Title: Decomposing global value chain (GVC) income for world fisheries

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Acknowledgments
The author would like to thank Stephen Kasperski and Daniel Lew for their useful comments on this paper.

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Abstract

Often, economic contribution and competitiveness of an industry has been examined using measures such as single-country output multiplier and exports. These measures fail if production of goods traded among countries is highly fragmented across countries, and if the production requires a large share of intermediate inputs imported from abroad. An accurate measure is the global value-added that is generated during the process of producing goods, and is dispersed across the globe. This study is the first to decompose the global value added of fish production for 10 selected countries, depending upon which industry and country the global value added is created, using a multi-country input-output (MCIO) model. I find, among other things, that for some of the 10 countries, the share of the global value added from fish production accounted for by foreign countries increases significantly over the 2000 – 2014 period, suggesting their growing dependence on foreign-sourced inputs. Overall, results indicate countries exhibit a considerable heterogeneity in the direction and the magnitude of the change over the period in the MCIO-based multipliers and global value chain (GVC) income and employment.

1. Introduction

Fish production contributes to the economies of many countries directly through generating jobs and income in the fish-producing industry and indirectly through supporting industries producing inputs that are supplied to the fish-producing industry. Global fish production (from both wild fisheries and aquaculture) increased dramatically for the past two decades. During the 1996-2005 period, the global annual average production of raw fish was 125.6 million tonnes. It increased to 178.8 million tonnes in 2018 or by 42.4% (FAO 2020). During the same period (i.e., from 1996/2005 to 2018), global human consumption of fish increased from 98.5 million tonnes to 156.4 million tonnes or by 58.8%. (FAO 2020).

Effective management of fisheries is important to the sustainable marine food supply to humans and to the economic well-being of people who depend on fish production. Since economic well-being of fishery-dependent people is a top concern of fishery managers in many countries, they are naturally interested in how much contribution their fish-producing activities make to creation of jobs and income in their economies and how competitive their fish-producing industry is compared to other countries.

Economic contribution (role, importance) of fish production is often quantified by output multipliers from a single-region (country) input-output (IO) model or indices constructed based on them. Some of the multiplier-based studies assess the economic contribution of fish production at a sub-national level. For instance, Seung and Waters (2006) examines the role of the seafood industry in Alaska using an indicator derived from multipliers calculated based on an Alaska social accounting matrix (SAM) model. Garza-Gil et al. (2017) quantifies the economic contribution of fishing and aquaculture to Galicia, Spain, using IO multipliers.

Other studies focus on the national-level contribution of fish production. For example, Dyck and Sumaila (2010) measures the contributions of capture fisheries in many different countries to their economies using output multipliers computed from national IO models. Sigfusson et al. (2013) examines the importance of fishing industry and the associated industries to the Icelandic economy. Recently, Cai et al. (2019) develops methods to measure the national-level economic contribution of fisheries and aquaculture to GDP based on IO models. The study presents a conceptual framework, and suggests internationally established methodology, standards and guidelines to gauge aquaculture and fisheries' economic contribution.[1] However, none of the previous studies assessing the economic contribution of a fish-producing industry use a multi-country IO (MCIO) framework. Therefore, the measures of the economic contribution from these previous studies fail to capture the effects from the inter-country trade flows (spillover effects and feedback effects).

Several studies evaluate the competitiveness of fish-producing industry of a country using the revealed comparative advantage (RCA, Balassa 1965) measure. For example, Tan et al. (2020) uses the RCA measure to examine the competitiveness of China's aquatic products based on its seafood exports. RCA is a traditional method often used to assess the competitiveness of an industry based on gross exports. This measure, however, is based on the assumption that all production activities needed to produce a final product (i.e., the product that is directly consumed by the final consumers) for exports occur within a country using only inputs produced within the country (Timmer et al. 2013). This assumption is not appropriate because in many cases, a large portion of the inputs used to produce goods and services in a country is imported from abroad and because the process of producing a final product is highly fragmented across the globe

[1] See Kim and Seung (2019) for a review of additional studies that examine the role or contribution of national or sub-national fisheries.

(Johnson and Noguera 2012; Koopman et al. 2012; Wang et al. 2013; Koopman et al. 2014). Therefore, RCA measures based on gross exports cannot correctly gauge the competitiveness of industries (fish-producing industry in this case).

The present study overcomes the limitations of these previous studies above by adopting the global value chain (GVC) income approach (Timmer et al. 2013) to evaluate economic contribution and competiveness of fish-producing industry. In doing so, this study uses a MCIO model constructed based on World Input Output Data (WIOD, http://www.wiod.org/release16). GVC income is defined as the sum of the stream of all value-added incomes generated along the global production chain. GVC income approach can trace the value added, along the global production chain, which is generated during the process of producing a final good (raw fish in the present study) in a country. The approach thus can show how much value added is generated within the country where the final good is produced and how much value added the other countries produce by exporting intermediate inputs to the country, thereby participating in the process of producing the final good in the country.

Using the MCIO model, this study calculates, for 10 selected countries, the changes in (i) the magnitude of the output multipliers for fish-producing industry and (ii) the economic contribution and competitiveness of the industry, which occur during the period 2000 - 2014. The 10 countries include Brazil, China, Indonesia, India, Japan, Korea, Mexico, Norway, Spain, and the United States. In assessing the contribution of the industry, this study uses GVC income and GVC employment.

This study is organized as follows. Section 2 describes the methods that I use, including the MCIO model, two measures of contribution (GVC income and GVC employment), and two

RCA measures (based on exports and GVC income). Section 3 provides a short description of the data used. Section 4 presents and discusses the results. Section 5 presents conclusions.

2. Method

2.1 Multi-country input-output (MCIO) model

Assume that there are G countries and N industries. Each of N industries produces one homogenous product. Thus, a total of GN different products are produced in the world. Each industry in a country uses K different factors of production. The industry also uses intermediate inputs that are produced within a country or imported from other countries. Products thus produced are used as intermediate inputs (either in home country or abroad) or used to meet the final demand (household demand, investment, and government demand) within the country or in the foreign countries. Let the value of products from industry i in country r (source) used as final consumption in country s (destination) be $f_{rs}(i)$. The products are either sold to final consumers in home country (s = r) or abroad (s ≠ r). Additionally, let the value of intermediate inputs from industry i in country r (source) used to produce output in industry j in country s (destination) be $m_{rs}(i,j)$. The intermediate inputs are either sold to industry j in home country (s = r) or to industry j abroad (s ≠ r). Then the market clearing condition of the product is written as:

$$y_r(i) = \sum_s f_{rs}(i) + \sum_s \sum_j m_{rs}(i,j), \qquad (1)$$

where $y_r(i)$ is the value of output from industry i in country r.

The relationship in Equation (1) represents an MCIO model that can be expressed in a matrix form as follows.

$$\begin{bmatrix} Y_1 \\ Y_2 \\ \vdots \\ Y_r \\ \vdots \\ Y_G \end{bmatrix} = \begin{bmatrix} A_{11} & A_{12} & \cdots & A_{1s} & \cdots & A_{1G} \\ A_{21} & A_{22} & \cdots & A_{2s} & \cdots & A_{2G} \\ \vdots & \vdots & \ddots & \vdots & \ddots & \vdots \\ A_{r1} & A_{r2} & \cdots & A_{rs} & \cdots & A_{rG} \\ \vdots & \vdots & \ddots & \vdots & \ddots & \vdots \\ A_{G1} & A_{G2} & \cdots & A_{Gs} & \cdots & A_{GG} \end{bmatrix} \begin{bmatrix} Y_1 \\ Y_2 \\ \vdots \\ Y_r \\ \vdots \\ Y_G \end{bmatrix} + \begin{bmatrix} F_1 \\ F_2 \\ \vdots \\ F_r \\ \vdots \\ F_G \end{bmatrix} . \qquad (2)$$

In the above model, $\mathbf{Y_r}$ (r = 1, 2, …, G) is an (N × 1) column vector of industry output for country r where N is the number of industries in the country, $\mathbf{A_{rs}}$ an (N × N) matrix of inter-country input (trade) coefficient matrix showing country s's purchases of intermediate inputs from r, and $\mathbf{F_r}$ an (N × 1) column vector of global final demand for industry output produced in country r. Here $\mathbf{F_r}$ includes the final demands from all countries for commodities produced in r.

The MCIO model can be solved for $\mathbf{Y_r}$, and expressed more compactly as:

$$\boldsymbol{Y} = (\boldsymbol{I} - \boldsymbol{A})^{-1}\boldsymbol{F}, \qquad (2)'$$

where **Y** is an (GN × 1) vector of industry outputs for all G countries and N industries, **A** an (GN × GN) matrix of MCIO input coefficients, **F** an (GN × 1) vector of final demand for all G regions, and $\mathbf{(I\text{-}A)^{-1}}$ the MCIO inverse (multiplier matrix). Matrix **A** contains element $a_{rs}(i,j) = m_{rs}(i,j)/y_s(j)$ which represents the value of output from industry i in country r used as intermediate inputs in industry j in country s per unit value of output in the destination industry (j) in the destination country (s). $\mathbf{(I\text{-}A)^{-1}}$ contains element $\alpha_{rs}(i,j)$ that represents the increase in the value of output in industry i in country r resulting from a one unit increase in the value of global final demand for output produced in industry i in country r , and includes both direct and indirect effects.

2.2. Decomposing global value added and employment

Figure 1 illustrates how a final demand for a product produced in a country generates value added in different industries and countries. In the figure, wide arrows show the direction of the flows of intermediate goods while narrow arrows show the generation of value added. In the figure, VA denotes value added. For example, VA2.1 denotes the value added generated in first (denoted "1") industry (or group of industries) of Country 2 (denoted "2"). The industry producing the final good is denoted E while the industries producing intermediate goods are denoted by A, B, C, and D.

When an industry (E in Figure 1) of a country (Country 3) produces a final good using intermediate inputs, the industry generates value added (VA3.1) in the country. The industry uses both domestically produced (D) and imported inputs from Country 2 (C). The industry supplying intermediate inputs in the country (D) to the industry that produces the final goods (E) will also create value added (VA3.2). Thus, the total value-added income generated in Country 3 is equal to VA3.1+VA3.2. Next, the industry in Country 2 (C) produces and exports the inputs to Country 3, generating value added (VA2.2). The industry (C) uses both domestically produced inputs (B) and foreign inputs (A). During the process of Bs producing inputs that are supplied to C, the industry (B) creates value added (VA2.1). Thus, the total value-added income created in Country 2 will be the sum of VA2.1+VA2.2. Finally, the industry in Country 1 (A) produces inputs that are sold to C in Country 2, generating value added (VA1).

Thus, during the process of producing the final product in Country 3, the value added will be generated in the three countries. Sum of all these value-added incomes is GVC income. Although for simplicity it is assumed in this example that there are no trade flows among industries A, B, and D, actual MCIO data may show non-zero trade flows among these industries. In addition, Industries A and B may directly provide inputs to industry E in the real data and industry D may supply some inputs to industry C.

