Creation and diversion of income and jobs: The case of the Korea – U.S. Free Trade Agreement

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Abstract

This paper calculates the economic benefits and losses of Korea and the United States that may be explicitly attributed to the creation, diversion and contraction of trade flows between them before and after the enforcement of the bilateral free trade agreement (KORUS). This is the first application of a novel estimation technique that relies on structural decomposition analysis to a bilateral trade relationship. The results do not support the perception of KORUS as a detrimental and job-killing agreement. In 2011-2015, net trade creation and alike effects with Korea helped generate nearly 22 thousand additional jobs in the U.S.

JEL Classification: D57, F14, F16

Keywords: trade creation; trade diversion; structural decomposition analysis; input-output table; KORUS FTA

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1 Introduction

The Korea – United States (KORUS) Free Trade Agreement (FTA), the second most commercially significant United States' trade agreement, entered into force in March 2012. In the first five years of its implementation, the U.S. trade deficit in goods with Korea increased by 75% (USTR, 2018). According to an estimate, this eliminated more than 95 thousand jobs in the U.S. between 2011 and 2015 (Scott, 2016). Although the U.S. International Trade Commission indicated that the bilateral merchandise trade deficit would be 56% larger without the agreement (USITC, 2016, p. 139), President Trump referred to the KORUS FTA as a "job killer" and requested that selected chapters of the agreement be renegotiated.

In Korea, the KORUS FTA was a less contentious issue. Korean officials largely praised the "win-win results" of the first five years of its implementation (Yoon, 2017) and analysts tend to view the agreement as providing benefits to both parties (*e.g.,* "KORUS Is Not Perfect", 2017). The Trump Administration's focus on the growing bilateral trade deficit, translated into job losses, is thought to lead to a gross oversimplification of the impact of KORUS (Suh, 2017). A Congressional Research Service report on KORUS FTA echoed this concern and asked "What are the best metrics to evaluate U.S. FTAs?" (Williams et al., 2018).

The case of KORUS highlights the importance of robust estimates of the economic effects of FTAs. Perceptions of lost income and jobs may directly inform trade policies, but they should be based on sufficient evidence. Whereas there were numerous attempts to quantify the expected outcomes of KORUS FTA prior to its signing, empirical investigations into its actual effects, somewhat surprisingly, are scarce. The author has identified three studies that provide such *ex-post* assessments.

Mattoo et al. (2017) employ an augmented gravity model and find that the FTA increased Korea – U.S. bilateral trade in the range between 14% and 40% and their combined imports from third countries by 4% in a period ending 2014. As their key interest is the overall significance of the "depth" of FTA provisions worldwide, they do not go beyond these aggregate results. Russ and Swenson (2019) econometrically estimate an import demand equation, showing that KORUS may have redirected $13.1 billion worth of U.S. imports away from third countries towards Korea in 2013 and $13.8 billion in 2014. The authors are able to disaggregate the implied gross trade diversion by good and by country of origin of imports. Half of U.S. import purchases diverted to Korean suppliers came from China, and the largest affected good category was apparel and other textiles, footwear, and leather goods. A key message from Russ and Swenson (2019) is that, although trade diversion under KORUS may have contributed substantially to the increasing U.S. bilateral trade deficit with Korea after 2012, it left the overall trade balance (across all trading partners) unchanged. This study, however, did not consider other FTA-related effects such as trade creation.

Wei et al. (2019) resort to a tool that is commonly used for the *ex-ante* assessment of FTA effects – the computable general equilibrium (CGE) model. They combine the Global Trade Analysis Project (GTAP) database with the actual import tariff reductions under KORUS and detailed records of U.S. – Korea merchandise trade, and run a simulation of tariff reduction as of 2014. This study concludes that KORUS generated mixed outcomes for the U.S. (GDP gain of $45 million and gross output loss of $142.7 million) while benefiting Korea (GDP and gross output gains of $162.3 million and $322.3 million, respectively). 34 out of 57 industries of the U.S. economy are estimated to incur gross output losses with the manufacturing of auto parts, machinery, and electronic equipment being the most affected. This points to potential job losses in manufacturing industries, although not explicitly measured by the authors. The impact on economic welfare appears to be positive in the order of well over \$300 million for each country.

KORUS was also included in the USITC (2016) investigation of the economic impact of trade agreements implemented by the U.S. since 1984, but results are only available in an aggregate form for all agreements combined.

Given its political relevance and economic significance, KORUS FTA continues to be an appealing case for testing state-of-the-art techniques in search of quantitative evidence of the FTA impacts on trade and economy. The models most commonly used for *ex-post* assessment isolate the FTA factor – *e.g.*, a dummy variable in gravity models or relative import tariff rates in import demand models – and econometrically estimate the response of an economic variable of interest (usually bilateral imports) to the introduction of this FTA factor.

This paper follows a different path adopting a novel methodology described by Muradov (2021a) that builds on structural decomposition analysis (SDA) in an inter-country input-output (ICIO) framework. This approach explores the changes in the country of origin of goods and services or, in other words, effects of substitution between country sources of supply. From the perspective of a home country, these changes may be classified into those that involve home country and partner country products and those between partner and third country products. Substitution of domestic products with imports from partner country is known as trade creation while the reverse process is import substitution. Switching the source of imports from third country to partner country is trade diversion, but it can also occur in reverse direction. The notions of trade creation and trade diversion appeared in Viner (1950) who introduced these to explain the effects of a customs union. They have since become indispensable for quantitative studies of FTAs but are notoriously difficult to measure. Muradov (2021a) utilises the information on the changes in the country of origin of products from a time series of ICIO tables and is able to calculate bilateral trade creation, diversion and contraction (another term for import substitution) as generic effects between countries that may or may not be linked by a trade agreement. He then examines the pattern of the said effects before and after FTAs came into force, between FTA and non-FTA partners.

One may find various advantages of the newly proposed input-output SDA-based measurements of trade creation and diversion. First is the flexibility of the measurement framework in terms of the dependent variable. It can be imports, output, value added, employment or essentially any socio-economic or environmental satellite account attached to the ICIO tables. Second is the flexibility in terms of detail and aggregation: results are at industry or product level in conformance with the ICIO table classification, for each country pair. These may be aggregated as appropriate across industries and/or countries, and may be obtained at each yearly interval for which the underlying tables are available. Third is the coverage of both goods and services that is a rare feature in existing studies. Fourth, the method exhaustively accounts for all types of changes in the country of origin, allowing for a simultaneous estimation of trade creation, diversion and import substitution within a single coherent framework. Fifth, the application of the method does not require choosing between alternative model specifications and estimators which is typical for gravity models. Nor does it require simulations with behavioural parameters as in the CGE-type models. Arbitrary decisions are therefore minimised while the underlying formulations align with the key national account identities and definitions.

This paper is the first consistent application of the input-output SDA to evaluate a bilateral FTA. It offers some methodological improvements over Muradov (2021a). These include a more precise decomposition technique for a particular case of SDA with a large array of factors within the Leontief inverse, the use of multiplicative decomposition side-by-side with additive decomposition, and the choice of stochastic approach as the default approach to obtain the matrix of bilateral allocation of market share losses to market share gains. The latter allows for computing measures of uncertainty and variability of results.

The objects of measurement are changes in value added and employment in both U.S. and Korea at the industry level and changes in GDP induced by bilateral trade creation and alike effects. Value added may be seen as gross incomes of industries generated from production activities prior to distribution. In addition to extending the frontiers of the methodology for the evaluation of FTAs, this study contributes to another strand of literature that explores how trade affects employment. Recent papers are concerned with the effect of the growing imports from China and the merchandise trade deficit on the U.S. employment, *e.g.*, Feenstra and Sasahara (2018), Lin et al. (2018), Wang et al. (2018), Dai et al. (2021). These papers utilise input-output accounts as data source and apply SDA or simplified decomposition techniques, but none of these aims at measuring the impact of trade creation or diversion on jobs in the U.S.

This study unfolds as follows. Section 2 offers a step-by-step exposition of the new method. Section 3 briefly describes the data used and discusses the results, including their sensitivity to the stochastic input in the SDA. This section concludes by comparing, where possible, the new results to those of previous studies. Section 4 provides a summary. Appendices A–E contain a step-by-step exposition of the new method for interested reader, and the online data appendix provides access to the entire set of results with codes for replication.[1]

2 Estimation of trade creation and trade diversion in the inter-country input-output framework

2.1 Setup and notation

An ICIO table records the monetary flows of goods and services within and between countries. Two matrices and four vectors are required to describe this table in matrix notation. In a world economy with K countries and N industries in each country, $\mathbf{Z}$ is a KN×KN block matrix of intermediate demand where an element z^{ij}_{rs} is the monetary value of the intermediate inputs supplied by the producing industry $i \in \{1, \ldots, N\}$ in country $r \in \{1, \ldots, K\}$ to the purchasing (using) industry $j \in \{1, \ldots, N\}$ in country $s \in \{1, \ldots, K\}$. $\mathbf{F}$ is a KN×K block matrix with elements f^{i}_{rs} denoting the value of the output of industry i in country r sold to final users in country s. Likewise, industry output is recorded in a KN×1 column vector $\mathbf{x}$ and value added in a 1×KN row vector $\mathbf{v}'$. An input-output system at basic prices must also include a 1×KN row vector $\mathbf{m}'_{\mathbf{Z}}$ and a 1×K row vector $\mathbf{m}'_{\mathbf{F}}$ of taxes less subsidies, respectively, on intermediate and on

[1] The research data appendix is available from Harvard Dataverse at https://doi.org/10.7910/DVN/DJR56O.

final products.[2]

Fundamental identities in an input-output table imply that total deliveries of products for intermediate and final use (*i.e.*, row sums for each industry) equal output: $\mathbf{Zi}+\mathbf{Fi}_K = \mathbf{x}$, where $\mathbf{i}$ and $\mathbf{i}_K$ are summation vectors of appropriate size that consist of ones.[3] Total expenditures on intermediate and primary inputs (*i.e.*, column sums for each industry) also add up to total output: $\mathbf{i}'\mathbf{Z} + \mathbf{m}'_{\mathbf{Z}} + \mathbf{v}' = \mathbf{x}'$.

In the demand-driven model (also referred to as the Leontief model), the key element is technical coefficients that describe the amount of intermediate inputs used in the production of each industry per one unit of its output. The matrix of technical coefficients results from the column-wise division of the matrix of intermediate demand by the vector of output: $\mathbf{A} = \mathbf{Z}\hat{\mathbf{x}}^{-1}$.[4] Then output may be expressed as a product of a matrix of multipliers and the matrix of final demand, aggregated to a column vector: $\mathbf{x} = (\mathbf{I} - \mathbf{A})^{-1}\mathbf{Fi}_K = \mathbf{LFi}_K$, where $\mathbf{L}$ is the Leontief inverse and $\mathbf{I}$ is the identity matrix. If the multipliers in the Leontief inverse are held constant, output is only a function of final demand which is usually treated as an exogenous variable.

2.2 Value added, GDP and employment in the ICIO framework

Gross value added at basic prices is defined as output valued at basic prices less intermediate consumption valued at purchasers' prices (United Nations et al., 2009, paragraph 6.77). Assume that intermediate consumption is valued at basic prices that is the preferred valuation for the analytical applications of input-output tables (United Nations, 2018, paragraph 2.108). Taxes less subsidies on intermediate products then need to be added to intermediate consumption to revalue it at purchasers' prices:

$$\mathbf{v}' = \mathbf{x}' - (\mathbf{i}'\mathbf{Z} + \mathbf{m}'_{\mathbf{Z}}) = \mathbf{i}'\hat{\mathbf{x}} - \mathbf{i}'\mathbf{A}\hat{\mathbf{x}} - \mathbf{m}'_{\mathbf{Z}} = (\mathbf{i}' - \mathbf{i}'\mathbf{A})\,\hat{\mathbf{x}} - \mathbf{m}'_{\mathbf{Z}} \tag{1}$$

Assume that the ICIO table differentiates taxes less subsidies on intermediate products by country of origin of products subject to those taxes.[5] This means that a K×KN matrix of taxes less subsidies on intermediate products $\mathbf{M_Z}$ is available, and vector $\mathbf{m}'_{\mathbf{Z}}$ may be rewritten as:

$$\mathbf{m}'_{\mathbf{Z}} = \mathbf{i}'\mathbf{M_Z} = \mathbf{i}'\big(\mathbf{T_Z} \circ (\mathbf{S}'_N\mathbf{Z})\big) = \mathbf{i}'\big(\mathbf{T_Z} \circ (\mathbf{S}'_N\mathbf{A}\hat{\mathbf{x}})\big) \tag{2}$$

where $\mathbf{T_Z} = \mathbf{M_Z} \oslash (\mathbf{S}'_N\mathbf{Z})$ denotes effectively applied net tax rates by country of origin and country-industry of destination, $\mathbf{S}_N$ is a KN×K industry aggregation matrix,[6] $\circ$ signifies the element-by-element multiplication (the Hadamard product), and $\oslash$ the element-by-element division.

Insert equation (2) into equation (1):

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[2] The prime symbol denotes a transpose of a matrix or a vector.

[3] The default dimensions of the summation vector and identity matrix is KN×1 and KN×KN, respectively. Otherwise their dimension is denoted by a lower index, *e.g.*, $\mathbf{i}_K$ is a K×1 summation vector of ones, and $\mathbf{I}_N$ is a N×N identity matrix.

[4] The circumflex or "hat" symbol above a vector denotes a transformation into a diagonal matrix.

[5] ICIO tables do not usually contain that information. However, such disaggregation is a distinctive feature of the 2018 release of the OECD ICIO tables used in this research. The author uses this additional information as it allows for a more accurate decomposition

[6] $\mathbf{S}_N$ is a block-diagonal matrix with a K×1 vector of ones in its diagonal blocks. It may be obtained from the following manipulation: $\mathbf{S}_N = \mathbf{I}_K \otimes \mathbf{i}_N$, where $\otimes$ is the Kronecker product.

$$\mathbf{v}' = (\mathbf{i}' - \mathbf{i}'\mathbf{A})\,\hat{\mathbf{x}} - \mathbf{i}'\big(\mathbf{T_Z} \circ (\mathbf{S}'_N\mathbf{A}\hat{\mathbf{x}})\,\big) = \big(\mathbf{i}' - \mathbf{i}'\big((\mathbf{1}_{K\times KN} + \mathbf{T_Z}) \circ (\mathbf{S}'_N\mathbf{A})\big)\big)\,\hat{\mathbf{x}}$$

where $\mathbf{1}_{K\times KN}$ is a K×KN matrix of ones. Using that $\mathbf{x} = \mathbf{LFi}_K$, transpose and rewrite the above equation:

$$\mathbf{v} = diag\,\big(\mathbf{i}' - \mathbf{i}'\big((\mathbf{1}_{K\times KN} + \mathbf{T_Z}) \circ (\mathbf{S}'_N\mathbf{A})\big)\big)\,\mathbf{x} = \Big(\mathbf{I} - diag\Big(\mathbf{i}'\big((\mathbf{1}_{K\times KN} + \mathbf{T_Z}) \circ (\mathbf{S}'_N\mathbf{A})\big)\Big)\Big)\,\mathbf{LFi}_K \tag{3}$$

"*diag*" in equation (3) signifies diagonalisation of a vector. Recalling that $\mathbf{L}$ is a function of $\mathbf{A}$, we can denote, for brevity, value added as a function of three variables, $\mathbf{v}(\mathbf{T_Z}, \mathbf{A}, \mathbf{F})$.

GDP is a summary measure of value added generated in an economy. Defined by the production approach, it is equal to "the value of output less intermediate consumption plus any taxes less subsidies on products not already included in the value of output" (United Nations et al., 2009, paragraph 16.47). Taxes less subsidies on intermediate products now need to be removed from the formula of GDP to avoid double counting:

$$\mathbf{y}' = \mathbf{x}'\mathbf{S}_N - \mathbf{i}'\mathbf{Z}\mathbf{S}_N + \mathbf{m}'_\mathbf{F} = \mathbf{i}'\hat{\mathbf{x}}\mathbf{S}_N - \mathbf{i}'\mathbf{A}\hat{\mathbf{x}}\mathbf{S}_N + \mathbf{m}'_\mathbf{F} = (\mathbf{i}' - \mathbf{i}'\mathbf{A})\,\hat{\mathbf{x}}\mathbf{S}_N + \mathbf{m}'_\mathbf{F} \tag{4}$$

where $\mathbf{y}'$ is a 1×K vector of GDP of K countries, and $\mathbf{m}'_\mathbf{F}$ is a 1×K vector of taxes less subsidies on final products.

If the ICIO table differentiates taxes less subsidies on final products by country of origin of products subject to those taxes, and a K×K matrix of taxes less subsidies on final products $\mathbf{M_F}$ is available, then vector $\mathbf{m}'_\mathbf{F}$ may be rewritten as:

$$\mathbf{m}'_\mathbf{F} = \mathbf{i}'\mathbf{M_F} = \mathbf{i}'\big(\mathbf{T_F} \circ (\mathbf{S}'_N\mathbf{F})\,\big) \tag{5}$$

where $\mathbf{T_F} = \mathbf{M_F} \oslash (\mathbf{S}'_N\mathbf{F})$ denotes effectively applied net tax rates by country of origin and country of destination.

