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Cadenas Globales de Valor y la importación para la exportación: nuevas medidas y metodologías

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Resumen: Esta tesis analiza la literatura existente y propone nuevas medidas para describir la participación de los sectores y los países en el comercio en Cadenas Globales de Valor (CGV) a partir de Matrices Insumo Producto Multipaís. Las medidas desarrolladas consideran las limitaciones de la información y de las métricas actualmente disponibles y plantean alternativas. A partir de medidas de participación, profundidad y posición en cadenas de valor, se describe el desempeño de países de América Latina en la fragmentación mundial de la producción. Las nuevas medidas permiten describir el rol de los países en las cadenas regionales de valor, la profundidad y el sesgo de la fragmentación regional vis a vis la global y la posición y largo de los sectores y países en las cadenas en las que participan como exportadores.

Palabras clave: Cadenas Globales de Valor, Matrices Insumo Producto, Comercio en Valor Agregado, *Upstreamness*, *Downstreamness*

Abstract: This thesis analyzes the current literature and proposes new measures to describe the participation of sectors and countries in Global Value Chains (GVC) based on Multi-Country Input-Output Tables. The measures developed consider the limitations of the information and metrics currently available and propose alternatives. Based on measures of participation, depth and position in value chains, the performance of Latin American countries in the global fragmentation of production is described. The new measures make it possible to describe the role of countries in regional value chains, the depth and bias of regional fragmentation vis-à-vis global fragmentation, and the position and length of sectors and countries in the chains in which they participate as exporters.

Keywords: Global Value Chains, Input Output Tables, Trade in Value Added, *Upstreamness*, *Downstreamness*

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Cadenas Globales de Valor y la importación para la exportación: nuevas medidas y metodologías

1) Introducción

La fragmentación de la producción mundial, estimulada por cambios tecnológicos y de gobernanza del comercio internacional dio lugar al auge del comercio de bienes intermedios y consecuentemente provocó que en cada bien final consumido participen generalmente varios países agregado valor. Esto motivó la construcción de matrices insumo-producto multipaís (WIOT, en inglés), que, integrando información nacional de Cuadros de Oferta y Utilización (COU) y datos estándar de comercio internacional, vinculan oferta y demanda de diferentes sectores y países. Estos proyectos han servido como base para la descripción de la **profundidad** (cuánto importan las Cadenas Globales de Valor -CGV- en la estructura económica de los países), **participación** (cuánto del comercio se inserta en cadenas) y **posición** (cuán cerca de la demanda final o de los factores primarios se ubican los sectores/países) en cadenas de valor. Estas medidas se están incorporando crecientemente al set de descriptores del perfil de comercio exterior de los países.

La utilización de WIOT tiene considerables ventajas analíticas pues brinda un marco estandarizado y de inmediata vinculación con otros instrumentos de amplio uso. En particular, dado que se basan en COU, son fácilmente comparables con la información sobre el Producto Interno Bruto, que también los utiliza. Así, las medidas mencionadas anteriormente se referencian directamente con variables tales como el Valor Agregado, la Producción y el empleo. Además de ser utilizadas para caracterizar a las CGV, las WIOT se han convertido en una herramienta central de análisis sobre ambiente (Copeland, Shapiro y Taylor 2021), efectos de política comercial (Caliendo y Parro 2015) y la distribución funcional del ingreso (Timmer, Miroudot, y de Vries 2019).

Esta tesis constituye un esfuerzo por mejorar el conjunto de métricas disponibles para estudiar la fragmentación de la producción en una región periférica para el comercio internacional. Cada uno de los artículos que la componen constituye el resultado de una alternativa a limitaciones de la información o de las herramientas disponibles en la actualidad. Las limitaciones de las WIOT se pueden clasificar en dos tipos. Por un lado, existen limitaciones de cobertura temporal, geográfica o agregación sectorial de las matrices y las medidas construidas a partir de éstas[1]. Por otro lado, la técnica estándar para la construcción de WIOT puede generar sesgos en sus resultados al aplicar herramientas típicas del análisis insumo- producto. Los tres artículos presentados pueden describirse como un intento para mejorar las limitaciones del primer tipo. Sin embargo, entiendo que es relevante mencionar a una buena parte de mi trabajo que se ha enfocado en contribuir a integrar información complementaria a la que surge de las WIOTs, aunque ninguno de los productos forma parte de los artículos de tesis.

En el Artículo "Medición de las Exportaciones de Uruguay en Valor Agregado en presencia de Regímenes Especiales de Comercio"[2] adapto la metodología de Koopman, Wang, y Wei (2012) -aplicada a la economía China para ilustrar el dualismo entre la industria "*processing exports*" y la tradicional- a la información disponible de utilización del régimen suspensivo de importaciones temporarias por parte de la industria exportadora uruguaya, mostrando que la integración de información específica a nivel de firma contribuye

[1] Al momento de escribir este texto, la WIOT que parece tener mejor balance entre cobertura temporal, geográfica y sectorial es la de MCIO-OECD, que contiene 24 años (1995-2018), 67 países (7 latinoamericanos) y 45 sectores. Sin embargo, tal cobertura estuvo disponible solo desde noviembre de 2021

[2] REVISTA DE ECONOMÍA del Banco Central del Uruguay, Vol. 23, Nº 2, Noviembre 2016. ISSN: 0797-5546

a mejorar la medición de la integración hacia atrás de las exportaciones manufactureras. Este artículo levanta el supuesto de homogeneidad de las empresas dentro de los sectores, recurriendo a información detallada de la estructura de abastecimiento importado de un subconjunto de firmas exportadoras uruguayas. Así, a partir de una Matriz Insumo Producto nacional, algunos sectores de la economía uruguaya serán divididos en dos sectores: uno tradicional, enfocado en el mercado interno y de forma marginal a las exportaciones, y otro que engloba al grueso de la industria manufacturera de exportación, que tiene en general una mayor intensidad de importaciones y menos valor agregado unitario que su par tradicional. De esta forma, la utilización de esta información incrementa la medida de *backward linkages*, mostrando que asumir idéntica estructura dentro de los sectores subestima la integración en cadenas.

La utilización de información administrativa de regímenes "*import to export*" es una línea de investigación que mantengo en la actualidad. Esta línea tiene la dificultad de que el acceso a ese tipo de información no está generalmente disponible. Resulta particularmente interesante poder utilizarla para criticar otro elemento clave en la construcción de las WIOD: el supuesto de proporcionalidad. Este supuesto surge de que la información del sector que utiliza un determinado insumo importado no está generalmente disponible, por lo que se asume que todos los sectores importadores utilizan determinado insumo con la misma estructura de orígenes. Este supuesto es contraintuitivo dada la idiosincrasia propia de las CGV, donde prevalece el comercio entre estructuras relacionadas. De Gortari (2019) lo incluye dentro del modelo "*roundaboaut*" característico de la mayoría de las métricas de las cadenas y muestra que, por lo menos en México, sesga las medidas. Se encuentra en vías de publicación el artículo "Importaciones para exportar y cadenas de valor en Argentina y Uruguay" realizado en coautoría con Lian Allub, Matías Garibotti y Pablo Sanguinetti, donde mostramos el uso de estos instrumentos en el tiempo para estos países y su utilidad para describir a las cadenas de valor. Lamentablemente, a pesar de varios intentos no he accedido a información con la misma calidad para Brasil, lo que impidió que realice un análisis de los supuestos de heterogeneidad y la proporcionalidad en el MERCOSUR a partir de matrices insumo producto, como era la idea original. El MERCOSUR tiene la peculiaridad de que, a pesar de tener baja integración hacia atrás, por la alta protección arancelaria de los insumos las empresas exportadoras tienden a usar intensivamente estos tipos de regímenes, aumentando la heterogeneidad entre las empresas orientadas al mercado doméstico y las orientadas al mercado exterior, por lo que es posible encontrar grandes sesgos en las matrices y métricas convencionales.

También es importante mencionar otras exploraciones alternativas para describir el comercio en cadenas más allá de las insumo- producto. En Lalanne (2021)[3], se analizan las exportaciones de Uruguay con las nuevas clasificaciones del comercio en Grandes Categorías Económicas (BEC Rev5), que incorpora una división del comercio de intermedios industriales en genéricos (menos integrados al tipo de relación de las Cadenas Globales de Valor) o idiosincráticos (más propios de las CGV). Este análisis mostró la tendencia de Uruguay a concentrar sus exportaciones cada vez más lejos de la demanda final en el siglo XXI y, al estar definido sobre productos más desagregados que los de una matriz, permite mejor vinculación con otras bases de datos disponibles como la política comercial, tributaria o el origen del capital. Este trabajo también ha sido replicado para América Latina en el Capítulo 6 del Informe Sobre Cadenas de Valor de la CAF[4].

Mientras la utilización de datos de insumos importados en la exportación puede ser vista como un intento de mejorar la descripción en cadenas hacia atrás, la utilización de clasificaciones que describan mejor el uso de las exportaciones puede ser vista como una alternativa para perfeccionar la descripción en cadenas hacia adelante.

[3] "La inserción internacional del Uruguay desde la perspectiva de las cadenas de valor: insumos para la política"
[4] Ver Capítulo 6 "Cadenas Globales de Valor" en "RED: Caminos para la integración: facilitación de comercio, infraestructura y cadenas globales de valor"(Sanguinetti et al. 2021)

La sección 2 de esta introducción presenta el trabajo “Measuring value circulation in regional chains: assessing two alternative methods in South America”[5], que corresponde al primer artículo de tesis, que se presenta en el capítulo 2. La sección 3 corresponde al Segundo artículo de mi tesis: “Size, Position and Length in Value Chains in Latin America”[6], que se presenta en el capítulo 3. La sección 4 introduce al tercer artículo: “Measures of Upstreamness and Downstreamness Defined on Exports”[7], presentado en el capítulo 4. Finalmente, la sección 5 presenta algunas consideraciones finales.

2) Métodos alternativos de desagregación de exportaciones brutas para medir participación en cadenas y aplicación al comercio regional

Entre los varios proyectos de WIOT disponibles, los más difundidos son WIOD (Timmer et al. 2015) y el proyecto TiVA de la OECD. Estos dos proyectos integran solamente a algunos países de América del Sur, mientras que los demás son incluidos como “resto del mundo”.

En años recientes han surgido algunos proyectos que tratan de atender esa limitación. La CEPAL tiene una serie de Matrices Insumo Producto que cubre la mayoría de las economías de América Latina (CEPAL 2016). Una matriz referenciada al año 2005 incluye los diez principales países de América del Sur y posteriores actualizaciones incorporaron a México y a 7 economías de Centroamérica y Caribe para los años 2011 y 2014[8]. Estas matrices están realizadas con la mejor información disponible de cada uno de los países de referencia y tienen una apertura sectorial más adecuada a la estructura productiva latinoamericana que los proyectos globales.

La principal limitación de la matriz de CEPAL es que no está integrada a matrices mundiales, es decir que se desconoce el uso que se le da a la producción latinoamericana una vez que ésta abandona el continente en forma de exportaciones. Precisamente, las medidas de participación en cadenas ponen particular interés en los encadenamientos hacia adelante, algo que queda “truncado” si se utilizan matrices incompletas[9].

El primer artículo de mi tesis adapta las descomposiciones de las exportaciones brutas más utilizadas a la existencia de matrices multipaís incompletas, es decir donde solamente una parte del mundo está representada, y realiza una aplicación para el comercio intrazona de América del Sur. El artículo es el resultado de un examen de la literatura de la medición del comercio en valor agregado doméstico, valor agregado extranjero, identificación del componente doblemente contabilizado y los encadenamientos hacia adelante y hacia atrás, que tiene en Koopman, Wang, y Wei (2014) su antecedente más conocido. Éste es una referencia en la literatura pues integra los conceptos de participación en cadenas hacia adelante y hacia atrás de Hummels, Ishii, y Yi (2001) con el Comercio en Valor Agregado de Johnson y Noguera (2012) y pone sobre la mesa el problema del valor doblemente contabilizado. Luego, Wang, Wei, y Zhu (2013, revisado en 2018) realizan una adaptación del método para obtener resultados bilaterales y sectoriales, lo que amplía mucho la aplicabilidad, que en Koopman, Wang, y Wei (2014) estaba restringida a las exportaciones totales de cada país. Sin embargo, desde su publicación el método de ambos artículos

[5] Este artículo fue aceptado y se encuentra en edición en la revista *Latin American Journal of Trade Policy*, editada por la Universidad de Chile. Una versión anterior figura como Documento de Trabajo N 6/2021 del Departamento de Economía

[6] Artículo aceptado y en proceso de edición por la Revista de Economía y Estadística, editada por la Universidad de Córdoba. Una versión anterior figura como Documento de Trabajo 04/2022 de la serie de CAF.

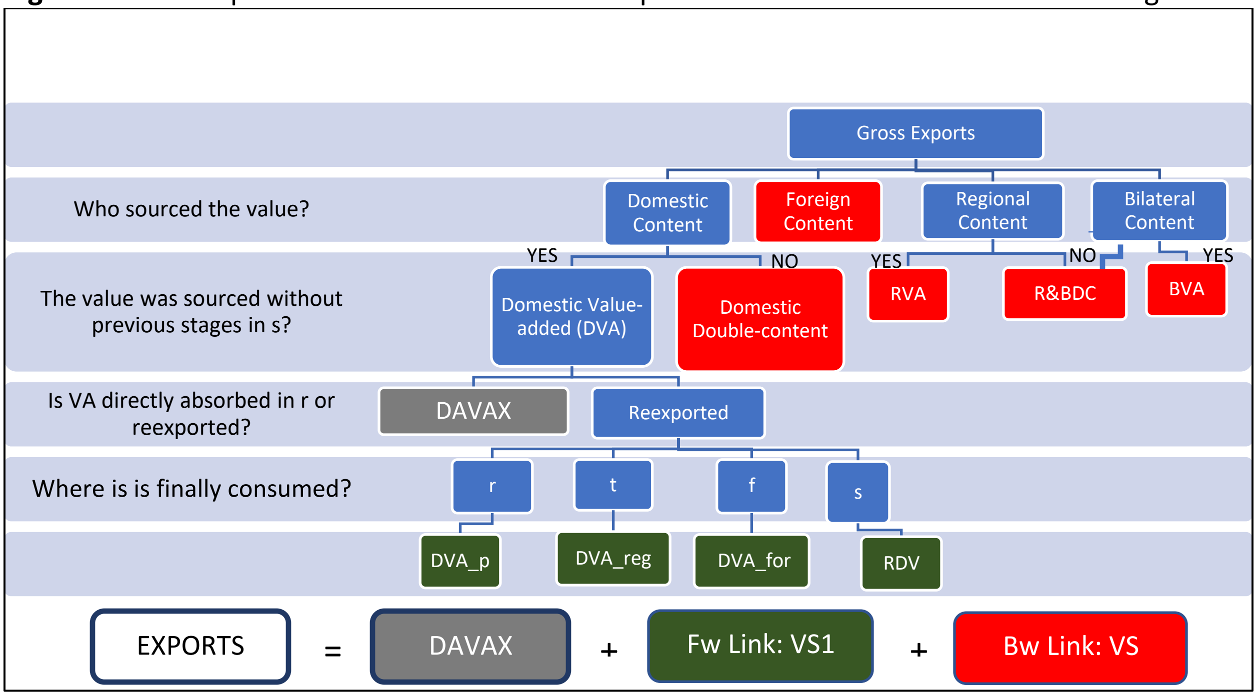
[7] Artículo enviado a la revista Cuadernos de Economía, de la Universidad Nacional de Colombia. En proceso de revisión

[8] He participado en la construcción de la matriz latinoamericana de CEPAL (CEPAL 2016) compilando información de Uruguay y de varios países centroamericanos en el marco de un proyecto internacional auspiciado por CEPAL.

[9] Banacloche, Cadarso, y Monsalve (2020) aplican la metodología de Koopman, Wang, y Wei (2014) para descomponer las exportaciones de los países de América del Sur utilizando la matriz de CEPAL, y deben realizar algunas reinterpretaciones de los términos originales

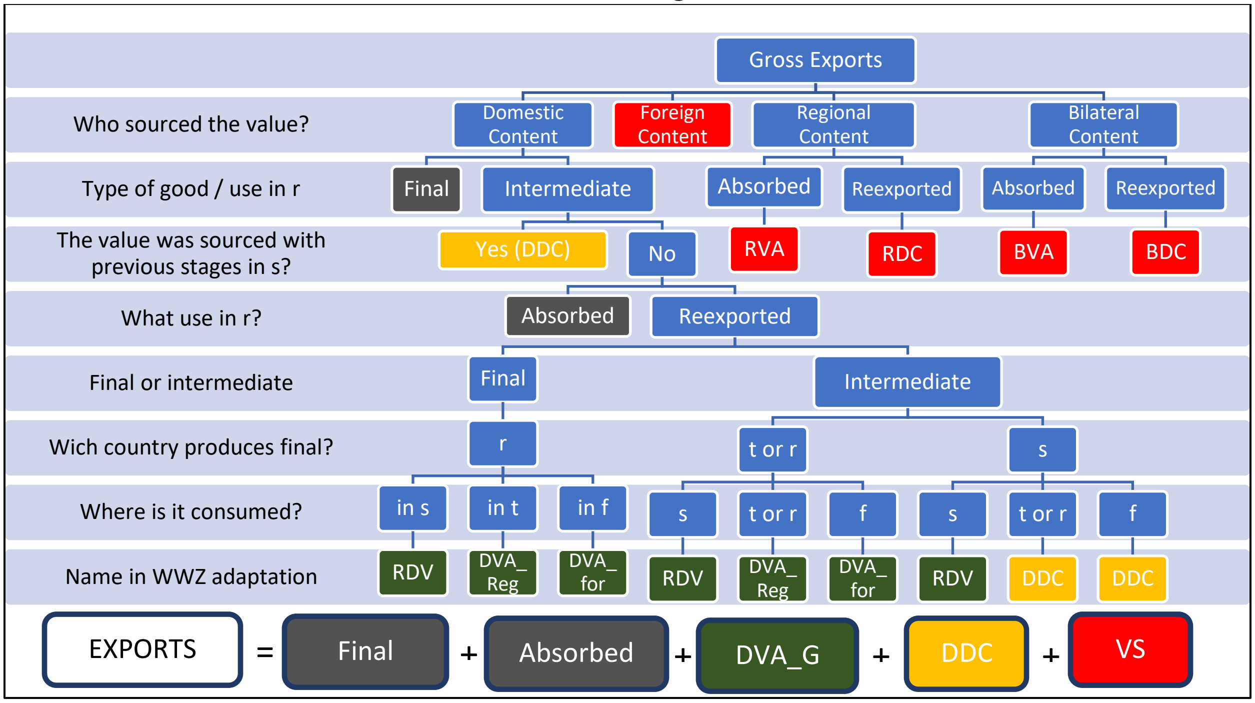
recibió críticas. Las más importantes refieren a la inconsistencia en el tratamiento del valor doméstico agregado en los bienes intermedios y en los bienes finales. De las varias alternativas propuestas (Los, Timmer, y de Vries 2016; Los y Timmer 2020; Nagengast y Stehrer 2016; Borin y Mancini 2015), la que resulta metodológicamente más clara es la de Borin y Mancini (2019), que es de amplio uso actualmente (World Bank 2019; Antras y Chor 2021). Sin embargo, Borin y Mancini (2019) no realizan una reconstrucción ni una cuantificación de las diferencias entre los métodos. Esta es la primera contribución de mi artículo. A partir de un análisis detallado de los procedimientos de descomposición de las exportaciones bilaterales que plantean ambos artículos es posible reconstruir la fuente de las diferencias y los impactos sobre la medición. El presente diagrama compara ambos métodos. La figura 1 corresponde a la adaptación de Borin y Mancini (2019) y la 2 a la de Wang, Wei, y Zhu (2013).

Figura 1. Descomposición *Source-Based* de las exportaciones bilaterales con matrices regionales



Nota: s corresponde al país exportador, r al importador regional, t a otro país regional y f a un país extra-regional.

Figura 2. Descomposición de exportaciones bilaterales basada en Wang, Wei and Zhu (2018) con matrices regionales.



Nota: s corresponde al país exportador, r al importador regional, t a otro país regional y f a un país extra-regional.

A pesar de que el artículo de Borin y Mancini (2019) argumentaba en forma sólida los fundamentos de su método, mi artículo muestra de forma más concreta los resultados de utilizar alternativas y en particular la tabla B1 del anexo (ver pág. 48) puede servir de base para explicar diferencias. Luego del auge del artículo de Koopman, Wang y Wei (2014), la importancia de una correcta medición del componente doblemente contabilizado ha tendido a perder importancia en la literatura de la medición. Actualmente, una división razonable de las exportaciones brutas en *backward linkages*, *forward linkages* y “comercio tradicional” (capturado por el DAVAX de Borin y Mancini) es el punto de partida idóneo para cualquier ejercicio de identificación de cadenas (Antras y Chor 2021)[10].

Además de la cuestión metodológica, el primer artículo de la tesis realiza una aplicación para las matrices regionales desarrolladas por la CEPAL. Como muestran las figuras 1 y 2, los métodos de descomposición de las exportaciones combinan una particular segmentación de las fuentes del valor (rastreando los orígenes a través de la función de producción de Leontief) con una segmentación de los usos o destinos (a través de las columnas). Para la adaptación de métricas concebidas para matrices globales a información regional es necesario introducir algunos términos a las formulaciones originales, complejizando el álgebra. En primer lugar, una parte del destino de la producción será extrazona, que por construcción se encuentra fuera del sistema, o sea no es posible rastrear los posibles usos que tiene la producción sudamericana una vez que es exportada extrazona. Para el sistema insumo producto, se trata como producción final. Adicionalmente, tampoco es posible identificar la forma de producción de los insumos que provienen de fuera de la región, por lo que estos también tendrán el tratamiento como si fueran exógenos al sistema. Así, el valor de la producción se integrará de valor agregado regional (incluyendo doméstico) y de contenido extrazona. Si bien es posible que los insumos de extrazona hayan sido elaborados con valor agregado regional, dada la escasa relevancia de América del Sur en el comercio

[10] Borin y Mancini muestran que para la identificación del valor agregado incorporado en las exportaciones (y para su complemento, los *backward linkages*) no es necesario trabajar con matrices multipaís sino que basta con matrices nacionales

mundial es razonable pensar que este valor regional reincorporado a la región a través de los insumos extrazona es despreciable a los efectos de la reconstrucción del valor.

El artículo ordena la segmentación de todos los flujos bilaterales sectoriales exportados de acuerdo a cuatro conceptos: Valor Agregado Doméstico directamente incluido en bienes finales ($DAVAX_{fin}$), VA Doméstico directamente incluido en intermedios directamente absorbidos por el importador ($DAVAX_{int}$), VA Doméstico reexportado por el importador (*Forward participation* en CGV) y Contenido importado en las exportaciones (*Backward participation* en CGV)[11]. Los resultados parten del análisis de esos cuatro términos, y luego profundizan la descomposición de los dos que miden la participación en cadenas: tanto los encadenamientos hacia adelante como hacia atrás se pueden desagregar según la región de destino (hacia adelante) y de origen (hacia atrás). El análisis muestra que el grueso de los encadenamientos en ambas direcciones conecta a las cadenas sudamericanas con la extrarregión, motivando la reflexión acerca de la importancia del comercio extrazona incluso para el comercio regional y la complementariedad entre ambos tipos de comercio[12].

Otra herramienta descriptiva propuesta en el artículo es una división del saldo de la balanza comercial regional en los cuatros términos mencionados. Esto permite analizar, de una forma novedosa, el rol de los países en las cadenas de valor. Brasil es el gran país superavitario en tres de los cuatro flujos, excepto en intermedios consumidos domésticamente donde tiene comercio balanceado. Chile se destaca como el principal articulador de las cadenas regionales sudamericanas, a partir de su condición de país de plataforma de entrada de valor extranjero a la región (incorporando insumos extrazona en sus exportaciones regionales) y de salida de valor regional (incorporando insumos sudamericanos en sus exportaciones extrazona).

Finalmente, el artículo aprovecha la información bilateral sectorial para identificar los flujos regionales más encadenados, destacando al sector químico entre Brasil y Argentina por sus altos encadenamientos hacia adelante y hacia atrás.

Respecto de diferencias en los resultados de acuerdo a las metodologías alternativas, el artículo reconoce que en un contexto de baja fragmentación regional de la producción no hay fuertes diferencias, sino que estas surgirán en la medida que las métricas se apliquen a regiones con mayor relevancia de uso de bienes intermedios regionales, tal como la Unión Europea o los países de la ASEAN.

3) Cadenas regionales y extrarregionales: medidas de profundidad y largo en América Latina

Una limitación del artículo anterior, insalvable al utilizar matrices regionales, es el hecho de que la integración regional debe ser estudiada en paralelo a la integración a los mercados globales.

La medición del involucramiento en cadenas globales de valor implica discriminar a la producción que participa directa o indirectamente del comercio internacional de la que no lo hace. Para ello se suele segmentar a la información de transacciones -de uso intermedio y de uso final- en las domésticas y las internacionales. La literatura de la economía regional tiene una larga tradición de uso de estas subparticiones de la información para la identificación de efectos intrarregionales, interregionales y combinados (Fan, Zhang, y Liao 2019). Si bien estos desarrollos pensados para la economía regional pueden ser aplicados al comercio internacional para describir adecuadamente la interacción entre la economía nacional, regional y global, en general no están definidos a partir del vector de exportaciones

[11] Otra contribución interesante de Borin y Mancini es que muestran que dicho valor también puede tener valor agregado doméstico integrado a los insumos, pero que este flujo también indica participación hacia atrás, por lo que debe ser tratado como el valor extranjero.

[12] En otras palabras, si se definen las cadenas de valor sudamericanas como los flujos que conectan por los menos tres países siendo al menos dos sudamericanos, en la mayoría de los flujos el tercer país no es Sudamericano.

brutas, que es la fuente tradicional del análisis en el campo del comercio internacional. Wang et al. (2017b; 2017a) partiendo de la matriz de valor agregado directo e indirecto incluido en la producción final, generan métricas completas que permiten describir la participación de los países en cadenas de valor y de posición a lo largo de una cadena.

El segundo proyecto de tesis se nutrió de un documento de trabajo elaborado a pedido de la CAF para describir la integración regional en cadenas de valor y que formó parte del último Reporte de Economía y Desarrollo (Sanguinetti et al. 2021). La metodología aplicada en el primer artículo no resultaba adecuada porque era de interés estudiar la participación en cadenas regionales vis a vis la participación en globales, y las matrices regionales no tienen la información para las segundas.

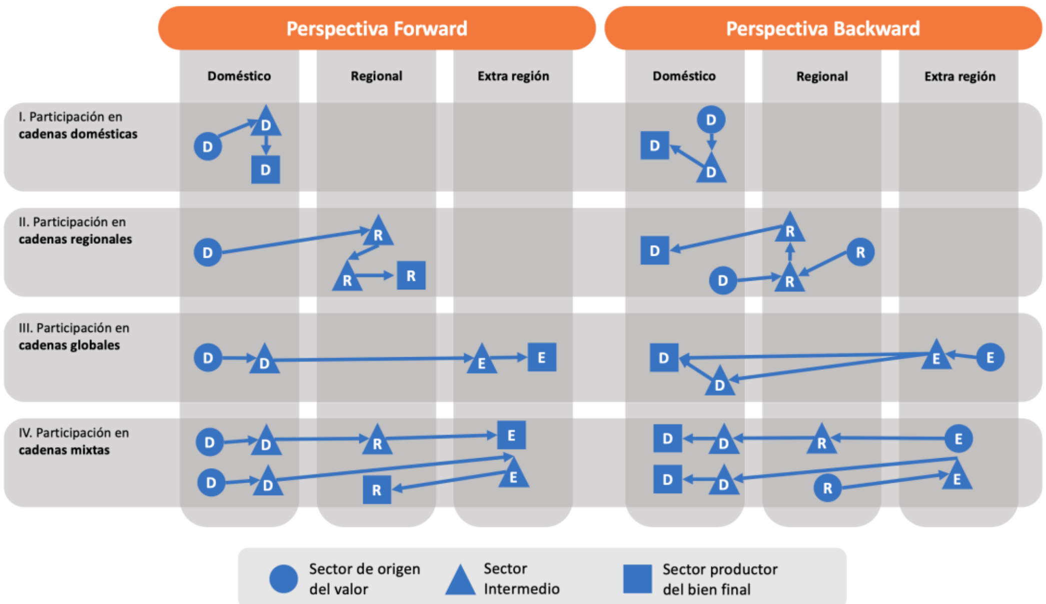
Este artículo construye sobre las métricas de Wang et al. (2017b; 2017a) para estudiar simultáneamente la participación, profundidad y posición de las cadenas globales y las regionales, que permite evaluar la integración regional vis a vis el impulso de la globalización. En ese sentido, tiene la referencia teórica de Antras y de Gortari (2019), que postulan una relación en forma de U invertida entre costos de comercio y participación en cadenas regionales: la reducción de los costos de comercio lleva a mayor participación en cadenas regionales en detrimento de las domésticas, pero luego de cierto umbral empieza a ser más relevante la participación en cadenas globales, en detrimento de las regionales.

Entonces, la adaptación de métricas globales con WIOT segmentadas es una segunda alternativa para el estudio de la integración regional. Para ello, adapté la técnica de descomposición utilizada en Borin y Mancini (2019) para discriminar la matriz inversa de Leontief sin restringir $(I-A)^{-1}$ entre los efectos de una subpartición A^s y la interacción entre ésta y su complemento: $(I-A)^{-1}=(I-A^s)^{-1}+(I-A^s)^{-1}(A-A^s)(I-A)^{-1}$.

Mediante la selección adecuada de las subparticiones y la aplicación secuencial sobre la matriz de valor agregado total en la demanda final es posible identificar cadenas domésticas (donde el valor agregado en la demanda final solo contiene encadenamientos domésticos), cadenas regionales (donde el valor agregado en la demanda final incluye encadenamientos domésticos combinados con comercio regional de intermedios), cadenas extrarregionales (donde el valor agregado doméstico se combina exclusivamente con producción de países de fuera de la zona) y cadenas mixtas (donde participa valor agregado doméstico, regional y extrarregional).

La matriz de valor agregado en producción de bienes finales habilita dos lecturas complementarias. Por un lado, una lectura "hacia adelante" de las cadenas de valor, partiendo del valor agregado de un sector país e identificando los sectores intermedios que lo usan hasta ser incluido en producción de bienes finales. Por otro lado, una lectura hacia atrás, que parte de la producción de bienes finales de un sector país y traza la secuencia de valor hasta los factores primarios.

Diagrama 1. Descomposición del Valor agregado según perspectiva y tipo de cadena en la que participa



La metodología desarrollada en mi artículo divide la matriz de valor agregado en demanda final de acuerdo a dos ecuaciones:

Perspectiva forward: El valor agregado se divide de acuerdo a dónde se integra a demanda final:

$$Va = \hat{V}BY = \hat{V}LY^D + \hat{V}LY^R + \hat{V}LY^F + \hat{V}LA^{reg-d}B^{reg}Y + \hat{V}LA^{-reg}B^{for}Y + \hat{V}LA^{-reg}B^{for}A^{-for}BY + \hat{V}LA^{reg-d}B^{reg}A^{-reg}BY$$

Los primeros tres términos corresponden a cadenas domésticas según el Diagrama 1. El primero corresponde con el valor directamente integrado y consumido domésticamente. Los otros corresponden al valor doméstico integrado (en base a la perspectiva *source- based*, desarrollada en el artículo anterior) en bienes finales exportados a la región ($\hat{V}LY^R$) o a la extrarregión ($\hat{V}LY^F$), una aproximación a las exportaciones tradicionales.

Los términos cuarto y quinto capturan las cadenas regionales y extrarregionales respectivamente. Ellas están definidas como el valor agregado en el país de referencia que cruza una frontera como intermedio y es transformado en bienes finales en la región de referencia, sea regional o extrarregional. Wang et al (2017a) dividen a estas cadenas en simples, cuando el valor cruzó solamente una frontera, y complejas, cuando cruzó más de una. Estas últimas son equivalentes a la participación *forward* de Borin y Mancini (2019). Por ese motivo, la definición de Wang et al (2017a) es más amplia que la de Borin y Mancini. De todas formas, mientras Wang et al (2017a) se aplica en referencia a todo el valor agregado de un país, Borin y Mancini (2019) se aplica solamente sobre las exportaciones. El último reporte de Cadenas de Valor de la OMC (OMC, 2021) compara los resultados de ambas formas de concebir la participación en cadenas. En mi artículo muestro que en América Latina las cadenas complejas representan el 15% de las Cadenas Regionales y el 35% de las Extrarregionales.

Finalmente, los términos seis y siete representan las cadenas mixtas: valor agregado de un país de la región que se integra en procesos productivos tanto en la región como en extrarregión. Hay dos términos dependiendo de la secuencia doméstico-regional-extrarregional o doméstico-extrarregional-regional. A pesar de representar alta fragmentación, estos flujos no se analizan por ser de muy baja significación.

La medida *backward* tiene una definición muy similar a la anterior:

$$Y^T = VB\hat{Y} = VL\hat{Y}^D + VL\hat{Y}^R + VL\hat{Y}^F + VB^{reg}A^{reg-d}L\hat{Y} + VB^{for}A^{-reg}L\hat{Y} + VBA^{-for}B^{for}A^{-reg}L\hat{Y} + VBA^{-reg}B^{reg}A^{reg-d}L\hat{Y}$$

Cada término es análogo al anterior, pero está definido a partir de la producción de bienes finales, trazando hacia atrás los países de origen del valor incorporado.

Ambas medidas se utilizan para describir la evolución de la profundidad de las cadenas de valor en las estructuras productivas de los países de América Latina. Para ello se utiliza la base de datos EORA, que a pesar de tener una apertura sectorial bastante menor que las otras WIOD disponibles, tiene mucho mayor cobertura de países y también temporal. Hay datos para 18 países de América Latina en el período 1990-2015. La amplia cobertura temporal de la base permite mostrar la evolución de la integración productiva desde los primeros años del "regionalismo abierto".

La evidencia descriptiva muestra que durante todo el período aumentó el peso de las actividades que involucran comercio exterior, en detrimento de las actividades puramente domésticas. Partiendo desde valores muy bajos, en general la integración regional (a partir de bienes finales y también en cadenas de valor) mostró mayor dinamismo que la integración global. De todas formas, el ritmo de integración regional fue notoriamente más bajo que el de regiones de referencia como Europa y los países de ASEAN más Corea, Japón y China. Esto pone en evidencia que los costos de comercio no bajaron lo suficiente, tal como sugiere evidencia reciente (Moncarz et al. 2021). A partir de una comparación de la integración hacia adelante (como proveedores de valor agregado) y hacia atrás (como usuarios de valor agregado extranjero) es posible definir el perfil de la participación. Una combinación de la posición (*forward* vs *backward*) con el tipo de cadena permite extraer algunas conclusiones. El país que se destaca en la integración es México, donde es clara la penetración del comercio en Cadenas de Valor. La evidencia muestra que México ha virado desde una posición neta de usuario (finalizador) en cadenas regionales, a tener una posición neta *forward* regional y *backward* extrarregional. Esto se explica por la sustitución de valor agregado norteamericano por asiático durante el período. Esto está en coincidencia con la etapa avanzada en reducción de costos de comercio de acuerdo a Antras y Chor (2019), donde las cadenas globales sustituyen a las regionales. En el resto de los países no se evidencia esta evolución, lo que permite aventurar que se encontrarían aún en la etapa de costos de comercio altos.

En un contexto comparado de baja participación general, otros resultados son la alta relevancia de la participación *forward* regional de Argentina, Paraguay y Bolivia, la alta participación *forward* global de Chile, Perú, Ecuador y Venezuela y *backward* global de los países centroamericanos. Brasil y Colombia, por su parte, muestran muy baja participación.

Las medidas de posición en las cadenas de valor, usualmente llamadas "Upstreamness" y "Downstreamness" tienen menos desarrollo teórico que las que miden la participación. Antràs et al. (2012) definieron a la u*pstreamness* como la distancia de la producción hacia la demanda final y Antràs y Chor (2013) a la *downstreamness* como la distancia de la producción hacia los factores productivos (valor agregado). La distancia es el número de etapas promedio que recorre dentro de la cadena productiva determinado flujo hasta ser demanda final (*upstreamness*) o análogamente desde el valor agregado hasta la producción (*downstreamness*).

Wang et al (2017b) es el primer artículo que adapta las medidas de posición y largo al comercio en cadenas de valor. Para ello, muestran el paralelismo entre la *upstreamness* de Antras et al (2012) y una agregación con perspectiva *forward* de la matriz de valor agregado en la demanda final y entre la medida de *downstreamness* de Antras y Chor (2013) y la perspectiva *backward*. Además, aprovechando su descomposición del valor agregado en términos domésticos, de comercio tradicional y en cadenas de valor, adaptan las métricas para medir el largo de esos flujos por separado. Uno de los aspectos interesantes de su adaptación es que los términos de cadenas de valor (que por definición abarcan producción en dos países) pueden ser visto como la suma de un término que mide el largo promedio de las etapas que transcurren dentro del país y un término que mide el largo que transcurre fuera del país (en mi tercer artículo utilizaré esta distinción).