With this, let **g** to be a GN×1 column vector of value-added coefficients. The element, $g_r(i)$, measures value-added generated per unit of output in industry i in country r. Let $\widehat{\boldsymbol{g}}$ be the diagonal matrix of dimension GN×GN whose elements on the main diagonal are the elements of **g**, then

$$\boldsymbol{v} = \widehat{\boldsymbol{g}}(\boldsymbol{I} - \boldsymbol{A})^{-1}\boldsymbol{F}, \tag{3}$$

where **v** is a GN×1 vector of value added for N industries for G countries. Given certain final demand levels in F, the element of **v**, $v_s(j)$, measures the contribution of the final demand levels to the value added in industry j of country s or how much of the value added engendered in the industry (j) is attributed to the final demand levels. Note that GVC income is the sum of the stream of value-added incomes earned by all factors in all countries that participate directly and indirectly in the production of a final product and is equal to the output value of the product.

First, let $VA_{ji}(s,r)$ be the value-added income generated in industry j in country s due to the global final demand for the product (raw fish in this study) from industry i in country r; this term $[VA_{ji}(s,r)]$ can be calculated using Equation (3) above. Then the value added in the origin industry (industry i) of the origin country (country r) generated by the global final demand for the product from the same industry (i) in the same country (r), denoted $VAS_{i,r}$, is

$$\boldsymbol{VAS_{i,r}} = \boldsymbol{VA_{ii}(r,r)}. \tag{4}$$

Total value added generated in all the other industries in country r due to the global final demand for the product in the country, denoted $TVAS_r$, is

$$\boldsymbol{TVAS_r} = \sum_{j \neq i} \boldsymbol{VA_{ji}(r,r)}. \tag{5}$$

Next, let $VFO_{i,r}$ be the value of final output produced in industry i in country r and let the total value-added income generated in country s due to production of i in r be $VAT_{s,i,r}$. Then,

$$\boldsymbol{VFO_{i,r}} = \sum_s \boldsymbol{VAT_{s,i,r}} = \sum_s \sum_j \boldsymbol{VA_{j,i}(s,r)}. \tag{6}$$

The total domestic (i.e., country r) value added ($DVA_{i,r}$) from production of i in r is simply

$$\boldsymbol{DVA_{i,r} = VAT_{r,i,r} = \sum_j VA_{ji}(r,r) = VAS_{i,r} + TVAS_r}. \tag{7}$$

Finally, the foreign value added ($FVA_{i,r}$) is equal to:

$$\boldsymbol{FVA_{i,r} = \sum_{s\neq r} VAT_{s,i,r} = VFO_{i,r} - DVA_{i,r}}. \tag{8}$$

Similarly, the following equation is used to gauge how much GVC employment is supported by the global final demand,

$$\boldsymbol{e = \hat{h}(I - A)^{-1}F}. \tag{9}$$

In this equation, **h** is a GN×1 column vector of employment coefficients. The element, $h_r(i)$, measures employment per unit of output produced in industry i in country r. $\boldsymbol{\hat{h}}$ is a diagonal matrix of dimension GN×GN whose elements on the main diagonal are the elements of **h**. **e** is an GN×1 vector of employment for N industries in G countries. Given certain final demand levels in **F**, the element in **e**, $e_s(j)$, measures the contribution of the final demand levels to the creation of employment in industry j of country s. Then, the GVC employment can be decomposed in a way similar to the GVC income decomposition (Equations 4-8 above).

2.3. Measuring competitiveness

To quantify the competitiveness of fish-producing industry for the selected countries, this study uses revealed comparative advantage (RCA, Balassa 1965) index. RCA index has been widely used to gauge the competitiveness of a commodity produced in a country. Assuming that there are N industries and G countries (regions), the traditional RCA (TRCA, Balassa 1965) for country r is defined as follows:

$$TRCA_i^r = \frac{e_i^r}{\sum_i^N e_i^r} \Bigg/ \frac{\sum_r^G e_i^r}{\sum_i^N \sum_r^G e_i^r}, \tag{10}$$

where e_i^r denotes exports of commodity i (produced in industry i) by region r. When the TRCA is larger than one, the industry in the country is said to have comparative advantage while it is said to have comparative disadvantage if the index is smaller than one.

However, the critical limitation of TRCA is that gross exports will overestimate the competitiveness of a country's industry if it uses a large portion of imported intermediate inputs when producing the exports. As an alternative, the present study also computes the RCA based on value-added income generated in a country. The new RCA based on value added (VRCA) is derived as:

$$VRCA_i^r = \frac{v_i^r}{\sum_i^N v_i^r} \Bigg/ \frac{\sum_r^G v_i^r}{\sum_i^N \sum_r^G v_i^r} . \qquad (11)$$

In this equation, v_i^r measures the GVC income accruing to country r resulting from global production of commodity i (i.e., the commodity produced in industry i) to meet the global final demand for the commodity, and therefore includes (i) the domestic (i.e., r) GVC income directly and indirectly generated from production of the commodity in country r and (ii) the domestic GVC income that is generated due to the country's production of intermediate inputs (mostly non-fish commodities) that are exported to other countries, and are used directly or indirectly for raw fish production in these other countries. $\sum_i^N v_i^r$ measures the total GVC income accruing to country r that results from global production of *all* N types of commodities. Thus, if a country's VRCA is larger than one for a commodity, it means that the country generates a higher share of its total GVC income (i.e., the GVC income from global production of *all* N types of commodities) accounted for by the global production of this commodity, compared to its global average. This does not necessarily mean that the country is a major exporter of the commodity because the country may produce intermediate inputs used in the global production of the commodity or because the commodity produced in the country may be mainly for meeting its domestic market.

3. Data

This study uses a multi-country input-output (MCIO) table from World Input-Output Database (WIOD) released in 2016 (http://www.wiod.org/release16). The database consists of 15 years of MCIO data (2000-2014) and covers 43 countries and 56 industries for each country. WIOD database also includes information on value-added income and final demand including exports for each industry in each country. The database additionally provides data on labor employment and compensation from Socio-Economic Accounts (SEA) in the database. This study uses (i) labor employment from SEA (labeled EMP in SEA) which is defined as the number of persons engaged, and includes self-employed persons and (ii) total labor compensation (labeled LAB in SEA) that corresponds to the labor employment (EMP). Fishing and aquaculture industry is separately identified in the database. For further details, see http://www.wiod.org/release16. I select top 10 countries that generates the largest revenue from fish production in 2014 based on the WIOD[2].

4. Results and Discussion

This study computes the output multipliers, decomposes GVC income and employment, and calculates RCA measures, for each of the 15 years (2000-2014) for each of the 10 countries. The full set of results are shown in Figures A.1-A.13 in Appendix. Discussion in this section

[2] According to World Bank data (https://data.worldbank.org/indicator/ER.FSH.PROD.MT), the top 10 countries include several countries such as Vietnam, Philippines, Russia, and Chile. However, since three of these countries (as Vietnam, Philippines, and Chile) are included in Rest of World (ROW) region in WIOD, analysis is not conducted for these three countries. In addition, WIOD does not have fish production data for Russia although this country is identified as a separate country in WIOD.

focuses on comparing the results (shown in Tables 1-3 and Figures 2-5) for the two end points (2000 and 2014), although it also discusses the results for the whole period (2000-2014) when necessary, referring to the figures in the Appendix.

4.1 Multipliers

I first calculate the total output multipliers for the 10 selected countries (Table 1, Figures A.1, A.2, and A.3). I compute two different types of output multipliers for each country – a domestic output multiplier[3] and a global output multiplier. Suppose that there is a one unit increase in the final demand for the raw fish produced in a country. Then, the domestic multiplier gauges the increase in the total industry output produced in the country, whereas the global multiplier measures the increase in the global total industry output. The difference between these two multipliers represents the impacts caused by the foreign-sourced inputs used in the country's raw fish production. Therefore, the larger the difference, the stronger the country's dependence on foreign inputs.

In 2000, China's fish-producing industry has the largest output multipliers (both domestic and global, 1.97 and 2.09, columns 2 and 3, Table 1). This means that fish production in the country has the largest effects (per unit of final demand) on both total domestic output and the total global output. The country's domestic multiplier is consistently larger than those of the other countries over the 2000 – 2014 period (Figure A.1). Japan and Norway are the two countries that have the next largest multipliers (both domestic and global multipliers) in 2000. The smallest domestic multipliers are obtained for Indonesia and India, probably because, for

[3] The domestic output multipliers computed in this study are different from the output multipliers that would be obtained from single-country IO models. This is because the domestic output multipliers from this study include the effects from international trade while the multipliers from single-country IO models do not.

these two countries, the share of revenue from fish production spent on intermediate inputs is very small. Instead, they may depend strongly on primary factors of production (especially labor). Spain's dependence on foreign inputs is the strongest in 2000 among the countries, as shown by the largest difference (0.32, column 4, Table 1) between global and domestic multipliers, followed by Norway (0.29) and Korea (0.23). India and Brazil are the two countries that rely the least on foreign inputs.

Over the period 2000 - 2014, multipliers for some countries increase (columns 2, 3, 5, 6, 8, and 9 in Table 1 and Figures A.1 - A2). These countries include Korea, Mexico, and Spain, among others. In particular, the multipliers for Spain increase rather significantly from 1.53 to 1.88 (domestic multiplier) and from 1.85 to 2.25 (global multiplier), suggesting that the country increases its share of intermediate inputs used in its raw fish production sourced from both itself and foreign countries. In contrast, multipliers for other countries decrease. Notably, the multipliers for the United States decrease significantly (Figures A.1 - A.2). The domestic multiplier for this country declines from 1.65 (2000) to 1.39 (2014) while the global multiplier decreases from 1.81 to 1.55. One possible explanation for this is the implementation of catch share systems in many US fisheries from the late 1990s (Brinson and Thunberg, 2016). Catch share programs in the United States have been shown to increase efficiency in the fish producing industries resulting in cost savings on intermediate inputs (Thunberg et al. 2015). The declining multipliers for this country may reflect the reduced use of intermediate inputs.

Table 1 also presents the difference between the two multipliers (domestic and global multipliers) for the two years (Columns 4 and 7) as well as the change in the difference between them over the period (Column 10), whereas Figure A.3 illustrates the temporal change in the difference between the two multipliers. Results indicate that, except for two countries (China and Indonesia), the difference between global and domestic multipliers becomes larger in 2014 than in 2000 (column 10, Table 1), further suggesting that the dependence on foreign inputs becomes stronger in 2014. In particular, the change in the difference between the two multipliers is striking, and is the largest for Japan (0.25), followed by Mexico (0.24), Korea (0.23), and Norway (0.13). Overall, results in Table 1 and Figures A.1 - A.3 indicate a considerable heterogeneity among different countries in the direction and the magnitude of the change in the multipliers over the time period.

