Measuring Trade in Value Added with Firm-Level Data

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The views expressed in this paper do not necessarily reflect the views of the NBB or of the IMF.

Motivation

- Global Value Chain (GVC) has become central to many policy debates.
  - GVC distinguishes between gross exports and exports of value added.
  - The rise in GVC participation: decline in value added content of exports.
  - Implications on trade balance, tariffs, spillovers, labor share, etc.

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- This paper: On the measurement of GVC participation.
  - Glass half-full: results consistent with expectations (both for CS and TS).
  - Glass half-empty: heroic assumptions involved.

Heroic assumptions

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  - Import content in exports understated by 10-25 percentage points of gross exports in China and Mexico (Koopman et al., 2012; De La Cruz et al., 2011).
- Computing underlying bias needs:
  - Information on domestic firm-to-firm transactions.
  - Firm-level data on international trade.

This paper

- Quantifies the underlying bias using detailed data from Belgium.
- Our measure of trade in value added: Vertical Specialization (VS) measure (Hummels et al., 2001).
  - Consider firms indexed by n. The VS measure for Belgium is given by

$$VS_B = \overset{1\times N}{\tilde{\mathbf{x}}}_{R,B} \left[\overset{N\times N}{I} - \overset{N\times N}{\tilde{\mathbf{x}}}_{B,B} \right]^{-1} \overset{N\times 1}{\mathbf{x}}_{B,R} / \iota' \overset{N\times 1}{\mathbf{x}}_{B,R}$$

    - ★ $\mathbf{x}_{R,B}$, $\mathbf{x}_{B,R}$: vectors of domestically absorbed imports and exports.
    - ★ $\mathbf{x}_{B,B}$: $N \times N$ matrix of domestic input flows.
    - ★ $\iota \equiv \overset{N\times 1}{\mathbf{1}}$.
    - ★ tilde transform flows into shares of destination gross output, $\tilde{x}_{i,j} = x_{i,j}/y_j$.
- Equivalent to value added to gross exports (VAX) measure with two countries.
  - Johnson and Noguera (2012), Koopman et al. (2012).

This paper

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  - Decomposes the bias into the "direct" and "indirect" components.

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  - Is the bias coming from the "direct" or "indirect" component?
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  - Is the bias coming from the "direct" or "indirect" component?
  - What are the key firm-level heterogeneity that produce the biases?
- Proposes ways to improve the standard IO table-based measures of GVC.

Key findings

- Sectoral aggregation biases the VS measure downwards in Belgium.
  - Much of the bias coming from the "direct" biases.
  - "Direct" biases due to positive correlation between import and export intensities.
  - But moderate magnitude of bias: 2 percent of gross exports on average.

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- If the "direct" bias account for most of the total biases in other countries:
  - Merging micro firm-level data with sectoral IO tables is a promising way to correct for biases.

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- If the "direct" bias account for most of the total biases in other countries:
  - Merging micro firm-level data with sectoral IO tables is a promising way to correct for biases.
- Application to firm-level datasets from other countries.
  - [Future:] Plan to expand sets of countries.

Literature

- Measures of GVC participation.
  - Hummels et al. (2001), Johnson and Noguera (2012), Koopman et al. (2012), Koopman et al. (2014), Johnson (2018).
- Addressing biases coming from sectoral aggregation.
  - De La Cruz et al. (2011), Feenstra and Jensen (2012), Koopman et al. (2012), Kee and Tang (2016), de Gortari (2018), Tang et al. (2018).
  - Saborío (2015) for Costa Rica, Hambÿe et al. (2018) for Belgium, Fetzer et al. (2018) for the U.S., Wu and Sabuhoro (2018) for Canada, Chong et al. (2018) for Netherlands, Yamano and Webb (2018) for OECD.

Roadmap

1. Characterizing the bias.
2. Application with Belgian data.
3. Correcting "direct" biases in other countries.

VS measure

- VS measure of Belgium, VS_B:

$$VS_B = \overset{1\times N}{\tilde{\mathbf{x}}}_{R,B}\left[\overset{N\times N}{I} - \overset{N\times N}{\tilde{\mathbf{x}}}_{B,B}\right]^{-1}\overset{N\times 1}{\mathbf{x}}_{B,R}/\iota'\overset{N\times 1}{\mathbf{x}}_{B,R}.$$

- Focus on the numerator of the VS measure, XVS_B:

$$\begin{aligned} XVS_B &= \overset{1\times N}{\tilde{\mathbf{x}}}_{R,B}\left[\overset{N\times N}{I} - \overset{N\times N}{\tilde{\mathbf{x}}}_{B,B}\right]^{-1}\overset{N\times 1}{\mathbf{x}}_{B,R} \\ &= \underbrace{\overset{1\times N}{\tilde{\mathbf{x}}}_{R,B}\overset{N\times 1}{\mathbf{x}}_{B,R}}_{XVS_B^{dir}} + \underbrace{\overset{1\times N}{\tilde{\mathbf{x}}}_{R,B}\overset{N\times N}{\tilde{\mathbf{x}}}_{B,B}\overset{N\times 1}{\mathbf{x}}_{B,R} + \cdots}_{XVS_B^{indir}}. \end{aligned}$$

XVS_B^{indir1}

Sector-level VS measure

- XVS_B comprises of nominal VS measures for each sector s, XVS_s, which are defined using exporting firms' sectors:

$$XVS_B = \sum_s XVS_s.$$

- The direct and indirect components of XVS_s:

$$XVS_s^{dir} = \sum_{n \in N_s} \frac{x_{R,n}}{y_n} x_{n,R}$$

$$XVS_s^{indir} = \underbrace{\sum_{n \in N_s} \sum_m \frac{x_{R,m}}{y_m} \frac{x_{m,n}}{y_n} x_{n,R}}_{XVS_s^{indir1}} + \sum_{n \in N_s} \sum_m \sum_l \frac{x_{R,l}}{y_l} \frac{x_{l,n}}{y_m} \frac{x_{m,n}}{y_n} x_{n,R} + \cdots .$$

Aggregation bias

- Can also compute XVS_s assuming representative firm in each 2-digit sector (IO table based):

$$XVS^{dir}_{IO,s} = \frac{\sum_{n \in N_s} x_{R,n}}{\sum_{n \in N_s} y_n} \sum_{n \in N_s} x_{n,R}$$

$$XVS^{indir1}_{IO,s} = \sum_k \frac{\sum_{m \in N_k} x_{R,m}}{\sum_{m \in N_k} y_m} \frac{\sum_{n \in N_s} \sum_{m \in N_k} x_{m,n}}{\sum_{n \in N_s} y_n} \sum_{n \in N_s} x_{n,R}$$

$$\vdots$$

- Define bias as:

$$XVS^{bias,dir}_s = XVS^{dir}_s - XVS^{dir}_{IO,s}$$

$$XVS^{bias,indir1}_s = XVS^{indir1}_s - XVS^{indir1}_{IO,s}$$

$$\vdots$$

Characterizing $XVS_s^{bias,dir}$

- The "direct" bias:

$$\begin{aligned} XVS_s^{bias,dir} &= XVS_s^{dir} - XVS_{IO,s}^{dir} \\ &= \sum_{n \in N_s} \Delta\alpha_n^M \Delta\alpha_n^X y_n. \end{aligned}$$

- Firms' import and export intensities are denoted as $\alpha_n^M = x_{R,n}/y_n$ and $\alpha_n^X = x_{n,R}/y_n$.
- Sectoral weighted means of these intensities are denoted as $\widetilde{\alpha}_s^M = \sum_{n \in N_s} x_{R,n} / \sum_{n \in N_s} y_n$ and $\widetilde{\alpha}_s^X = \sum_{n \in N_s} x_{n,R} / \sum_{n \in N_s} y_n$.
- We write the firm-level deviations from these weighted means as $\Delta\alpha_n^M = \alpha_n^M - \widetilde{\alpha}_s^M$ and $\Delta\alpha_n^X = \alpha_n^X - \widetilde{\alpha}_s^X$.

Characterizing $XVS_s^{bias,dir}$

- The direct bias is the numerator of the weighted covariance between the intensities α_n^M and α_n^X, with weights being firms' sales:

$$XVS_s^{bias,dir} = N_s \bar{y}_s \times cov^{w(y_n)} \left(\alpha_n^M, \alpha_n^X \right).$$

- If firms that are import intensive also tend to be export intensive, then $XVS_s^{bias,dir} > 0$, and the IO table based VS measure would be downward biased.
- To interpret the direct bias, one can also isolate out the unweighted covariance between α_n^M and α_n^X.

Characterizing $XVS_s^{bias,dir}$

- The direct bias can be re-written as:

$$\begin{aligned} XVS_s^{bias,dir} =& N_s \bar{y}_s cov(\alpha_n^M, \alpha_n^X) \\ &+ N_s \left(\bar{\alpha}_s^X - \tilde{\alpha}_s^X\right) cov(\alpha_n^M, y_n) + N_s \left(\bar{\alpha}_s^M - \tilde{\alpha}_s^M\right) cov(\alpha_n^X, y_n) \\ &+ N_s \bar{y}_s \left(\bar{\alpha}_s^M - \tilde{\alpha}_s^M\right)\left(\bar{\alpha}_s^X - \tilde{\alpha}_s^X\right) + \sum_{n \in N_s} \left(\alpha_n^M - \bar{\alpha}_s^M\right)\left(\alpha_n^X - \bar{\alpha}_s^X\right)(y_n - \bar{y}_s)\,. \end{aligned}$$

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- The remaining four terms account for the impact of variation in firm size.
  - Simple import/export covariance needs to be adjusted for interactions with firm size.
    - ★ If import intensive firms are large, then $cov(\alpha_n^M, y_n) > 0$.

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- The remaining four terms account for the impact of variation in firm size.
  - Simple import/export covariance needs to be adjusted for interactions with firm size.
    - ⋆ If import intensive firms are large, then $cov(\alpha_n^M, y_n) > 0$.
  - Simple import/export covariance is based on a distorted average import and export intensities.
    - ⋆ If import intensive firms are large, then $\bar{\alpha}_s^M < \tilde{\alpha}_s^M$.

Characterizing $XVS_s^{bias,indir1}$

- The "first indirect" bias:

$$\begin{aligned} XVS_s^{bias,indir1} =& XVS_s^{indir1} - XVS_{IO,s}^{indir1} \\ =& \sum_{n\in N_s}\sum_{k\in S}\sum_{m\in N_k} \Delta\alpha_m^M \tilde{\alpha}_{k,s}\tilde{\alpha}_s^X y_n + \sum_{n\in N_s}\sum_{k\in S}\sum_{m\in N_k} \tilde{\alpha}_k^M \Delta\alpha_{m,n}\Delta\alpha_n^X y_n \\ &+ \sum_{n\in N_s}\sum_{k\in S}\sum_{m\in N_k} \Delta\alpha_m^M \Delta\alpha_{m,n}\tilde{\alpha}_s^X y_n + \sum_{n\in N_s}\sum_{k\in S}\sum_{m\in N_k} \Delta\alpha_m^M \Delta\alpha_{m,n}\Delta\alpha_n^X y_n, \end{aligned}$$

where $\Delta\alpha_{m,n} = \alpha_{m,n} - \tilde{\alpha}_{k,s}$, with $\tilde{\alpha}_{k,s} = \frac{1}{N_k}\frac{\sum_{n\in N_s}\sum_{m\in N_k} x_{m,n}}{\sum_{n\in N_s} y_n}$.

