Value added trade: A tale of two concepts

Robert Stehrer

The Vienna Institute for International Economic Studies (wiiw)

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Overview

- Two concepts of value added "flows"
  - ⋆ Value added in trade
  - ⋆ Trade in value added
  - ⋆ But: terminology is used differently
- "Net trade" in value added
  - ⋆ Total
  - ⋆ Bilateral
- Comparison to other related concepts

Multi-national accounting and indicators of production fragmentation

- Narrow and broad offshoring measure (Feenstra and Hanson, 1999)
- Vertical specialization (Hummels et al., 2001)
- Foreign and domestic value added content of exports (...)
- Value added exports (Johnson and Noguera, 2012)
- Decomposition of value added exports (Koopman et al., 2010; Stehrer, 2012b)
- Trade balances in VA terms (Stehrer, 2012a)
- Factor content of trade with traded intermediates (Trefler and Zhu, 2010)
- Global value chain approach (Timmer et al., 2012)
- International upstreamness/downstreamness, Distance to consumer (Antras et al. 2012; Fally, 2012)
- Average propagation length (Dietzenbacher, 2007)

A tale of two concepts

- Two concepts of value added "flows" across countries
  - Domestic and foreign value added embodied in a country's gross exports/imports:
    - Akin to Hummels et al. (2001) VS1 measure (in VA terms rather than gross output terms)
    - Consideration from supply side (where inputs are sourced from)
  - Value added created in one country due to consumption in other countries:
    - Consideration from demand side (value added created for consumption abroad)
- Concepts are closely tied to each other
- Provides insights in estimating bilateral value added flows and double counting

Concepts

Net trade in gross terms

$$\mathrm{NX}^{rs} = \mathrm{X}^{rs} - \mathrm{M}^{rs} = \mathrm{X}^{rs} - \mathrm{X}^{sr}$$

$$\mathrm{NX}^{r} = \mathrm{X}^{r} - \mathrm{M}^{r} = \sum_{s} \mathrm{X}^{rs} - \sum_{s} \mathrm{M}^{rs} = \sum_{s} \mathrm{X}^{rs} - \sum_{s} \mathrm{X}^{sr}$$

Domestic and foreign value added content of exports and imports (Value Added in trade - VAiT)

Domestic and foreign value added embodied in a country's exports and imports

Other terminology: ...

$$
\begin{aligned}
\mathrm{DomVAiX}^r &= (\mathbf{v}^r)'(\mathbf{I}-\mathbf{A})^{-1}\mathbf{x}^r \\
\mathrm{ForVAiX}^r &= (\mathbf{v}^{-r})'(\mathbf{I}-\mathbf{A})^{-1}\mathbf{x}^r \\
\mathrm{DomVAiM}^r &= (\mathbf{v}^r)'(\mathbf{I}-\mathbf{A})^{-1}\mathbf{m}^r \\
\mathrm{ForVAiM}^r &= (\mathbf{v}^{-r})'(\mathbf{I}-\mathbf{A})^{-1}\mathbf{m}^r \\
\mathrm{DirForVAiM}^r &= \mathrm{trace}\left((\hat{\mathbf{v}}^{-r})'(\mathbf{I}-\mathbf{A})^{-1}\hat{\mathbf{m}}^r\right)
\end{aligned}
$$

- Expressed as a share of exports in gross terms (or imports)
- By definition: $\mathrm{X} = \mathrm{DVAiX} + \mathrm{FVAiX}$
- Akin to Hummels et al. (2001) VS measure

Consider country 1

Value added content of exports

$$\mathbf{VAiX}^1 = \hat{\mathbf{v}}\mathbf{L}\hat{\mathbf{x}}^1 \begin{pmatrix} v^1 l^{11} x^{1*} & v^1 l^{12} 0 & v^1 l^{13} 0 \\ v^2 l^{21} x^{1*} & v^2 l^{22} 0 & v^2 l^{23} 0 \\ v^3 l^{31} x^{1*} & v^3 l^{32} 0 & v^3 l^{33} 0 \end{pmatrix} = \begin{pmatrix} \mathrm{VAiX}^{1*(1)} & 0 & 0 \\ \mathrm{VAiX}^{1*(2)} & 0 & 0 \\ \mathrm{VAiX}^{1*(3)} & 0 & 0 \end{pmatrix}$$

Value added content of imports from 2 and 3

$$\mathbf{VAiM}^1 = \hat{\mathbf{v}}\mathbf{L}\hat{\mathbf{m}}^1 \begin{pmatrix} v^1 l^{11} 0 & v^1 l^{12} x^{21} & v^1 l^{13} x^{31} \\ v^2 l^{21} 0 & v^2 l^{22} x^{21} & v^2 l^{23} x^{31} \\ v^3 l^{31} 0 & v^3 l^{32} x^{21} & v^3 l^{33} x^{31} \end{pmatrix} = \begin{pmatrix} 0 & \mathrm{VAiX}^{21(1)} & \mathrm{VAiX}^{31(1)} \\ 0 & \mathrm{VAiX}^{21(2)} & \mathrm{VAiX}^{31(2)} \\ 0 & \mathrm{VAiX}^{21(3)} & \mathrm{VAiX}^{31(3)} \end{pmatrix}$$

This concept is closely related to VS measures (e.g. Hummels et al., 2001) - the import content of exports:

$$\mathrm{FVAiX}^r = (\mathbf{v}^{-r})'\mathbf{L}\mathbf{x}^r = \sum_{s,s\neq r} (\mathbf{v}^s)'\mathbf{L}^{sr}\mathbf{x}^{r*} \qquad \text{in \% of gross (=value added) exports}$$

Relates to HIY VS1 measure (based on world IO table):