Insert equation (5) into equation (4) and, using that $[(\mathbf{i}' - \mathbf{i}'\mathbf{A})\,\hat{\mathbf{x}}]' = (\widehat{\mathbf{i}' - \mathbf{i}'\mathbf{A}})\mathbf{x}$, and $\mathbf{x} = \mathbf{LFi}_K$, transpose and rewrite equation (4):

$$\mathbf{y} = \mathbf{S}'_N(\widehat{\mathbf{i}' - \mathbf{i}'\mathbf{A}})\mathbf{x} + \mathbf{m_F} = \mathbf{S}'_N\,\Big(\mathbf{I} - \widehat{\mathbf{i}'\mathbf{A}}\Big)\,\mathbf{LFi}_K + \big(\mathbf{T_F} \circ (\mathbf{S}'_N\mathbf{F})\,\big)'\mathbf{i} \tag{6}$$

GDP is now a function of intermediate input requirements, final demand and net tex rates on final products, $\mathbf{y}(\mathbf{A}, \mathbf{F}, \mathbf{T_F})$.

If $\mathbf{e}$ is a KN×1 vector of employment by industry, in persons or number of jobs, and $\mathbf{e}_c = \mathbf{e}\hat{\mathbf{x}}^{-1}$ is a vector of employment coefficients, in persons or number of jobs per one dollar of industry output, then employment can be expressed as a function of intermediate input requirements and final demand:

$$\mathbf{e} = \hat{\mathbf{e}}_c\mathbf{x} = \hat{\mathbf{e}}_c\mathbf{LFi}_K \tag{7}$$

Employment is therefore a function of three independent variables, $\mathbf{e}(\mathbf{e}_c, \mathbf{A}, \mathbf{F})$.

2.3 Hierarchical structural decomposition

SDA is a way to attribute the change in the dependent variable – usually a product of various matrices and vectors, referred to as determinants or factors – to the changes in each of those factors. In the additive case, we look for the following decompositions of value added, GDP and employment:

$$\begin{aligned}
\Delta\mathbf{v}(\mathbf{T_Z}, \mathbf{A}, \mathbf{F}) &= \Delta\mathbf{v}(\mathbf{T_Z}) + \Delta\mathbf{v}(\mathbf{A}) + \Delta\mathbf{v}(\mathbf{F}) \\
\Delta\mathbf{y}(\mathbf{A}, \mathbf{F}, \mathbf{T_F}) &= \Delta\mathbf{y}(\mathbf{A}) + \Delta\mathbf{y}(\mathbf{F}) + \Delta\mathbf{y}(\mathbf{T_F}) \\
\Delta\mathbf{e}(\mathbf{e}_c, \mathbf{A}, \mathbf{F}) &= \Delta\mathbf{e}(\mathbf{e}_c) + \Delta\mathbf{e}(\mathbf{A}) + \Delta\mathbf{e}(\mathbf{F})
\end{aligned}$$

This paper adopts nested or hierarchical structural decomposition: $\Delta\mathbf{v}(\mathbf{A})$, $\Delta\mathbf{v}(\mathbf{F})$, $\Delta\mathbf{y}(\mathbf{A})$, $\Delta\mathbf{y}(\mathbf{F})$, $\Delta\mathbf{e}(\mathbf{A})$ and $\Delta\mathbf{e}(\mathbf{F})$ will be further decomposed into changes of the underlying factors. This allows us to handle factors in groups, and makes the SDA procedure more manageable.

The next-level decomposition builds on a factorisation of the matrix of technical coefficients $\mathbf{A}$ and the matrix of final demand $\mathbf{F}$. Let us write the former as follows:

$$\mathbf{A} = \mathbf{A}^{cou} \circ \left(\mathbf{S}'_K \mathbf{A}^{ind} \hat{\mathbf{a}}\right) \tag{8}$$

where $\mathbf{S}_K$ is a N×KN country aggregation matrix.[7] $\mathbf{A}^{ind}$ is an N×KN matrix that allocates total industry requirements for intermediate inputs $\mathbf{a}' = \mathbf{i}'\mathbf{A}$ to the industry sources of those inputs or, by and large, to homogenous groups of individual products:

$$\mathbf{A}^{ind} = \mathbf{S}_K \mathbf{A} \hat{\mathbf{a}}^{-1}$$

This matrix is usually referred to as the matrix of normalised total intermediate input (or technical) coefficients (see, *e.g.*, Duan et al., 2018) and is thought to describe technology, or "production recipe" in input-output models. Note that the industries that supply intermediate inputs are aggregated across all countries at this stage. $\mathbf{A}^{cou}$ is a KN×KN matrix that distributes intermediate inputs across the countries of their origin:[8]

$$\mathbf{A}^{cou} = \mathbf{A} \oslash \left(\mathbf{S}'_K \mathbf{S}_K \mathbf{A}\right)$$

To sum up, changes in $\mathbf{a}$ describe the substitution between primary and intermediate inputs, changes in $\mathbf{A}^{ind}$ describe the substitution between the industry sources of intermediate inputs and changes in $\mathbf{A}^{cou}$ describe the substitution between the country sources of intermediate inputs. It is customary to interpret changes in $\mathbf{a}$ as changes in the efficiency of the use of intermediate inputs or as outsourcing process, changes in $\mathbf{A}^{ind}$ as changes in industry technology and changes in $\mathbf{A}^{cou}$ as changes in trade patterns. Together, changes in $\mathbf{a}$, $\mathbf{A}^{ind}$ and $\mathbf{A}^{cou}$ define the change in $\mathbf{A}$ and $\mathbf{L}$.

In case of additive decomposition, we can now write $\Delta\mathbf{v}(\mathbf{A}) = \Delta\mathbf{v}(\mathbf{a}) + \Delta\mathbf{v}(\mathbf{A}^{ind}) + \Delta\mathbf{v}(\mathbf{A}^{cou})$, which also applies to changes in GDP and employment.

[7] $\mathbf{S}_K$ is obtained by replicating an N×N identity matrix horizontally K times: $\mathbf{S}_K = \mathbf{i}'_K \otimes \mathbf{I}_N$. In equation (8), the transpose of $\mathbf{S}_K$ copies an N×KN matrix K times vertically to obtain a KN×KN matrix.

[8] Note that in case an element in $\mathbf{A}^{cou}$ results from division of zero by zero, it should be made equal to zero. This occurs if industry j in country s does not purchase input from industry i in the given period. The same rule applies to $\mathbf{A}^{ind}$, $\mathbf{a}'$ and $\mathbf{A}$, though such cases are less likely to occur.

Factorisation of $\mathbf{F}$ is similar:

$$\mathbf{F} = \mathbf{F}^{cou} \circ \left(\mathbf{S}'_K \mathbf{F}^{ind} \hat{\mathbf{f}}\right) \tag{9}$$

$\hat{\mathbf{f}}$ is a diagonalised 1×K row vector that contains the values of total domestic final demand in each country in the input-output system. It sums the columns of $\mathbf{F}$: $\mathbf{f}' = \mathbf{i}'\mathbf{F}$. $\mathbf{F}^{ind}$ is an N×K matrix that allocates total demand for final products to the industry sources of those products:

$$\mathbf{F}^{ind} = \mathbf{S}_K \mathbf{F} \hat{\mathbf{f}}^{-1}$$

This matrix describes the product structure of final demand expenditure that is subject to change because of consumer or investor preferences. Finally, $\mathbf{F}^{cou}$ is a KN×K matrix that distributes the demand for final products across the countries of their origin:

$$\mathbf{F}^{cou} = \mathbf{F} \oslash (\mathbf{S}'_K \mathbf{S}_K \mathbf{F})$$

We decompose the corresponding change in value added as $\Delta\mathbf{v}(\mathbf{F}) = \Delta\mathbf{v}(\mathbf{f}) + \Delta\mathbf{v}(\mathbf{F}^{ind}) + \Delta\mathbf{v}(\mathbf{F}^{cou})$.

2.4 Deeper decomposition of the changes in the country of origin of intermediate and final products

Moving to the final level of this hierarchical structural decomposition, we admit that the changes in the country of origin of intermediate and final products aggregate information on such effects as trade creation and trade diversion:

$$\Delta\mathbf{A}^{cou} = \Delta\mathbf{A}^{TC} + \Delta\mathbf{A}^{TD} + \Delta\mathbf{A}^{TR} = \sum_{s=1}^{K}\sum_{r\neq s}^{K} \Delta\mathbf{A}^{TC}_{rs} + \sum_{s=1}^{K}\sum_{r\neq s}^{K} \Delta\mathbf{A}^{TD}_{rs} + \sum_{s=1}^{K}\sum_{r\neq s}^{K} \Delta\mathbf{A}^{TR}_{rs} \tag{10}$$

$$\Delta\mathbf{F}^{cou} = \Delta\mathbf{F}^{TC} + \Delta\mathbf{F}^{TD} + \Delta\mathbf{F}^{TR} = \sum_{s=1}^{K}\sum_{r\neq s}^{K} \Delta\mathbf{F}^{TC}_{rs} + \sum_{s=1}^{K}\sum_{r\neq s}^{K} \Delta\mathbf{F}^{TD}_{rs} + \sum_{s=1}^{K}\sum_{r\neq s}^{K} \Delta\mathbf{F}^{TR}_{rs} \tag{11}$$

$\Delta\mathbf{A}^{TC}$ and $\Delta\mathbf{F}^{TC}$ are, respectively, KN×KN and KN×K matrices that sum up trade creation among all countries in the input-output system. $\Delta\mathbf{A}^{TC}_{rs}$ and $\Delta\mathbf{F}^{TC}_{rs}$ are bilateral matrices of trade creation, for each home country s and partner country r. As a country does not create trade with itself, there must be $K(K-1)$ bilateral matrices of trade creation with respect to intermediate demand and $K(K-1)$ bilateral matrices with respect to final demand. Multilateral matrices of trade diversion, $\Delta\mathbf{A}^{TD}$ and $\Delta\mathbf{F}^{TD}$, need to be broken down into $K(K-1)$ bilateral matrices in the same way. Note that there are two alternate ways to count trade diversion: (1) where imports from partner country replace imports from third countries, that is diversion towards partner, and (2) where imports from third countries replace imports from partner country, that is diversion away from partner.

Trade creation and trade diversion together capture all but one type of change in the country of origin of products purchased by intermediate or final users in the home country. Missing is the shift of market shares where users at home prefer buying domestic products instead of imported products from the partner country. This type of change in the supply of products may be recognised as import substitution and is counter to trade creation. It is termed hereinafter "trade contraction" and denoted by the upper index *TR*. Including trade contraction effect in our analysis ensures the exhaustive coverage of all changes in the country of origin of products that satisfy intermediate and final demand.

It must be unambiguously stressed that the matrices of trade creation (diversion, contraction) cannot be observed. Trade statistics from whatever source may provide information on the change in trade (export, import) shares. However, it remains unknown whether export or import share of one partner changed at the expense of another partner. As regards the ICIO tables, the attribution of the entries in $\Delta\mathbf{A}^{cou}$ and $\Delta\mathbf{F}^{cou}$ to trade creation, diversion or contraction with selected partners is uncertain (not unique) if the number of countries exceeds three.[9]

Although the matrices of bilateral trade creation (diversion, contraction) cannot be observed, they can be estimated. A core novelty of Muradov (2021a) is a procedure to generate these estimates in the ICIO framework.

Matrices $\Delta\mathbf{A}^{cou}$ and $\Delta\mathbf{F}^{cou}$ contain the information on the changes in the domestic and foreign suppliers' shares of the purchases of intermediate inputs by industries and final products by consumers/investors. For example, in matrix $\Delta\mathbf{A}^{cou}$, each $s.j$-th column captures market shares that domestic industries and industries in partner/third countries lost or gained in the intermediate demand of industry j in home country s. Allocation of market share losses to market share gains on a bilateral basis unveils the redistribution of market shares among all trading partners. This may be thought of as adding another dimension to each column of $\Delta\mathbf{A}^{cou}$ and $\Delta\mathbf{F}^{cou}$. Formally, the problem is to estimate an unknown target matrix with the known column and row totals where, in case of intermediate demand, column totals contain market share losses and row totals contain market share gains for industry j in country s. A matrix updating method, such as RAS (see, *e.g.*, Miller and Blair, 2009, chap.7), is well posed to address this problem, provided that an initial matrix that serves as a starting point in the projection is available. The choice of the initial matrix affects the target matrix. For example, setting the initial matrix to a matrix of ones in the $j.j$-th elements (intersections of the same industries) and zeros elsewhere ensures a bi-proportional allocation of market share losses to market share gains. Here we will turn to a stochastic approach and will allow the elements in the initial matrix to be drawn from the standard uniform distribution. The initial matrix is generated 400 times followed by the RAS balancing routine, separately for intermediate and final demand, giving a sample of 400 multilateral estimates of $\Delta\mathbf{A}^{TC}$, $\Delta\mathbf{A}^{TD}$ (both towards partner and away from partner), $\Delta\mathbf{A}^{TR}$, $\Delta\mathbf{F}^{TC}$, $\Delta\mathbf{F}^{TD}$ (both ways) and $\Delta\mathbf{F}^{TR}$. These multilateral estimates are manually disaggregated into bilateral estimates for the use in SDA.

We assume that the sample mean is a good approximation of the "true" results. This approach also allows computing the standard deviation of each estimate, test the sample for normality and check the differences between the sample mean, or baseline estimate, and alternative estimates. Further details on the estimation procedure may be found in Muradov (2021a).

The ultimate result is KN$\times$1 vectors of changes in value added of all industries in

[9] If an input-output system only features three countries, the changes in the country of origin may always be unequivocally allocated to trade creation, diversion and contraction because there is only one partner and one third country.

all countries induced by trade creation (diversion, contraction) in the intermediate or final demand of home country s with respect to partner country r. In case of additive decomposition, these include $\Delta\mathbf{v}(\Delta\mathbf{A}_{rs}^{TC})$, $\Delta\mathbf{v}(\Delta\mathbf{A}_{rs}^{TD})$, $\Delta\mathbf{v}(\Delta\mathbf{A}_{rs}^{TR})$, or $\Delta\mathbf{v}(\Delta\mathbf{F}_{rs}^{TC})$, $\Delta\mathbf{v}(\Delta\mathbf{F}_{rs}^{TD})$, $\Delta\mathbf{v}(\Delta\mathbf{F}_{rs}^{TR})$. A sum of the relevant terms provides a measure of total changes in value added because of, *e.g.*, trade creation in the r–s pair that we write for brevity as $\Delta\mathbf{v}_{rs}^{TC} = \Delta\mathbf{v}(\Delta\mathbf{A}_{rs}^{TC}) + \Delta\mathbf{v}(\Delta\mathbf{F}_{rs}^{TC})$.

In vector $\Delta\mathbf{v}_{rs}^{TC}$, the N×1 block $\left(\Delta\mathbf{v}_{rs}^{TC}\right)_k$ corresponds to the changes in value added in all N industries of the k-th country in the ICIO system in response to trade creation in the r–s pair. In study of a bilateral relationship we may be primarily interested in setting k equal to r and s. Note that the changes in industry value added of country s are two-way: as a result of trade creation that affects its own demand as home country, $\left(\Delta\mathbf{v}_{rs}^{TC}\right)_s$, and trade creation that affects the demand of country r in the s–r pair where r is home country and s is partner country, $\left(\Delta\mathbf{v}_{sr}^{TC}\right)_s$. The sum of the two may reasonably be treated as net trade creation. This applies to the other two effects[10] and other dependent variables. Note that the dimension of results for the changes in GDP, *e.g.*, $\Delta\mathbf{y}(\Delta\mathbf{A}_{rs}^{TC})$, is K×1.

A more detailed description of the SDA procedure, including the multiplicative decomposition, may be found in Appendices A–E.

3 Data and results

3.1 Data

For an empirical application of the proposed method, this paper utilises the 2018 edition of the OECD Inter-Country Input-Output tables (OECD, 2018). Included in the tables are 64 countries (of which 28 are non-OECD members) plus an aggregate category of the rest of the world. The industry breakdown includes 36 industries defined in line with the ISIC Rev.4.[11] Annual time series of the ICIO tables are at current prices for the period 2005-2015.

An important note is that the OECD ICIO tables are not available at previous year prices which would allow to isolate the effect of price changes, and the structural decomposition analysis here applies to data at current prices. However, this may not be a serious reason for concern as long as we compare trade creation with trade diversion and trade contraction, or trade creation (diversion, contraction) for one country as the home country, partner country or third country. It is reasonable to expect that price changes affect the relevant variables in the same way. Furthermore, recent studies (Timmer et al., 2016; Duan et al., 2018) that run SDA in a multi-regional input-output framework do not find that using data at current prices significantly distorts the results in relative terms.