En este artículo aprovecho la descomposición realizada para estudiar el largo de las cadenas regionales vis a vis las extrarregionales en el contexto latinoamericano. Encuentro que hay una reducción del largo de las etapas domésticas durante el período, y que esta reducción está asociada con mayor participación en las cadenas extrarregionales, pero no en las cadenas regionales. Si consideramos la reducción del número de etapas como una medida de la especialización de los países, puede plantearse la idea que la integración global ha especializado más a los países, pero la regional no lo ha hecho. Esto puede ser otro argumento a favor de la idea de falta de impulso a la reducción de barreras al comercio en la región.

4) Medidas de largo y posición en cadenas a partir de exportaciones brutas

La exploración de la literatura de largo de cadenas y la insatisfacción con las medidas reseñadas más arriba motivó el tercer artículo de mi tesis.

Las medidas de posición de los sectores o países en las cadenas están teniendo una importancia creciente. Algunos trabajos las usan como variable explicativa para introducir tipo de participación (por ejemplo, Reshef y Santoni 2022) y los modelos teóricos sobre decisión de *offshoring* también distinguen entre el tipo de industria a partir de estos conceptos (por ejemplo, Alfaro et al. 2019).

Las medidas estándar de *Upstreamness* y *Downstreamness*, a partir de las cuales algunos autores definen el largo de las cadenas, están definidas para la producción total de una industria en un país, y también se agregan en países o en industrias. A lo largo de una cadena, todas las etapas productivas que se realizan en un país son contabilizadas en ambas medidas. Una de las limitaciones que tienen la agregación de medidas basadas en la producción es que produce correlación positiva entre ambas medidas. Los países que tienen alto valor *downstream* también tienen alto valor *upstream*, lo cual se explica por la mencionada redundancia en la contabilización. Esto genera que la descripción de la especialización de los países a lo largo de las cadenas de valor quede velada por el largo general que contienen las estructuras productivas.

Como mencionan acertadamente Antràs y Chor (2018), un país sin comercio internacional tiene la misma medida global *upstream* que *downstream*, y la diferencia entre ambas medidas obedece a la especialización en el comercio internacional, sea como proveedor de insumos (lo que aumenta la medida *upstream*) o como usuario de insumos importados (lo que aumenta la medida *downstream*). Sin embargo, no resulta útil que para medir la especialización en la era de las cadenas de valor se utilicen las distancias respecto de la situación de no comercio.

La medida de Wang et al. (2017a), que proponen la ratio entre la *upstreamness* y la *downstreamness*, tiene la fortaleza de que, al ser aplicada sobre subconjuntos de cadenas, aísla las actividades puramente domésticas, que por definición no tienen ningún sesgo hacia la *upstreamness* o *downstreamness* (son por definición balanceadas), de las actividades del comercio internacional. Sin embargo, la medida de participación en cadenas que proponen no resulta totalmente explicativa de la especialización de los países. Para Wang et al, la participación hacia adelante corresponde a valor agregado que se exporta como intermedio y se integra en un proceso en otro país, mientras que la participación hacia atrás se corresponde al uso de valor agregado en la producción de bienes finales. De acuerdo a esa definición, si un país participa en las etapas intermedias de una cadena, solo la distancia hacia adelante es contabilizada, mientras que la medida hacia atrás no es capturada por el país, pues no se trata de un bien final sino de un bien intermedio.

La definición de medidas a partir de las exportaciones genera una descripción mucho más útil de la posición de los países en el comercio internacional. Entonces, mi tercera línea de investigación consiste en discutir las medidas de referencia de la literatura y evaluar una alternativa para las medidas de posición que a mi juicio es más consistente con el resto de la literatura de profundidad y participación, que está definida a partir del vector de exportaciones.

El tercer artículo de la tesis propone definir a la *upstreamness* como la distancia entre las exportaciones y la demanda final. La distancia se mide como el número de etapas en promedio que hay entre exportaciones y demanda final. Las exportaciones de bienes y servicios finales ya son demanda final, por lo que tienen distancia cero. Las exportaciones de bienes y servicios intermedios que se integrarán directamente en producción de bienes finales en el país importador tienen distancia uno, las de intermedios que se utilizan por productores de intermedios para producir finales tienen distancia dos, y así sucesivamente.

Para estimar la *downstreamness* se rastrea el sector-país de origen del valor agregado incluido en las exportaciones brutas y se pondera cada término por el número de veces que el valor es contabilizado en la producción hasta ser exportado. El valor agregado directamente incluido por los exportadores tiene distancia uno, el valor agregado incluido por los proveedores directos del exportador tiene distancia dos y así sucesivamente[13].

A partir de estas medidas se definen dos medidas adicionales. El largo de cadenas en las que participa un determinado sector país se calcula como la suma de la *dowstreamness* y la *upstreamness*, y la posición relativa de un determinado sector país en una cadena es la contribución relativa de la *dowstreamness* al largo total.

Para medir la posición de un país (o sector – país) en la cadena es necesario tomar en cuenta tanto el largo total de la cadena en la que se ubica, como la contribución de cada una de las dos medidas al mencionado largo. La *downstreamness* está definida por la función de producción del país y su estructura de abastecimiento (y la de sus proveedores), mientras que para el *upstreamness* es determinante el uso que le dan otros países a la producción del país de referencia.

Todas las medidas están definidas para un sector- país pero se pueden agregar a nivel de país y a nivel de sector. También admiten una agregación global.

La definición de medidas de *upstreamness* y *downstreamness* a partir de las exportaciones para describir a los países genera resultados más apropiados que sus antecedentes. En primer lugar, excluye las actividades que no están relacionadas al comercio internacional, que son el grueso de la actividad de los países y sesgan los resultados. Grandes sectores como la salud, la educación o la construcción, solo son considerados en la medida que exporten, algo que sucede en muy baja proporción. A diferencia de las medidas basadas en la producción, las medidas *downstream* y *upstream* refieren a conjuntos diferentes

[13] Resulta útil dividir a este largo hacia atrás de las exportaciones según si las etapas productivas fueron domésticas o internacionales. Entonces, utilizando como en los anteriores artículos la equivalencia entre $B = L + LA^F B$, el largo hacia atrás se dividirá en una contribución doméstica al largo de las cadenas y una contribución internacional

de producción[14]: la *upstreamness* considera las etapas una vez que el bien o servicio ha abandonado el país, al tiempo que la *downstreamness* considera solo la producción hacia atrás, desde los factores productivos hasta la exportación. Esto hace que naturalmente se puedan sumar ambas medidas en el largo de cadenas. En el mismo sentido, son consistentes con una definición de cadenas como flujos desde el valor agregado hasta la demanda final. Las etapas desde el valor agregado hasta las exportaciones corresponden a la *downstreamness* y desde las exportaciones hasta la demanda final a la *upstreamness*.

La sección empírica del artículo aplica las medidas desarrolladas a la información que surge de las matrices WIOD. Esta elección se realizó porque los artículos de referencia (Antràs y Chor 2018; Miller y Temurshoev 2017; Wang et al. 2017a) utilizan esta fuente, y es de interés replicar los datos de los otros artículos para minimizar las fuentes de diferencia entre métodos. Este tipo de medidas requiere de matrices con alta desagregación sectorial. En contraposición, este artículo no realiza una descripción de América Latina ya que solo México y Brasil están representados en WIOD, aunque resulta directo poder hacerlo con otras matrices[15].

El resultado más importante es la verificación de que existe una correlación negativa entre *upstreamnes* y *dowstreamness* definidas a nivel de país, a diferencia de lo que muestran los artículos de referencia. Como ya se mencionó, esto se debe a la redundancia en el cómputo de las etapas en las industrias integradas cuando no se discrimina a las exportaciones del resto. La correlación negativa implica que el largo total en cadenas definidas sobre exportaciones varía menos que la upstreamness y la downstreamness por separado, pues se tienden a compensar. Esto es consistente con la especialización de los países a lo largo de la cadena de valor. También el artículo pone en manifiesto que, dado el carácter regional de las CGV, la fragmentación es diferente en cada "fábrica global": México es *downstream* en cadenas americanas, que son cortas (o sea, hay más valor agregado en cada etapa y por lo tanto menos etapas), mientras que China lo es en las cadenas más largas, que son las asiáticas. La especialización es mayor en Asia: China se posiciona cerca de la demanda final[16] (aunque realiza varias etapas domésticas), Corea, Taiwán y Japón proveen intermedios y Australia y Rusia son proveedores *upstream*. Finalmente, Europa se posiciona en una situación intermedia, y se destacan algunos países como finales de cadenas (Chequia, Hungría) y otros con alto peso en servicios (Suiza, Reino Unido, Irlanda).

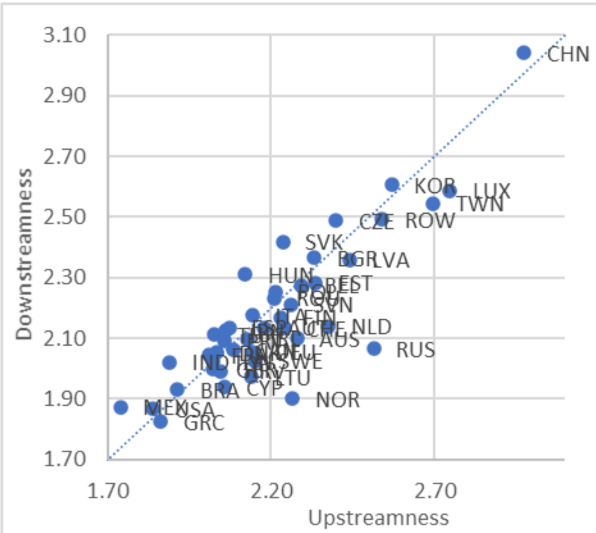
[14] En la medida que una (mínima) parte de los insumos importados utilizados pueden tener valor agregado doméstico, estrictamente un flujo de valor podría formar parte de ambas medidas. Esto sucede cuando los países exportan un intermedio (se contabiliza en la Upstreamness) y luego lo importan y vuelven a utilizar (se contabiliza en la *Downstreamness*). Esto no presenta un problema en la medida que este "loop" en la producción indica cadenas largas. Este "loop" da cuenta del componente doblemente contabilizado del comercio y tiene una prevalencia muy baja

[15]La aplicación de las medidas propuestas con la matriz MCIO OECD correspondiente a 2018 muestra a México con cadenas algo más largas que el promedio hacia atrás y sobre todo muy cerca de la demanda final, a Costa Rica y Argentina participando en cadenas muy cortas, y a Brasil, Colombia, Chile y Perú participando en cadenas desde una posición muy *Upstream.* En particular, Chile, Perú y Brasil están entre los países que aumentaron más su *Upstreamness* en el período 1995-2018 y México es uno de los pocos que no la aumentó.

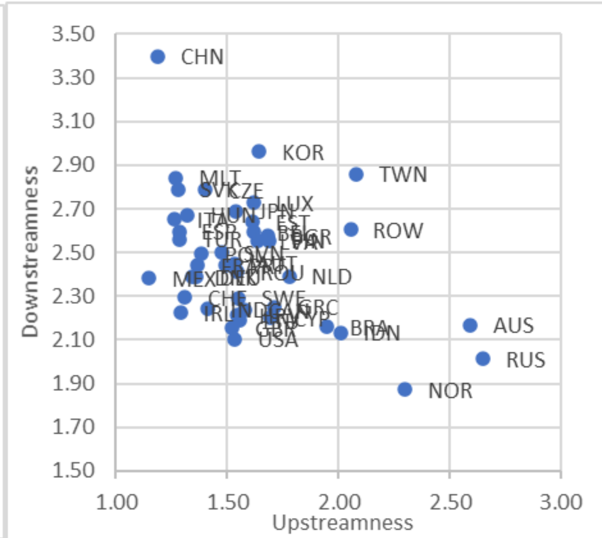
[16] Esta matriz no permite ver la nueva tendencia en la fragmentación de la cadena asiática, donde se ha tendido a deslocalizar las etapas finales en otros países diferentes a China (por ejemplo, Vietnam, Camboya y Myanmar). La matriz ICIO OECD lo muestra de forma más clara.

Gráfico 1. Upstreamness y Downstreamnes de los países con medidas alternativas

a) Antras y Chor (2018)



b) Basadas en Exportaciones



El artículo también distingue entre la contribución doméstica a la *downstreamness* de la que se importa en los insumos, mostrando que, salvo China, los países más *downstream* lo son por el largo de los insumos importados. Otros resultados realizados permiten descomponer los cambios en largo y posición de acuerdo a si cambió la composición de la canasta exportada, por ejemplo, si un país se especializó más en productos con alguna característica -*upstream* o *downstream*-, o si cambió la forma de producción, abastecimiento o uso del producto. El análisis también permite evaluar la posición de los países en sectores específicos, que pueden servir como marco para análisis sectoriales. Por ejemplo, la cadena de material electrónico aparece como mucho más fragmentada y especializada que la cadena de fabricación de vehículos y autopartes.

5) Consideraciones finales

Los tres artículos presentados en esta tesis son el resultado del análisis de herramientas (matrices y medidas) disponibles para describir el desempeño de los países de la región en el comercio en cadenas de valor. Como resultado del trabajo se obtienen nuevas métricas para aplicar sobre matrices insumo producto multipaís. Los procedimientos tienen en común la consideración simultánea del destino o uso que se da a la producción (o a un subconjunto de esta: las exportaciones) y del origen del valor incorporado en dicha producción. Las definiciones contenidas en estos artículos pueden ser utilizadas para analizar cualquier región del mundo. A la hora de elegir la métrica adecuada, deben considerarse las limitaciones y ventajas que ofrece cada base de datos y el problema en particular que se quiere abordar.

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<u>MEASURING VALUE CIRCULATION IN REGIONAL CHAINS: ASSESSING TWO ALTERNATIVE METHODS IN SOUTH AMERICA</u>

Abstract:

Since Hummels, Ishii and Ye (2001) seminal work there have been lots of proposals for measuring participation in global value chains with input-output tables. Conjointly to the development of measures, several projects created Inter-Country Input-output tables. To the extent that integrating data of different origins requires strong assumptions and confidence in sources, some projects keep more detailed inter country input-output tables at a regional level. In this paper I adapt two of the most complete methods conceived for global Input-output tables to the case of regional tables, and I use them to analyze the intraregional value chain trade of South America. Besides characterizing the trade in this region, this paper identifies and asses the differences between adaptations of Borin and Mancini (2019) source-based decomposition of gross exports and the Wang, Wei and Zhu (2018) method.

Resumen:

A partir del artículo de Hummels, Ishii y Ye (2001) se han propuesto varias medidas para medir la participación de los paises en cadenas globales de valor. Conjuntamente con el desarrollo de medidas, diversos proyectos crearon Matrices Insumo Producto Multipaís para representar mejor el comercio mundial. Dado que integrar información de muchos países requiere de supuestos fuertes y confianza en las fuentes, algunos proyectos mantienen información detallada en matrices insumos producto regionales. En este artículo se adaptan dos de los métodos más completos concebidos para matrices globales al caso de matrices regionales y se aplican para describir el comercio intraregional en cadenas en América del Sur. Además de esta caracterización, el artículo mide las diferencias entre la metodología source-based de Borin y Mancini (2019) y el método de Wang, Wei y Zhu (2018).

JEL: E16, F14, F15.

Keywords: trade in value-added; global value chains; regional integration, inter-country input-output tables

I. Introduction

One of the salient facts of current era of globalization is the interlink between sectors across countries and the international circulation of value-added. This connection of countries across intermediates goods give rise to new theoretical lectures of the fundaments of trade (Eaton and Kortum 2002), a reevaluation of gains of trade (Caliendo and Parro 2015) and led to modification in global governance of multilateral trade (Baldwin 2012).

Traditional data on gross trade flows fails in describe some of salient features of globalization (Yi 2003) and national input-output tables also brings a partial view of international sharing of production (Hummels, Ishii, and Yi 2001). In recent years there have been several projects of integration of world input-output tables (Tsigas, Wang, and Gehlhar (2012), Johnson and Noguera (2012), Timmer et al. (2015), Lenzen et al. (2013)) and also the measures of integration on global value chains have been improved. Using these data, literature developed a full set of measures to characterize size, evolution, position, length, or depth of global value chains (GVC). Inter country input-output tables link sectors of different countries and enable a complete evaluation of relationships between final demand, intermediate domestic and foreign demand and value-added.

As a natural extension of input-output analysis, measures of value-added in trade identify the forward and backward linkages of international trade. Hummels, Ishii, and Yi (2001) set the most used definition of backward linkages, capturing the relationship between exports and the origin of value. They label it Vertical Share (VS). They also defined, without proposing a measure, the forward linkages of exports as the value-added of a country included in exports of other countries. Also, Johnson and Noguera (2012) defined the “value-added in exports” as the value-added sourced in a country and consumed in another.

Koopman, Wang and Wei (2014) set a methodology that decomposes gross exports of countries in domestic value-added, foreign content and double counted terms, integrating the previous measures of participation in global value chains (Hummels, Ishii, and Yi 2001; Johnson and Noguera 2012; Daudin, Rifflart, and Schweisguth 2011) in a single scheme. Despite being a benchmark and a reference in the literature, Koopman, Wang and Wei (2014) decomposition do not enables further appliances in less-than overall levels. Wang, Wei and Zhu (2013, revised 2018) -henceforth WWZ- develop an accounting exercise that arrives to same Koopman, Wang and Wei (2014) categories but make possible bilateral, sector and bilateral- sector lectures. All the traditional and most widely used measures can be analyzed within WWZ framework. Los, Timmer, and de Vries (2016), Los and Timmer (2020), Miroudot and Ye (2018) and Johnson (2018), based in the “hypothetical extraction method”, also split gross exports in domestic value-added, foreign value-added and double counting content. Also, Borin and Mancini (2015; 2019) develops a more general framework for decompositions of gross exports that identifies domestic or foreign value-added and double counting according to the required level of analysis (overall, bilateral, sectoral) and the purpose of the inquiry. Following Nagengast and Stehrer (2016) they show that some flows can be defined as value-added or as double-content depending on the perspective followed.

All these contributions are conceived for data that aims to represent input-output relationships of the entire world. Nevertheless, Regional Input-output Tables have a long tradition and recent international projects restored their importance (IDE JETRO 2010; European Commission 2018; CEPAL 2016). There can be many reasons for building regional instead of world multi country input-output tables, e.g., this can be the way to include small countries negligible at global level, some more detailed data can be preferred but is not available at global level or the industry classification of global projects may not be useful for some purposes. In fact, despite being labeled as Global, most international sharing arrangements started as regional outsourcing and later they spread out their influence (Johnson and Noguera 2017).

The use of regional input-output tables arises to some modification in metrics and interpretation. First, final demand is reinterpreted and regional and extra-regional will be considered apart. Second, imported intermediate inputs are split in regional and extra-regional, leading to another source of value. While regional inputs enter to model as in reference literature, extra-regional imports receive a different treatment. This adaptation only holds here if it is assumed that there is no regional or domestic value-added in extra-regional sourced inputs, or the value is negligible. Clearly, this assumption only is reasonable if the region is small or remote enough, like in the case of South America in relationship with the world. Global estimations of domestic value-added in imported inputs for Brazil validates this operational assumption (Koopman, Wang, and Wei 2014; Los and Timmer 2020).

Adapting global metrics to regional input-output tables, in this paper I develop a Source- Based decomposition of regional exports based in Borin and Mancini (2019) and I apply it to characterize the kind and degree of regional integration of South American countries using the regional Input-output tables launched by the Economic Commission for Latin America and the Caribbean (CEPAL 2016)[1]. I develop also and alternative decomposition of regional exports based in Wang, Wei, and Zhu (2018) in order to illustrate more clearly the differences in both methods. All references mentioned here are based on different account segregation of terms that combine value-added, international and domestic linkages, and final demand. As long as Borin and Mancini (2019) and Wang, Wei, and Zhu (2018) are the more parsimonious and complete references in each strand of literature, I use both in order to discuss and asses the differences between methods. Borin and Mancini (2019) can be considered a representant of a strand of literature compatible with hypothetical extraction method and Wang, Wei, and Zhu (2018) can be considered the best effort to apply Koopman, Wang, and Wei (2014) in a bilateral basis.

The method developed here builds a bridge between both methodologies and it allows a lecture in different levels according with the alternatives methodological approaches (Wang et al. (2017b) vis a vis Borin and Mancini (2019)).

This paper includes this introduction and three sections more. Section II introduces the methodological aspects of discussion and builds the accounting segregation used and the differences among methods. Then, section III shows the results of the application for regional trade of South American Countries, and section IV draws some conclusions.

[1]Banacloche et al. (2020) also uses CEPAL (2016) input-output table to characterize South American integration with an adaptation of Koopman, Wang and Wei (2014) to regional input-output tables. As the framework used only applies for total exports, their analysis is done at this level.

II. Tracing value in bilateral exports with regional input-output tables

i. General notation and definitions

Table 1 shows a regional input-output table with G regional countries $\{s, r, t \in G\}$ and the rest of world composed by H extra regional (also labeled as “foreign” in this article) countries $\{\, h \notin G, h \in H\}$.

Table 1. Regional input-output table

Destination / Source		Intermediate use				Final regional use			Foreign use			Output
		1	2	…	G	1	…	G	1’	…	H	
Intermediate Inputs from region	**1**	Z^{11}	Z^{12}	$\cdots$	Z^{1G}	Y^{11}	$\cdots$	Y^{1G}	$Y^{11'}$	$\cdots$	Y^{1H}	X^{1}
	2	Z^{21}	Z^{22}	$\cdots$	Z^{2G}	Y^{21}	$\cdots$	Y^{2G}	$Y^{21'}$	$\cdots$	Y^{2H}	X^{2}
	⋮	$\vdots$	$\vdots$	$\ddots$	$\vdots$	$\vdots$	$\ddots$	$\vdots$	$\vdots$	$\ddots$	$\vdots$	
	G	Z^{G1}	Z^{G2}	$\cdots$	Z^{GG}	Y^{G1}	$\cdots$	Y^{GG}	$Y^{G1'}$	$\cdots$	Y^{GH}	X^{G}
Intermediate foreign Inputs	**1’**	$Z^{1'1}$	$Z^{1'2}$	$\cdots$	$Z^{1'G}$							
	2’	$Z^{2'1}$	$Z^{2'2}$	$\cdots$	$Z^{2'G}$							
	⋮	$\vdots$	$\vdots$	$\ddots$	$\vdots$							
	H	Z^{H1}	Z^{H2}	$\cdots$	Z^{HG}							
Value-added		Va^{1}	Va^{2}	$\cdots$	Va^{G}							
Total Output		$(X^{1})^{T}$	$(X^{2})^{T}$	$\cdots$	$(X^{G})^{T}$							

Source: Own Elaboration

$Z^{sr}\{s, r \in G\}$ is an NxN matrix of intermediate inputs produced in country s and used in country r, $\tilde{Z}^{hr}\{r \in G, h \notin G, h \in H\}$ is an NxN matrix of intermediate inputs imported by r from country h, Y^{sr} is an Nx1 vector of final goods produced in country s and consumed in country r, $Y^{sh}$is an vector of intermediate and final goods produced in country s and exported to country h, $X^{s}$is an Nx1 vector of output of country s and $Va^{s}$is a 1xN vector of direct value-added in country s. T is the transpose operator. In a general notation, final demand Y and production X can be expressed as NGx1 vectors, Z is a NGxNG matrix, $\tilde{Z}$ is a NHxNG matrix and Va is a 1xNG vector.

The international Leontief matrix $A = Z\hat{X}^{-1}$ enables the usual notation in input-output analysis. The international Leontief inverse matrix is defined as: $B = (I - A)^{-1}$.

Each A^{sr} is an NxN matrix containing the ratios of utilization of origin s in the production of country r. The main block diagonal (s=r) corresponds to domestic intermediate transactions, whereas when s≠r is the case of international trade of intermediates.

Each sub matrix B^{sr} is the total output necessary in each n sector of country s to fulfill one additional unit of final demand in each n sector of r. Analogously, we can define the local Leontief inverse matrix as a measure for total domestic output necessary in each n sector to fulfill one additional unit of final demand without considering international sourcing of intermediates:

$$L = (I - A^{D})^{-1}.$$

From the perspective of user, gross output X can be split according to destination.

$$X = AX + Y^D + Y^R + Y^F \quad (1)$$

Where A accounts only for intrarregional intermediate inputs. Y^Daccounts for domestic final demand, Y^R accounts for intrarregional final demand and Y^Fincludes both intermediate and final demand from countries out of matrix. Note that intermediate exports to extra-zone will be treated as final demand. For simplification, all foreign countries are treated as one: $Y^{sF} = \sum_h^H Y^{sh}$.

From the perspective of the sources of value in production, output is produced according to a function of production that includes domestic and regional inputs included in Z, foreign inputs included in $\tilde{Z}$ and value-added:

$$X^T = u\hat{X} = uZ + w\tilde{Z} + \tilde{V} = A\hat{X} + wA^X\hat{X} + \tilde{V} = uA\hat{X} + F\hat{X} + V\hat{X} \quad (2)$$

Where u and w are 1xNG and 1xNH vectors of ones, $F = wA^X$ is a 1xNG vector containing the sum of extra-regional inputs included in one unit of production and $A^X$is an NHxNG matrix containing ratios of use of foreign intermediates as a share of production $A^X = \tilde{Z}\hat{X}^{-1}$. $\tilde{Z}$ is the NHxNG matrix of foreign use of intermediates. Post-multiplying by $\hat{X}^{-1}$ we get the partition of sources of value:

$$u = uA + F + V = F(I - A)^{-1} + V(I - A)^{-1} = FB + VB = u\hat{F}B + u\hat{V}B \quad (3)$$

There is a key assumption that must be made to adapt world-level definitions to an incomplete set of information: Exports to extra zone must be treated as being only in final goods. Although this does not seem very realistic, the only important issue is to assure that there is no regional value-added returned to the region embedded in intermediates. Therefore, all exports to extra zone are consumed abroad so there is no regional or domestic value-added in foreign inputs. While in some big and open trading blocs it seems unreasonable, in another remoter, small sized and closed ones the assumption does not seems so unrealistic. In their application of Koopman, Wang and Wei (2014) in South America, Banacloche, Cadarso, and Monsalve (2020) also consider this limitation.

The second innovation is the fact that there is foreign supply of inputs. Then, the production in a country s will involve domestic value-added, value-added generated in a regional partner (V^r, V^t) and foreign content included in foreign inputs (F). Note that as long as there is not a complete foreign input-output table, it cannot distinguish between foreign value-added and foreign double-content. Therefore, I will refer to that as foreign content (including both genuine value-added and double content) instead of foreign value-added[2].

Borin and Mancini (2019) show that it would be useful to define a matrix of intermediates that excludes the international trade of intermediates sourced in s ($A^{st} = 0 \; \forall t \neq s$):

$$A_s = \begin{bmatrix} A^{11} & A^{12} & \dots & A^{1s} & \dots & A^{1G} \\ A^{21} & A^{22} & \dots & A^{2s} & \dots & A^{2G} \\ \dots & \dots & \ddots & \dots & \dots & \vdots \\ 0 & 0 & 0 & A^{ss} & \cdots & 0 \\ \dots & \dots & \dots & \dots & \ddots & \vdots \\ A^{G1} & A^{G2} & \dots & A^{Gs} & \dots & A^{GG} \end{bmatrix}.$$

The inverse of this matrix is: $B_s = (I - A_s)^{-1}$.

Borin and Mancini (2019) shows that International Leontief Inverse Matrix B can be expressed as the addition of two matrices, being the first B_s and the complement the interaction of complete

[2] Banacloche et al. (2020) name this input as imported content, in order to show that it could also have domestic or regional content.

and incomplete matrix ($B = B_s + B_s A_s B$). For country s as user, this relationship can be expressed separately for country s sourcing itself and the rest (t):

$$B^{ss} = L^{ss} + L^{ss} \sum_{u \neq s}^{G} A^{su} B^{us} \quad (4)$$

$$B^{ts} = B_s^{ts} + B_s^{ts} \sum_{t \neq s}^{G} A^{su} B^{us} \quad (5)$$

It can be showed that $L^{ss} = B_s^{ss}$, that is, (4) is a particular case of (5) when s=t. While (4) is of general use in literature (Koopman, Wang, and Wei 2014; Wang et al. 2017b; Wang, Wei, and Zhu 2018), Equation (5) is key in the hypothetical extraction strand of literature (Miroudot and Ye 2018; Los, Timmer, and de Vries 2016; Los and Timmer 2020).

Equation (4) split total effects of demand of s in production of s in pure domestic and international induced effects. The second term of (4) accounts for the effects originated in s and affecting s not directly through domestic linkages but indirectly through linkages that s has with other countries that in turn depends on s. Equation (5) splits relationship between production and demand in s and t in a similar way: B_s^{ts} accounts for effects of demand in s on production in t without considering the requirements of inputs sourced in s that sectors in t could have. B_s^{ts} assures that the effect of demand in s in production in t does not contain value-added in s induced by international trade. The complement is the effect of demand in s that t faces that includes some stages of production in s.

ii. A new source-based decomposition of bilateral exports using Regional Input-output Tables

Borin and Mancini (2019) define the Directly Absorbed Value-added in Trade as:

$$DAVAX^{sr} = V^s L^{ss} Y^{sr} + V^s L^{ss} A^{sr} L^{rr} Y^{rr} \quad (6)$$

This is the measure of the trade from s to r that only crosses one border. It correspond to value-added sourced in exporting country s and directly sent to r, both for direct consumption ($DAVAX\_fin^{sr} = V^s L^{ss} Y^{sr}$) or as intermediate but transformed and directly consumed in destination ($DAVAX\_int^{sr} = V^s L^{ss} A^{sr} L^{rr} Y^{rr}$).

$DAVAX^{sr}$ is at the core of the GVC participation ratio used in the 2020 World Development Report (World Bank 2019) at a country level. In fact, this index is defined as the difference between gross exports and $DAVAX$. So, $GVCX^s = uE^{s*} - DAVAX^{s*}$. As long as some authors include $DAVAX\_int^{sr}$ as a measure of "simple" participation in GVC (Wang et al. 2017b), the point is still matter of controversy. Nevertheless, this discussion does not affect our benchmark.

Following Borin and Mancini (2019), we will divide overall participation in regional value chains in backward and forward. Forward participation is the value-added sourced in s that is not consumed directly in r, so is included in its exports. Backward participation is the domestic, regional and foreign value-added and double counted flows included in the imported inputs that s uses in their exports to r. As Borin and Mancini (2019) note, this concept is exactly the same as (Hummels, Ishii, and Yi 2001) pioneering definition of Vertical Share and differs from Koopman, Wang, and Wei (2014) and Wang, Wei, and Zhu (2018).

Then, gross exports will be divided according to four terms. The two first are defined in (7), the third are forward linkages and the fourth are backward linkages:

$$E^{sr} = DAVAX\_fin^{sr} + DAVAX\_int^{sr} + RVC\_fwd^{sr} + RVC\_bwd^{sr} \quad (7)$$

Borin and Mancini (2019) shows that domestic value-added in exports is the sum of the three first terms and defines the global value chains trade as the sum of the last two. For descriptive purposes, it is useful to divide both Forward and Backward terms.

RVC_fwd^{sr} is divided according to where value-added is finally consumed. A convenient division is the importer country (DVA_p^{sr}), another regional partner (DVA_reg^{sr}), the country of origin (RDV^{sr}) and, for data with incomplete input out tables, extra-zone markets (DVA_for^{sr}):

$$RVC\_fwd^{sr} = DVA\_p^{sr} + DVA\_reg^{sr} + RDV^{sr} + DVA\_for^{sr} \quad (8)$$

DVA_p^{sr} represents the value-added sourced in s and directly exported by it, transformed in r, reexported to another regional country (labeled t) and finally consumed in r. Note that it includes some kind of back-and-forth trade from r to t.

DVA_reg^{sr} represents the value-added sourced in s, transformed in r and finally consumed in a third country. Al least two regional countries participate in production. Note that this flow is forward linkages in the relationship between s and r but is backward linkages in the relationship between r and t.

RDV^{sr} is value-added exported from s to r but finally consumed in s. This term, defined as Reflecting Trade by Daudin, Rifflart, and Schweisguth (2011) and Koopman, Wang, and Wei (2014), does not belong to "Value-added in Exports" concept defined firstly by Johnson and Noguera (2012), because it is not consumed abroad.

DVA_for^{sr} is value-added sourced in s, transformed in r and exported to extra-zone by r or another regional country. As long as we assume that foreign inputs do not contain regional value, this flow is consumed in extra-zone. This flow is regional trade induced by foreign demand and reflects the fact that, even if we are analyzing regional trade, foreign demand should be considered in the framework (Banacloche, Cadarso, and Monsalve 2020). This term arises as a consequence of working with regional instead of global complete input-output tables.

Backward linkages have a different nature than forward and thus the split follows a distinct interpretation. Nevertheless, the aggrupation according to source of value follows the same logic. Backward linkages are divided in Domestic sourced Double Counted term, bilateral value-added, regional value-added, regional double counted and foreign content.

$$RVC\_bwd^{sr} = DDC^{sr} + BVA^{sr} + RVA^{sr} + RDC^{sr} + FC^{sr} \quad (9)$$

Domestic double-content (DDC^{sr}) is value-added sourced by s but in previous stages of production, that is, it enters in this flow included in imported inputs that s makes from regional countries (remember that there is no regional value-added in extra zone inputs).

BVA^{sr} and RVA^{sr} are partner and other regional value-added included in s exports. The source-based method assures that this value-added do not contains any stage in s. RDC^{sr} is regional (including partner) double counted flow. It arises from the fact that some foreign value-added could already have been counted in other intermediates exports from s to a regional partner and then finally included in exports from s to r.

Another source of value in gross regional exports is foreign input used in production (FC^{sr}). It could be included directly by s or indirectly by a partner through regional intermediates used by s (see DFC and RFC in table below). From the perspective of the identification of backward linkages there is not much relevancy in distinguishing both kinds of flows, except if estimation of foreign content is done at overall regional exports. In that case just direct term should be counted and indirect is redundant, given that it is already included in another flow. Table 2 includes the definition of each term.

Table 2. A source- based Bilateral decomposition of gross exports from s to r with regional input- output tables

Term	Subterm	Formula
$DAVAX_{fin}$	---	$(V^sL^{ss})^T \# Y^{sr}$
$DAVAX_{int}$	---	$(V^sL^{ss})^T \# (A^{sr}L^{rr}Y^{rr})$
RVC_fwd	DVA_p (1)	$(V^sL^{ss})^T \# (A^{sr}(B^{rr}-L^{rr})Y^{rr})$
	DVA_p (2)	$(V^sL^{ss})^T \# \left(A^{sr}\sum_{t\neq s,r}^{G} B^{rt}Y^{tr}\right)$
	DVA_reg (1)	$(V^sL^{ss})^T \# \left(A^{sr}\sum_{t\neq s,r}^{G} B^{rt}Y^{tt}\right)$
	DVA_reg (2)	$(V^sL^{ss})^T \# \left(A^{sr}\sum_{t}^{G} B^{rt}\sum_{u\neq s,r,t}^{G} Y^{tu}\right)$
	DVA_for	$(V^sL^{ss})^T \# \left(A^{sr}\sum_{t}^{G} B^{rt}\sum_{t}\sum_{h}^{H} Y^{th}\right)$
	RDV	$(V^sL^{ss})^T \# \left(A^{sr}\sum_{t}^{G} B^{rt}Y^{ts}\right)$
RVC_bwd	DDC	$\left(V^sL^{ss}\sum_{t\neq s}^{G} A^{st}B^{ts}\right)^T \# E^{sr}$
	BVA	$(V^rB_s^{rs})^T \# E^{sr}$
	RVA	$\left(\sum_{t\neq s,r}^{G} V^tB_s^{ts}\right)^T \# E^{sr}$
	RDC	$\left(\sum_{t\neq s}^{G} V^tB_s^{ts}\sum_{u\neq s}^{G} A^{su}B^{us}\right)^T \# E^{sr}$
	DFC	$(F^sL^{ss})^T \# E^{sr}$
	RFC	$\left[\left(F^sL^{ss}\sum_{t\neq s}^{G} A^{st}B^{ts}\right)^T + \left(\sum_{t\neq s}^{G} F^tB^{ts}\right)\right] \# E^{sr}$

Source: Own Elaboration

Appendix A shows the demonstration of decomposition. The steps include dividing gross exports according to the source of value (using Eq. (3)). While domestic value-added is divided according to final consumption place (using eq (1) and regarding direct consumption and other flows), no-domestic value is divided according to the source of value and the way it enters in s production (directly or indirectly). Also, the relationships between B and L stated in Eq (4) and between B and B_s stated in Eq (5) are used for the purpose of split Domestic and Foreign Content respectively in Value-added and Double Counted terms.

iii. Conceptual discussion in measuring value-added in gross exports and their incidence in regional analysis

Despite being a reference in the literature, Koopman, Wang, and Wei (2014) gained several critics in last years. Johnson (2018) highlights that there is inconsistency in Koopman, Wang and Wei (2014) because intermediate goods are contained both in exports and in production used to fulfill exports. He argues that if they are measured in exports, they should be extracted from input requirement matrix for production. By doing so (working with a matrix that extracts A^{sr} from A) one can track from exports to output and then from output to value-added. Despite being done for Koopman, Wang and Wei (2014) decomposition, this comment applies also for WWZ. Borin and Mancini (2019) classify all decompositions according to the treatment of this issue: they find that Johnson (2018), Los, Timmer, and de Vries (2016), Los and Timmer (2020), Miroudot and Ye (2018) and themselves account for a correct treatment of possible endogeneity of intermediate in exports and that Koopman, Wang, and Wei (2014), WWZ and Nagengast and Stehrer (2016) override this problem.