4.2 Decomposing GVC income

I decompose in this section the GVC income generated directly and indirectly from fish producing activity in a country into four components – (i) the value added in the fish-producing industry (industry i) of the country of origin (country r) ($VAS_{i,r}$), (ii) total value-added generated in all the other industries in country r ($TVAS_r$), (iii) the total domestic (i.e., country r) value added ($DVA_{i,r}$), and (iv) the foreign value added ($FVA_{i,r}$).

The GVC income generated in the fish-producing industry ($VAS_{i,r}$) is computed using Equation (4), and is reported in columns 2 (for 2000) and 3 (for 2014) in Table 2. GVC income created in the other industries within the country ($TVAS_r$) is calculated using Equation (5), and is shown in columns 5 and 6. The total domestic GVC income ($DVA_{i,r}$) is calculated using Equation (7), and is presented in columns 8 and 9. Finally, total foreign GVC income ($FVA_{i,r}$) is computed using Equation (8), and is shown in columns 11 and 12. Note that results from the decomposition (Table 2) are shown in percentage of the total value of the final output ($VFO_{i,r}$). The results for all the years (2000-2014) are presented in Figures A.4 - A.7.

For example, in 2000, 92.1% of the GVC income from US fish-producing activity (last row, column 8, Table 2), is generated within the United States with the remainder (7.9%) created outside the country. The domestic share of value added (92.1%) is further decomposed into direct (59.4%, column 2) and indirect (32.7%, column 5) effects, depending on which industry (industries) the value added is generated – in fish producing industry or in the other industries of the country. 59.4% of the GVC income generated along the GVC due to US fish-producing activity is accounted for by the industry where the production occurs (i.e., the US fish-producing industry). The non-fish producing industries in United States, which provide inputs to the fish-producing industry, account for 32.7% of the GVC income. Non-fish producing industries outside the United States generate 7.9% of total GVC income during the process of producing intermediate inputs (non-fish commodities) directly and indirectly used in US fish production. Spain, Norway, and Korea are the three countries whose fish producing activity makes the largest contribution to value added in foreign countries in 2000. 14.5%, 12.9%, and 11.3%, respectively, of their GVC income are engendered in foreign countries (column 11).

The FVA share for 6 of the 10 countries increases over the period (columns 11 and 12 in Table 2 and Figure A.7), which means that the corresponding DVA share decreases by the same percentage (column 8 and 9 in Table 2 and Figure A.6). This suggests that the dependence of these six countries on inputs sourced from foreign countries increases over the period. This is consistent with the finding in Table 1 (Column 7) and Figure A.2 that the global output multipliers for these six countries increase during the period, and that in 2014, the global multipliers for five of these six countries are larger than two while in 2000 only 1 of the 10 countries has the global multiplier that exceeds two (China). It is notable that Mexico, Japan, and

Korea are the three countries whose FVA share increases by the largest percentage (9.3%, 9.0%, and 7.2% respectively, Column 13 in Table 2).

This finding is in line with the findings from previous GVC studies which generally report that FVA shares generally increase over time, indicating that global fragmentation of their production intensifies over time. For example, Los et al. (2015) reports that the top three product groups that experience the largest increases in FVA shares over the period from 1995 to 2008 are petroleum products (20.8%), basic and fabricated products (12.5%), and electronic products (10.8%).

The share of GVC income generated within the fish-producing industry (VAS_{ir} in Equation (4)) in 2000 varies widely from 59.1% (Japan) to 95.9% (India) indicating significant differences in the production functions of the industry across countries (Table 2, column 2, Figure A.4). The highest GVC income share for India's fish-producing industry (95.9%) suggests that the industry's expenditures on intermediate inputs are a very small fraction of its total revenue, and that the industry relies heavily on primary factors of production (especially labor).[4] This finding accords with the result that the country's fish-producing industry has very low multipliers (Table 1) and with the extremely large ratio of value added to output (Figure 2). Compared to other countries, Japan has the smallest value-added share (59.1%) accruing to the industry. Results indicate that domestic non-fish production share ($TVAS_r$) for this country (34.9%, column 5, Table 2) comprises a large portion of the remainder (100% - 59.1% = 40.9%) with its FVA share being only 6%. This suggests that fish production in Japan in 2000 relies

[4] WIOD indicates that the share of total revenue from fish production in India accounted for by value added is extremely high; the share is 0.95 in 2000 and 0.98 in 2014 (Figure 2). This is not surprising because India's fish producing industry is very labor-intensive, overhead and fixed capital costs are marginal, and intermediate inputs are generally cheap (Sharma and Ye 2020, Personal communications, FAO).

much more on domestic inputs than on foreign inputs. Spain has the largest FVA share (14.5%) in 2000.

The fish-producing industry's share of GVC income for five countries decreases rather significantly during the period (columns 2, 3, and 4 in Table 2, Figure A.4). The largest decrease is observed for Mexico (17.9%) and Spain (15.5%). Over half of the decrease for Mexico is absorbed in foreign value added (9.3%, column 13) as the country increases reliance on foreign inputs whereas the remainder (8.6%) is absorbed in non-fish producing industries within the country (column 7). Compared to Mexico, the decrease in the fish-producing industry's GVC income share for Spain is absorbed mostly in non-fish producing domestic industries without changing its foreign value share significantly. The drastic decrease in the fish-producing industry's share of GVC income for these two countries (Mexico and Spain) may be related to the fact that the value-added coefficients (Figure 2) for these countries decline significantly during the period.

In stark contrast, the industry's GVC income share for the United States increases significantly by 14.8% (Column 4 in Table 2 and Figure A.4). Most of the increase occurs at the cost of a reduction in the share of non-fish producing industries within the country (13.2%, Column 7 in Table 2 and Figure A.5). As mentioned above, the dramatic decrease (13.2%) in its dependence on inputs from other domestic industries may be related to the efficiencies gained through the introduction of several catch share programs in the country. Total domestic GVC income share in 2000 ranges from 85.5% (Spain) to 99.0% (India) (Table 2, column 8).

4.3 Decomposing GVC employment

I also decompose the GVC employment generated due to fish production in the countries depending on which country and industry the employment occurs (Table 3 and Figures A.8-A11). Norway has the lowest GVC employment share in 2000 attributed to its fish-producing industry (39.7%, column 2, Table 3); only 39.7% of total GVC employment supported by the final demand for fish produced in Norway is within the industry of the country. This may be related to the finding above that the industry's GVC income share (59.9%, Table 2) for the same year is very low due to the fact that the country's fish production relies heavily on both domestic-sourced (27.2%) and foreign-sourced (12.9%) intermediate inputs (Table 2).

The employment share for all the other industries combined for Norway is 28.9% (Table 3), meaning that 28.9% of the GVC employment is used to produce intermediate inputs in the country that are used directly and indirectly for fish production in the country. India has the highest GVC employment share for the industry in 2000 (99.1%) with all of the remainder (0.9%) in the other industries of the country. Again this suggests that the fish-producing industry in the country is very labor-intensive as shown in Figure 3 that illustrates that country has the highest employment coefficients (i.e., the ratio of employment to output) in 2000. It is also possible that the industry uses a very small amount of intermediate inputs, and that the prices the intermediate inputs are very low. Results for the country are consistent with the finding above that the country's GVC income share for the industry is also the highest (95.9%, Table 2).

In 2000, compared to other countries, US fish-producing industry has the strongest capability of generating employment in foreign countries. A very large share (36.3%, Table 3) of the GVC employment generated due to US fish production occurs in foreign countries. This portion of employment is in the industries in the foreign countries that produce and supply inputs directly or indirectly to the US fish-producing industry. The next two countries that generate the largest foreign employment (per unit of final demand for fish) in 2000 are Norway and Korea. The foreign employment shares for these two countries (Norway and Korea) are 31.4% and 28.9%, respectively, in the year.

Over the period, six countries experience a decrease in the fishing industry's employment share (column 4 in Table 3 and Figure A.8). The largest decrease in the share is reported for Norway (13.7%), followed by Spain (11.3%). For the former (Norway), the employment share of all the other domestic industries combined also declines by 2.8% (see also Figure A.9) with the total decline in the domestic share amounting to 16.5% (See also Figure A.10). This means that, during the period, the foreign share of the employment for the country increases by the same percentage (i.e., 16.5%, See also Figure A.11). The United States saw the largest increase in the industry's employment share (24.9%). With the other industries' share declining by 6.3%, the net increase in the total domestic employment share for the country is 18.6%, which means that the foreign share decreases by the same percentage. This result is consistent with the finding above for the United States that the industry's GVC income share, the share of other industries' GVC income, and the FVA share change in the same direction as the industry's GVC employment, the share of other industries' GVC employment, and the foreign employment share, respectively (Table 2). One conspicuous difference between the change in FVA share in GVC income and the change in foreign employment share in GVC employment for the United States is that the latter declines dramatically (by 18.6%, Table 3) while the former decreases only slightly (by 1.6%, Table 2).

Domestic employment share ranges from 63.7% (US) to 100% (India) in 2000. As shown in Table 3, over the period, the domestic share does not change significantly for most countries except Norway and the United States (See also Figure A.10). The drastic change in the total domestic employment share for these two countries is driven mostly by the significant change in its industry share.

4.4 Revealed comparative advantage

When measured in exports of raw fish (Figure 4 and Figure A.12), Norway is the country whose fish-producing industry is the most competitive with its highest TRCA value, compared to other countries, in 2000. The country's TRCA value in the year is 9.52 which means that the fraction of the country's total exports accounted for by its raw fish exports is over nine times larger than its global average. The next two countries that have the highest TRCA are India (4.96) and Indonesia (2.93). Results indicate that, when measured in exports, the raw fish producing industry in these countries is a very important industry, compared to other countries. Some countries (Mexico and US) have very low TRCA values in 2000. During the 2000 – 2014 period, the competitiveness decreases for most countries (except Mexico, Norway, and the United States; Figure 4 and Figure A.12). It is notable that the competitiveness of Norway's raw fish-producing industry increases rather significantly.

When the competitiveness of fish production is measured in terms of GVC income (VRCA; Figure 5 and Figure A.13), significantly different results are obtained. In 2000, three countries (China, Indonesia, and India) have higher VRCA values than Norway which has the highest TRCA value (Figure 4). In that year, China's VRCA value is the largest (6.91), meaning that the fraction of China's total GVC income (i.e., the GVC income from global production of *all* types of commodities) accounted for by the global production of raw fish is almost seven (6.91) times larger than the global average. Note that China's GVC income is generated during the process of global production of raw fish, and includes not only the GVC income from raw fish production in the country but also the GVC income that is generated within the country due to the country's production of intermediate inputs that are supplied (i) to the fish-producing industry within the country, (ii) to the fish-producing industry in other countries and (iii) to non-fish producing industries in these other countries that sell intermediate inputs to the their fish-producing industry.

