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Decomposition of value added in gross exports: a critical review

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Abstract

Purpose – The purpose of this paper is to settle the methodological debate on the decomposition of value added in gross exports, proposing a standard, exposing the drawbacks of the alternatives and quantifying the differences.

Design/methodology/approach – This paper systematizes the analytical framework and assesses and quantifies the various methodologies and its main differences.

Findings – The decomposition method of Borin and Mancini (2023), using a source-based approach and an exporting country perspective, should be considered as the standard for decomposing the value added in gross exports. This study finds that alternative approaches and perspectives are methodologically inferior, and that tailored perspectives do not provide an increase in accuracy that compensates their drawbacks.

Originality/value – This paper's contribution is fourfold: it rejects the alleged equivalence between approaches and perspectives, defending the superiority of a particular method, approach and perspective; it gives quantitative examples of the differences between them; it proves that the drawbacks of tailored perspectives do not compensate their alleged accuracy (as they do not result in big quantitative differences with the standard perspective); and it argues that no valid standard decomposition can forego the calculation of value added exported, which requires the expression of exports in terms of final demand.

Keywords Global value chains, Value added exports, Input–output tables, Trade in value added

Paper type Literature review

1. Introduction

Since the 1990s, the world has witnessed a rapid expansion of international trade, powered by the rise of global value chains (GVC). A vast literature has analyzed the drivers of firms' decision to fragment their production internationally, including declining transport, information and communication costs, the sharp increase in technological progress and lower political and economic barriers to trade and capital flows (Amador and Cabral, 2016; Baldwin, 2016; World Bank, 2019). The financial crisis, the COVID pandemic and geopolitical tensions have contained the expansion of GVC, as efficiency gains must now be weighed against various risks, but there is not yet evidence of a clear reshoring trend (Baldwin, 2022).

The fragmentation of production entails an increased role of intermediate products in global trade: between 1995 and 2018 exports of intermediate products represented, on average, 58% of total exports (with 60% for goods and 53% for services) [1]. As a result, statistics expressed in terms of value added (that can considerably differ from gross values)

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might be more accurate to reflect the reality of globalization, especially for complex goods and services.

However, statistical systems have not been able to catch up with the rhythm of globalization. Trade in national accounts is calculated in terms of value added, but with no geographical breakdown. Customs statistics only provide sectoral and geographical breakdown for goods, but details for services are scarce. They also fail to consider the multiple times that intermediate products cross the border.

The need for statistical tools that measure not only economic interrelations between countries but also between industries in different countries led in the mid-2010s to the development of fully fledged international input–output tables (IOTs) [2] and a parallel debate in the economic literature of how to decompose value added in gross exports, with contributions of Daudin *et al.* (2011), Johnson and Noguera (2012), Foster-McGregor and Stehrer (2013), Koopman *et al.* (2014), Wang *et al.* (2013), Los *et al.* (2016), Los and Timmer (2018), Nagengast and Stehrer (2016), Johnson (2018), Arto *et al.* (2019), Miroudot and Ye (2017, 2021) and Borin and Mancini (2017, 2023). Multiple approaches and perspectives have been proposed, not always in a clear manner.

Our aim is to settle the debate in the literature and propose a standard of decomposition of value added in exports using a specific method, approach and perspective, filtering out variations proposed in the literature that are only marginally relevant. For that, after presenting in Section 2 a general analytical standard framework, in Section 3 we will highlight the drawbacks of other alternatives and provide some final arguments. In Section 4, we will quantify the differences in methods, approaches and perspectives and consider sectoral aspects frequently overlooked, before summarizing our conclusions in Section 5.

2. A standard for the decomposition of value added in gross exports

We will consider a traditional international IOT framework with $s = 1...G$ countries, $r = 1...G$ partner countries and $i = 1...N$ sectors. Let $\mathbf{Z}$ be the intermediate input matrix (dimension $GN \times GN$), Y the final demand matrix ($GN \times G$), VA the value added matrix ($1 \times GN$) and X the production matrix ($GN \times 1$). Submatrices are defined for each country s (and sometimes partner r). The standard demand model, dated back to Leontief (1936), can be expressed as $\mathrm{AX} + \mathrm{Y} = \mathrm{X}$, where $\mathrm{A} = \mathrm{Z/X}$, establishing a relation between production and final demand:

$$\mathrm{X} = (\mathrm{I} - \mathrm{A})^{-1}\mathrm{Y} = \mathrm{BY} \tag{1}$$

The global inverse Leontief matrix B represents the increase in production X induced by an increase in final demand Y. Each element B_{sr} reflects the production effort of country s to satisfy a simultaneous increase of one unit in the final demand of all sectors in country r.

Value added VA can also be considered as a vectorial proportion V of the production X ($\mathrm{V} = \mathrm{VA/X}$), and expressed for country s in terms of global demand:

$$\mathrm{VA}_s = \mathrm{V}_s\mathrm{X}_s = \mathrm{V}_s\sum_{j}^{G}\sum_{r}^{G}\mathrm{B}_{sj}\mathrm{Y}_{jr} \tag{2}$$

Equation (2) can be broken down into value added produced and absorbed in s and value added produced in s and absorbed abroad:

$$VA_s = V_s \sum_{j}^{G} B_{sj} Y_{js} + V_s \sum_{j}^{G} \sum_{r \neq s}^{G} B_{sj} Y_{jr} \tag{3}$$

The second term in (3) is usually referred to as value added exported VAX_s (Johnson and Noguera, 2012).

The resulting vector (of dimension $1 \times G$), however, does not reflect for each partner r the value added of s *exported* to r, but only the value added *absorbed* in r. Although the sum for all partners, i.e. the total value added of s absorbed *anywhere*, is equal to the total VAX *anywhere*, a correct bilateral measure of VAX_{sr} should show the value added of s exported to r *regardless of where this value added is eventually absorbed*, requiring therefore a different calculation method.

