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Participation and Vertical Specialization in Iran's Economic Activities

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ABSTRACT

The purpose of this paper is to analyze Iran's role in the global value chain (GVC) using data from the 2016 Inter-country Input-Output (ICIO) tables. By examining Iran's forward and backward GVC participation indicators, the study aims to provide insights into the country's level of integration within international production networks. This paper adopts a Borin and Mancini (2023) approach, utilizing the ICIO tables to calculate Iran's forward and backward GVC participation indicators. These indicators serve as proxies for assessing Iran's involvement in producing inputs for re-export and using imported inputs for export-oriented production, respectively. The methodology involves rigorous data analysis and interpretation to derive meaningful insights. The findings of this study reveal that Iran plays a negligible role in the global value chain. Both forward and backward GVC participation indicators indicate limited integration with international production networks. This suggests a relatively isolated position for Iran in terms of GVC activities, highlighting potential challenges and opportunities for the country's economic development. This paper contributes to the literature by providing a comprehensive analysis of Iran's position in the global value chain using the latest available data. By focusing on forward and backward GVC participation indicators, the study offers novel insights into Iran's level of integration within international production networks. The findings have implications for policymakers, researchers, and practitioners interested in understanding Iran's economic dynamics and identifying strategies for enhancing its participation in the global economy.

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1. Introduction

International production, trade and investments are increasingly organised within so-called global value chains (GVCs) where the different stages of the production process are located across different countries. Globalisation motivates companies to restructure their operations internationally through outsourcing and offshoring of activities. One of the most significant changes in the nature of international trade in the past two decades is the division of the production chain with various stages of production in different countries. Companies utilize manufacturing facilities in different countries to take advantage of powerful locational benefits such as proximity to markets and access to relatively cheap production factors. This international production is accompanied by an increase in the trade of components and parts, while countries are vertically connected – meaning that international production compels countries to specialize in specific stages of goods production. In this case, a "sequential production mode" emerges, where a country imports a good from another country, uses that good as an input in its own production, and then exports its final product to the next country. The time sequence concludes when the final product reaches its ultimate destination. Researchers use the term "vertical specialization" to describe this production method. The goods and services we buy are composed of inputs from various countries around the world. However, the flows of goods and services within these global production chains are not always reflected in conventional measures of international trade. The joint OECD – WTO Trade in Value-Added (TiVA) indicators are designed to better inform policy makers by providing new insights into the commercial relations between nations. Global value chains have become a dominant feature of world trade, encompassing developing, emerging, and developed economies. The whole process of producing goods, from raw materials to finished products, is increasingly carried out wherever the necessary skills and materials are available at competitive cost and quality. In the past, simple indicators (such as market share, geographic composition of imports and exports, bilateral

trade balance, sectoral specialization indices, etc.) could provide a satisfactory picture of a country's role in international markets and its evolution over time. With the increasing fragmentation of production, these indicators have become insufficient. Hummels, Ishii, and Yi in 2001, introduced the measure of "vertical specialization" (VS) as one of the first and most popular indicators of a country's participation in the stages of the global production chain. However, as they pointed out, this is a partial measure of participation in global value chains as it only considers downstream links. They also suggest considering the exports of intermediate products that are later processed and re-exported as the VS1 measure, which has been further pursued and introduced by other researchers, including Borin and Mancini (2023). This paper focuses on the measures introduced by Borin and Mancini (2023). To implement this method in the Iranian economy, the Inter-Country Input-Output table for the year 2016, which includes Iran and is supported by the Chamber of Commerce, Industries, Mines, and Agriculture of Iran, is used. For this purpose, the paper is organized as follows: first, a review of the literature on the subject is provided. Then, the study's model and methodology are outlined, followed by the presentation of data and empirical results, and finally, a summary is provided.

2. Theoretical literature and research background

Vertical specialization involves the increasing coherence of production processes in a sequential and vertical trade chain that extends across many countries, with each country specializing in specific stages of the production sequence. Therefore, the production of a final product involves the participation of many economies, with specialists from different countries in various sectors of the vertical production chain. This phenomenon has been extensively studied by trade economists. Vertical specialization, meaning the use of imported inputs in the production of goods that are exported, implies that:

- The production sequence of a good involves at least two countries.
- During this sequence, the good passes through at least two international

borders. This index includes the content of both direct and indirect imported inputs in exports. This means that imported inputs in exports are considered as a single unit without distinguishing between the part that originated outside the country and the part that was originally produced by the country itself, re-imported the country, and then re-exported.