[10] Net trade creation and net trade contraction may be positive or negative subject to a combination of these effects for one country as home country and partner country, because usually $\left(\Delta\mathbf{v}_{rs}^{TC}\right)_s < 0$, $\left(\Delta\mathbf{v}_{sr}^{TC}\right)_s > 0$, $\left(\Delta\mathbf{v}_{rs}^{TR}\right)_s > 0$ and $\left(\Delta\mathbf{v}_{sr}^{TR}\right)_s < 0$. Trade diversion towards partner (*TDin*) usually benefits this partner, $\left(\Delta\mathbf{v}_{rs}^{TDin}\right)_r > 0$, while trade diversion away from partner (*TDout*) does not, $\left(\Delta\mathbf{v}_{rs}^{TDout}\right)_r < 0$. Trade diversion effects in whatever direction tend to be neutral or insignificant for home country. Therefore, net trade diversion *in* is usually positive and net trade diversion *out* negative.

[11] The manufacturing industries in China and Mexico are additionally disaggregated into those operating in standard mode and those operating in processing exports mode. The industry breakdown for China and Mexico was aligned here with the uniform 36-industry classification of other countries because details on processing exports are not relevant for this investigation.

That said, future research will surely benefit from time series of ICIO tables at previous year prices.

Data on employment are sourced from the OECD Trade in eMployment (TiM) Database, released in 2019 (Horvát et al., 2020).

The USITC DataWeb facility is the source of data on the U.S. MFN and KORUS tariffs, KORUS programme utilisation and imports from Korea. These data are available at the 8-digit tariff line level of the Harmonized Tariff Schedule of the United States (HTS) and are used to calculate the weighted average tariffs for agricultural and industrial goods, including the *ad valorem* equivalents of specific rates, aggregated to the OECD ICIO classification. Korea's preferential tariff rates are directly obtained from the Tariff Schedule of Korea (Annex 2-B to the KORUS FTA) at the national 10-digit tariff line level, while its MFN rates at the 10-digit level and imports data at the 6-digit level are downloaded from, respectively, the UN TRAINS and Comtrade databases via the World Integrated Trade Solution (WITS).[12]

3.2 Aggregate results: impact on GDP and employment

We will first consider the aggregate changes in Korea's and the U.S. GDP induced by all three types of substitution effects in bilateral trade. For example, these changes in the U.S. GDP can be formally described by the following expression:

$$\begin{aligned} &\left(\Delta \mathbf{y}^{TC}_{KOR-USA}\right)_{USA} + \left(\Delta \mathbf{y}^{TC}_{USA-KOR}\right)_{USA} + \left(\Delta \mathbf{y}^{TDin}_{KOR-USA}\right)_{USA} + \left(\Delta \mathbf{y}^{TDin}_{USA-KOR}\right)_{USA} + \\ &+ \left(\Delta \mathbf{y}^{TDout}_{KOR-USA}\right)_{USA} + \left(\Delta \mathbf{y}^{TDout}_{USA-KOR}\right)_{USA} + \left(\Delta \mathbf{y}^{TR}_{KOR-USA}\right)_{USA} + \left(\Delta \mathbf{y}^{TR}_{USA-KOR}\right)_{USA} \end{aligned}$$

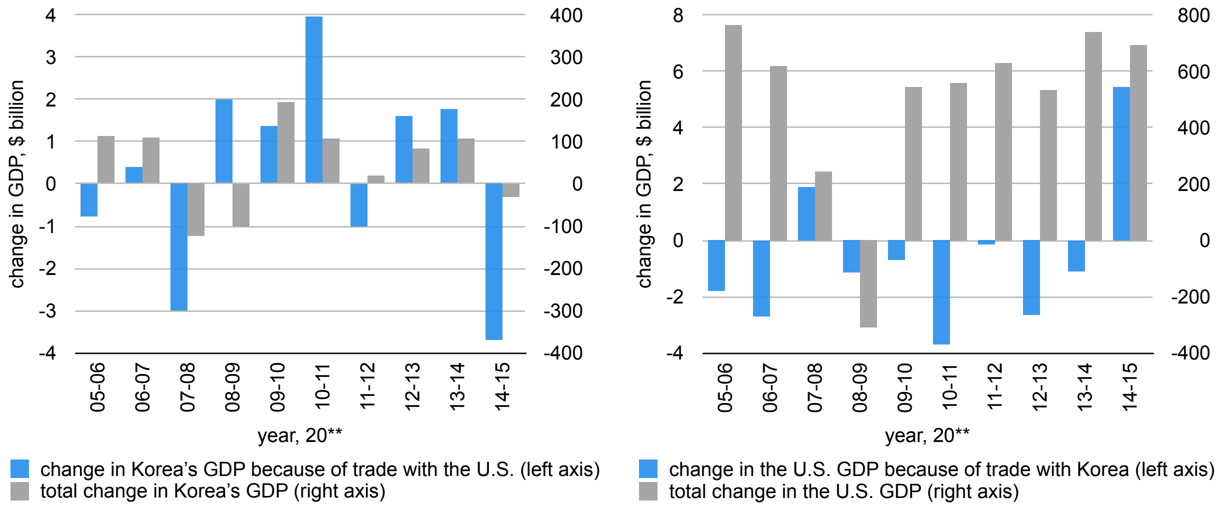
The first and the second terms in the sum above correspond to the net trade creation effect on the U.S. GDP, the third to sixth terms correspond to net trade diversion towards partner (*in*) and away from partner (*out*), and the last two terms correspond to net trade contraction. The additive decomposition is more convenient for visualisation, but the multiplicative one would largely lead to the same conclusions as it gauges the same effects in relative (growth) terms.

It must be stressed here that the decomposition described in Section 2 does not establish a causal relationship between the effects of trade creation (diversion, contraction) on GDP, value added, employment and the preferences or incentives introduced by the KORUS FTA. Changes in the country of origin of products in bilateral trade may occur between FTA parties and between countries that do not have an FTA. We shall therefore treat the results of the decomposition as estimates of trade creation and other related effects of which some part can be generated by the FTA regime. We will compare these estimates before and after the enforcement of KORUS. Later, we will explore whether these may be explained by KORUS preferences.

Korea experienced both increments and losses of GDP because of the substitution effects in trade with the U.S. in 2005-2015. As figure 1a shows, the increments are

[12] As part of the calculation of the weighted average tariffs by industry, the author compiled correspondence tables from the HS Nomenclature 2007 and 2012 Editions to the OECD ICIO industry classification. This required transitions between the HS and the Central Product Classification (CPC), between CPC and the International Standard Industrial Classification of All Economic Activities (ISIC) Rev.4 using the correspondence tables published by the UN Statistics Division, followed by an aggregation of ISIC Rev.4 codes into the OECD ICIO industry codes. Further details and the correspondence tables may be found in the online Appendix H.

somewhat smaller and losses are larger after the introduction of KORUS in 2012. The same effects tended to reduce the U.S. GDP, except for two yearly intervals, 2007-2008 and 2014-2015. The U.S. GDP growth in 2014-2015 because of trade effects with Korea may have outweighed the GDP losses since the KORUS FTA came into force in 2012, see figure 1b. The estimates of the GDP growth for individual yearly intervals may be misleading because the underlying data are at current prices, but a comparison of the GDP changes induced by the trade effects in question and total GDP change is meaningful. The absolute value of the contribution of the U.S.-related trade effects to the total change of Korea's GDP averaged at 3%, reaching its maximum in 2014-2015 (12%). The share of the U.S. GDP change that is attributable to the trade effects with Korea did not exceed 1%.



(a) Change in Korea's GDP

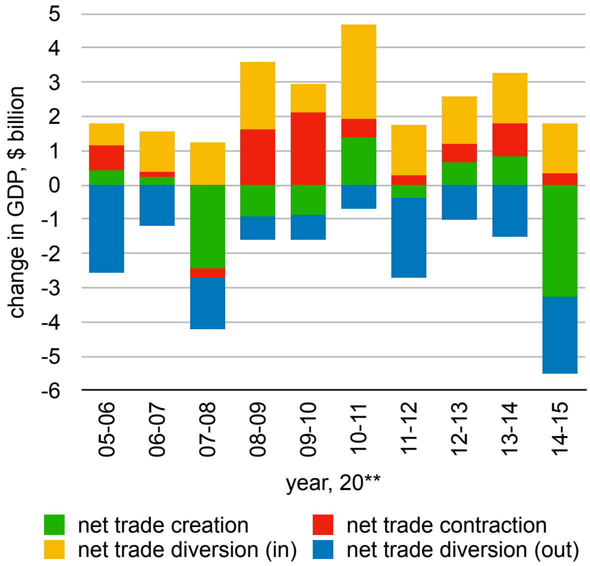
(b) Change in the U.S. GDP

Figure 1: Change in Korea's and the U.S. GDP, including the changes induced by bilateral trade effects in 2005-2015, $ billion

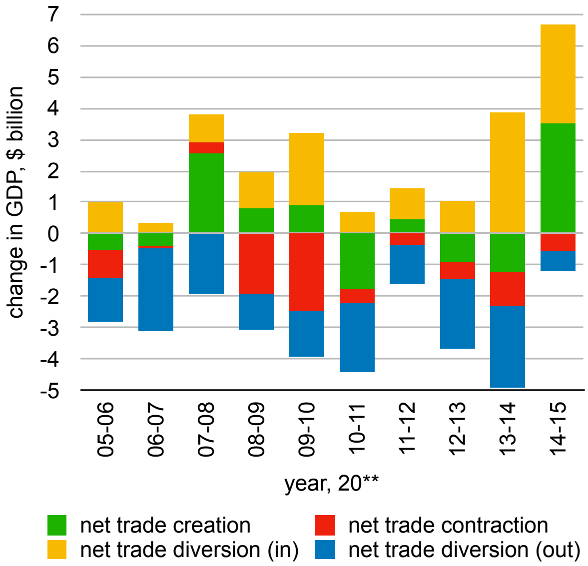
Source: OECD ICIO tables (2018 release), author's calculations (detailed results are in the online Appendix A).

A decomposition into the underlying effects in figure 2 shows that bilateral trade creation, diversion and contraction affected the GDP of both countries before and after the KORUS FTA came into force. One may observe that the net trade creation effects on Korea's and the U.S. GDP mirror each other. This is in line with our expectation: by shifting sources of supply, trade creation redistributes income between home country and partner country, and very little leaks to third countries via global value chains. This is also true for trade contraction. However, trade diversion towards and away from partner is not symmetric because it redistributes income between partner country and third countries. Hence the asymmetric behaviour of the aggregate changes in GDP because of all three effects in figure 1. Interestingly, in 2005-2006 and 2011-2012 these changes are negative for both Korea and the U.S.

There is no uniform pattern in the composition of GDP changes induced by the three effects in 2005-2015. It is neither apparent that the KORUS FTA altered the magnitude and combination of these effects in any specific way. If trade creation and trade diversion towards partner are responses to the enforcement of the FTA, Korea may have derived limited benefit in terms of GDP in the first three years of KORUS. But trade creation in favour of Korea may also be seen in 2005-2007 and 2010-2011. Trade diversion generated additional GDP growth for Korea, in particular, in 2008-2009 and 2010-2011 when market access preferences under KORUS were not available (see figure 2a). In the U.S., the predominance of trade diversion towards the U.S. as partner in 2013-2015 and positive trade creation in 2014-2015 (figure 2b) indicates that U.S. suppliers successfully replaced third country and domestic competitors in the Korean market. Enhanced market access under KORUS may explain this result. However, trade creation was also positive for the U.S. in 2007-2010, and trade diversion toward the U.S. was significant in 2005-2006 and 2007-2010.



(a) Change in Korea's GDP



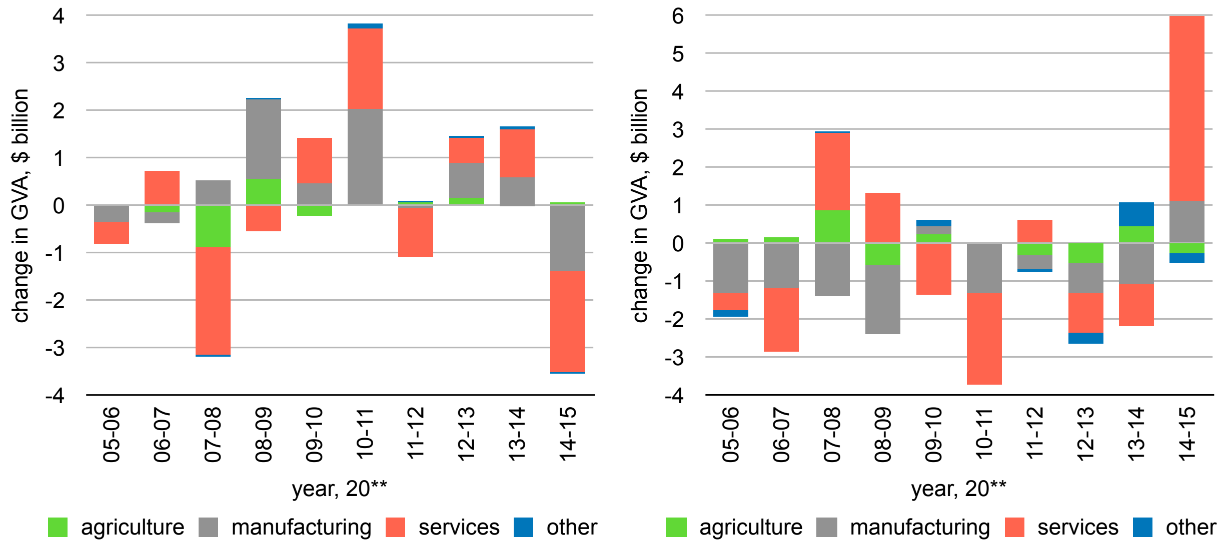
(b) Change in the U.S. GDP

Figure 2: Change in Korea's and the U.S. GDP induced by bilateral trade effects in 2005-2015, $ billion
Source: OECD ICIO tables (2018 release), author's calculations (detailed results are in the online Appendix A).

Two effects that largely describe reduced trade with partner country – trade diversion away from partner and trade contraction – are also persistent throughout the entire period of investigation. Net trade contraction has benefited Korea for nearly the whole decade and peaked in 2008-2010 which is a typical implication of the "great trade collapse" (see Muradov, 2021a). Under KORUS, American exporters faced the same import-substituting behaviour of Korean firms and consumers, compared to that in 2005-2006 or 2010-2011. GDP reduction because of losses of import market shares to suppliers from third countries (net trade diversion *out* in figure 2) has also been common, in particular, for the U.S. This is not surprising given Korea's active signing of FTAs with other trade partners, including an FTA with the EU provisionally applied since July 2011, followed by a possible diversion of trade flows.

Although the contribution of the KORUS FTA is not obvious, the U.S. GDP gain was historically high at the fourth year of the agreement, driven by a combination of positive net trade creation and trade diversion *in* that was not observed in previous years.

Another breakdown, utilising the results from the decomposition of changes in industry value added, shows the contribution of aggregate groups of industries to the changes



(a) Change in Korea's GVA

(b) Change in the U.S. GVA

Figure 3: Change in Korea's and the U.S. Gross Value Added (GVA) in 2005-2015, with contributions of aggregate groups of industries, $ billion
Note: Other industries include mining, electricity, gas, water supply and construction.
Source: OECD ICIO tables (2018 release), author's calculations (detailed results are in the online Appendix A).

of GDP induced by trade creation and related effects. We will disregard net taxes on products and treat the variable decomposed as Gross Value Added (GVA).[13]

The products of manufacturing industries made up from 79% to 85% of total gross exports from Korea to the U.S. in 2005-2015 and are thought to be largely responsible for the growing U.S. trade deficit under KORUS. Figure 3 confirms that Korean manufacturing industries tended to derive net benefit and those in the U.S. suffered losses because of creation, diversion and contraction of bilateral trade. However, this occurred before KORUS, and the magnitude of the combined trade effects in the pre-KORUS period appears to be larger than after it was launched. At the fourth year of KORUS implementation, the manufacturing in the U.S. generated additional and non-negligible income while Korean manufacturers incurred losses.

Services contributed from 15% to 21% of Korea's exports to the U.S. and from 45% to 55% of the U.S. exports to Korea in 2005-2015. In both Korea and the U.S., service industries largely shaped net gains or losses of value added induced by the substitution effects in bilateral trade in most yearly intervals. This may be an implication of domestic value chains where service providers may be ultimately responsible for some value added content of traded goods. It is worth noting that 2014-2015 was the only yearly interval within the period under study when the net effect was positive and significant for both manufacturing and services in the U.S.

The changes in employment in Korea and the U.S. induced by shifts in their bilateral trade closely resemble the respective changes in GDP (or GVA). This is an expected result, given that both employment and value added describe primary inputs to production and

[13] Recall that GDP is the sum of value added across all industries plus taxes less subsidies on products. Net taxes on products were within the range of 8-10% of Korea's GDP and 3-4% of the U.S. GDP in 2005-2015.

are proportional to output. The estimates from the additive decomposition in absolute terms – number of persons employed or number of jobs – are thought to be less prone to the current price bias and give a good sense of the effects in question.