We know that the matrix product VB is a linear combination by columns, reflecting the percentage of value added induced both by domestic inputs and by imported inputs. For country s:

$$\sum_{t}^{G} V_t B_{ts} = V_s B_{ss} + \sum_{t \neq s}^{G} V_t B_{ts} = \iota \tag{4}$$

where ι is a vector of one of dimension $1 \times N$. Multiplying the above expression by the vector of total exports of country s E_s, we obtain the basic decomposition of the value added in gross exports into two elements: the domestic content (DC) in value added and the foreign content (FC) in value added:

$$\underbrace{V_s B_{ss} E_s}_{DC} + \underbrace{\sum_{t \neq s}^{G} V_t B_{ts} E_s}_{FC} = \iota E_s \tag{5}$$

For simplicity, we have not considered the sectoral point of view. If we wanted to keep a sectoral breakdown from the point of view of *sector of origin* of value added, V_s should be diagonalized as $\widehat{V_s}$. This is the case when analyzing the value added induced by final demand VBY. However, the analysis of value added induced by gross exports VBE normally follows an *exporting sector* point of view, requiring a full diagonalization of $\widehat{V_s B_{ss}}$ and $\widehat{V_t B_{ts}}$.

The delimitation of value added in (5) has two shortcomings: there are exports of value added that are not really value added, and there are exports of value added that are not really exports.

On the one hand, "false" value added stems from the existence of double counting, which occurs because exports include both final and intermediate goods, and the latter often cross the border several times. For example, if Spain exports steel to the UK for the manufacturing of engines later reimported by Spain and incorporated into exported vehicles, the steel exports would be counted twice. The steel in vehicles would not real value added, but reexport of already-computed domestic value added (DVA), so it should be deducted as double counting.

On the other hand, "false" exports result from the fact that a part of total exports returns to the exporting country to be absorbed internally. For example, if Spain exports automotive components to Germany for the manufacturing of a vehicle later imported into Spain, the components will indeed constitute value added, but cannot be considered exports. This returned value added is called "reflection" as per Koopman *et al.* (2014).

Therefore, the first term in (5), the DC in value added, should be decomposed into "pure" DVA and domestic double counting (DDC, or reexported DVA); in turn, "pure" DVA should be broken down into value added actually exported (VAX) and reflection (REF, or reimported DVA), as shown in Figure 1.

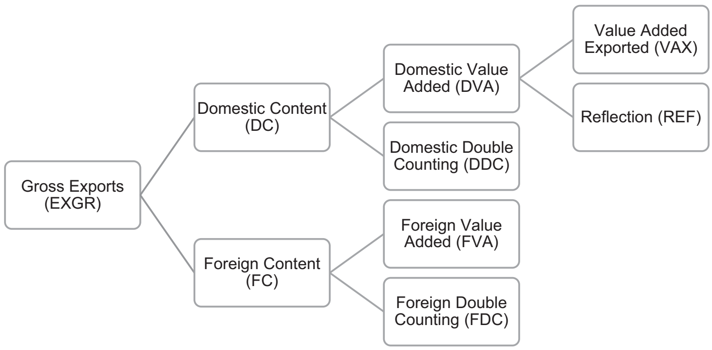
This reasoning is equally applicable, in the double counting part, for the foreign value added (FVA) content (FC). A part of the FC incorporated in the manufacturing of exports might later be reimported and reexported and should be recorded as foreign double counting (FDC), different from the "pure" FVA.

To define "double counting," we must set a spatial perimeter, so that every item that exits that perimeter more than once will be considered as double counting. The most logical is the territorial border of the exporting country, because it is the one used in traditional concepts of value added such as GDP [3].

When defining that perimeter, we should consider that the global Leontief inverse matrix B incorporates, by definition, the value added generated in successive demand cycles of intermediate goods, thus incurring in double counting for those goods.

If we want to isolate the DVA of a certain country s, considering the items that exit the border only once (to avoid double counting), we must use a coefficient matrix that excludes the export of intermediate goods of s. The coefficient matrix A that includes only domestic and imported inputs from country s is called extraction matrix of s:

$$A^{\not s} = \begin{bmatrix} A_{11} & A_{11} & \cdots & A_{1s} & \cdots & A_{1G} \\ A_{21} & A_{22} & \cdots & A_{2s} & \cdots & A_{2G} \\ \vdots & \vdots & \ddots & \vdots & \vdots & \vdots \\ 0 & 0 & 0 & A_{ss} & 0 & 0 \\ \vdots & \vdots & \vdots & \vdots & \ddots & 0 \\ A_{G1} & A_{G2} & \cdots & A_{Gs} & \cdots & V_{GG} \end{bmatrix} \quad (6)$$



Source: Authors based on Borin and Mancini (2023)

Figure 1.
Decomposition of value added in gross exports

From this matrix, we derive a global Leontief inverse matrix with extraction of country s $B^{\not s} = \left(I - A^{\not s}\right)^{-1}$, reflecting the induced effect in global production by global demand if country s could receive inputs from other countries, but not provide them.

The extraction matrix of s $A^{\not s}$ should not be confused with the domestic coefficient matrix A_d, which includes neither exports nor imports of inputs by any country (i.e. only domestic inputs). The resulting inverse matrices are also different: in the first case, we would have a global inverse extraction matrix of s $B^{\not s}$, whereas in the second case we would have a block diagonal matrix L of local Leontief inverse matrices, where each submatrix $L_{ss} = (I - A_{ss})^{-1}$ shows the induced effect of the own inputs of s, as if it did not have access to foreign markets. The difference between the domestic global Leontief inverse matrix B_{ss} and the local Leontief inverse L_{ss} would be the additional impulse derived from country s's integration into global value chains.