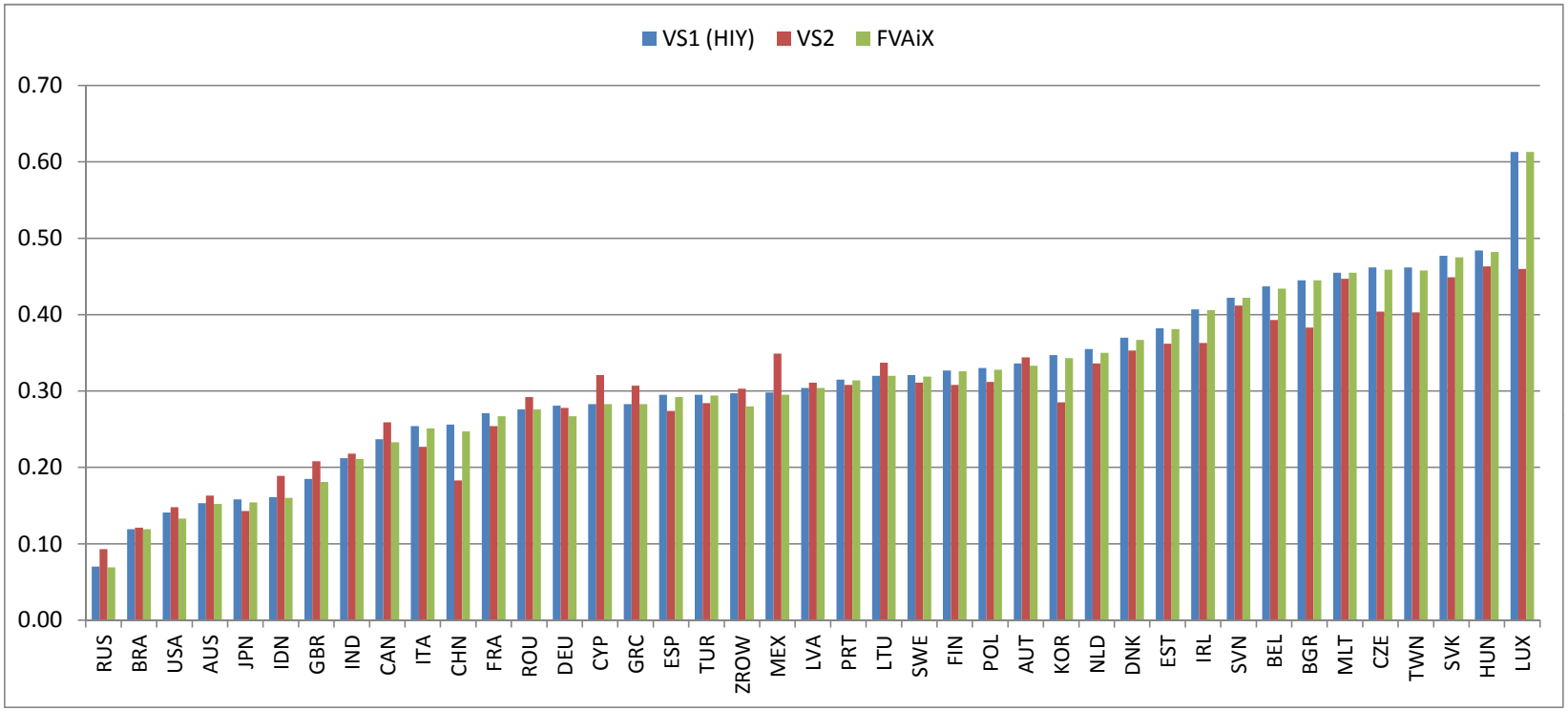
$$\mathrm{VS2}^r = (\mathbf{1}^{-r})'\mathbf{L}\mathbf{x}^r = \sum_{s,s\neq r} \mathbf{1}'\mathbf{L}^{sr}\mathbf{x}^{r*} \qquad \text{in \% of gross output needed for exports}$$

If based on domestic and import IO tables:

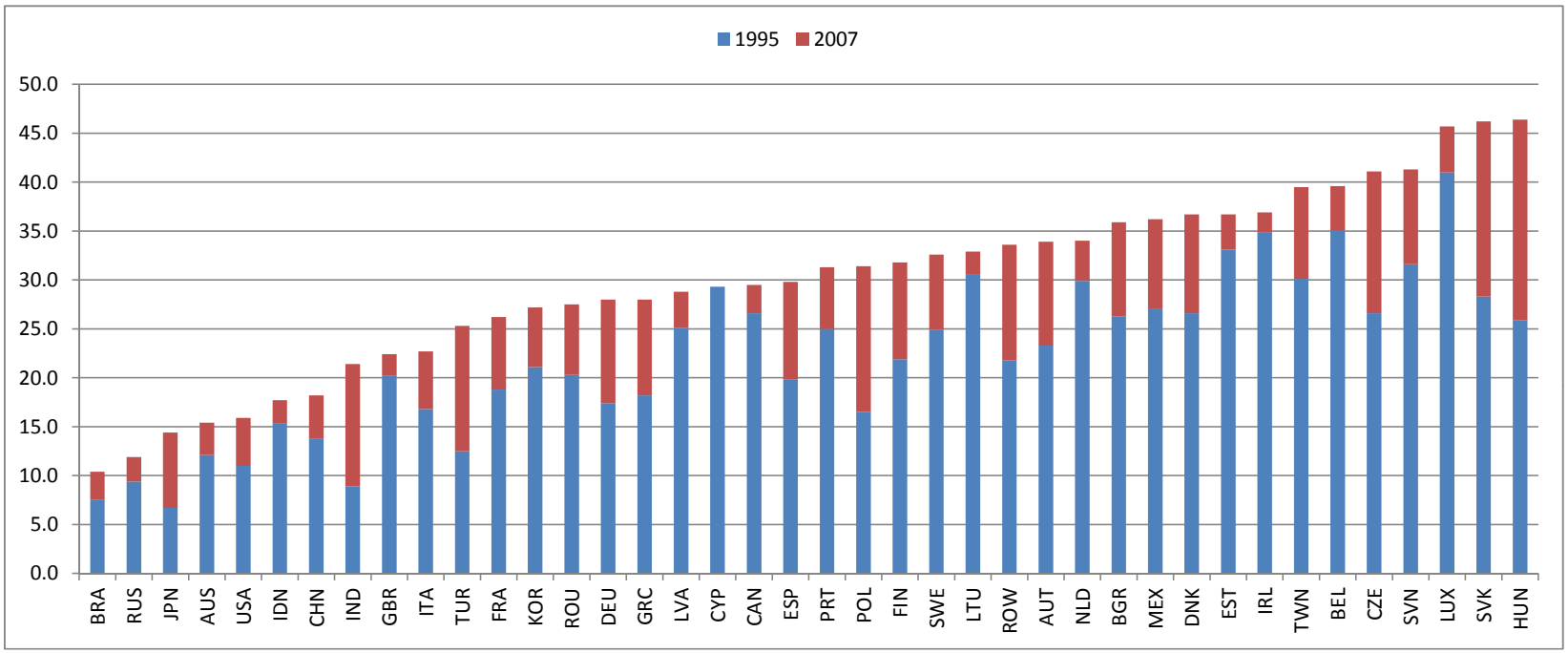
$$\mathrm{VS1}^r = \sum_{s,s\neq r} \mathbf{1}'\mathbf{A}^{sr}\tilde{\mathbf{L}}^{rr}\mathbf{x}^{r*} \qquad \text{in \% of gross exports}$$