1. Negative if large firms tend to be import intensive within sectors.
2. Positive if export intensive firms supply more intensively from other firms.
3. Positive if firms supply more intensively from firms that are more import intensive.
4. Positive if export intensive firms supply more intensively from import intensive firms.

Roadmap

1. Characterizing the bias.

2. Application with Belgian data.
   - Convey macro representativeness of the dataset.
   - Compare firm-level vs. aggregated VS measures and decompose the biases.

3. Correcting "direct" biases in other countries.

Data

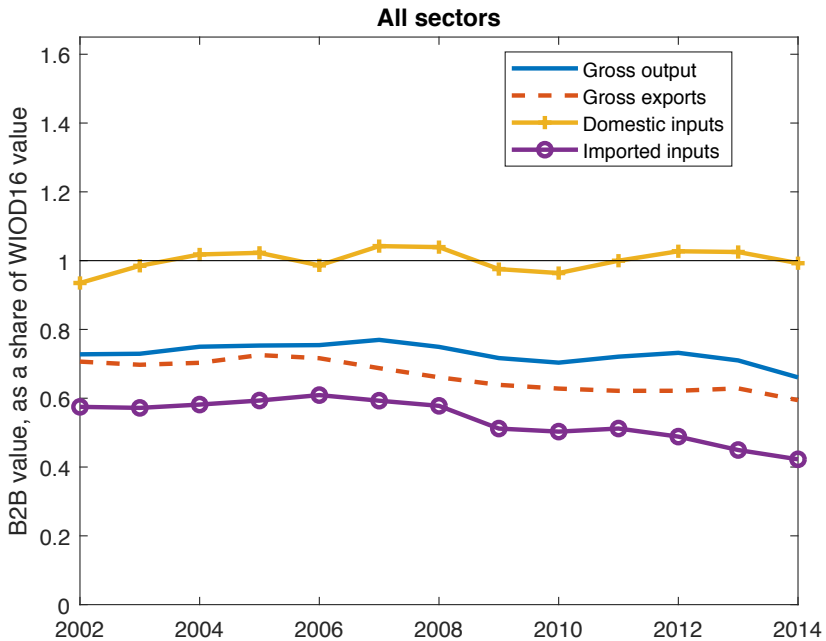
Construct ingredients of the VS measure ($x_{R,n}$, $x_{m,n}$, $x_{n,R}$, y_n) both at the firm-level and at the sector-level (NACE 2-digit).

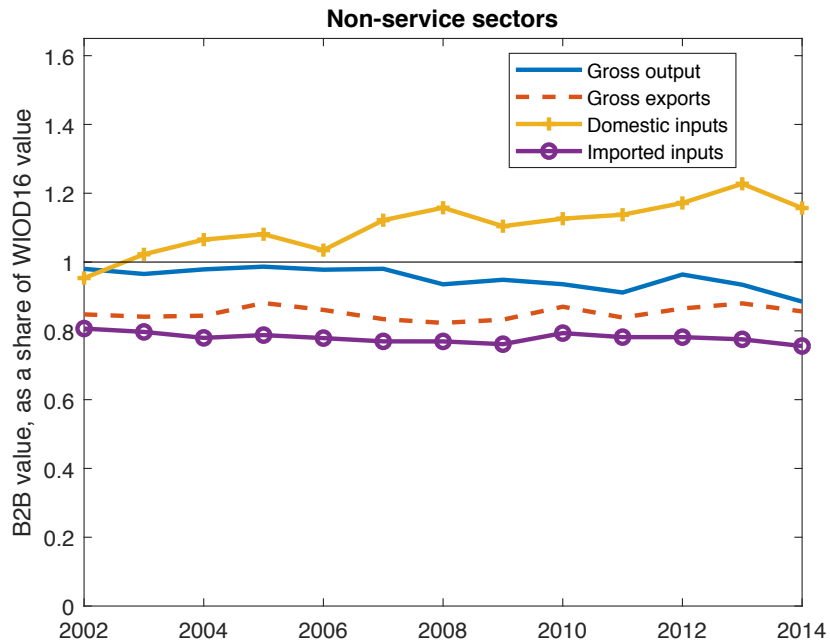
- National Bank of Belgium Business-to-Business Transaction Dataset (Dhyne, Magerman and Rubinova, 2015).
  - Panel of VAT-ID-to-VAT-ID transactions among the universe of Belgian enterprises, over 2002-2014.
- Match VAT-IDs with primary sector (4-digit), annual accounts and country-product (CN 8-digit) level international trade dataset.
- Sample:
  - Consider VAT-IDs that report positive labor costs in their annual accounts.
  - Keep VAT-ID as unit of observation, not the aggregated firm-level (unlike Tintelnot et al., 2018, Kikkawa et al., 2018).

Variable construction

- Domestically absorbed imports $x_{R,n}$ and exports $x_{n,R}$:
  - Construct from international trade dataset. ▸ Re-exports
  - Use BEC classification to classify imports to either imported intermediate goods or to capital/consumption goods.
- Domestic input flows $x_{m,n}$:
  - Construct from the B2B dataset.
- Gross output y_n:
  - Sum of value added, inputs from other enterprises, and absorbed imports.
  - Use value added reported in the annual accounts. ▸ Alternative
  - Output for capital formation/consumption is $\max\{\text{gross output} - \text{B2B sales} - \text{exports}, 0\}$.