Los and Timmer (2020) argues that WWZ decomposition is mathematically valid but arbitrary because it lacks an economic model behind the choosing of accounting segregation. More important, they criticize the fact that the sum of value-added in exports of WWZ bilateral decomposition over all countries is equal to overall value-added in exports. This value-added is included in doubled counting term, but it should be included in bilateral relationship. Interestingly, Los and Timmer (2020) argue that the difference between the sum of bilateral value-added in exports (according to their method exposed there and also in Los, Timmer and de Vries (2016)) and overall value-added in exports is a measure of the importance of *loops* and so a measure of WWZ bias. From selection of biggest countries and using WIOD for 2014, they find that Germany has the largest double counting of VAX (1,8%) and Australia and Brazil the lowest (0,1%).

A more complete analysis of Koopman, Wang, and Wei (2014) (and by extension of WWZ) method is done by Borin and Mancini (2015; 2019). First, as Los and Timmer (2020) and WWZ, they state that there is no such thing as a unique method to account for value-added in disaggregated trade flows, so each empirical question has to address the proper measure. The concept of value-added and foreign content must be precisely defined in each exercise. They argue that the boundaries must be defined at the proper level, being the whole country, a bilateral relationship or even a bilateral sectoral one. The specific sectoral bilateral relationship is the relevant perimeter, and only the items that enter multiple times in this trade flow should be considered as double counted. Note that Koopman, Wang and Wei (2014) and WWZ have a broader concept of double counted, especially in the foreign content split in foreign value and double counted. They consider as double counted all the trade that crosses foreign borders many times, even if it is not the border of the country of reference. Miroudot and Ye (2018) develops a framework based in hypothetical extraction method consistent with Los, Timmer, and de Vries (2016) an apply it to WIOD 2014, finding systematic difference –in both directions- with Koopman, Wang and Wei (2014) method.

The second critic is that in Koopman, Wang and Wei (2014) there is an arbitrary and inconsistent selection of when a cross border is value-added and when is double counted. Given that in the value-added sourced in *s* and included in final demand in *r* there could be several countries participating as intermediate producers, it should be clear the border of reference used to define both value-added and double counted (Nagengast and Stehrer 2016). Two extreme cases are presented in the literature: the source- based and the sink- based approaches. In the source- based approach the value-added is recorded as closely as possible to the moment when it is produced. Every cross border beyond the first is double counted. As an example, using (4) the value-added of *s* in final exports to r, $V^s B^{ss} y^{sr}$, can be split in $V^s L^{ss} y^{sr} + V^s L^{ss} \sum_{t\neq s}^{G} A^{st} B^{ts} y^{sr}$, where the first term is source-based value-added and the second is source-based double counting. In the sink-based approach the value-added is recorded as closely as possible to the moment where it is ultimately absorbed in the production of final goods. Following the same example, the value-added of s in final exports to r is totally value-added $V^s B^{ss} y^{sr} + 0$, because there is no further transformation after leaving *s* country by last time. Borin and Mancini (2019) points that Koopman, Wang and Wei (2014) and WWZ split domestic content of exports with a mixed approach, treating final exports with sink- based and intermediate exports with source- based approach. Table 3 shows an example of both methods for Domestic Content of Exports ($V^s B^{ss} E^{sr} = V^s B^{ss} y^{sr} + V^s B^{ss} A^{sr} X^r$).

Table 3. Sink and source-based method of decomposition of gross exports: an example

Type of good	Term	Source- based		Sink- based	
		Value-added	Double Counted	Value-added	Double Counted
Final	$V^s B^{ss} y^{sr}$	$V^s L^{ss} y^{sr}$	$V^s L^{ss} \sum_{t \neq s}^{G} A^{st} B^{ts} y^{sr}$	$V^s B^{ss} y^{sr}$	0
Inter-mediate	$V^s B^{ss} A^{sr} X^r$	$V^s L^{ss} A^{sr} X^r$	$V^s L^{ss} \sum_{t \neq s}^{G} A^{st} B^{ts} A^{sr} X^r$	$V^s B^{ss} A^{sr} L^{rr} X_r^{(\to sY*)}$	$V^s B^{ss} A^{sr} L^{rr} B_{rs}^{s} E^{s*}$

Source: Own elaboration based on (Borin and Mancini 2019)

Where: $X_j^{(\to sY*)} = y^{rr} + \sum_{r \neq t}^{G} y^{rt} + \sum_{r \neq t}^{G} A^{rt} \left(\sum_{u \neq s}^{G} \sum_{v}^{G} B_{tu}^{s} y^{uv} + B_{ts}^{s} y^{ss} \right)$, captures all production of *r* that is not used in exports of *s*.

WWZ methodology follows as closely as possible the Koopman, Wang and Wei (2014) method and philosophy. The unique difference is that WWZ allocate the entire pure double counted as vertical share measure, instead of excluding the domestic part of double counting as Koopman, Wang and Wei (2014) do. By following so closely that reference, WWZ main decomposition do not have a clear-cut interpretation, as it pointed in the references cited above. In the revised version of the original paper, the authors include as Appendix D an alternative decomposition that departs somewhat from Koopman, Wang and Wei (2014) and is more consistent (though not completely) with a source- based criteria, at least in the splitting of domestic content.

Despite having some comparison between several methods,[3] there is not a direct algebraic nor quantitative assessment between WWZ and Borin and Mancini (henceforth B&M) source-based decomposition. Figure 1 and 2 depict the logic of both decomposition and the aggrupation of terms in broad categories. While Borin and Mancini (2019) goes directly to tracking previous flows of value in sourcing country, WWZ are primary interested in tackling possible use of value redundantly in destination. Table B1 in Appendix B compares algebraically both methodologies, grouping term by term.

[3] See Appendix C of Borin and Mancini (2015) for a comparison between their source-based method and Koopman, Wang and Wei and Section 5.1 of Borin and Mancini (2019) for an perspective- based classification of alternative methods.

Figure 1. A Source-Based decomposition of Bilateral Exports with regional input-output tables.

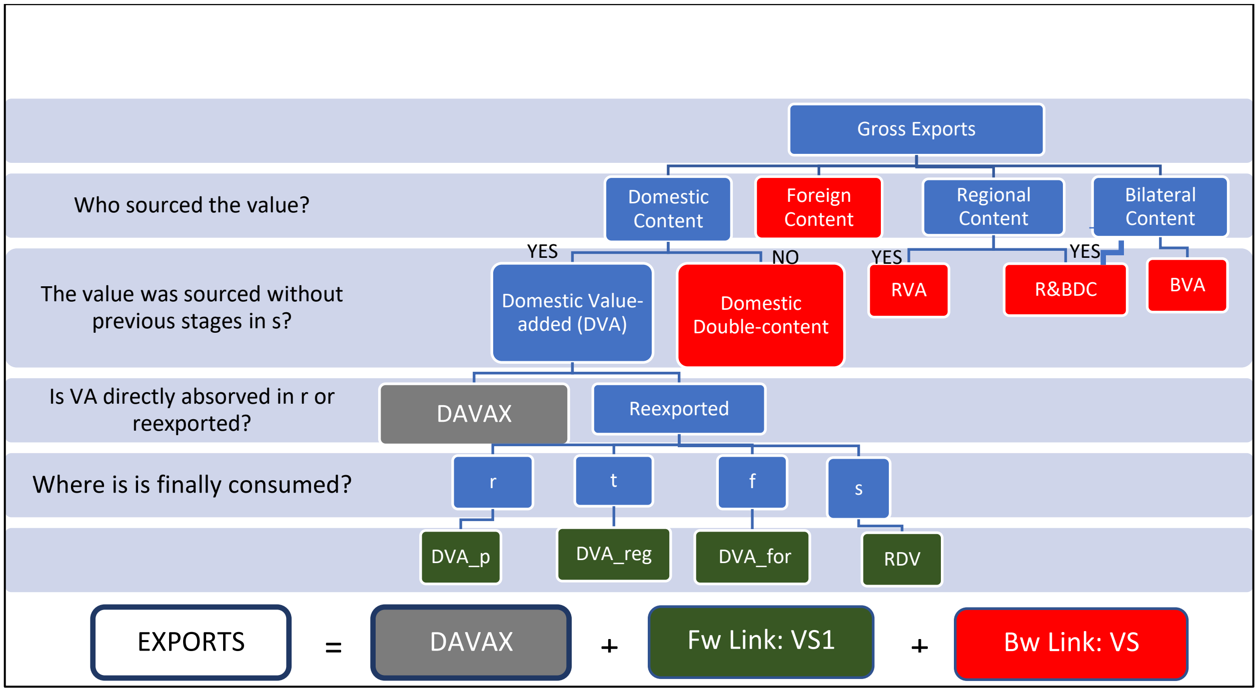


Figure 2. A Wang, Wei and Zhu (2018) based decomposition of Bilateral Exports with regional input-output tables.

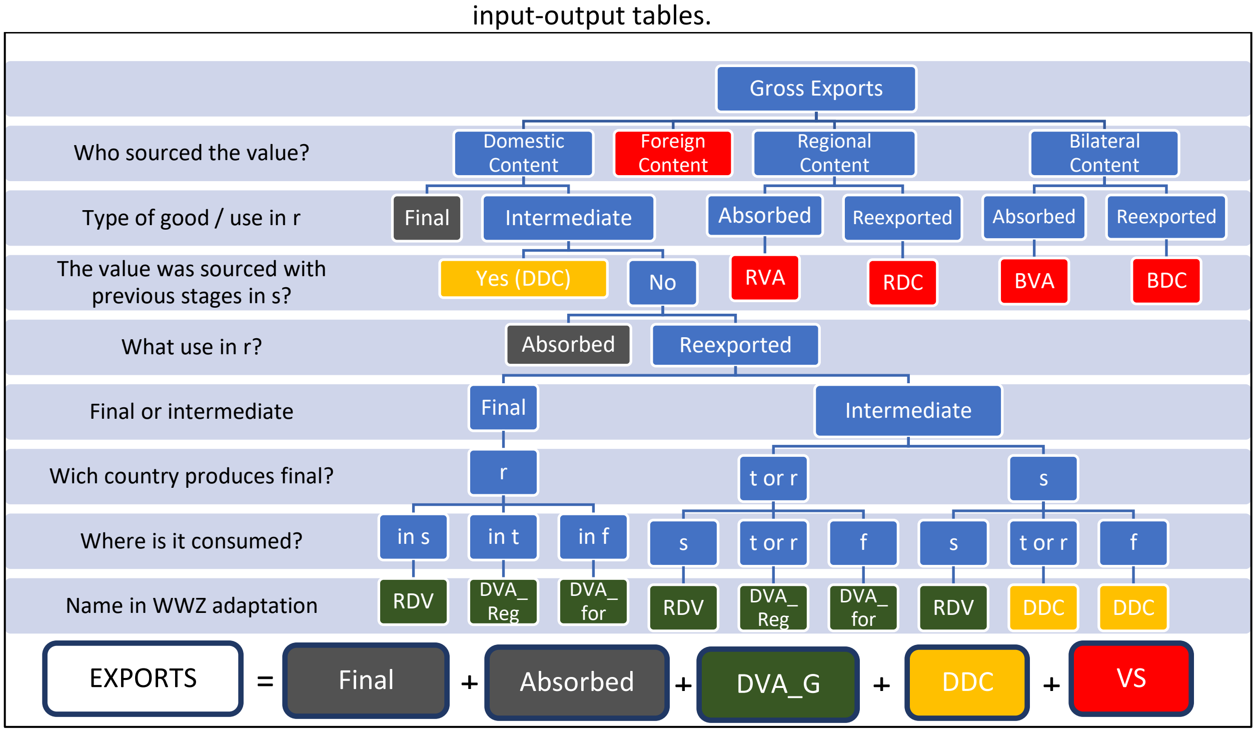


Table B1 in Appendix shows that the relevant differences among two methods rely on the value-added included in final goods, in the terms accounting for Domestic Doble Counting and in the measures in Bilateral and Regional Value-added (BVA, RVA) and Regional Double Counted (RDC).

The difference between the first term according to B&M source-based decomposition ($DAVAX_{fin}$) and Value-added included in final good accord to WWZ is:

$$Dif1:\ (V^s B^{ss})^T \# Y^{sr} - DAVAX_{fin} = \left(V^s L^{ss} \sum_{t \neq s}^{G} A^{st} B^{ts} \right)^T \# (Y^{sr})$$

This value is part of DDC in the decomposition followed in this paper and can be named: "Indirect domestic value-added included in exports of final goods". This value corresponds to domestic value-added included in foreign intermediates used by domestic country in final good exports. So WWZ only counts as double just the share that is used in intermediates. But some intermediates are directly consumed at destination an so they should receive the same treatment as if they were final goods. This is the inconsistency that some authors point at WWZ decomposition, as pointed above. $Dif1$ is Domestic Value-added in WWZ but not in B&M source-based approach. Note that if we apply B&M sink-based approach the difference with WWZ arise in the treatment of intermediates instead of final. While "indirect domestic value-added in exports of final goods" will be both counted as value-added, WWZ will label as double counted a part of intermediates that should also be treated as value-added. That is why Borin and Mancini (2019) asserts that WWZ uses a "mixed" (either source nor sink) approach for Domestic Content.

The second difference arises in the treatment of Forward Linkages. While B&M considers also the Direct Domestic value-added in intermediate goods re-imported by source country and further reexported, WWZ excludes this flow from DVA and treats it as a portion of Double Counting.

$$Dif2: DVA_{reg\_2}^{B\&M} + DVA_{for\_2}^{B\&M} - (DVA_{reg_2}^{WWZ} + DVA_{for_2}^{WWZ}) = (V^s L^{ss})^T \\ \# \left(A^{sr} B^{rs} \sum_{t \neq s}^{G} Y^{st} + A^{sr} B^{rs} \sum_{h}^{H} Y^{sh} \right)$$

As a consequence, both methodologies measure Domestic Value-added in Other Countries Exports in a different way and so propose alternative measures of Hummels, Ishii, and Yi (2001) concept of Forward Vertical Specialization (VS1). B&M label this flow as Forward Linkages and WWZ as DVA_G.

The third main difference among techniques is the split of bilateral and regional value-added and double-content terms. In both methods the sum of regional, bilateral, and double counted terms gives the same value:

$$\left(\sum_{t \neq s}^{G} V^t B^{ts} \right)^T \# (E^{sr})$$

Nevertheless, there are differences in the definition of each term.

Table 4 shows the differences. For simplicity, BVA and RVA are consolidated.[4]

[4] Using $\sum_{t \neq r,s}^{G} V^t B^{ts} + V^r B^{rs} = \sum_{t \neq s}^{G} V^t B^{ts}$

Table 4. Bilateral and Regional Content decomposition. Bilateral, Regional and Double Counted Value according to B&M and WWZ

BVA, RVA and RDC	B&M	WWZ
$\left(\sum_{t\neq s,r}^{G} V^t B_s^{ts}\right)^T \# (Y^{sr} + A^{sr}L^{rr}Y^{rr})$	BVA and RVA	BVA and RVA
$\left(\sum_{t\neq s,r}^{G} V^t B_s^{ts}\right)^T \# (A^{sr}L^{rr}E^{r*})$	BVA and RVA	RDC
$\left(\sum_{t\neq s}^{G} V^t B_s^{ts} \sum_{u\neq s}^{G} A^{su}B^{us}\right) \# (Y^{sr} + A^{sr}L^{rr}Y^{rr})$	RDC	BVA and RVA
$\left(\sum_{t\neq s}^{G} V^t B_s^{ts} \sum_{u\neq s}^{G} A^{su}B^{us}\right) \# (A^{sr}L^{rr}E^{r*})$	RDC	RDC

Source: Own Elaboration

The first term captures the foreign value that does not contain any stage of production in *s* before being effectively used in *s* in his exports to *r* and that is directly consumed there. Last term includes foreign value that already had had a stage of production in *s* before being reimported again by *s* and used in their exports to *r* but are in turn reexported by *r*. This term, almost negligible, is considered double counted in both methods. The second and third term contain the differences among methods. B&M consider as double counted only the foreign value that is effectively used more than once by *s*, and they do not care about the use that *r* does of this value. WWZ consider as double counted the foreign value that country s includes in its exports and that country *r* will in turn include in its own exports. In conclusion, B&M try to identify a loop in production in s and WWZ try to assess the multiple crossing of intermediates in a more general way. Section III.iii shows that WWZ method give rise to a bigger share of double counting in foreign content. Also, in their method double counting is more prevalent in countries that exports to another exporters. In turn, in B&M method double counting is a producer issue.

III. Tracing regional value chains in the bilateral trade in South America

i. General results: following the value-added and foreign content

Our decomposition of regional trade on a bilateral basis is applied to the versions 2005 and 2011 of the ECLAC input-output tables. Details of this matrix can be founded in CEPAL (2016).[5] Appendix C lists the 40 sectors.

Table 5 show the aggregated results for each country as exporter. In 2011, 82% of total regional exports are value-added directly included in the sourcing country (VAX in Johnson and Noguera (2012) definition), while 18% is Backward integration in global value chains ($BwLE$). This ratio ranks

[5] The matrix can be downloaded in https://www.cepal.org/sites/default/files/events/files/matrizlatina2011_compressed_0.xlsx

from 12% for Venezuela to 25% for Chile and Bolivia. Half of the value-added directly included by exporter is included in intermediates than are consumed directly in country of destination ($DAVAX_{int}$). This -in the terminology of (Wang et al. 2017b)- Single Regional Value Chain is pervasive in Bolivian and Venezuelan regional exports, which rely heavily in mineral products.

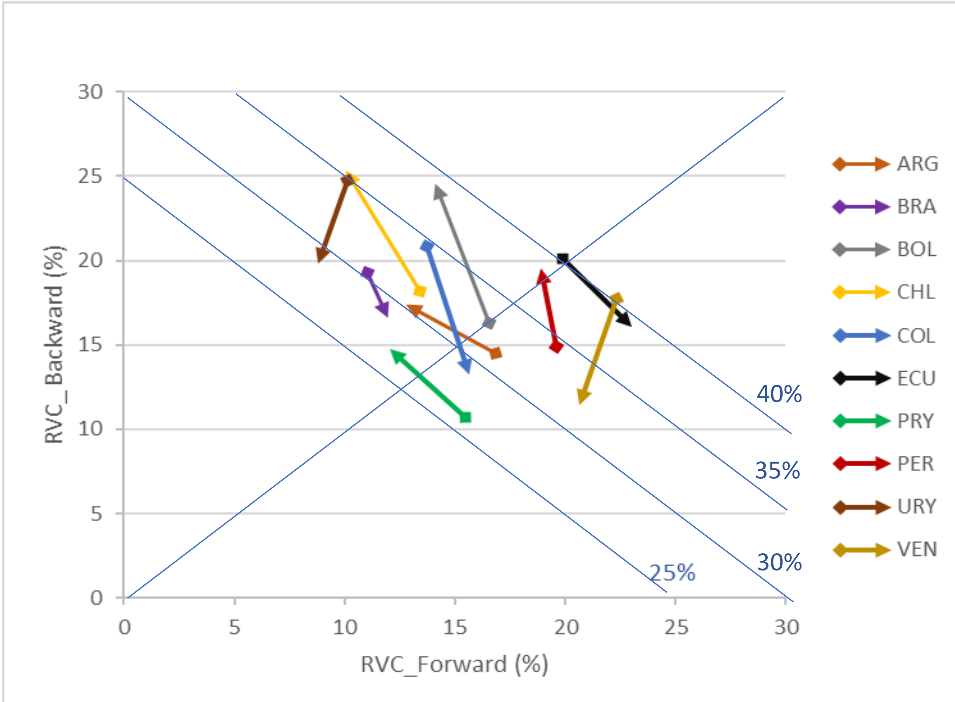
Domestic Value-added in Final goods ($DAVAX_{fin}$) is important for Brazil and Paraguay regional exports. In both countries a third of total regional exports rely in this concept. 13% of total regional exports is value-added originated in the exporting country not directly consumed in importing country but reexported anywhere ($FwLE$). Table C2 in Appendix show the same estimation for 2005. In the period, $DAVAX_{fin}$ globally declined by 5 percentage points and $DAVAX_{int}$ raised, while Forward linkages declined by 1 percentage points and Backward remained nearly unchanged. Decline in $DAVAX_{fin}$was especially important in Chile, Bolivia, Colombia and Uruguay. While in Bolivia and Chile they were partially compensated by rise in Backward and $DAVAX_{int}$, in Colombia and Uruguay Backward also declined and the compensation is due to $DAVAX_{int}$.

Table 5. **Accounting segregation of South America intra zone trade. In million dollars and percentages. 2011**

	Regional exports	Share of Value-added in Exports (in %)			Share of Foreign and double counted
		$DAVAX_{fin}$	$DAVAX_{int}$	$FwLE$	$BwLE$
Argentina	35,966	26	43	13	17
Brazil	53,742	35	36	12	17
Bolivia	7,394	5	57	14	25
Chile	16,898	27	37	10	25
Colombia	12,907	19	52	16	13
Ecuador	7,514	19	42	23	16
Paraguay	4,238	34	39	12	15
Peru	9,616	25	36	19	20
Uruguay	5,620	21	50	9	20
Venezuela	6,290	1	67	21	11
TOTAL	**160,185**	**27**	**42**	**13**	**18**

Source: Own elaboration

Figure 3. **RVC participation by type. Evolution 2005-2011. In % of gross exports to region.**

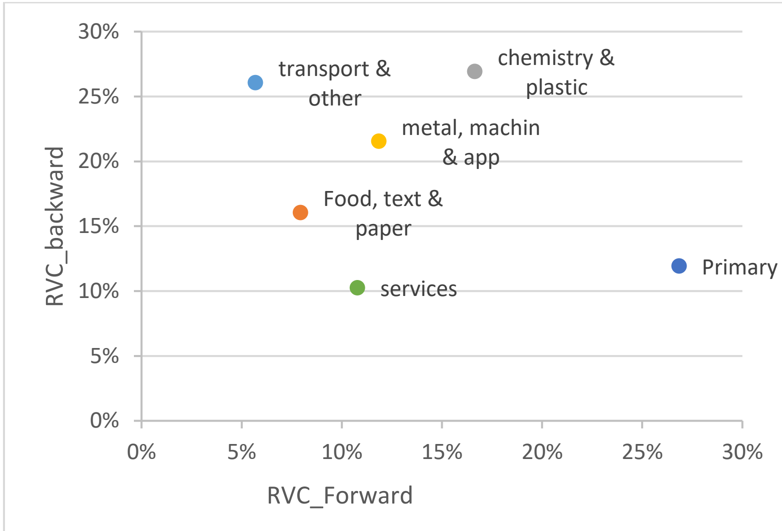


Source: Own Elaboration

Figure 3 summarizes the participation of regional value chains in regional trade by exporting country and shows the change in time. The starting dot of the arrow is 2005 and the end is 2011. Countries above the 45 degrees line have more backward participation and countries below are more forward. All countries have a RVC total share that ranks between 25% and 40%. Figure shows that Ecuador, Perú, Bolivia and Venezuela are the countries where RVC terms are higher but, except in Bolivia, in these countries regional trade is less relevant. Chile and Uruguay are the more backward biased countries and Paraguay is the country with less participation in the period. Argentina and Brazil, the biggest participants in regional trade tend to have a similar backward biased participation. Given that they trade manufacturing goods in the region, it should be expected more backward share, but results shows that these closed economies tend to incorporate little foreign content in exports.

It could be argued that the low level of values capturing RVC trade is due to aggregation effect, where primary and agriculture- based industry products prevail in trade. Nevertheless, Figure 4 shows that results for industry are not conclusively different from aggregated ones. Therefore, GVC trade in South America is scarce even in manufacturing products. In chemistry and plastic sectors, total Forward and Backward linkages account for 44% of exports, and in Transport Equipment industry they account for 32% of exports.

Figure 4. **GVC participation in regional South American trade, by exporting sector. Year 2011. In million dollars.**

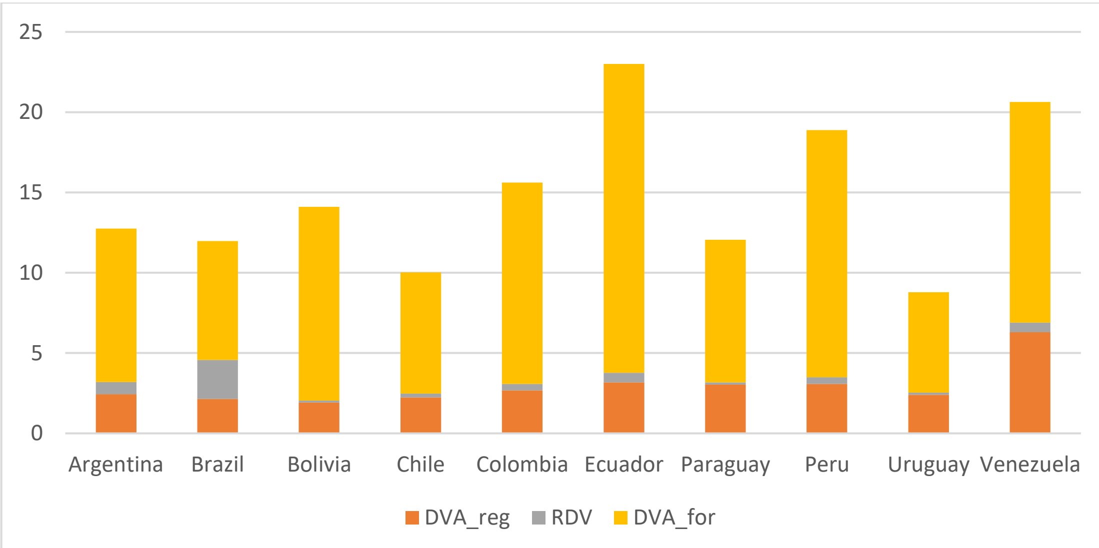


Source: Own elaboration

For the global value chain analysis, it is useful to focus on the nature of Forward and Backward Linkages of exports and imports. Table 2 showed the decomposition of both flows. While Forward linkages can be divided according to the final consumption of the value, for backward linkages it is relevant the source of value. In this paper, both flows are divided according to the exporter, the importer, third regional countries, and extra-zone. Also, for Backward Linkages genuine value-added must be divided from double counted.

Figure 5 shows that Extra-regional demand is the main important source of forward linkages in region. 10 out of 13 percentage points of total forward linkages are induced by extra-zona demand, showing the importance on global trade for South American internal trade. In Ecuador, 19% of regional exports are induced by foreign demand of regional partners. The second term in importance is third country demand, except for Brazil where its own demand accounts for 2,4% of its regional exports.

Figure 5. **Forward Linkages divided according to final consumption as shares of total regional exports by Country**

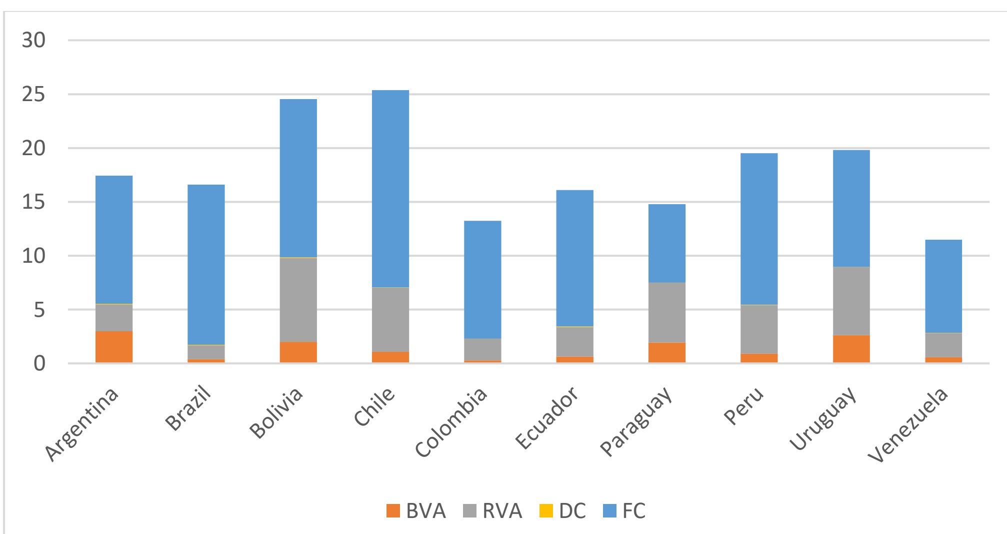


Note: *DVA_reg*: Value consumed in the region (includes DVA_p); *RDV*: value consumed in exporting country; *DVA_for*: Value exported to extra-zone. See table B2 in Appendix for a formal definition.

Source: Own elaboration

Figure 6 shows a similar picture in the case of Backward Linkages: 14% of total Backward Linkages are included in inputs sourced in extra-regional countries.

Figure 6. **Backward Linkages divided according to sourcing of value as shares of total regional exports by Country**

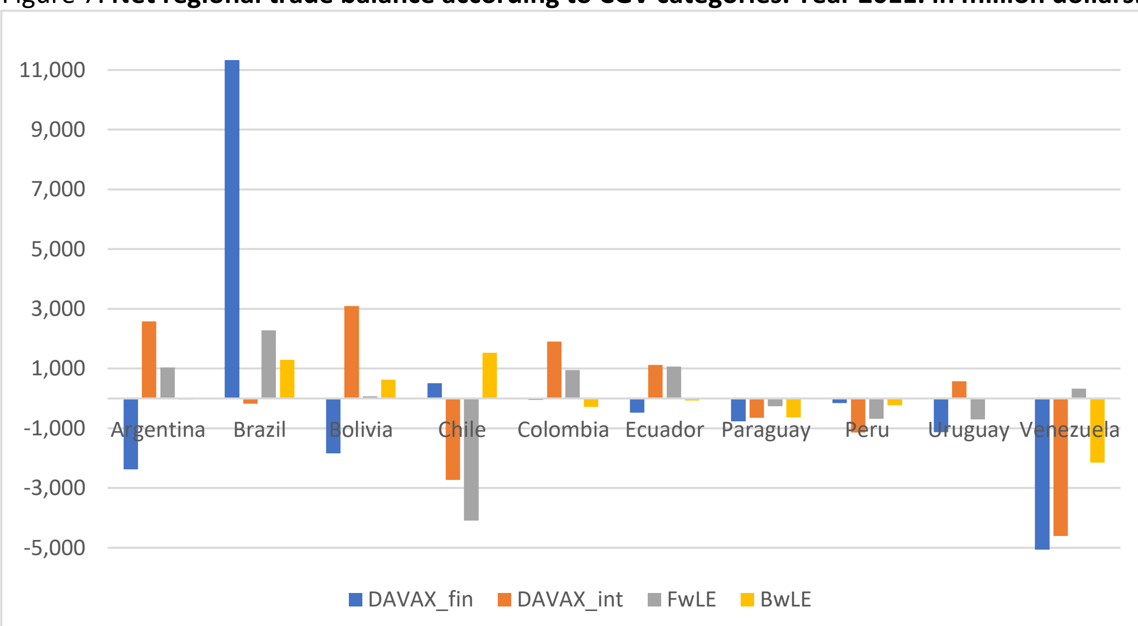


Note: *BVA*: Value-added originated in importing country; RVA Value-added originated in a third country of the region; *DC*: Double counted terms (domestic and region); *RDFC* Foreign Content. See table B2 in Appendix for a formal definition.

Source: Own elaboration

A useful property of the bilateral decomposition method is that it enables a comparison between the position of the country as exporter and its position as importer, giving rise to a GVC meaningful interpretation of balance of trade. Figure 7 decomposes the regional trade balance (export minus imports) according to the kind of trade considered. Argentina is a net importer and consumer of regional value-added directly embedded in final goods, mostly by their relationship with Brazil, which accounts for a huge surplus in value-added in final goods in the region. Venezuela, Bolivia and Uruguay (these two in relative terms) are important destinations of value-added exports in final goods. The picture is very different when trade of intermediates directly consumed in destination is considered ($DAVAX_{int}$). This is the unique flow where Brazil does not hold surplus, basically due to imports of gas from Bolivia. Argentina and Colombia are also net exporters of valued added in intermediates directly consumed by importer and Chile and Venezuela are net importers. A comparison with 2005 (Appendix) shows that Argentina worsened the trade deficit in the period, switching from a balanced position in value-added in final goods to a deficit and reducing the surplus position in intermediates. While Brazil was the sole net exporter of foreign value-added in 2005, six years later it shares this position with Chile.

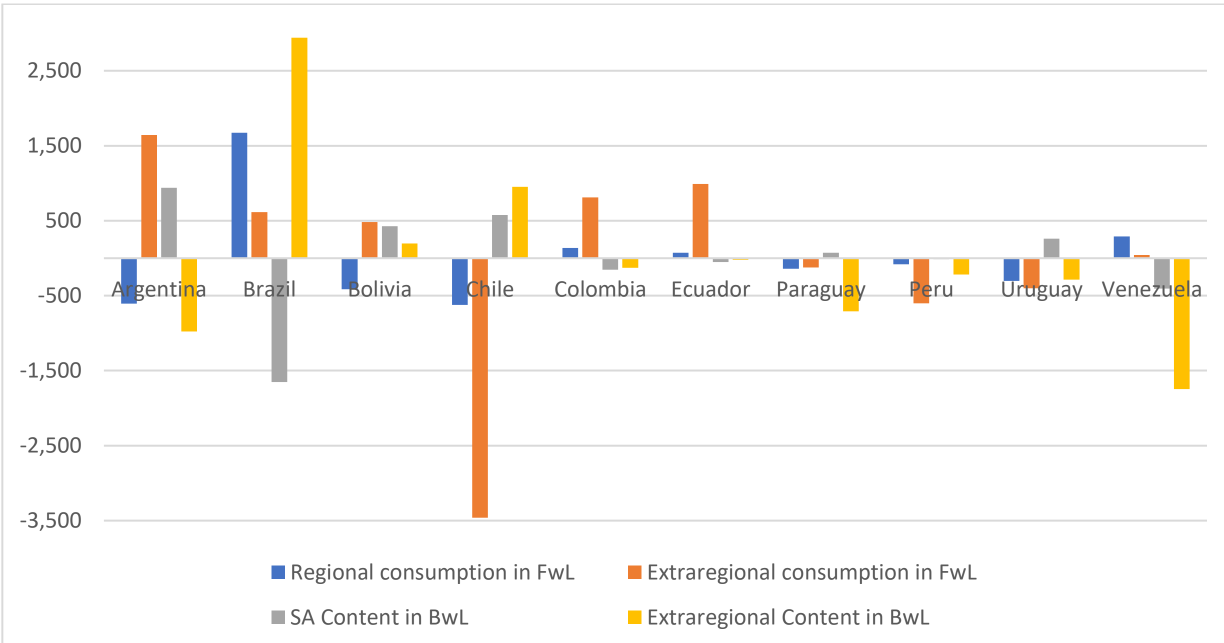
Figure 7. **Net regional trade balance according to CGV categories. Year 2011. in million dollars.**



Source: Own elaboration

The trade balance perspective is useful also for analyzing the net participation of countries in Regional Value Chains. Figure 8 should be interpreted carefully. In the forward linkages, a positive net value means that a country participates more as a source of value than as a platform (first importer, second exporter), that is, the value-added of a country is used in exports of another regional partner. A negative value in net forward linkage means that this country is positioned as platform of regional value. In the backward linkages, countries with net positive flow are platforms for regional or foreign value and countries with net negative flow are receivers of this value.

Figure 8. **Net participation of countries in Backward and Forward Linkages according to region of sourcing and destination**



Source: Own elaboration

The net negative value of Chile in extra-regional consumption in Forward Linkages is outstanding. Chile outperform in this flow due to it linkages with Asian and North American markets. In its foreign exports Chile carries value-added from Argentina, Brazil and Ecuador. Brazil is the main source of regional value-added that circulates in South America. In the Backward Linkages view, Chile and Brazil are main responsible for circulation of foreign inputs in South American trade, and Venezuela and Argentina are the main net importer and consumer of it. Because of both Forward and Backward perspectives, Chile arises as the main platform of value-added circulation between South America and the rest of the World, and Argentina as the main source of value.

ii. Bilateral and sector perspective: pinpointing RVC trade in South America

Table 5 showed that despite of being largely composed by direct absorbed value-added trade ($DAVAX$), there is some amount of trade related to international value chains. Backward and Forward Linkages trade accounts for 31% of regional exports.

Table 6 shows the top 20 bilateral sector flows in terms of Forward Linkages ($FwLE$). They are the core of forward linkages integration in GVC in South America. As noted before, most of this trade is due to foreign demand that enhances regional trade. Top 20 flows account for 38% of total $FwLE$. The average ratio of $FwLE$ on exports of this group is 29%, doubling total average (14%). Energy sector dominates this kind of flow. Petroleum, mining (even non- energy mining) and electricity and gas are among the top. The participation of Chile as an importer of regional inputs and using them in their own exports is remarkable. The role of foreign demand in Chilean exports of Mining to Brazil is also remarkable. There are also heavy forward linkages in Ecuador exporting Mining to Peru and Bolivia doing the same to Brazil and Argentina. Given the little economic size of Bolivia, this flow is very relevant. Outside motor vehicles and petroleum, there is only one manufacturing sector in the top ten: one fifth of Brazilian exports of basic chemical products to Argentina is value-added that is again included in Argentinean exports (mostly in the agriculture exports to extra zone).

Table 6. – **Forward participation in global value chains.** Top bilateral sectors: million dollars and shares (of total trade and of bilateral sector flow).