Resulting measures are quite similar

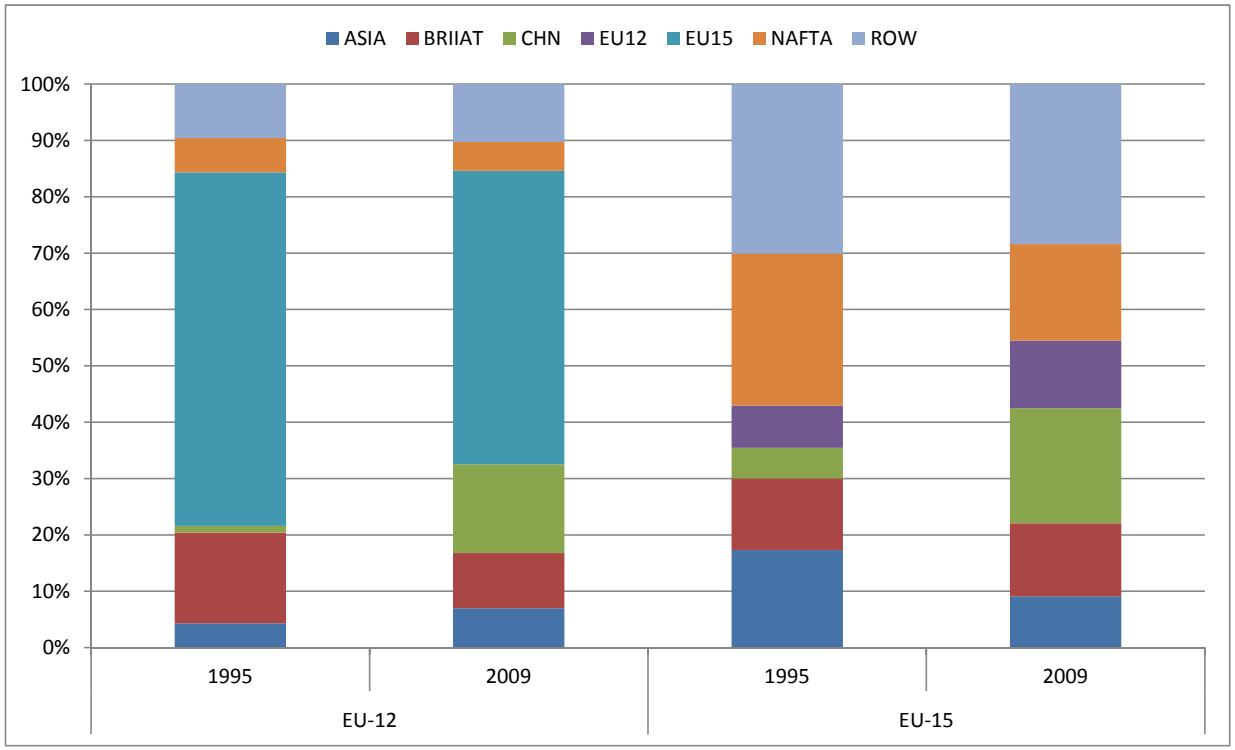
Comparison of three indicators, 2007



Evolution of vertical specialisation (VS2), 1995 and 2007



Sourcing structure of foreign content of exports, 1995 and 2007



Source: WIOD; author's calculations

Trade in value added (TiVA)

Value added created in a country due to final consumption elsewhere

Other terminology: ...

Value added exports (VAX) - J&N (2012) - are defined as

$$\mathrm{VAX}^r = (\mathbf{v}^r)'(\mathbf{I} - \mathbf{A})^{-1}\mathbf{f}^{-r}$$

Analogously, the value added imports (VAM) can be defined as

$$\mathrm{VAM}^r = (\mathbf{v}^{-r})'(\mathbf{I} - \mathbf{A})^{-1}\mathbf{f}^{r}$$

- Expressed relative to gross exports (VAX ratio; Johnson and Noguera, 2012)