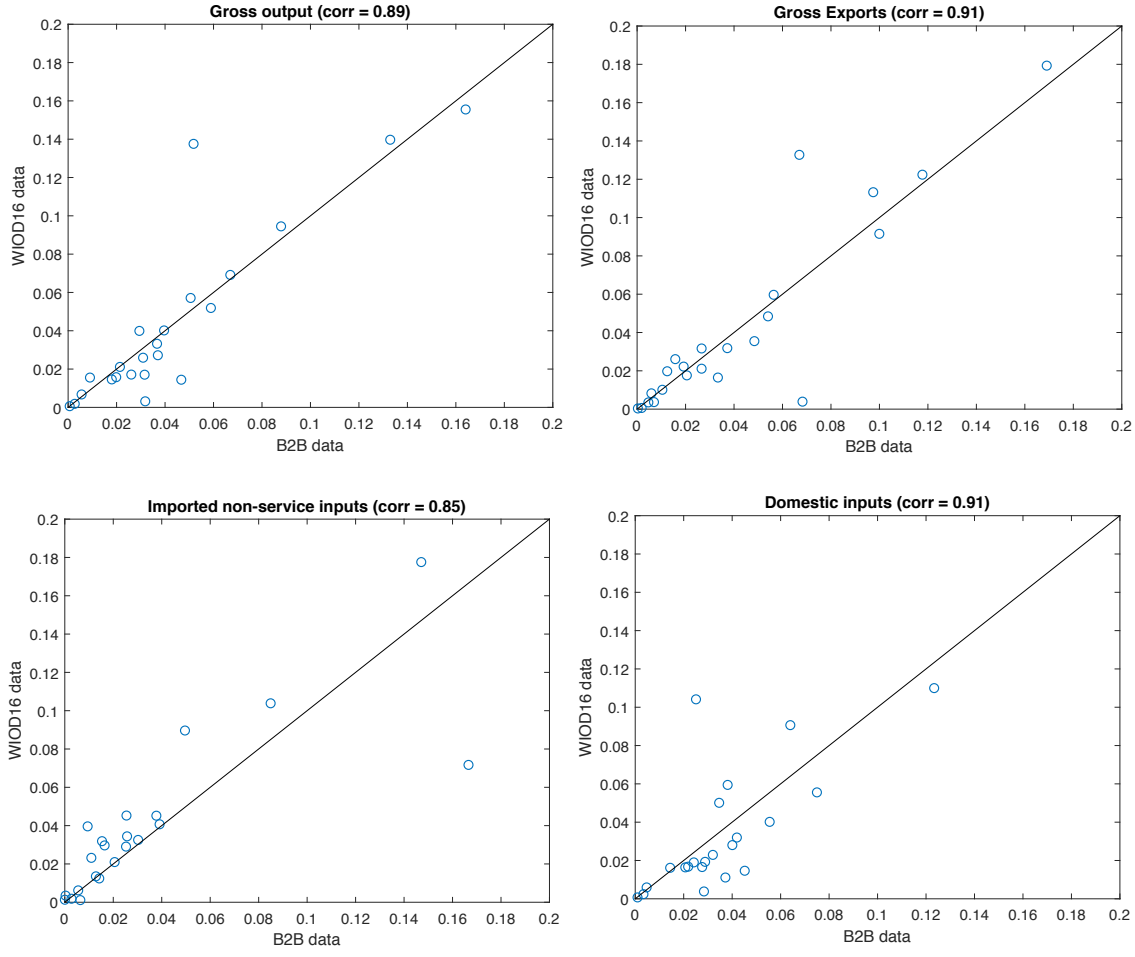
Aggregate variables





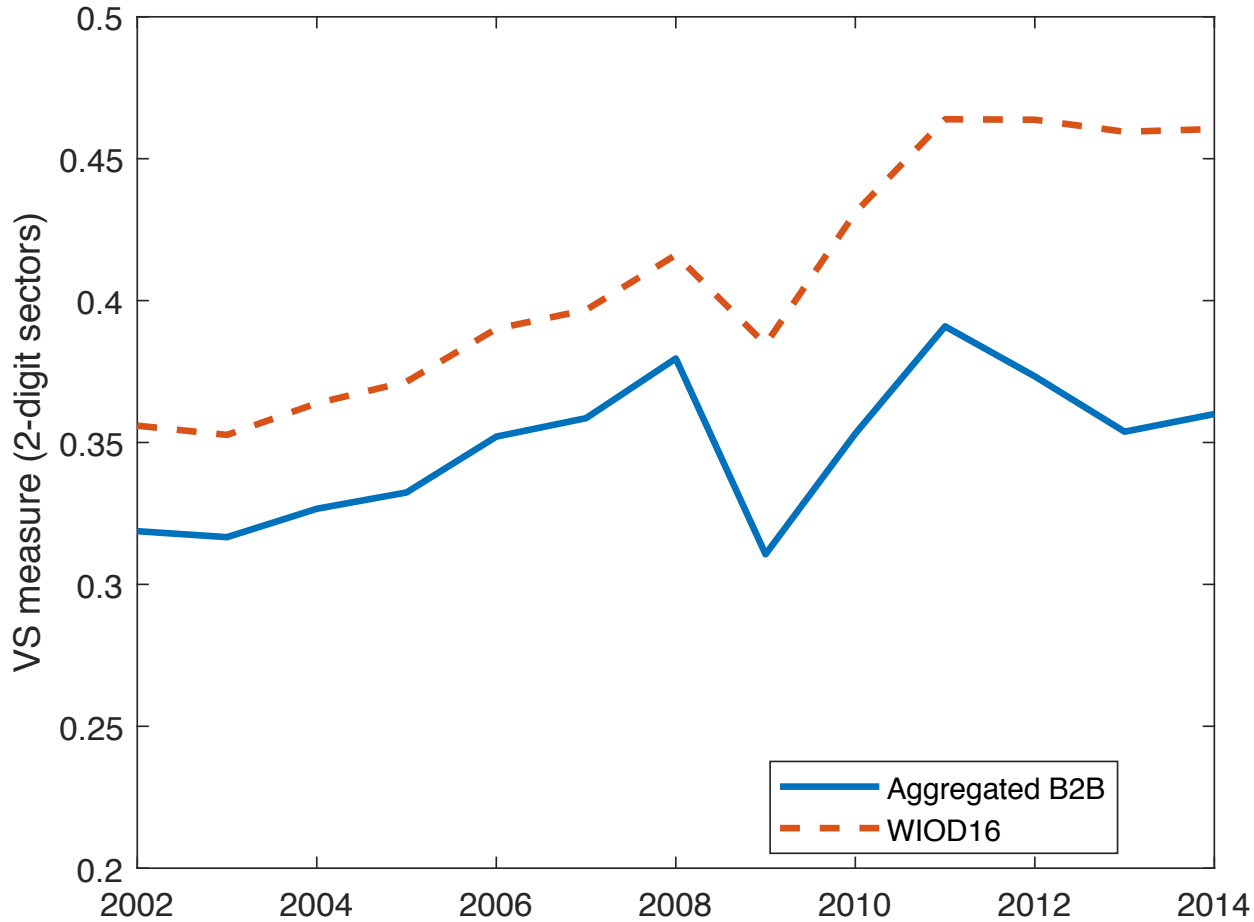
- alt VA

Sectoral shares for non-service manufacturing 2-digit sectors

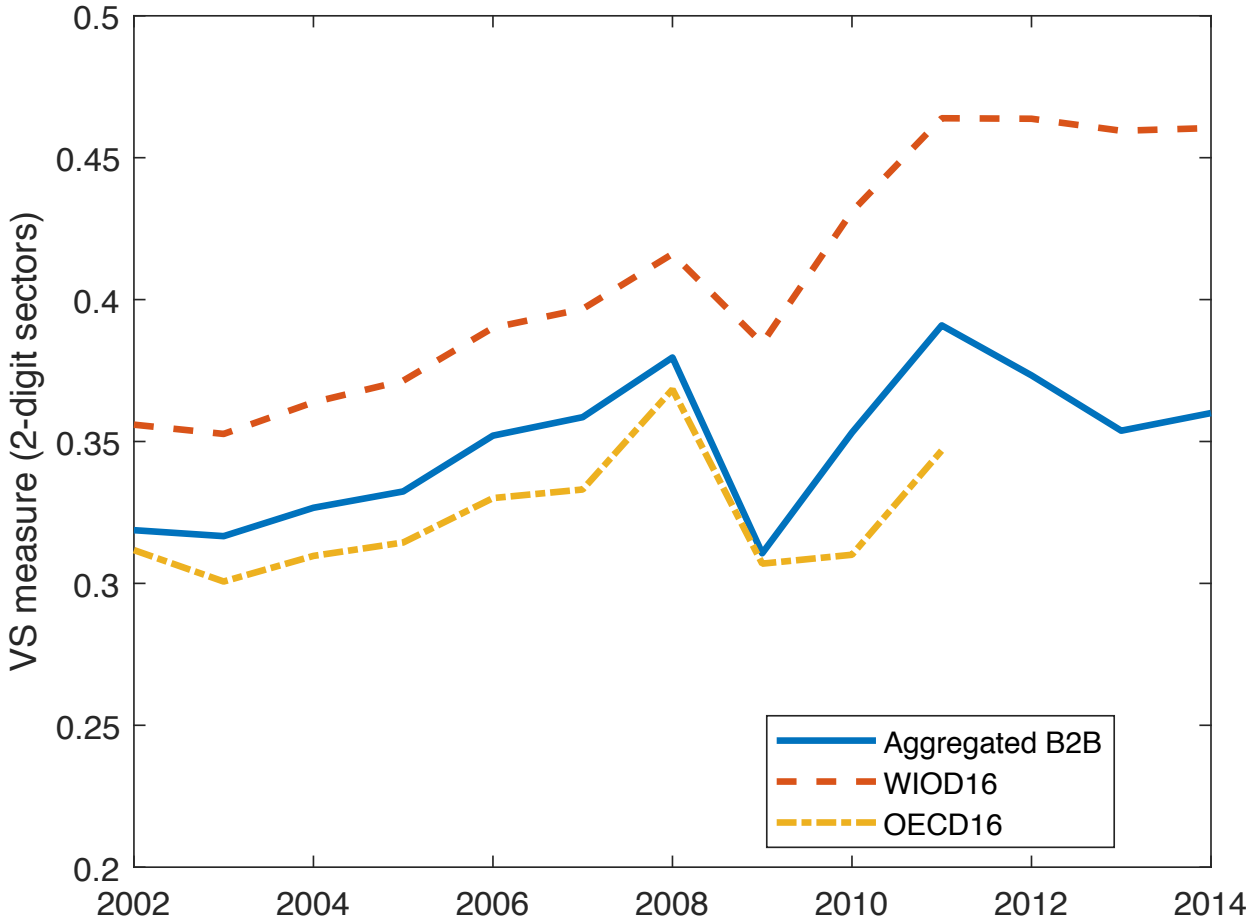


▸ alt VA

VS measures


0.5
0.45
0.4
0.35
0.3
0.25
0.2
VS measure (2-digit sectors)
2002
2004
2006
2008
2010
2012
2014
Aggregated B2B
WIOD16

VS measures (with OECD)



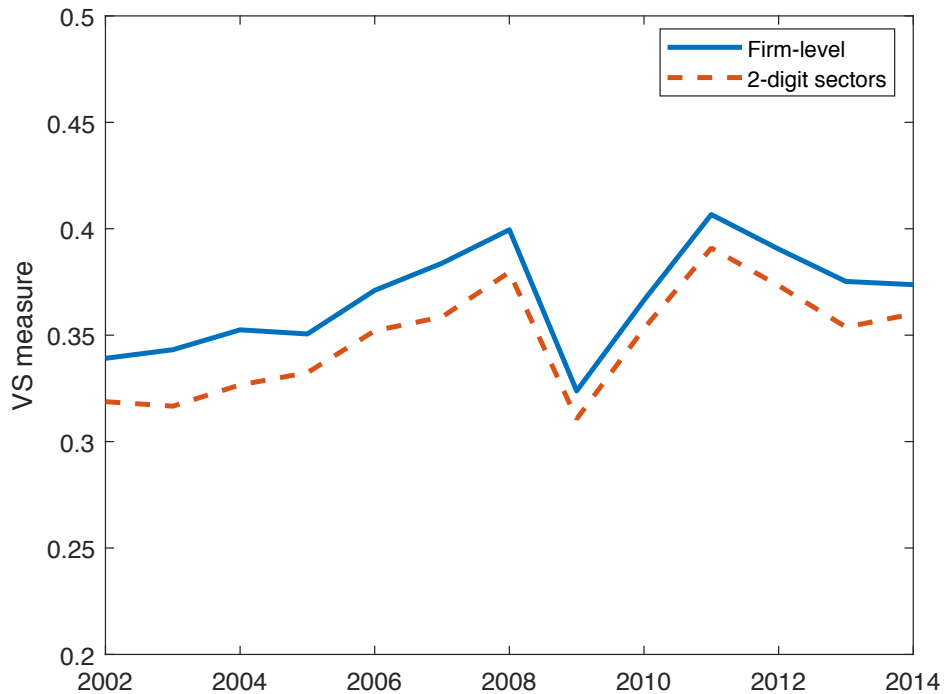
- include re-exports

Macro representative?

- B2B data accounts for the majority of int'l trade, output and intermediate consumption in the WIOD.
- Remaining differences may come from the data's limitations in the coverage of retail/wholesale and service activities, or treatments of re-exports.
- From here work within the B2B dataset to study the role of aggregation biases on VS measures.

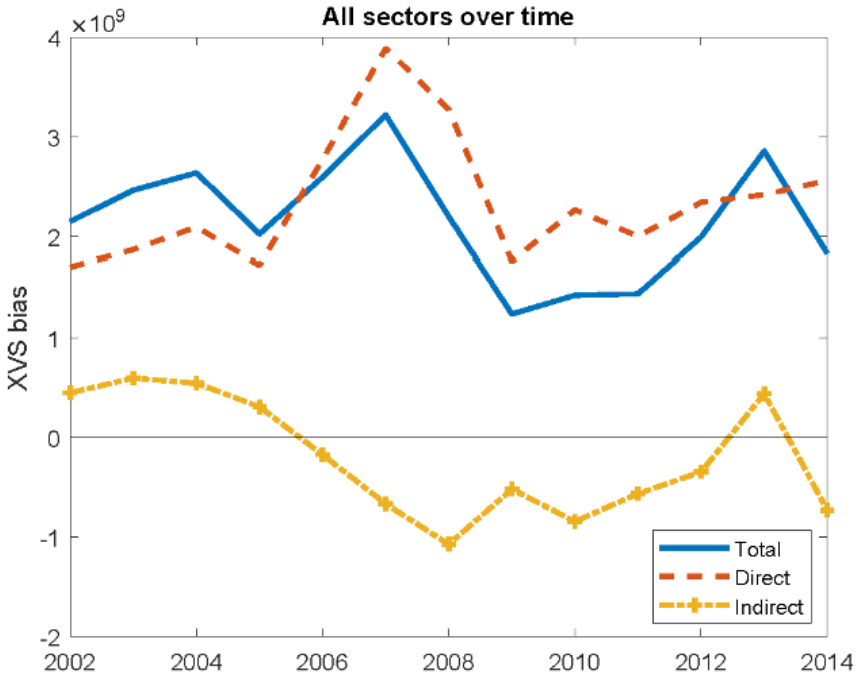
VS measures, aggregated vs. firm-level

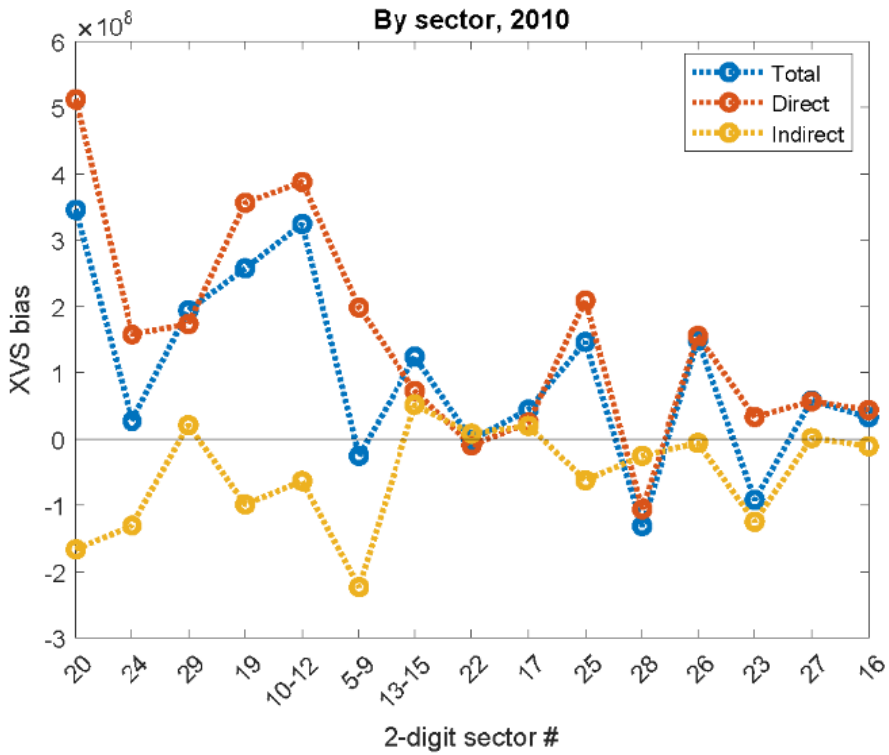
- Sectoral aggregation biases the VS measure downwards, by around 2 percentage points of gross exports.