Exporter	Importer (reexporter)	Sector	Value	share in total FwLE trade $\frac{FwLE^{s,r,n}}{\sum_s \sum_r \sum_n FwLE^{s,r,n}}$	Share of FwLE in exports $\frac{FwLE^{s,r,n}}{E^{s,r,n}}$
BRA	CHL	Mining (energy)	1,139	5.3	34
ECU	PER	Mining (energy)	872	4.0	46
BRA	ARG	Motor vehicles	837	3.9	9
COL	CHL	Mining (energy)	669	3.1	37
PER	CHL	Mining (non energy)	608	2.8	64
ECU	CHL	Mining (energy)	443	2.0	35
BOL	BRA	Mining (energy)	399	1.8	15
CHL	BRA	Mining (non energy)	344	1.6	35
ARG	BRA	Agriculture	308	1.4	13
CHL	BRA	Non - ferrous metals	284	1.3	15
ARG	CHL	Mining (energy)	280	1.3	33
ARG	BRA	Bussines se-rvices	280	1.3	14
ARG	BRA	refined petroleum	260	1.2	13
VEN	BOL	refined petroleum	259	1.2	48
BRA	ARG	Iron and steel	241	1.1	23
BRA	ARG	Basic chemical products	228	1.1	21
BOL	ARG	Mining (energy)	206	1.0	12
VEN	ECU	refined petroleum	189	0.9	26
PER	COL	Non - ferrous metals	186	0.9	47
COL	PER	Mining (energy)	175	0.8	49

Source: Own Elaboration

Table 7 shows the top 20 bilateral sector flows in terms of backward linkages ($BwLE$). Although they explain more than top forward (41% vs 38%), both sides bilateral flows in automotive sector of Argentina and Brazil account for 13,4%. This trade is ruled by a bilateral treaty and is highly monitored by both administrations, so high deviations from balanced trade are precluded. Table 7 shows that Argentinean exports rely more on foreign content than Brazilian (43% vs 19%), but 19 percentage point out of 43 are regional value-added, mostly from Brazil. Bolivian exports of mining product to neighboring Brazil and Argentina contains 29% of foreign content. As it appears in both lists and its shares of both forward (21%) and backward (31%) complex regional value chains are higher than average, Brazilian exports to Argentina of **Basic Chemical products** appear to be the most integrated in RVC bilateral sector in the region. In the period between 2005 and 2011 the backward linkages share remained unchanged at 31% but forward linkages reduced four percentage points, in favor of single regional value chains. Also, this bilateral sector reduced by a half its importance in total regional trade in the period.

Table 7. **Backward participation in global value chains.** Top bilateral sectors: million dollars and shares (of total trade and of bilateral sector flow).

Exporter	Importer	Sector	Value	share in total BwLE trade $\frac{BwLE^{s,r,n}}{\sum_s \sum_r \sum_n BwLE^{s,r,n}}$	Share of BwLE in exports $\frac{BwLE^{s,r,n}}{E^{s,r,n}}$
ARG	BRA	Motor vehicles	1,956	6.9	43
BRA	ARG	Motor vehicles	1,869	6.5	19
BOL	BRA	Mining (energy)	768	2.7	29
BOL	ARG	Mining (energy)	486	1.7	29
CHL	BRA	Non-ferrous metals	364	1.3	20
BRA	CHL	Mining (energy)	333	1.2	10
BRA	ARG	Basic chemical products	325	1.1	31
ARG	BRA	Refined petroleum	321	1.1	16
BRA	ARG	Other chemical products	299	1.0	26
BRA	ARG	Machinery and equip.	270	0.9	20
ARG	BRA	Basic chemical products	264	0.9	36
BRA	ARG	Iron and steel	229	0.8	22
CHL	BRA	Basic chemical products	201	0.7	38
ARG	BRA	Agriculture	199	0.7	8
BRA	ARG	Electrical machinery and apparatus, nec	176	0.6	22
BRA	ARG	Rubber and plastic prods.	167	0.6	22
BRA	URY	Refined petroleum	160	0.6	29
BRA	ARG	Refined petroleum	154	0.5	29
BRA	ARG	Radio, television and communication	150	0.5	42
CHL	PER	Transportation	149	0.5	45

Source: Own Elaboration

iii. A comparison between two methods of gross exports accounting decomposition

As mentioned in section II, table B1 in Appendix includes a comparison between two methods of decomposition of gross exports. Most notable differences are the treatment of “Indirect Value-added sourced in *s* exported to *r*”, treatment of “Direct Domestic Value-added reimported in *s* and further reexported” and in identification of regional value-added and double counting in backward linkages. While WWZ method follows Koopman, Wang and Wei (2014) as close as possible, the authors in Appendix D of their paper develops an alternative decomposition that uses DAVAX definition both for final and intermediates, and identifies as GVC trade the “indirect value-added” consumed in *r*. While the alternative formulation of WWZ solves the first difference among methods, the second and third remains.

Table 8 shows the split of Gross exports according to WWZ and their differences with the Source Based approach followed here. There are two causes besides the low differences among methods: most of value is added in sourcing country without international sharing of production and as long as working without a complete matrix inhibit splitting Foreign Content in value-added and double counted, the magnitudes of differences of this significant flow cannot be sized in this paper. The exam of the very difference among the estimation of both domestic and regional double counting illustrates the idea that if both methods apply in a more integrated region and a complete input-output table the divergence will be bigger. Both columns and rows containing Domestic and Regional and Bilateral Double Counting (DDC and B&RDC) shed light into the differences between alternative approaches.

Table 8. **Gross Exports decomposition according to B&M source- based and Differences with WWZ. In million dollars. Year 2011**

		WWZ								
		DVA (fin+int)	DVA_reg	DVA_for	RDV	DDC	B&RVA	RDC	FC	Total
B&M	DAVAX	110,012								110,012
	VAX_reg+p	34	4,016			32				4,082
	VAX_for			15,562		156				15,717
	RDV				1,824					1,824
	DDC	32				43				75
	B&RVA						6,503	341		6,844
	RDC						4	0.2		5
	FC								21,626	21,626
	Total	110,079	4,016	15,562	1,824	230	6,508	341	21,626	160,185

Source: Own Elaboration

IV. Conclusions

South American participation in global value chains is limited to sourcing of intermediate commodities from primary factors so the level of value-added in exports is high for every country of the region. Into the extent that the pattern of intra-regional trade is different than global, it could be useful to adapt and apply global measures to new regional available data.

Results do not show a radically different pattern when considering regional input-output tables and focus on regional trade. Regional sharing of production in South America is scarce. Most trade is in domestic value-added and is mainly consumed in importing country without further circulation. Regional Value Chains trade, measured as the sum of Forward and Backward linkages of regional exports, accounts for almost one third of total. Most of both kind of linkages are due to participation of foreign countries, even as sources of value (in Backward Linkages) or destination (in Forward Linkages).

Chile arises as the main platform for partners value indirect integration to global markets. That is, a big share of forward linkages consumed out of the region uses Chile as a second manufacturing country. Main partners in this flow are Argentina, Ecuador, and Peru and these links are mostly in mining sectors.

Apart from these flows related to mining, the bilateral relationship in manufacturing between Brazil and Argentina also is outstanding, especially in basic chemistry. Nevertheless, as long as the main manufacturing exporter of the region tend to use low share of regional or foreign inputs, backward linkages are less than expected in manufactures. Given the importance of Colombia in the North part of the continent, it should be expected more participation in flows.

The article showed that foreign markets are important even for regional integration and that it could be necessary to design smart systems of rules of origin and circulation in order to build strong regional platforms and benefit from economies of scale.

Low level of integration in intermediates shrank the quantitatively differences of using alternative decomposition methods for identifying chains and flows. Nevertheless, the article showed that if the level of manufacturing sharing increases, it could be needed accurate measures for a proper diagnostic.

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Appendix

A- Demonstration of bilateral decomposition of gross exports (Table 2)

Using Eq (3) in the case of sourcing country s yields:

$$\text{(A1)} \qquad {u_n}^T = (\textstyle\sum_t V^t B^{ts})^T + (\sum_t F^t B^{ts})^T$$

Where $u_n$is a 1xN vector. Using element wise multiplication (#), (A1) can be operated on every element of the vector of gross exports E^{sr}.

$$\text{(A2)} \qquad E^{sr} = (\textstyle\sum_t V^t B^{ts})^T \# E^{sr} + (\sum_t F^t B^{ts})^T \# E^{sr}$$

The first term is regional value-added included in gross exports. It can be divided according to the sourcing country in s, the bilateral partner r and the rest of regional countries t.

$$\text{(A3)} \qquad E^{sr} = (V^s B^{ss})^T \# E^{sr} + (V^r B^{rs})^T \# E^{sr} + \left(\textstyle\sum_{t\neq r,s} V^t B^{ts}\right)^T \# E^{sr} + (\sum_t F^t B^{ts})^T \# E^{sr}$$

The fourth term of (A3) is Foreign Content in exports. It can be split in $\sum_t F^t B^{ts} = \sum_{t\neq s} F^t B^{ts}$+$F^s B^{ss}$ and $F^s B^{ss}$ can be further divided using Eq. (4) in $F^s L^{ss} + F^s L^{ss} \sum_{t\neq s}^{G} A^{st} B^{ts}$. Then:

$$\text{(A4)} \qquad (\textstyle\sum_t F^t B^{ts})^T \# E^{sr} = F^s L^{ss} \# E^{sr} + (\sum_{t\neq s} F^t B^{ts} + F^s L^{ss} \sum_{t\neq s}^{G} A^{st} B^{ts}) \# E^{sr} = DFC + RFC$$

Using (5), the second term of (A3) is

$$\text{(A5)} \qquad V^r B^{rs} \# E^{sr} = V^r B_s^{rs} \# E^{sr} + (V^r B_s^{rs} \textstyle\sum_{t\neq s}^{G} A^{st} B^{ts}) \# E^{sr}$$

And again using (5) in the third term of (A3) yields:

$$\text{(A6)} \; \left(\textstyle\sum_{t\neq r,s} V^t B^{ts}\right)^T \# E^{sr} = \left(\sum_{t\neq r,s} V^t B_s^{ts}\right)^T \# E^{sr} + \left(\sum_{t\neq r,s} V^t B_s^{ts} \sum_{t\neq s}^{G} A^{su} B^{us}\right)^T \# E^{sr}$$

The first term of (A5) is BVA, the first term of (A6) is RVA, the second term of (A5) and (A6) can be consolidated in one: $(\sum_{t\neq s} V^t B_s^{ts} \sum_{t\neq s}^{G} A^{su} B^{us})^T \# E^{sr}$.

Then, second and third term of (A3) are bilateral and regional value-added and regionally sourced double counted terms:

$$\text{(A7)} \qquad (V^r B^{rs})^T \# E^{sr} + \left(\textstyle\sum_{t\neq r,s} V^t B^{ts}\right)^T \# E^{sr} = V^r B_s^{rs} \# E^{sr} + \left(\sum_{t\neq r,s} V^t B_s^{ts}\right)^T \# E^{sr} + (\sum_{t\neq s} V^t B_s^{ts} \sum_{t\neq s}^{G} A^{su} B^{us})^T \# E^{sr} = BVA + RVA + RDC$$

Equation (4) is used again in order to split first term of (A3), that is, domestic content included in exports, in direct valued added and indirect. According to a source-based definition, the second is double counted.

$$\text{(A8)} \qquad (V^s B^{ss})^T \# E^{sr} = (V^s L^{ss})^T \# E^{sr} + (V^s L^{ss} \textstyle\sum_{t\neq s}^{G} A^{st} B^{ts}) \# E^{sr}$$

The second term is DDC^{sr}. Note that part of DDC^{sr}, $(V^s L^{ss} \sum_{t\neq s}^{G} A^{st} B^{ts}) \# Y^{sr}$, is considered Double Counted trade in this scheme, but is part of value-added according to Koopman, Wang, and Wei (2014) and WWZ and also is value-added in the sink-based decomposition of gross exports (Borin and Mancini 2019). This flow corresponds to domestic value-added included in intermediates exported abroad, returned home and included in s exports to r. According to source- based criteria, this flow was considered value-added the first time it leaved s, and should be double counted afterwards.

The first term of (A8) can be further divided using a simple division of exports between final and intermediate goods, $E^{sr} = Y^{sr} + A^{sr}X^{r}$.

$$\text{(A9)} \quad (V^{s}L^{ss})^{T}\#E^{sr} = (V^{s}L^{ss})^{T}\#Y^{sr} + (V^{s}L^{ss})^{T}\#A^{sr}X^{r}$$

The first term is $DAVAX\_fin^{sr}$. The second term will be divided according to the place of final production and consumption. The division according to the place of final production in s, r and t, yields:

$$\text{(A10)} \quad X^{r} = \sum_{t} B^{rt}Y^{t*} = B^{rs}Y^{s*} + B^{rr}Y^{r*} + \sum_{t\neq s,r} B^{rt}Y^{t*}$$

Each term of (A10) is further divided according to location of demand (A11). The first term in each Equation represents demand from s, the second represents demand from r, the third represents demand from t and the fourth represent demand from extrazone. In the case of third countries (A11c), it is also necessary to identify an extra term capturing a fourth destination in regional trade, different from s, r and t.

$$\text{(A11a)} \quad B^{rs}Y^{s*} = B^{rs}\left(Y^{ss} + Y^{sr} + \sum_{t\neq s,r} Y^{st} + \sum_{h} Y^{sh}\right)$$

$$\text{(A11b)} \quad B^{rr}Y^{r*} = B^{rr}\left(Y^{rs} + Y^{rr} + \sum_{t\neq s,r} Y^{rt} + \sum_{h} Y^{rh}\right)$$

$$\text{(A11c)} \quad B^{rt}Y^{t*} = B^{rt}\left(Y^{ts} + Y^{tr} + Y^{tt} + \sum_{h} Y^{th} + \sum_{u\neq t,s,r} Y^{tu}\right)$$

Every term in (A11) is identified with an ordinal, e.g. (A11b2) stand for second term of equation b: $B^{rr}Y^{rr}$; (A11c4) stand for fourth term of equation c: $B^{rt}\sum_{h} Y^{th}$.

All terms of (A11) are included in the second term of (A9). Table A1 shows the relationship between these terms and definition of table 2.

Table A1. Relationship between terms of (A11) inserted in (A9) and concepts

Terms	Formula	Concept
A11a1+ A11b1+ A11c1	$(V^{s}L^{ss})^{T}\#A^{sr}\sum_{t} B^{rt}Y^{ts}$	RDV^{sr}
A11a2+ A11a3+A11b3+A11c5	$(V^{s}L^{ss})^{T}\#A^{sr}\sum_{t\neq s,r} B^{rr}Y^{rt} + (V^{s}L^{ss})^{T}\#A^{sr}\sum_{t\neq r} B^{rt}\sum_{u\neq t,s,r} Y^{tu}$	$DVA\_reg\_2^{sr}$
A11a4+A11b4+A11c4	$(V^{s}L^{ss})^{T}\#A^{sr}B^{rr}\sum_{h} Y^{rh} + (V^{s}L^{ss})^{T}\#A^{sr}\sum_{t\neq r} B^{rt}\sum_{h} Y^{th}$	DVA_for^{sr}
A11c2	$(V^{s}L^{ss})^{T} \# \left(A^{sr}\sum_{t\neq s,r}^{G} B^{rt}Y^{tr}\right)$	$DVA\_p\_2^{sr}$
A11c3	$(V^{s}L^{ss})^{T} \# \left(A^{sr}\sum_{t\neq s,r}^{G} B^{rt}Y^{tt}\right)$	$DVA\_reg\_1^{sr}$
A11b2	$(V^{s}L^{ss})^{T} \# (A^{sr}L^{rr}Y^{rr})$	$DAVAX\_int^{sr}$
	$(V^{s}L^{ss})^{T} \# (A^{sr}(B^{rr} - L^{rr})Y^{rr})$	$DVA\_p\_1^{sr}$

Then, Table A1 shows that second term of (A9) is equal to the sum of $DAVAX\_int$ and RVC_fwd. Then, inserting (A9) in (A8), and (A4), (A7) and (A8) in (A3) retrieves a completely source- based decomposition of bilateral gross exports according to GVC terms.

B- Comparison between a Decomposition of bilateral exports based in Borin and Mancini (2019) and a decomposition based in Wang, Wei y Zhu (2018) with regional inter country tables.

Table B1. Comparison between accounting segregation of bilateral exports with regional input-output tables according to Borin and Mancini method and Wang, Wei and Zhu method.

Subterm B&M	Based on B&M	Based on WWZ	Reference in WWZ
$DAVAX_{fin}$	$(V^sL^{ss})^T \# Y^{sr}$	$(V^sB^{ss})^T \# Y^{sr}$	1
$DAVAX_{int}$	$(V^sL^{ss})^T \# (A^{sr}L^{rr}Y^{rr})$	$(V^sL^{ss})^T \# (A^{sr}B^{rr}Y^{rr})$	2
DVA_p (1)	$(V^sL^{ss})^T \# (A^{sr}(B^{rr}-L^{rr})Y^{rr})$		
DVA_p (2)	$(V^sL^{ss})^T \# \left(A^{sr}\sum_{t\neq s,r}^{G} B^{rt}Y^{tr}\right)$	$(V^sL^{ss})^T \# \left(A^{sr}B^{rr}\sum_{t\neq s,r}^{G} Y^{rt}\right)$	4
DVA_reg (1)	$(V^sL^{ss})^T \# \left(A^{sr}\sum_{t\neq s,r}^{G} B^{rt}Y^{tt}\right)$	$(V^sL^{ss})^T \# \left(A^{sr}\sum_{t\neq r,s}^{G} B^{rt}Y^{tt}\right)$	3
DVA_reg (2)	$(V^sL^{ss})^T \# \left(A^{sr}\sum_{t\neq s}^{G} B^{rt}\sum_{u\neq s,r,t}^{G} Y^{tu}\right)$	$(V^sL^{ss})^T \# \left(A^{sr}\sum_{t\neq s,r}^{G} B^{rt}\sum_{u\neq s,t}^{G} Y^{tu}\right)$	5
	$(V^sL^{ss})^T \# \left(A^{sr}B^{rs}\sum_{t\neq s}^{G} Y^{st}\right)$	$(V^sL^{ss})^T \# \left(A^{sr}B^{rs}\sum_{t\neq s}^{G} Y^{st}\right)$	9
DVA_for	$(V^sL^{ss})^T \# \left(A^{sr}\sum_{t\neq s}^{G} B^{rt}\sum_{t}\sum_{h}^{H} Y^{th}\right)$	$(V^sL^{ss})^T \# \left(A^{sr}\sum_{t\neq s,r}^{G} B^{rt}\sum_{t}\sum_{h} Y^{th} + \left(A^{sr}B^{rr}\sum_{h} Y^{rh}\right)\right)$	---
	$(V^sL^{ss})^T \# \left(A^{sr}B^{rs}\sum_{h}^{H} Y^{sh}\right)$	$(V^sL^{ss})^T \# \left(A^{sr}B^{rs}\sum_{h}^{H} Y^{sh}\right)$	9
RDV	$(V^sL^{ss})^T \# \left(A^{sr}\sum_{t}^{G} B^{rt}Y^{ts}\right)$	$(V^sL^{ss})^T \# \left(A^{sr}\sum_{t}^{G} B^{rt}Y^{ts}\right)$	6,7 and 8
DDC (1)	$\left(V^sL^{ss}\sum_{t\neq s}^{G} A^{st}B^{ts}\right)^T \# E^{sr}$	$\left(V^sL^{ss}\sum_{t\neq s}^{G} A^{st}B^{ts}\right)^T \# (A^{sr}X^r)$	10
BVA	$(V^rB_{\not s}^{rs})^T \# E^{sr}$	$(V^rB^{rs})^T \# Y^{sr}$	11
		$(V^rB^{rs})^T \# (A^{sr}L^{rr}Y^{rr})$	13
RVA	$\left(\sum_{t\neq s,r}^{G} V^tB_{\not s}^{ts}\right)^T \# E^{sr}$	$\left(\sum_{t\neq s,r}^{G} V^tB^{ts}\right)^T \# Y^{sr}$	12
		$\left(\sum_{t\neq r,s}^{G} V^tB^{ts}\right)^T \# (A^{sr}L^{rr}Y^{rr})$	14
RDC	$\left(\sum_{t\neq s}^{G} V^tB_{\not s}^{ts}\sum_{u\neq s}^{G} A^{su}B^{us}\right)^T \# E^{sr}$	$(V^rB^{rs})^T \# (A^{sr}L^{rr}E^{r*})$	15
		$\left(\sum_{t\neq r,s}^{G} V^tB^{ts}\right)^T \# (A^{sr}L^{rr}E^{r*})$	16
DFC	$(F^sL^{ss})^T \# E^{sr}$	$\left(\sum_{t}^{G} F^tB^{ts}\right)^T \# (Y^{sr}+A^{sr}X^r)$	----
RFC	$\left[\left(F^sL^{ss}\sum_{t\neq s}^{G} A^{st}B^{ts}\right)^T + \left(\sum_{t\neq s}^{G} F^tB^{ts}\right)\right] \# E^{sr}$		

Source: Own Elaboration

C. ECLAC Latin American Input-output Table

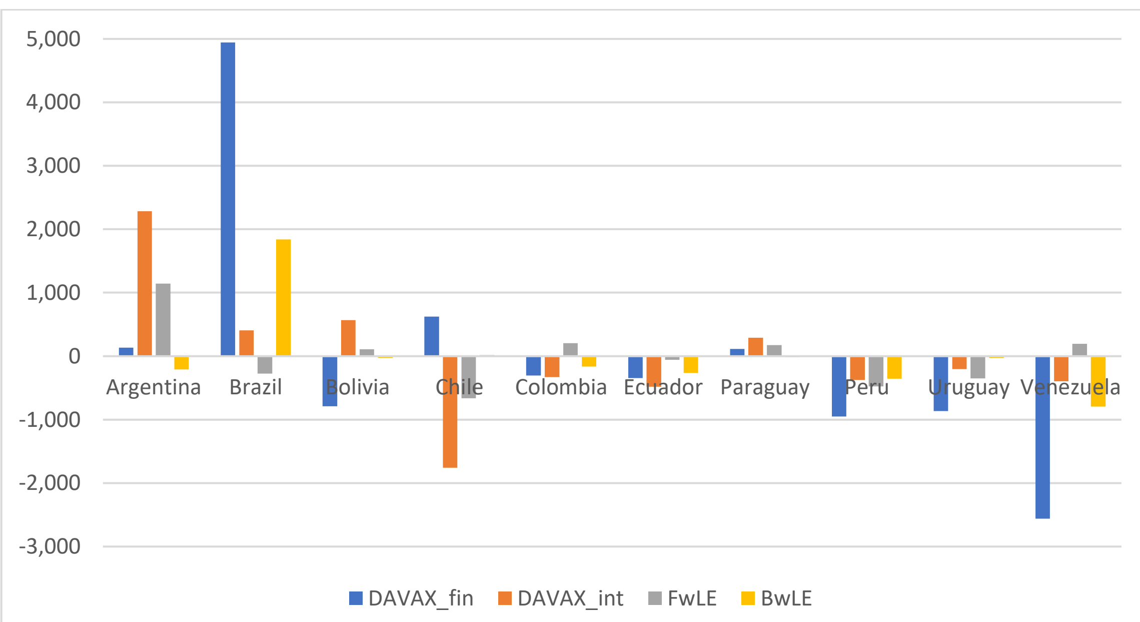
Sector	Description
01	Agriculture and forestry
02	Hunting and fishing
03	Mining and quarrying (energy)
04	Mining and quarrying (non-energy)
05	Meat and meat products
06	Wheat products and pasta
07	Sugar and confectionery
08	Other processed food
09	Beverage
10	Tobacco
11	Textiles
12	Apparel
13	Footwear
14	Wood and products of wood and cork
15	Pulp, paper, printing and publishing
16	Coke, refined petroleum and nuclear fuel
17	Basic chemical products
18	Other chemical products (excluding pharmaceuticals)
19	Pharmaceuticals
20	Rubber and plastics products
21	Other non-metallic mineral products
22	Iron and steel
23	Non-ferrous metals
24	Fabricated metal products, except machinery and equipment
25	Machinery and equipment nec (excluding electrical machinery)
26	Office, accounting and computing machinery
27	Electrical machinery and apparatus, nec
28	Radio, television and communication equipment nec
29	Medical, precision and optical instruments
30	Motor vehicles, trailers and semi-trailers
31	Aircraft and spacecraft
32	Other transport equipment
33	Manufacturing nec; recycling (include furniture)
34	Electricity and gas
35	Construction
36	Transportation
37	Post and telecommunication
38	Finance and insurance
39	Business services of all kinds
40	Other services

Table D1**. Accounting segregation of South America intra zone trade. In million dollars and percentages. 2005**

	Regional exports	Share of Value-added in Exports (in %)			Share of Foreign and double counted
		DAVAX_fin	DAVAX_int	FwLE	BwLE
Argentina	15,991	28	41	17	14
Brazil	19,525	39	31	11	19
Bolivia	2,176	15	52	17	16
Chile	8,201	41	27	13	18
Colombia	4,572	27	38	14	21
Ecuador	2,340	23	37	20	20
Paraguay	2,062	38	36	15	11
Peru	3,614	17	49	20	15
Uruguay	1,512	29	36	10	25
Venezuela	2,977	8	52	22	18
TOTAL	**62,971**	31	37	15	17

Source: Own elaboration

Figure D1**. Net regional trade balance according to CGV categories. Year 2005. in million dollars**.



Source: Own Elaboration

Size and Position in Value Chains in Latin America with a regional Perspective

Abstract

This article develops a framework that divides global value chains into regional and extra-regional and studies the participation of Latin American countries in the international fragmentation of production over 25 years of globalization. Measures of depth, position, and length are developed for each kind of value chain. Between 1990 and 2015 the engagement in activities related to international trade increased in every country in Latin America and the prevalent way of integration is in Extra-Regional Value Chains. While South America engages mostly in value chains as a source of value added transformed by others, Central America participates more as the end of chains and Mexico switched its position to a net forward position in regional value chains. Finally, the article examines the relationship between participation and length of the domestic segment of chains, finding that participation in Extra-Regional value chains is associated with the shortness of stages, while in regional integration this does not happen.

Resumen

Este articulo desarrolla un marco para dividir a las cadenas de valor global en regionales y extrarregionales y estudia la participación de los países de América Latina en la fragmentación internacional de la producción en 25 años de globalización. Se desarrollan medidas de profundidad, posición y longitud para cada tipo de cadena de valor. Entre 1990 y 2015, la participación en actividades relacionadas con el comercio internacional se incrementó en todos los países de América Latina, y la forma prevalente de integración es en Cadenas de Valor Extrarregionales. Mientras América del Sur se involucra en cadenas de valor proveyendo valor agregado transformado por otros, América Central participa más en el final de las cadenas y México modificó su posición neta hacia ser más proveedor que usuario en las cadenas de valor regionales. Finalmente, el trabajo examina la relación entre la participación y la longitud del segmento doméstico de las cadenas de valor, encontrando que la profundización en la participación en cadenas extrarregionales está asociada a un acortamiento de las cadenas, mientras que eso no ocurre en las regionales.

I. Introduction

Nearby 1990 Latin American countries engaged in a process of openness of their economies and integration of their markets through multiple trade agreements signed with regional partners and also with non-Latin American countries. This strategy was very heterogeneous across the subcontinent. Mexico is engaged in the United States-Mexico-Canada Agreement (USMCA) which explains most of its trade. Central American countries have trade agreements with North American partners and Costa Rica also have treaties with many developed countries. South American countries are involved in an incomplete free trade zone (under many ALADI agreements) and there are big differences between Atlantic coastal countries, which belong to MERCOSUR and are relatively closed economies, and Pacific coastal ones, which have a strong network of trade agreements with developed and emerging countries (Moncarz et al. 2021).

Meanwhile, developments in infrastructure and information and communication technology and changes in the governance of global trade fed the second wave of globalization characterized by growing rates of international trade systematically higher than gross domestic product, giving rise to the "era of the global value chains (GVC)" (Antras and Chor 2021). Nowadays, several countries participate in the different stages of production of a good, generating a rise in the trade of intermediate goods and a dissociation between gross exports and the domestic value added included in them (Koopman et al., 2014). In this context, both regionalization and globalization changed the structure of supply and demand in Latin American countries.

One of the key facts of involvement in the international sharing of production is the position that industries in countries perform along the value chains. Since the seminal work of Hummels, Ishii, and Yi (2001), literature identified the forward and backward participation in value chains. Most complete accounting split of gross exports (Koopman, Wang, and Wei 2014; Borin and Mancini 2019) or value added (Wang et al. 2017b) focuses on identifying both types of participation. While forward participation focuses on the role of an industry as international supplier of intermediates, backward participation captures the role of industries as users of foreign value[1].

There is not a clear theoretical statement of what should be expected from these alternative ways to participate in value chains and their links with economic development (Antras and Chor 2021). Nevertheless, some works find some evidence on GVC backward participation and productivity (Los and Timmer 2020) and other aspects of development (World Bank 2019). Also, industries exporting upstream tend to have more output volatility (Olabisi 2020).

Even though there have been early noted that international supply chains tend to be more regional than global (Johnson and Noguera 2012), only few articles build a framework for separate identification of both kinds of fragmentation. Antràs and de Gortari (2020) develop a Ricardian model derived from Eaton and Kortum (2002) finding that downstream participation in global value chains tends to be more elastic to changes in trade costs. They model the geography of value chains finding that, departing from high trade costs, both regional and global value chains rise relative to domestic chains, but if trade cost continues declining only global value chains remains, because comparative advantage (fueling global sourcing) prevails over proximity.

[1] See the latest WTO Global Value Chain Development Report (Xing, Gentile, and Dollar 2021) for a comparison of methods based in value added and method based in gross exports.

Inter-country input-output tables link sectors of different countries and enable a complete evaluation of relationships between final demand, intermediate -domestic and foreign-demand and the value added. In recent years there have been several projects of integration of world input-output tables (WIOT)[2]. Using these data, economic literature developed a set of measures to characterize the size, position, or length of GVCs.

Most of these measures are conceived for GVC and so the regional character of value chains, noted early by Johnson and Noguera (2012), is less frequently studied within a comprehensive framework. Many reasons can justify the inclusion of a regional dimension in measures. First, the regional integration approach needs a benchmark to contrast results, and domestic and extra-regional results are the best candidates. Also, trade policy with regional partners has its issues not always shared with global -or multilateral- trade policy. Finally, is well documented that globalization is a result of the offshoring of firms and frequently this strategy starts with nearshoring and then expands worldwide. While regional integration studies using input-output tables have a long tradition in regional economics, there seems to be a certain divorce in the toolkits used by regional economics and those used by international economics.

While participation in GVC of some Latin American countries like Mexico have been widely studied (De La Cruz et al. 2011; De Gortari 2019) as an example of vertical regional sharing, there is still missing a comprehensive approach on the evolution and kind of participation in value chains. One of the main difficulties is that, in contrast to the situation of European countries, there are few Latin American countries in most used WIOTs.

Blyde, Volpe Martincus, and Molina (2014) uses input-output tables of the GTAP project to estimate participation in value chains of Latin American for a given year. The Economic Commission of Latin America and The Caribbean (ECLAC) launched Regional Input Output Tables for 18 Latin American Countries (ECLAC 2016) that have been used in research that focuses on total trade (Banacloche, Cadarso, and Monsalve 2020), regional trade (Amar and Torchinsky Landau 2019; Lalanne 2021) or both (Durán Lima and Banacloche 2021). While these articles are very useful for depicting the main characteristics of regional trade of intermediates, they have limitations derived from the use of a Regional Input Output Table instead of a WIOT.

The main limitation of regional tables is that the chains, defined form value added to final demand, are only fully depicted when all value is added in the countries belonging to the region. Exports to extra-regional countries are treated as is they were all in final products and imports of intermediates are treated as if they were all foreign value added. This limitation is especially important in measures of length and position in chains, where value-added and final demand are key concepts. A second weakness of regional tables is that they do not enable comparison between regional and global participation in value chains. Finally, at least until now, the time span of regional tables in Latin America is reduced, they cover Latin America for 2005[3], 2011 and 2014. The interesting period from 1990 to 2003 remains uncovered. Note that this includes the beginning of the impulse of “open regionalism”, the crisis of Tequila in 1994 and Argentina in 2001 and the early stages of the rise of China as a global producer.

Literature on macro measures of participation in GVC from WIOTs can be divided in literature on value added in final goods, decomposition of gross exports, and positioning in GVCs (Antras and

[2] Some examples of projects are: Tsigas et al. (2011), Johnson and Noguera (2012), Timmer et al. (2015), Lenzen et al. (2013)

3 Only ten South American Countries

Chor 2021). While Durán Lima and Banacloche (2021) display and present measures of the first and second type, Amar and Torchinsky Landau (2019) and Lalanne (2021) focus on the decomposition of gross exports. Nevertheless, there is still lacking a description of Latin America from the perspective of position and length of chains[4].

This article adapts global measures developed by Wang et al. (2017a,b) to divide total activity into domestic, regional, and extra-regional. By doing so, it identifies exclusively domestic, regional, or extra-regional value chains and a residual category comprising mixed value chains. Using the EORA database (Lenzen et al., 2013), I depict the evolution of value added in Latin American countries according to the participation in each type of trade in 1990-2015. Then, this article presents fully integrated measures of participation, position and length of value chains over 25 years of globalization and regional integration. The framework allows comparison with performance in other regions of reference, such as Europe and Asia.

Wang et al. (2017b) develop a measure of participation in global value chains, arising from the decomposition of total final goods and services production, splitting the value added in domestic stages from the foreign value added and also considering the place of final consumption. According to Wang et al. (2017b), total production can be split into pure domestic value added included in domestic consumed production, pure domestic value added included in final goods and services exported and global value chain production, characterized by international trade of intermediates and so vertical specialization.

Wang et al. (2017a) defines new measures of length of production and upstreamness. These measures rely conceptually on the existing literature (Antràs and Chor, 2013; Antràs et al., 2012; Fally, 2012), but they are applied to WIOT instead of local matrices. In this sense, their work is close to Antràs and Chor (2018) and Miller and Temurshoev (2017), with the difference that their measures are defined as ratios of value added instead of ratios of production. Also, they apply the length of production in each of the terms defined in Wang et al. (2017b), leading to a new set of measures of GVC participation that considers both domestic and international value chains.

Both Wang et al. (2017b,a) measures of participation in GVC and length are used in the 2017, 2019 and 2021 Global Value Chain Development Report (WTO, 2017, 2021). These two contributions help us to understand the evolution of depth and length of GVC participation. They show how GVC activities gained participation in total value-added and raised their length until the 2008-09 crises and then they stopped their pace and slightly shortened

These measures rely on a parsimonious decomposition of value-added included in the output according to two perspectives. First, for the exports of intermediates, they decompose the demand, that is, the use that is made in a country or sector of destination. Second, they decompose the supply, that is, the source of value added included in the production. In all cases, both the final demand-the destination- and the origin of value –the supply- is decomposed according to domestic and foreign.

This article contributes to the literature of measuring regional integration adapting a framework conceived for global production. In this sense, it relates to Antràs and de Gortari (2020) measure of regional value chains in North America, Fan et al. (2019) measure of regionalization in China or Bolea et al. (2019) measure of different patterns of value chains in Europe. Also based on Borin and Mancini (2019) measure of participation in Global Value Chains, World Bank's Global Value Chains

[4] Lalanne (2020) applies measures of length and position (upstreamness and downstreamness) for Uruguay using ECLAC Regional IO tables. As said before, these measures applied with Regional IOT are truncated to regional linkages.

Report 2020 also applies measures of regionalization of international value chains (WorldBank, 2019). Furthermore, this article reveals some aspects not showed before on previous analysis on Latin American fragmentation of supply chains. Particularly, it describes the length of Latin American regional and extra regional value chains.

This paper includes, in addition to this introduction, three sections. Section II introduces the methodological scheme built in previous work and develops the adaptation of these measures to divide trade in traditional and value chains trade, defining regional, extra regional and mixed value chains participation. Section III shows the results of the application for Latin America and discusses some features of the regional value chains and Section IV draws some conclusions.

II. Measures of depth, length, and position in Domestic, Regional, Extra Regional, and Mixed Value Chains

i. General notation and definitions

Intercountry input-output tables organize the world supply and demand according to a structure akin to depicted in Table 1. To apply the algebraic decomposition defined in this article, regional countries must be arranged in the first rows and columns and extra-regional are placed subsequently. Countries s and t belong to region G $\{s, t \in G\}$ and f and k are countries of the rest of world H $\{ f, k \notin G; f, k \in H\}$. Then, there are G+H countries in the table.