Consider country 1

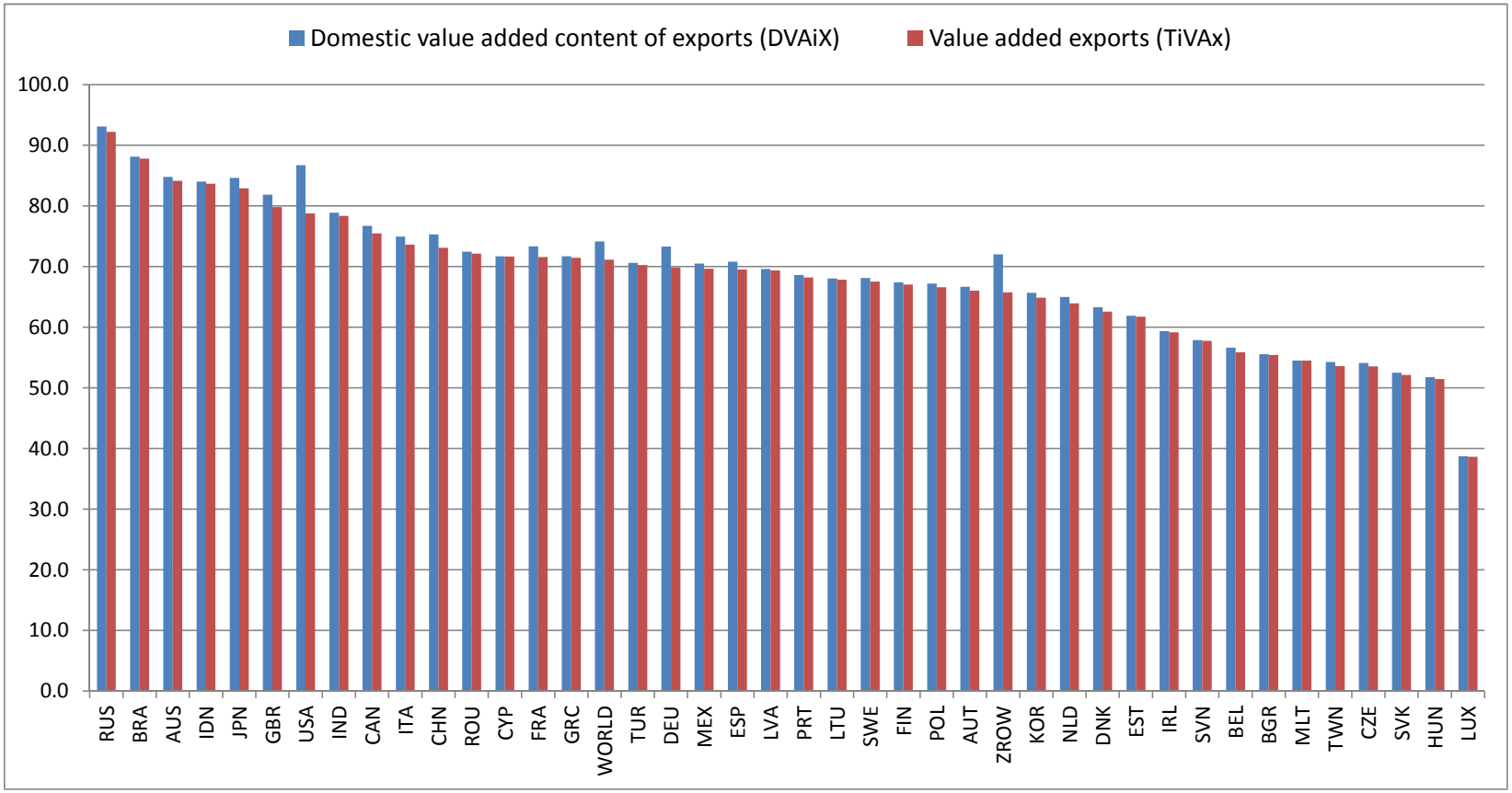
Value added created in 1 due to final consumption (domestic and imported) in 2 and 3

$$\mathrm{VAX}^r = \begin{pmatrix} v^1 & 0 & 0 \end{pmatrix} \mathbf{L} \begin{pmatrix} 0 + f^{12} + f^{13} \\ 0 + f^{22} + f^{23} \\ 0 + f^{23} + f^{33} \end{pmatrix}$$

Value added created in 2 and 3 due to final consumption (domestic and imported) in 1

$$\mathrm{VAM}^r = \begin{pmatrix} 0 & v^2 & v^3 \end{pmatrix} \mathbf{L} \begin{pmatrix} f^{11} + 0 + 0 \\ f^{21} + 0 + 0 \\ f^{31} + 0 + 0 \end{pmatrix}$$

A comparison



On (bilateral) net trade in gross and value added terms

Net trade

(For details see Stehrer, 2012a)

$$
\begin{aligned}
\mathrm{NX}^r &= \mathrm{X}^r - \mathrm{M}^r \\
\mathrm{NTiVA}^r &= \mathrm{VAX}^r - \mathrm{VAM}^r \\
\mathrm{NVAiT}^r &= (\mathrm{DomVAiX}^r + \mathrm{ForVAiX}^r) - (\mathrm{DomVAiM}^r + \mathrm{ForVAiM}^r)
\end{aligned}
$$

$$
\mathrm{NX}^r = \mathrm{NTiVA}^r = \mathrm{NVAiT}^r
$$

$$
\mathrm{NVAiT}^r = \mathbf{v}'\mathbf{L}\mathbf{t} = \mathbf{1}'(\mathbf{I}-\mathbf{A})(\mathbf{I}-\mathbf{A})^{-1}\mathbf{t} = \mathbf{1}'\mathbf{t} = \mathrm{NX}^r \qquad \text{with} \qquad \mathbf{t} = \begin{pmatrix} x^{1*} \\ -x^{21} \\ -x^{31} \end{pmatrix}
$$

$$
\begin{aligned}
\mathrm{NTiVA}^r &= \mathbf{v}^r\mathbf{L}\mathbf{f}^{-r} - \mathbf{v}^{-r}\mathbf{L}\mathbf{f}^r \\
&= \mathbf{v}^r\mathbf{L}\mathbf{f}^{-r} + \mathbf{v}^r\mathbf{L}\mathbf{f}^r - \mathbf{v}^r\mathbf{L}\mathbf{f}^r - \mathbf{v}^{-r}\mathbf{L}\mathbf{f}^r \\
&= \mathbf{v}^r\mathbf{L}\mathbf{f} - \mathbf{v}\mathbf{L}\mathbf{f}^r \\
&= \mathbf{v}^r\mathbf{y} - \mathbf{1}'\mathbf{f}^r \\
&= y^r - \mathbf{1}'\mathbf{f}^r \\
&= \mathrm{NX}^r
\end{aligned}
$$

$$
\begin{aligned}
y^r &= \mathbf{1}' \left[\begin{pmatrix} \mathbf{f}^{rr} \\ \mathbf{f}^{sr} \\ \mathbf{f}^{tr} \end{pmatrix} + \begin{pmatrix} \mathbf{t}^{rs} + \mathbf{t}^{rt} \\ -\mathbf{t}^{sr} \\ -\mathbf{t}^{tr} \end{pmatrix} \right] \\
&= \mathbf{1}' \begin{pmatrix} \mathbf{f}^{rr} + \mathbf{t}^{rs} + \mathbf{t}^{rt} \\ \mathbf{f}^{sr} - \mathbf{f}^{sr} - \mathbf{z}^{sr} \\ \mathbf{f}^{tr} - \mathbf{f}^{tr} - \mathbf{z}^{tr} \end{pmatrix} \\
&= \mathbf{1}' \left\{ \begin{pmatrix} \mathbf{f}^{rr} + \mathbf{f}^{rs} + \mathbf{f}^{rt} \\ \mathbf{0} \\ \mathbf{0} \end{pmatrix} + \begin{pmatrix} \mathbf{z}^{rs} + \mathbf{z}^{rt} \\ -\mathbf{z}^{sr} \\ -\mathbf{z}^{tr} \end{pmatrix} \right\}
\end{aligned}
$$