The asymmetric response of employment to the bilateral trade creation and related effects is more pronounced than that of GDP. These effects depressed the employment in Korea in 2005-2008. In 2007-2008 alone, the loss amounted to 123.3 thousand employed persons, almost equally affecting agriculture (59.2 thousand) and services (66.2 thousand). This outcome was mostly driven by net trade creation, *i.e.*, losses of domestic sales to the U.S. competitors. Meanwhile, the overall employment in Korea increased by 144.9 thousand persons. In 2008-2011, agriculture and service industries in Korea regained some jobs via trade contraction, while services also benefited from U.S. trade diversion towards Korea. The number of the employed in Korea was on the rise, including an increase by 71.1 thousand persons in 2010-2011 that remains the highest for the trade effects and within the period under study. After KORUS came into force, trade with the U.S. helped to increase the employment in Korea in 2012-2014, but generated losses in 2011-2012 and 2014-2015, the latter totalling 62.1 thousand employed persons, primarily because of trade creation in services.

The U.S. recorded continuous loss of jobs because of the substitution effects in trade with Korea, except for two yearly intervals, 2007-2008 and 2014-2015. The magnitude of changes was smaller than in case of Korea: the maximum loss of 39.4 thousand jobs in 2010-2011 and the maximum gain of 52.7 thousand jobs in 2014-2015. Hit by trade creation with Korea and Korea's diversion of import purchases away from the U.S. suppliers, manufacturing tended to lose jobs except a minimal increase in 2009-2010 (0.7 thousand jobs) and a non-negligible gain in 2014-2015 (5.2 thousand jobs). For the service industries, on the contrary, net trade creation was mostly positive which helped generate additional jobs in 2007-2009, 2011-2012 and 2014-2015. The fourth year of KORUS brought the U.S. service providers 50.3 additional jobs thanks to replacing both Korean (trade creation) and third country (trade diversion *in*) competitors in the Korean market.

Table 1 summarises the changes in employment in Korea and the U.S. by comparing two four-year periods before and after the KORUS FTA came into force, with a breakdown into the aggregate groups of industries. It is clear that before KORUS, Korea derived a net benefit in terms of the number of jobs from the evolving bilateral trade with the U.S. Manufacturing was the primary beneficiary, followed by services. The U.S. incurred a net loss of jobs, mostly in manufacturing and in services. The next four years reversed the outcomes. Korea's employment shrank with the agriculture being the only beneficiary. The U.S. recorded a net surplus of new jobs, mostly generated in service industries, though manufacturing jobs continued to decline.

Although the review of the aggregate results above is not conclusive with respect to the impact of KORUS, one may observe that, as a country subject to the substitution effects in bilateral trade, the U.S. under KORUS ended up in a position that was no worse than that before KORUS. This is not true for Korea.

A complete report with the estimates of GDP, industry value added and employment changes for all effects, all industries and all yearly intervals is in the online Appendix A.

The discussion in the next subsections focuses on the results for the U.S. because the implementation of the KORUS FTA was a much more contentious issue there than in Korea.

Table 1: Changes in employment in Korea and the U.S. before and after the enforcement of the KORUS FTA

	Korea, thousand persons		U.S., thousand jobs	
	2007-2011	2011-2015	2007-2011	2011-2015
Total changes in employment	811.50	1691.80	-7346.00	10679.10
Changes in employment induced by bilateral trade creation, diversion and contraction, including:	44.01	-25.02	-34.09	21.92
agriculture	-31.59	16.56	7.54	-6.47
manufacturing	58.33	0.24	-29.30	-10.99
services	16.70	-42.60	-12.09	39.65
other industries	0.57	0.79	-0.24	-0.27

Source: OECD ICIO tables (2018 release), OECD TiM Database (2019 release), author's calculations (detailed results are in the online Appendix A).

3.3 Results at the industry level

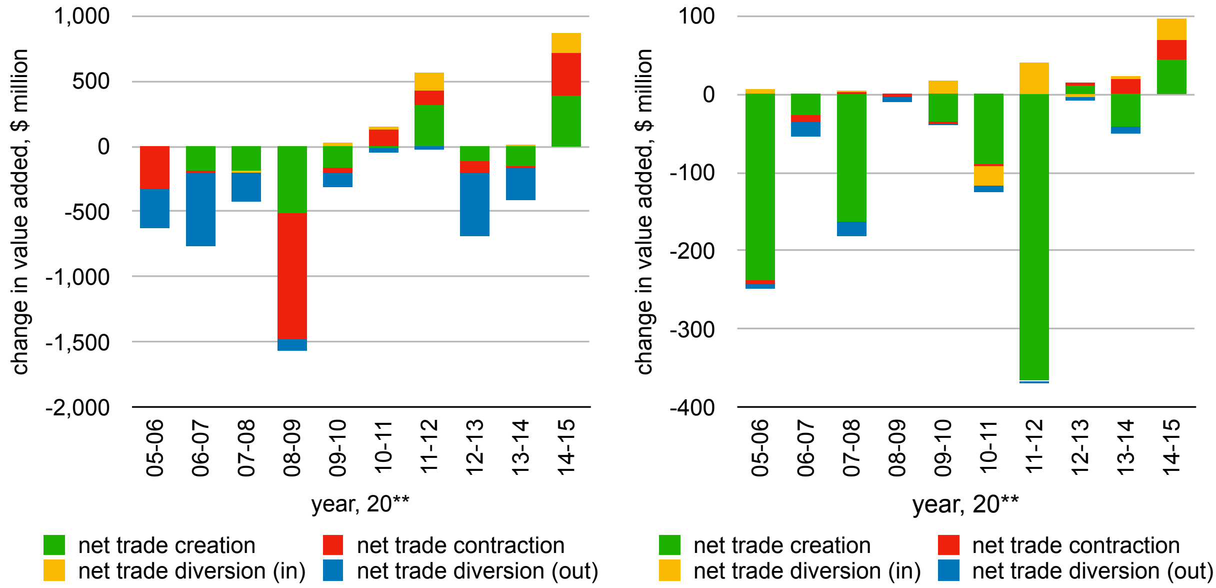
Unlike most other industries, agriculture in the U.S. tended to benefit from additional value added in the pre-KORUS period thanks to the overwhelming trade creation in favour of the U.S. Once KORUS became operational, it ran into losses. The underlying effects – trade diversion away from the U.S. as partner and trade contraction in favour of Korean producers – were unlikely to be driven by this FTA.

An average manufacturing industry in the U.S. lost some shares in both domestic and Korean markets to either Korean or third country suppliers in 2005-2014 which reduced its value added, except for a marginal increase in 2009-2010. It was only in 2014-2015 that positive net trade creation and limited trade diversion away from the U.S. contributed to the growth of manufacturing value added. Two industries in figure 4 exemplify typical results for the U.S. manufacturing: production of computer, electronic and optical products and production of motor vehicles, trailers and semi-trailers. The former was selected because Korea-related changes in its value added were the largest in absolute terms for all manufacturing industries, and the latter because the automotive production was a sensitive issue in bilateral FTA negotiations.[14]

The trend of changes in value added in figure 4 can be characterised as a slow motion from overwhelmingly negative before KORUS to intermittently and marginally positive after KORUS. Computer and electronics producers generated less value added in 2005-2010 as they lost part of their shares in the domestic market to Korean producers (trade creation) and part of those shares in the Korean market to Korean producers (trade contraction) and third country producers (trade diversion *out*). They began regaining their share of sales in the domestic market already in 2010-2011, that is one year before KORUS and partly displaced Korean and third country producers in the Korean market in 2011-2012 and 2014-2015. The automotive industry suffered from reduced incomes because it lost part of its share in the domestic market to Korean competitors in 2005-2012 (trade creation), and the maximum loss was in the first year of KORUS that is

[14] In February 2011, the U.S. Trade Representative and the Minister for Trade of the Republic of Korea exchanged side letters to the agreement where they revised the schedule for the elimination of customs duties on motor vehicles.

not typical for most other manufacturing industries. In 2013-2015, American automotive producers regained some share of sales in the domestic market (trade contraction) and even in the Korean market (trade creation, trade diversion *in*), but those gains were marginal compared to the loss in 2011-2012.



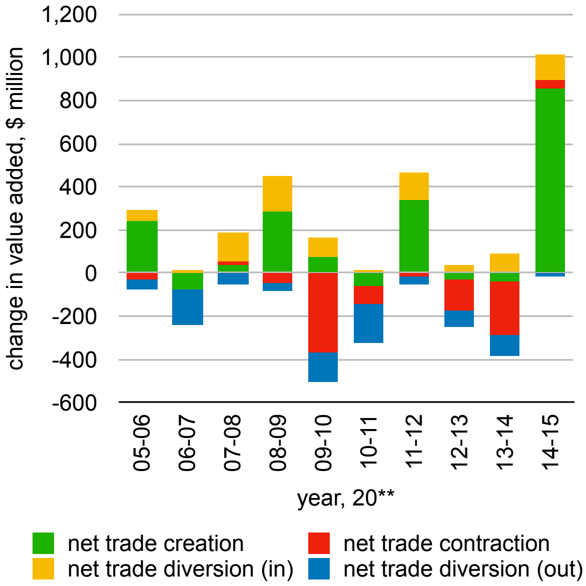
(a) Computer, electronic and optical products (D26)

(b) Motor vehicles, trailers and semi-trailers (D29)

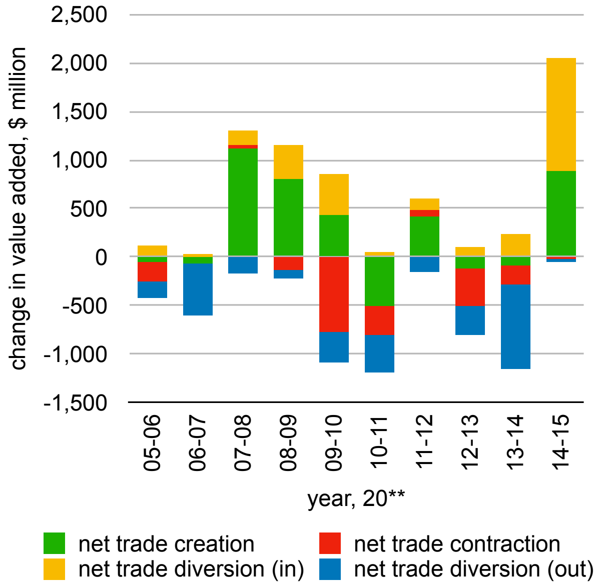
Figure 4: Change in the value added of selected U.S. manufacturing industries induced by trade with Korea, in 2005-2015, $ million
Source: OECD ICIO tables (2018 release), author's calculations (detailed results are in the online Appendix A).

An average service industry in the U.S. generated additional value added when the share it gained in the Korean market prevailed over the share it lost in the American market (positive net trade creation). This occurred in 2007-2009, 2011-2012 and 2014-2015. Net trade creation was also positive in 2009-2010, but the decline of market share in Korea in favour of local industries (trade contraction) dragged down the incomes of American service providers. In other yearly intervals, their reduced incomes may be explained by Korea's switching the sources of imports away from the U.S. (trade diversion *out*).

To visualise these effects, figure 5 focuses on two industries where the magnitude of changes of value added was the largest among all service industries: financial and insurance services and other business services. The latter include a large array of professional, scientific and administrative services: legal, accounting, management, architectural, engineering, scientific research and development, advertising and market research, rental and leasing, employment, security and investigation services, activities of travel agencies, tour operators and other administrative and business support activities. Driven by a varied composition of trade creation, diversion and contraction, the combined net change of value added oscillated in a sinusoid-like motion, and the chart in figure 5b is more typical for all service industries. The pattern of changes under KORUS does not seem to differ from that before the agreement entered into force with the exception of 2014-2015 when the gains of market shares in the Korean market at the expense of Korean and third country suppliers propelled value added upwards to the maximum change in the decade. In 2012-2014, incomes shrank because the impact of shares lost in the Korean market prevailed over that of shares gained in the U.S. market. The corresponding effects, trade contraction and trade diversion away from the U.S. as an exporter, are usually not expected to originate in the FTA regime.



(a) Financial and insurance activities (D64T66)



(b) Other business sector services (D69T82)

Figure 5: Change in the value added of selected U.S. service industries induced by trade with Korea, in 2005-2015, $ million
Source: OECD ICIO tables (2018 release), author's calculations (detailed results are in the online Appendix A).

Note that a change in value added of one industry induced by trade creation or alike effects does not only occur because the producers pertaining to this industry gain or lose their market shares. Beyond direct supplier, these shifts in sales and, hence, in production, may propagate via value chains to indirect suppliers. Given that service content of goods is nowadays a ubiquitous phenomenon, service industries are thought to be subject to considerable indirect value added changes that originate in market share changes faced by products of manufacturing. The contribution of indirect trade creation, diversion and contraction effects may be an appealing question for a further investigation.

Table 2 disaggregates the estimates of changes in employment in the U.S. from table 1 and lists the industries that generated or lost the largest number of jobs after the KORUS FTA came into force. The top "winners", as may be expected, include service industries. Aside from the other business sector services, these industries generated more jobs after KORUS than before it thanks to reduced trade diversion away from the U.S. and trade contraction, increased trade creation and trade diversion towards the U.S. Interestingly, some of these service industries were weakly involved in direct bilateral trade: accommodation and food services only contributed about 3% of total U.S. export to Korea and 1% of Korea's exports to the U.S., and education services contributed, respectively, 1.5% and 0.1% in 2005-2015. The impact on these industries' jobs may be another implication of domestic and global value chains that indirectly link the producers of goods and services. The principal "losers" include agriculture and manufacturing industries. The automotive

Table 2: Industries with the largest gains and losses in employment in the U.S. induced by changes in trade with Korea

		Change in employment, thousand jobs				
Industry (ICIO code)	Year	TC	TD*in*	TD*out*	TR	Total
Accommodation and food services (D55T56)	2007-11	-0.48	0.64	-1.76	-8.20	-9.80
	2011-15	7.11	4.91	-0.62	-0.28	11.12
Other business sector services (D69T82)	2007-11	21.00	10.53	-10.52	-12.65	8.36
	2011-15	11.14	15.94	-13.98	-5.37	7.72
Transportation and storage (D49T53)	2007-11	1.90	2.05	-5.97	5.42	3.39
	2011-15	3.59	6.05	-1.96	-0.07	7.61
Financial and insurance activities (D64T66)	2007-11	2.24	2.73	-2.55	-2.96	-0.55
	2011-15	5.71	1.96	-1.21	-1.98	4.48
Education (D85)	2007-11	2.15	1.26	-1.25	-2.36	-0.19
	2011-15	3.59	2.04	-1.07	-0.44	4.13
Publishing, audiovisual and broadcasting activities (D58T60)	2007-11	0.58	0.51	-0.50	-0.07	0.53
	2011-15	0.08	0.29	-0.37	-1.59	-1.59
Motor vehicles, trailers and semi-trailers (D29)	2007-11	-2.43	-0.01	-0.31	-0.07	-2.82
	2011-15	-2.32	0.38	-0.09	0.29	-1.74
Basic metals (D24)	2007-11	-2.24	0.71	-0.95	-0.56	-3.03
	2011-15	-1.68	0.22	-1.35	-0.35	-3.16
Other transport equipment (D30)	2007-11	0.51	3.50	-2.86	0.95	2.10
	2011-15	-2.09	2.00	-2.77	-1.02	-3.88
Agriculture, forestry and fishing (D01T03)	2007-11	11.44	4.29	-2.36	-5.83	7.54
	2011-15	0.09	4.89	-8.53	-2.92	-6.47
All industries	2007-11	33.39	42.95	-62.09	-48.33	-34.09
	2011-15	20.74	70.43	-52.33	-16.91	21.92

Note: TC is trade creation, TD*in* is trade diversion towards partner, TD*out* is trade diversion away from partner and TR is trade contraction.
Source: OECD ICIO tables (2018 release), OECD TiM Database (2019 release), author's calculations (detailed results are in the online Appendix A).

industry stands out for less jobs lost under KORUS than before it.

3.4 What is the actual impact of the KORUS FTA?

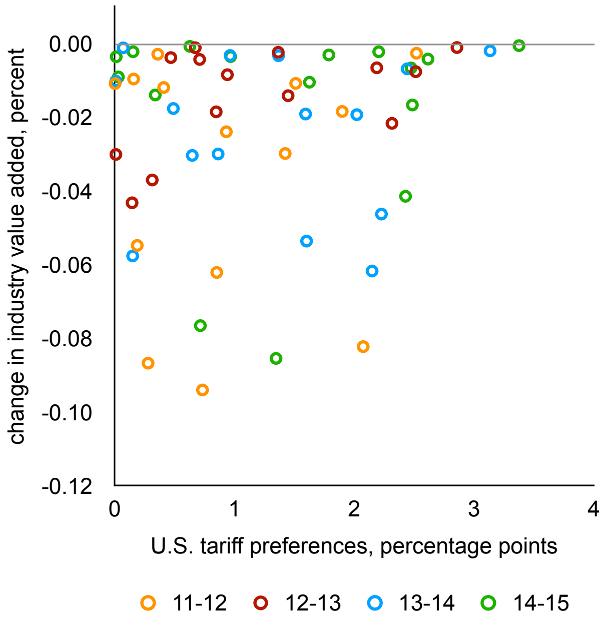
In this subsection, we will examine whether trade creation and diversion effects on incomes and employment in the U.S. are associated with liberalisation of bilateral trade under KORUS. We will not consider trade contraction and trade diversion away from partner because these effects, although detected in Korea – U.S. bilateral trade under KORUS, ran counter to the logic of the FTA preferences. These effects could be responses to other policies, measures or events, *e.g.*, changes in relative prices, protection of domestic industries, FTAs with third countries.

