of the global value chain;
- a participation index for the intensity of a country-sector’s engagement in global value chains; and
- a position index for the location of a country sector on a global value chain, or the relative distance of a particular production stage to both ends of a global value chain.

We thus can provide a comprehensive picture of each country/sector pair’s GVC activities from multiple dimensions.

By estimating these indexes according to real world data, we produce a large set of indicators. We hope these indexes could be widely used by both theoretical and empirical economists in advancing studies for economics of global supply chains.
The intuition and derivation of production length

\[ X_{vd}^{ss} = \hat{V}^s Y^{ss} + 2\hat{V}^s A^{ss} Y^{ss} + 3\hat{V}^s A^{ss} A^{ss} Y^{ss} + ... = \hat{V}^s (I - A^{ss})^{-1} (I - A^{ss})^{-1} Y^{ss} - \hat{V}^s I^{ss} I^{ss} Y^{ss} \]

\[ DVA_{D}^{ss} = \hat{V}^s Y^{ss} + \hat{V}^s A^{ss} Y^{ss} + \hat{V}^s A^{ss} A^{ss} Y^{ss} + ... = \hat{V}^s I^{ss} Y^{ss} \]

\[ DVA_{F}^{sr} = \hat{V}^s Y^{sr} + \hat{V}^s A^{ss} Y^{sr} + \hat{V}^s A^{sr} \sum_{t} Y^{rt} + \hat{V}^s A^{ss} A^{ss} Y^{sr} + \hat{V}^s A^{ss} A^{sr} \sum_{t} Y^{rt} + \hat{V}^s A^{sr} \sum_{t} A^{ru} \sum_{t} Y^{ut} + ... = \hat{V}^s I^{ss} E^{sr} \]

\[ X_{vd}^{sr} = \hat{V}^s Y^{sr} + (2\hat{V}^s A^{ss} Y^{sr} + \hat{V}^s A^{sr} \sum_{t} Y^{rt}) + (3\hat{V}^s A^{ss} A^{ss} Y^{sr} + 2\hat{V}^s A^{ss} A^{sr} \sum_{t} Y^{rt} + \hat{V}^s A^{sr} \sum_{t} A^{ru} \sum_{t} Y^{ut}) + ... = \hat{V}^s L^{ss} A^{sr} \sum_{t} B^{ru} \sum_{t} Y^{vl} \]

\[ X_{vf}^{sr} = 0 + (0 + \hat{V}^s A^{sr} \sum_{t} Y^{rt}) + (0 + \hat{V}^s A^{ss} A^{sr} \sum_{t} Y^{rt} + 2\hat{V}^s A^{sr} \sum_{t} A^{ru} \sum_{t} Y^{ut}) + ... = \hat{V}^s L^{ss} A^{sr} \sum_{t} B^{ru} \sum_{t} Y^{vl} \]
Backward Linkage based participation index

Start from the column balance condition of ICIO table, we can decompose final goods production based on backward inter-industry, cross-country linkage:

\[ X^{*s} = B^{ss}Y^{ss} + \sum_{r \neq s} B^{sr}Y^{rs} + \sum_{r \neq s} B^{rr}Y^{rs} = L^{ss}Y^{ss} + \sum_{r \neq s} L^{rr}Y^{rs} + \sum_{r \neq s} L^{rr} \sum_{u \neq r} \sum_{t} A^{ru} \sum_{t} B^{ut}Y^{ts} \]

\[ Y^{*s} = \sum_{r} V^{r} X^{rs} = V^{s} L^{ss}Y^{is} + \sum_{r \neq s} V^{r} L^{rr}Y^{rs} + \sum_{r \neq s} V^{r} L^{rr} A^{rs} L^{ss}Y^{is} + \sum_{r} V^{r} L^{rr} \sum_{u \neq r} \sum_{t} A^{ru} \sum_{t} B^{ut}Y^{ts} \]

\[ Y^{*s} = \sum_{r} V^{r} X^{rs} = V^{s} L^{ss}Y^{is} + \sum_{r \neq s} V^{r} L^{rr}Y^{rs} + \sum_{r \neq s} V^{r} L^{rr} A^{rs} L^{ss}Y^{is} + \sum_{r} V^{r} L^{rr} \sum_{u \neq r} \sum_{t} A^{ru} \sum_{t} B^{ut}Y^{ts} \]