Bilateral:

$$\mathrm{NX}^{rs} \neq \mathrm{NTiVA}^{rs}$$

For VAiT concept not straightforward how to define bilateral net trade:

$$\mathbf{NVAiT}^{12} = \hat{\mathbf{v}}\mathbf{L}\hat{\mathbf{t}}^{12} = \begin{pmatrix} v^1 l^{11} t^{12} & -v^1 l^{12} t^{21} & 0 \\ v^2 l^{21} t^{12} & -v^2 l^{22} t^{21} & 0 \\ v^3 l^{31} t^{12} & -v^3 l^{32} t^{21} & 0 \end{pmatrix}$$

Under conditions - "symmetry" and "adding-up" - that

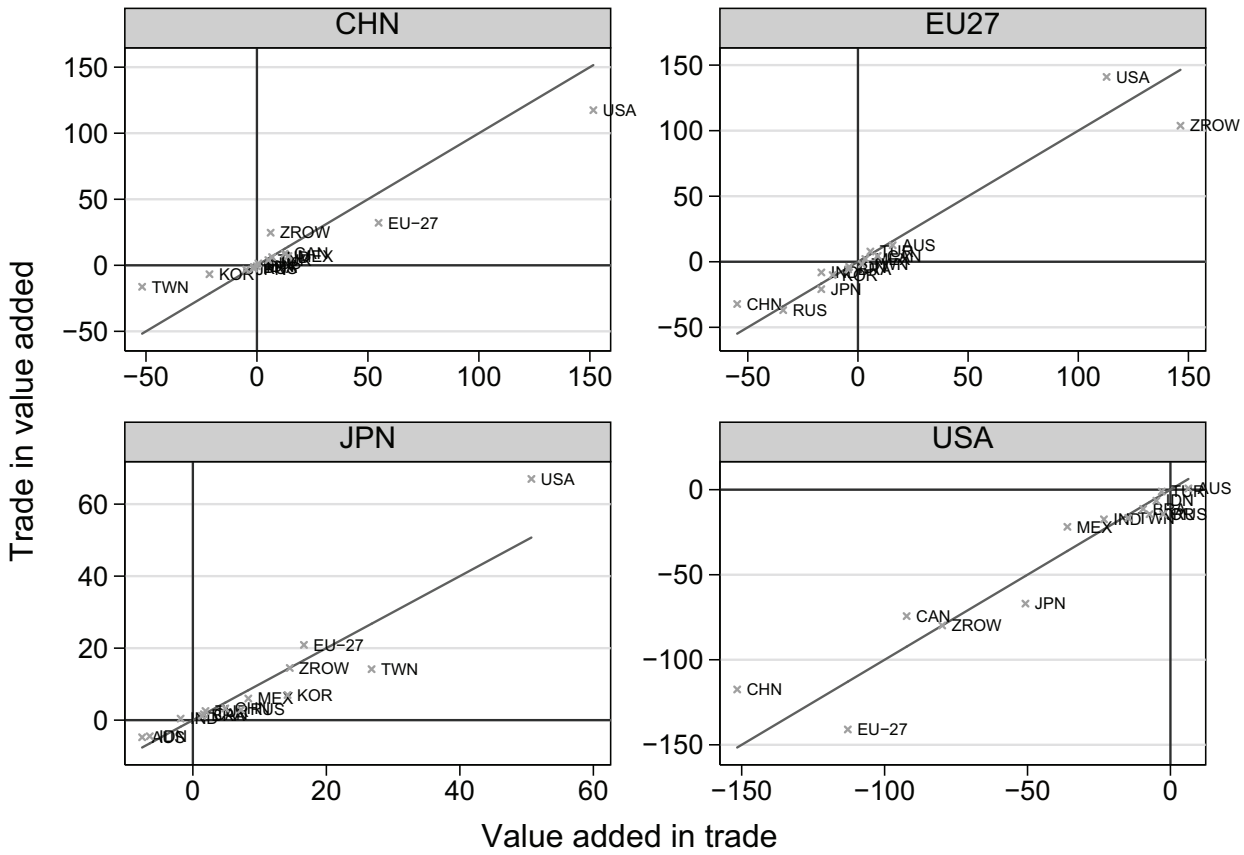
$$\mathrm{NVAiT}^{rs} = -\mathrm{NVAiT}^{sr} \qquad \text{and} \qquad \sum_s \mathrm{NVAiT}^{rs} = \mathrm{NVAiT}^{r}$$

it holds that

$$\sum_s \mathrm{NX}^{rs} = \sum_s \mathrm{NVAiT}^{rs} = \sum_s \mathrm{NTiVA}^{rs} \neq \sum_s \mathrm{DirNVAiT}^{rs}$$