There are two reasons to focus on the manufacturing industries in the U.S.: their significance for the evaluation of KORUS and data availability. The KORUS FTA is a comprehensive agreement that introduced improved market access for goods and services, new commitments to address technical barriers to trade, greater protection for intellectual property rights, additional disciplines for safeguard measures and other commitments. Preferential tariffs for goods originating in member countries are a significant and the only directly measurable outcome of the implementation of the KORUS FTA. Quantification of trade restrictions for services is a known problem. Whereas synthetic measures of market access for services are available (*e.g.*, the OECD Services Trade Restrictiveness Index), they only cover market access on the MFN basis, ignoring bilateral preferences.

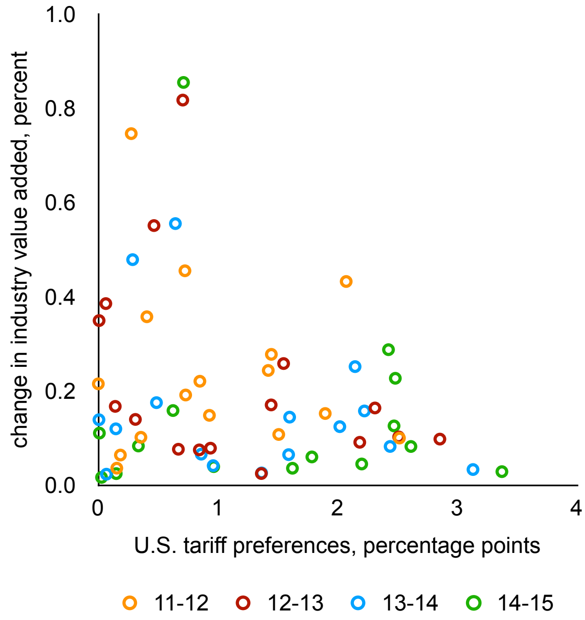
The preferential access for Korean goods to the U.S. market could have resulted in their increased imports, displacing sales of American producers of the like goods and reducing their incomes and employment. Such causation of negative trade creation effect is the key argument of the critics of KORUS. This is not confirmed in figure 6a where the trade creation effect on value added of agriculture and 16 manufacturing industries in the U.S. is plotted against the U.S. tariff preferences for goods of the respective industries originating from Korea. It is apparent that there is virtually no correlation between the two indicators. Figure 6b is a similar snapshot of a possible relationship between tariff preferences in the U.S. and trade diversion. However, as observed earlier, diversion of U.S. imports towards Korea would have mostly neutral effect on the U.S. industries and positive effect on Korean industries. Changes in value added of Korean industries are therefore used to show the impact of trade diversion. Again, there is no clearly discernible correlation. Introducing one-year time lag between tariff preferences and the growth of industry value added does not alter the findings from figure 6. Note that, unlike in the previous figures, trade creation and diversion in figure 6 are not on the net basis and are estimated from the multiplicative decomposition.

The U.S. tariff preferences were quite low, with the simple average at 1.2 percentage points (p.p.) in 2012 and 1.6 p.p. in 2015, and not exceeding 3 p.p. for the products of nearly all industries (see the online Appendix H for details). Only for textiles, wearing apparel, leather and related products was the preference margin sizeable at 5.1 p.p. in 2012 and 8.7 p.p. in 2015. Negative trade creation for this industry in the U.S. was steadily growing in 2006-2012, reaching the maximum in 2011-2012, but then dropped to nearly zero in 2013-2015. In general, there are no signs that the U.S. industries subject to the largest preferences for the like imported products incurred more losses due to trade creation with Korea under KORUS than in the preceding period. This finding is also true for industry performance in Korea where the KORUS preferences averaged at 4.1 p.p. in 2012 and 5.6 p.p. in 2015.

Production of computer, electronic and optical products that contributed the largest changes in value added in the U.S. manufacturing due to the shifting trade with Korea (recall figure 4) incurred smaller losses because of trade creation with the introduction of KORUS preferences as shown in figure 7a. This is quite typical for most manufacturing industries in the U.S. Some industries experienced a sharp drop of value added in the first year of KORUS, but smaller or minimal loss of value added in the subsequent years, for example, the automotive industry (see figure 7b), production of textiles, wearing apparel, leather and related products. This can also be discerned for electrical equipment, machinery and other equipment manufacturing where the maximum reduction of value added induced by trade creation occurred already one year prior to the introduction of KORUS preferences. Only a few industries demonstrate what can be considered a response of trade creation effect to the KORUS preferences, though this response is uneven and weak in selected yearly intervals. The examples include the chemical and



(a) Change in industry value added in the U.S. induced by trade creation in the U.S. *vs.* U.S. tariff preferences under KORUS



(b) Change in industry value added in Korea induced by trade diversion towards Korea in the U.S. *vs.* U.S. tariff preferences under KORUS

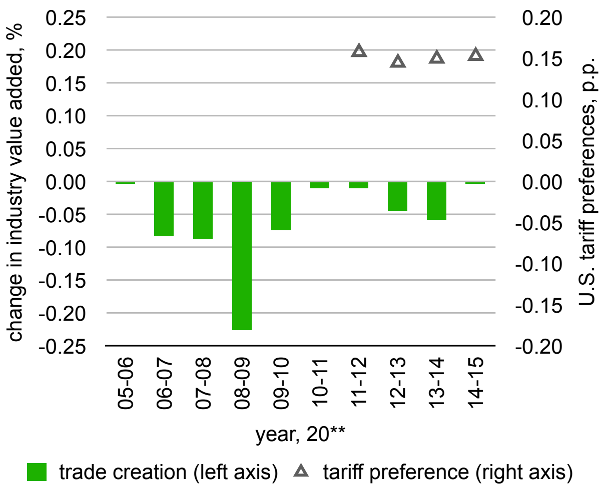
Figure 6: Changes in the value added of agriculture and manufacturing industries induced by trade creation and trade diversion in the U.S. market *vs.* the U.S. tariff preferences for goods under the KORUS FTA, in 2012-2015

Note: Tariff preferences are defined in 2012, 2013, 2014 and 2015 as differences between the MFN tariff rate and KORUS tariff rate.

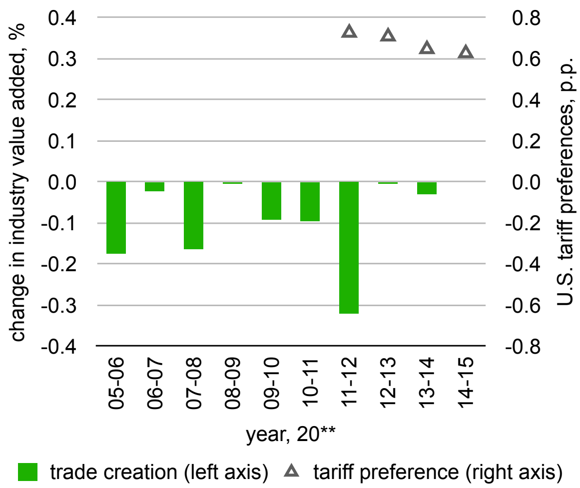
Source: OECD ICIO tables (2018 release), USITC DataWeb, author's calculations (detailed results are in the online Appendices A and H).

pharmaceutical industry (figure 7c), production of fabricated metal products (figure 7d) and petroleum refining.

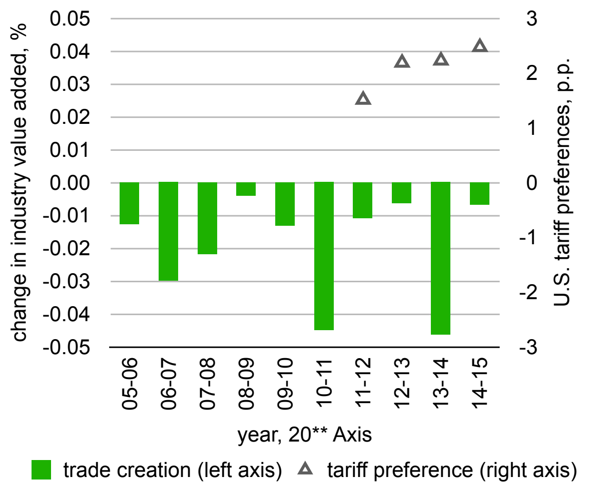
By and large, KORUS tariff preferences do not appear to drag down the incomes of American industries via the trade creation effect. We should, however, acknowledge two other factors that may affect the results. First, the tariff preferences are not automatic and are not used by part of Korean exporters or U.S. importers. The preference utilisation, computed from the USITC data as the share of imports from Korea under the KORUS programme, did not exceed 4% for computer, electronic and optical products and 25% for motor vehicles. It reached 50% for chemicals and pharmaceutical products and 48% for fabricated metal products (see the online Appendix H for details). For food products and beverages, textiles and apparel, the utilisation rates were even higher, up to 64% and 70%, respectively, but the negative impact of trade creation decreased. Another point to take into account is that the preference margins analysed here are directly applicable to products whereas the growth of value added results from both direct and indirect effects that propagate via value chains. Therefore, a smaller part of value added loss in one industry may be recorded because of trade creation effect on another industry.



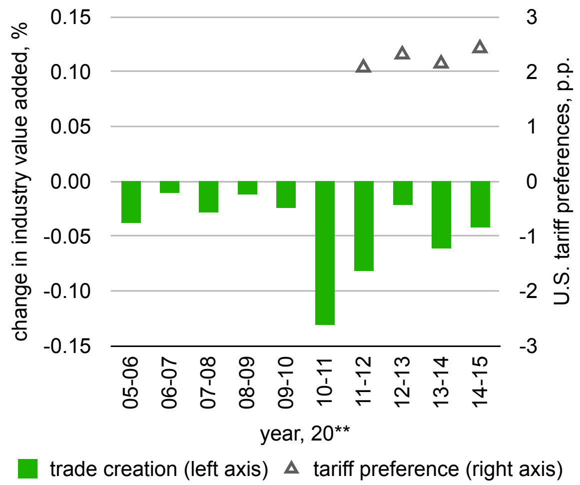
(a) Computer, electronic and optical products (D26)



(b) Motor vehicles, trailers and semi-trailers (D29)



(c) Chemicals and pharmaceutical products (D20T21)



(d) Fabricated metal products (D25)

Figure 7: Changes in the value added of selected U.S. industries induced by trade creation in the U.S. market *vs.* the U.S. tariff preferences under the KORUS FTA
Note: Tariff preferences are defined in 2012, 2013, 2014 and 2015 as differences between the MFN tariff rate and KORUS tariff rate.
Source: OECD ICIO tables (2018 release), USITC DataWeb, author's calculations (detailed results are in the online Appendices A and H).

3.5 Sensitivity and variability of results

Whereas the elements of the initial matrix to estimate the bilateral allocation of market share changes are drawn from the standard uniform distribution at each Monte Carlo run (see Section 2.4), the distribution of the results – changes in value added, employment or GDP induced by the trade effects in question – is not uniform. It tends to have bell-like shape with a peak. Formal normality tests do not confirm that this distribution is normal in most samples. The Lilliefors test shows that the null hypothesis that the results are normally distributed cannot be rejected in 25% of samples at 5% significance level and the Shapiro-Wilk test shows the same in only 17% of samples.[15]

Apparently, normality is rejected in samples where the distribution of results is skewed. This is also the reason why the sample mean is different from the mode and, therefore, our baseline estimate may not have the highest probability of occurrence. In some cases, setting the initial matrix in the RAS balancing procedure to a block-diagonal matrix of ones provides an alternative estimate that is closer to the sample mode, yet the number of such cases is limited (please see the online Appendix G for selected visualisations).

Variation around the sample mean within the range of one standard deviation alters the baseline estimates of changes in industry value added and employment by no more than 30% in 96% of samples.[16] In 56-57% of samples the standard deviation is within 10% of the mean, and for the samples of changes in GDP, this share reaches 66%. Such variability of results does not affect the findings. Importantly, the estimates that largely define net changes in GDP, industry value added and employment fluctuate relatively little and never switch sign. The standard deviation of the baseline estimates is reported in the online Appendix B. See also visualisations in the online Appendix G.

Lastly, the simplified solution with the initial matrix in the RAS balancing procedure set to a block-diagonal matrix of ones provides alternative estimates that are very close to the baseline estimates. The mean absolute percentage error of the former from the latter in terms of industry value added and employment is 1.4% and in terms of the GDP it is 1.1%. In at least half of the samples this deviation is less than 1%.[17] This simplified approach therefore offers a reasonable shortcut to the SDA without repeated Monte Carlo runs which saves time and computational resources.

3.6 Comparison to other studies

The results of this study are not directly comparable to the earlier results of either *ex-ante* modelling or *ex-post* estimation of the economic effects of the KORUS FTA because of

[15] These pertain to the additive decomposition of changes in industry value added. The outcomes of the tests are nearly identical for the multiplicative decomposition and for the respective decompositions of changes in employment. The normality of the distribution of GDP changes is supported in 25% of samples by the Lilliefors test and 21% by the Shapiro-Wilk test. There are 5600 samples at the industry level (excluding "Private households with employed persons", D97T98) and 160 samples of GDP results. Full reports with the outcomes of the Lilliefors and Shapiro-Wilk tests are in the online Appendices C and D.

[16] Only covering the results of additive decomposition, excluding the samples where the mean is close to zero – trade diversion *in* and *out* for home country.

[17] The mean absolute percentage error (MAPE) is usually applied to quantify the difference between two matrices of which one is the "true" matrix and another is a "tested" matrix. It is equal to the arithmetic mean of the absolute values of deviations of each element in a tested matrix from the same element in the true matrix in percentage terms. Here MAPE is measured with respect to the results of the additive decomposition organised in two arrays, tested and true. See a detailed report, including the results of the multiplicative decomposition, in the online Appendices E and F.

different measurement concepts. Yet we are able to review some of the findings from the existing studies in the light of the newly obtained evidence.

We confirm that diversion of U.S. imports from third countries towards Korea occurred in 2012-2014 as identified by Russ and Swenson (2019). However, we detect this effect well before the KORUS FTA came into force in 2012 and do not find that it was significantly influenced by KORUS tariff preferences.

According to Wei et al. (2019), the GDP gain from the reduction of import tariffs by 2014 is \$45 million for the U.S. (only 0.0003% of the baseline 2011 GDP level) and \$162 million for Korea (0.01%). The calculation in this paper shows that net trade creation and net trade diversion *in* effects in sum account for an annual average of +\$1.4 billion of the U.S. GDP and +\$1.8 billion of Korea's GDP in 2011-2014. Because of the reasons discussed in Section 3.4, very little of these gains may be attributed to the tariff preferences under KORUS. Therefore, our new estimates do not conflict with the finding of Wei et al. (2019) that the KORUS-related GDP gain was marginally low for the U.S. and somewhat more significant for Korea.

Whereas the studies of KORUS do not address the FTA effects on employment, a newer strand of literature explores the linkages between trade and employment focusing on the U.S. – China bilateral trade and increasingly uses inter-country input-output data. For example, Feenstra and Sasahara (2018) estimate that the growing imports from China cost the U.S. 1.4 million jobs in manufacturing and another 1 million in services over 1995-2011 where one half of the latter were due to the indirect effect of merchandise imports. They, however, do not provide the same estimate for the U.S. exports to China. This is addressed by Wang et al. (2018) who find that the net employment effect from trading with China was positive for the U.S. in 2000-2014, adding 1.02% of jobs per year (-0.34% in manufacturing and +1.37% in non-manufacturing industries). In contrast to previous studies, they encountered strong evidence that the downstream effect is positive, *i.e.*, the use of imported Chinese inputs raises the U.S. employment. Lin et al. (2018) calculate that, in 2000-2009, China's exports to the U.S. created 471 thousand jobs in the U.S., mostly in service sectors, whereas U.S. exports to China created 907 thousand jobs in China, mostly in manufacturing sectors. Dai et al. (2021) run SDA showing that U.S. – China trade accounted for a decline of 858 thousand jobs in the U.S. in 2000-2007, but contributed to the creation of 54 thousand jobs in 2007-2014. Jobs were mostly lost in manufacturing and generated in agriculture and services. Only about 2% of all job losses was due to imports from China.