It is worth highlighting that for *each country s* we will have a full global extraction matrix $B^{\not s}$ (dimension $GN \times GN$), but only one local L_{ss} matrix (dimension $N \times N$). At the same time, the submatrix $B^{\not s}_{ss}$ of $B^{\not s}$ coincides [4] with the local Leontief matrix L_{ss}, i.e.:

$$B^{\not s}_{ss} = L_{ss} \tag{7}$$

We can now separate the components of pure value added from the double counting. From expression (5), it can be proved (Borin and Mancini, 2023, p. 10) that the production induced by country s can be expressed as the sum of the production induced by its own inputs and the production induced by the exchange of inputs with the rest of the world:

$$B_{ss} = B^{\not s}_{ss} + \left(B_{ss} - B^{\not s}_{ss}\right) = B^{\not s}_{ss} + B^{\not s}_{ss} \sum_{j \neq s}^{G} A_{sj} B_{js} \tag{8}$$

Substituting equation (8) in equation (5), we have:

$$\iota E_{sr} = \underbrace{\underbrace{V_s B^{\not s}_{ss} E_{sr}}_{DVA} + \underbrace{V_s \left(B_{ss} - B^{\not s}_{ss}\right) E_{sr}}_{DDC}}_{DC} + \underbrace{\underbrace{\sum_{t \neq s} V_t B^{\not s}_{ts} E_{sr}}_{FVA} + \underbrace{\sum_{t \neq s} V_t \left(B_{ts} - B^{\not s}_{ts}\right) E_{sr}}_{FDC}}_{FC} \tag{9}$$

or, using the equivalence of equation (8):

$$\iota E_{sr} = \underbrace{\underbrace{V_s L_{ss} E_{sr}}_{DVA} + \underbrace{V_s L_{ss} \sum_{j \neq s} A_{sj} B_{js} E_{sr}}_{DDC}}_{DC} + \underbrace{\underbrace{\sum_{t \neq s} V_t B^{\not s}_{ts} E_{sr}}_{FVA} + \underbrace{\sum_{t \neq s} V_t B^{\not s}_{ts} \sum_{j \neq s} A_{sj} B_{js} E_{sr}}_{FDC}}_{FC} \tag{10}$$

After separating DVA from double counting, we must identify what part of exports will end up reimported and absorbed by s. To distinguish where an item is ultimately absorbed, we need to express equation (10) in terms of final demand. Following Borin and Mancini (2023), we can expand the DVA value $V_s L_{ss} E_{sr}$ into:

$$\mathrm{DVA}_{sr}=\mathrm{V}_s\mathrm{L}_{ss}\left(\mathrm{Y}_{sr}+\mathrm{A}_{sr}\mathrm{L}_{rr}\mathrm{Y}_{rr}+\mathrm{A}_{sr}L_{rr}\sum_{j\neq r}Y_{rj}+A_{sr}\mathrm{L}_{rr}\sum_{j\neq r}\mathrm{A}_{rj}\sum_{k}\sum_{l}\mathrm{B}_{jk}\mathrm{Y}_{kl}\right) \quad (11)$$

From (11) we can disaggregate the third and fourth terms to obtain the value added effectively exported by s (VAX) and the reflection. The VAX will be the items that, once fully processed as final goods, do not return to s:

$$\mathrm{VAX}_{sr}=\mathrm{V}_s\mathrm{L}_{ss}\left(\mathrm{Y}_{sr}+\mathrm{A}_{sr}\mathrm{L}_{rr}\mathrm{Y}_{rr}+\mathrm{A}_{sr}\mathrm{L}_{rr}\sum_{j\neq r,s}\mathrm{Y}_{rj}+\mathrm{A}_{sr}\mathrm{L}_{rr}\sum_{j\neq r}\mathrm{A}_{rj}\sum_{k}\sum_{l\neq s}\mathrm{B}_{jk}\mathrm{Y}_{kl}\right) \quad (12)$$

Borin and Mancini (2023) call the two first terms in equation (16) "directly absorbed value added exported" or DAVAX, the value added of s which is both exported and directly absorbed as final goods in country r without the participation of productive systems of third countries.

The reflection (REF) will be the items that, once fully processed as final goods, eventually return to s:

$$\mathrm{REF}_{sr}=\mathrm{V}_s\mathrm{L}_{ss}\left(\mathrm{A}_{sr}\mathrm{L}_{rr}\mathrm{Y}_{rs}+\mathrm{A}_{sr}\mathrm{L}_{rr}\sum_{j\neq r}\mathrm{A}_{rj}\sum_{k}\mathrm{B}_{jk}\mathrm{Y}_{ks}\right) \quad (13)$$

Note that the bilateral VAX_{sr} in equation (12) now reflects the value added of s exported to r regardless of where this value added is eventually absorbed (and excluding double counting or value added returning to s).

DDC would consequently be:

$$\mathrm{DDC}_{sr}=\sum_{t\neq s}\mathrm{V}_t\left(\mathrm{B}_{ts}-\mathrm{B}_{ts}^{\not s}\right)\mathrm{E}_{sr}=\mathrm{V}_s\mathrm{L}_{ss}\sum_{j\neq s}\mathrm{A}_{sj}\mathrm{B}_{js}\mathrm{E}_{sr} \quad (14)$$

FVA can also be expanded in terms of final demand, obtaining a similar expression to that of equation (11) with $B_{ts}^{\not s}$ terms (that exclude intermediate inputs provided by s):

$$\mathrm{FVA}_{sr}=\sum_{t\neq s}\mathrm{V}_t\mathrm{B}_{ts}^{\not s}\left(\mathrm{Y}_{sr}+\mathrm{A}_{sr}\mathrm{L}_{rr}\mathrm{Y}_{rr}+\mathrm{A}_{sr}\mathrm{L}_{rr}\sum_{j\neq r}\mathrm{Y}_{rj}+\mathrm{A}_{sr}\mathrm{L}_{rr}\sum_{j\neq r}\mathrm{A}_{rj}\sum_{k}\sum_{l}\mathrm{B}_{jk}\mathrm{Y}_{kl}\right) \quad (15)$$

with FDC being:

$$\mathrm{FDC}_{sr}=\sum_{t\neq s}\mathrm{V}_t\left(\mathrm{B}_{js}-\mathrm{B}_{ts}^{\not s}\right)\mathrm{E}_{sr}=\sum_{t\neq s}\mathrm{V}_t\mathrm{B}_{ts}^{\not s}\sum_{j\neq r}\mathrm{A}_{sj}\mathrm{B}_{js}\mathrm{E}_{sr} \quad (16)$$

The abovementioned decomposition, proposed by Borin and Mancini (2023), provides a consistent framework that can also be used for the calculation of bilateral GVC-related indicators. Thus, the concept of DAVAX allows us to define the GVC-related flows (GVC_{sr}) as the export flows not directly absorbed by the importer, i.e. $\mathrm{E}_{sr}-\mathrm{DAVAX}_{sr}$. These flows cross at least two international borders, i.e. they are reexported at least once before being absorbed in final demand, what can be considered as a sufficient condition to be part of an international production network (Borin and Mancini, 2023, p. 13).