The second measure, proposed by Hummels et al. (2001) and labeled as VS1, focuses on vertical specialization from the export side and measures the value of indirectly exported intermediate exports through third countries to the final destination. While some metrics for GVC participation have been developed, such as the share of imported input in gross output, total inputs, or exports, these metrics do not precisely indicate a country's level of participation in such global chains. This is because they cannot evaluate the extent to which imported intermediates are used in a country's exports compared to domestic production (Aslam et al., 2017). Following the original article by Hummels et al. (2001), various indicators have been proposed to measure a country's integration into international production networks. Using some value-added trade components, Koopman et al. (2010) suggests one of the most widely used indicators for GVC participation in the literature in this field. They measure GVC participation using the Foreign Value Added (FVA) component and the "Domestic Value Added Indirect (DVX)" component, representing the domestic value added in intermediate goods re-exported by partner countries. Specifically, FVA is referred to as a measure of "backward participation," considering the imported intermediate inputs used for standardized exports. DVX indicates the share of domestic sectors in exports to other countries and shows the level of participation in GVCs for relatively upstream industries. In the absence of company-level data that would enable a complete measurement of participation in global value chains (GVCs), significant efforts have been made to combine information from customs offices with nationally focused input-output tables. The most commonly used among them is the World Input-Output Database (WIOD; Timmer et al., 2015), a joint project led by

researchers at the University of Groningen, and its enhanced version developed by the Asian Development Bank (ADB). Also, the Trade in Value Added (TiVA) database compiled by the OECD and the global supply chain database EORA (Lenzen et al., 2013) developed by a team of researchers at the University of Sydney have been used.

Despite limitations, these global input-output databases can be used to measure the globalization of production processes in recent years and how countries and sectors participate in GVCs. They align with several features of GVC linkages, as described by Antràs (2020) under the concept of "broad GVC participation." Some articles in this literature have facilitated the way by conceptualizing and quantifying the shared production and trade in value-added. In particular, Hummels, et al. (2001) claim that the minimum condition for considering trade related to GVC is that it must pass through at least two borders. Based on this literature, Borin and Mancini (2015) demonstrated how trade related to GVC can be calculated using inter-country input-output tables. This can be observed as the sum of two natural measures of cross-border GVC links: forward GVC participation (i.e., producing and exporting inputs that are re-exported) and backward GVC participation (i.e., using imported inputs to produce goods that are exported outside the country). Such concepts are now widely accepted as standards in the literature (see Antràs and Chor, 2021; Belotti, Borin, and Mancini, 2021; Borin and Mancini, 2017, 2019, and 2023; Wang, Wei, and Zhu, 2017).

3. Methodology

The model presented by Borin and Mancini (2023) provides a comprehensive decomposition based on domestic and foreign value added in bilateral exports. In this model, all indicators are based on the standard Input-Output tables between G countries and N sectors. Here, Esr is the N×1 vector of country s exports to country r, Xs is the N×1 vector of gross value added produced by country s, A is the global matrix of input-output coefficients GN×GN, B is the global Leontief inverse matrix for the entire

inter-country model, and Vs is the 1×N vector representing the share of value added embodied in each unit of gross value added produced by country s. Borin and Mancini (2023) suggest separating the value-added components by modifying matrix B in a way that allows the production process to be sliced along the external borders of the exporting country. For operationalizing this approach, it is useful to consider the representation of the global Leontief inverse matrix as the sum of an infinite series of gross value added produced in all upstream stages of the production process. The production process can be divided along the country's external borders by cutting off export connections at each stage of the above series. From a mathematical perspective, the coefficients of matrix A, which directly determine the intermediate inputs from country s, become zero. Then, the corresponding global Leontief inverse matrix is as follows:

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

Specifically, one can observe the following relationship:

$$B_{is} = B_{is}^{\$} + B_{is}^{\$} \sum_{j \neq s}^{G} A_{sj} B_{js} \tag{2}$$

Where i can be either s or another country. The relationship in equation (2) can be used to modify the bilateral version decomposition, allowing the separation of "value-added" and "double-counted" terms in each part. For the internal components, it is noteworthy that $B_{ss}^{\$}$ is called the local Leontief matrix $[\mathrm{I} - \mathrm{A_{ss}}]^{-1}$.

$$u_N E_{sr} = V_s B_{ss}^{\$} E_{sr} + V_s B_{ss}^{\$} \sum_{j \neq s} A_{sj} B_{js} E_{sr} + \sum_{t \neq s}^{G} V_t B_{ts}^{\$} E_{sr} + \sum_{t \neq s}^{G} V_t B_{ts}^{\$} \sum_{j \neq s} A_{sj} B_{js} E_{sr} \tag{3}$$

The above equation reports a source-based bilateral export decomposition based on the main elements identified in Koopman et al. (2014). Double-counted items are measured by isolating a portion of a country's exports to r that has been previously exported by s in the previous stage of the production process. According to Borin and Mancini (2023), with a country-perspective and

source-based approach, the directly absorbed value added in exports, indicating the value added produced in s and directly absorbed by the importing country r without re-export, is presented as follows (i.e., DAVAXsr):

$$DVAX_{sr} = V_s(I - A_{ss})^{-1}Y_{sr} + V_s(I - A_{ss})^{-1}A_{sr}(I - A_{rr})^{-1}\,Y_{rr} \quad (4)$$