Table 1 **Regional input-output table**

Destination / Source		**Intermediate regional**			**Intermediate extra-regional**			**Final regional use**			**Final extra-regional use**			**Output**
		1	…	G	1’	…	H	1	…	G	1’	…	H	
Inputs from region	**1**	Z^{11}	$\cdots$	Z^{1t}	$Z^{11'}$	$\cdots$	Z^{1k}	Y^{11}	$\cdots$	Y^{1t}	$Y^{11'}$	$\cdots$	Y^{1k}	X^1
	s	Z^{s1}	$\cdots$	Z^{st}	$Z^{s1'}$	$\cdots$	Z^{sk}	Y^{s1}	$\cdots$	Y^{st}	$Y^{s1'}$	$\cdots$	Y^{sk}	X^s
	⋮	$\vdots$	$\ddots$	$\vdots$	$\ddots$	$\vdots$		$\vdots$	$\ddots$	$\vdots$	$\vdots$	$\ddots$	$\vdots$	$\vdots$
	G	Z^{t1}	$\cdots$	Z^{tt}	$Z^{t1'}$	$\cdots$	Z^{tk}	Y^{t1}	$\cdots$	Y^{tt}	$Y^{t1'}$	$\cdots$	Y^{tk}	X^t
extra regional Inputs	**1’**	$Z^{1'1}$	$\cdots$	$Z^{1't}$	$Z^{1'1'}$	$\cdots$	$Z^{1'k}$	$Y^{1'1}$	$\cdots$	Y^{1t}	$Y^{1'1'}$	$\cdots$	$Y^{1'k}$	$X^{1'}$
	f	$Z^{f'1}$	$\cdots$	Z^{ft}	$Z^{f1'}$	$\cdots$	Z^{fk}	Y^{f1}	$\cdots$	Y^{ft}	$Y^{f1'}$	$\cdots$	Y^{fk}	X^f
	⋮	$\vdots$	$\ddots$	$\vdots$	$\vdots$	$\ddots$	$\vdots$	$\vdots$	$\ddots$	$\vdots$	$\vdots$	$\ddots$	$\vdots$	$\vdots$
	H	Z^{k1}	$\cdots$	Z^{kt}	$Z^{k1'}$	$\cdots$	Z^{kk}	Y^{k1}	$\cdots$	Y^{kt}	$Y^{g1'}$	$\cdots$	Y^{kk}	X^k
Value Added		Va^1	$\cdots$	Va^t	$Va^{1'}$	$\cdots$	Va^k							
Total Output		$(X^1)^T$	$\cdots$	$(X^t)^T$	$(X^{1'})^T$	$\cdots$	$(X^k)^T$							

Source: Own Elaboration

Where Z^{st} is an NxN matrix of intermediate inputs produced in country s and used in country t, Y^{st} is an Nx1 vector of final goods produced in country s and consumed in country t, $X^s$is an Nx1 vector of output of country s and $Va^s$is a 1xN vector of direct value added in country s. T is the transpose operator. Terms labeled with k instead of t have analogous interpretations.

It is useful to aggregate every destination of final demand faced by regional countries according to the sourcing country and sector, but distinguishing demand in domestic (Y^D)[5], regional demand of regional products (excluding domestic; Y^R) and extra-regional final demand sourced by regional countries (Y^F). Also, all demand (domestic, regional, and extra-regional) faced by extra-regional countries is aggregated in Y^H. All these are N(G+H)x1 vectors and the sum equals to total final demand.

$$Y = Y^D + Y^R + Y^F + Y^H \tag{1}$$

In a general notation, final demand Y, and production X can be expressed as N(G+H)x1 vectors, Z is an N(G+H)xN(G+H) matrix and Va is a 1xN(G+H) vector.

The Leontief matrix $A = Z\hat{X}^{-1}$ enables the usual notation in input-output analysis. The operator $\widehat{\ }$ indicates that the vector is expressed as a diagonal matrix. The usual segmentation of production is:

$$X = AX + Y \tag{2}$$

Each A^{sr} is an NxN matrix containing the ratios of the utilization of origin s in the production of country r. In the main diagonal s=r and correspond to domestic intermediate supply, whereas when s≠r is the case of international trade of intermediates.

The International Leontief inverse matrix is defined as:

$$B = (I - A)^{-1} \tag{10}$$

Each submatrix B^{sr} is the total output necessary in each n sector of the country s to fulfill one additional unit of final demand in each n sector of r (B^{sf} has the same interpretation).

From the column perspective, the output is the result of the combination of intermediate inputs plus the value-added (Va). This equation illustrates the Leontief production function:

$$X^T = u\hat{X} = uZ + Va = uA\hat{X} + V\hat{X} \tag{4}$$

Where V is a 1xN(G+H) row vector of ratios of value added to product and u is a 1xN(G+H) vector of ones. Posmultiplying by $\hat{X}^{-1}$ the expression gives rise to the decomposition formula for production:

$$u = uA + V \rightarrow uI - uA = u(I - A) = V \rightarrow u = V(I - A)^{-1} = VB \rightarrow u = u\hat{V}B \tag{5}$$

Final demand or total output can be split using (5) according to the country and sector of origin of value. $\hat{V}B$ has some useful properties. Postmultiplied by a diagonal matrix of final demand it leads to complete decomposition of value added included in it. On the direction of any column, the sectoral output is divided according to the country/sector of origin of the value, and the total sum of the column equals the final demand of each sector. On the direction of rows, the value added of a country/sector is divided according to the country/sector of final use, and the total sum equals the total value added of this country/sector[6].

Wang et al. (2017a) split total requirements (A) in domestic (A^D) and international (A^F). Then $A^F X$ represent the international trade in intermediates. In this paper will be necessary further decompositions of A. The key technical step to obtain domestic, regional, and extra-regional results

[5] Note that Y^D excludes domestic demand of countries outside the region.
[6] $\hat{V}B\hat{Y}u^T = Va$ and $u\hat{V}B\hat{Y} = Y^T$

is defining auxiliary matrices that are in fact submatrices of A and their complements. Appendix A shows the definition of A^D, A^d, A^{reg} and A^{ext} and their complements A^F, A^{-reg}, A^{reg-d} and A^{-ext} used in the method. A^D is a block diagonal matrix containing domestic requirements and zeros otherwise, A^d contains domestic requirements only for regional countries, A^{reg} contains all requirements of regional countries ad zeros otherwise and A^{ext} contains requirements only with origin and destination between non-regional countries and zeros otherwise.

It should be defined also the Leontief Inverses matrix of these partitions of A.

$$L' = (I - A^D)^{-1}; \qquad L = \left(I - A^d\right)^{-1}; \qquad B^{reg} = (I - A^{reg})^{-1}; \quad B^{ext} = (I - A^{ext})^{-1}$$

Given that A^D, A^d, A^{reg} and A^{ext} are subparts of A, then L', L, B^{reg} and B^{ext} are a smaller amount of B.

The hypothetical extraction method followed by an important strand of the literature in GVC (Los, Timmer, and de Vries (2016), Los and Timmer (2020), Miroudot and Ye (2018), Johnson (2018)) apply an equivalency between Leontief inverse matrix and some partition of it. Following this literature and Borin and Mancini (2019) a set of relationships will be defined. See Wang et al. (2017a) for a demonstration of (6) and Appendix A for a demonstration of (7), (8), and (9).

As long as $A = A^D + A^{\mathrm{F}}$, it can be shown that:

$$B = L' + \mathrm{L}'A^{\mathrm{F}}B \tag{6}$$

As long as $A = A^{reg} + A^{-reg}$, it can be shown that:

$$B = B^{reg} + B^{reg}A^{-reg}B \tag{7}$$

Analogously, given that $A^{reg} = A^d + A^{reg-d}$:

$$B^{reg} = L + LA^{reg-d}B^{reg} \tag{8}$$

Finally, as long as $A = A^{ext} + A^{-ext}$, it can be shown that:

$$B = B^{ext} + B^{ext}A^{-ext}B \tag{9}$$

i. Measuring the participation in Global Value Chains

At global value, total value-added equals total final demand. The link between value added in the sector *i* of country s and the final demand of sector j in country r is represented by the N(G+H)xN(G+H) matrix $\hat{V}B\hat{Y}$.

$$\hat{V}B\hat{Y} = \begin{bmatrix} v_1^1 b_{11}^{11} y_1^1 & v_1^1 b_{12}^{11} y_2^1 & \cdots & v_1^1 b_{1j}^{1r} y_j^r \\ v_2^1 b_{21}^{11} y_1^1 & v_2^1 b_{22}^{11} y_2^1 & \cdots & v_2^1 b_{2j}^{2r} y_j^r \\ \vdots & \vdots & \ddots & \vdots \\ v_i^s b_{i1}^{s1} y_1^1 & v_i^s b_{i2}^{s1} y_2^1 & \dots & v_i^s b_{ij}^{sr} y_j^r \end{bmatrix}$$

The generic term $v_i^s b_{ij}^{sr} y_j^r$ represents the total direct and indirect value added sourced in sector *i* of country s (v_i^s) included in final goods production of sector j in country r (y_j^r).

Note that $\hat{V}B\hat{Y}$ show the splitting of value-added contribution to final goods production irrespective of where they are consumed, as also a strand of literature does (Los, Timmer, and de Vries 2016;

Timmer et al. 2015; Los and Timmer 2020). Johnston (2018) labels this option as the "GVC Income" view because it traces the value added embodied in final goods by source country along the value chain. Los and Timmer (2018) also use this view to define their VAX_P concept, that is the value added exported for final production[7].

$\hat{V}B\hat{Y}$ enables two perspectives of value chain analysis. In the row perspective, the value added sourced in a country sector is used in the production of final goods of other sectors and countries. This view originates in the sourcing of value in some country sector and ends its circulation (as intermediate) when is included in a final product. This is the forward perspective, and it goes from the sourcing sector to final use. In the direction of columns, the production of final goods is divided according to the country sector or origin of value. This view goes from the final production and tracks backward where the value was included. This is the backward perspective. The forward perspective is useful to characterize the circulation of value that a country has while the backward perspective is more suited to analyze the sourcing function of production. In the following sections, I will get some measures according to either one or the other perspective. It is important to remark that, if $\hat{V}B\hat{Y}$ is used as the starting point, always one of the two perspectives must be chosen.

The forward perspective of value chains: Following the use of domestic value added

Applying (7) in $\hat{V}B\hat{Y}$, we get:

$$\hat{V}B\hat{Y} = \hat{V}B^{reg}\hat{Y} + \hat{V}B^{reg}A^{-reg}B\hat{Y} \tag{10}$$

Substituting B^{reg} in (10) using (8) we get:

$$\hat{V}B\hat{Y} = \hat{V}L\hat{Y} + \hat{V}LA^{reg-d}B^{reg}\hat{Y} + \hat{V}LA^{-reg}B\hat{Y} + \hat{V}LA^{reg-d}B^{reg}A^{-reg}B\hat{Y}$$

Also, B in the third term can be decomposed using (9).

$$\hat{V}B\hat{Y} = \hat{V}L\hat{Y} + \hat{V}LA^{reg-d}B^{reg}\hat{Y} \\ + \hat{V}LA^{-reg}B^{ext}\hat{Y} + \hat{V}LA^{-reg}B^{ext}A^{-ext}B\hat{Y} + \hat{V}LA^{reg-d}B^{reg}A^{-reg}B\hat{Y}$$

First-term accounts for domestic value added included in final goods without border crossing of intermediates. It can be divided according to the destination of final goods, using Eq. (1).

$$\hat{V}B\hat{Y} = \hat{V}L\hat{Y}^{D} + \hat{V}L\hat{Y}^{R} + \hat{V}L\hat{Y}^{F} + \hat{V}L\hat{Y}^{H} + \hat{V}LA^{reg-d}B^{reg}\hat{Y} + \hat{V}LA^{-reg}B^{ext}\hat{Y} + \\ \hat{V}LA^{-reg}B^{ext}A^{-ext}B\hat{Y} + \hat{V}LA^{reg-d}B^{reg}A^{-reg}B\hat{Y} \tag{11}$$

Eq. (11) is a generalization of Wang et al (2017a) to the case of regional and extra-regional countries[8]. Each term of (11) is an N(G+H)xN(G+H) matrix. Pos-multiplying each term by an N(G+H)x1 vector of ones (u^T) we get accounting segregation of value added of each country-sector according to their participation in value chains and international trade. This split only holds for the first NG rows that represent the countries of the region. The NH following rows do not have interest from the perspective of regional value added.

---

[7] An alternative matrix can be defined by the country of consumption of final goods leading to Johnston and Noguera (2012) "valued added in exports", which traces value added from sourcing to consumption. Note that this alternative matrix is a N(G+H)x(G+H) matrix, where rows denote the country sector of origin and columns indicates country of consumption.

[8] It can be shown that if the region is the entire world and so the extra region is null (A^{-reg}=0; $\hat{Y}^{F}$=0), only the first, second, and fifth terms are non-null. In this case, we get $\hat{V}B\hat{Y} = \hat{V}L\hat{Y}^{D} + \hat{V}L\hat{Y}^{F} + \hat{V}LA^{F}B\hat{Y}$, which is Wang et al (2017a) disaggregation.

$$\hat{V}B\hat{Y}u^{T} = \hat{V}BY = Va = \hat{V}LY^{D} + \hat{V}LY^{R} + \hat{V}LY^{F} + \hat{V}LA^{reg-d}B^{reg}Y + \hat{V}LA^{-reg}B^{ext}Y + \hat{V}LA^{-reg}B^{ext}A^{-ext}BY + \hat{V}LA^{reg-d}B^{reg}A^{-reg}BY \tag{12}$$

Now, instead of matrices, we get seven vectors. The first NG rows are each sector of the G regional countries. Each flow is presented in table A1 in Appendix A.

The first term of (12) is the pure domestic value added included in local production for domestic demand. This value added does not cross any border. This term represents the activity of a country not related to international trade. Except for some small countries, this term accounts for most of the activity of a country. Analogously, $\hat{V}L\hat{Y}^{R}$is pure domestic value added in final goods exports to a regional partner. This value added only crosses borders once. The third term is analogous to the second but for extra-regional instead of regional consumption. The sum of the first, second, and third terms of Eq (12) is the value added of a country directly included in the production of final goods without crossing any border. Note that, as long as the production of final goods in a country can use foreign inputs, this value is lower than final goods production itself.

The rest of the terms (4 to 7) of Eq (12) is value added included in the export of intermediates and so involve any kind of Global Value Chains trade. The fourth term is the value added included in final goods produced in a regional country without any further stage in extra zone. It is labeled as Regional Value Chains (RVC) because it entails regional trade of intermediates but, at least from the perspective of the sourcing country s, it does not include extra-regional stages. RVC represents two or more regional countries sharing a chain of production. The fifth term is the value added in intermediates that are exported to extra-regional countries and transformed there into final goods without further participation of any regional country (including s). It is labeled as EVC in opposition to RVC and it represents the integration of a country with extra-regional production instead of regional integration. The final two terms, sixth and seventh, are the more complex and less sizable. They account for value added in s that is exported as intermediate and included in chains that involve both regional and extra-regional countries. As will be noted later, these chains have a minimum length of three, because it intervenes in at least one stage in the domestic country, one stage in the regional country, and one stage in the extra-regional country. The difference between terms sixth and seventh is the order of the operation, while in the former the order of value-added flow is domestic-extra regional-regional in the latter the sequence is domestic-regional-extra regional. They are labeled as Mixed Value Chains.

The backward perspective of value chains: Tracking the origin of value

Summing $\hat{V}B\hat{Y}$ across columns leads to the total final production of each country sector. After some manipulation analogous to the forward perspective[9], we get a disaggregation of final demand according to the origin of value.

$$u\hat{V}B\hat{Y} = VB\hat{Y} = Y^{T} = VL\hat{Y}^{D} + VL\hat{Y}^{R} + VL\hat{Y}^{F} + VB^{reg}A^{reg-d}L\hat{Y} + VB^{ext}A^{-reg}L\hat{Y} + VBA^{-ext}B^{ext}A^{-reg}L\hat{Y} + VBA^{-reg}B^{reg}A^{reg-d}L\hat{Y} \tag{13}$$

The first, second, and third terms account for the domestic value added directly included in the country of reference in domestic, regional, and extra-regional final demand respectively. The fourth term is the regional value added included in final production without any stage outside the region.

[9] The method includes using again (7), (8), (9) and the following equivalencies: $B^{reg}A^{-reg}B = BA^{-reg}B^{reg}$; $LA^{reg-d}B^{reg} = B^{reg}A^{reg-d}L$ and $B^{ext}A^{-ext}B = BA^{-ext}B^{ext}$

That is, the regional value added that after some regional circulation is used by the country of reference in its production of final products. It represents the backward view of regional integration in Value Chains. The fifth term is the extra-regional value added used in domestic final production without any stage in the rest of the region. It represents the backward view of participation in Extra regional Value Chains, as defined before. The sixth and seventh terms are both mixed value chains from a backward perspective.

Single and complex value chains and links with other measures of participation in value chains

At this point, it is useful to point out that RVC and EVC include flows of intermediates that cross borders at least one time. This means that includes intermediates imported by a country that are not further exported but simply used in domestic production. The multiple border crossing of intermediates is one of the most salient features of globalization and is behind the increasing divorce between statistics of trade and level of activity (Koopman, Wang, and Wei 2014). Some recognized measures define value chain participation as the share of value added in exports that cross borders twice or more (Borin and Mancini 2019).

To capture these flows Wang et al. (2017a) split the global value chains term according to single and complex value chains, both for forward and backward perspectives. Appendix C shows an adaptation of these measures to the scheme developed here, a comparison with Borin and Mancini's (2019) measures, and the empirical results of this exercise. An analysis of both kinds of measures of participation is also included in the 2021 WTO Report on Global Value Chains (Xing, Gentile, and Dollar 2021).

ii. Measuring the length and the position

Fally (2012), Antràs et al. (2012), and Antràs and Chor (2013) introduced definitions of product length, upstreamness, and dowstreamness in global value chains, using the concept of "Average Propagation Length" defined in Bosma, Romero Luna, and Dietzenbacher (2005). In doing so, they used the United States input-output table and did some adjustments to fit with international trade. Later, Antràs and Chor (2018) and Miller and Temurshoev (2017) used these definitions to characterize countries and sectors with World Input-Output Tables. While both articles find a strong correlation between upstreamness and downstreamness, Miller and Temurshoev (2017) show that these measures can be regarded as alternative row and column sums of the same set of information, and define the Output Upstreamness and Input Downstreamness to characterize sector and country position in global value chains.

This literature measures output upstreamness, from output to final demand, as the average number of times that the value is counted until it is included in a final good. Alternatively, define the input downstreamness as the average number of times that the value added has been counted until it is included in the output.

While using the same concepts behind previous definitions of upstreamness, downstreamness, and length of production, Wang et al. (2017b) point out that those measures are inconsistent because they start from the gross output and have been defined as gross measures, whereas, if defined from primary factors to the production of final goods, upstreamness and downstreamness of a particular country/sector in a global production network are the two faces of the same coin. Wang et al.

(2017b) state that both concepts are useful only concerning production length, and so they measure the relative distance of a particular production stage (country – sector) to the origin of value and the final production.

In a matrix notation, Wang et al. (2017b) define the average length of a chain as the element-wise ratio of two matrices:

$$PL = \frac{\hat{V}BB\hat{Y}}{\hat{V}B\hat{Y}} \tag{14}$$

The denominator is a matrix equivalent to $v_i^s b_{ij}^{sr} y_j^r$, that is, the total value added from a country sector included in final production from another country sector. The numerator is, like in Antràs and Chor (2018), the average number of times that the value-added originated in a sector of a country is counted as output in final production from another country sector. PL represents the weighted average of times that the value added of a country´s sector is counted as output in final production, and the weights are the amount added itself.

As mentioned earlier, the average length is useful if defined as a row or column sum. As in previous measures (Antràs et al. 2012; Miller and Temurshoev 2017), the forward perspective or producer's perspective of length is the row sum of the Ghosh inverse Matrix (H). This yields an N(G+H)x1 vector.

$$PLv = \frac{\hat{V}BB\hat{Y}u^T}{\hat{V}B\hat{Y}u^T} = \frac{\hat{V}BBY}{\hat{V}BY} = Hu^T \tag{15}$$

Analogously, the backward perspective or user's perspective, of length is the column sum of the Leontief inverse Matrix. This yields a 1xN(G+H) vector.

$$PLy = \frac{u\hat{V}BB\hat{Y}}{u\hat{V}B\hat{Y}} = \frac{VBB\hat{Y}}{VB\hat{Y}} = uB \tag{16}$$

While the forward- perspective traces the average number of times that value added of sector i of country s is counted in production until it is transformed into final demand in sector j of country r, the backward perspective traces the average number of stages that final production of sector *i* in country *s* must undergo from primary inputs. Wang et al. (2017b) apply the measures to the decomposition stated in Wang et al. (2017a), instead of doing it for the general set of information. By doing so, they can isolate the length of each specific kind of chain: there is a length for pure domestic chains, a length for traditional trade chains, and a length for global value chains. They define a length of chains for each of these three terms of their decomposition of $\hat{V}B\hat{Y}$.

Following Wang et al. (2017b) method, I divide the forward perspective of the total length of chains in the length of each term of Eq (12). By doing so, it could be identified the length of chains according to the kind of integration being considered. Each term of the regional or extra-regional value chain can be divided into two linkages: those taking place in the sourcing country and those taking place in the regional / extra-regional partner. The usefulness of this division is not only conceptual but also operative. Without dividing RVC or GVC total sharing into the stages that ensued before the first border crossing and the rest, it is not possible to get a formula for the accounting.

Appendix C shows the formula of forward-perspective length of chains for each term of Eq (12) and demonstrates the results. Equation (16) sets that there can be also a backward perspective of the length of chains, considering the number of stages that value added can have before being used as final goods by country of reference. Instead of using Eq (12), this perspective must use the backward-looking decomposition of Eq (13). The method and the algebra are like the forward-perspective case and so they will be omitted.

III. Measuring regional and global integration in value chains in Latin America

The data used is extracted from EORA- UNTACD database and covers in principle 189 countries and 26 sectors for the period 1990-2015. Data consists of a matrix of local and international intermediate transactions, local and international final demand, and value added (Lenzen et al. 2013). Despite having less disaggregation than other databases such as WIOD, their extensive period and availability of data for every Latin American country make it a database useful for studies for developing regions.

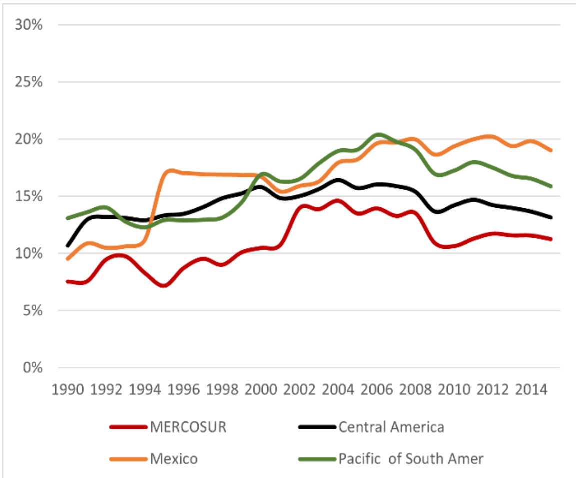
i. The overall evolution of the international trade-related activity

Based on Eq (12), Figure 1 and Table 2 shows the evolution of value added in activities related to international trade in the period from 1990 to 2015 for selected regions. Table D1 in Appendix shows the disaggregation of table 2 for each Latin American country in the sample. The overall picture of the figure and tables shows some salient features that cannot be retrieved form databases with less time and country coverage. First, despite being a minor share of economic activity of countries, the value related to international trade increased for all regions. Most of the increase was in the first part of the period and there is a reversal of globalization after the global crisis except in Europe. Second, Europe and East Asia started at a higher level, but they are also the most dynamic regions, while America is lagged. Third, regionalization was the driving force of internationalization, especially in Asia.

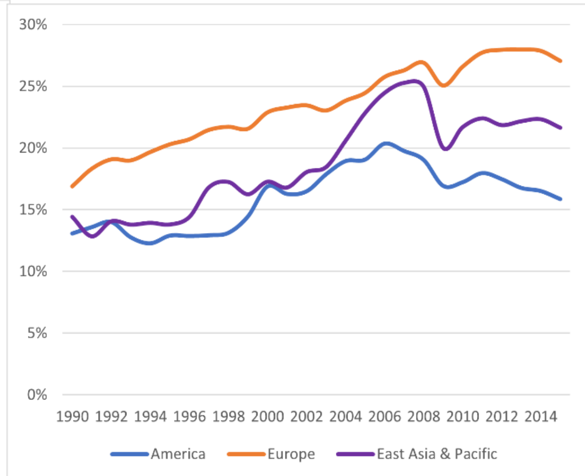
In Latin America[10], Mexico experienced a strong rise in the integration in the early years of the agreement with the USA and Canada and is the most engaged in international sharing of production, with a regional profile. The rest of regions experienced less integration, especially MERCOSUR. Departing from lower levels, every region in Latin America experienced a higher pace of regionalization than integration with global markets. The results confirm the findings of Moncarz et al. (2021) that most part of the continent is lagged in fragmentation of production and that regional integration is below levels of other regions of reference.

[10] For Mexico, the trade with the USA and Canada will be labeled as regional and the rest is extra-regional. For the seven Central American Countries (including also Dominican Rep.), the trade among themselves will be regional and the rest is extra-regional. Finally, for the ten South American countries the same definition holds, that is trade among themselves is considered regional while the rest is considered extra-regional. Appendix E shows the definition of each region and the countries that, for computational aspects or for having problems in data were left behind.

Figure 1. **Share of activities related to international trade in value added**



a) Global manufacturing hubs



b) Latin America

Source: Own elaboration using EORA

Table 2. **Share of activities related to trade by type of activity**. In % of value added

	1990				2015			
	Final goods and services		Value Chains		Final goods and services		Value Chains	
	Regional	Extra regional	Regional	Extra regional	Regional	Extra regional	Regional	Extra regional
Latin America								
Mexico	2.8	0.5	3.7	2.2	7.1	1.2	7.5	2.5
Central America	0.6	3.9	0.7	5.4	1.4	5.4	1.3	4.9
MERCOSUR	0.5	1.7	0.9	4.3	1.7	2.2	2.1	5.0
SA Pacific	0.5	2.5	1.2	7.8	1.3	2.5	2.2	8.9
Global Factories								
Europe	4.7	2.2	8.0	2.3	6.3	3.9	11.2	4.6
ASEAN + 3	2.0	3.4	3.6	4.7	3.8	4.2	6.8	5.6
North America	1.0	1.9	1.9	4.2	1.8	2.2	3.2	4.3

Source: Own elaboration using EORA

ii. Size and Position of Latin American Countries in Regional and Global value chains

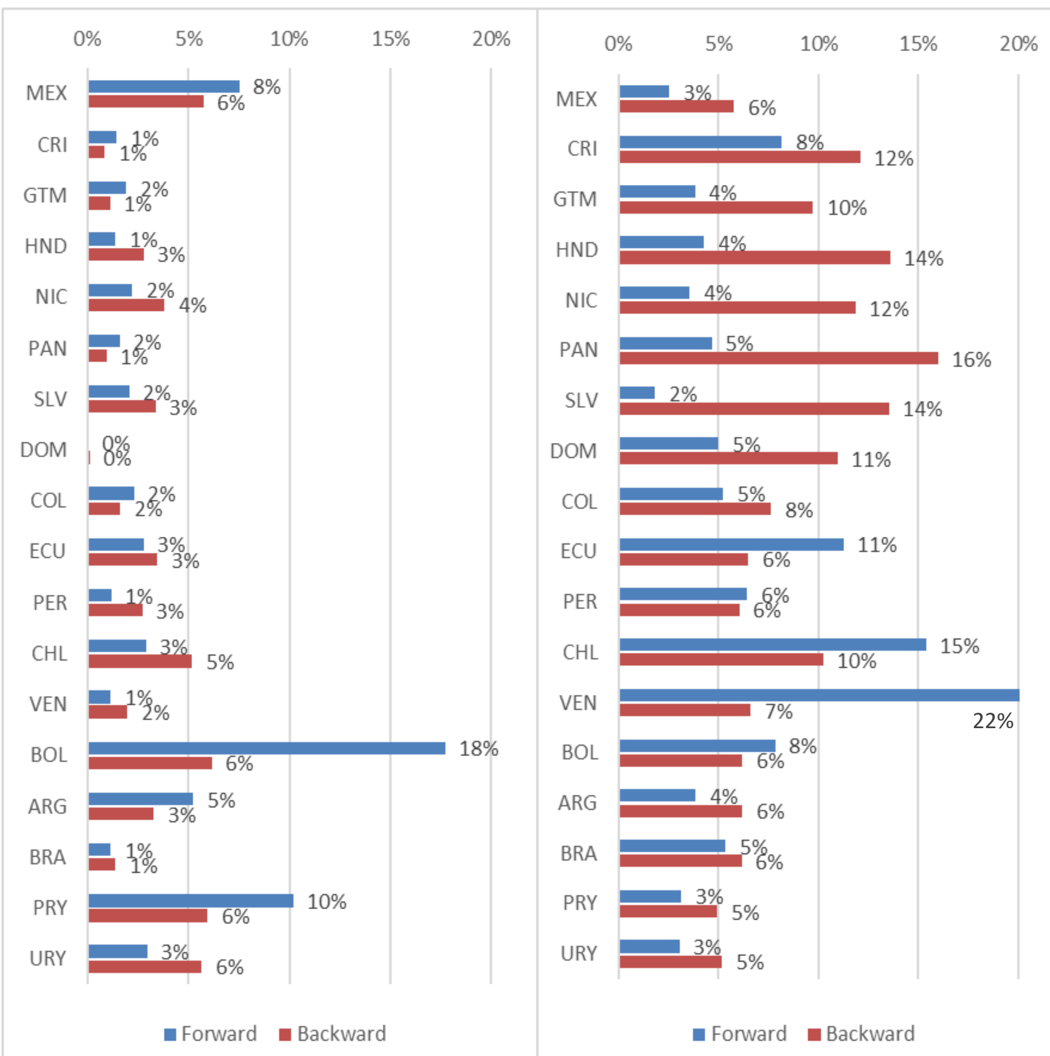
As Wang et al. (2017a) point out, the role of a country in value chains cannot be completely described only by analyzing the use or destination of its own value added, but should also consider the use that it does of other countries' value. That is, the backward perspective must complement the forward. In Wang et al. (2017a) framework, the comparison between forward and backward linkages makes sense only for value chain terms because the terms that capture domestic value added in final goods production do not show differences at a country level.

Figure 2 shows the backward and forward position for all Latin American countries, as a share of their own value added in Regional and Extra regional chains.

Figure 2. **Forward and Backward participation in value chains. As shares in value added of each country.** Years 2014-15

a) RVC

b) EVC



Source: Own elaboration

A comprehensive study of results presented in Figures 1 and 2 and Tables 2 and D1 get the following findings. Argentina, Bolivia, Paraguay and México raised its importance in forward and regional value chains. Mexico is usually showed as a typical example of backward integration in value chains (World Bank 2019). Nevertheless, if we consider only the regional interaction of this value, Mexico changed its position in the period. Graph D2 in Appendix shows the evolution of Mexico in the period in RVC and EVC both in a forward and backward basis. The reason behind the surprising wave in Mexico is the increasing use of extra regional inputs in its production, mostly from China. Comparing both extremes of the data period, Mexico raised their forward participation in RVC, that is, it includes more domestic value in intermediates sold to USMCA but raised its backward participation only in EVC, not in RVC, that is, the share of USMCA value in their total production remained at low levels. This result is consistent with Antràs and De Gortari (2020) finding of a U-shaped relation in integration and trade costs and is probably behind the renegotiation of the rules of origin included in the USMCA Treaty, where more tighten rules for non-partner inputs were set in several sectors. The other Latin American countries do not show this pattern, which is consistent with being in an early stage of reduction of trade costs, as is shown in Moncarz et al. (2021).

The rest of South American countries perform strong involvement in EVC (except Uruguay) but their differ in the bias. Chile, Ecuador and Venezuela are forward biased and Brazil, Colombia and Perú, despite being also strong exporters of mineral-based commodities to global markets, perform balanced positions. Chile performs also an outstanding involvement in backward chains, both regional and extra regional.

Every Central American country experienced a rise in EVC participation until the global crisis and a fall thenceforth. Every Central American countries' participation in EVC is backward biased, showing that these countries tend to participate in international trade at the end of global chains. RVC in Central America are less important but they have a rising tendency.

iii. Exploring the sources of length in global value chains

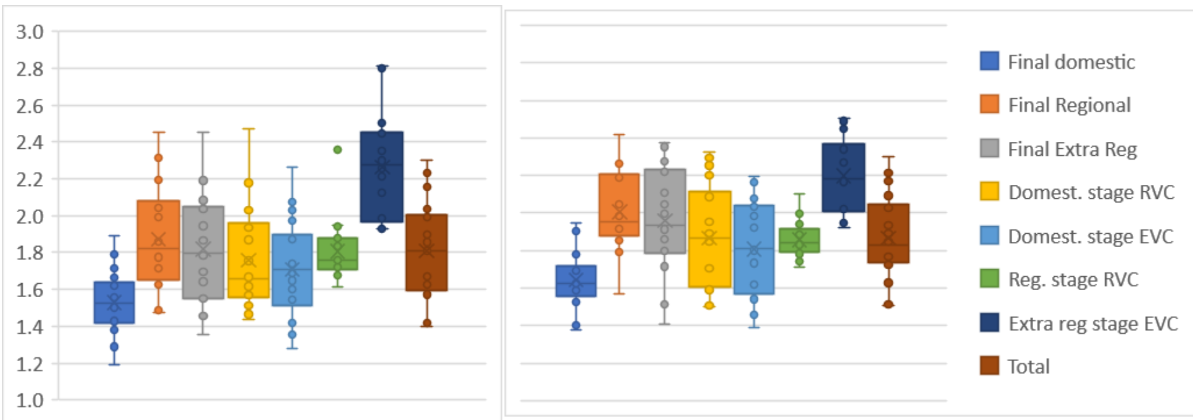
Section II.iii showed the adaptation of Wang et al. (2017a) to the framework of regional and global value chains. Appendix B (Table B2) showed the decomposition of total length in Domestic, Regional, Extra regional, and Mixed Value Chains from a forward perspective.

Figure 3 shows the dispersion of average length of chains considering every component of table C1 divided by their corresponding term of Equation (11). Figure D1 in the Appendix shows the evolution by country in each term.

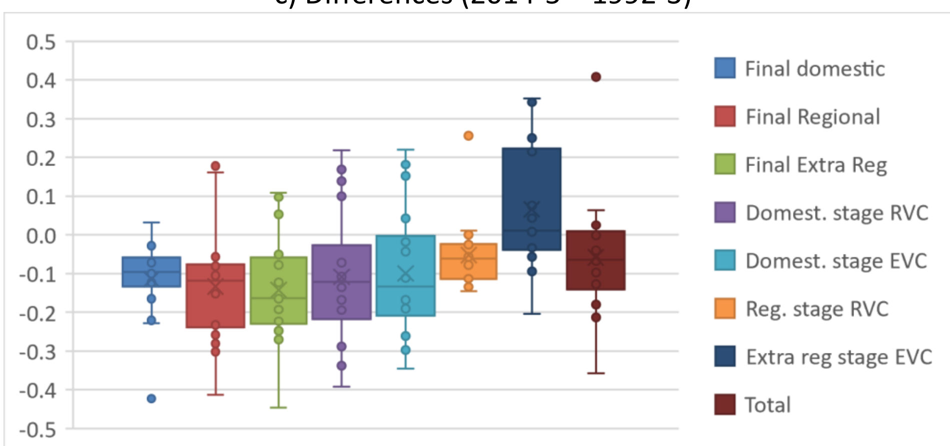
Domestic value chains for domestic consumption are systematically shorter than other stages. Domestic length in final good exports decreased considerably in the period, with a special pace in extra-regional exports of final goods. The domestic stage of Regional and Extra regional value chains also decreased and are consistently higher in RVC. The extra regional length of EVC is higher than any other and increased in the period, showing higher fragmentation of production in the world. As a result of these changes, the total length of chains decreased in Latin American countries, except in Bolivia, where the rising importance of the relatively long regional stage of RVC counterweighted the decreasing trend in domestic stages.

Figure 3- **Dispersion of average length of chains according to segment. Forward perspective. Latin American countries.** Years 1992/3 and 2014/5 and differences between periods.

a) 2014-15 b) 1992-93



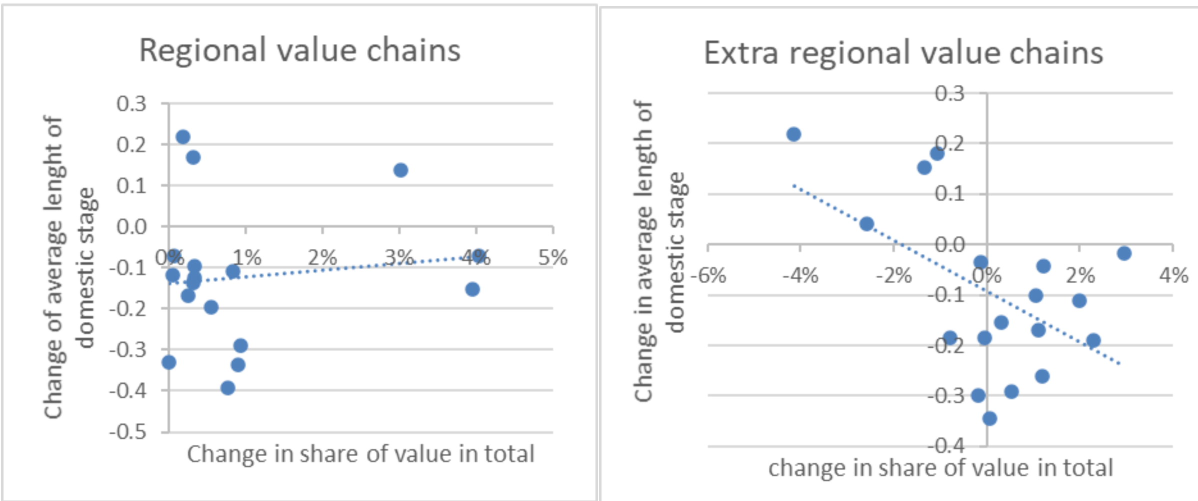
c) Differences (2014-5 – 1992-3)



Source: Own elaboration using EORA

The average length of a chain in a country could be a useful indicator of how participation in Global Value Chains determines the specialization of a Country. Figure 4 relates the variation of participation in chains (as a share of value added) with the variation of length of the domestic stage of value chains, showing that the countries that increased their involvement in extra-regional value chains decreased more the domestic length of their chain. In regional trade this relationship is less clear, giving the idea that the participation in regional value chains did not result in increasing specialization of Latin American countries.