From these GVC-related flows, and following the efforts of Hummels *et al.* (2001), Daudin *et al.* (2011), Koopman *et al.* (2014) and Wang *et al.* (2013), bilateral versions of traditional indicators of vertical specialization can be obtained, both for backward linkages (VS) and for forward linkages (VS1), the latter as the difference between GVC_{sr} and VS.

3. Methodological limitations of other approaches and perspectives

If we define "approach" as the sequential perimeter of what to consider as value added and "perspective" as the spatial perimeter of what to record as value added, we could say that, so far, we have followed a source-based approach and an exporting country perspective. We will now show how other approaches and perspectives are methodologically inferior.

3.1 Source-based versus sink-based approach

In a source-based approach, a domestic item is considered "domestic value added" *the first time it is exported*, and a foreign item is considered "foreign value added" *the first time it is reexported* (the rest being recorded as double counting). But we could also devise a sink-based approach, by which a domestic item is considered "domestic value added" *the last time it is exported*, and a foreign item is considered "foreign value added" *the last time it is reexported* (the rest being recorded as double counting). This distinction was initially introduced by Nagengast and Stehrer (2016), and implies the use of the global matrix B for the linkage effects (as all successive rounds of exports of intermediates should be included in the value added until the final shipment). However, this might require some adjustments in the definition of exports in terms of absorption.

Although this approach could be acceptable, and in fact has been proposed as an alternative by Nagengast and Stehrer (2016), Los and Timmer (2018), Borin and Mancini (2023) or Miroudot and Ye (2021), we think that it is inferior to the source-based approach.

To understand why, let us suppose a world with three countries, A, B and C. Country A exports \$1 of VA to B, which later comes back as \$2 (with \$1 of additional value added). Then country A incorporates an additional \$1 and exports to C for a total amount of \$3. The decomposition of those flows from a source- and sink-based approach is reflected in Table 1:

In a source-based approach, exports from A to B would record DVA for \$1; exports from A to C would also record DVA for \$1 (new VA) plus \$1 of double-counted DVA (the VA of A previously processed in B) plus \$1 of FVA (VA from B). From the point of view of information, exports from A to B do not show that the VA exported to B will be later reexported, but data of exports from A to C clearly reflect the sourcing of VA.

In a sink-based approach, exports from A to B would only record double-counted DVA for \$1 (VA absorbed abroad); exports from A to C would record \$2 of DVA (\$1 previously processed in A plus an additional \$1), plus another \$1 of FVA (VA from B). From the point of view of information, data of exports from A to B correctly reflect that the VA of A will not

Table 1. Source- and sink-based approaches

	Source-based		Sink-based	
Component	A→B	A→C	A→B	A→C
DVA	1	1	0	2
DDC	0	1	1	0
FVA	0	1	0	1
Gross exports	1	3	1	3

Source: Author, based on Borin and Mancini (2019) be absorbed in B, and data of exports from A to C show that the VA of A is absorbed in C but not that half of that VA required previous processing abroad.

Therefore, the sink-based approach misrepresents the economic importance of global value chains. In the example, by looking at the source-based data, policymakers can correctly infer not only the importance of the economic relations between A and B and between A and C, but also that flows from A to C require an active economic exchange with third countries (B, in this case); however, by looking only at the sink-based data, policymakers might wrongly deduce that flows between A to C just need direct imports from B (the FVA, 1 in both cases), and not that those imports are processed goods which initially came from A. Thus, the decision, for instance, to replace B by D as provider of inputs could have unintended economic consequences for A. In other words, by putting the focus on where the absorption takes place, the sink-based approach underestimates the importance of global value chains and the economic interdependence with the rest of the world, therefore, devaluating the rich information contained in IOTs.

This does not mean, of course, that a sink-based approach might not be useful for specific economic analyses, e.g. to study the relationship between production and final demand (Borin and Mancini, 2023, p. 5), but it should not be put on an equal footing with the source-based approach which, despite its limitations, offers a more balanced picture of today's economic interdependence.

On the contrary, it is important to mention that, even though the sink-based approach uses mainly matrix B instead of L for the calculation of most terms of value added (as international processing is considered value added until the "ultimate shipment"), the use of the extraction matrix is eventually unavoidable. This is because, when trying to isolate the last time that all items from s are exported to r, we need to distinguish, within the exports of intermediates of s that are processed in r and reexported as intermediates to be processed in third countries, which part is absorbed elsewhere *without going again through s*. This problem can only be solved algebraically (see Supplementary Data) by using the inverse matrix with extraction of the exports of intermediates from s, i.e. matrix $B^{\not s}$ (Borin and Mancini, 2023, p. 15).

3.2 Exporting country perspective vs alternative perspectives

As for the perspective or spatial perimeter, the logical choice is the country perspective (including here any group of countries acting as a block) but we can define alternative perspectives by altering the extraction matrix A to be considered. A *bilateral* perspective would make zero not all exports of intermediates of s, but only the intermediates exported to country r, a *sector* perspective would make zero the exports of intermediates of s in sector i for all countries, and a *sector-bilateral* perspective would make zero the exports of intermediates of s to r for sector i. These alternatives thus narrow down the concept of double counting.