Decomposition, direct vs. indirect

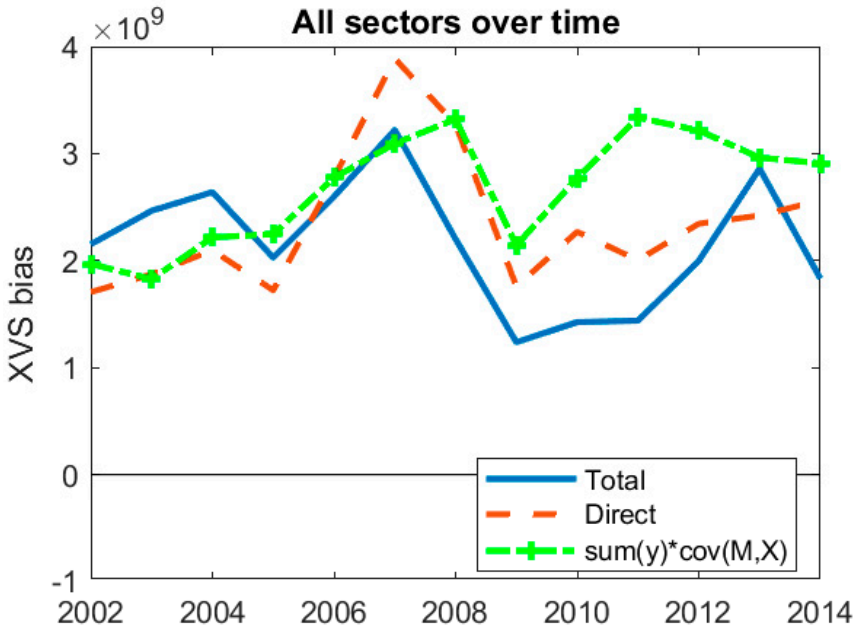
- Most of the biases coming from the "direct" bias.
- Import intensive firms are export intensive, $\sum_{n \in N_s} \Delta\alpha_n^M \Delta\alpha_n^X y_n > 0$.

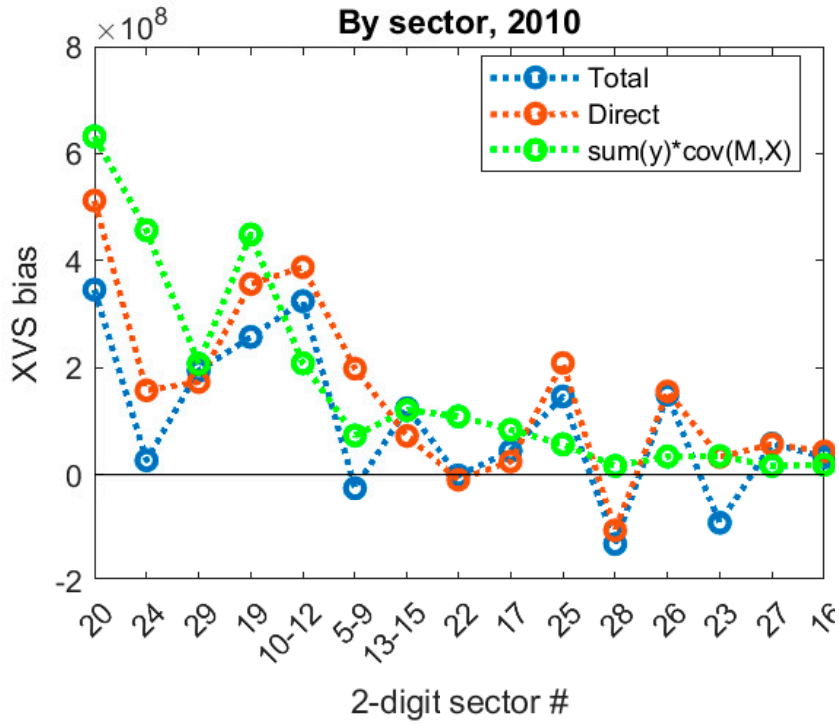




Characterizing $XVS_s^{bias,dir}$

- The correlation exists across firm size bins, as weighted covariance close to unweighted covariance, $\sum_{n \in N_s} \left(\alpha_n^M - \bar{\alpha}_s^M\right)\left(\alpha_n^X - \bar{\alpha}_s^X\right)$.

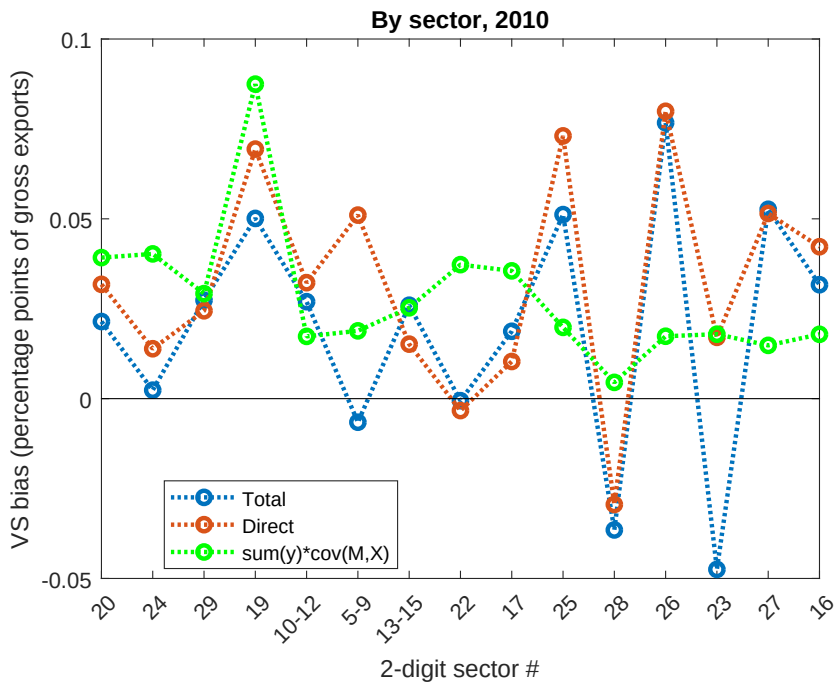




▸ Decompose into five

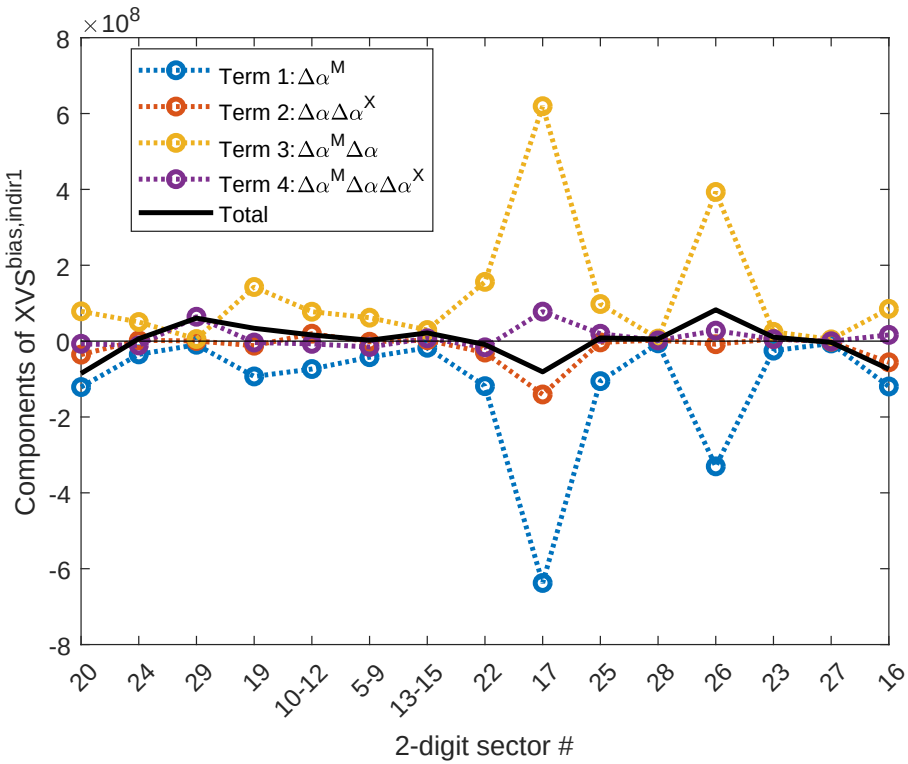
$VS_s^{bias,dir}$ BY SECTOR

- The difference between the direct biases and the simple covariance terms stem from the positive covariance between trade intensities and firm size.
  - Simple import/export covariance needs to be adjusted for interactions with firm size.
  - Simple import/export covariance is based on a distorted average import and export intensities.



Characterizing $XVS_s^{bias,indir1}$

- Term 1: large firms tend to be import intensive.
- Term 3: firms supply more intensively from import intensive firms.
- Terms 2 and 4: export intensive firms do not always supply more intensively from other firms.



Roadmap

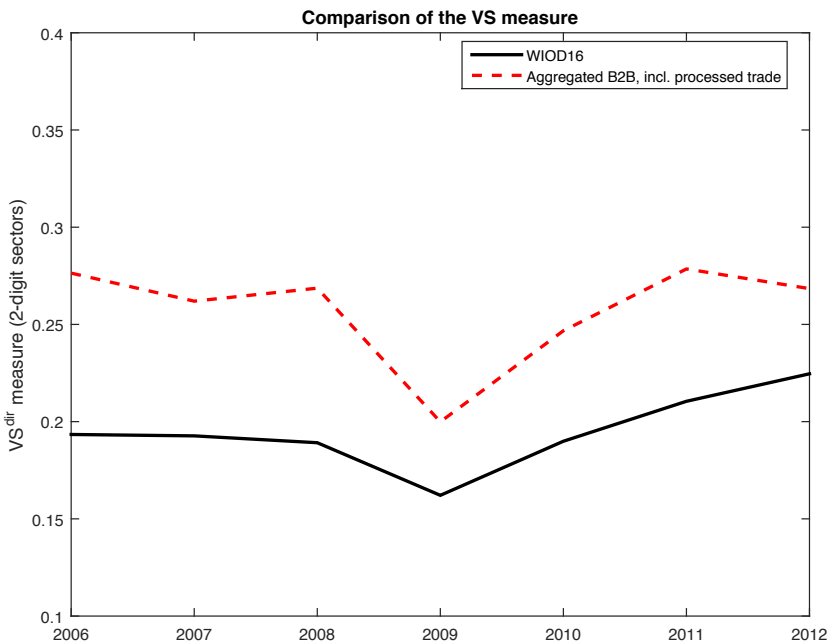
1. Characterizing the bias.
2. Application with Belgian data.
3. Correcting "direct" biases in other countries.