There are two key points where the findings of the above mentioned papers and this paper converge. First is the importance of service industries in terms of job creation or destruction. Although services are less involved in cross-border trade than goods, service jobs are not less responsive to the shifts in the direction and intensity of trade. Clearly, this is an implication of domestic and global value chains that transmit trade "shocks" between manufacturing or agriculture and services. Second, the perceived negative developments in bilateral trade – *e.g.*, growing trade deficit, trade creation and other adverse substitution effects – do not automatically translate into job losses. Korea – U.S. trade relationship is another case where the growing trade imbalance, thought to be engendered by the launch of the KORUS FTA, is not associated with depressing effect on total employment. Therefore, a consistent analysis must be capable of unbundling the myriad of factors that directly and indirectly affect employment, including competition at home, in partner country market and third country markets.

4 Conclusions

In the spirit of Viner (1950), this investigation utilises the concepts of trade creation and trade diversion, redefining these in the inter-country input-output framework as effects of substitution between countries of origin of intermediate inputs and final products. Import substitution – termed here trade contraction – is also included for the exhaustiveness of the analysis. The measurement of these effects shows whether imports displace domestic production or *vice versa*, whether exports shrink or expand at the expense of third country competitors and how all these affect the economic performance of exporters and importers. In practice, such measurements have been difficult as trade creation and alike effects cannot be observed. Historically, they have been estimated indirectly as responses of trade flows to the emergence of trade agreements or introduction of preferential import tariffs. This paper offers what can be reasonably called direct, rather than indirect, joint estimation of all substitution effects in bilateral trade where the necessary information is extracted from the inter-country input-output tables and additionally balanced by a recognised procedure. Structural decomposition analysis helps distilling these effects from other effects that define the changes of an economic variable of interest.

An application of the novel estimation approach to the case of Korea – U.S. trade unequivocally reveals that bilateral trade creation, diversion and contraction affected both countries before and after they entered into an FTA in 2012. The total net effect was small and mostly positive for Korea, accounting for 3% of its annual GDP growth in 2005-2015, but negligible and mostly negative for the U.S., averaging at less than 1% of its GDP growth. There is no indication that tariff preferences under KORUS reinforced or somehow changed the composition of the effects in question. However, in 2014-2015, the U.S. benefited from trade diversion in the Korean market and record high net trade creation, deriving additional 0.8% of the GDP growth and generating 52.7 thousand jobs, while Korea lost 12% of its GDP growth and 62.2 thousand jobs. KORUS was probably a catalyst of this outcome, but the critical appraisals in the U.S. tend to ignore it.

The absence of correlation between KORUS preferences and trade creation or diversion may be explained by the low preference utilisation and by the value chain effect. A loss of direct sales in domestic or foreign market may be at least partly offset by gains from increasing indirect sales via downstream channels. A more important finding, in line with Muradov (2021a), is that trade creation, diversion and contraction seem to have stochastic nature and persist with or without preferential trade regimes. Interestingly, import substitution does not disappear after the enforcement of KORUS FTA, although it may be limited to smaller amounts.

At industry level, in both Korea and the U.S., services largely shaped the net gains or losses of value added and employment induced by trade creation and other effects in most yearly intervals. In 2014-2015, service job gains in the U.S. and losses in Korea outweighed, respectfully, the total economy-wide losses and gains of jobs in three preceding yearly intervals. Positive and significant trade creation was much more typical for service industries than for manufacturing. These results stress the importance of accounting for industries that produce goods and services in a unified framework when evaluating FTAs. The critical perception of the outcomes of KORUS and other FTAs may persist because the contribution of services is neglected. Indeed, if only agriculture and manufacturing are considered in this investigation, the conclusions would be dire for the U.S.

It is too early to conclude whether KORUS has helped the U.S. to consistently address the losses from the changing pattern of trade with Korea in the pre-FTA period. Yet the view of the KORUS FTA as entirely damaging and job-killing cannot be supported with the new approach to evaluating FTAs.

The novel approach tested in this paper produced the most detailed account of bilateral trade creation, diversion and contraction effects on value added and employment. The estimates are available for each annual interval, industry, effect, for home and partner countries and can be easily aggregated while the uncertainties can be controlled. The estimates can also be disaggregated into effects for intermediate and final products, or direct and indirect (value chain) effects, subject to research requirements. The results of this research may enrich the information available to analysts and policy makers in participating countries for their understanding of the causes of income or job losses and evaluation of trade agreements. To obtain superior results with the method put to a test in this paper, it is desirable to build time series of inter-country input-output tables at previous year prices and to increase their industry and/or product resolution.

Research data

The online appendix includes detailed results and replication data and is available from Harvard Dataverse at https://doi.org/10.7910/DVN/DJR56O. Interactive visualisations of results similar to those in figures 2, 4, 5 covering value added and employment for both Korea and the U.S. are available at the author's site https://sites.google.com/view/kirillmuradov/my-research/visualisations.

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Appendices

A Introduction into structural decomposition analysis

Structural decomposition analysis is a way to attribute the change in a product of various matrices and vectors – referred to as determinants or factors – to the changes in each of those factors. For example, the additive decomposition of output as a product of the Leontief inverse and final demand may proceed in two equivalent forms, with the subscripts denoting years 0 and 1:

$$\Delta \mathbf{x} = \mathbf{x}_1 - \mathbf{x}_0 = \mathbf{L}_1\mathbf{F}_1\mathbf{i}_K - \mathbf{L}_0\mathbf{F}_0\mathbf{i}_K = (\Delta\mathbf{L})\mathbf{F}_1\mathbf{i}_K + \mathbf{L}_0(\Delta\mathbf{F})\mathbf{i}_K \tag{A.1a}$$

$$\Delta \mathbf{x} = \mathbf{x}_1 - \mathbf{x}_0 = \mathbf{L}_1\mathbf{F}_1\mathbf{i}_K - \mathbf{L}_0\mathbf{F}_0\mathbf{i}_K = (\Delta\mathbf{L})\mathbf{F}_0\mathbf{i}_K + \mathbf{L}_1(\Delta\mathbf{F})\mathbf{i}_K \tag{A.1b}$$

where Δ is the difference operator. The same expressions written in terms of variables of only year 0 or year 1 contain the so called interaction terms:

$$\Delta \mathbf{x} = \mathbf{x}_1 - \mathbf{x}_0 = \mathbf{L}_1\mathbf{F}_1\mathbf{i}_K - \mathbf{L}_0\mathbf{F}_0\mathbf{i}_K = (\Delta\mathbf{L})\mathbf{F}_0\mathbf{i}_K + \mathbf{L}_0(\Delta\mathbf{F})\mathbf{i}_K + (\Delta\mathbf{L})(\Delta\mathbf{F})\mathbf{i}_K \tag{A.2a}$$

$$\Delta \mathbf{x} = \mathbf{x}_1 - \mathbf{x}_0 = \mathbf{L}_1\mathbf{F}_1\mathbf{i}_K - \mathbf{L}_0\mathbf{F}_0\mathbf{i}_K = (\Delta\mathbf{L})\mathbf{F}_1\mathbf{i}_K + \mathbf{L}_1(\Delta\mathbf{F})\mathbf{i}_K - (\Delta\mathbf{L})(\Delta\mathbf{F})\mathbf{i}_K \tag{A.2b}$$

The largely accepted way to combine the two decompositions and drop the interaction terms is to take an average of equations (A.1a) and (A.1b) which is equivalent to taking the average of equations (A.2a) and (A.2b):

$$\Delta \mathbf{x} = (\Delta\mathbf{L})\frac{1}{2}(\mathbf{F}_0 + \mathbf{F}_1)\mathbf{i}_K + \frac{1}{2}(\mathbf{L}_0 + \mathbf{L}_1)(\Delta\mathbf{F})\mathbf{i}_K \tag{A.3}$$

The two terms on the right-hand side of equation (A.3) capture what in gravity model literature is called counterfactual. The first term is the change in industry outputs that would be observed if the technology of production changes and final demand remains the same. The second term corresponds to the changes in industry outputs that would occur if the technology is the same and final demand changes. Ideally, such decomposition should be performed on the variables at constant prices so that prices are not another factor that affects the result.

To write the multiplicative variant of the decomposition of $\mathbf{x}$, we will use the fraction sign and $\oslash$ interchangeably for the element-by-element division, $\circ$ for the element-by-element multiplication (the Hadamard product) and the superscript $\circ\frac{1}{2}$ for the power that applies on the element-by-element basis:

$$\mathrm{P}\mathbf{x} = \mathbf{x}_1 \oslash \mathbf{x}_0 = \left(\frac{\mathbf{L}_1\mathbf{f}_0}{\mathbf{L}_0\mathbf{f}_0} \circ \frac{\mathbf{L}_1\mathbf{f}_1}{\mathbf{L}_0\mathbf{f}_1}\right)^{\circ\frac{1}{2}} \circ \left(\frac{\mathbf{L}_0\mathbf{f}_1}{\mathbf{L}_0\mathbf{f}_0} \circ \frac{\mathbf{L}_1\mathbf{f}_1}{\mathbf{L}_1\mathbf{f}_0}\right)^{\circ\frac{1}{2}} \tag{A.4}$$

P is the ratio operator and $\mathrm{P}\mathbf{x}$ corresponds to the growth of output.

The logic of the hierarchical structural decomposition employed in this paper is portrayed in in figure A.1 for the case of industry value added. If the decomposed variable is the change in GDP or employment, the logic is the same except one variable: changes in net taxes on intermediate products need to be replaced by changes in net taxes on final products or, respectively, by changes in employment coefficients. The next sections of this supplementary material discuss the step-by-step derivation of the necessary formulae.

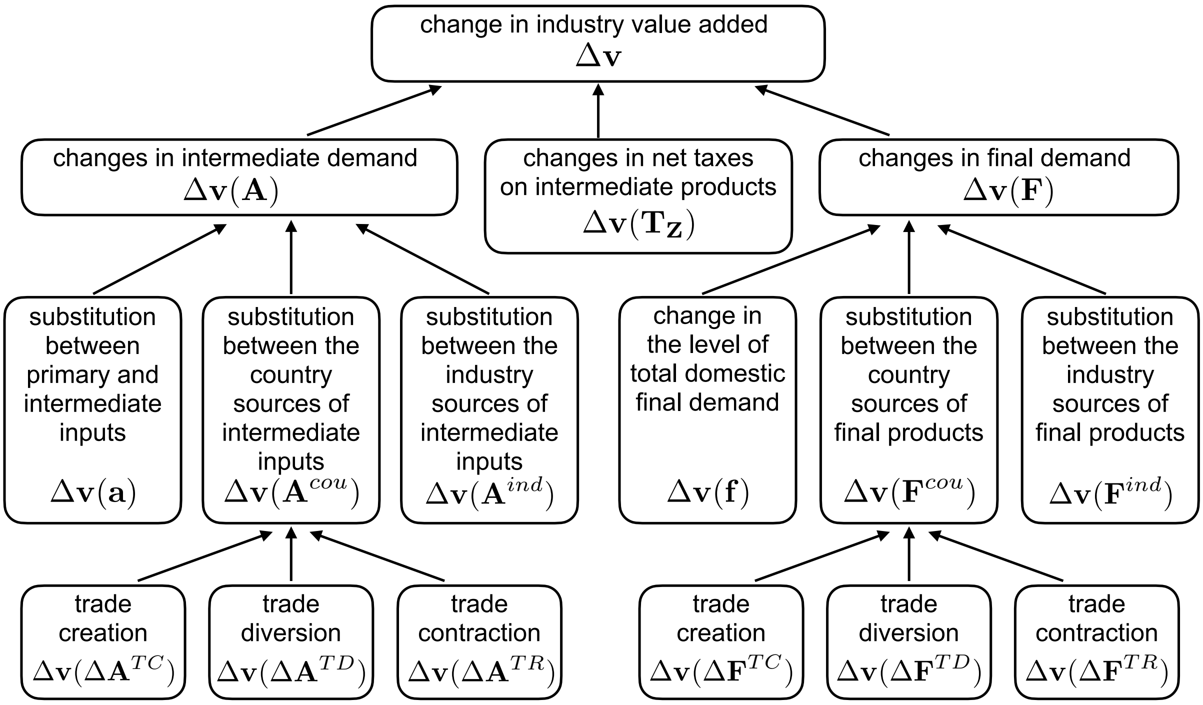

Figure A.1: Outline of the hierarchical structural decomposition of the change in industry value added to estimate trade creation and alike effects

B Decomposition of value added and employment at industry level

Gross value added at basic prices is defined as output valued at basic prices less intermediate consumption valued at purchasers' prices (United Nations et al., 2009, paragraph 6.77). Assume that intermediate consumption is valued at basic prices that is the preferred valuation for the analytical applications of input-output tables (United Nations, 2018, paragraph 2.108). Taxes less subsidies on intermediate products then need to be added to intermediate consumption to revalue it at purchasers' prices:

$$\mathbf{v}' = \mathbf{x}' - (\mathbf{i}'\mathbf{Z} + \mathbf{m}'_{\mathbf{Z}}) = \mathbf{i}'\hat{\mathbf{x}} - \mathbf{i}'\mathbf{A}\hat{\mathbf{x}} - \mathbf{m}'_{\mathbf{Z}} = (\mathbf{i}' - \mathbf{i}'\mathbf{A})\,\hat{\mathbf{x}} - \mathbf{m}'_{\mathbf{Z}} \tag{B.1}$$

Assume that the ICIO table differentiates taxes less subsidies on intermediate products by country of origin of products subject to those taxes.[18] This means that a K×KN matrix of taxes less subsidies on intermediate products $\mathbf{M_Z}$ is available, and vector $\mathbf{m}'_{\mathbf{Z}}$ may be rewritten as:

$$\mathbf{m}'_{\mathbf{Z}} = \mathbf{i}'\mathbf{M_Z} = \mathbf{i}'\big(\mathbf{T_Z} \circ (\mathbf{S}'_N\mathbf{Z})\big) = \mathbf{i}'\big(\mathbf{T_Z} \circ (\mathbf{S}'_N\mathbf{A}\hat{\mathbf{x}})\big) \tag{B.2}$$

where $\mathbf{T_Z} = \mathbf{M_Z} \oslash (\mathbf{S}'_N\mathbf{Z})$ denotes effectively applied net tax rates by country of origin and country-industry of destination and $\mathbf{S}_N$ is a KN×K industry aggregation matrix.[19]

Insert equation (B.2) into equation (B.1):

[18] ICIO tables do not usually contain that information. However, such disaggregation is a distinctive feature of the 2018 release of the OECD ICIO tables used in this research. The author uses this additional information as it allows for a more accurate decomposition

[19] $\mathbf{S}_N$ is a block-diagonal matrix with a K×1 vector of ones in its diagonal blocks. It may be obtained from the following manipulation: $\mathbf{S}_N = \mathbf{I}_K \otimes \mathbf{i}_N$, where $\otimes$ is the Kronecker product.

$$\mathbf{v}' = (\mathbf{i}' - \mathbf{i}'\mathbf{A})\,\hat{\mathbf{x}} - \mathbf{i}'\big(\mathbf{T_Z} \circ (\mathbf{S}'_N\mathbf{A}\hat{\mathbf{x}})\,\big) = \big(\mathbf{i}' - \mathbf{i}'\big((\mathbf{1}_{K\times KN} + \mathbf{T_Z}) \circ (\mathbf{S}'_N\mathbf{A})\big)\big)\,\hat{\mathbf{x}}$$

where $\mathbf{1}_{K\times KN}$ is a K×KN matrix of ones. Using that $\mathbf{x} = \mathbf{LFi}_K$, transpose and rewrite the above equation:

$$\mathbf{v} = diag\,\big(\mathbf{i}' - \mathbf{i}'\big((\mathbf{1}_{K\times KN} + \mathbf{T_Z}) \circ (\mathbf{S}'_N\mathbf{A})\big)\big)\,\mathbf{x} = \Big(\mathbf{I} - diag\Big(\mathbf{i}'\big((\mathbf{1}_{K\times KN} + \mathbf{T_Z}) \circ (\mathbf{S}'_N\mathbf{A})\big)\Big)\Big)\,\mathbf{LFi}_K \tag{B.3}$$

"*diag*" in equation (B.3) signifies diagonalisation of a vector. Recalling that $\mathbf{L}$ is a function of $\mathbf{A}$, we can denote, for brevity, value added as a function of three variables, $\mathbf{v}(\mathbf{T_Z}, \mathbf{A}, \mathbf{F})$. The change in value added from year 0 to year 1 in terms of increment and growth is equal to:

$$\Delta\mathbf{v} = \mathbf{v}_1 - \mathbf{v}_0 = \mathbf{v}(\mathbf{T}_{\mathbf{Z},1}, \mathbf{A}_1, \mathbf{F}_1) - \mathbf{v}(\mathbf{T}_{\mathbf{Z},0}, \mathbf{A}_0, \mathbf{F}_0) \tag{B.4}$$

$$\mathrm{P}\mathbf{v} = \mathbf{v}_1 \oslash \mathbf{v}_0 = \frac{\mathbf{v}(\mathbf{T}_{\mathbf{Z},1}, \mathbf{A}_1, \mathbf{F}_1)}{\mathbf{v}(\mathbf{T}_{\mathbf{Z},0}, \mathbf{A}_0, \mathbf{F}_0)} \tag{B.5}$$