Figure 4. **Change in average length and in share of value in total value added of Latin American Countries**. Change in 2014/5 relative to 1992/93. In differences.



Source: Own elaboration using EORA

IV. Concluding remarks.

The use of measures of involvement in both regionalization and globalization with WIOT along 25 years of integration can help to describe some aspects of the process of internalization that remain unveiled in previous work that study the performance of Latin American countries in value chains.

Departing from low levels, participation in RVC rose at higher pace than participation in EVC. It is known that value chains are more regional than global (World Bank 2019) but it Latin America there is still prevalent the international sharing of production with extra regional partners.

From 1990 to 2015, the engagement on activities related to international trade as a share of total activity grew in most countries of Latin America, with a stop around the global crisis of 2008-09. Nevertheless, except for Mexico, every subregion of Latin America still maintains a level of interaction with international markets lower than the Western and Central European or the Southeast and East Asian countries.

While the participation in global value chains was increasing in most countries of the sample, there are strong differences in the type of participation measured as the position in the value chain and in the geographical scope of the trade. Mexico, Argentina, Bolivia, and Paraguay strongly increased their involvement in RVC as the source of value (forward). Central American countries, despite having increased their participation in value chains, still underperform compared with Mexico. Nevertheless, they have an increasing regional trade pattern.

Trade cost of Mexico are lower than other Latin American regions (Moncarz et al 2021) and, consistently with Antràs and the Gortari (2020) relationship between trade cost and domestic, regional and global value chain participation, this article finds a reversal in the regionalization of Mexican participation characteristic of the second stage in trade costs reduction, while the other countries appear to be still in early high trade costs stages.

Adapting methodologies for studying length and position in value chains with a regional scope, this article describes by first time the length of chains in Latin America, discriminating both domestic and international stages in both RVC and EVC. This article shows how dividing the participation in the value chain can be useful to analyze the sources of the change in length of chains and found a negative association between participation and length of chains in Latin American countries, that is, the countries more involved (in terms of their own activity) in value chains tend to increase the specialization in the production process, essentially in Extra Regional Value Chains. In other words, participation in EVC was a major driving force for reduction in length of domestic stages, while regional was not.

This preliminary finding encourages more systematic research about the relationship in participation and length of chains not only in Latin America but in other more integrated regions.

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Appendix

A- Measures of participation in value chains: Definitions and Algebra

1. **Definitions**

Subpartitions of A used in section II.i:

$$A^{D}=\begin{bmatrix} A^{ss} & \dots & 0 & 0 & \dots & 0 \\ \vdots & \ddots & \vdots & \vdots & \ddots & \vdots \\ 0 & \cdots & A^{tt} & 0 & \cdots & 0 \\ 0 & \cdots & 0 & A^{ff} & \cdots & 0 \\ \vdots & \ddots & \vdots & \vdots & \ddots & \vdots \\ 0 & \cdots & 0 & 0 & \cdots & A^{kk} \end{bmatrix};A^{F}=A-A^{D}=\begin{bmatrix} 0 & A^{su} & A^{st} & A^{sf} & \dots & A^{sk} \\ A^{us} & \ddots & \vdots & \vdots & \ddots & \vdots \\ A^{ts} & \cdots & 0 & A^{tf} & \cdots & A^{tk} \\ A^{fs} & \cdots & A^{ft} & 0 & \cdots & A^{fk} \\ \vdots & \ddots & \vdots & \vdots & \ddots & \vdots \\ A^{ks} & \cdots & A^{kt} & A^{kf} & \cdots & 0 \end{bmatrix}$$

$$A^{reg}=\begin{bmatrix} A^{ss} & \dots & A^{st} & 0 & \dots & 0 \\ \vdots & \ddots & \vdots & \vdots & \ddots & \vdots \\ A^{ts} & \cdots & A^{tt} & 0 & \cdots & 0 \\ 0 & \cdots & 0 & 0 & \cdots & 0 \\ \vdots & \ddots & \vdots & \vdots & \ddots & \vdots \\ 0 & \cdots & 0 & 0 & \cdots & 0 \end{bmatrix};A^{-reg}=A-A^{reg}=\begin{bmatrix} 0 & \dots & 0 & A^{sf} & \dots & A^{sk} \\ \vdots & \ddots & \vdots & \vdots & \ddots & \vdots \\ 0 & \cdots & 0 & A^{tf} & \cdots & A^{tk} \\ A^{fs} & \cdots & A^{ft} & A^{ff} & \cdots & A^{fk} \\ \vdots & \ddots & \vdots & \vdots & \ddots & \vdots \\ A^{ks} & \cdots & A^{kt} & A^{kf} & \cdots & A^{kk} \end{bmatrix}$$

$$A^{d}=\begin{bmatrix} A^{ss} & \dots & 0 & 0 & \dots & 0 \\ \vdots & \ddots & \vdots & \vdots & \ddots & \vdots \\ 0 & \cdots & A^{tt} & 0 & \cdots & 0 \\ 0 & \cdots & 0 & 0 & \cdots & 0 \\ \vdots & \ddots & \vdots & \vdots & \ddots & \vdots \\ 0 & \cdots & 0 & 0 & \cdots & 0 \end{bmatrix}; \qquad A^{reg-d}=A^{reg}-A^{d}=\begin{bmatrix} 0 & A^{su} & A^{st} & 0 & \dots & 0 \\ A^{us} & \ddots & \vdots & \vdots & \ddots & \vdots \\ A^{ts} & \cdots & 0 & 0 & \cdots & 0 \\ 0 & \cdots & 0 & 0 & \cdots & 0 \\ \vdots & \ddots & \vdots & \vdots & \ddots & \vdots \\ 0 & \cdots & 0 & 0 & \cdots & 0 \end{bmatrix}$$

$$A^{ext}=\begin{bmatrix} 0 & \dots & 0 & 0 & \dots & 0 \\ \vdots & \ddots & \vdots & \vdots & \ddots & \vdots \\ 0 & \cdots & 0 & 0 & \cdots & 0 \\ 0 & \cdots & 0 & A^{ff} & \cdots & A^{fk} \\ \vdots & \ddots & \vdots & \vdots & \ddots & \vdots \\ 0 & \cdots & 0 & A^{kf} & \cdots & A^{kk} \end{bmatrix};A^{-ext}=A-A^{ext}=\begin{bmatrix} A^{ss} & \dots & A^{st} & A^{sf} & \dots & A^{sk} \\ \vdots & \ddots & \vdots & \vdots & \ddots & \vdots \\ A^{ts} & \cdots & A^{tt} & A^{tf} & \cdots & A^{tk} \\ A^{fs} & \cdots & A^{ft} & 0 & \cdots & 0 \\ \vdots & \ddots & \vdots & \vdots & \ddots & \vdots \\ A^{ks} & \cdots & A^{kt} & 0 & \cdots & 0 \end{bmatrix}$$

2. Algebra

Demonstration of (7), (8), (9)

Demonstration of (7):

$$B=B^{reg}-B^{reg}A^{-reg}B$$

$$\begin{aligned} B^{reg}A^{-reg}B=B^{reg}(A-A^{reg})B= & \ (I-A^{reg})^{-1}(A-A^{reg})(I-A)^{-1} \\ & =\left(I+A^{reg}+A^{reg^2}+A^{reg^3}+\cdots\right)(A-A^{reg})(I+A+A^2+A^3+\cdots)= \end{aligned}$$

$$\left(A+A^{reg}A+A^{reg^2}A+A^{reg^3}A+\cdots-A^{reg}-A^{reg^2}-A^{reg^3}-A^{reg^4}\right)(I+A+A^2 \\ +A^3+\cdots)=$$

$$A+A^{reg}A+A^{reg^2}A+A^{reg^3}A+\cdots-A^{reg}-A^{reg^2}-A^{reg^3}-A^{reg^4}+$$

$$A^2 + A^{reg}A^2 + A^{reg^2}A^2 + A^{reg^3}A^2 + \cdots - A^{reg}A - A^{reg^2}A - A^{reg^3}A - A^{reg^4}A +$$

$$A^3 + A^{reg}A^3 + A^{reg^2}A^3 + A^{reg^3}A^4 + \cdots - A^{reg}A^2 - A^{reg^2}A^2 - A^{reg^3}A^2 - A^{reg^4}A^2 + \cdots =$$

$$A + A^2 + A^3 + A^4 + \cdots - A^{reg} - A^{reg^2} - A^{reg^3} - A^{reg^4} + \cdots =$$

$$(I + A + A^2 + A^3 + A^4 + \cdots) - (I + A^{reg} + A^{reg^2} + A^{reg^3} + A^{reg^4} + \cdots) =$$

$$= B - B^{reg}$$

Demonstration of (9):

$$B = B^{ext} - B^{ext}A^{-ext}B$$

Replacing B^{ext} instead of B^{reg} and A^{-ext} instead of A^{-reg} and apllying the same logic as above relationship is demostrated.

Demonstration of (8):

$$B^{reg} = L - LA^{reg-d}B^{reg}$$

Replacing L instead of B^{reg} in Eq (7), B^{reg} instead of B and A^{reg-d} instead of A^{-reg} and apllying the same logic as above relationship is demostrated.

3 Table

Table A1. Accounting segregation of value added according to circulation. Forward perspective

Term	Name	Concept
$\hat{V}LY^D$	Pure domestic Value Added	Domestic VA included directly in domestically consumed final goods
$\hat{V}LY^R$	Traditional exports to the region	DVA included directly in final goods exported to the region
$\hat{V}LY^F$	Traditional exports to extra-region	DVA included directly in final goods exported to extra region
$\hat{V}LA^{reg-d}B^{reg}Y$	Regional Value Chains	DVA incorporated to the production of final goods in the region without stages in extra-region
$\hat{V}LA^{-reg}B^{ext}Y$	Extra Regional Value Chains	DVA in intermediates exported to extra-region for production of final goods without stages in any country of the region
$\hat{V}LA^{-reg}B^{ext}A^{-ext}BY$ $\hat{V}LA^{reg-d}B^{reg}A^{-reg}BY$	Mixed Value Chains	DVA in intermediates included in production of final goods where both regional and extra-regional countries participate

Source: Own elaboration

Appendix B- Measures of Length in Value Chains

1. Algebra of Domestic Length of RVC and Regional Length of RVC.

Note: This Appendix includes only the algebra for RVC ($\hat{V}LA^{reg-d}B^{reg}Y$). Replacing A^{reg-d} by A^{-reg} and B^{reg} by B^{ext}, the same can be done for EVC.

$$
\begin{aligned}
\hat{V}LA^{reg-d}B^{reg}Y &= \hat{V}\left(I - A^{d}\right)^{-1}A^{reg-d}(I - A^{reg})^{-1}Y \\
&= \hat{V}\left(I + A^{d} + \left(A^{d}\right)^{2} + \left(A^{d}\right)^{3} + \left(A^{d}\right)^{4} + \cdots\right)A^{reg-d}(I + A^{reg} + (A^{reg})^{2} \\
&\quad + (A^{reg})^{3} + (A^{reg})^{4} + \cdots)Y \\
&= \hat{V}A^{reg-d}\hat{Y} + \hat{V}A^{d}A^{reg-d}\hat{Y} + \hat{V}A^{reg-d}A^{reg}\hat{Y} + \hat{V}A^{d}A^{d}A^{reg-d}\hat{Y} \\
&\quad + \hat{V}A^{d}A^{reg-d}A\hat{Y} + \hat{V}A^{reg-d}A^{reg}A^{reg}\hat{Y} + \cdots.
\end{aligned}
$$

So, total value added in Regional Value Chains can be divided in infinite terms that multiply some domestic stages and some regional stages. X_d accounts for stages occurring before the cross border (A^{reg-d}) and X_f accounts for the cross border and the stages occurring after. Total stages are $X_d + X_f$. Dividing the chains in this way, we can reproduce the logic of the original method of counting stages.

Table B1: Accounting for stages in regional value chains according to place of production

Total Stages	Value Added	Stages before A^{reg-d}	Stages in A^{reg-d} and after	Weight in X_d	Weight in X_i
2	$\hat{V}A^{reg-d}\hat{Y}$	$\hat{V}$	A^{reg-d}	1	1
3	$\hat{V}A^{d}A^{reg-d}\hat{Y}$	$\hat{V}A^{d}$	A^{reg-d}	2	1
3	$\hat{V}A^{reg-d}A^{reg}\hat{Y}$	$\hat{V}$	$A^{reg-d}A^{reg}$	1	2
4	$\hat{V}A^{d}A^{d}A^{reg-d}\hat{Y}$	$\hat{V}A^{d}A^{d}$	A^{reg-d}	3	1
4	$\hat{V}A^{d}A^{reg-d}A\hat{Y}$	$\hat{V}A^{d}$	$A^{reg-d}A^{reg}$	2	2
4	$\hat{V}A^{reg-d}A^{reg}A^{reg}\hat{Y}$	$\hat{V}$	$A^{reg-d}A^{reg}A^{reg}$	1	3
5	$\hat{V}A^{d}A^{d}A^{d}A^{reg-d}\hat{Y}$	$\hat{V}A^{d}A^{d}A^{d}$	A^{reg-d}	4	1
5	$\hat{V}A^{d}A^{d}A^{reg-d}A^{reg}\hat{Y}$	$\hat{V}A^{d}A^{d}$	$A^{reg-d}A^{reg}$	3	2
5	$\hat{V}A^{d}A^{reg-d}A^{reg}A^{reg}\hat{Y}$	$\hat{V}A^{d}$	$A^{reg-d}A^{reg}A^{reg}$	2	3
5	$\hat{V}A^{reg-d}A^{reg}A^{reg}A^{reg}\hat{Y}$	$\hat{V}$	$A^{reg-d}A^{reg}A^{reg}A^{reg}$	1	4
…					

Total Value added in RVC ($\hat{V}LA^{reg-d}B\hat{Y}$) can be split in the terms of second column of table B1:

$$
\begin{aligned}
VY\_RVC = {} & \hat{V}A^{reg-d}\hat{Y} + \hat{V}A^{d}A^{reg-d}\hat{Y} + \hat{V}A^{reg-d}A\hat{Y} + \hat{V}A^{d}A^{d}A^{reg-d}\hat{Y} + \hat{V}A^{d}A^{reg-d}A\hat{Y} \\
& + \hat{V}A^{reg-d}AA\hat{Y} + \hat{V}A^{d}A^{d}A^{d}A^{reg-d}\hat{Y} + \hat{V}A^{d}A^{d}A^{reg-d}A\hat{Y} \\
& + \hat{V}A^{d}A^{reg-d}AA\hat{Y} + \hat{V}A^{reg-d}AAA\hat{Y} + \cdots =
\end{aligned}
$$

$$
\begin{aligned}
= {} & \hat{V}(I + A^{d} + (A^{d})^{2} + \cdots)A^{reg-d}\hat{Y} + \hat{V}(I + A^{d} + (A^{d})^{2} + \cdots)A^{reg-d}A\hat{Y} \\
& + \hat{V}(I + A^{d} + (A^{d})^{2} + \cdots)A^{reg-d}A^{2}\hat{Y} + \cdots \\
& = \hat{V}(I - A^{d})^{-1}A^{reg-d}(I - A)^{-1}\hat{Y} = \hat{V}LA^{reg-d}B\hat{Y}
\end{aligned}
$$

Domestic Length of RVC ($X_{d_{RVC}}$) account for the stages that occur in the economy of reference:

$$
\begin{aligned}
X_{d_{RVC}} = {} & \hat{V}A^{reg-d}\hat{Y} + \hat{V}A^{reg-d}A^{reg}\hat{Y} + 2\hat{V}A^{d}A^{reg-d}\hat{Y} + 3\hat{V}A^{d}A^{d}A^{reg-d}\hat{Y} \\
& + 2\hat{V}A^{d}A^{reg-d}A^{reg}\hat{Y} + \hat{V}A^{reg-d}A^{reg}A^{reg}\hat{Y} + 4\hat{V}A^{d}A^{d}A^{d}A^{reg-d}\hat{Y} \\
& + 3\hat{V}A^{d}A^{d}A^{reg-d}A^{reg}\hat{Y} + 2\hat{V}A^{d}A^{reg-d}A^{reg}A^{reg}\hat{Y} \\
& + \hat{V}A^{reg-d}A^{reg}A^{reg}A^{reg}\hat{Y} + \cdots \\
& = \hat{V}A^{reg-d}(I + A^{reg} + A^{reg}A^{reg} + \cdots)\hat{Y} \\
& + 2\hat{V}A^{d}A^{reg-d}(I + A^{reg} + A^{reg}A^{reg} + \cdots)\hat{Y} \\
& + 3\hat{V}A^{d}A^{d}A^{reg-d}(I + A^{reg} + A^{reg}A^{reg} + \cdots)\hat{Y} + \cdots \\
& = \hat{V}(I + 2A^{d} + 3A^{d}A^{d} + \cdots)A^{reg-d}(I + A^{reg} + A^{reg}A^{reg} + \cdots)\hat{Y} =
\end{aligned}
$$

$$
= \hat{V}\left(I + A^{d} + A^{d^2} + \cdots\right)(I - A^{d})^{-1}A^{reg-d}B^{reg}\hat{Y} = \hat{V}LLA^{reg-d}B^{reg}\hat{Y}
$$

While international length of RVC ($X_{i_{RVC}}$) account for the stages that happen after the input abandoned the country of reference

$$
\begin{aligned}
X_{i_{RVC}} = {} & \hat{V}A^{reg-d}\hat{Y} + 2\hat{V}A^{reg-d}A^{reg}\hat{Y} + \hat{V}A^{d}A^{reg-d}\hat{Y} + \hat{V}A^{d}A^{d}A^{reg-d}\hat{Y} \\
& + 2\hat{V}A^{d}A^{reg-d}A^{reg}\hat{Y} + \widehat{3V}A^{reg-d}A^{reg}A^{reg}\hat{Y} + \hat{V}A^{d}A^{d}A^{d}A^{reg-d}\hat{Y} \\
& + 2\hat{V}A^{d}A^{d}A^{reg-d}A^{reg}\hat{Y} + 3\hat{V}A^{d}A^{reg-d}A^{reg}A^{reg}\hat{Y} \\
& + 4\hat{V}A^{reg-d}A^{reg}A^{reg}A^{reg}\hat{Y} + \cdots = \\
& = \hat{V}(I + A^{d} + A^{d}A^{d} + \cdots)A^{reg-d}\hat{Y} \\
& + 2\hat{V}(I + A^{d} + A^{d}A^{d} + \cdots)A^{reg-d}A^{reg}\hat{Y} \\
& + 3\hat{V}(I + A^{d} + A^{d}A^{d} + \cdots)A^{reg-d}A^{reg}A^{reg}\hat{Y} + \cdots
\end{aligned}
$$

$$
= \hat{V}LA^{reg-d}B^{reg}\left(I + A^{reg} + A^{reg^2} + \cdots\right)\hat{Y} = \hat{V}LA^{reg-d}B^{reg}B^{reg}\hat{Y}
$$

Total length of RVC chains is $X_{d_{RVC}}$+$X_{i_{RVC}}$=$\hat{V}LLA^{reg-d}B^{reg}\hat{Y} + \hat{V}LA^{reg-d}B^{reg}B^{reg}\hat{Y}$

The average times that value added from sector *i* of country *s* involved in regional value chains is counted as output is: $\frac{X_{i_{RVC}}+X_{i_{RVC}}}{VY\_GVC} = \frac{\hat{V}LLA^{reg-d}B^{reg}\hat{Y}+\hat{V}LA^{reg-d}B^{reg}B^{reg}\hat{Y}}{\hat{V}LA^{reg-d}B^{reg}\hat{Y}}$.

This method applied to every term of Eq (11) yields the following terms. The numerator of total length of chains ($\hat{V}BBY$) is splitted in the subsequent terms of Table B2.

Table B2. Measures of forward perspective of length in value chains

Name	Formula	Concept
TOTAL	$\hat{V}BBY$	Total forward length of chains
Pure domestic Value Added	$\hat{V}LLY^{D}$	Length of pure domestic chains
Traditional exports to region	$\hat{V}LLY^{R}$	Length of domestic chains for regional export of final goods
Traditional exports to extra region	$\hat{V}LLY^{F}$	Length of domestic chains for extra regional export of final goods
Regional Value Chains	$\hat{V}LLA^{reg-d}B^{reg}Y$	Domestic length of RVC
	$\hat{V}LA^{reg-d}B^{reg}B^{reg}Y$	Regional length of RVC
Extra Regional Value Chains	$\hat{V}LLA^{-reg}B^{ext}Y$	Domestic length of GVC
	$\hat{V}LA^{-reg}B^{ext}B^{ext}Y$	Extra regional length of GVC
Mixed Value Chains	$\hat{V}LLA^{-reg}B^{ext}A^{-ext}BY$	Domestic length of mixed chains type 1
	$\hat{V}LA^{-reg}B^{ext}B^{ext}A^{-ext}BY$	Extra regional length of mixed chains type 1
	$\hat{V}LA^{-reg}B^{ext}A^{-ext}BBY$	Global length of mixed chains type 1
	$\hat{V}LLA^{reg-d}B^{reg}A^{-reg}BY$	Domestic length of mixed chains type 2
	$\hat{V}LA^{reg-d}B^{reg}B^{reg}A^{-reg}BY$	Regional length of mixed chains type 2
	$\hat{V}LA^{reg-d}B^{reg}A^{-reg}BBY$	Global length of mixed chains type 2

Appendix C- Single and complex value chains and links with other measures of participation in value chains

Regional value chains in forward-perspective (fourth term of Eq 12) can be divided into single and complex chains according to (C1):

$$RVC_{fw} = SRVC_{fw} + CRVC_{fw} = \hat{V}LA^{reg-d}LY^{D} + \hat{V}LA^{reg-d}(B^{reg}Y - LY^{D}) \qquad \text{(C1)}$$

Note that the first term of Eq. (C1) contains only one term linked to international trade (A^{reg-d}) and the rest of the terms are local ($\hat{V}$, L and Y^{D}). The second term, that is complex value chains, is calculated as the difference between total and single. Note that $B^{reg} \geq L$ and $Y \geq Y^{D}$, then, once the intermediate is exported from the sourcing country, the complex chains can be the result of cross bordering of intermediates or final products.

The calculus for extra regional value chains is similar but some extra notation is required. The final production for domestic use in extra regional countries (Y^{DE}) is a subpart of Y^{H}(see eq 1). Then, $Y^{H} = Y^{DE} + Y^{*}$, where Y^{*} is the share of the final production of extra regional countries that is exported. Both Y^{DE} and $Y^{*}$are N(G+H)x1 vectors. L' is defined in Eq. 6.

$$EVC_{fw} = SEVC_{fw} + CEVC_{fw} = \hat{V}LA^{-reg}L'Y^{DE} + \hat{V}LA^{-reg}(B^{ext}Y - L'Y^{DE}) \qquad \text{(C2)}$$

The definition of single and complex in the backward perspective is analogous and so it will be omitted.

Borin and Mancini (2019)

defined the Hummels et. al (2001) classical indexes of Vertical Share (VS) (for backward participation) and VS1 (for forward participation) in an overall formula. They define the GVC participation ratio used in the 2020 World Development Report (World Bank 2019) at a country level as $GVCX^{s} = uE^{s*} - DAVAX^{s*}$, where last term is defined as:

$$DAVAX^{s*} = \sum_{r \neq s}^{G} V^{s}L^{s}Y^{sr} + \sum_{r \neq s}^{G} V^{s}L^{s}A^{sr}L^{r}Y^{rr} \qquad \text{(C3)}$$

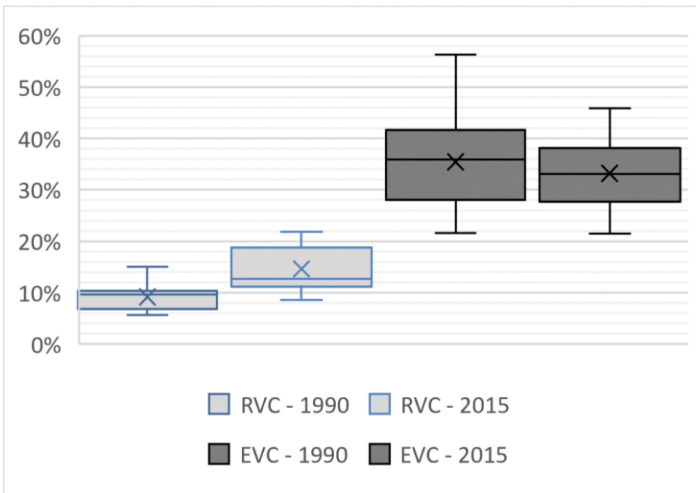
DAVAX is the value added exported from s to r that is directly absorbed there, without any further border crossing. The first term is equivalent to traditional exports in the Wang et al. (2017a) scheme and the second is equivalent to single value chains. Given that these terms are netted from total exports the remaining is GVC participation, it is straightforward to conclude that Borin and Mancini's (2019) measure of GVC trade captures the same transactions as the WWYZa "Complex GVC trade". The difference between Borin and Mancini (2019) and Wang et al. (2017a) Complex CGV ratio participation is that whereas the latter measure is based on value added terms, Borin and Mancini (2019) measure is based on gross export.

While the former is useful to size the penetration of GVC in economic activity, the latter is used to characterize specifically international trade. An analysis of both Measures of participation is included in the 2021 Report on Global Value Chains (XING, GENTILE, and DOLLAR 2021).

While in Single Value Chains the value added crosses borders just once and is consumed in destination, the attribute of Complex is the multiple border crossing. In the forward perspective, it means that value added exported by country s to country r is then reexported by r as another intermediate or final good. This flow gives rise to double counting of value added if gross exports are used[11].

Eq (C1) and (C2) show the division among single and complex value chains. Figure C1 shows the dispersion of the share of complex value chains in total in two periods for Latin American countries, according to the kind of value chain. Complex accounts for about a third of ERV in both periods. While in Central American countries and in Mexico the share of the complex in total in ERV decreased in the period, in most South American countries the trend was the opposite. In RVC, Complex VC shares a small portion of the total, but the magnitude raised about 50% in the period.

Figure C1. **Dispersion of share of Complex Value Chains in Total Value Chain, by kind of Chain. 1990 and 2015.** Latin American countries



Source: Own elaboration based on EORA

The distinction made between simple and complex is useful for the purpose of comparing the measures used in this article with some measures commonly used in the literature. Borin and Mancini (2019) set a measure of participation in GVC that includes classic Vertical Share (VS) measure of backward participation and a new measure for VS1 concept of forward participation (Hummels, Ishii, and Yi 2001).

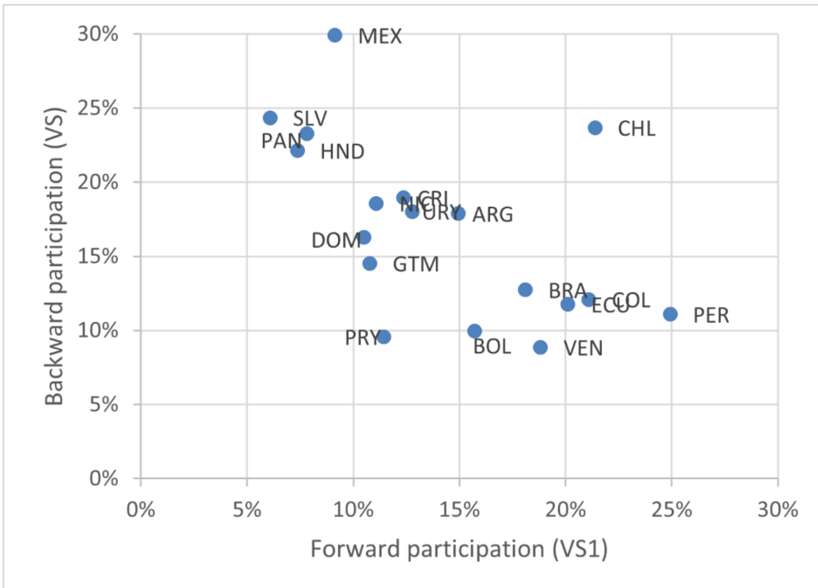
Figure C2 shows the forward and backward participation in GVC indexes according to Borin and Mancini's (2019) methodology. The sum of backward and forward participation gives the total participation in value chains. Most countries range between 35% and 25% of total participation, and backward linkages prevail over forward[12]. Chile, Mexico, and Peru are the countries with

[11] Double counted value is the difference between imported content and genuine foreign value included in gross exports of a country. It arises from the fact that foreign intermediates sourced from country s can include value from another country and that this value was already counted in the relationship among s and their supplier, so the following cross border of this value should not be considered as value added. See (Koopman, Wang, and Wei 2014; Los, Timmer, and de Vries 2016; Los and Timmer 2020). (Koopman, Wang, and Wei 2014; Los, Timmer, and de Vries 2016; Los and Timmer 2020; Borin and Mancini 2019).Double counting is the cause of the gap among Gross Exports and Value Added Exports.

[12] Note that with Borin and Mancini (2019) definition Backward and Forward linkages are not symmetric concepts. While forward linkages is a value- added concept and thus is net value accounted only in the first border crossing, backward linkages includes double counting value. For this reason, at an overall level

higher participation of GVC in trade. While Mexico is heavily backward, Peru is strongly forward, and Chile appears as both Forward and Backward. Paraguay appears as the country less integrated into value chains.

Figure C2. **Forward and Backward participation in Global Value Chains in Latin America.** 2015



Source: Own elaboration using EORA

backward linkages are higher than forward. While every forward participation is by definition backward participation in another relationship, some part of backward participation is value already counted as backward in another flow.

Appendix D. Additional Tables and Figures

Table D1. Share of activities related to trade by type of activity. In percentages of value added

	1990				2015			
	Final goods and services		Value Chains		Final goods and services		Value Chains	
	Regional	Extra regiona l	Region al	Extra regiona l	Region al	Extra regiona l	Region al	Extra regiona l
Mexico	2.8	0.5	4.6	2.5	7.0	1.2	6.6	4.1
Dominican Rep	0.0	4.3	0.0	9.3	0.0	5.5	0.1	7.5
Costa Rica	0.5	4.4	0.6	10.4	1.3	7.0	1.1	9.5
Guatemala	0.7	3.4	0.9	8.2	1.9	4.2	1.5	6.2
Honduras	0.6	4.6	1.1	10.7	1.2	7.2	2.1	8.4
Nicaragua	0.7	1.9	1.2	6.5	1.5	3.1	2.9	6.8
Panama	1.4	4.4	0.8	14.1	2.4	4.3	1.2	8.9
El Salvador	0.6	1.9	0.9	6.4	2.1	4.4	2.7	7.0
Argentina	0.7	1.2	1.1	2.3	2.9	1.9	4.2	4.7
Bolivia	1.0	1.1	2.6	5.0	3.8	1.4	11.6	6.6
Brazil	0.4	1.8	0.6	5.2	1.3	2.3	1.3	5.8
Chile	0.9	4.9	3.1	14.2	2.3	4.5	4.1	12.4
Colombia	0.5	1.5	1.1	5.8	1.0	1.3	1.9	5.7
Ecuador	0.7	5.5	2.2	10.4	2.1	3.7	3.0	8.5
Peru	0.2	1.8	1.1	5.3	0.7	1.9	1.9	6.0
Paraguay	1.3	7.3	6.0	7.9	3.4	1.9	7.8	3.7
Uruguay	2.1	2.4	3.1	6.0	3.4	1.9	4.1	3.9
Venezuela	0.4	2.2	1.1	15.8	0.6	1.9	1.5	14.3

Source: Own elaboration using EORA

Figure D1. Average length of chains of Latin American Countries. Years 1992/2 and 2014/5.

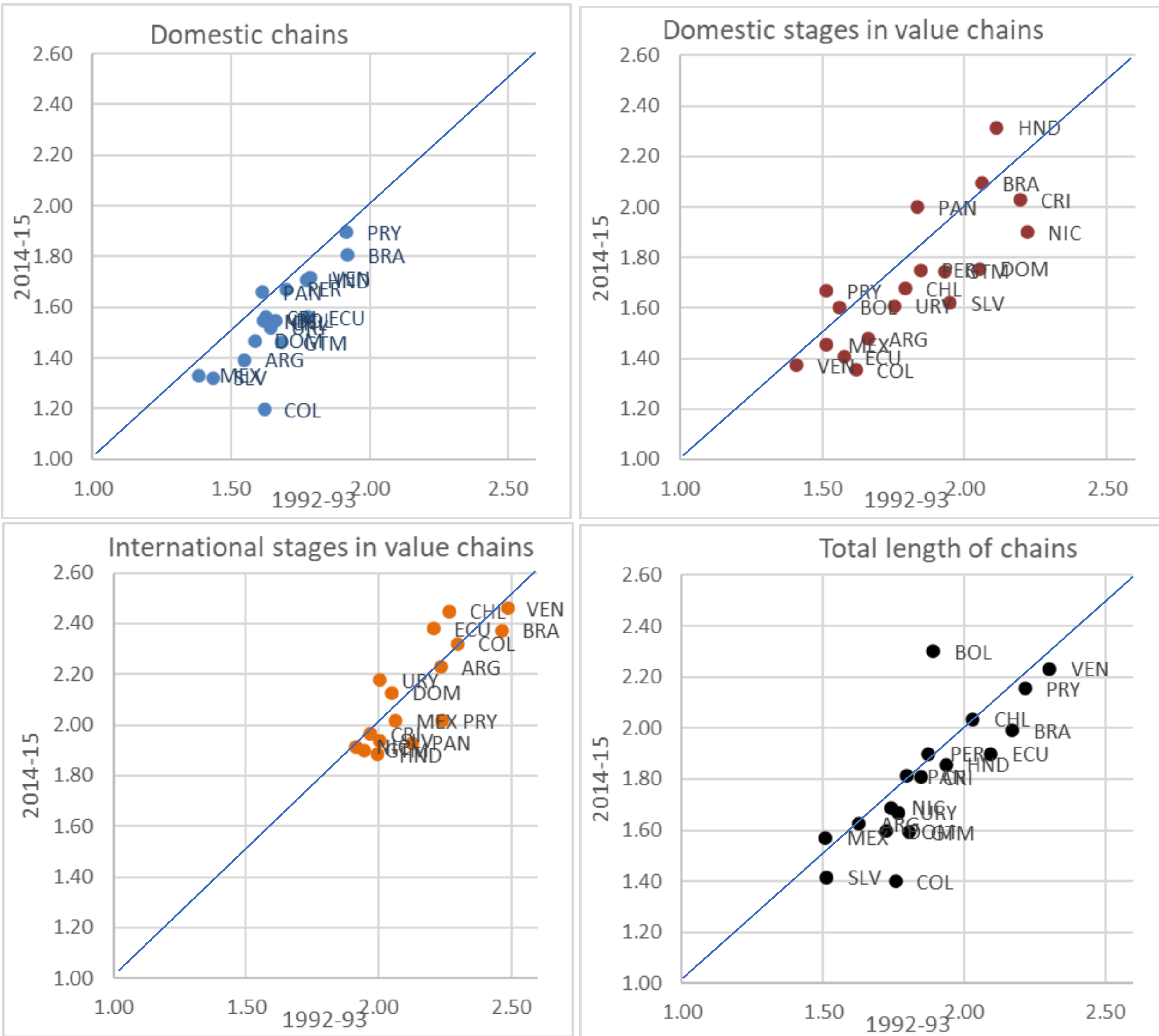


Figure D2. Evolution of Mexican position in RVC and EVC. Share of forward and backward participation on value added. 1990-2015

Appendix E: Data and regions

Regions considered, and other criteria applied.

Region	Countries	ISO – Code
North America	Canada, Mexico, United States	CAN, MEX, USA
Central America	Dominican Republic, Costa Rica, El Salvador, Guatemala, Honduras, Nicaragua, Panama	DOM, CRI, SLV, GTM, HON, NIC, PAN
South America	Argentina, Brazil, Bolivia, Chile, Colombia, Ecuador, Peru, Paraguay, Uruguay, Venezuela	ARG, BRA, BOL, CHL, COL, ECU, PER, PAR, URY, VEN
European Union and EFTA Countries	Austria, Belgium, Bulgaria, Switzerland, Czech Rep., Germany, Denmark, Spain, Finland, France, United Kingdom, Greece, Croatia, Hungary, Ireland, Italy, Lithuania, Luxembourg, Netherlands, Norway, Poland, Portugal, Romania, Slovakia, Slovenia, Sweden	AUT, BEL, BGR, CHE, CZE, DEU, DNK, ESP, FIN, FRA, GBR, GRC, HRV, HUN, IRL, ITA, LTU, LUX, NLD, NOR, POL, PRT, ROU, SVK, SVN, SWE
ASEAN + 3	China, Hong Kong SAR, China, Indonesia, Japan, Korea Rep., Lao PDR, Malaysia, Myanmar	CHN, HKG, IDN, JPN, KOR, LAO, MYS, MMR, NZL, PHL, SGP, TWN, THA, VNM
Rest	44 countries	
Dropped because of computational problems	Azerbaijan, Kazakhstan, Ukraine,	AZE, KAZ, UKR
Dropped by size	78 countries will less than 0,05% of world GDP outside LAC	

Measures of upstreamness and downstreamness defined on exports

Abstract

In this article I propose measures of Upstreamness and Downstreamness of International Production. Both measures are defined as distance from exports either to final demand (Upstreamness) or to primary factors (Downstreamness) and can be summed in a single measure of length of chains in international trade. The relative contribution of downstreamness to total length of chains indicates the relative position of a country-sector, a country or a sector in global value chains. I show the usefulness of these measures to highlight some aspects of international participation in value chains that cannot be deduced from previous measures.