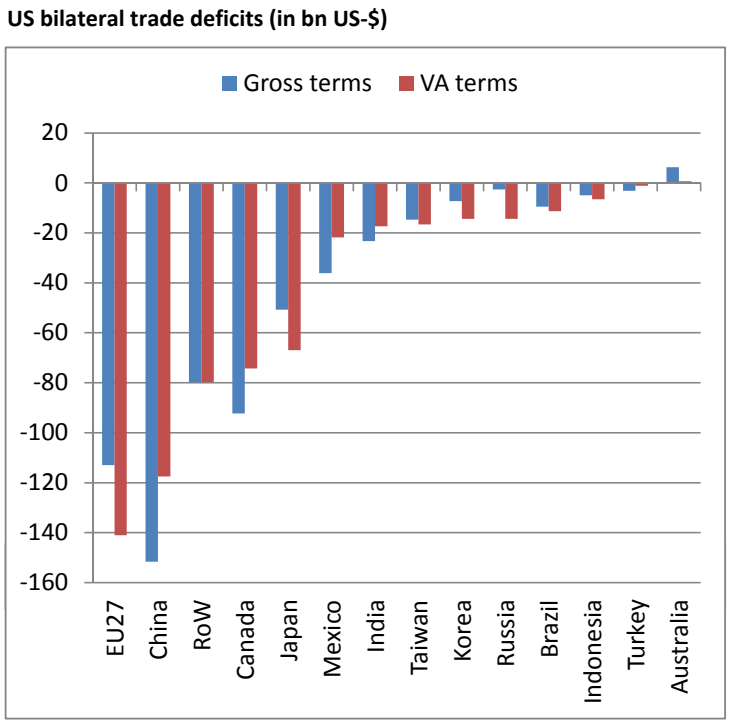
Results

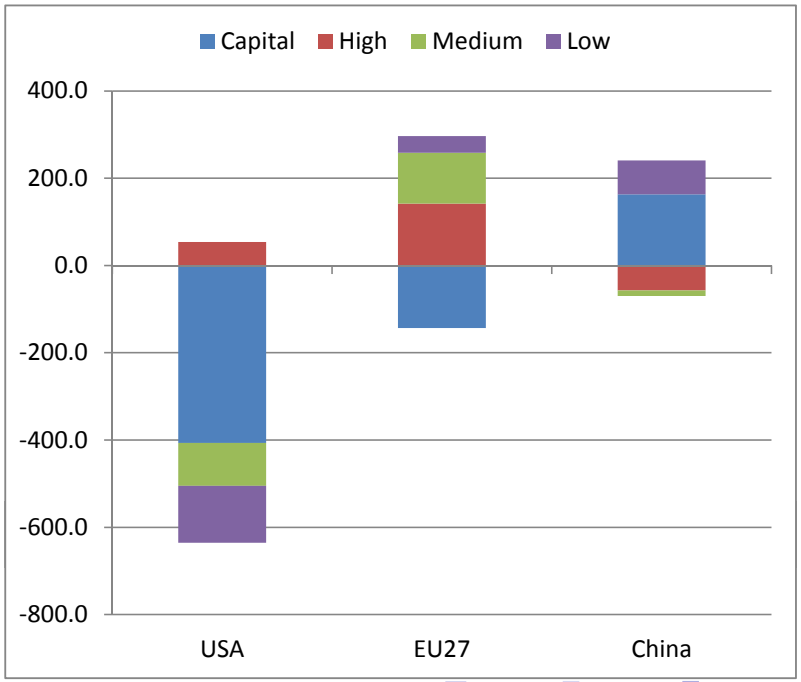
2005, bn US-$



Trade balances

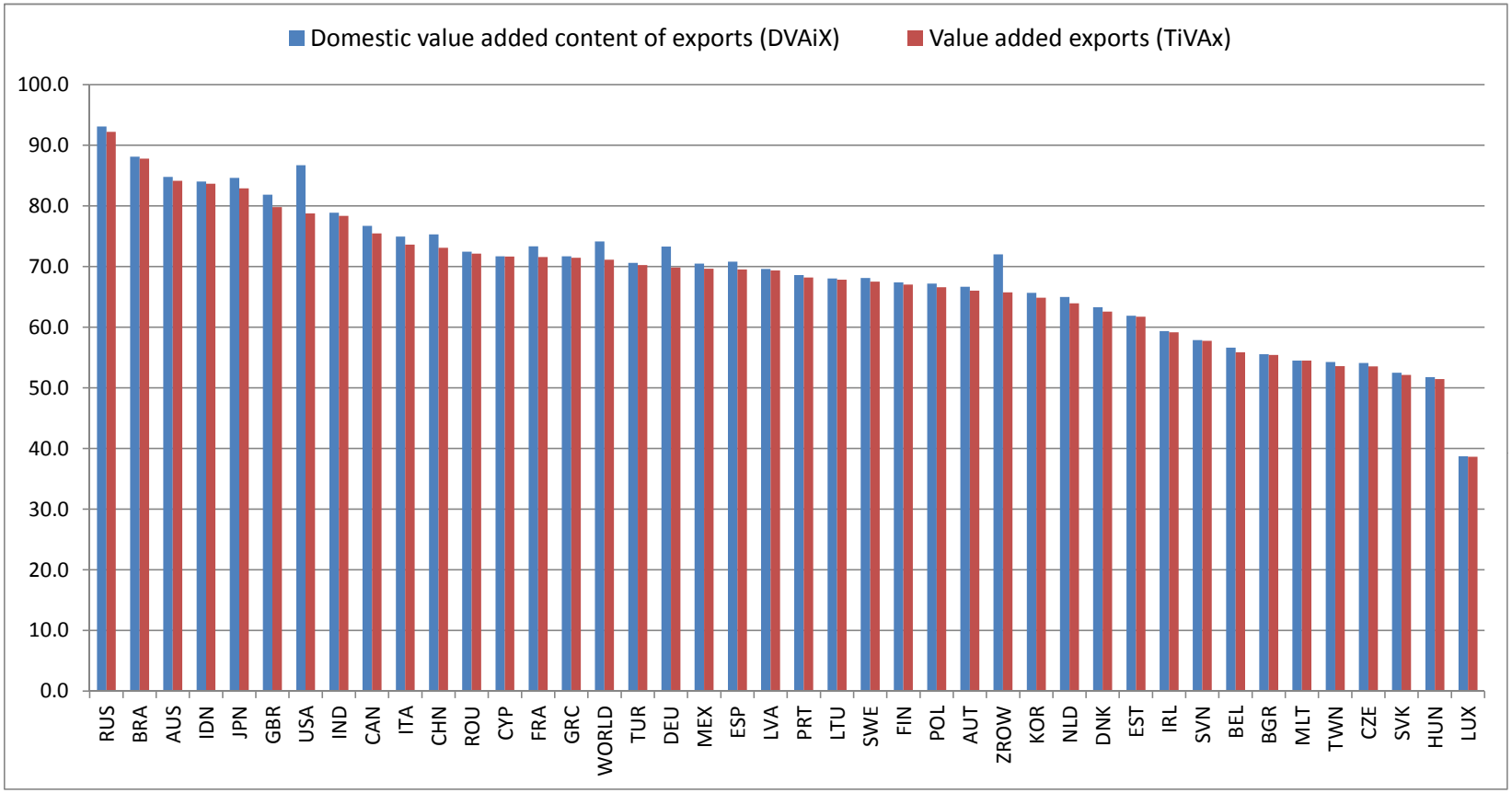
- A countries trade balance in VA terms equals trade balance in gross trade
  - As reflects a country's savings
  - However, in bilateral terms this is different
  - Trade balances by factors of production