The next two countries that have the largest VRCA values in 2000 are Indonesia (6.22) and India (4.48). Results in Figures 4 and 5 indicate that the country whose fish-producing industry is the most competitive under TRCA is not necessarily be the country which is the most competitive in generating GVC income from global fish production under VRCA. Over the period, the competitiveness of six countries in engendering GVC income from global fish production declines when measured by VRCA, as shown by the lower values VRCA in 2014 than in 2000 (Figure 5 and Figure A.13). Notably, China's competitiveness decreases significantly; its VRCA value decreases from 6.91 to 2.38 during the period. Among the four countries whose VRCA increases, Norway experiences the largest increase (from 1.36 to 2.66). The remarkable differences in the two measures (TRCA and VCRA) reflect the variations in the countries' dependence on domestic versus foreign-sourced intermediates and the differences in the production functions of the industry.

5. Conclusion and summary of findings

International trade nowadays is characterized by a strong fragmentation of production. Further, firms in a country use increasingly larger share of foreign-sourced inputs in their production. Yet, economic contribution of an industry is often evaluated using output multipliers from single-country IO models. Moreover, conventional methods quantify the competitiveness of an industry based on the assumption that all the activities for production of a final product occurs within a country using only the inputs produced within the country. This is not a valid assumption. Previous studies (e.g., Johnson and Noguera 2012; Wang et al. 2013; Timmer et al. 2013; Koopman et al. 2014; and Los et al. 2015) address this issue by decomposing the total value of exports or final demand into different value-added components depending on where (in which industry and in which country) the global value added is generated.

None of the previous studies implement GVC income decomposition for fish production. The present study fills this void by decomposing the GVC income and employment from fish production for selected countries. This study elucidates the importance of adopting a GVC income perspective, indicating the limitations of (i) output multipliers from single-country IO models, when assessing the contribution of fish producing industry and (ii) export-based RCA measure when evaluating the industry's competitiveness. Fishery (and aquaculture) managers for a country may make decisions using only the indicators constructed based on the revenue from fish production, the output multipliers from single-country IO models, or the magnitude of fish exports. This study clearly indicates that these indicators fail if the fish-producing industry uses a large share of inputs from abroad.

Major findings are as follows. First, the foreign value-added share from fish production for 6 of the 10 countries increases over the period (2000-2014), suggesting that their dependence on foreign-sourced inputs increases over the period. For five of the six countries (Japan, Korea, Mexico, Norway, and Spain), the higher foreign value-added shares in 2014 are driven mostly by lower value-added shares for their fish producing industry. For these countries, the difference between global and domestic output multipliers becomes significantly larger in 2014 than in

2000 (except Spain). In contrast, for four countries (China, Indonesia, India, and the United States), the fish-producing industry's dependence on foreign-sourced inputs decreases over the period.

Second, India has the highest share of GVC income attributed to its fish-producing industry in both 2000 and 2014, suggesting that the industry in this country is very labor intensive, and that the share of total revenue from fish production spent on intermediate inputs is very small probably due to their low prices. The industry's share of GVC income for five countries (especially Mexico and Spain) decreases rather significantly during the period. In stark contrast, the industry's GVC income share for the United States increases significantly.

Third, in 2000, compared to other countries, US fish-producing industry has the strongest capability of generating employment in foreign countries. A very large share of the GVC employment from US fish production is created in foreign countries. The next two countries that generate the largest foreign employment (per unit of final demand for fish) in the same year are Norway and Korea.

Fourth, when measured in exports of raw fish, Norway's fish-producing industry is the most competitive throughout the period 2000 - 2014. However, when the competitiveness is gauged in terms of GVC income (VRCA), significantly different results are obtained. During most of the period, three countries (China, Indonesia, and India) are more competitive than Norway under VRCA.

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Table 1 Multipliers

	2000			2014			Change (2014-2000)		Change in difference between global and domestic multipliers
(1)	Domestic (2)	Global (3)	Global – Domestic (4) = (3)-(2)	Domestic (5)	Global (6)	Global – Domestic (7) = (6)-(5)	Domestic (8) = (5)-(2)	Global (9) = (6)-(3)	(10) = (7)-(4)
Brazil	1.35	1.42	0.07	1.35	1.44	0.09	0.00	0.02	0.02
China	1.97	2.09	0.12	2.01	2.11	0.1	0.04	0.02	-0.02
Indonesia	1.29	1.43	0.14	1.20	1.29	0.09	-0.09	-0.14	-0.05
India	1.08	1.10	0.02	1.03	1.05	0.02	-0.05	-0.05	0.00
Japan	1.77	1.89	0.12	1.74	2.11	0.37	-0.03	0.22	0.25
Korea	1.52	1.75	0.23	1.71	2.17	0.46	0.19	0.42	0.23
Mexico	1.55	1.7	0.15	1.76	2.15	0.39	0.21	0.45	0.24
Norway	1.69	1.98	0.29	1.69	2.11	0.42	0.00	0.13	0.13
Spain	1.53	1.85	0.32	1.88	2.25	0.37	0.35	0.40	0.05
US	1.65	1.81	0.16	1.39	1.55	0.16	-0.26	-0.26	0.00

Table 2 Value added distribution (%)

	Domestic						Domestic total (DVA)			Foreign (FVA)		
	Fish-producing industry (VAS)			Other industries (TVAS)								
(1)	2000 (2)	2014 (3)	change (4) =(3)-(2)	2000 (5)	2014 (6)	change (7) =(6)-(5)	2000 (8) =(2)+(5)	2014 (9) =(3)+(6)	change (10) =(9)-(8)	2000 (11)	2014 (12)	change (13) =(12)-(11)
Brazil	78.9	79.2	0.3	17.3	16.9	-0.4	96.2	96.1	-0.1	3.8	3.9	0.1
China	60.7	61.6	0.9	34	34.3	0.3	94.7	95.9	1.2	5.3	4.1	-1.2
Indonesia	78.9	86.5	7.6	14.9	10.3	-4.6	93.8	96.8	3.0	6.2	3.2	-3.0
India	95.9	98.2	2.3	3.1	1.2	-1.9	99	99.4	0.4	1.0	0.6	-0.4
Japan	59.1	53.7	-5.4	34.9	31.3	-3.6	94	85	-9.0	6.0	15.0	9.0
Korea	67.5	57.1	-10.4	21.2	24.4	3.2	88.7	81.5	-7.2	11.3	18.5	7.2
Mexico	63.7	45.8	-17.9	29.6	38.2	8.6	93.3	84	-9.3	6.7	16.0	9.3
Norway	59.9	54.7	-5.2	27.2	28.1	0.9	87.1	82.8	-4.3	12.9	17.2	4.3
Spain	62.2	46.9	-15.3	23.3	37.7	14.4	85.5	84.6	-0.9	14.5	15.4	0.9
US	59.4	74.2	14.8	32.7	19.5	-13.2	92.1	93.7	1.6	7.9	6.3	-1.6

Note: For 2000, domestic (column 8) and foreign (column 11) shares add up to 100%. Similarly, for 2014, the two shares (column 9 and column 12) add up to 100%.

Table 3 Employment distribution

	Domestic						Domestic total			Foreign		
	Fish producing industry			Other industries								
(1)	2000 (2)	2014 (3)	change (4) =(3)-(2)	2000 (5)	2014 (6)	change (7) =(6)-(5)	2000 (8) =(2)+(5)	2014 (9) =(3)+(6)	change (10) =(9)-(8)	2000 (11)	2014 (12)	change (13) =(12)-(11)
Brazil	90.7	86.9	-3.8	8.4	11.4	3.0	99.1	98.3	-0.8	0.9	1.7	0.8
China	82.9	78.0	-4.9	16.8	21.0	4.2	99.7	99.0	-0.7	0.3	1.0	0.7
Indonesia	91.9	94.2	2.3	7.6	5.5	-2.1	99.5	99.7	0.2	0.5	0.3	-0.2
India	99.1	99.6	0.5	0.9	0.4	-0.5	100.0	100.0	0.0	0.0	0.0	0.0
Japan	66.4	64.8	-1.6	16.5	17.9	1.4	82.9	82.7	-0.2	17.1	17.3	0.2
Korea	48.4	44.1	-4.3	22.7	25.9	3.2	71.1	70.0	-1.1	28.9	30.0	1.1
Mexico	84.0	89.8	5.8	13.6	8.1	-5.5	97.6	97.9	0.3	2.4	2.1	-0.3
Norway	39.7	26.0	-13.7	28.9	26.1	-2.8	68.6	52.1	-16.5	31.4	47.9	16.5
Spain	67.4	56.1	-11.3	16.1	24.6	8.5	83.5	80.7	-2.8	16.5	19.3	2.8
US	47.6	72.5	24.9	16.1	9.8	-6.3	63.7	82.3	18.6	36.3	17.7	-18.6

Note: For 2000, domestic (column 8) and foreign (column 11) shares add up to 100%. Similarly, for 2014, the two shares (column 9 and column 12) add up to 100%.