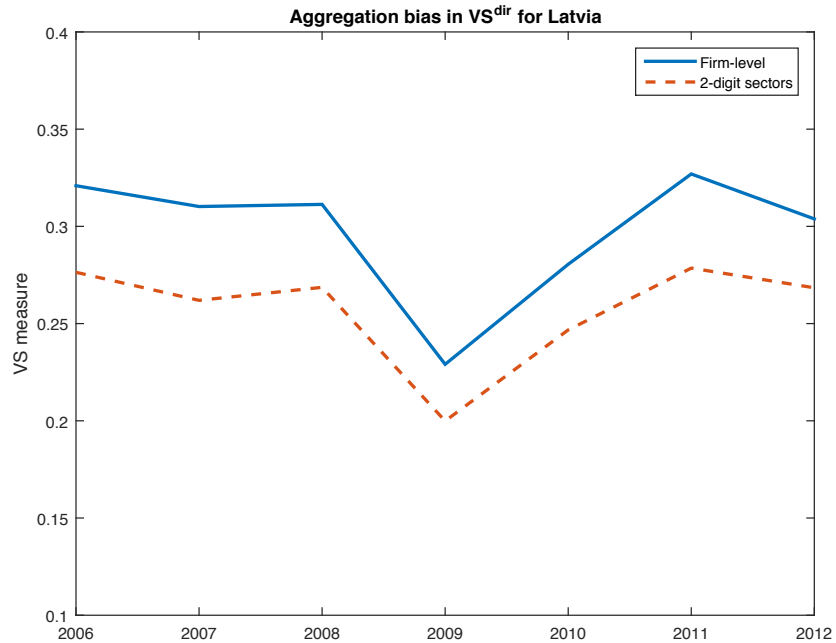
Improving the measurement

- The direct bias accounts for large part of total bias in Belgium.
- Correcting for the direct bias do not need "firm-to-firm" information.
  - Only need firm-level information on import/export intensity, sales.
- Combining with sectoral IO tables and firm-level micro data would improve the VS measure for other countries.
  - More up-to-date estimates, with no need to wait 5 years for new IO tables.
  - If direct bias is dominant as in Belgium, such measures have small aggregation biases.

Latvia (all firms)

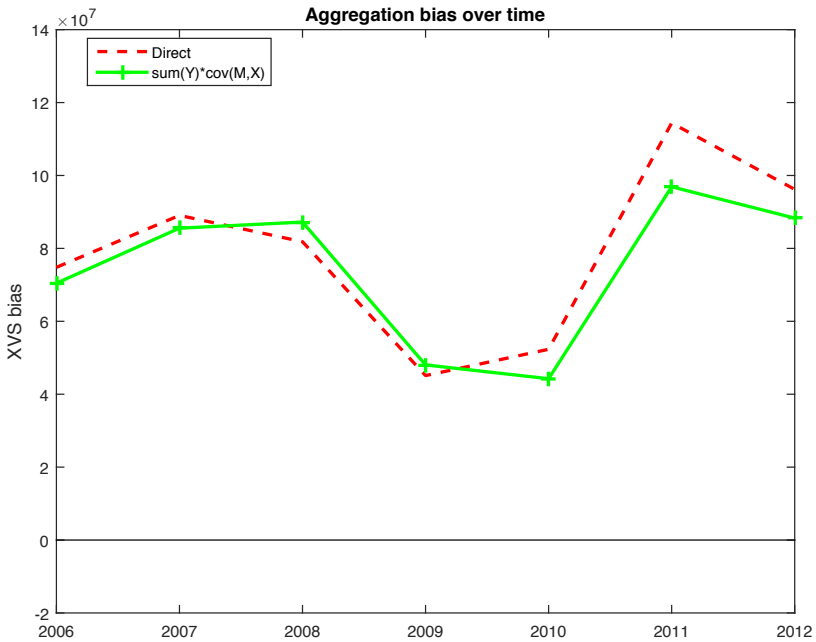
- Direct VS measure and its bias

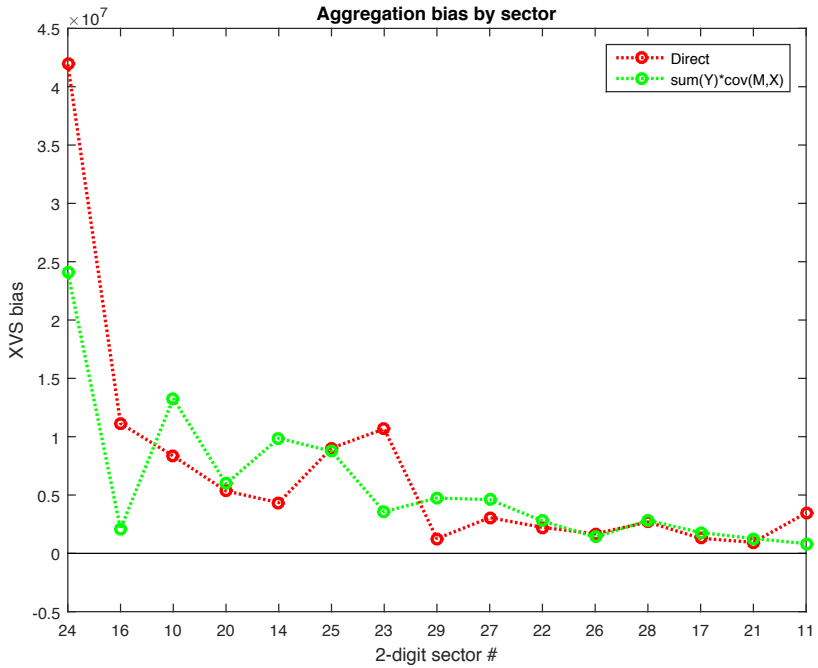




Latvia, $XVS_s^{bias,dir}$

- Unweighted covariance between α_n^M and α_n^X closely follows $XVS_s^{bias,dir}$.

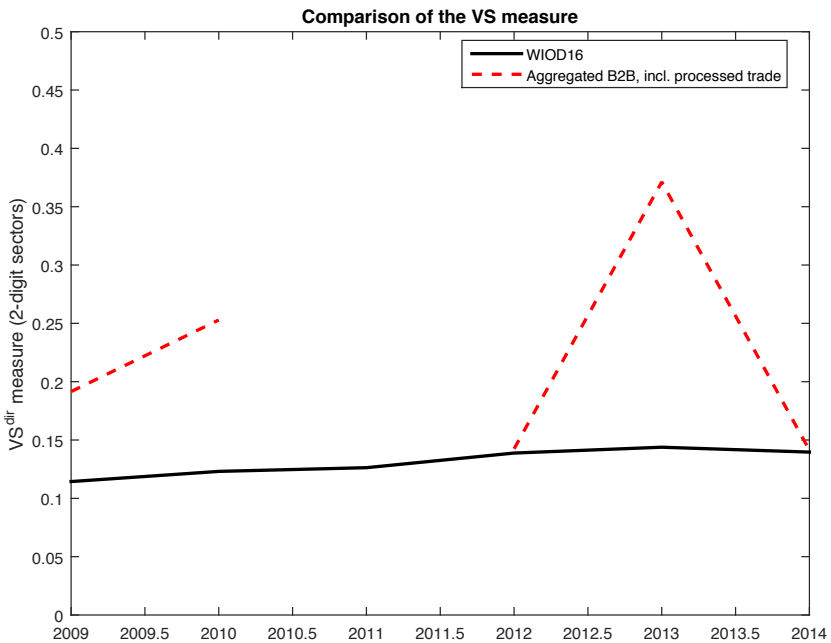


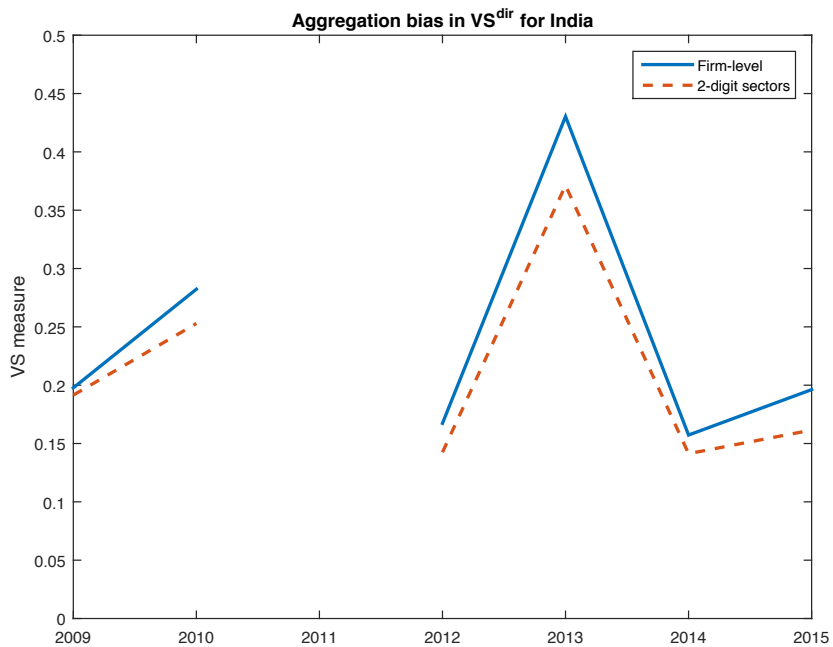


▸ In terms of ratio

India (ASI, Manufacturing)