DAVAX is a measure of what is fully produced domestically and consumed abroad and the intermediate inputs that are (fully) produced domestically and used by the importing country for the production of final goods for its domestic market. From this perspective, it identifies "traditional" trade versus international shipments made under global value chains (GVC-related trade). In other words, "GVC-related trade" includes all traded items that cross at least two international borders, meaning they are exported at least once before being absorbed in final demand. This can be considered a sufficient condition for a traded good to be part of an international production network. In a bilateral trade flow, "GVC-related trade" can be measured by simply excluding the domestic value directly absorbed by its importer (DAVAXsr) from the gross exports of the country:

$$GVC_{sr} = u_N E_{sr} - DAVAX_{sr} \quad (5)$$

Thus, the GVC share in bilateral exports is

$$GVC_{sr} = \frac{GVCX_{sr}}{u_N E_{sr}} \quad (6)$$

Which can be calculated for the entire exporting country:

$$GVC_s = \frac{\sum_{r \neq s}^{G} GVCX_{sr}}{u_N E_{sr}} \quad (7)$$

The GVC-related trade index proposed above is not the first one based on ICIO tables to measure the connections of GVCs in international shipments. Following the original paper by Hummels et al. (2001), various measures of a country or region's integration into international production networks have been suggested. The "vertical specialization" index by Hummels et al. (2001) is probably one of the earliest and most popular of these measures. However,

as pointed out by the authors themselves, it is a partial measure of participation in global value chains, as it considers only backward linkages. To consider forward linkages, Hummels et al. (2001) also propose taking into account exports of intermediate goods that are later processed and re-exported (labeling it VS1). However, they do not suggest a precise formula for this action, as it can only be implemented within a complete ICIO framework.

By leveraging the source-based bilateral decomposition, an accurate measurement of the share of exports related to backward linkages can be provided (previous GVC or VS1 in Hummels et al., 2001 nomenclature). This can be calculated as the difference between DVA and DAVAX. Then, the overall indicator of equation (6), GVC, can be decomposed into a "backward" component related to the VS index and a "forward" component, which can be considered the first proper implementation of VS1.

$$GVC_{sr} = GVC\ backward_{sr} + GVC\ forward_{sr} \tag{8}$$

Where

$$GVC\ backward_{sr} = \frac{V_s(I-A_{ss})^{-1}\sum_{j\neq s}A_{sj}B_{js}E_{sr}+\sum_{t\neq s}^{G}V_tB_{ts}E_{sr}}{u_NE_{sr}} \tag{9}$$

And

$$GVC\ forward_{sr} = \frac{V_s(I-A_{ss})^{-1}A_{sr}(I-A_{rr})^{-1}(\sum_{j\neq r}Y_{rj}+\sum_{j\neq r}A_{rj}\sum_k\sum_{l\neq s}B_{jk}Y_{kl}\ )}{u_NE_{sr}} \tag{10}$$

Regarding the overall "GVC-related trade" index, its subcomponents can also be calculated for the total exports of a country (or even at the global level). It is noteworthy that the previous GVC proposed by Borin and Mancini (2023) is different from the one suggested by Koopman et al. (2014) as VS1s since they calculate it by aggregating the production content of a country embedded in the exports of other countries. While the GVC previous index is part of a country's exports (similar to VS), it may not necessarily align with the requirement for the measure proposed by Koopman et al. (2014). Equation (10) measures the share of a country's

exports related to previous GVC links in a way that corresponds to how the previous GVC (i.e., VS) is measured. Ultimately, other studies have measured participation in previous GVCs of a country by identifying components of exports that are later re-exported by the direct importer, relying on either Koopman et al.'s (2014) gross export decomposition or alternately, on Wang et al. (2013) exports decomposition. The issue is that these methods do not correctly allocate a country's exports between the share that is directly absorbed by importers and the share that is re-exported. Measures of participation in GVCs are also inaccurate. (Rahman and Zhao, 2013; Cappariello and Felettigh, 2015; Ahmed et al., 2017; Altomonte et al. 2018).

4. Data

In this paper, to operationalize this topic in Iran, Jahangard et al. (2023), with the support of the Research Center of the Chamber of Commerce, Industries, Agriculture and Mines of Iran, added the national IO table for the year 2016 compiled by the Central Bank of Iran to the Inter-Country Input-Output (ICIO) table. They incorporated the national Input-Output (IO) table for the year 2016, compiled by the Central Bank of Iran, into the Inter-Country Input-Output (ICIO) table. This comprehensive approach involved a dataset featuring 42 activities and 68 countries (see Appendix A), measured in million dollars. In the ICIO table for 2016, Iran's economy is categorized among the rest of the world countries, with the study integrating data for the year 2016 according to the Iranian Central Bank. Therefore, the ICIO table represents a global economy with 67 countries (J), including a category named "Rest of the World," and 42 activities (S)[1].