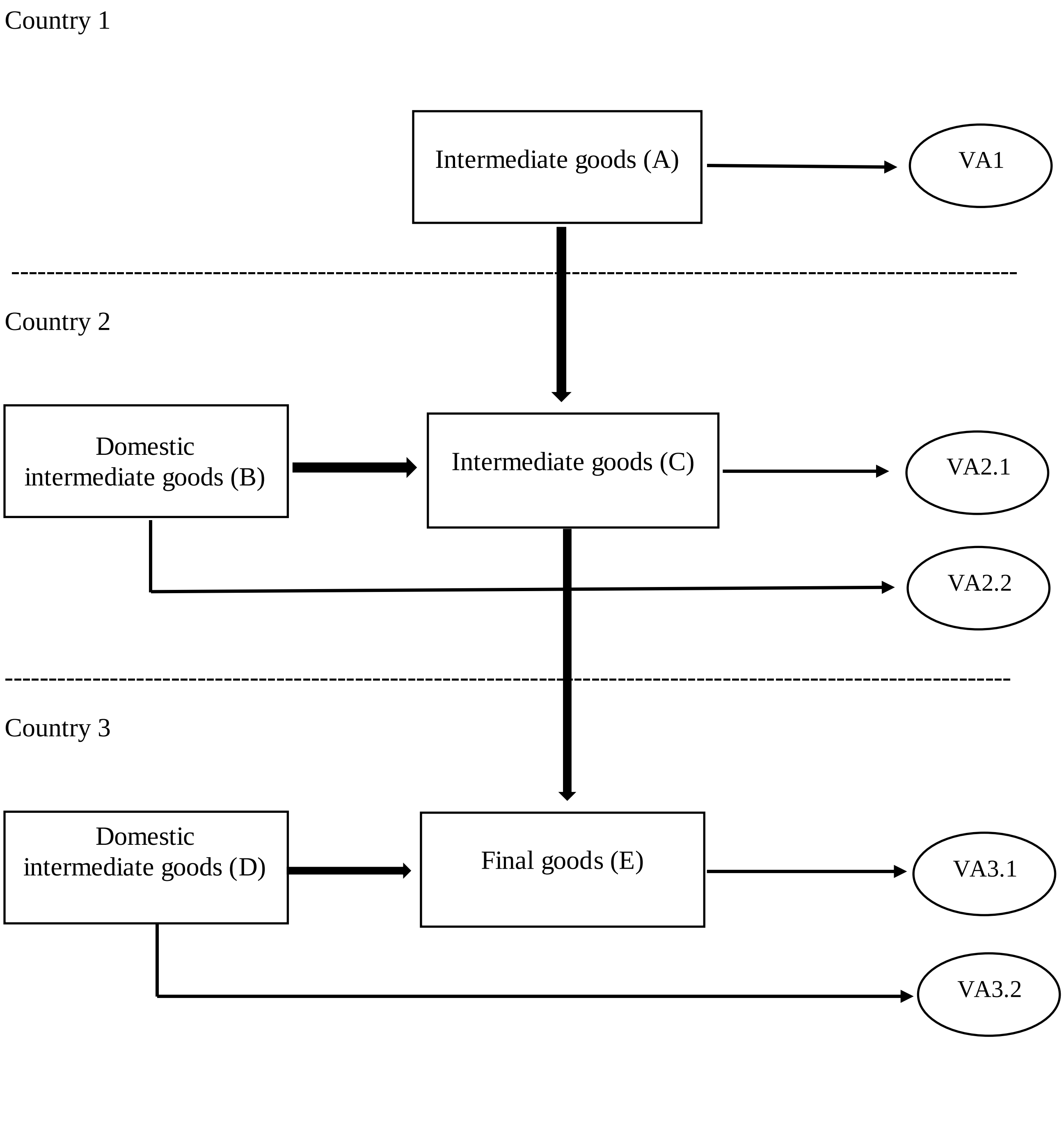

Figure 1 Simplified schematic representation of value added generation along GVC (adapted from Los et al. 2015)