The use of targeted perspectives has been defended by some authors (Los and Timmer, 2018) as a more accurate form of assessing the value added (e.g. the GDP) exposed to a given trade flow but it has some drawbacks form a theoretical and practical point of view:

- No additivity. Although targeted perspectives only marginally change the formulation of equation (9), for bilateral perspectives $B_{ss}^{\not s} \neq L_{ss}$ and equation (10) would not hold anymore, and sectoral perspectives would require the export matrix E_{sr} to be adjusted [5]. The advantage of an exporting country perspective is that it keeps a consistent accounting approach for different levels of aggregation of trade flows, so the sum of indicators on a bilateral, sector and sector–bilateral level coincide with the aggregated ones. This is not the case for tailored accounting perspectives. Additivity, however, seems a logical requirement for standard indicators, as inconsistency across different levels of aggregation would discourage its use.

- No relation with global value chain indicators. As we saw above, the exporting country perspective allows a clear identification of global value chain–related flows, through the concept of DVA directly absorbed by the importing partner (DAVAX), needed to compute the GVC-related trade (as all exports not directly absorbed by importer) that has become the standard measure in the literature to quantify GVCs and GVC participation (Antràs and Chor, 2022). DAVAX, however, is not available in tailored perspectives.
- Computing burden. As we have seen, the use of an exporting country perspective requires the calculation of *G* global inverse extraction matrices, one per country. With tailored perspectives the required number of extraction matrices becomes difficult to handle. If we wanted to calculate value added indicators for all countries in a single year in a database like the 2021 version of the OECD TiVA, instead of the 67 inverse extraction matrices for the country perspectives we would require 4,422 in a bilateral perspective, 3,015 in a sectoral perspective and almost 200,000 in a sector–bilateral perspective. Of course, this argument would be debatable if the differences between indicators were considerable but, as we will see in Section 4.2, this is not the case.

The concept of "world" perspective, which extends the concept of double counting, presents more problems. Unlike the country perspective, which considers double counting all flows that exit *the exporter's border* more than once, the world perspective considers double counting all flows that cross *any border* more than once. Therefore, the applicable coefficient matrix would be the domestic coefficient matrix A_{d}. In this case, B_{ss}^{g} would still be equal to L_{ss}, but B_{ts}^{g} would become zero, so FVA would also be zero and all FC would be FDC (Miroudot and Ye, 2021, p. 77). We disagree here with Borin and Mancini (2023, app. E), who present a formulation of FVA and FDC with world perspective that deviates from the extraction matrix-based framework.

It is clear, then, that the origin of most discrepancies in the literature on the decomposition of value added in gross exports lays in the use of different versions of the matrix B. The multiplicity of approaches and perspectives has not helped clarify the framework, but rather the opposite: the attempt to include all possibilities, even those that might have economic sense only in very specific cases, has delayed the consolidation of a valid and consistent method.

3.3 Time to settle the debate

We believe that the state of the debate is already reap for assessing the advantages and shortcomings of the main methodological contributions in the economic literature.

We must start by acknowledging the importance of the seminal contribution of Koopman *et al.* (2014). They present the first framework for decomposing the value added in gross exports, setting the bases for the methodological debate, and should be given credit for providing the first definitions of DVA and FVA, and the concepts of reflection and double counting. However, their method has shown some methodological limitations and internal inconsistencies:

- They only propose a decomposition method for aggregated exports but fail to decompose the value added in bilateral exports.

- Although they consistently use the global Leontief inverse B (therefore implicitly adopting a sink-based approach), some terms are not correctly calculated from a sink-based approach, as pointed out by Borin and Mancini (2023).
- They use a country perspective for DVA, but a world perspective for FVA.

Wang *et al.* (2013) overcome some of the limitations of Koopman *et al.* (2014), proposing a framework to decompose the value added in bilateral gross exports. However, they also show some limitations:

- They do not use a consistent approach for their decomposition, using the source-based approach for most terms of the DVA (with the local Leontief inverse L) but incorrectly including the global Leontief inverse B in some cases, therefore, incorporating some double-counted items.
- They also follow a different perspective for DVA and FVA, as they replicate the framework of Koopman *et al.* (2014). Miroudot and Ye (2021) prove that they use a variation of the world perspective for the FC.

Nagengast and Stehrer (2016) are the first to introduce the distinction between the source-based and the sink-based approach. They are particularly interested in the bilateral trade balances, and they develop a specific decomposition for that purpose. However, despite acknowledging the importance of considering as value added only the flows that have "not left country *s* for processing abroad previously" (Nagengast and Stehrer, 2016, p. 1285), and therefore the need to use the local Leontief inverse matrix L, they eventually fail to use it systematically and end up incurring in double counting. They also calculate the FVA with the global Leontief inverse matrix B and avoid dealing with sectoral issues.

Los and Timmer (2018) realize that using the global Leontief inverse matrix B in the basic decomposition leads to inconsistencies, as exports of intermediates produce double counting. They propose for the first time the use of extraction matrices to delimitate exports from a country perspective. Their only shortcoming is that they limit their analysis to the DVA and forget to mention the need of a similar approach for the FVA.

It is Borin and Mancini (2023) who, for the first time, propose a general framework for both DC and FC using extraction matrices and lay out a complete decomposition of value added in exports using a consistent approach and perspective for both. They distinguish two sequential scopes or approaches (source- and sink-based) and a long list of spatial scopes or perspectives (world, country, bilateral and sector–bilateral). By doing that, they attempt to present all previous decompositions as particular cases of their general framework, even while pointing out some of the abovementioned inconsistencies. Unfortunately, this catch-all strategy does not help clarify what the most appropriate framework would be.