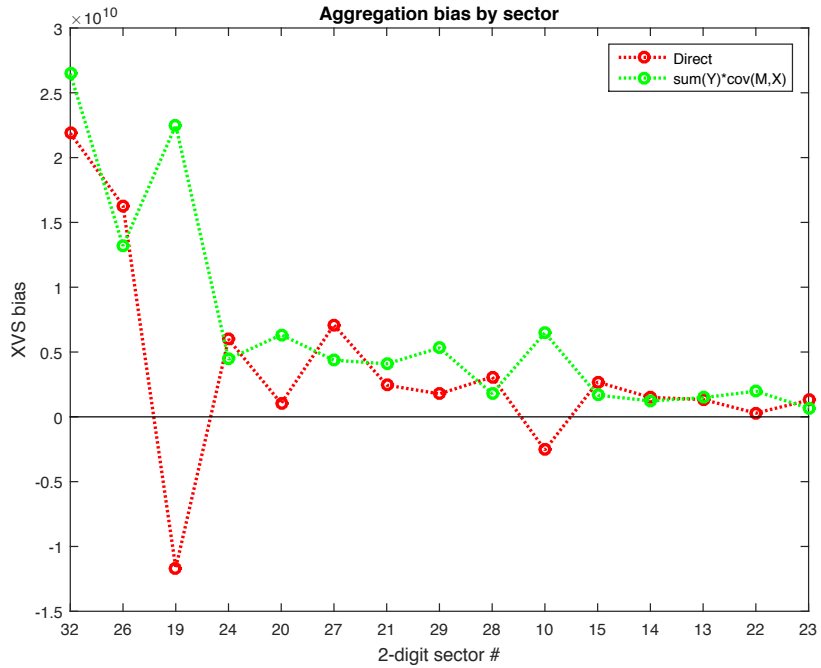
- Direct VS measure and its bias





India

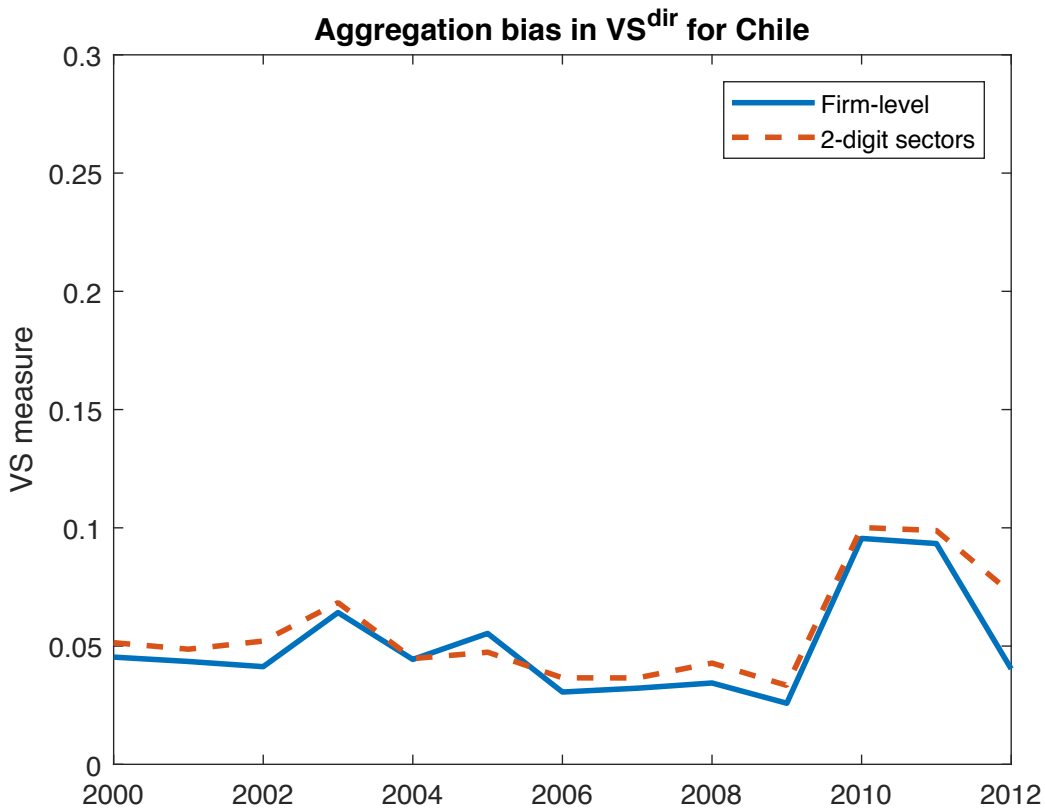
- For most sectors, unweighted covariance between α_n^M and α_n^X closely follows $XVS_s^{bias,dir}$.



▸ In terms of ratio

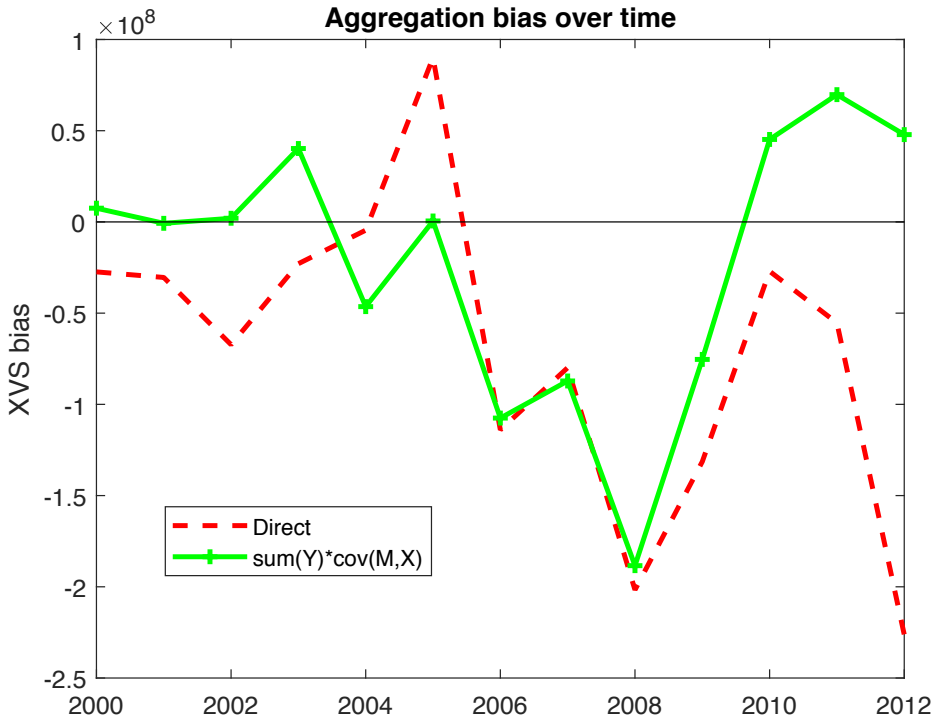
Chile (ENIA, Manufacturing)

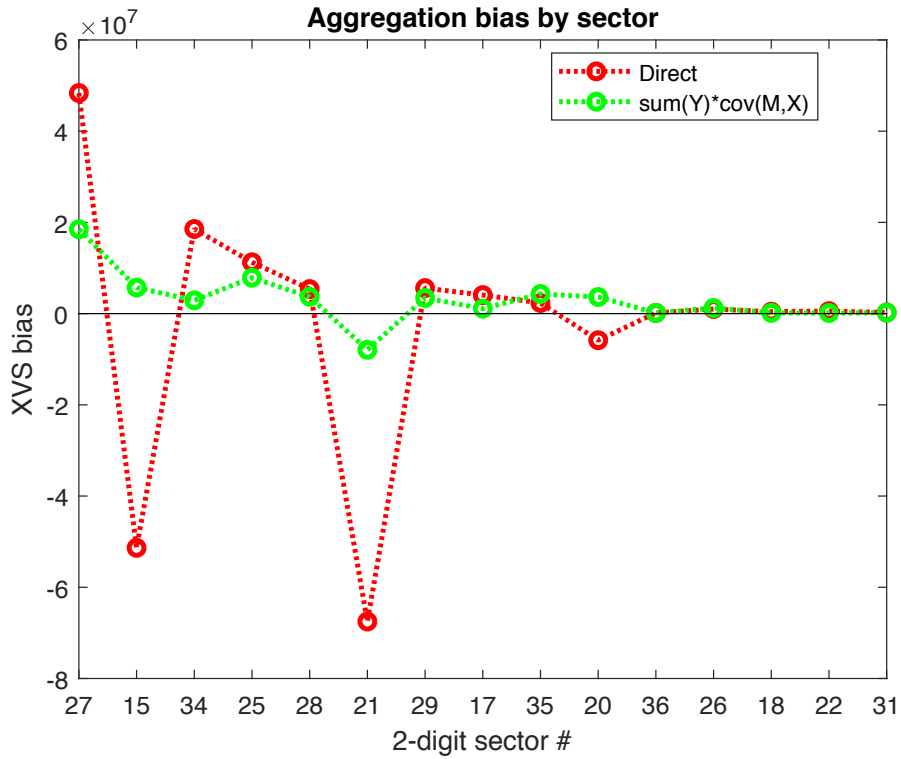
- Low VS measure, small (positive) biases



Chile

- Larger role in firm-size heterogeneity interacted with α_n^M and α_n^X.





▸ In terms of ratio

Conclusions

- This paper evaluates the aggregation bias on sectoral IO table based GVC measures.
- Sectoral aggregation biases the VS measure downwards, though moderate in magnitude.
  - Positive correlation between export and import intensities within sectors.
- Our results suggest that firm/trade microdata merged with sectoral IO table (via the "direct" measure) can be used to better gauge the evolution of countries' GVC involvement.
  - Add analyses of other countries.

Thank you!

APPENDIX

Treatment of re-exports

- Domestically absorbed imports $x_{R,n}$ and exports $x_{n,R}$ exclude re-exports.
- Identify re-exported imports if an enterprise imports and exports the same good in a given year.
  - For each VAT-ID-product-level, re-exports are the minimum of the value of exports and the value of imports, when the value of both imports and exports are positive.

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Alternative measure of value added

- In our baseline specification, the gross output of enterprises do not necessarily match the output reported in the annual accounts.
- As an alternative, we construct value added measures that are consistent with the output reported in the annual accounts.
- Compute value added as
  $\max\{\text{output in annual accounts} - \text{B2B purchases} - \text{imports}, 0\}$.

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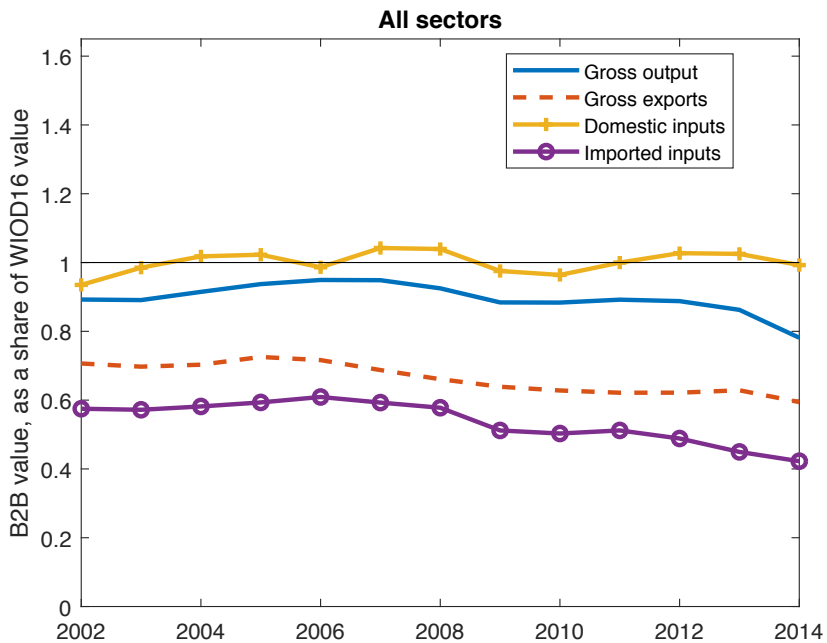
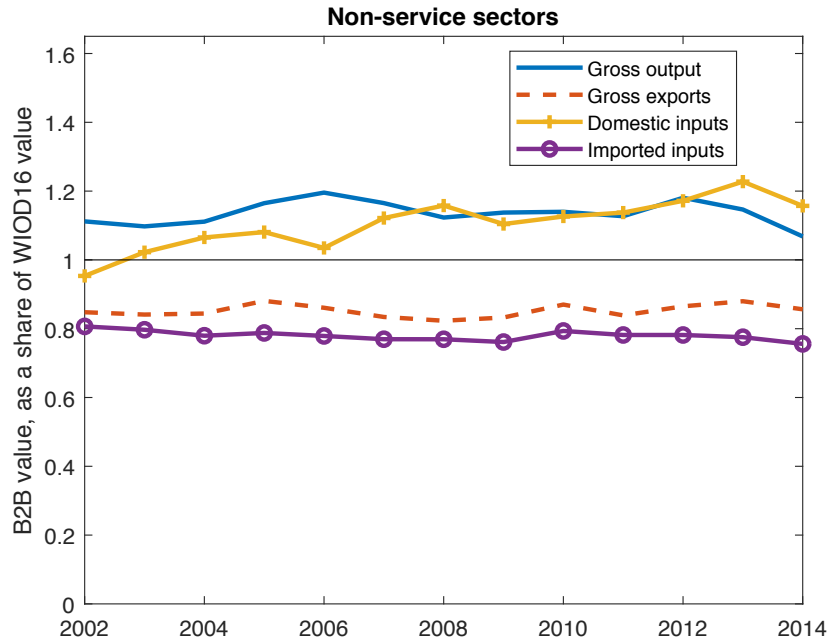
Aggregate variables (alt VA)