Changing one variable while holding the two other constant, we can decompose the change in value added. For example, the change in value added because of the change of the intermediate input requirements is given by four terms with the averaging and weighting that arises from the total decomposition of $\Delta\mathbf{v}$ or $\mathrm{P}\mathbf{v}$:[20]

$$\begin{aligned}\Delta\mathbf{v}(\mathbf{A}) = {} & \frac{1}{3}\big(\mathbf{v}(\mathbf{T}_{\mathbf{Z},1}, \mathbf{A}_1, \mathbf{F}_1) - \mathbf{v}(\mathbf{T}_{\mathbf{Z},1}, \mathbf{A}_0, \mathbf{F}_1)\big) + \frac{1}{3}\big(\mathbf{v}(\mathbf{T}_{\mathbf{Z},0}, \mathbf{A}_1, \mathbf{F}_0) - \mathbf{v}(\mathbf{T}_{\mathbf{Z},0}, \mathbf{A}_0, \mathbf{F}_0)\big) + \\ & + \frac{1}{6}\big(\mathbf{v}(\mathbf{T}_{\mathbf{Z},1}, \mathbf{A}_1, \mathbf{F}_0) - \mathbf{v}(\mathbf{T}_{\mathbf{Z},1}, \mathbf{A}_0, \mathbf{F}_0)\big) + \frac{1}{6}\big(\mathbf{v}(\mathbf{T}_{\mathbf{Z},0}, \mathbf{A}_1, \mathbf{F}_1) - \mathbf{v}(\mathbf{T}_{\mathbf{Z},0}, \mathbf{A}_0, \mathbf{F}_1)\big)\end{aligned} \tag{B.6}$$

$$\begin{aligned}\mathrm{P}\mathbf{v}(\mathbf{A}) = {} & \left(\frac{\mathbf{v}(\mathbf{T}_{\mathbf{Z},1}, \mathbf{A}_1, \mathbf{F}_1)}{\mathbf{v}(\mathbf{T}_{\mathbf{Z},1}, \mathbf{A}_0, \mathbf{F}_1)}\right)^{\circ\frac{1}{3}} \circ \left(\frac{\mathbf{v}(\mathbf{T}_{\mathbf{Z},0}, \mathbf{A}_1, \mathbf{F}_0)}{\mathbf{v}(\mathbf{T}_{\mathbf{Z},0}, \mathbf{A}_0, \mathbf{F}_0)}\right)^{\circ\frac{1}{3}} \circ \\ & \circ \left(\frac{\mathbf{v}(\mathbf{T}_{\mathbf{Z},1}, \mathbf{A}_1, \mathbf{F}_0)}{\mathbf{v}(\mathbf{T}_{\mathbf{Z},1}, \mathbf{A}_0, \mathbf{F}_0)}\right)^{\circ\frac{1}{6}} \circ \left(\frac{\mathbf{v}(\mathbf{T}_{\mathbf{Z},0}, \mathbf{A}_1, \mathbf{F}_1)}{\mathbf{v}(\mathbf{T}_{\mathbf{Z},0}, \mathbf{A}_0, \mathbf{F}_1)}\right)^{\circ\frac{1}{6}}\end{aligned} \tag{B.7}$$

Another variable of interest that influences the change in value added is final demand:

$$\begin{aligned}\Delta\mathbf{v}(\mathbf{F}) = {} & \frac{1}{3}\big(\mathbf{v}(\mathbf{T}_{\mathbf{Z},1}, \mathbf{A}_1, \mathbf{F}_1) - \mathbf{v}(\mathbf{T}_{\mathbf{Z},1}, \mathbf{A}_1, \mathbf{F}_0)\big) + \frac{1}{3}\big(\mathbf{v}(\mathbf{T}_{\mathbf{Z},0}, \mathbf{A}_0, \mathbf{F}_1) - \mathbf{v}(\mathbf{T}_{\mathbf{Z},0}, \mathbf{A}_0, \mathbf{F}_0)\big) + \\ & + \frac{1}{6}\big(\mathbf{v}(\mathbf{T}_{\mathbf{Z},1}, \mathbf{A}_0, \mathbf{F}_1) - \mathbf{v}(\mathbf{T}_{\mathbf{Z},1}, \mathbf{A}_0, \mathbf{F}_0)\big) + \frac{1}{6}\big(\mathbf{v}(\mathbf{T}_{\mathbf{Z},0}, \mathbf{A}_1, \mathbf{F}_1) - \mathbf{v}(\mathbf{T}_{\mathbf{Z},0}, \mathbf{A}_1, \mathbf{F}_0)\big)\end{aligned} \tag{B.8}$$

[20] The decomposition that is consistent with the index number theory requires computing all unique decomposition forms for each factor. Muradov (2021b) reviews the averaging and weighting schemes that apply to these decomposition forms.

$$\mathrm{P}\mathbf{v}(\mathbf{F}) = \left(\frac{\mathbf{v}(\mathbf{T}_{\mathbf{Z},1},\mathbf{A}_1,\mathbf{F}_1)}{\mathbf{v}(\mathbf{T}_{\mathbf{Z},1},\mathbf{A}_1,\mathbf{F}_0)}\right)^{\circ\frac{1}{3}} \circ \left(\frac{\mathbf{v}(\mathbf{T}_{\mathbf{Z},0},\mathbf{A}_0,\mathbf{F}_1)}{\mathbf{v}(\mathbf{T}_{\mathbf{Z},0},\mathbf{A}_0,\mathbf{F}_0)}\right)^{\circ\frac{1}{3}} \circ$$
$$\circ \left(\frac{\mathbf{v}(\mathbf{T}_{\mathbf{Z},1},\mathbf{A}_0,\mathbf{F}_1)}{\mathbf{v}(\mathbf{T}_{\mathbf{Z},1},\mathbf{A}_0,\mathbf{F}_0)}\right)^{\circ\frac{1}{6}} \circ \left(\frac{\mathbf{v}(\mathbf{T}_{\mathbf{Z},0},\mathbf{A}_1,\mathbf{F}_1)}{\mathbf{v}(\mathbf{T}_{\mathbf{Z},0},\mathbf{A}_1,\mathbf{F}_0)}\right)^{\circ\frac{1}{6}} \tag{B.9}$$

To ensure that the results are not distorted by price changes, all variables on the right side of equations (B.4) and (B.5) need to be valued at the same prices, preferably at the base year prices.

If $\mathbf{e}$ is a KN×1 vector of employment by industry, in persons or number of jobs, and $\mathbf{e}_c = \mathbf{e}\hat{\mathbf{x}}^{-1}$ is a vector of employment coefficients, in persons or number of jobs per one dollar of industry output, then employment can be expressed as a function of intermediate input requirements and final demand:

$$\mathbf{e} = \hat{\mathbf{e}}_c\mathbf{x} = \hat{\mathbf{e}}_c\mathbf{LFi}_K \tag{B.10}$$

Employment can also be compactly written as a function of three variables, $\mathbf{e}(\mathbf{e}_c, \mathbf{A}, \mathbf{F})$, and the change in employment by industry is equal to:

$$\Delta\mathbf{e} = \mathbf{e}_1 - \mathbf{e}_0 = \mathbf{e}(\mathbf{e}_{c,1},\mathbf{A}_1,\mathbf{F}_1) - \mathbf{e}(\mathbf{e}_{c,0},\mathbf{A}_0,\mathbf{F}_0) \tag{B.11}$$

$$\mathrm{P}\mathbf{e} = \mathbf{e}_1 \oslash \mathbf{e}_0 = \frac{\mathbf{e}(\mathbf{e}_{c,1},\mathbf{A}_1,\mathbf{F}_1)}{\mathbf{e}(\mathbf{e}_{c,0},\mathbf{A}_0,\mathbf{F}_0)} \tag{B.12}$$

The change in $\mathbf{e}$ can be further decomposed into changes associated with the increment or growth of the component variables as in the case of value added above, in equations (B.6) - (B.9).

C Decomposition of GDP

GDP is a summary measure of value added generated in an economy. Defined by the production approach, it is equal to "the value of output less intermediate consumption plus any taxes less subsidies on products not already included in the value of output" (United Nations et al., 2009, paragraph 16.47). Taxes less subsidies on intermediate products now need to be removed from the formula of GDP to avoid double counting:

$$\mathbf{y}' = \mathbf{x}'\mathbf{S}_N - \mathbf{i}'\mathbf{Z}\mathbf{S}_N + \mathbf{m}'_{\mathbf{F}} = \mathbf{i}'\hat{\mathbf{x}}\mathbf{S}_N - \mathbf{i}'\mathbf{A}\hat{\mathbf{x}}\mathbf{S}_N + \mathbf{m}'_{\mathbf{F}} = (\mathbf{i}' - \mathbf{i}'\mathbf{A})\,\hat{\mathbf{x}}\mathbf{S}_N + \mathbf{m}'_{\mathbf{F}} \tag{C.1}$$

where $\mathbf{y}'$ is a 1×K vector of GDP of K countries, and $\mathbf{m}'_{\mathbf{F}}$ is a 1×K vector of taxes less subsidies on final products.

If the ICIO table differentiates taxes less subsidies on final products by country of origin of products subject to those taxes, and a K×K matrix of taxes less subsidies on final products $\mathbf{M}_{\mathbf{F}}$ is available, then vector $\mathbf{m}'_{\mathbf{F}}$ may be rewritten as:

$$\mathbf{m}'_{\mathbf{F}} = \mathbf{i}'\mathbf{M}_{\mathbf{F}} = \mathbf{i}'\big(\mathbf{T}_{\mathbf{F}} \circ (\mathbf{S}'_N\mathbf{F})\big) \tag{C.2}$$

where $\mathbf{T}_{\mathbf{F}} = \mathbf{M}_{\mathbf{F}} \oslash (\mathbf{S}'_N\mathbf{F})$ denotes effectively applied net tax rates by country of origin and country of destination.

Insert equation (C.2) into equation (C.1) and, using that $[(\mathbf{i}' - \mathbf{i}'\mathbf{A})\,\hat{\mathbf{x}}]' = (\widehat{\mathbf{i}' - \mathbf{i}'\mathbf{A}})\mathbf{x}$, and $\mathbf{x} = \mathbf{LFi}_K$, transpose and rewrite equation (C.1):

$$\mathbf{y} = \mathbf{S}'_N(\widehat{\mathbf{i}' - \mathbf{i}'\mathbf{A}})\mathbf{x} + \mathbf{m_F} = \mathbf{S}'_N\left(\mathbf{I} - \widehat{\mathbf{i}'\mathbf{A}}\right)\mathbf{LFi}_K + \left(\mathbf{T_F} \circ (\mathbf{S}'_N\mathbf{F})\right)'\mathbf{i} \tag{C.3}$$

For brevity, we express GDP as a function of intermediate input requirement, final demand and net tex rates on final products, $\mathbf{y}(\mathbf{A}, \mathbf{F}, \mathbf{T_F})$. The change in GDP from year 0 to year 1 may now be explained in terms of the changes of $\mathbf{A}$, $\mathbf{F}$ and $\mathbf{T_F}$:

$$\Delta\mathbf{y} = \mathbf{y}_1 - \mathbf{y}_0 = \mathbf{y}(\mathbf{A}_1, \mathbf{F}_1, \mathbf{T}_{\mathbf{F},1}) - \mathbf{y}(\mathbf{A}_0, \mathbf{F}_0, \mathbf{T}_{\mathbf{F},0}) \tag{C.4}$$

$$\mathrm{P}\mathbf{y} = \mathbf{y}_1 \oslash \mathbf{y}_0 = \frac{\mathbf{y}(\mathbf{A}_1, \mathbf{F}_1, \mathbf{T}_{\mathbf{F},1})}{\mathbf{y}(\mathbf{A}_0, \mathbf{F}_0, \mathbf{T}_{\mathbf{F},0})} \tag{C.5}$$

The decomposition with respect to $\mathbf{A}$ and $\mathbf{F}$ then proceeds as in equations (B.6) - (B.9). This paper adopts a nested or hierarchical structural decomposition. Therefore, at the next level, we pursue a deeper decomposition of $\mathbf{A}$ and $\mathbf{F}$, trying to isolate the changes in the country of origin of intermediate and final products.

D Next-level decomposition of the changes in intermediate and final demand

A factorisation of the matrix of technical coefficients $\mathbf{A}$ helps unveiling various sources of changes in intermediate demand:

$$\mathbf{A} = \mathbf{A}^{cou} \circ \left(\mathbf{S}'_K\mathbf{A}^{ind}\hat{\mathbf{a}}\right) \tag{D.1}$$

where $\mathbf{S}_K$ is a N×KN country aggregation matrix.[21] $\mathbf{A}^{ind}$ is an N×KN matrix that allocates total industry requirements for intermediate inputs $\mathbf{a}' = \mathbf{i}'\mathbf{A}$ to the industry sources of those inputs or, by and large, to homogenous groups of individual products:

$$\mathbf{A}^{ind} = \mathbf{S}_K\mathbf{A}\hat{\mathbf{a}}^{-1}$$

This matrix is usually referred to as the matrix of normalised total intermediate input (or technical) coefficients (see, *e.g.*, Duan et al., 2018) and is thought to describe technology, or "production recipe" in input-output models. Note that the industries that supply intermediate inputs are aggregated across all countries at this stage. $\mathbf{A}^{cou}$ is a KN×KN matrix that distributes intermediate inputs across the countries of their origin:[22]

$$\mathbf{A}^{cou} = \mathbf{A} \oslash (\mathbf{S}'_K\mathbf{S}_K\mathbf{A})$$

To sum up, changes in $\mathbf{a}$ describe the substitution between primary and intermediate inputs, changes in $\mathbf{A}^{ind}$ describe the substitution between the industry sources of intermediate inputs and changes in $\mathbf{A}^{cou}$ describe the substitution between the country sources of

[21] $\mathbf{S}_K$ is obtained by replicating an N×N identity matrix horizontally K times: $\mathbf{S}_K = \mathbf{i}'_K \otimes \mathbf{I}_N$. In equation (D.1), the transpose of $\mathbf{S}_K$ copies an N×KN matrix K times vertically to obtain a KN×KN matrix.

[22] Note that in case an element in $\mathbf{A}^{cou}$ results from division of zero by zero, it should be made equal to zero. This occurs if industry j in country s does not purchase input from industry i in the given period. The same rule applies to $\mathbf{A}^{ind}$, $\mathbf{a}'$ and $\mathbf{A}$, though such cases are less likely to occur.

intermediate inputs. It is customary to interpret changes in $\mathbf{a}$ as changes in the efficiency of the use of intermediate inputs or as outsourcing process, changes in $\mathbf{A}^{ind}$ as changes in industry technology and changes in $\mathbf{A}^{cou}$ as changes in trade patterns. Together, changes in $\mathbf{a}$, $\mathbf{A}^{ind}$ and $\mathbf{A}^{cou}$ define the change in $\mathbf{A}$ and $\mathbf{L}$.