Resumen

Este artículo desarrolla medidas de *Upstreamness* y *Downstreamness* de la producción internacional. Ambas medidas están definidas como distancia entre las exportaciones ya sea con la demanda final (*upstreamness*) o con los factores primarios (*downstreamness*) y pueden resumirse en una medida simple de largo de cadenas en el comercio internacional. La contribución relativa de la d*ownstreamness* al largo total indica la posición relativa de un sector-país, un país o un sector en las cadenas de valor. La utilización de estas medidas muestra algunos aspectos de la participación internacional en cadenas de valor que no pueden obtenerse con las medidas de referencia

Keywords: Global Value Chains, Upstreamness, Downstreamness.

JEL No: D57; F14

I. Introduction

The literature on the measurement of global value chains based on multi-countryinput-output tables (MCIO) has undergone a great development in recent years. Among the most important lines of research are the measurement of trade in value added (Johnson, 2018; Johnson and Noguera, 2012; Los and Timmer, 2020), the decomposition of gross exports to identify domestic and foreign valued added and double-counted component (Arto et al., 2019; Borin and Mancini,2019; Koopman et al., 2014; Los et al., 2016; Nagengast and Stehrer, 2016; Wang et al., 2013), which gives rise to measures of participation of countries or country-sectors in value chains (Borin and Mancini, 2019; Los et al., 2015; Wang et al., 2013) and finally measures of length and position in chains, commonly defined as upstreamness and downtreamnes (Antràs and Chor, 2018; Miller and Temurshoev, 2017; Wang et al., 2017b).

In measures of participation or depth of value chains, in well-known the conceptual difference between measures that are based on a decomposition of gross exports (Arto et al., 2019; Borin and Mancini, 2019; Los and Timmer, 2020; Wang et al., 2013) and those based on countries' total production or value added (Knez et al., 2021; Wang et al., 2017a). In the latter, a distinction is made between value added (or final output) that does not relate to international production from that which does.

However, the most widespread measures of length and position in chains are defined on total production and there is lack of measures defined directly on exports. The initial measures were performed with the U.S. domestic input output table (Antras et al., 2012; Fally, 2012) with an adjustment for international trade, and after the availability of MCIO were performed for total production without distinguishing international trade from local-driven production (Antras and Chor, 2018; Miller and Temurshoev, 2017).

Antras et al. (2012) define *upstreamness* as the distance from production to final demand and is measured as the number of times production is accounted for until it is incorporated into a final god. Antras and Chor (2013) define *downstreamness* as the distance to primary factors, and it is defined as the number of times value added is accounted for in a production process until it is incorporated into a country's output[1].

The definitions of Antras and Chor (2018) consolidates previous ones and coincides with the proposed by Miller and Temurshoev (2017), so in this paper their measures will be labeled as 'AC-MT'. Wang et al. (2017b) define measures based on a matrix that tracks the value-added originating in each country-sector included in the final demand of a given country-sector. To better distinguish domestic chains from global chains, these authors decompose the matrix according to participation in both domestic and global chains, following the method of Wang et al. (2017a). It is on the last term that they characterize the position of the countries, either

[1]In order to be more indicative, Miller and Temurshoev (2017) define as 'Output Upstreamness' the distance to the final product (i.e. focusing on the forward linkagesof a given product) and 'Input Downstreamness' the distance of production with respect to primary factors, i.e. focusing on backward linkages. These authors show that at the aggregate level both measures coincide, and that they differ at the country, sector or country sector level because the sales structure (at a given level) doesnot coincide with the input supply structure

forward, adding the value added included in chains across a row, or backward, decomposing the final production of goods defined along a column.

Despite both contributions are valuable, they have some limitations to be fully indicative of the role of countries. ’AC-MT’ measures do not distinguish international from domestic trade, and therefore it is not possible to interpret differences in positions solely by the indices. As shown for example in Wang et al. (2017a) or Dollar et al. (2017), more than three quarters of the world’s output is consumed in the same country where it is generated and therefore does not result in international trade. While for some types of description it may be useful to have a global view of a country’s production, for specific analyses of international trade it may be useful to work with the reference of gross exports, as they appear in the statistics. Given that the measures of Wang et al. (2017b) neither are defined on gross exports, they also lack an easy or directly indicative interpretation for international trade. According to their definition, international trade is divided into intermediates and final goods, and in the forward perspective (tracing linkages to final consumption) only the former is integrated into chains. Therefore, part of what is commonly considered participation in chains is established in the domestic component. Furthermore, the measures of position defined by these authors, which propose the ratio between forward and backward lengths, can give rise to erroneous readings because denominator and numerator are defined on different sets of information, that is, on different chains.

One of the properties of Wang et al. (2017a) is that it shows that Upstream- ness and *downstreamness* are concepts relative to a given chain length, and therefore distance measures cannot be compared without taking this aspect into account. Nevertheless, they define a forward and a backward length and define position as a ratio between the two, so that the notion of absolute length is overshadowed by the measure of position.

This paper follows the tradition of decomposing gross exports that is done in the works of Borin and Mancini (2019), Koopman et al. (2014), Los and Timmer (2020), Wang et al. (2013). The difference is that while these works create measures of depth or participation in chains and position bias (Forward or Backward), here I present measures of length and position in chains. The advantage of using gross exports is that their interpretation is straightforward and familiar in international trade, and it is through them that countries are inserted into global chains. They also allow a direct and more integrated analysis of the measures created to describe forward and backward participation.

In addition, the measures presented have the property of being additive, i.e. the total length in chains can be divided into a forward length, as distance to the final consumer, and a backward length, from exports to primary factors. In addition to the additivity of both measures, the position of a country, sector or country sector is naturally defined as the relative distance to one end in a given length of chain (either backward, towards productive factors or forward, towards the final consumer). In that sense, they also have a familiar interpretation to the GVC participation measures of (Borin and Mancini, 2019), where there is a total measure that can be decomposed into a forward and a backward term[2].

[2] Borin et al. (2021) propose a new measure of participation where they correct for the bias toward overstating backward participation in GVC that previous benchmarkmeasures have, such as Borin and Mancini (2019)

This article is composed of this introduction and three more sections. The second section presents the benchmark measures for measuring position and length in chains using MCIO according to total output (Antras and Chor, 2018; Miller and Temurshoev, 2017) and distinguishing trade in value chains from traditional trade (Wang et al., 2017b); and presents the measures proposed in this article. The third section compares some common and some different results that emerge from the three sets of measures using data from World Input Output Database (WIOD) (Los et al., 2015) and deepens the analysis with the measure proposed in this article. Finally, the fourth section outlines some conclusions of the analysis.

2) Measures of upstreamness, downstreamness and relative position in value chains

2.1 General notation and definitions

Multi country input output (MCIO) tables organize the world output according to the destination (on the direction of the columns) and the source of value (on the direction of the rows) according to table 1. The world is organized in G countries and production and use in each country is organized in N sectors.

Table 1: **Multi country input output table**

Destination	Intermediate use			Final use			Output
Source	1	…	G	1	…	G	
1	Z^{11}	$\cdots$	Z^{1t}	Y^{11}	$\cdots$	Y^{1t}	X^{1}
s	Z^{s1}	$\cdots$	Z^{st}	Y^{s1}	$\cdots$	Y^{st}	X^{s}
$\vdots$	$\vdots$	$\ddots$	$\vdots$	$\vdots$	$\ddots$	$\vdots$	$\vdots$
G	Z^{t1}	$\cdots$	Z^{tt}	Y^{t1}	$\cdots$	Y^{tt}	X^{t}
Value Added	Va^{1}	$\cdots$	Va^{t}				
Output	$(X^{1})^{T}$	$\cdots$	$(X^{t})^{T}$				

Source: Own Elaboration

Where $Z^{st}$is a NxN matrix of intermediate inputs produced in country s and used in country t, Y^{st} is a *Nx1* vector of final goods produced in country s and consumed in country t, X^{s} is a *Nx1* vector of output of country s and V as is a 1xN vector of direct value added in country s. *T* is the transpose operator. All intermediate transaction can be arranged in a *NGxNG* matrix: Z. Final demand is divided in two vectors: $Y^{D}$is a vector of NGx1 that accounts for domestic demand (every Y^{st} where $s = t$) and Y^{F} is a vector of NGx1 that aggregates over all foreign final demand of every country-sector (every Y^{st} where $s = t$). Then, total final demand can be split in domestic and foreign ($Y = Y^{D}$+Y^{F}). Also, X is a vector of NGx1 that accounts for production in each country-sector and Va is a 1xNG vector of direct value added in every country sector.

The Leontief matrix$A = Z\hat{X}^{-1}$ enables the usual notation in input-output analysis. The operator ˆ indicates that the vector is expressed as a diagonal matrix. The usual decomposition of production is:

$$X = AX + Y \quad (1)$$

The International Leontief inverse matrix is defined as:

$$B = (I - A)^{-1} \rightarrow X = BY \tag{2}$$

Analogously, the Gosh matrix $J = \hat{X}^{-1}Z$ expresses intermediate use as shares of total use. The alternative decomposition of output is:

$$X^T = X^T J + Va \tag{3}$$

Then, the International Gosh inverse matrix is defined as:

$$H = (I - J)^{-1} \rightarrow X^T = (Va)H \tag{4}$$

It will be useful to express the value added as shares of output: $V = Va\hat{X}^{-1}$. From the column perspective, the output is the result of the combination of intermediate inputs plus the value added (Va). This equation illustrates the Leontief function of production:

$$X^T = u\hat{X} = uZ + Va = uA\hat{X} + V\hat{X}^T \tag{5}$$

Where u is an 1xG vector of ones. Posmultiplying by X^{-1} the expression is $u = uA + V$. That gives rise to the decomposition formula for production.

$$uI - uA = u(I - A) = V \rightarrow u = V(I - A)^{-1} = VB \rightarrow u = u\hat{V}B \tag{6}$$

Since it enables splitting any vector, this equation is crucial in the references. In particular, a unit of output can be decomposed according to the country and sector of origin of the value. $\hat{V}B$ has some useful properties. Postmultiplied by a diagonal matrix of final demand it leads to a complete decomposition of value added included in it. On the direction of any column, sectoral output is divided according to the country-sector of origin of the value, and total sum of column equal the final demand of each sector. On the direction of rows, the value added of a country-sector is divided according to the country-sector of final use, and total sum equal total value added of this country/sector[1]. But $\hat{V}B$ can be used to split other vectors different than final demand, such as output or exports.

A contains both domestic and foreign coefficients of input utilization, that canbe split in a matrix of domestic requirements (A^D) and a matrix of international requirements (A^F) (Wang et al., 2017a). Then $A^F X$ represent the international trade in intermediates.

$$A^D = \begin{bmatrix} A^{ss} & \dots & 0 \\ \vdots & \ddots & \vdots \\ 0 & \cdots & A^{tt} \end{bmatrix};\ A^F = A - A^D = \begin{bmatrix} 0 & A^{su} & A^{st} \\ A^{us} & \ddots & \vdots \\ A^{ts} & \cdots & 0 \end{bmatrix}$$

It should be defined also the Local Leontief Inverse matrix of partition of A.

$$L = (I - A^D)^{-1}$$

[1] $\hat{V}B\hat{Y}u^T = Va$ and $u\hat{V}B\hat{Y} = Y^T$

2.2 References of the literature

Defined over world production

Using the notion of Average Propagation Length, used by Dietzenbacher and Romero (2007) to measure the distance between two sectors, Antras et al. (2012) and Fally (2012) define the upstreamness of a sector as the number of stages that the production of a sector transits to the final demand. Analogously, Antras and Chor (2013) define the downstreamness as the distance of output from the productive factors. Then, Antras and Chor (2018) and Miller and Temurshoev (2017) apply it on an MCIO to measure the degree of upstreamness and downtreamness of global production[1].

Using the algebra and terminology of Miller and Temurshoev (2017), the definition of 'Output Upstreamness' of AC-MT is[2]:

$$OU = \hat{X}^{-1}(I + 2A + 3A^2 + \cdots)Y = \hat{X}^{-1}BBY = \hat{X}^{-1}B\hat{X}u^T = Hu^T$$

And for 'Input Downstreamness'[3]:

$$ID = Va(I + 2J + 3J^2 + \cdots)\hat{X}^{-1} = VaHH\hat{X}^{-1} = u\hat{X}H\hat{X}^{-1} = uB$$

Defined over value added included in final demand

The definitions of Wang et al. (2017b) start from the matrix of value added included in the final demand: $\hat{V}B\hat{Y}$. This *NGxNG* matrix contains in each cell the direct and indirect value added of a sector-country of origin (corresponding to the row) included in the final demand of a given sector-country (indicated in the column). This calculation includes the direct relationships between row and column and also all the indirect relationships connecting these two sectors. The output included in this value-added flow is the number of times that value has been counted as output in that relationship. Again, the method of counting stages applies.

$$\hat{V}BB\hat{Y}$$

The ratio between the production counted and the value added in each cell is the average length of each relationship.

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[1]Antràs and Chor (2018) further propose simpler measures of upstreamness and downstreamness that are highly correlated with the previous ones. The simple measure are simply the ratio between final demand and production for upstreamness (the higher the ratio the lower the upstreamness) and the ratio between direct value added and production for downstreamness (the higher the ratio the higher the downstreamness), both at a sector level.

[2] The first equation uses the equivalence $(1 + 2A + 3A^2 + \cdots) = BB$ and the last uses the equivalence between Leontief and Gosh inverse matrices: $\hat{X}^{-1}B\hat{X} = H$ (see Appendix for demonstration of both equivalences).

[3] Again, first equation uses the equivalence $(1 + 2J + 3J^2 + \cdots) = HH$ and the last uses the equivalence between Leontief and Gosh inverse matrices: $B = \hat{X}H\hat{X}^{-1}$ (see Appendix)

$$\frac{\hat{V}BB\hat{Y}}{\hat{V}B\hat{Y}}$$

The Upstreamness measure of Wang et al. (2017b) for total output is the ratio between the sum of each row of the numerator and the denominator.

$$U_W^{Tot} = \frac{\hat{V}BB\hat{Y}u^T}{\hat{V}B\hat{Y}u^T} = \frac{\hat{V}BBY}{\hat{V}BY}$$

Simplifying the value added and using $X = BY$ it can be seen that the total forward chain length measure from Wang et al. (2017b) matches that from AC-MT: $U_W^{Tot} = OU$

The downstreamness measure of Wang et al. (2017b) for total output is the ratio of the aggregation of each column of the numerator and the denominator. It again coincides with the 'Input Downstreamness' measure.

$$D_W^{Tot} = \frac{u\hat{V}BB\hat{Y}}{u\hat{V}B\hat{Y}} = \frac{VBB\hat{Y}}{VB\hat{Y}} = \frac{VBB}{VB} = \frac{uB}{u} = uB = ID$$

However, Wang et al. (2017b) apply their measures not on total output, but estimate a measure for each of the components of total output according to the decomposition of total output developed in Wang et al. (2017a):

$$\hat{V}B\hat{Y} = \hat{V}L\hat{Y}^D + \hat{V}L\hat{Y}^F + \hat{V}LA^F B\hat{Y}$$

The first component is the term that includes value added integrated in exclusively domestic chains that are consumed domestically, the second term is domestic value added that is included in final production that is exported, and the third term is properly value added integrated in value chains. Wang et al. (2017b) analysis of global value chains focuses in the third term. As for total production, a length of production is identified for each term and divided by the value added included in that flow. For domestic and final goods chains the average length is simply:

$$AL_{dom} = \frac{\hat{V}LL\hat{Y}^D}{\hat{V}L\hat{Y}^D};\ AL_{fin} = \frac{\hat{V}LL\hat{Y}^F}{\hat{V}L\hat{Y}^F}$$

However, for the length of the value chains term it is necessary to distinguish domestic stages, i.e. the linkages that happen before the value added crosses the border, and international stages, i.e. the linkages that happen after the value added left the country of reference[1].

$$AL_{CGV} = \frac{\hat{V}LLA^F B\hat{Y} + \hat{V}LA^F BB\hat{Y}}{\hat{V}LA^F B\hat{Y}}$$

Again, there is a forward perspective, which starts from the value added included in a country sector and evaluates whether it was integrated in an exclusively domestic flow, in the

[1]This reference to "before" and "after" is formulated for the forward perspective. In the backward perspective the value added first had international stages and then is integrated into the production of final goods in the country of reference

production of a final good or associated with value from other countries on its way to being incorporated into a final good.

The length of chains in the forward-looking perspective is, for the CGV term:

$$AL_{CGV\_V} = \frac{\hat{V}LLA^F BY + \hat{V}LA^F BBY}{\hat{V}LA^F BY}$$

There is also a backward perspective, which starts from the final production of a country sector and identifies the imported inputs that were used and their value added, and from there counts the number of stages the production had.

$$AL_{CGV\_Y} = \frac{VLLA^F B\hat{Y} + VLA^F BB\hat{Y}}{VLA^F B\hat{Y}}$$

Wang et al. (2017b) define the position of a sector-country in value chains as the quotient of both ratios. A value greater than one indicates that the country- sector has a longer forward than backward length, i.e. that sector is further away from final consumption than from primary factors and is therefore positioned upstream in the value chain. The aggregation of all sectors generates measures for the countries.

Note that the Wang et al. (2017b) measure of position in value chains is defined on two sets of information that refer to different flows. The upstreamness measure counts the average number of stages that the value added of a country sector went through until it was integrated into a final good, provided that between the reference value added and the final production there is international trade of intermediates (represented by the matrix A^F). The downstreamness measure is positioned on the final goods production of a country sector, and counts the average distance in stages since the value added was incorporated. Again, only value added that entered the country of reference through international trade in intermediates is counted, while domestic value added that is combined with these inputs is not considered to be integrated into chains.

In both AC-MT and Wang et al. (2017b) measures, the length of a chain isa concept that cannot be summarized in a number, since there is still a forward (upstreamness) and a backward (downstreamness) measurement. This is solved in the proposed measures below.

2.3 Measures based on gross exports

Two measures are defined for gross exports and three direct combination of these measures gives measures of length and position of exports in global value chains:

1. Distance from exports to final demand: Upstreamness

This measure counts the average number of times a sector/country’s exports are accounted for in production until they are incorporated into final demand. Like the forward linkages defined by the literature on measuring chain participation (Borin and Mancini, 2019; Koopman et al., 2014; Los and Timmer, 2020), it depends on the type of good being exported and the use made of the good at destination, rather than in the exporting country itself.

According to eq. 1, total production is divided into intermediate and final production. Gross exports can be divided into intermediate and final exports

$$E = A^F X + Y^F \tag{7}$$

Using the Leontief inverse matrix B and eq. 2, exports then can be decomposed as follows:

$$E = A^F BY + Y^F = A^F(I-A)^{-1} + Y^F = Y^F + A^F(I + A + A^2 + A^3 + \cdots)Y \tag{8}$$

Exports are divided according to the number of stages to final demand. The first term is directly the final demand, so no additional stage is required. The number of additional stages is zero. The second term ($A^F Y$) represents exports of intermediates that are directly included in final demand. The number of stages is one. The third term ($A^F AY$) corresponds to two additional stages, until included in the final demand. Then, the total production is measured as follows:

$$U_E = 0.Y^F + A^F(1.I + 2.A + 3.A^2 + 4.A^3 + \cdots)Y \tag{9}$$

From Antras et al. (2012) we can see that the term in parentheses is (BB), therefore, the average number of stages that exports have until being included in final demand is:

$$U_e = \frac{U_E}{E} = \frac{A^F BBY}{E} \tag{10}$$

U_e then is a vector that arises as a ratio of vectors. It is generally defined of size NGx1, and each row shows the average forward length of exports of sector N of country G. U_e is defined exclusively for the sectors that actually exported. By conveniently aggregating U_E and E for the sectors of a country, we can express U_e also as a vector of Gx1, where the average forward length of exports of each country is indicated. Also, an alternative aggregation of U_e can lead to a vector of *N*x1, indicating the world average length of exports of each sector.

2. Distance from exports to primary factors: Downstreamness

This backward-looking measure counts how many stages on average the value added had until it was incorporated into a country's gross exports. These stages may have been domestic or international.

To estimate downstreamness it is necessary to track the sector-country of origin of the value added included in gross exports. V was defined as a row vector that includes coefficients from value added to output. Any output vector can be split using VB to identify the sector of origin of the value added (Borin and Mancini, 2019).

$$E^T = VB\hat{E} = V(I + A + A^2 + A^3 + A^4 + \cdots)\hat{E} \tag{11}$$

Each of the terms is a row vector and corresponds to value added in exports at a production stage. The first term is $V\hat{E}$, that is, a row vector that directly contains the value added by the producer of exports. The second term, $VA\hat{E}$, is the value added by all input producers purchased by the exporter in each sector for its production (can be domestic or international).

The third term, $VAA\hat{E}$, is the value added by the input producers used by the input producers used by the exporters, and so on. It is possible to weight each term by the number of times the value is accounted for in production. Furthermore, the sum of the value added by all producers at each stage is the value of exports. Then, the distance from exports to value added can be defined as:

$$D_e = \frac{D_E}{E^T} = \frac{V(1.I+2.A+3.A^2+4.A^3+5A^4+\cdots)\hat{E}}{E^T} = \frac{VBB\hat{E}}{E^T} \tag{12}$$

It is useful to divide the numerator of the backward length of exports according to whether it was domestic or international stages that production underwent.

$$D_E = VBB\hat{E} = D_{E\_dom} + D_{E\_int} = VLL\hat{E} + VBBA^F L\hat{E} \tag{13}$$

The first term accounts for the domestic value added chained in exports without stages abroad. It measures the circulation of domestic value added in the exporting productive structure until it is included in exports. The second term accounts for the circulation of imported inputs in the domestic economy. Each time an imported input is included in a stage in a chain that belongs to exports, this value is counted. Both first and second terms form the domestic contribution to the backward length of chains (D_{E_dom}). The third terms accounts for the stages that international inputs performed before entering in the productive structure of the exporting country. This is the international contribution to the downstreamness (D_{E_int}).

It should be noted that the definition of domestic is bounded to the value included in domestic economy after importing inputs. It can be domestic value also in imported inputs (Koopman et al., 2014), but for the purpose of manipulating international matrices a statement should be done about the moment of considering domestic and international. Here, we will follow the source-based perspective (Borin and Mancini, 2019, Nagengast and Stehrer, 2016) and thus the definition of domestic will be reduced to the last time that a portion of value enters in the country of reference. The alternative assumption is considering a Sink-based perspective, where all value generated in a country should be counted as domestic in a flow, irrespective of their circulation. See Borin and Mancini (2019) for a discussion of the advantages and consequences of using both methods. The proper definition is key when value has to be divided in domestic value, foreign value and double counted but it is not important when analyzing length and position of chains.

It is also possible to define $D_{e_{dom}} = {D_{E_{dom}}}/{E^T}$ and $D_{e_{int}} = {D_{E_{int}}}/{E^T}$. The domestic and international contribution to downstreamness is an average of the relative importance of domestic value added and imported inputs and also of the complexity of the productive structure of the exporting country and its suppliers.

3. Length of chains in which exports are involved

The sum of these two measures is the length of global value chains in a country's exports. U_e is a vector of NG rows defined between zero and infinite, being zero if a country sector exports exclusively final goods. D_e is a vector of NG columns defined between one and infinite, being one if the country sector does not use inputs from other sectors. Both measures can be defined for countries by aggregating across all sectors of a country.

The measures have the advantage over the previous ones in that they are defined for exports, and therefore dialogue better with measures of participation in international trade. In addition, unlike the previous, measures defined here can be aggregated into a single measure of total chain length in which exports are involved.

The total length of the chains, measured from primary factors to the production of final goods, in which exports participate, is defined as follows:

$$LC = U_e + D_e^T \tag{14}$$

LC is a row vector of dimension NG and ranks between one and infinite. Minimum length of one corresponds to an export of a final good done exclusively by value added in the exporting sector, that is, without using inputs from another sector. By conveniently aggregating for every sector in a country, it can be transformed into a vector of dimension G.

4. Relative Position of exports in value chain

Once the total length is defined, the Relative Position can set as a ratio:

$$RP = \frac{D_e^T}{LC} \tag{15}$$

The Relative Position of a country-sector in a value chain ranks between zero and one. Value close to zero indicates a country-sector that is located at the beginning of a chain, that is, the country-sector is used several times by other country-sectors before being included in final demand, but it used relatively low inputs from another sector. This is the case of a sector-country with long upstreamness and short downstreamness. A value close to one indicates that the value added included in the export transited by many intermediate sectors and it is close to the end of the chains. This is the case of a sector country with short upstreamness and long downstreamness.

Nevertheless, it should be useful to build a measure of Relative position that can be compared with references of the literature.

5. Balanced Relative Position of exports in value chains

$$BRP = \frac{D_e^T}{U_e + 1} \tag{16}$$

As long as upstreamness if defined starting in zero, adding one to it will make it comparable with AC-MT and Wang et al. (2017b) measures of position. Note that the latter is defined inversely to Eq. 16, as the ratio between upstreamness and downstreamness. BRP ranks between zero and infinite. Values above one represent a downstream biased position, and values above one represent an upstream biased position.

Despite these measures of resume, in order to measure the position of a country (or sector-country) in the chain, it is necessary to take into account both the total length of the chain in which it is located and the contribution of each of the two measures to this length. downstreamness is defined by the country's production function and its supply structure (and that of its suppliers), while upstreamness is determined by the use that other countries make of the country's production. This way of decomposing the results has several utilities. Since the final position and length is a weighted average of the position and length in each sector, a country's position can be divided into 'structural' and 'particular'. The 'structural' position arises from the composition of exports, while the 'particular' is the difference between the position and the structural one, which arises from the country's own production and supply structure and the characteristics of the markets supplied. Countries may become more upstream or downstream simply because of what they export, or they may have their own idiosyncrasy.

3) Compared results of the methodologies

The estimation of the results will be done with WIOD data for the period 2000- 2014 (2016 version, Los et al. (2015)). 56 sectors (based on ISIC 4, compatible with SNA version 2008) from 44 countries are surveyed. It should be reminded that AC-MT and Wang et al. (2017b) measures of length for upstreamness and downstreamness defined for a total MCIO are equal, that is, the differences only arise at the country-sector, country or sector level (Miller and Temurshoev, 2017, Wang et al., 2017b).

3.1General evolution of chain length

Table 2: **Chain length measures. Selected years from 2000-2014**

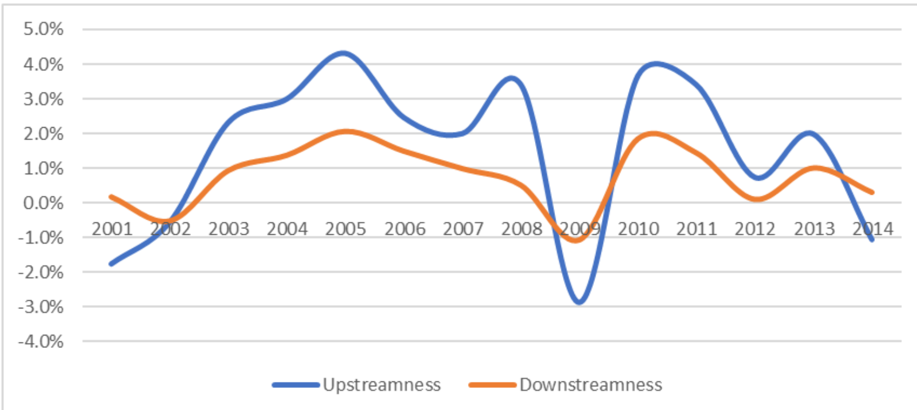
	Measure	2000	2002	2004	2006	2008	2010	2012	2014	Annual growth
Reference	AC-MT Total	2.01	1.98	2.04	2.13	2.19	2.20	2.26	2.31	1.0%
in	Wang et al.: Total	1.93	1.90	1.94	2.01	2.06	2.05	2.10	2.13	0.7%
literature	Wang et al: Domest	1.69	1.67	1.67	1.69	1.71	1.73	1.75	1.78	0.4%
	Wang et al: GVC	4.01	3.98	4.05	4.18	4.24	4.30	4.37	4.43	0.7%
Based in	Upstreamness	1.32	1.28	1.35	1.45	1.53	1.54	1.60	1.62	1.5%
Gross	Downstreamness	2.29	2.29	2.34	2.42	2.46	2.48	2.52	2.55	0.8%
Exports	Length	3.61	3.57	3.69	3.87	3.99	4.01	4.12	4.16	1.0%

Source: Own elaboration based in WIOD version 2016

All measures reported show a growth in the total length of global value chains. The AC-MT measure shows a growth rate of 1% per year over the period. Total growth over 14 years of the base period is 15%, which shows that this was a period of great dynamics in the fragmentation of production. The total Wang et al. (2017b) measure shows a lower growth of 0.7% per year. It should be remained that the difference between the two measures is that while the AC-MT measure weights each country sector by production, the Wang et al. (2017b) measure weights them by value added. The breakdown of Wang et al. (2017b) between domestic chains (including exports of final goods) and global value chains indicates that the latter are the driving force behind productive fragmentation, since they increased at a faster rate than domestic chains (especially in the first part of the period). On average, global value chains, i.e. value-added circuits to final demand that have some type of shared production between countries, changed from having 4 stages in 2000 to having 4.4 in 2014.

Gross export-based measures also indicate a lengthening of the chains. The growth rate coincides with that of AC-MT (1% per year). The division of growth between forward (upstreamness) and downstream (downstreamness) growth indicates that the chains lengthened more in the former direction. The rate of forward growth is almost double the rate of downstream growth. In total, the Upstreamness of exports increased from 1.32 to 1.62, while the backward length increased from 2.29 to 2.55. Recall that the first measure starts at 0 (if all exports are final goods) and the second starts at 1 (if all exports are composed of value added directly incorporated by the exporting firm). In total, the length of chains defined over gross exports rose from 3.61 to 4.16 in the period. The relative position measure went from 0.64 to 0.61. This skewed growth in chain length toward increasing forward length implies that exports moved "backward" in the chain in relative terms. Figure 1 also shows that the lengthening of chains occurred mainly between 2003 and 2008.

Figure 1: **Annual growth rate of World upstreamness and downstreamness based on gross exports.**



Source: Own elaboration based in WIOD.

3.2 Evolution of Upstreamness and Downstreamness at a country level

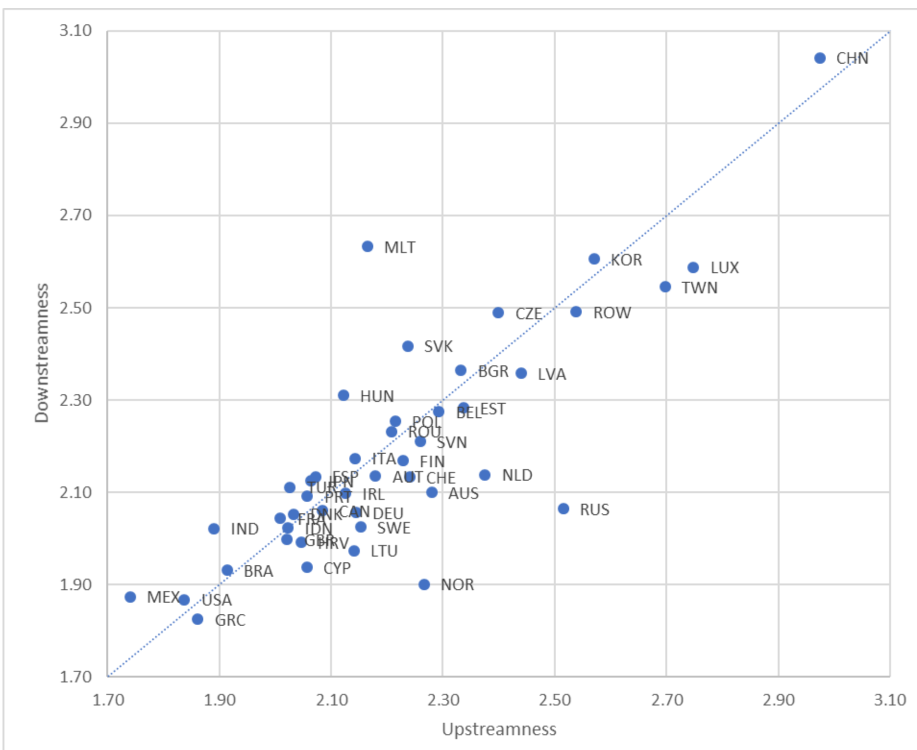
This section shows the evolution of the countries in the global measures. For this purpose, measures were constructed to aggregate all country sectors. All measures are a ratio, so the aggregation is performed on the numerator and denominator and then the ratio is calculated. The position of the countries will be a weighted average of the position of the country-sectors of each country.

Measures of Upstreamness and Downstreamness defined on total output

Figure 2 shows the AC-MT Output Upstreamness and Input Downstreamness measures. As both articles point out, both measures are strongly correlated. This high correlation, qualified as Puzzling according to Antras and Chor (2018), shows that countries with large distance to final demand also have large distance to value added. It is clear from Miller and Temurshoev (2017) that both measures are the reverse side of the same coin. As Antras and Chor (2018) point out, if a country's total value added is equal to final output, both measures are identical for a country. This equality occurs in closed economies. Therefore, the difference between the upstreamness and downstreamness measures indicates the result of the productive specialization of countries in the global economic structure. Antras and Chor (2018) indicate that as countries become more integrated into world trade it would be expected a greater specialization and therefore less correlation between the two measures. However, as they point out, the evidence shows increasing correlation in the period studied[1].

As can be seen in Figure 2, China differs from the rest of the countries. The country has a length of 3, with a slight bias towards higher downstreamness. Mexico and USA are at the antipodes, with a chain length of less than 2 and, in the case of Mexico, a bias towards greater downstreamness. Brazil is a major exporter of primary minerals, but this is not reflected in these measures, where it appears close to both final demand and value added. Figure A1 in the appendix shows the same graph but in variations between 2000 and 2014. Taiwan, China and the Rep. of Korea are the countries that most increased the length of theirtotal production in the period. Taiwan and China with a bias towards higher upstreamness and Korea in a more balanced way. Taiwan changed from having a slightly downstream position in 2000 to being an upstream country in 2014 andChina is reducing its downstream position. Almost all countries increased the length of their production. The exception is Turkey, which reduced its length inboth measures, while Australia, Norway, Canada, Finland and Indonesia reducedin one direction but compensated with increases in the other.

Figure. 2: **AC-MT Measures of Upstreamness and Downstreamness at a country level. Year 2014**



Source: Own elaboration based in WIOD.

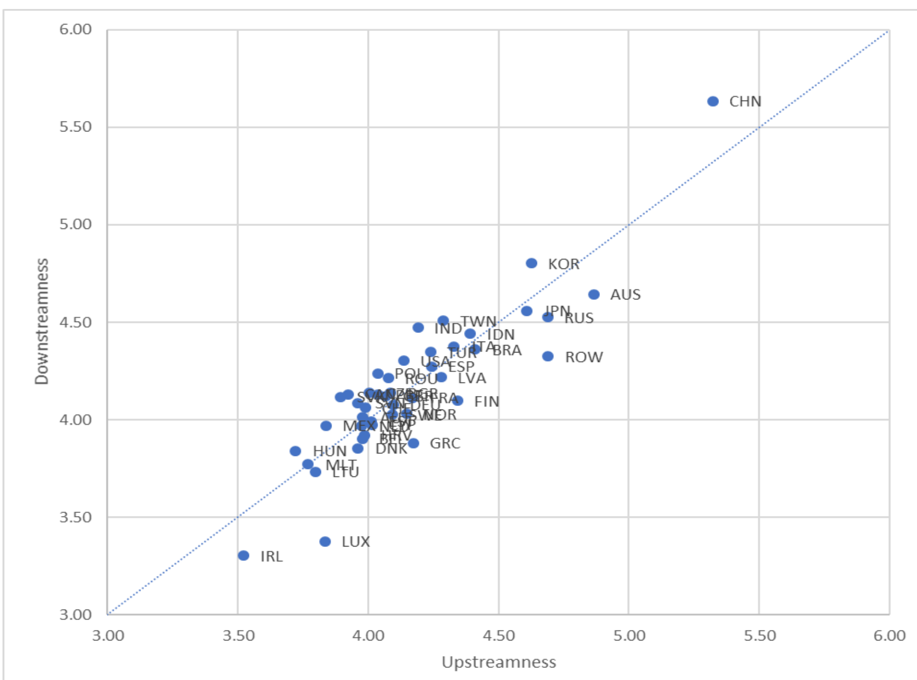
Measures of length splitting GVC from domestic component

[1] Both Antras and Chor (2018) and Miller and Temurshoev (2017) use the 2015 version of WIOD, that covers 1995-2001. Anyway, the general results hold for the 2016 version of WIOD

The plot of Upstreamness and Downstreamness measures defined on total production from Wang et al. (2017b) shows almost exactly the same information as those of AC-MT. The correlation between the two measures is 95% for upstreamness and 96% for downstreamness, so their analysis is not of interest. However, it is useful to analyze the term that captures participation in value chains. Recall that AC-MT indicated that if a country did not participate in value chains, both measures coincide at the country level. Precisely, the domestic term in Wang et al. (2017b) captures domestic production[2]. and is shown to be the same in the forward and backward perspective. In summary, the length of production is a weighted average of the length of domestic production[3] and the length of production in value chains, but it is the second term that characterizes the position of countries and along global value chains.