Miroudot and Ye (2021) take a step forward and defend the use of the source-based approach and the country perspective, and they even provide a more elegant formulation of the general Borin and Mancini (2023) decomposition:

$$\mathrm{E}_{sr} = \underbrace{\underbrace{\mathrm{V}_s \mathrm{B}^{\not{s}}_{ss} \mathrm{E}_{sr}}_{\text{DVA}} + \underbrace{\mathrm{V}_s [\mathrm{B}^{\not{s}} \mathrm{A}^s \mathrm{B}]_{ss} \mathrm{E}_{sr}}_{\text{DDC}}}_{\text{DC}} + \underbrace{\underbrace{\sum_{t \neq s} \mathrm{V}_t \mathrm{B}^{\not{s}}_{ts} \mathrm{E}_{sr}}_{\text{FVA}} + \underbrace{\sum_{t \neq s} \mathrm{V}_t [\mathrm{B}^{\not{s}} \mathrm{A}^s \mathrm{B}]_{ts} \mathrm{E}_{sr}}_{\text{FDC}}}_{\text{FC}} \tag{17}$$

where $\mathrm{B}^{\not{s}}$ is the global Leontief inverse with extraction of *s* and $\mathrm{B}^{\not{s}}_{ss}$ its submatrix (Miroudot and Ye call them B^* and B^*_{ss}, respectively), B is the ordinary global Leontief inverse and A^s (A^I for Miroudot and Ye) is $A - A^{\not s}$. Their formulation remains valid for several perspectives and in the basic source-based approach and country-perspective is equivalent to the formulation of Borin and Mancini (2023) in (9).

However, Miroudot and Ye (2021) refuse to further decompose their framework in terms of final demand, evading the thorny issue of assessing the consistency of the source- and sink-based approaches. They merely say that having two approaches does not make sense because the DVA and the FVA already "have a certain origin and destination," i.e. the origin and destination of gross exports (Miroudot and Ye, 2021, p. 69). For them, using subcomponents leads to a problematic definition of temporal sequence (source/sink) and should be avoided.

This is, from our point of view, unacceptable, given that a breakdown in terms of demand is essential for at least three reasons:

(1) To distinguish between the value added generated by final exports and intermediate exports, the latter being only correctly expressed for a certain level of final demand, as pointed out by Wang *et al.* (2013, p. 10)

(2) To calculate the key indicator for trade in value added, the VAX. Without decomposing the DVA in terms of final demand, there can be no VAX, and without VAX a big part of the interest of the decomposition of the value added in gross export disappears. Segregating the VAX from the reflection and the double counting is part of the essence of the decomposition problem, and undertaking that task inevitably requires assumptions.

(3) To calculate the reflection (REF), which should be a tool to perfect the national statistics of value added. If a country exports an item and this item eventually returns to the country to be reexported (with additional value added incorporated), the income elements of the value added (compensation of employees and gross operating surplus) should only appear once as true value added.

To reinforce their position, Miroudot and Ye (2021) point out that, in any case, the definition of double counting as the value added that has crossed the country's border "more than once" makes economic sense, but not statistical sense, because the input–output framework "cannot tell us how many times the added value has crossed borders," because "there are many paths through which the added value can reach the final consumers and these are unknown" (Miroudot and Ye, 2021, p. 70). They follow Los and Timmer (2018) affirming that the input–output matrix has collapsed the different stages of production and any definition of "double counting" requires specific assumptions that do not have to be met.

Although this consideration has a trace of truth, we think it is just one of the multiple statistical limitations of the international input–output model, not more problematic than the production or the proportionality assumptions [6]. True, any international IOT is a simplified version of reality, but this is not enough reason to claim the impossibility of finding a "simple formula for calculating foreign value added" nor for the "lack of consensus in (. . .) what the meaning of 'physical border' is in terms of available statistics." Once theoretical assumptions have been made (and those regarding the source-based approach are perfectly acceptable), decomposition methods should only be assessed in terms of methodological consistency.

4. Quantifying alternative decompositions

The complexity of the current input–output databases and the computational burden of implementing the different methodologies has undoubtedly hindered the practical implications of using a specific one. We will now quantify the differences between methods, approaches and perspectives, using the 2021 edition of the OECD Inter-Country Input–Output Tables (OECD, 2021a) and the software *exvatools* (Feás, 2023) [7].

4.1 Approaches

Table 2 shows a comparative decomposition of the value added in Spain's gross exports according to the source- and sink-based methodologies of Borin and Mancini (2023), Koopman *et al.* (2014) and Wang *et al.* (2013), abbreviated here as BM, KWW and WWZ, respectively.

We can see that:

- The total DC and total FC are equivalent, regardless of the decomposition method or the breakdown level.

		World			EU-27			Extra EU-27		
Sector	VA comp.	BM source	BM sink	WWZ/ KWW*	BM source	BM sink	WWZ	BM source	BM sink	WWZ
Total	EXGR	467,540	467,540	467,540	250,831	250,831	250,831	216,709	216,709	216.709
	DC	356,208	356,208	356,208	191,214	191,214	191,214	164,994	164,994	164.994
	DVA	355,100	355,100	355,100	190,593	190,293	190,436	164,507	164,807	164.664
	VAX	351,947	351,947	351,947	188,086	187,786	187,929	163,860	164,160	164.018
	REF	3,153	3,153	3,153	2,507	2,506	2,507	646	647	646
	DDC	1,108	1,108	1,108	620	921	778	488	187	330
	FC	111,333	111,333	111,333	59,618	59,618	59,618	51,715	51,715	51.715
	FVA	110,888	110,888	86,710	59,367	59,250	42,729	51,521	51,637	43.982
	FDC	445	445	24,623	251	367	16,889	194	77	7.733
Goods	EXGR	257,516	257,516	257,516	142,148	142,148	142,148	115,368	115,368	115.368
	DC	171,410	171,410	171,410	95,535	95,535	95,535	75,875	75,875	75.875
	DVA	170,510	170,680	170,575	95,022	94,921	94,955	75,488	75,759	75.620
	VAX	168,529	168,696	168,594	93,437	93,334	93,369	75,092	75,362	75.224
	REF	1,981	1,984	1,981	1,585	1,587	1,585	396	397	396
	DDC	900	730	836	513	614	581	387	116	255
	FC	86,106	86,106	86,106	46,613	46,613	46,613	39,493	39,493	39.493
	FVA	85,738	85,712	65,587	46,402	46,287	32,491	39,336	39,425	33.096
	DDC	368	394	20,519	211	326	14,122	157	68	6.397
Services	EXGR	210,024	210,024	210,024	108,683	108,683	108,683	101,341	101,341	101.341
	DC	184,797	184,797	184,797	95,678	95,678	95,678	89,119	89,119	89.119
	DVA	184,590	184,420	184,525	95,571	95,371	95,481	89,019	89,048	89.044
	VAX	183,418	183,250	183,353	94,650	94,452	94,560	88,768	88,798	88.793
	REF	1,172	1,169	1,172	921	919	921	251	250	251
	DDC	207	378	272	107	307	197	100	71	75
	FC	25,227	25,227	25,227	13,005	13,005	13,005	12,222	12,222	12.222
	FVA	25,150	25,176	21,123	12,965	12,963	10,237	12,185	12,213	10.886
	FDC	77	51	4,104	40	41	2,767	37	10	1.336