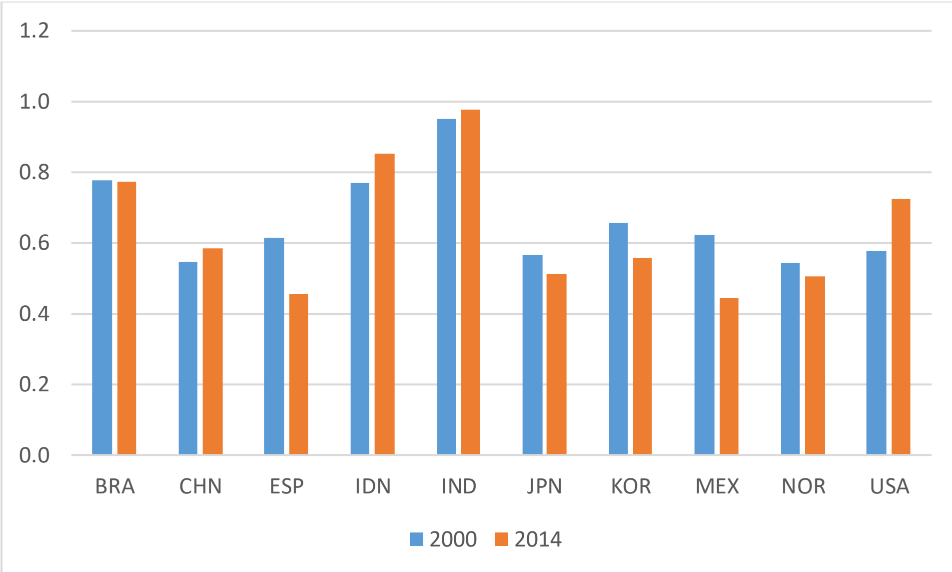

Figure 2 Value-added coefficients of fish-producing industry

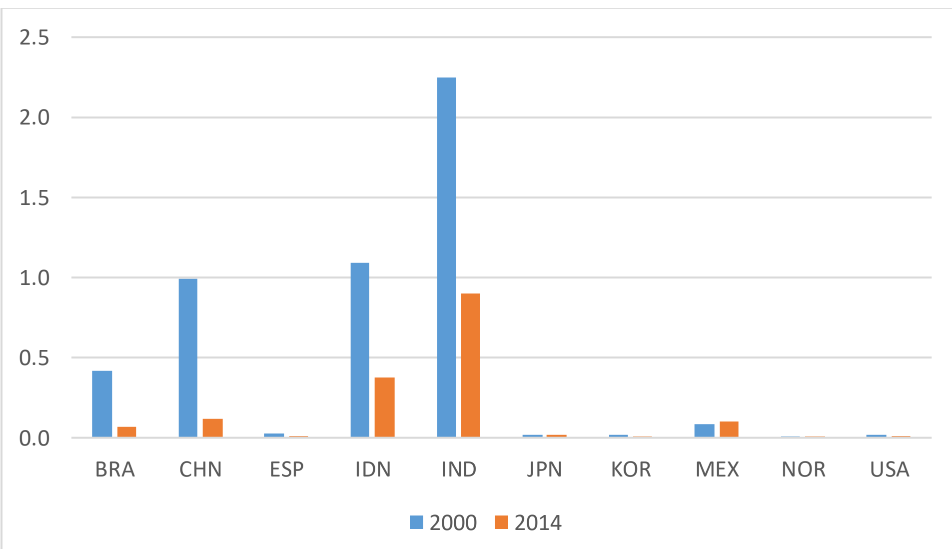

Figure 3 Employment coefficients of fish-producing industry

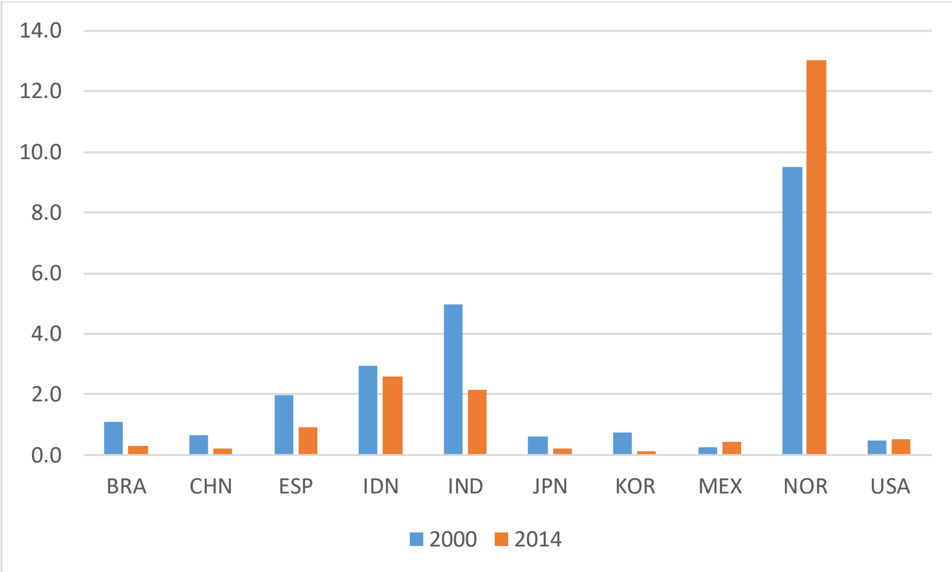

Figure 4 Export-based RCA

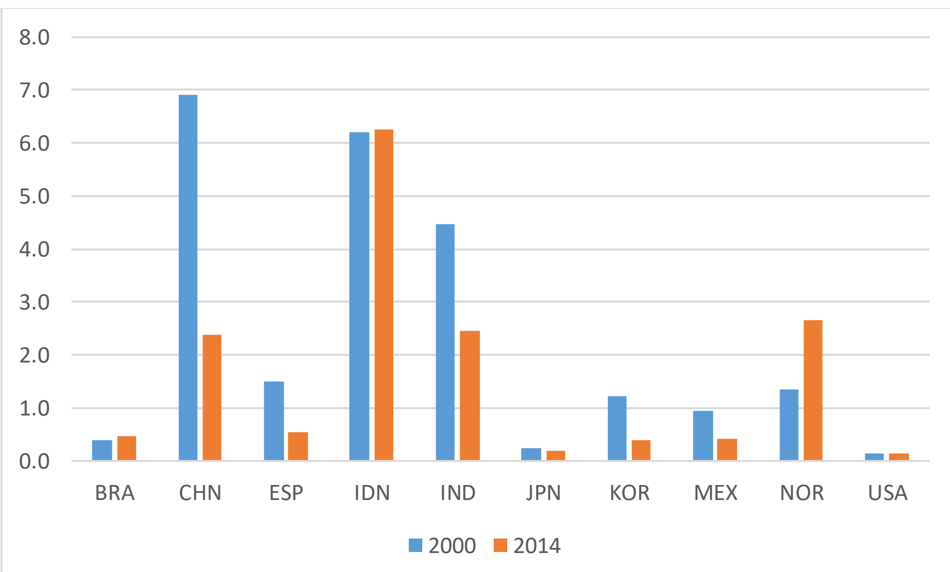

Figure 5 GVC income-based RCA

Appendix

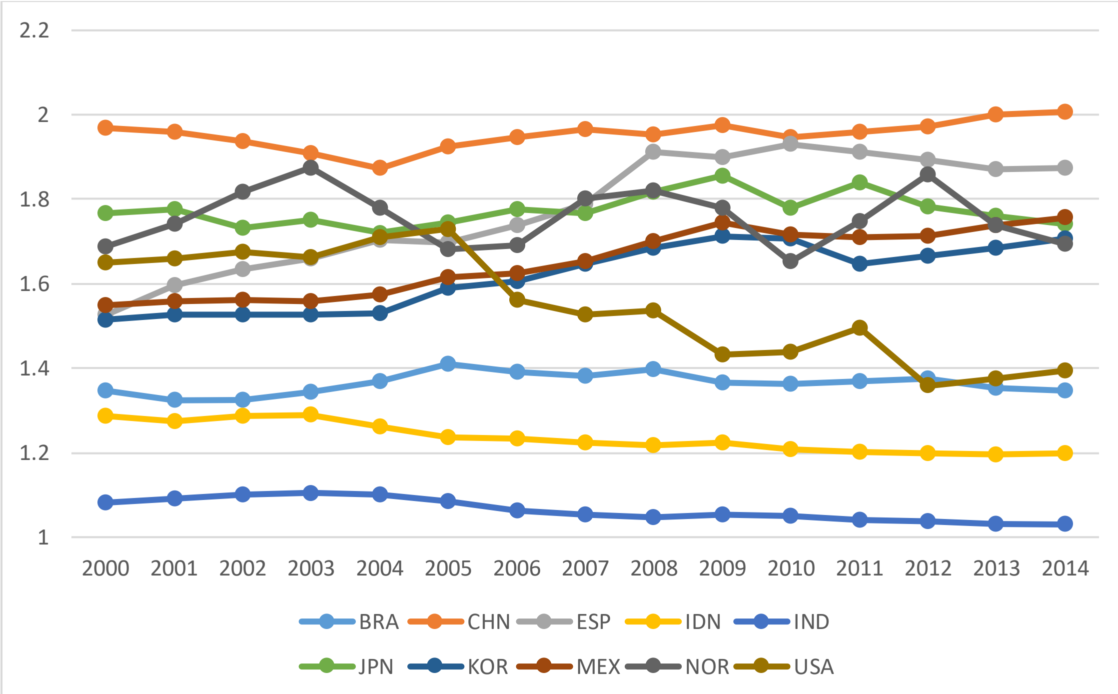

Figure A.1 Domestic multiplier

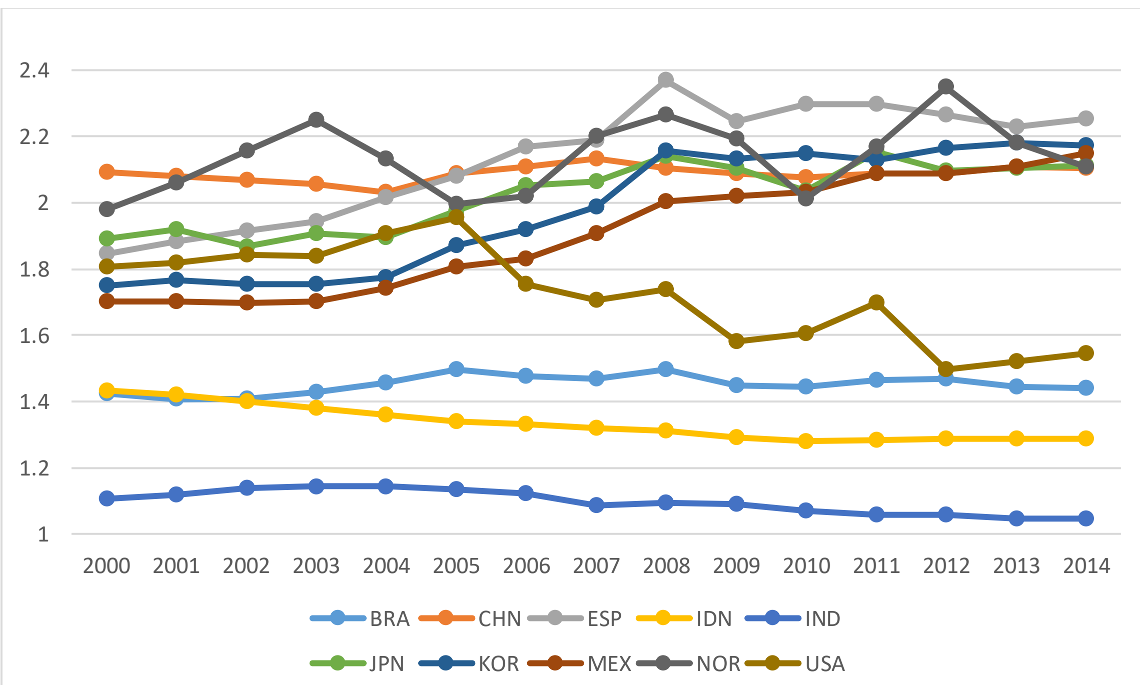

Figure A.2 Global multiplier

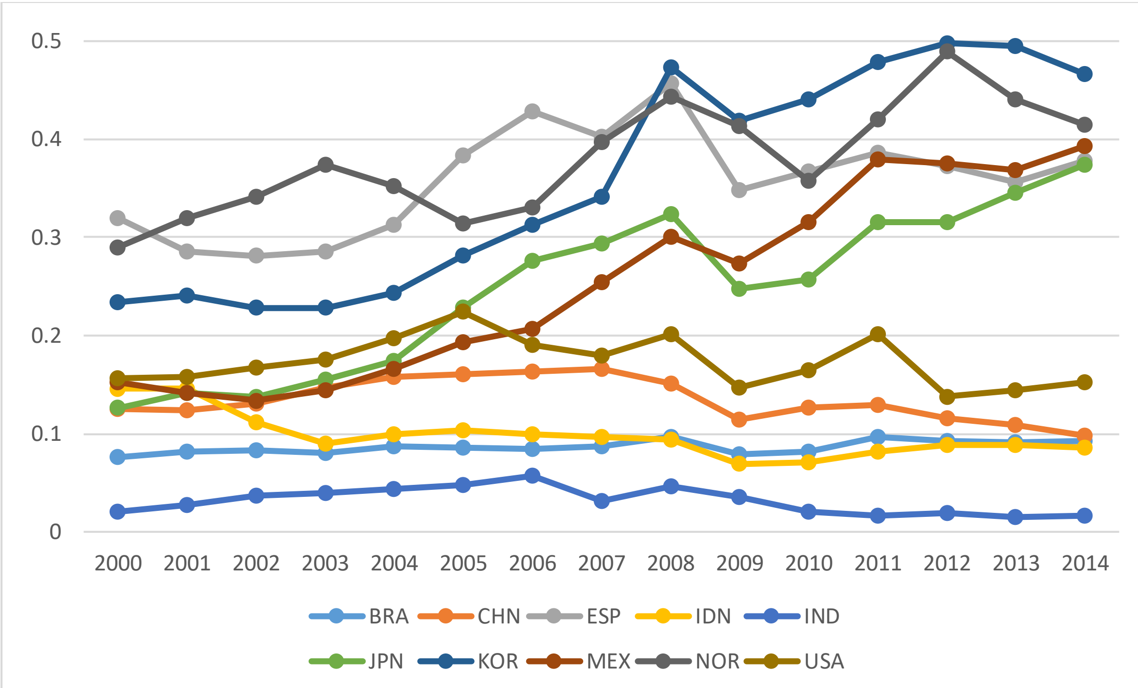

Figure A.3 Difference between global and domestic multipliers

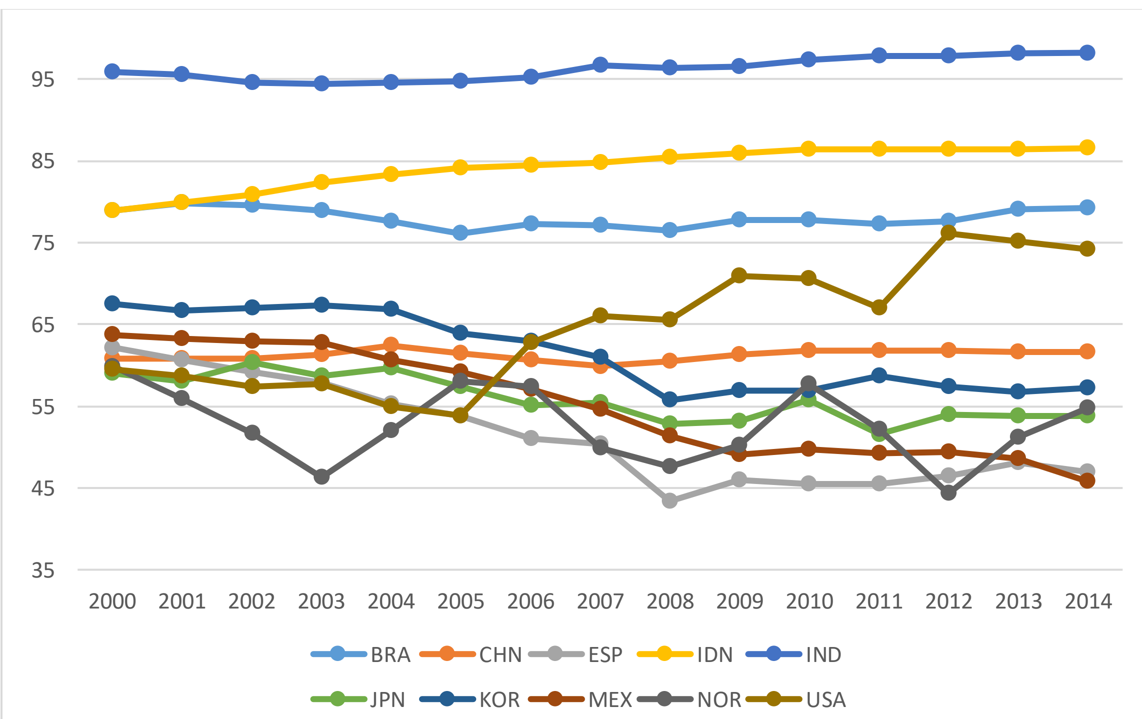

Figure A.4 Share of value-added for fish-producing industry (%)

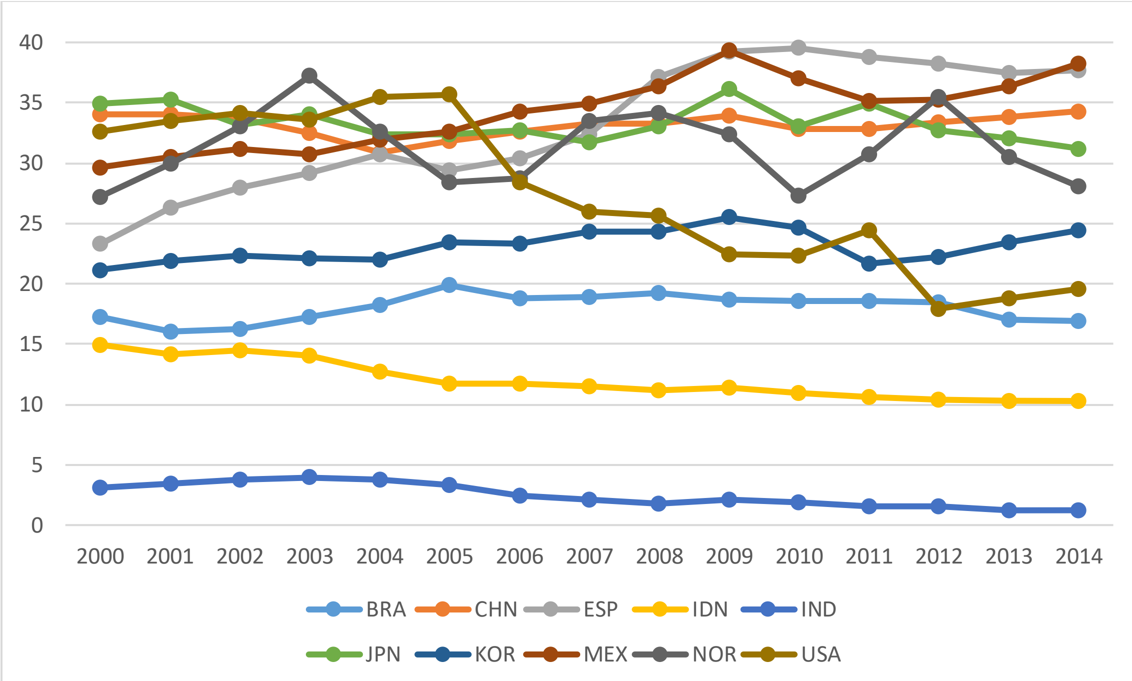

Figure A.5 Share of value-added for all the other industries combined (%)