Figure 3 shows the measure of length in forward and backward value chains. Again, China stands out from the rest, exhibiting a considerably longer length than the rest. Rep. Korea and Taiwan also have a longer length in the GVC component than the rest and a backward bias, while Australia, Russia and Rest of the world have significant forward length. The graph also shows that USA is located in longer chains than indicated by the measure based on total production, so it is possible that this is due to a high weighting of non-integrated production in chains.

Figure 3: **Wang et al. (2017b) measures of Upstreamness and Downstreamness at a country level for GVC component. 2000-2014**



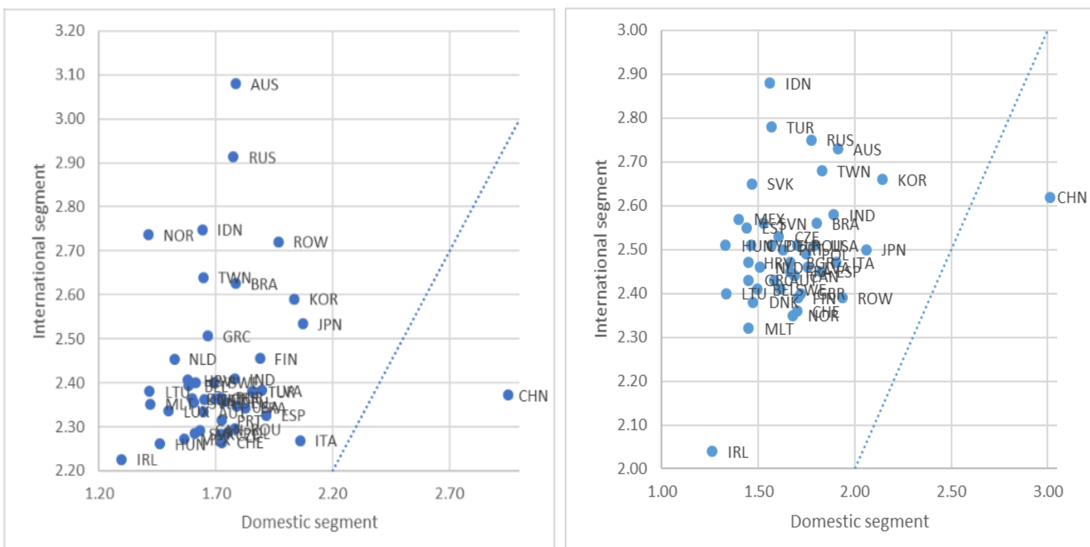
Source: Own elaboration based in WIOD.

[2] Wang et al. (2017b) distinguish between local production that is consumed domestically from which is integrated into final goods that are exported. While the former are referred to as purely domestic production, the latter is considered "traditional trade". In this presentation both flows will be considered within the domestic, because the interest is in the term that captures the value chains and in particular the forward or backward bias

[3] An examination of domestic length indicates marked differences between China and the rest of the world. While China has a length of 2.6, the length of the rest of the countries varies between 1.3 (in the case of Ireland and Luxembourg, countries witha high weight of services) and 1.8 (in the case of Russia, the Rest of the World and Australia)

Figure 4 shows that China has a very different production structure from the rest. In the GVCs in which it participates as a value supplier (i.e. it sells an intermediate product in international markets,4a), China adds an average of almost three production stages, Italy, Japan and the Republic of Korea add slightly more than two, while the rest of the countries add less than two. Once this value has left the country of origin, an average of 3 stages are added to the production of Australia and Russia, while in the rest of the countries between 2 and 3 are incorporated. Mineral and energy producers (Australia, Russia, Norway, Brazil, Rest of the world) and also large producers of industrialized inputs transformed into final demand in other countries (Taiwan, Rep. of Korea and Japan) holds a remarkable position. When countries are considered as users (4b), China again stands out from the rest, as it adds more stages than the rest. Mexico is the only country where domestic stages are on average somewhat higher than international stages. This may be related to the fact that its supply comes mainly from a single country, the USA.

Figure 4: **Wang et al. (2017b) measures of Upstreamness (a) and Downstreamness at a country level for GVC component, according to segment. 2000-2014**



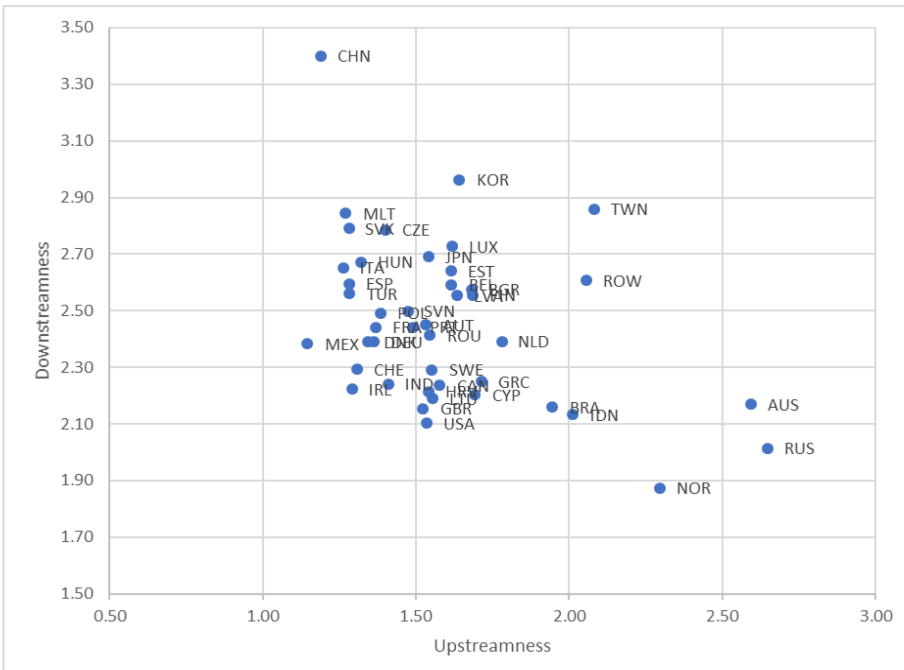
(a) Countries as source of value (b) Countries as final users of value

Source: Own elaboration based in WIOD.

Measures based in Gross Exports

The measures developed in this article yield results that are partly similar to the previous ones, but also show other aspects of the countries' international position in GVC, that remain hidden in the literature of reference. Figure 5 depicts the upstreamness and downstreamness of gross exports. China is not so far from the rest of countries as in previous measures. Taiwan, Australia, Rest of the World, Russia, Rep. of Korea, China and Luxembourg are the countries with the largest measured export shares. The latter country was considered to have very short global value chains according to the Wang et al. (2017b) methodology, but very long total production according to AC-MT. The negative correlation between upstreamness and downstreamness, not found in other measures, result in a length of chains that vary less than both measures separately[4]. While Australia and Russia (and with shorter chains also Norway) have a strong bias towards forward participation, China stands out for its large backward participation. The graph also highlights other commodity producers such as Brazil or Indonesia with high Upstreamness, and also allows us to distinguish some European end- of-chain countries, such as Slovakia, Czech Republic, Hungary or Italy. Mexico again stands out as a country with short chains and a bias towards very low forward linkages. Countries with a strong presence of services, such as the USA, Great Britain, Ireland or Switzerland, also have particularly short export chains. For example, the USA and Switzerland have a total length of 3.6, 0.6 below world average.

Figure 5: **Upstreamness and Downstreamness of Exports.2014**

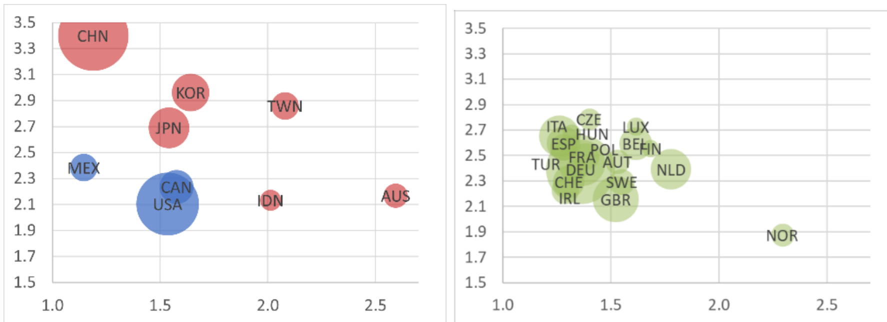


Source: Own elaboration based in WIOD.

Figure 6 highlights the position of the main countries of the three global factories of the world: America (6a), Asia -Pacific (6a) and Europe (6b). Asian factory is more specialized and with higher length. America performs with less fragmentation and so shorter chains and Europe appears in a intermediate position. Some assembling countries as Czech Republic, Hungary, Poland and Turkey are identified. Also, it can be highlighted the role of exporter of services, like Ire- land, Switzerland and United Kingdom.

[4] The coefficient of variation of Upstreamness at a country level in 2014 was 0.21, for downstreamness was 0.12 and for Total Length was 0.08

Figure 6: **Upstreamness and Downstreamness of countries in Global Factories**

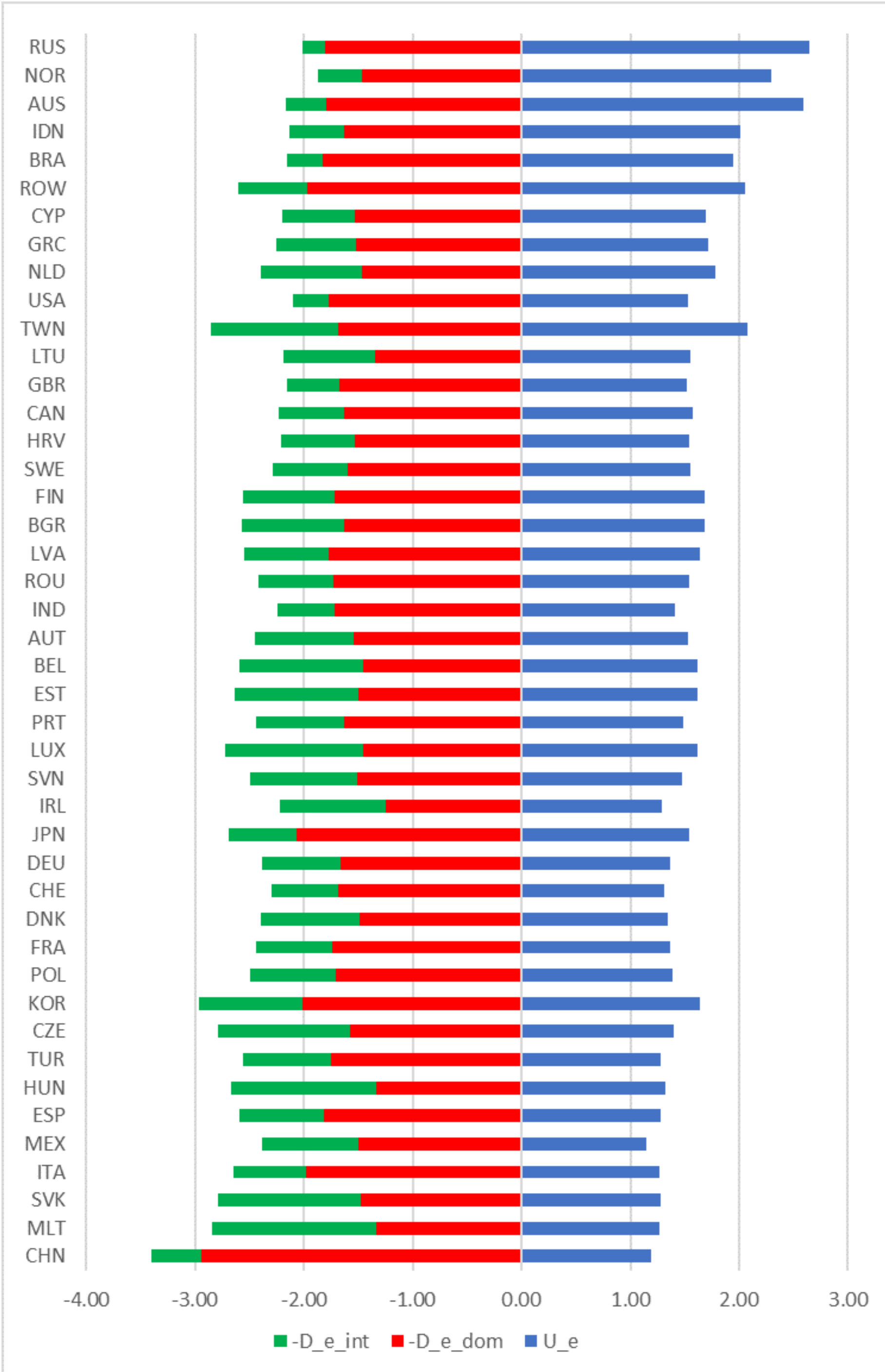


(a) America (blue) and Asia Pacific (red) (b) Europe

Source: Own elaboration based in WIOD.

Figure 7 shows the same information but with emphasis on chain length and its contribution. Dowstreamness is graphed in the negative axis. Red and green bars correspond to the backward length of exports. Red bars correspond to the contribution to length caused by production in the exporting country and green bars show the length before production enters the reference country (see Eq13). The blue bars show the forward length. Relative position is constructed as the ratio between downstreamness and total length (Eq.15). The countries are ordered from the most upstream positioned (Russia) to the most downstream (China). The most upstream country in the sample has a relative position of 0.43, i.e. 57% of the length occurs after Russia exported the product. Norway and Australia have a similar position, i.e. they are countries that are located at the beginning of the value chains. Among the countries closest to the beginning of the chains are, surprisingly, the USA and Taiwan, where 58% of the length occurs before export by these countries but 42%- a relatively high number- occurs after. At the other extreme is China, which, as we mentioned earlier, is one of the countries with the longest chains. 74% of production stages of Chains where China belongs occur before the country exports its products, while 26% occur after. In addition, as shown by comparing the red bar with the green bar, almost all of these stages in China are explained by domestic production. The rest of the countries that are positioned far from the beginning of the chains (with the exception of Italy, Spain and the Republic of Korea) tend to import a lot of "long" chains in their imported intermediate inputs and contribute relatively little domestically (see, e.g., Hungary and Slovakia).

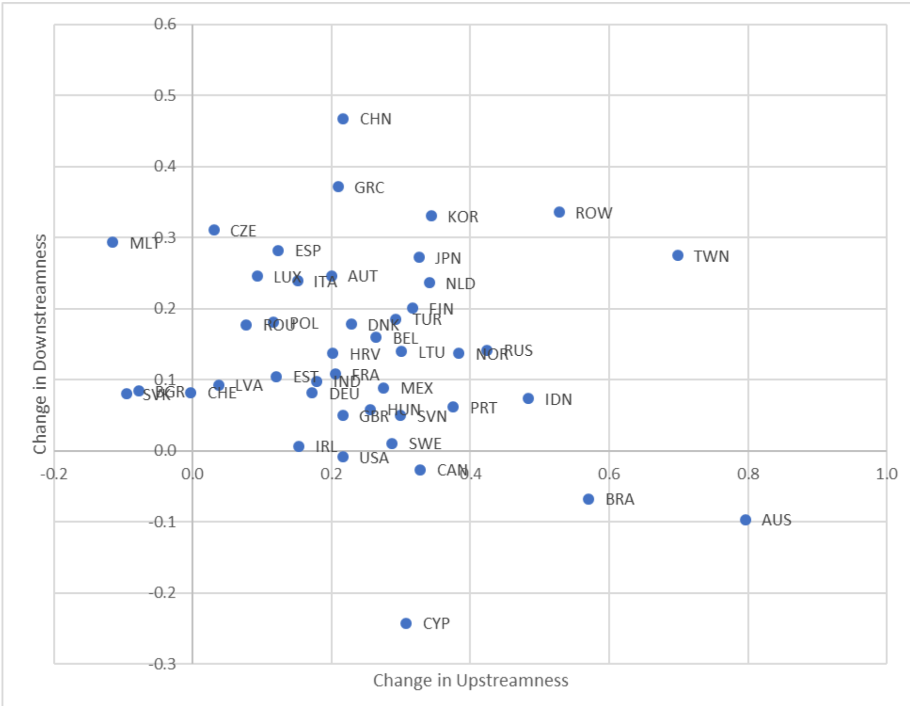
Figure 7: **Lenght of Chains based in Exports and Relative Contribution of Downstreamness (domestic and international) and Upstreamness. 2014**



Source: Own elaboration based in WIOD.

Figure 8 shows the change in Upstreamness and Downstreamness in the period analyzed. As mentioned, this change was biased towards an increase in forward length. Australia, Brazil and Taiwan strongly increased their distance to final goods, moving towards the center of the Value Chain. While Taiwan did so in both directions, the others mentioned reduced their backward length. USA and Canada also became more upstream in the period, basically by not increasing their backward length and moving far from final demand. On the other hand, Slovakia, Czech Republic, Bulgaria, Romania and Spain increased their backward length without practically changing their forward length. The Czech Republic became the most downstream European country in the sample, displacing Hungary, which grew in the opposite direction. Mexico had a similar evolution to the average, although with a certain bias away from downstream demand. Japan and the Republic of Korea experienced fairly high and balanced growth in the length of their chains.

Figure 8: **Change in Upstreamness and Downstreamness 2000-2014** ***Source:*** **Ownelaboration based in WIOD.**

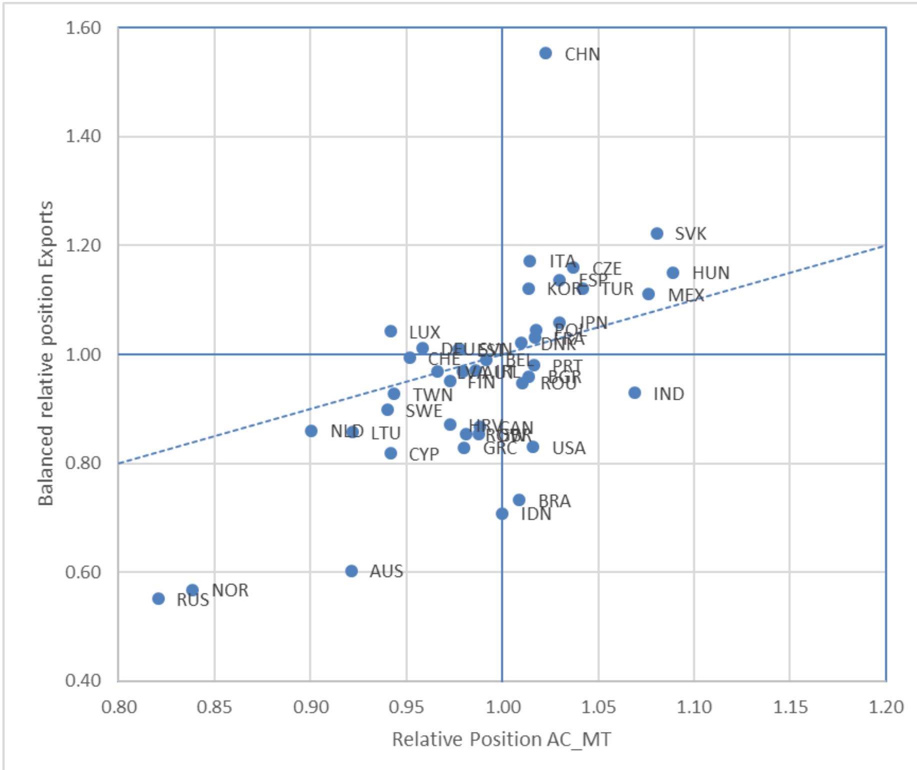


Source: Own elaboration based in WIOD.

The Balanced Relative Position defined in the previous section (see equa- tion 16) allows comparing the position of the countries according to each of the methodologies surveyed. The BRP will be compared with the ratio between Downstreamness and Upstreamness that arises from the AC-MT measures and from Wang et al. (2017b) measures for GVC. In the latter case, the measure used is the inverse of the Relative Position measure defined precisely by the authors.

Figure 9 compares the BRP from gross exports with those derived from the AC-MT measures. The positive correlation indicates that both measures tend to place countries in the same space. This is consistent with Antras and Chor (2018) finding that it is international trade that causes countries to be Upstream or Downstream. However, some differences arise. First, export measures naturally generate less balanced positions. Secondly, the countries in quadrants 2 and 4 show a relative position in different directions according to each measure. The cases of Brazil, USA and Indonesia stand out with higher downstreamness according to AC-MT but are upstream according to export-based measures. On the other hand, Germany, Switzerland and Luxembourg are Upstream according to AC-MT but appear balanced on the export-based measure. The comparison between China and Mexico is also useful. Both countries are downstream according to both measures, but Mexico stands out as much more downstream according to AC-MT and China much more according to the BRP.

Figure 9: **Balanced Relative Position of Exports and Ratio of Upstreamness to Downstreamness according to AC-MT.** Year 2014



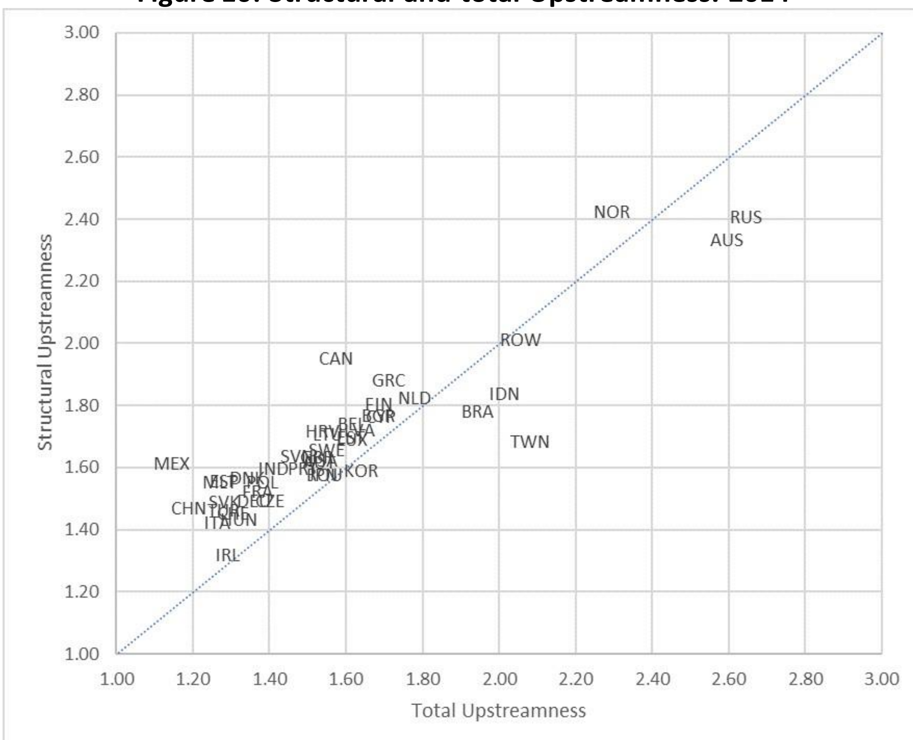
Source: Own elaboration based in WIOD.

Figure A.3 in the appendix shows the comparison between the BRP on ex- ports and the inverse of the Relative Position measure of Wang et al. (2017b) The results are similar. The countries that are classified as Downstream according to Wang et al. (2017b) but upstream according to the BRP are USA, Canada, Indonesia, India, Taiwan and United Kingdom.

Countries with idiosyncratic performance

The information constructed is useful for assessing the performance of countries in value chains beyond their export basket. In each of the two possible directions (forward and backward), 'particular' performance is constructed as the difference between the length actually achieved and the 'estructural' length, that is the length that would indicate an average performance according to the sectoral structure exported by the country. To evaluate this result, it is convenient to analyze each of the performances separately. Figure 10 shows the measure of total (effective) Upstreamness versus structural performance, i.e. what Upstreamness would be expected according to the weight of each sector in its exports. The distance to the 45% degree line measures the size of the 'particularity'. Russia, Australia and Norway have an export structure that positions them far from final demand. However, while Russia and Australia have a larger effective distance than their structure indicates, Norway has a smaller one. Recall that export- based upstreamness does not depend on what the exporting country does, but on the use it makes of the product at destination. It is possible then that Australia and Russia have this performance because their sales are more concentrated in longer markets, especially China, while Norway has them in shorter markets, typically America and Europe. Taiwan also imports part of its length because it has exposure to a long-chain market, China. Brazil and Indonesia also have a longer forward length than would be expected based on their exports, possibly because of their greater exposure to China. On the other hand, although Mexico's structure would indicate an Upstreamness close to the average (1.53), in fact Mexico has a much greater proximity to final demand. This must be related to the fact that it sells mainly to the United States, a market that is very close to final demand. The same is true for Canada, which has a trade structure typical of an upstream country, but does not perform as such. On the other hand, China also has a greater proximity to final demand than would be expected given its structure.

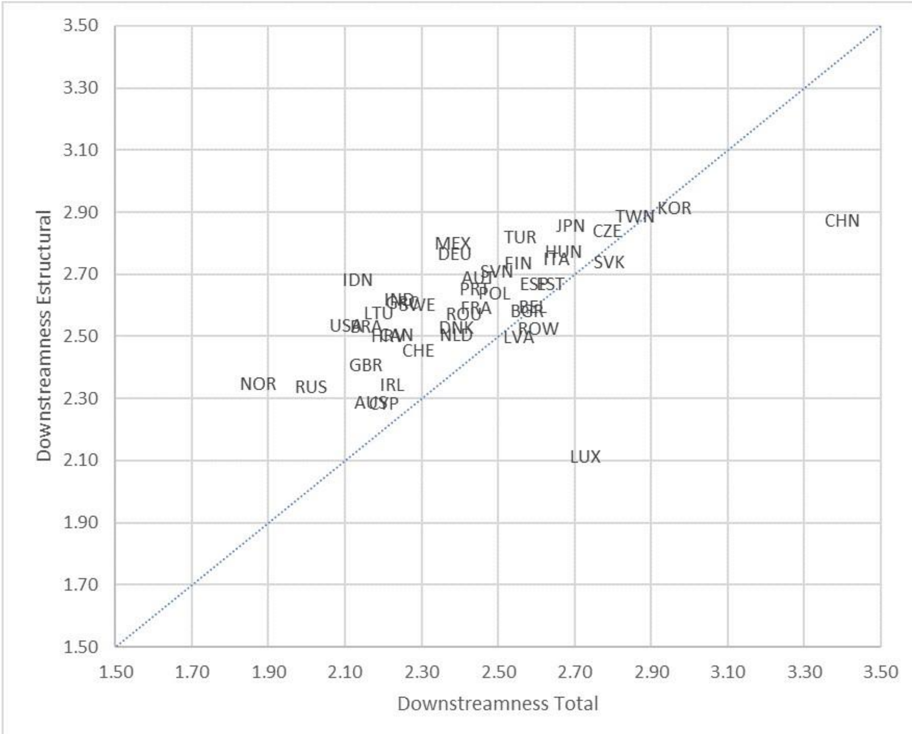
Figure 10: Structural and total Upstreamness. 2014



Source: Own elaboration based in WIOD.

Figure 11 shows the same information for Downstreamness. It naturally high- lights the performance of China, which has a much longer backward length than its trade indicates. This is because this country is the one with the highest do- mestic linkages. Of the other countries, only Luxembourg exhibits a much higher downstreamness than would be expected. Most countries have a lower distance to productive factors than their structure indicates. The big weight of China and its structural difference with the rest of the countries explains this difference. Among the countries that are furthest away from their Structural Downstream- ness are large exporters of manufactured goods, such as Mexico, Germany, USA and Indonesia. Asian countries that have a similar structure (Japan, Taiwan, Rep. of Korea), do not move away from their structural position. This is also related to the greater length of Asian production.

Figure 11: **Structural and total Downstreamness. 2014**



Source: Own elaboration based in WIOD

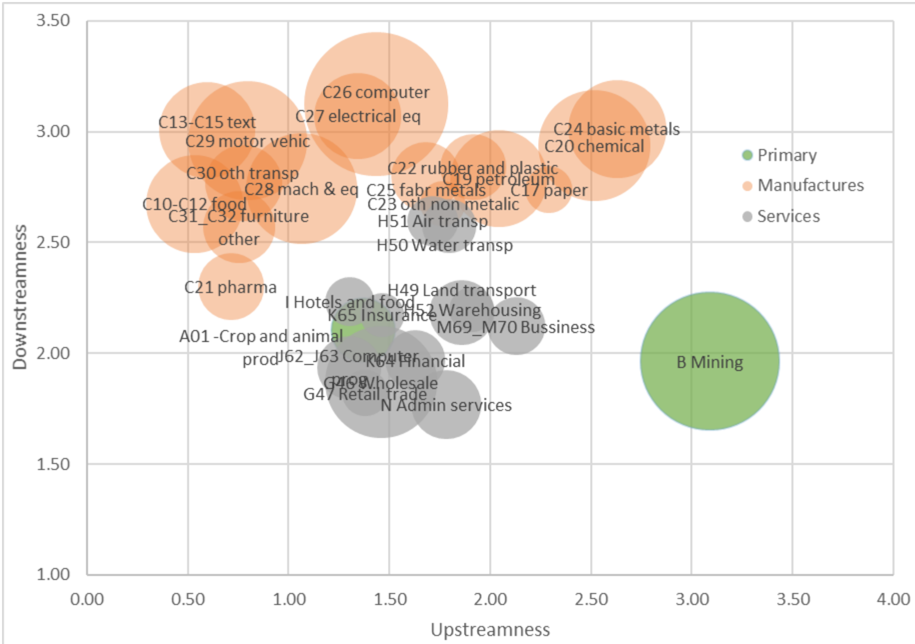
The total length of chains can also be broken down into particular and structural. Graph A.3 in the Appendix shows its evolution. Mexico is the country whose total length is furthest from what its structure indicates, since it is shorter forwards and shorter backwards. Mexico has a structural length identical to Rep. of Korea, but a result of its structure of sales and function of production, it per- forms a length one step shorter than the Asian country (3.5 Mexico and 4.6 Rep. of Korea).

3.3 Sector and Country specific length and position

Upstreamness and Downstreamness at a sector level

Figure 12 shows the Upstreamness and Downstreamness of the top 30 (out of 56) exporting sectors. The size of bubbles represents importance in total exports. As shown in the graph, the differences in the distance to final demand (upstreamness) are very large, while the distances to value added (downstreamness) are quite similar. In particular, all manufacturing sectors report an average distance of between 2.6 and 3.1, except pharmaceuticals. This is in contrast to the primary and tertiary sectors which have a distance to value added of between 1.8 and 2.2, except for transportation where it is higher. Upstreamness reports large differences. Mining stands out for its large average distance to final demand. Also, base metals, chemicals, petroleum and fabricated metals report significant distances, while electrical material, computers and machinery and equipment have an intermediate distance to final demand. Finally, the motor vehicles, textiles, pharmaceuticals and food sectors are very close to the final consumer. Among services, the closest to the final consumer are Computer programming, accommodation and food, financial services and trade, while business and administrative services are further away.

Figure 12: **Upstreamness and Downstreamness of exporting sectors. 2014**



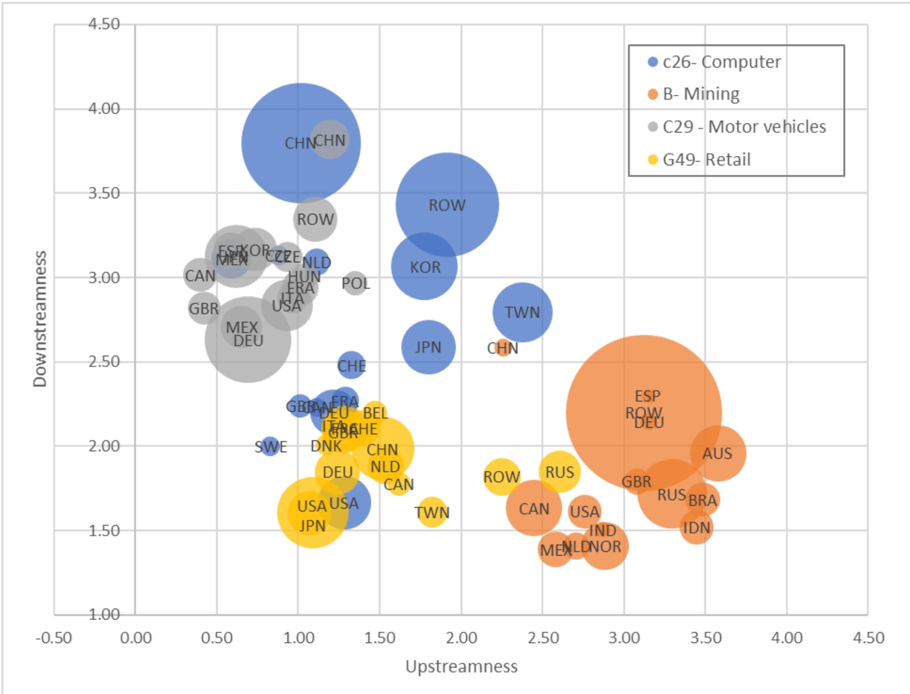
Source: Own elaboration based in WIOD.

Sector-country analysis of Position

The information at the country sector level completes the description. Figure 13 shows the position of the four main exporting sectors in the database and the top ten exporting countries in each sector. The size of the bubbles represents the importance of each country-sector in exports. The top four sectors have quite different positions.

In the Computer equipment sector, China appears as the one with the highest Downstreamness and one of the lowest Upstreamness, contrasting strongly with the position of the USA, where the proximity to value added prevails. The other Asian countries in the sample have a much greater distance to downstreamness than China, and also less distance to value added. The European countries are in an intermediate position and without major differences between them, except for the Netherlands, which has high downstreamness, and Sweden, which is very close to final demand. The second largest sector is mining, which, as we saw in Figure 12, is particularly far from final demand. There are no major differences between countries, although the three North-American countries have less Upstreamness. The third most important sector in international trade is Motor Vehicles, where Germany appears as the main exporter. There, the countries are similarly positioned close to final demand in relatively long backward chains. China differs from the rest in that it is much longer backward, although it does not stand out for its proximity to final demand, as in other sectors. The fourth most important sector is Retail, which is characterized by a short chain. The USA has great weight in this sector and it is also shorter than the other countries. This sector contributes to the short position, both 'structural' and, 'particular' of the USA.

Figure 13: **Upstreamness and Downstreamness of top 10 exporting countries in top 4 exporting sectors. 2014**



Source: Own elaboration based in WIOD.

4. Conclusions

Specialization through international trade organized in global value chains tends to place countries in different segments of the supply chain. Using the information available from the construction of multi-country input-output tables, in recent years there have been improvements in the metrics for measuring the participation and depth of trade in value chains. The vast majority of the literature on chain measurement uses gross exports as the reference for the measures.

However, the literature measuring the location of sectors and countries in value chains has taken a country's production (Antras and Chor, 2018; Miller and Temurshoev, 2017) or only a portion of international trade (Wang et al., 2017b) as the benchmark. The measures proposed in this paper, based on gross exports, show some particularities of the international fragmentation of production that remain veiled in the benchmark measures. Based on WIOD between 2000 and 2014, we find that on average exports are integrated into value chains that elongate forward (i.e., away from final demand) and backward (i.e., away from value added) but do so in a way that is biased toward greater forward distance. Whereas in previous measures there was a strong positive correlation between the two measures, in the measures proposed in this paper the correlation is negative: countries with longer forward length tend to have shorter backward length, which is consistent with a given length of chains and with countries locating in different segments.

The Asian factory (constituted in the database by China, Japan, Taiwan and the Republic of Korea) has longer value chains than the European or American factory -and in the period they have increased their distance from the rest- and differences are identified among the participants. China's exports are very distant from primary factors (due to the length of its domestic chains) and close to final demand, while the other countries mentioned are also distant (although less so) from primary factors, but also from final demand. China also stands out because the vast majority of its backward distance is explained by domestic production stages, while in the rest of the countries (especially the smaller ones) the international circulation of foreign inputs is an important part of the length of the chains. The greater length of Chinese chains is not necessarily due to the composition of their exports, which are intensive in traditionally long sectors, but the analysis at the country sector level shows that China is consistently closer to final demand, but specially further away from primary factors.

The American factory (consisting of USA, Mexico and Canada) is particularly short both forward and backward, and countries are positioned differently according to the measures. For example, according to Wang et al. (2017b) the three countries are downstream (and for AC-MT only Canada is not), but this is not consistent with specialization within the bloc. The export-based measures indicate that Mexico is downstream and the United States and Canada are upstream.

European manufacturing is in an intermediate rank in position and length. The Czech Republic, Slovakia, Italy, Spain and Poland are the most downstream countries, while the Netherlands and Great Britain are upstream. The analysis also places countries with a strong weight of mining in exports, such as Australia, Norway, Russia, Canada and Brazil, especially upstream.

The analysis of the idiosyncratic components of chain participation indicates that Australia, Russia and Brazil, as suppliers to China, inherit their long forward length, while Norway and Canada, suppliers to the shortest factories in America and Europe, inherit their low forward length.

While the USA, Brazil and Indonesia appear as countries close to final demand if one considers all production, the profile of their exports shows them to be further upstream in the chain.

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