Note: *The aggregate (total) decomposition of WWZ matches that of KWW for all the specified components
Source: Author. Data calculated using OECD ICIOT tables (2021 edition) for year 2018

Table 2. Comparative decomposition of value added in Spain's gross exports according to different methodologies (US$ million, 2018)

- The three methods are also equivalent aggregating for *all countries and all sectors*, as differences are compensated in the aggregation process; a mathematical proof appears in Borin and Mancini (2023).
- When considering *sectoral exports* only, differences appear, but are relatively reduced for DVA, VAX, REF and DDC. They are bigger, however, for FVA and FDC, as the method of Wang *et al.* (2013) has a different perspective for FC (with a wider concept of double counting).
- The biggest differences appear when we consider *bilateral exports* (here EU and non-EU), because that is where most methodological discrepancies appear. Note one exception: the REF, where the Borin and Mancini (2023)-source and the Wang *et al.* (2013) decompositions coincide, although there are differences in its internal components.

It is interesting to break down these elements, at least for the value added exported, into that induced by final goods and induced by intermediate goods, as seen in Table 3.

4.2 Perspectives

As discussed in Section 3.2, tailored perspectives are not only less consistent than the exporter perspective, but they are extremely unpractical. To additionally prove our point, we can make a comparison of the difference between the exporting sector perspective and the bilateral, sector and sector–bilateral perspective for the main indicators. We will use the 2021 edition of the OECD TiVA database (ICIO Inter-Country Input-Output tables) for the year 2018, including all countries in the bilateral and sectoral perspective, a sample of 23 (representing 75% of all exports) for the sectoral–bilateral perspective. We will also group the 45 sectors of the database in 29 for the sector and sector–bilateral perspective (see Supplementary Data for details).

We will calculate the global inverse extraction matrices and produce the basic indicators (including VAX and REF) for the bilateral, sector and sector–bilateral perspective and compare them with their equivalent in the exporting country perspective. To make

Table 3.
Subdecomposition of value added exports (VAX) in Spain's gross exports according to different methodologies (US$ million, 2018)

		World			EU-27			Extra EU-27		
Sector	VA comp.	BM source	BM sink	WWZ*	BM source	BM sink	WWZ	BM source	BM sink	WWZ*
Total	VAX, total	351,947	351,947	351,947	188,086	187,786	187,929	163,860	164,160	164,018
	Finals	183,365	183,908	183,908	94,120	94,410	94,410	89,246	89,498	89,498
	Interm.	168,581	168,038	168,038	93,967	93,376	93,519	74,615	74,662	74,520
Goods	VAX, total	168,529	168,696	168,594	93,437	93,334	93,369	75,092	75,362	75,224
	Finals	77,511	77,934	77,934	41,507	41,738	41,738	36,003	36,195	36,195
	Interm.	91,018	90,762	90,660	51,929	51,596	51,631	39,089	39,167	39,029
Services	VAX, total	183,418	183,250	183,353	94,650	94,452	94,560	88,768	88,798	88,793
	Finals	105,854	105,974	105,974	52,612	52,672	52,672	53,242	53,303	53,303
	Interm.	77,564	77,276	77,379	42,038	41,781	41,888	35,526	35,496	35,491

Note: *The aggregate (total) decomposition of WWZ matches that of KWW
Source: Author, using OECD ICIO tables (2021 edition) data for year 2018

differences comparable, we will express them as a percentage of the total respective exports, and calculate the mean, the median and a selection of percentiles. Results are shown in Table 4:

As we can see, tailored perspectives reduce the value of the DDC and therefore increase the DVA for a given DC. For the DVA or VAX, the difference represents only 0.23% of sector–bilateral exports, 0.14% of bilateral exports and 0.11% of bilateral exports when compared with the exporting country perspective. Deviations over 0.5% of exports only occur on the tails of the distribution, and the highest deviations (amounting to 1.1%) happen only in the sector–bilateral perspective in the 1% tails. Practically all the difference is absorbed by the VAX, and the reflection practically remains unaltered. Kernel density distributions for the data are shown in the online Supplementary Data.

Therefore, we can conclude that using the exporting sector perspective instead of tailored perspectives is not only methodologically sounder, more consistent and compatible with useful indicators of global value chain trade but it also incurs in a really small cost in terms of accuracy.