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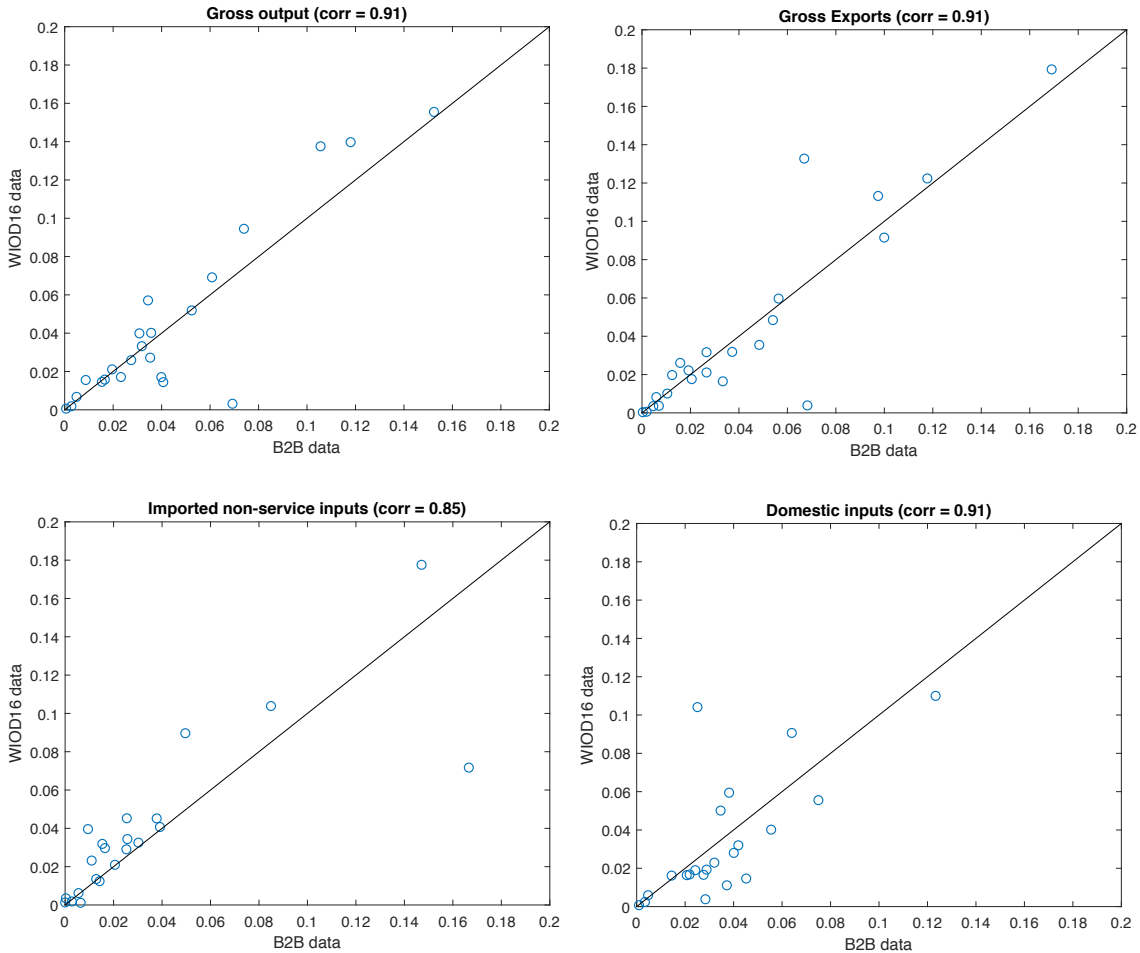
Sectoral shares for non-service manufacturing 2-digit sectors (alt VA)



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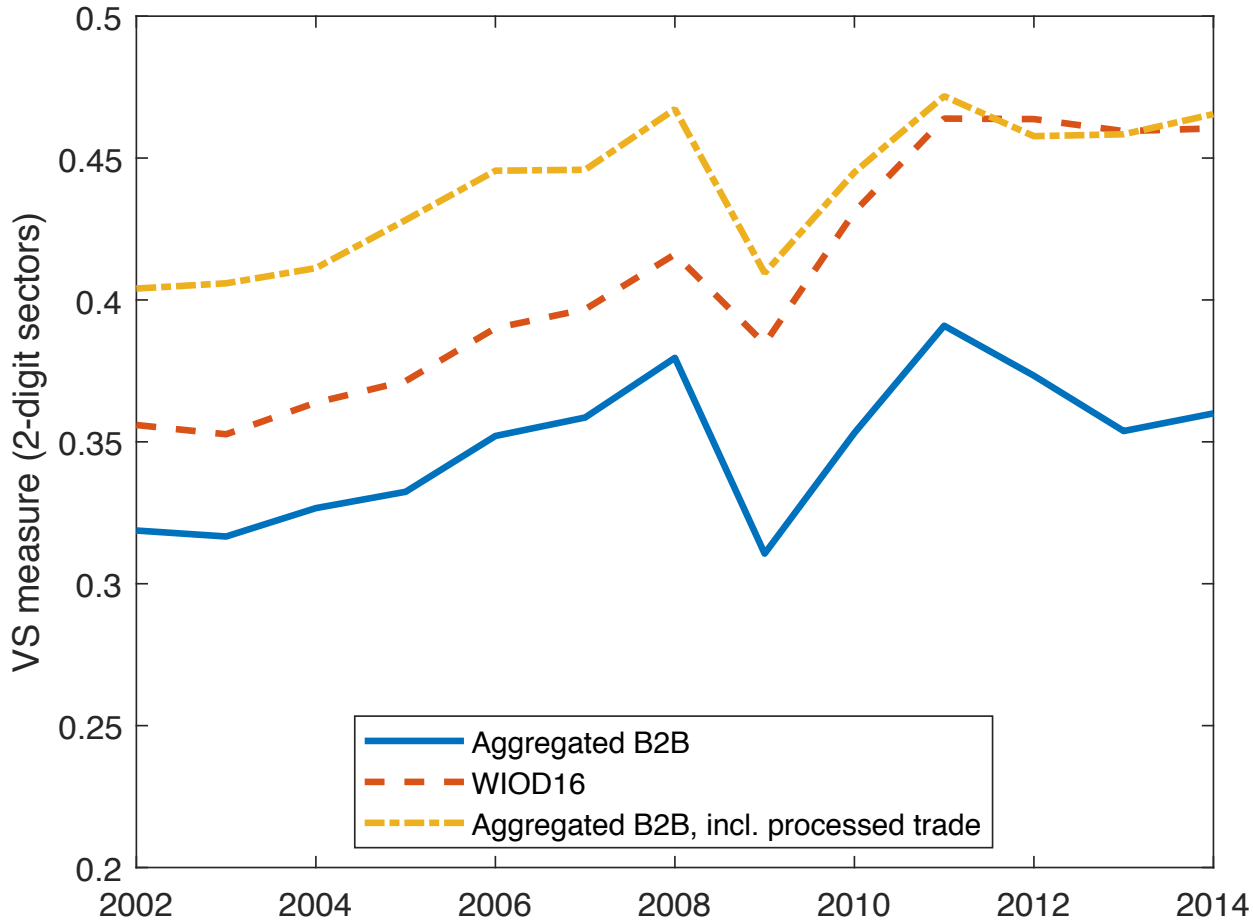
VS measures (with re-exports)



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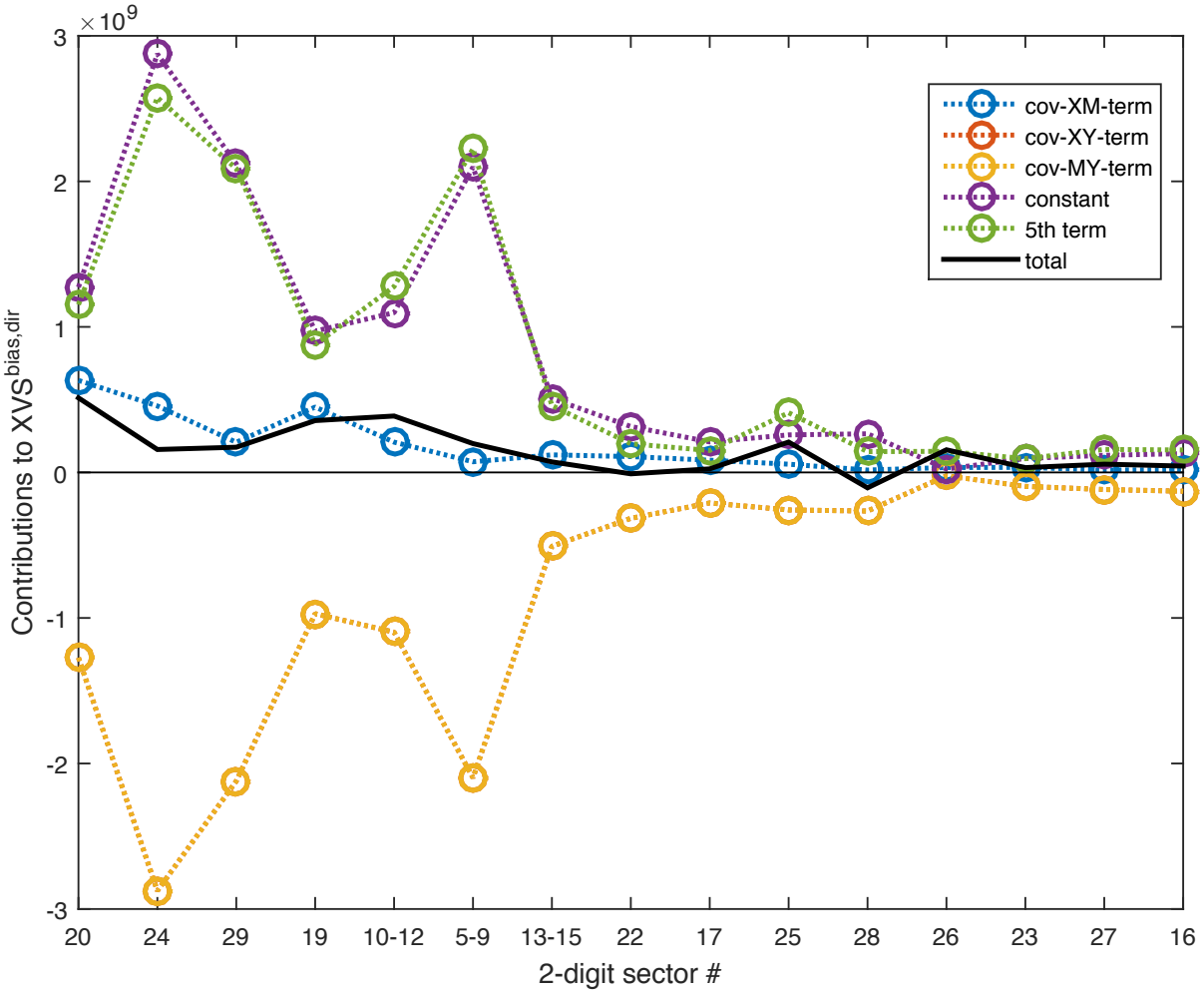
Decomposing $XVS_s^{bias,dir}$