A tale of two concepts? A decomposition

A comparison



Decomposition of a country's gross exports into VA components

(For details see Stehrer, 2012a)

- Applying decomposition method of Koopman et al. (2010) at bilateral level
- 2 countries, aggregate level

Using VAiT concept:

$$\mathrm{VA}(e^{12}) = \mathrm{VA}(a^{12}x^2 + f^{12}) = v^1 l^{11} f^{12} + v^2 l^{21} f^{12} + v^1 l^{11} a^{12} x^2 + v^2 l^{21} a^{12} x^2$$

Applying property of inverse matrices ($\mathbf{X}\mathbf{X}^{-1} = \mathbf{I}$)

$$\mathrm{VA}(e^{12}) = \underbrace{\underbrace{\underbrace{v^1 l^{11} f^{12} + v^1 l^{12} f^{22}}_{\mathrm{VAX}^{12}} + \underbrace{v^1 l^{12} f^{21} + v^1 l^{12} a^{21} x^1}_{\mathrm{DVAiM}^{12}}}_{\mathrm{DVAiX}^{12}} + \underbrace{v^2 l^{21} f^{12} + v^2 l^{21} a^{12} x^2}_{\mathrm{FVAiX}^{12}}}$$

$$\mathrm{VA}(e^{12}) = \underbrace{\underbrace{\underbrace{v^1 l^{11} f^{12} + v^1 l^{12} f^{22}}_{\mathrm{VAX}^{12}} + \underbrace{v^1 l^{12} f^{21} + v^1 l^{12} a^{21} x^1}_{\mathrm{DVAiM}^{12}}}_{\mathrm{DVAiX}^{12}} + \underbrace{v^2 l^{21} f^{12} + v^2 l^{21} a^{12} x^2}_{\mathrm{FVAiX}^{12}}}$$

$$\mathrm{VA}(e^{21}) = \underbrace{\underbrace{\underbrace{v^2 l^{21} f^{11} + v^2 l^{22} f^{21}}_{\mathrm{VAX}^{21}} + \underbrace{v^2 l^{21} f^{12} + v^2 l^{21} a^{12} x^2}_{\mathrm{DVAiM}^{21}}}_{\mathrm{DVAiX}^{21}} + \underbrace{v^1 l^{12} f^{21} + v^1 l^{12} a^{21} x^1}_{\mathrm{FVAiX}^{21}}}$$

- Note: $\mathrm{DVAiM}^{12} = \mathrm{FVAiX}^{21}$ and $\mathrm{DVAiM}^{21} = \mathrm{FVAiX}^{12}$
- DVAiM and FVAiX are double-counted in trade statistics
- For GDP only FVAiX is double-counted
- Difference in VAiT and TiVA concept is whether or not DVAiM ("returned VA") is included or not
- Net trade: NTiVA = VAX^{12}-VAX^{21}=NX

This generalizes to 3 (and more) countries

$$
\begin{aligned}
\mathrm{VA}(e^{12}) \quad = \quad & \underbrace{v^1 l^{11} f^{12} + v^1 l^{12} f^{22} + v^1 l^{13} f^{32}}_{\mathrm{VAX}^{12}} + \underbrace{v^1 l^{12} f^{21} + v^1 l^{12} a^{21} x^1}_{\mathrm{DVAiM}^{12}} \\
& \underbrace{\underbrace{+ \underbrace{v^2 l^{21} f^{12} + v^2 l^{21} a^{12} x^2}_{\mathrm{FVAiX}^{12(2)}} + \underbrace{v^3 l^{31} f^{12} + v^3 l^{31} a^{12} x^2}_{\mathrm{FVAiX}^{12(3)}}}_{\mathrm{FVAiX}^{12}}}_{} \\
& + (v^1 l^{12} f^{23} + v^1 l^{12} a^{23} x^3) - (v^1 l^{13} f^{32} + v^1 l^{13} a^{32} x^2)
\end{aligned}
$$

- Additional terms (capturing third-country value added trade flows) cancel out when summing over partner countries
- Similar when calculating bilateral and total net trade
- Thus, at aggregate level same results as for TiVA concept
- When applying again property of inverse matrices, this results in X=DVAiX+FVAiX

Relationship to VAiT concept

$$
\begin{aligned}
\mathrm{VA}(e^{12}) + \mathrm{VA}(e^{13}) \quad = \quad & \underbrace{\underbrace{\underbrace{v^1 l^{11} f^{12}}_{\mathrm{DVAiFDX}^{12}} + \underbrace{v^1 l^{11} a^{12} x^2}_{\mathrm{DVAiIIX}^{12}}}_{\mathrm{DVAiX}^{12}} + \underbrace{\underbrace{v^1 l^{11} f^{13}}_{\mathrm{DVAiFDX}^{13}} + \underbrace{v^1 l^{11} a^{13} x^3}_{\mathrm{DVAiIIX}^{13}}}_{\mathrm{DVAiX}^{13}} + \right. \\
& \underbrace{\underbrace{\underbrace{v^2 l^{21} f^{12} + v^2 l^{21} a^{12} x^2}_{\mathrm{FVAiX}^{12(2)}} + \underbrace{v^3 l^{31} f^{12} + v^3 l^{31} a^{12} x^2}_{\mathrm{FVAiX}^{12(3)}}}_{\mathrm{FVAiX}^{12}} + \right. \\
& \left. \left. \underbrace{\underbrace{\underbrace{v^3 l^{31} f^{13} + v^3 l^{31} a^{13} x^3}_{\mathrm{FVAiX}^{13(3)}} + \underbrace{v^2 l^{21} f^{13} + v^2 l^{21} a^{13} x^3}_{\mathrm{FVAiX}^{13(2)}}}_{\mathrm{FVAiX}^{12}} \right.}_{\mathrm{FVAiX}^{12}} \right. \\
= \quad & \mathrm{DVAiX}^1 + \mathrm{FVAiX}^1
\end{aligned}
$$