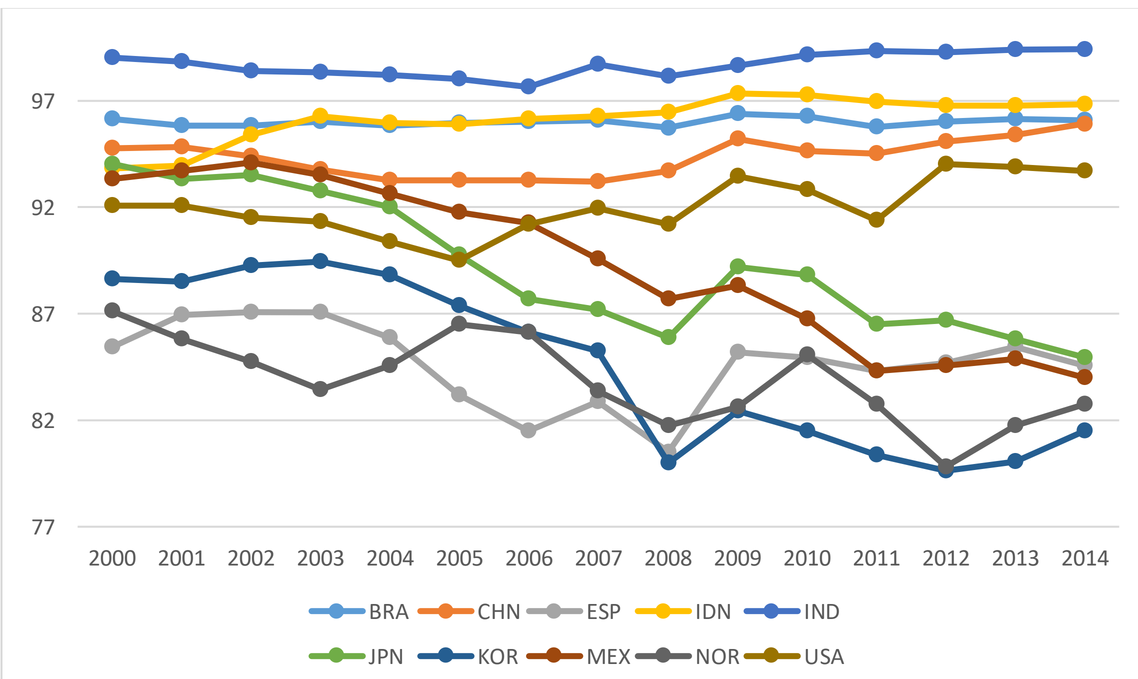

Figure A.6 Share of domestic value added (%)

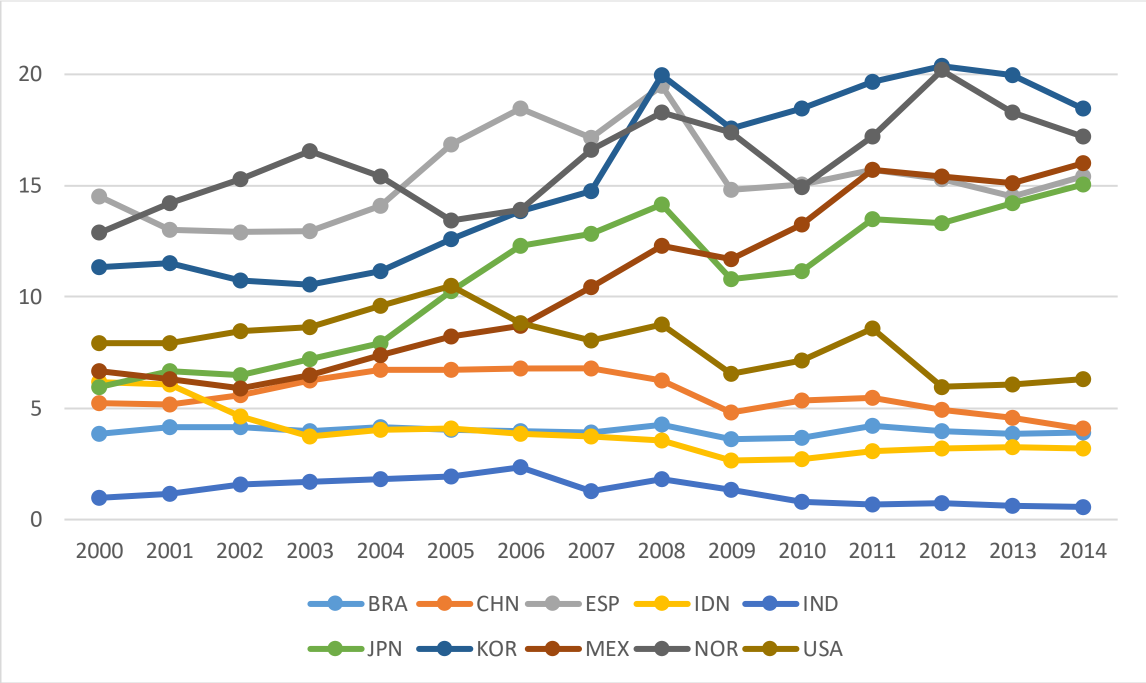

Figure A.7 Share of foreign value added (%)

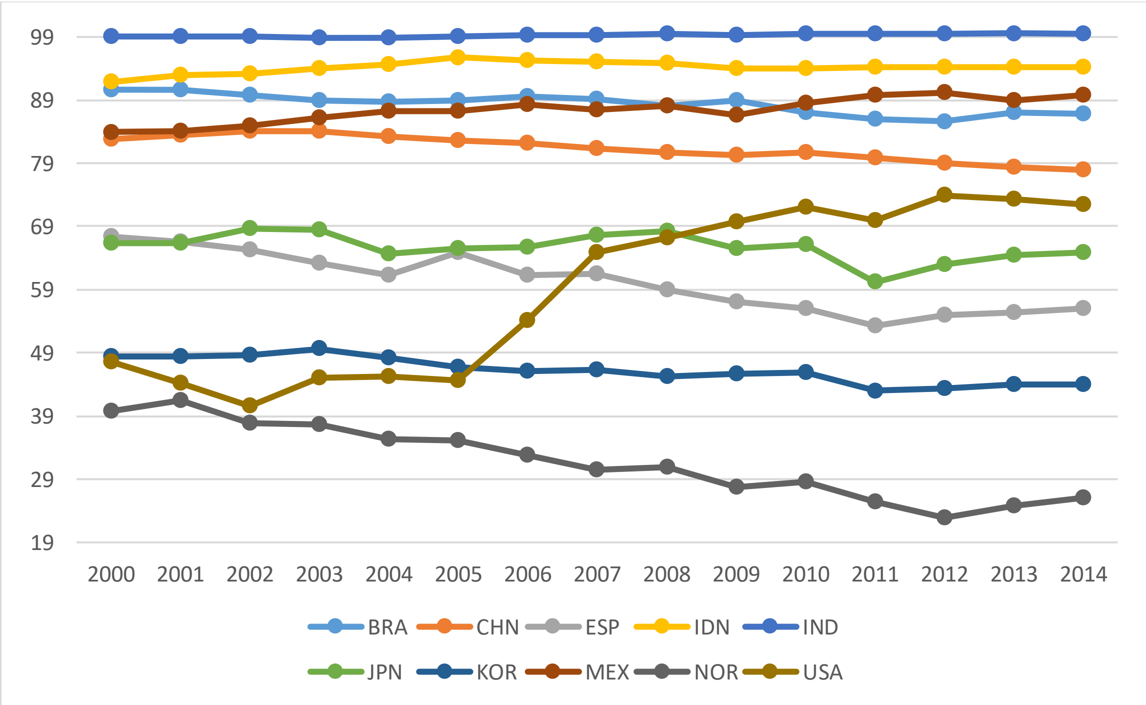

Figure A.8 Share of employment for fish-producing industry (%)

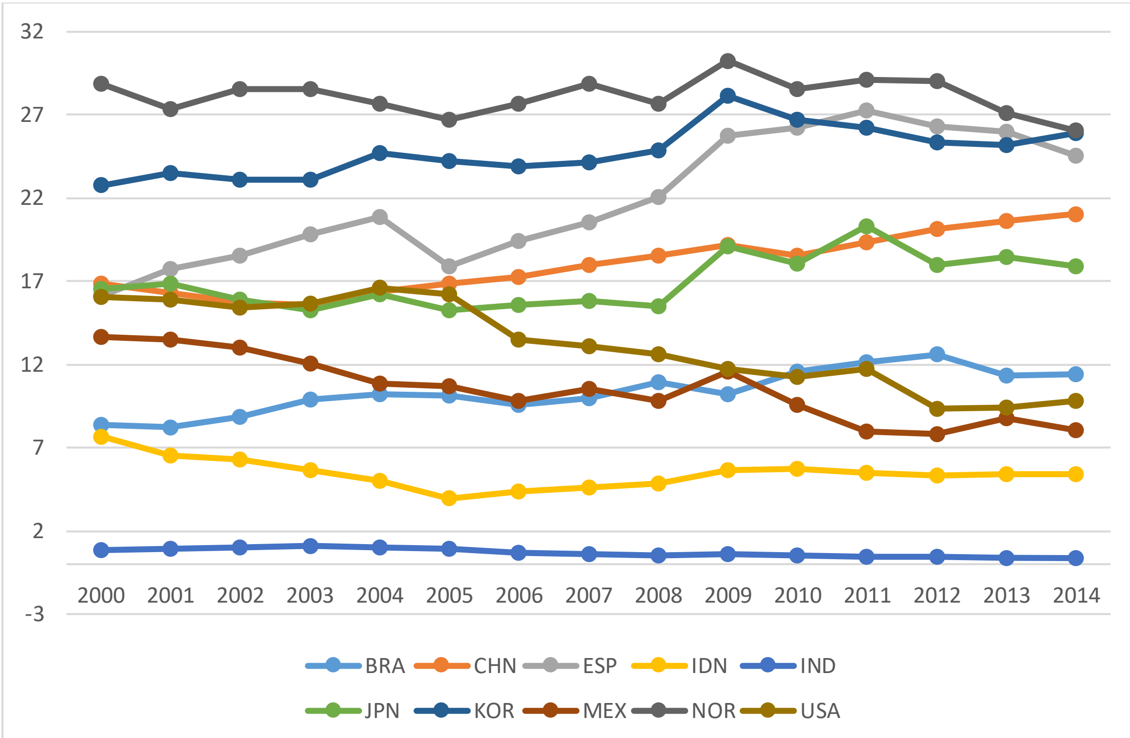

Figure A.9 Share of employment for all the other industries combined (%)