Insert equation (D.1) into equation (B.3) and write value added as a function of five variables, $\mathbf{v}(\mathbf{T_Z}, \mathbf{A}^{cou}, \mathbf{A}^{ind}, \mathbf{a}, \mathbf{F})$. Our variable of interest is $\mathbf{A}^{cou}$ as it contains information on the change in the country of origin of products, and we look for components in $\Delta\mathbf{v}(\mathbf{A})$ and $\mathrm{P}\mathbf{v}(\mathbf{A})$ that are solely associated with changes in $\mathbf{A}^{cou}$. The first term from equation (B.6) can be decomposed as follows, using the weighting and aggregation scheme with three variables:

$$
\begin{aligned}
&\frac{1}{3}\big(\mathbf{v}(\mathbf{T}_{\mathbf{Z},1}, \mathbf{A}_1, \mathbf{F}_1) - \mathbf{v}(\mathbf{T}_{\mathbf{Z},1}, \mathbf{A}_0, \mathbf{F}_1)\big) = \\
&= \frac{1}{9}\big(\mathbf{v}(\mathbf{T}_{\mathbf{Z},1}, \mathbf{A}_1^{cou}, \mathbf{A}_1^{ind}, \mathbf{a}_1, \mathbf{F}_1) - \mathbf{v}(\mathbf{T}_{\mathbf{Z},1}, \mathbf{A}_0^{cou}, \mathbf{A}_1^{ind}, \mathbf{a}_1, \mathbf{F}_1)\big) + \\
&+ \frac{1}{9}\big(\mathbf{v}(\mathbf{T}_{\mathbf{Z},1}, \mathbf{A}_1^{cou}, \mathbf{A}_0^{ind}, \mathbf{a}_0, \mathbf{F}_1) - \mathbf{v}(\mathbf{T}_{\mathbf{Z},1}, \mathbf{A}_0^{cou}, \mathbf{A}_0^{ind}, \mathbf{a}_0, \mathbf{F}_1)\big) + \\
&+ \frac{1}{18}\big(\mathbf{v}(\mathbf{T}_{\mathbf{Z},1}, \mathbf{A}_1^{cou}, \mathbf{A}_1^{ind}, \mathbf{a}_0, \mathbf{F}_1) - \mathbf{v}(\mathbf{T}_{\mathbf{Z},1}, \mathbf{A}_0^{cou}, \mathbf{A}_1^{ind}, \mathbf{a}_0, \mathbf{F}_1)\big) + \\
&+ \frac{1}{18}\big(\mathbf{v}(\mathbf{T}_{\mathbf{Z},1}, \mathbf{A}_1^{cou}, \mathbf{A}_0^{ind}, \mathbf{a}_1, \mathbf{F}_1) - \mathbf{v}(\mathbf{T}_{\mathbf{Z},1}, \mathbf{A}_0^{cou}, \mathbf{A}_0^{ind}, \mathbf{a}_1, \mathbf{F}_1)\big)
\end{aligned} \tag{D.2}
$$

Decomposing the rest three terms from equation (B.6) with respect to $\mathbf{A}^{cou}$ in a similar way and adding them up yields $\Delta\mathbf{v}(\mathbf{A}^{cou})$. Such approach effectively addresses the problem of dependent determinants (see Dietzenbacher et al., 2000). A similar decomposition in the multiplicative form is:

$$
\begin{aligned}
\left(\frac{\mathbf{v}(\mathbf{T}_{\mathbf{Z},1}, \mathbf{A}_1, \mathbf{F}_1)}{\mathbf{v}(\mathbf{T}_{\mathbf{Z},1}, \mathbf{A}_0, \mathbf{F}_1)}\right)^{\circ\frac{1}{3}} &= \left(\frac{\mathbf{v}(\mathbf{T}_{\mathbf{Z},1}, \mathbf{A}_1^{cou}, \mathbf{A}_1^{ind}, \mathbf{a}_1, \mathbf{F}_1)}{\mathbf{v}(\mathbf{T}_{\mathbf{Z},1}, \mathbf{A}_0^{cou}, \mathbf{A}_1^{ind}, \mathbf{a}_1, \mathbf{F}_1)}\right)^{\circ\frac{1}{9}} \circ \left(\frac{\mathbf{v}(\mathbf{T}_{\mathbf{Z},1}, \mathbf{A}_1^{cou}, \mathbf{A}_0^{ind}, \mathbf{a}_0, \mathbf{F}_1)}{\mathbf{v}(\mathbf{T}_{\mathbf{Z},1}, \mathbf{A}_0^{cou}, \mathbf{A}_0^{ind}, \mathbf{a}_0, \mathbf{F}_1)}\right)^{\circ\frac{1}{9}} \circ \\
&\circ \left(\frac{\mathbf{v}(\mathbf{T}_{\mathbf{Z},1}, \mathbf{A}_1^{cou}, \mathbf{A}_1^{ind}, \mathbf{a}_0, \mathbf{F}_1)}{\mathbf{v}(\mathbf{T}_{\mathbf{Z},1}, \mathbf{A}_0^{cou}, \mathbf{A}_1^{ind}, \mathbf{a}_0, \mathbf{F}_1)}\right)^{\circ\frac{1}{18}} \circ \left(\frac{\mathbf{v}(\mathbf{T}_{\mathbf{Z},1}, \mathbf{A}_1^{cou}, \mathbf{A}_0^{ind}, \mathbf{a}_1, \mathbf{F}_1)}{\mathbf{v}(\mathbf{T}_{\mathbf{Z},1}, \mathbf{A}_0^{cou}, \mathbf{A}_0^{ind}, \mathbf{a}_1, \mathbf{F}_1)}\right)^{\circ\frac{1}{18}}
\end{aligned} \tag{D.3}
$$

The above example uses the first term from equation (B.7). The other three terms are subject to the same decomposition, which ensures that the Hadamard product of the results is equal to $\mathrm{P}\mathbf{v}(\mathbf{A}^{cou})$.

The decomposition of the change in final demand builds on a factorisation of $\mathbf{F}$ that is analogous to the factorisation of $\mathbf{A}$ above:

$$
\mathbf{F} = \mathbf{F}^{cou} \circ \left(\mathbf{S}_K' \mathbf{F}^{ind} \hat{\mathbf{f}}\right) \tag{D.4}
$$

$\hat{\mathbf{f}}$ is a diagonalised 1×K row vector that contains the values of total domestic final demand in each country in the input-output system. It sums the columns of $\mathbf{F}$: $\mathbf{f}' = \mathbf{i}'\mathbf{F}$. $\mathbf{F}^{ind}$ is an N×K matrix that allocates total demand for final products to the industry sources of those products. This matrix describes the product structure of final demand expenditure that is subject to change because of consumer or investor preferences. $\mathbf{F}^{ind}$ may be calculated as follows:

$$\mathbf{F}^{ind} = \mathbf{S}_K \mathbf{F} \hat{\mathbf{f}}^{-1}$$

Finally, $\mathbf{F}^{cou}$ is a KN×K matrix that distributes the demand for final products across the countries of their origin:

$$\mathbf{F}^{cou} = \mathbf{F} \oslash (\mathbf{S}'_K \mathbf{S}_K \mathbf{F})$$

Inserting equation (D.4) into equation (B.3) leads to another expression of value added as a function of five variables, including final demand components $\mathbf{v}(\mathbf{T_Z}, \mathbf{A}, \mathbf{F}^{cou}, \mathbf{F}^{ind}, \mathbf{f})$. Each term from equations (B.8) and (B.9) should now be decomposed with respect to $\mathbf{F}$ as shown in equations (D.2) and (D.3), and their aggregation will yield, respectively, $\Delta\mathbf{v}(\mathbf{F}^{cou})$ and $\mathrm{P}\mathbf{v}(\mathbf{F}^{cou})$.

The scheme explained above also applies to the deeper decomposition of employment and GDP.

E Completing the decomposition

The changes in the country of origin of intermediate and final products implicitly aggregate information on such effects as trade creation and trade diversion:

$$\Delta\mathbf{A}^{cou} = \Delta\mathbf{A}^{TC} + \Delta\mathbf{A}^{TD} + \Delta\mathbf{A}^{TR} = \sum_{s=1}^{K}\sum_{r\neq s}^{K} \Delta\mathbf{A}_{rs}^{TC} + \sum_{s=1}^{K}\sum_{r\neq s}^{K} \Delta\mathbf{A}_{rs}^{TD} + \sum_{s=1}^{K}\sum_{r\neq s}^{K} \Delta\mathbf{A}_{rs}^{TR} \quad \text{(E.1)}$$

$$\Delta\mathbf{F}^{cou} = \Delta\mathbf{F}^{TC} + \Delta\mathbf{F}^{TD} + \Delta\mathbf{F}^{TR} = \sum_{s=1}^{K}\sum_{r\neq s}^{K} \Delta\mathbf{F}_{rs}^{TC} + \sum_{s=1}^{K}\sum_{r\neq s}^{K} \Delta\mathbf{F}_{rs}^{TD} + \sum_{s=1}^{K}\sum_{r\neq s}^{K} \Delta\mathbf{F}_{rs}^{TR} \quad \text{(E.2)}$$

$\Delta\mathbf{A}^{TC}$ and $\Delta\mathbf{F}^{TC}$ are, respectively, KN×KN and KN×K matrices that sum up trade creation among all countries in the input-output system. $\Delta\mathbf{A}_{rs}^{TC}$ and $\Delta\mathbf{F}_{rs}^{TC}$ are bilateral matrices of trade creation, for each home country s and partner country r. As a country does not create trade with itself, there must be $K(K-1)$ bilateral matrices of trade creation with respect to intermediate demand and $K(K-1)$ bilateral matrices with respect to final demand. In the same way, other matrices describe trade diversion (TD) and trade contraction (TR) on multilateral or bilateral basis. The procedure to estimate these matrices is briefly described in Section 2.4 of the main text of the paper.

The split of $\Delta\mathbf{A}^{cou}$ and $\Delta\mathbf{F}^{cou}$ into bilateral matrices of trade creation, diversion and contraction as shown in equations (E.1) and (E.2) is useful for both additive and multiplicative decompositions. An insertion of equation (E.1) into equations (D.2) and (D.3) and the isolation of changes pertaining to each r–s pair and each effect is, however, problematic because matrices $\Delta\mathbf{A}_{rs}^{TC}$, $\Delta\mathbf{A}_{rs}^{TD}$ and $\Delta\mathbf{A}_{rs}^{TR}$ are nested within the Leontief inverse. Another complication is a very large number of factors: there are $K(K-1)$ matrices $\Delta\mathbf{A}_{rs}^{TC}$, $3K(K-1)$ matrices for all three effects, and the same numbers with respect to final demand. With dozens of countries in ICIO tables, the calculation of an exact decomposition becomes extremely cumbersome or infeasible.[23] An aggregation of

[23] The calculation of $\Delta\mathbf{v}$, $\Delta\mathbf{e}$ or $\Delta\mathbf{y}$ that is only associated with $\Delta\mathbf{A}_{rs}^{TC}$ and is consistent with the index number theory requires computing $2^{3K(K-1)-1}$ unique decomposition forms for the selected factor and

third countries into the rest of the world category, cutting the number of countries to 3, is not an acceptable solution because this may significantly bias the results (see Muradov, 2021a).

Various simplifications or "shortcuts" exist to ensure that the calculations are manageable. This paper adopts one of those "shortcuts" that was shown to provide the best approximation to the results of a full and exact decomposition (Muradov, 2021b). The changes in the country of origin – in case of intermediate demand here – induced solely by trade creation between a home country s and a partner country r are summarised in two forms, $\mathbf{A}_1^{cou} - \Delta\mathbf{A}_{rs}^{TC}$ and $\mathbf{A}_0^{cou} + \Delta\mathbf{A}_{rs}^{TC}$. The former models the structure of origin of intermediate products if trade creation in the r–s pair is the only change in the orientation of trade flows before year 1. The latter models the same after year 0. To show how to insert the respective terms in the decompositions at previous levels, we only decompose the first term from equation (D.2) as a function of $\Delta\mathbf{A}_{rs}^{TC}$:

$$\begin{aligned}&\frac{1}{9}\big(\mathbf{v}(\mathbf{T}_{\mathbf{Z},1}, \mathbf{A}_1^{cou}, \Delta\mathbf{A}_{rs}^{TC}, \mathbf{A}_1^{ind}, \mathbf{a}_1, \mathbf{F}_1) - \mathbf{v}(\mathbf{T}_{\mathbf{Z},1}, \mathbf{A}_0^{cou}, \Delta\mathbf{A}_{rs}^{TC}, \mathbf{A}_1^{ind}, \mathbf{a}_1, \mathbf{F}_1)\big) \approx \\ &\approx \frac{1}{18}\big(\mathbf{v}(\mathbf{T}_{\mathbf{Z},1}, \mathbf{A}_1^{cou}, \mathbf{A}_1^{ind}, \mathbf{a}_1, \mathbf{F}_1) - \mathbf{v}(\mathbf{T}_{\mathbf{Z},1}, (\mathbf{A}_1^{cou} - \Delta\mathbf{A}_{rs}^{TC}), \mathbf{A}_1^{ind}, \mathbf{a}_1, \mathbf{F}_1)\big) + \\ &+ \frac{1}{18}\big(\mathbf{v}(\mathbf{T}_{\mathbf{Z},1}, (\mathbf{A}_0^{cou} + \Delta\mathbf{A}_{rs}^{TC}), \mathbf{A}_1^{ind}, \mathbf{a}_1, \mathbf{F}_1) - \mathbf{v}(\mathbf{T}_{\mathbf{Z},1}, \mathbf{A}_0^{cou}, \mathbf{A}_1^{ind}, \mathbf{a}_1, \mathbf{F}_1)\big)\end{aligned} \tag{E.3}$$

and the first term from equation (D.3):

$$\begin{aligned}&\left(\frac{\mathbf{v}(\mathbf{T}_{\mathbf{Z},1}, \mathbf{A}_1^{cou}, \Delta\mathbf{A}_{rs}^{TC}, \mathbf{A}_1^{ind}, \mathbf{a}_1, \mathbf{F}_1)}{\mathbf{v}(\mathbf{T}_{\mathbf{Z},1}, \mathbf{A}_0^{cou}, \Delta\mathbf{A}_{rs}^{TC}, \mathbf{A}_1^{ind}, \mathbf{a}_1, \mathbf{F}_1)}\right)^{\circ\frac{1}{9}} \approx \\ &\approx \left(\frac{\mathbf{v}(\mathbf{T}_{\mathbf{Z},1}, \mathbf{A}_1^{cou}, \mathbf{A}_1^{ind}, \mathbf{a}_1, \mathbf{F}_1)}{\mathbf{v}(\mathbf{T}_{\mathbf{Z},1}, (\mathbf{A}_1^{cou} - \Delta\mathbf{A}_{rs}^{TC}), \mathbf{A}_1^{ind}, \mathbf{a}_1, \mathbf{F}_1)}\right)^{\circ\frac{1}{18}} \circ \left(\frac{\mathbf{v}(\mathbf{T}_{\mathbf{Z},1}, (\mathbf{A}_0^{cou} + \Delta\mathbf{A}_{rs}^{TC}), \mathbf{A}_1^{ind}, \mathbf{a}_1, \mathbf{F}_1)}{\mathbf{v}(\mathbf{T}_{\mathbf{Z},1}, \mathbf{A}_0^{cou}, \mathbf{A}_1^{ind}, \mathbf{a}_1, \mathbf{F}_1)}\right)^{\circ\frac{1}{18}}\end{aligned} \tag{E.4}$$

This procedure applies to all terms in equations (D.2) and (D.3). The decomposition completes by collecting and inserting all terms back into equations (B.6) and (B.7).

The result is KN×1 vectors of changes in value added of all industries in all countries induced by trade creation in the intermediate demand of home country s with respect to partner country r that we denote, for brevity, as $\Delta\mathbf{v}(\Delta\mathbf{A}_{rs}^{TC})$ and $\mathrm{P}\mathbf{v}(\Delta\mathbf{A}_{rs}^{TC})$. A similar decomposition of equations (B.8) and (B.9) with respect to $\Delta\mathbf{F}^{TC}$ yields results for final demand, $\Delta\mathbf{v}(\Delta\mathbf{F}_{rs}^{TC})$ and $\mathrm{P}\mathbf{v}(\Delta\mathbf{F}_{rs}^{TC})$. A sum or, respectively, a product of these terms provides a measure of total changes in value added because of trade creation in the r–s pair: $\Delta\mathbf{v}_{rs}^{TC} = \Delta\mathbf{v}(\Delta\mathbf{A}_{rs}^{TC}) + \Delta\mathbf{v}(\Delta\mathbf{F}_{rs}^{TC})$ and $\mathrm{P}\mathbf{v}_{rs}^{TC} = \mathrm{P}\mathbf{v}(\Delta\mathbf{A}_{rs}^{TC}) \circ \mathrm{P}\mathbf{v}(\Delta\mathbf{F}_{rs}^{TC})$.

In vector $\Delta\mathbf{v}_{rs}^{TC}$, the N×1 block $\left(\Delta\mathbf{v}_{rs}^{TC}\right)_k$ corresponds to the changes in value added in all N industries of the k-th country in the ICIO system in response to trade creation in the r–s pair. In study of a bilateral relationship we may be primarily interested in setting k equal to r and s. Note that the changes in industry value added of country s are two-way: as a result of trade creation that affects its own demand as home country, $\left(\Delta\mathbf{v}_{rs}^{TC}\right)_s$,

applying a complex weighting and averaging scheme. For example, in a decomposition with 60 countries, the number of decomposition forms to be computed for each country pair is 2^{10619}. This number is in fact even higher because of the hierarchical decomposition. Muradov (2021b) explains these complications in more detail.

and trade creation that affects the demand of country r in the s–r pair where r is home country and s is partner country, $\left(\Delta\mathbf{v}_{sr}^{TC}\right)_s$. The sum of the two may reasonably be treated as net trade creation. This applies to the other two effects[24] and other dependent variables.

[24] Net trade creation and net trade contraction may be positive or negative subject to a combination of these effects for one country as home country and partner country, because usually $\left(\Delta\mathbf{v}_{rs}^{TC}\right)_s < 0$, $\left(\Delta\mathbf{v}_{sr}^{TC}\right)_s > 0$, $\left(\Delta\mathbf{v}_{rs}^{TR}\right)_s > 0$ and $\left(\Delta\mathbf{v}_{sr}^{TR}\right)_s < 0$. Trade diversion towards partner ($TDin$) usually benefits this partner, $\left(\Delta\mathbf{v}_{rs}^{TDin}\right)_r > 0$, while trade diversion away from partner ($TDout$) does not, $\left(\Delta\mathbf{v}_{rs}^{TDout}\right)_r < 0$. Trade diversion effects in whatever direction tend to be neutral or insignificant for home country. Therefore, net trade diversion *in* is usually positive and net trade diversion *out* negative.