- Summing up and applying property of inverse matrices again results in VAiT concept
- Justifies to use total (i.e. intermediates and final goods) exports
- Special case: An oil-exporting country would also export 'domestic value added'
- This approach allows to computationally cheaper decomposition

Selected results on double counting

Decomposition for world, by year

in % of gross exports

	Domestic value added in exports										Foreign value added in exports		
	VAX ratio				Returned domestic value added								
	Total	Final goods	Inter-mediates	Indirect (in third country)	Final goods	Inter-mediates	Total	Total	Double counting in trade	Double counting in GDP	Final goods	Inter-mediates	Total
1995	78.3	29.9	41.6	6.9	1.2	1.4	2.6	80.9	21.7	19.1	8.0	11.1	19.1
1996	78.2	29.7	41.6	6.9	1.2	1.4	2.6	80.8	21.9	19.3	8.1	11.1	19.3
1997	78.1	29.3	42.0	6.8	1.2	1.4	2.6	80.7	22.0	19.3	8.0	11.3	19.3
1998	77.6	30.6	39.7	7.3	1.3	1.4	2.7	80.3	22.5	19.7	8.6	11.2	19.7
1999	76.8	30.0	39.4	7.4	1.4	1.5	2.9	79.7	23.2	20.3	8.8	11.6	20.3
2000	74.7	27.8	39.1	7.8	1.4	1.7	3.1	77.8	25.3	22.2	9.3	12.9	22.2
2001	75.0	28.4	38.6	8.0	1.4	1.6	3.0	78.0	25.0	22.0	9.4	12.7	22.0
2002	75.3	28.9	38.3	8.0	1.4	1.6	2.9	78.2	24.7	21.8	9.4	12.5	21.8
2003	74.7	28.3	38.3	8.2	1.3	1.6	2.8	77.6	25.3	22.4	9.4	13.0	22.4
2004	73.2	26.2	38.8	8.3	1.2	1.7	2.9	76.1	26.8	23.9	9.4	14.4	23.9
2005	72.5	25.3	39.0	8.3	1.1	1.8	3.0	75.5	27.5	24.5	9.5	15.0	24.5
2006	71.5	24.4	38.7	8.4	1.1	1.9	3.1	74.6	28.5	25.4	9.6	15.8	25.4
2007	71.1	24.2	38.4	8.5	1.1	1.9	3.0	74.1	28.9	25.9	9.6	16.2	25.9
2008	69.6	22.5	38.6	8.6	1.1	2.2	3.3	72.9	30.4	27.1	9.6	17.4	27.1
2009	73.4	25.1	40.4	7.9	1.0	1.8	2.8	76.3	26.6	23.7	8.9	14.8	23.7

Decomposition for selected countries, 2007

in % of gross exports

	Domestic value added in exports										Foreign value added in exports		
	VAX ratio				Returned domestic value added								
	Total	Final goods	Inter-mediates	Indirect (in third country)	Final goods	Inter-mediates	Total	Total	Double counting in trade	Double counting in GDP	Final goods	Inter-mediates	Total
USA	78.8	25.4	45.5	7.9	3.9	4.1	8.0	86.7	21.2	13.3	4.8	8.5	13.3
ZROW	65.8	15.3	43.7	6.8	1.8	4.5	6.3	72.0	34.3	28.0	9.2	18.8	28.0
DEU	69.8	29.0	32.5	8.3	1.3	2.2	3.5	73.3	30.2	26.7	10.8	15.9	26.7
WORLD	**71.1**	**24.2**	**38.4**	**8.5**	**1.1**	**1.9**	**3.0**	**74.1**	**28.9**	**25.9**	**9.6**	**16.2**	**25.9**
CHN	73.1	35.6	30.1	7.4	0.4	1.8	2.2	75.3	26.9	24.7	11.8	13.0	24.7
GBR	79.8	24.9	44.5	10.4	1.0	1.1	2.1	81.9	20.2	18.1	7.0	11.2	18.1
FRA	71.6	30.8	31.9	8.9	0.8	1.0	1.8	73.3	28.4	26.7	11.8	14.9	26.7
JPN	82.9	29.7	42.1	11.2	0.7	1.1	1.7	84.6	17.1	15.4	5.0	10.4	15.4
ITA	73.6	33.2	31.4	9.0	0.5	0.8	1.3	74.9	26.4	25.1	10.9	14.2	25.1
ESP	69.5	29.0	31.6	8.9	0.5	0.8	1.3	70.8	30.5	29.2	12.8	16.5	29.2
CAN	75.5	22.3	47.5	5.7	0.6	0.7	1.2	76.7	24.5	23.3	9.8	13.5	23.3
NLD	63.9	23.3	31.8	8.9	0.4	0.7	1.0	65.0	36.1	35.0	13.6	21.5	35.0
RUS	92.2	9.2	65.2	17.9	0.4	0.4	0.9	93.1	7.8	6.9	0.8	6.2	6.9

Summary

- Two concepts of "value added trade" considered
- Different concepts - different interpretations - similar outcomes
  - Supply side considerations (VS)
  - Demand side
- Net trade positions are unchanged in aggregate, but not bilateral
- Decomposition yields further insights
  - Relation between supply and demand concepts
  - For bilateral considerations
  - Computational methods

(Related) References

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