\[ Y^{*s} = \sum_{r} V^{r} X^{rs} = V^{s} L^{ss}Y^{is} + \sum_{r \neq s} V^{r} L^{rr}Y^{rs} + \sum_{r \neq s} V^{r} L^{rr} A^{rs} L^{ss}Y^{is} + \sum_{r} V^{r} L^{rr} \sum_{u \neq r} \sum_{t} A^{ru} \sum_{t} B^{ut}Y^{ts} \]

\[ Y^{*s} = \sum_{r} V^{r} X^{rs} = V^{s} L^{ss}Y^{is} + \sum_{r \neq s} V^{r} L^{rr}Y^{rs} + \sum_{r \neq s} V^{r} L^{rr} A^{rs} L^{ss}Y^{is} + \sum_{r} V^{r} L^{rr} \sum_{u \neq r} \sum_{t} A^{ru} \sum_{t} B^{ut}Y^{ts} \]

\[ Y^{*s} = \sum_{r} V^{r} X^{rs} = V^{s} L^{ss}Y^{is} + \sum_{r \neq s} V^{r} L^{rr}Y^{rs} + \sum_{r \neq s} V^{r} L^{rr} A^{rs} L^{ss}Y^{is} + \sum_{r} V^{r} L^{rr} \sum_{u \neq r} \sum_{t} A^{ru} \sum_{t} B^{ut}Y^{ts} \]

\[ Y^{*s} = \sum_{r} V^{r} X^{rs} = V^{s} L^{ss}Y^{is} + \sum_{r \neq s} V^{r} L^{rr}Y^{rs} + \sum_{r \neq s} V^{r} L^{rr} A^{rs} L^{ss}Y^{is} + \sum_{r} V^{r} L^{rr} \sum_{u \neq r} \sum_{t} A^{ru} \sum_{t} B^{ut}Y^{ts} \]

\[ Y^{*s} = \sum_{r} V^{r} X^{rs} = V^{s} L^{ss}Y^{is} + \sum_{r \neq s} V^{r} L^{rr}Y^{rs} + \sum_{r \neq s} V^{r} L^{rr} A^{rs} L^{ss}Y^{is} + \sum_{r} V^{r} L^{rr} \sum_{u \neq r} \sum_{t} A^{ru} \sum_{t} B^{ut}Y^{ts} \]

\[ Y^{*s} = \sum_{r} V^{r} X^{rs} = V^{s} L^{ss}Y^{is} + \sum_{r \neq s} V^{r} L^{rr}Y^{rs} + \sum_{r \neq s} V^{r} L^{rr} A^{rs} L^{ss}Y^{is} + \sum_{r} V^{r} L^{rr} \sum_{u \neq r} \sum_{t} A^{ru} \sum_{t} B^{ut}Y^{ts} \]

\[ Y^{*s} = \sum_{r} V^{r} X^{rs} = V^{s} L^{ss}Y^{is} + \sum_{r \neq s} V^{r} L^{rr}Y^{rs} + \sum_{r \neq s} V^{r} L^{rr} A^{rs} L^{ss}Y^{is} + \sum_{r} V^{r} L^{rr} \sum_{u \neq r} \sum_{t} A^{ru} \sum_{t} B^{ut}Y^{ts} \]

GVC Participation Index can be defined as:

\[
\text{Term 3 : } FVY \_ GVC
\]

Final products produced

\[
= \frac{\text{Term 3a : } FVY \_ GVC \_ r + \text{Term 3b : } FVY \_ GVC \_ s + \text{Term 3c : } FVY \_ GVC \_ t}{\text{Final products produced}}
\]
To further check the reasonableness of our GVC position index, we tested whether it is negatively correlated with the backward linkage GVC participation index.

- Foreign value added are accumulated from upstream to downstream. As a result, downstream producers are expected to have a larger foreign value added share in their production.
Estimation Results

- **Production Length Index** (Use forward linkage based indexes as examples)
  - Estimation Results
  - Has the length of Global Value Chains become longer or shorter over time?

- **GVC Position Index** [*selected examples, work still in progress*]

- **GVC Participation Index**
  - Estimation Results
  - Why the new “GVC Participation Index” is better?

- **Indexes application**
  - GVC length, participation intensity, production line positions and the economic shocks of the recent global financial crisis