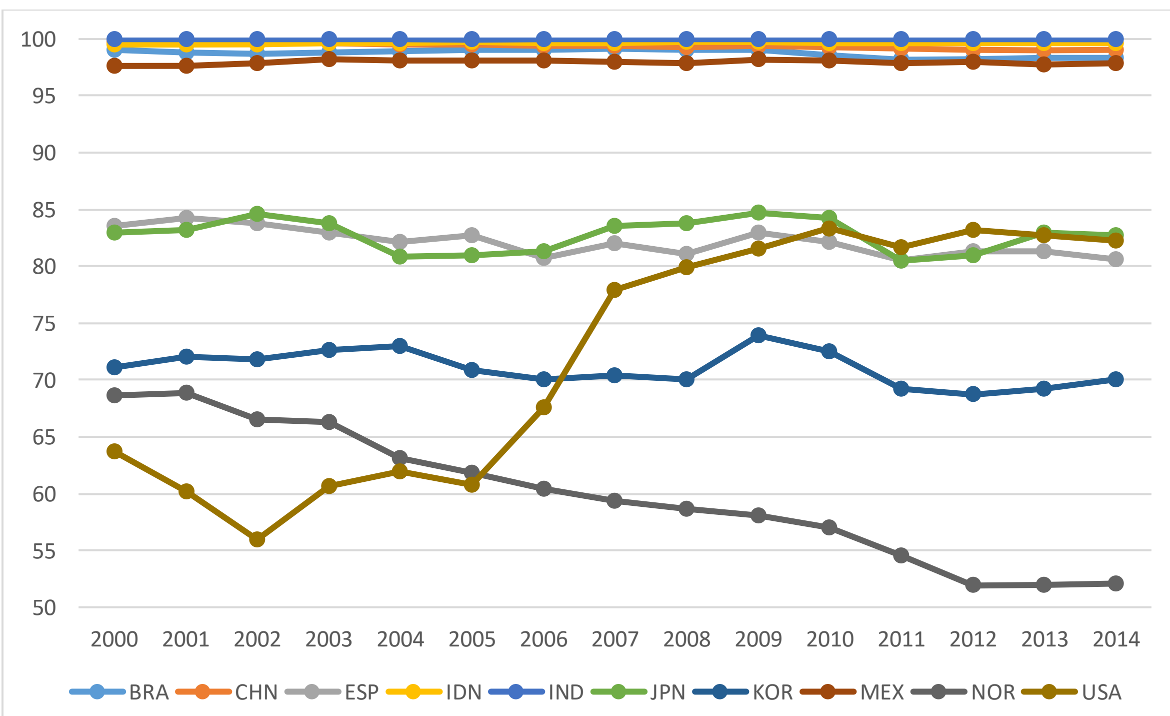

Figure A.10 Share of domestic employment (%)

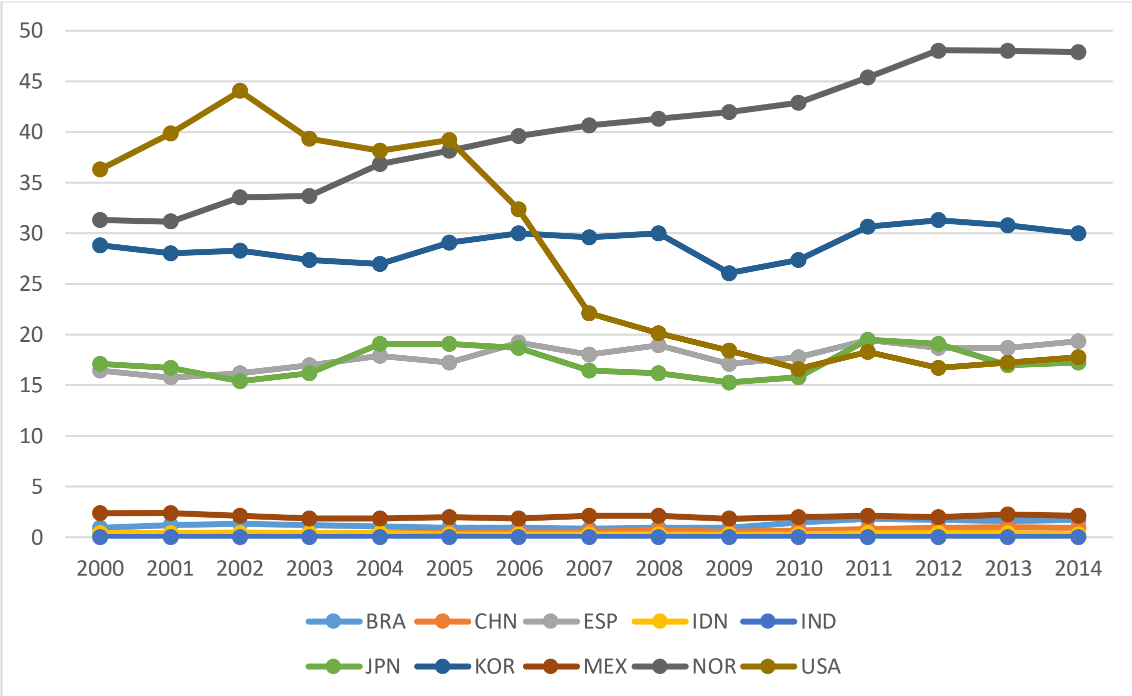

Figure A.11 Share of foreign employment (%)

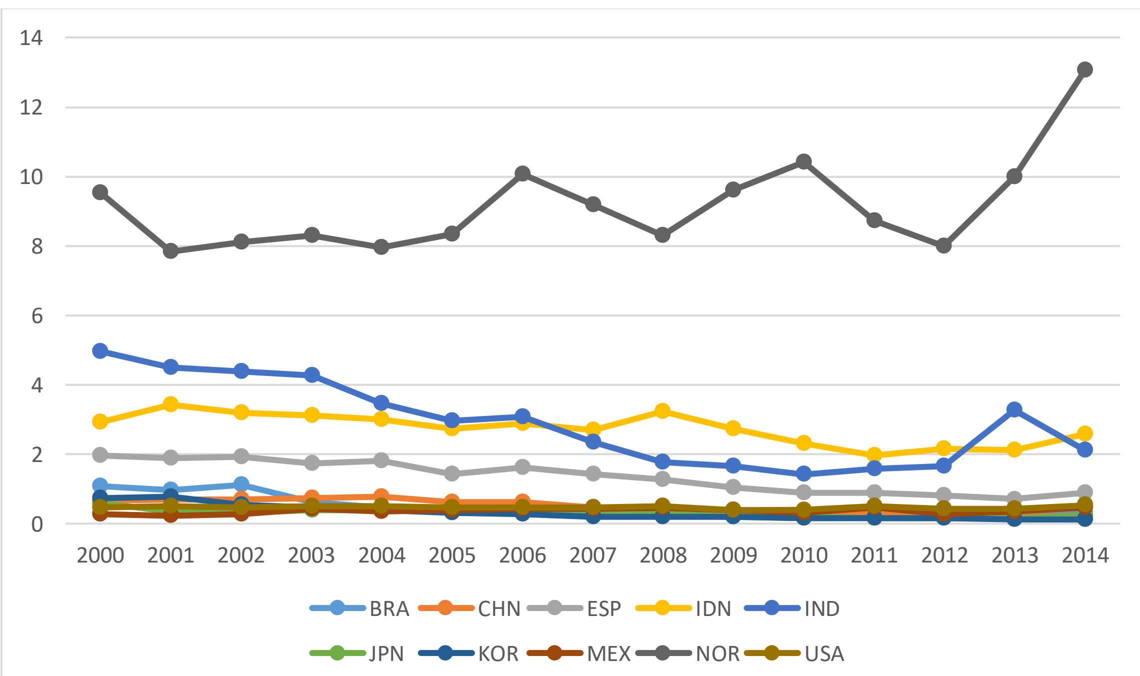

Figure A.12 Export-based RCA (TRCA)

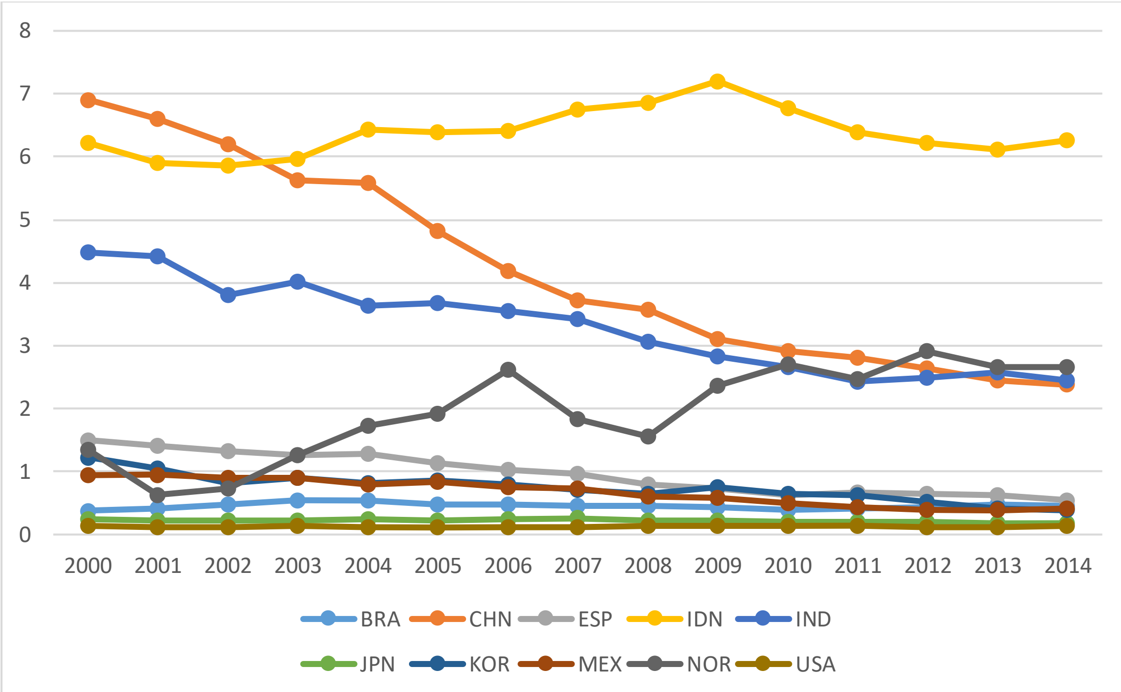

Figure A.13 GVC income-based RCA (VRCA)