4.3 Other considerations: sector of origin vs exporting sector

It is also interesting to note the frequently overlooked impact of the sectoral point of view, i.e. the type of diagonalization of the product VB, on VAX. In most decompositions, VAX is calculated using an exporting sector point of view ($\widehat{V_sB_s}$), whereas the VAX of Johnson and Noguera, equivalent to the OECD indicator FFD_DVA ("Domestic value added embodied in foreign final demand"), uses a sector of origin of value added point of view ($\widehat{V_sB_s}$) (OECD, 2021b, p. 37). Figure 2 shows that, between 1995 and 2018, world VAX with an exporting sector point of view (Borin and Mancini) was on average a 48% bigger in manufacturing

Indicator	Mean	Median	1%	5%	25%	75%	95%	99%
Bilateral								
DVA	0.1422	0.0913	0.0031	0.0089	0.0276	0.2098	0.4272	0.8433
VAX	0.1408	0.0909	0.0031	0.0089	0.0276	0.2083	0.4125	0.8221
REF	0.0014	0.0001	0.0000	0.0000	0.0000	0.0005	0.0069	0.0240
DDC	−0.1422	−0.0913	−0.8433	−0.4272	−0.2098	−0.0276	−0.0089	−0.0031
FVA	0.0635	0.0323	0.0008	0.0022	0.0089	0.0999	0.2180	0.3231
FDC	−0.0635	−0.0323	−0.3231	−0.2180	−0.0999	−0.0089	−0.0022	−0.0008
Sector								
DVA	0.1138	0.0655	0.0000	0.0037	0.0224	0.1478	0.3704	0.7508
VAX	0.1121	0.0653	0.0000	0.0037	0.0223	0.1470	0.3675	0.7255
REF	0.0017	0.0001	0.0000	0.0000	0.0000	0.0007	0.0057	0.0280
DDC	−0.1138	−0.0655	−0.7508	−0.3704	−0.1478	−0.0224	−0.0037	0.0000
FVA	0.0439	0.0231	0.0000	0.0011	0.0063	0.0614	0.1625	0.2362
FDC	−0.0439	−0.0231	−0.2362	−0.1625	−0.0614	−0.0063	−0.0011	0.0000
Sector–bilateral								
DVA	0.2296	0.1717	0.0087	0.0363	0.1003	0.2899	0.5989	1.1142
VAX	0.2267	0.1709	0.0087	0.0362	0.0997	0.2879	0.5894	1.0802
REF	0.0030	0.0004	0.0000	0.0000	0.0001	0.0014	0.0115	0.0476
DDC	−0.2296	−0.1717	−1.1142	−0.5989	−0.2899	−0.1003	−0.0363	−0.0087
FVA	0.0846	0.0609	0.0004	0.0043	0.0283	0.1182	0.2397	0.3846
FDC	−0.0846	−0.0609	−0.3846	−0.2397	−0.1182	−0.0283	−0.0043	−0.0004

Source: Author, using OECD ICIO tables (2021 edition) data for year 2018

Table 4. Differences in tailored perspectives vs exporting sector perspective (percentage of total respective exports)

and a 33% smaller in services than with an origin point of view (OECD) due to servicification, i.e. the intensive use of services as inputs for the manufacturing sector. These differences would disappear if we calculated the decomposition using an origin perspective, and only bilateral differences would remain.

5. Conclusions

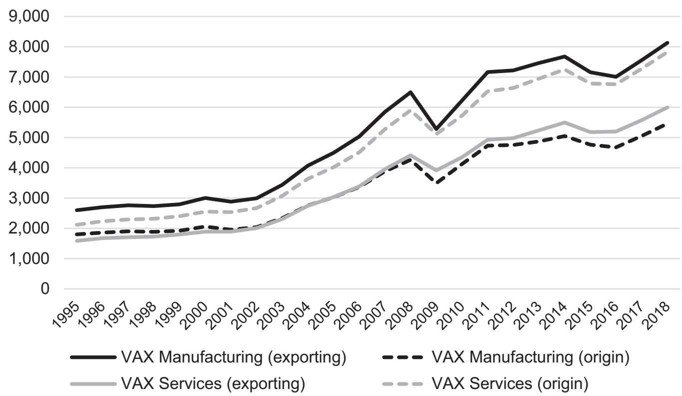
This article has made a critical analysis of the literature on the decomposition of value added in exports.

We have reviewed the methodological inconsistencies in the literature before Borin and Mancini (2023), and seen that the use of multiple approaches and perspective for very specific cases should not hide the general validity of the source-based approach and the exporting perspective, which should be considered the standard for decomposing value added in exports.

Alternative approaches like the sink-based, or alternative perspectives like the world, bilateral, sector or sector–bilateral (using tailor-made extraction matrices), though theoretically possible and useful for very specific analyses, do not deserve the same status, and seem more a gentle way of rescuing the validity of the pioneering works in the literature of value added in exports than an indispensable methodological tool.

We have proven the methodological superiority of the source-based approach with exporting perspective and given quantitative examples of the differences between alternative methods, approaches and perspectives. We have also shown that the drawbacks of tailored perspectives do not compensate their alleged accuracy (as they do not result in big quantitative differences with the standard perspective); and we have stated that any valid standard decomposition requires the calculation of the VAX, so the expression of exports in terms of final demand is always a must.

We believe that the methodologic debate is ripe enough so that the bilateral VAX with a source-based approach and an exporting perspective becomes an integral part of the available and widely used statistical indicators for the analysis of globalization.



Source: Author using OECD's ICIO tables (2021 edition) data and own calculations

Figure 2.
World VAX in manufacturing and business services using a sector of origin vs an exporting sector point of view (millions of US$)

Notes

1. Own calculations with data from the OECD Trade in Value Added (TiVA) database (2021).
2. The most relevant are the OECD TiVA database (OECD, 2021a), the World Input–Output Database (Timmer *et al.*, 2015), the Eora database (Lenzen *et al.*, 2013) and the ADB Multiregional Input Output database (Asian Development Bank, 2020).
3. Gross domestic product (GDP) follows a territorial perimeter (VA generated in the physical territory of a specific country, regardless of where productive factors are located), unlike gross national product, which follows a personal perimeter (VA generated by workers or companies with habitual residence in a specific country, regardless of where the VA is generated).
4. We will see later that this that does not hold in case of some specific alternative perspectives.
5. A detailed formulation of these alternative perspectives can be seen in Borin and Mancini (2023) or, in a more general way, in Miroudot and Ye (2021).
6. For a detailed description of the assumptions included in the international IOT framework, see OECD (2018, pp. 9–10).
7. An alternative would be using the Stata package ICIO (Belotti *et al.*, 2021).

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Supplementary data

Supplementary data for this article can be found online.

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