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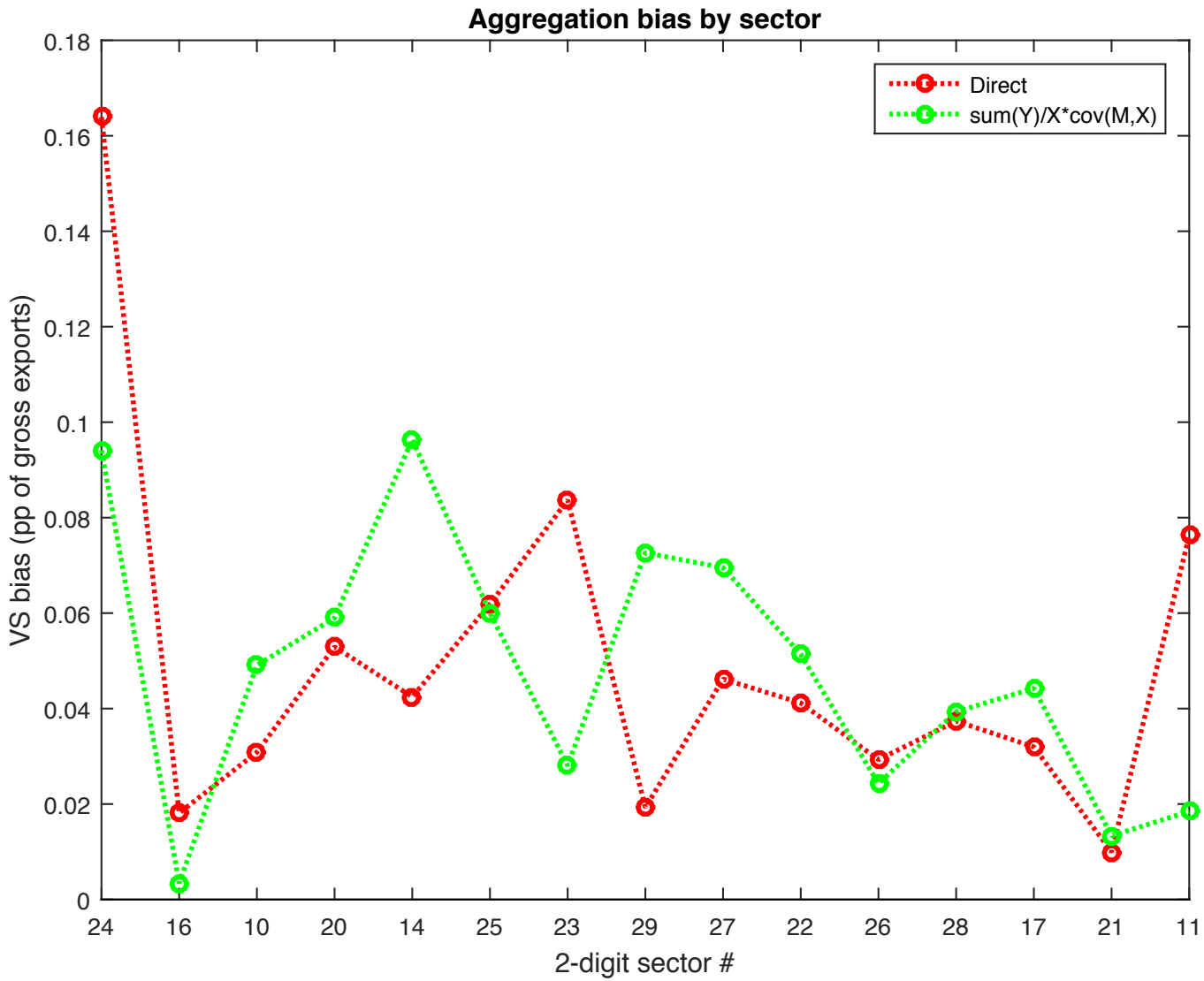
Latvia, $VS_s^{bias,dir}$



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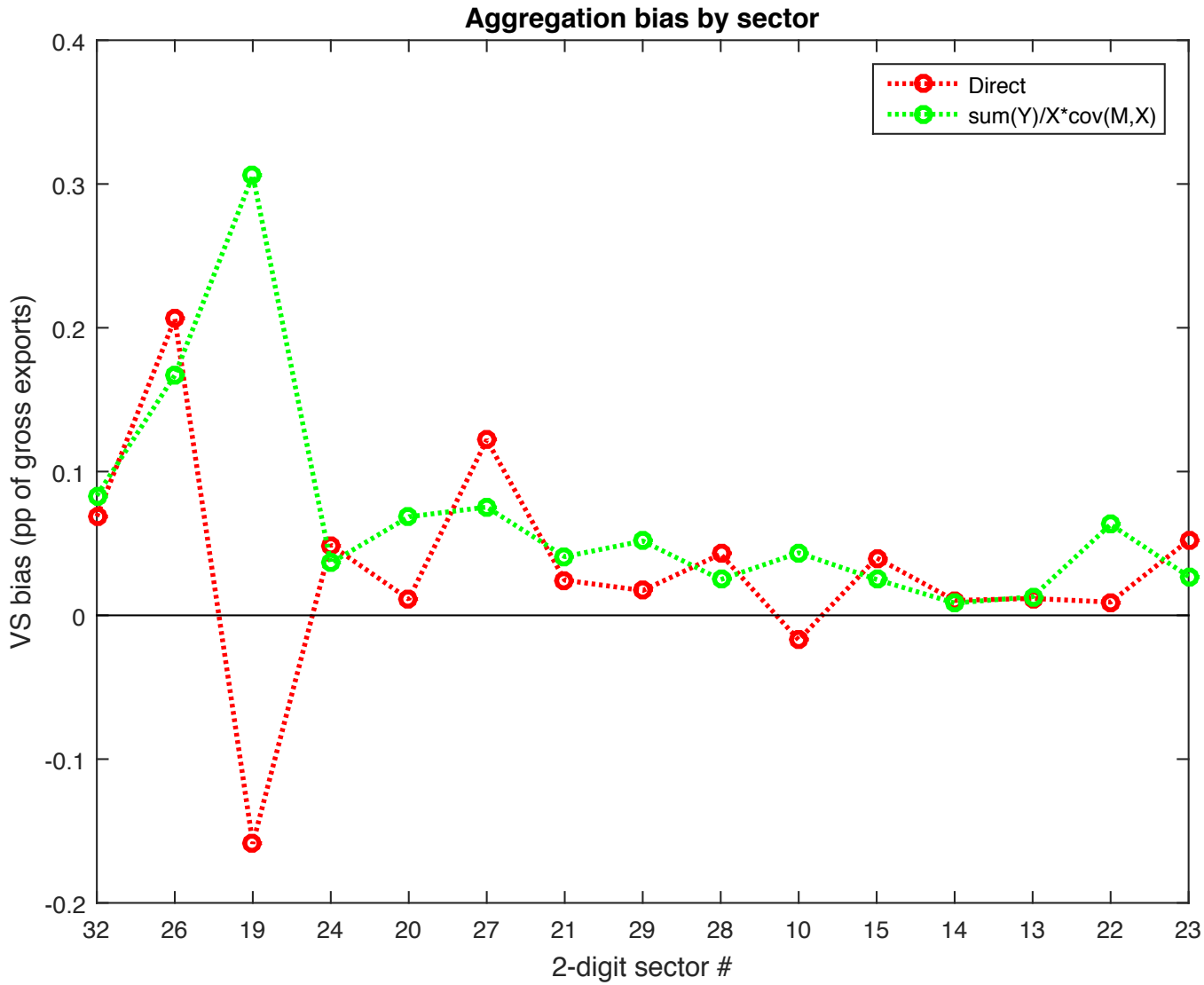
India, $VS_s^{bias,dir}$



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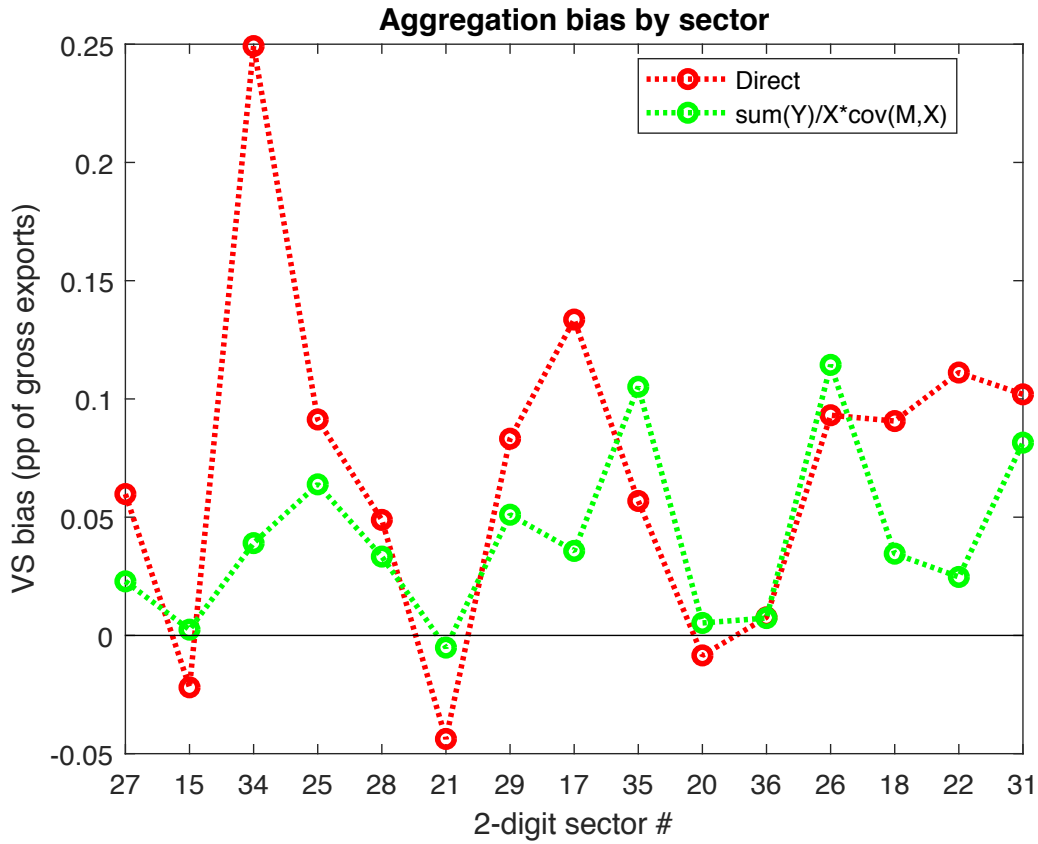
Chile, $VS_s^{bias,dir}$



▸ Back

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