The final demand in this context includes household consumption, non-profit institutions serving households, government consumption, gross fixed capital formation, and changes in inventories. The Value-Added matrix

1. 2016 has been a relatively good year for Iran's economy after the JCPOA, and the results of this research prove it. But in the following years, especially from 2018 onwards, these results should have changed a lot. which this table is not able to show and readers should pay attention to this point. Of course, the author does not have the latest information in this regard.

illustrates the value added for primary factors employed in the production of activities in each country. Iran has been seamlessly integrated into an extensive database of international production and consumption, capturing all value-added flows. This ICIO table surpasses the scope of national IO tables, providing a detailed account of the origin and destination of all exchange flows based on activity, along with each intermediate or final use for these flows.According to the ICIO table, Iran's economy in 2016 showcased approximately $460.5 billion in gross value added, $752.4 billion in output, $97.3 billion in gross exports (comprising $13.1 billion as final exports and $84.2 billion as intermediate exports), and $86.1 billion in imports (with $42.5 billion as final imports and $43.5 billion as intermediate imports). The data is presented at base prices and assumes a fixed structure for selling the produced products.

5. Results

Table (1) illustrates the level of GVC, as well as previous and backward GVC in the economies of various countries using Borin and Mancini's (2023) source-based method and country perspective approach. The statistics indicate that the average participation or share of GVC in the gross global exports of the Iranian economy is 35.49%, and despite the utilization of oil and mineral resources, it is less than the global economic average (35.75%). In other words, among the 68 countries present in the ICIO table, Iran has less participation in the global economy than 44 world countries. However, this participation in the global value chain has a separate implication for Iran, indicating that this upstream position is not necessarily due to high-skilled activities in Iran, primarily arising from Iran's status as an exporter of raw materials, which should be considered in analyses.

Specifically, as mentioned, the overall bilateral GVC participation from Iran to country r can be decomposed into a "backward" component related to the VS index or vertical specialization and a "forward" component. Iran's position in terms of the global value chain has been more affected by the

backward component than the forward one. From the perspective of the backward component, Iran has less participation in the global value chain than just Colombia, Laos, Russia, Saudi Arabia, and Slovakia, and more than other countries in the table. However, from the perspective of the forward component, this pattern contradicts, and Iran falls into the category of countries with the lowest position in the global value chain. These two facts are shown in Figures 1 to 3. These observations indicate that Iran's economy, particularly in terms of the backward component of the global value chain, plays a minor role in the global value chain. In other words, Iran's upstream position in the global value chain, resulting from oil and mineral resources, is mainly associated with the backward component, and the role of the forward component or vertical specialization is negligible.

Table 1. GVC Participation and Vertical Specialization of Different Countries (Million $)

Country	GVC	GVCB	GVCF	GVC. S	GVCB.S	GVCF.S
AUS	78753.3	29035.28	49718.02	30.71%	11.32%	19.39%
AUT	82860.65	50846.42	32014.23	43.77%	26.86%	16.91%
BEL	128556.6	84579.51	43977.09	47.77%	31.43%	16.34%
CAN	155015.5	106660.3	48355.22	34.15%	23.50%	10.65%
CHL	23536.45	9981.48	13554.97	33.95%	14.40%	19.55%
CZE	12809.44	5562.53	7246.91	31.05%	13.48%	17.57%
DNK	4605.38	2896.44	1708.94	25.86%	16.27%	9.60%
EST	73697.07	53538.87	20158.2	53.40%	38.80%	14.61%
FIN	51495.54	32185.89	19309.65	36.98%	23.11%	13.87%
FRA	7137.96	5059.04	2078.93	46.22%	32.76%	13.46%
DEU	33164.31	19411.96	13752.35	42.26%	24.74%	17.52%
GRC	249879.6	139843	110036.6	36.36%	20.35%	16.01%
HUN	503167.2	274141.8	229025.5	37.86%	20.63%	17.23%
ISL	15996.85	9753.38	6243.47	30.25%	18.44%	11.81%
IRL	57604.23	44966.4	12637.83	55.54%	43.35%	12.18%
ISR	3365.11	2090.63	1274.48	36.12%	22.44%	13.68%
ITA	158967.7	128019.3	30948.43	49.00%	39.46%	9.54%
JPN	27086.57	16457.69	10628.88	30.57%	18.57%	11.99%
KOR	184456.1	104806.9	79649.28	34.39%	19.54%	14.85%

Country	GVC	GVCB	GVCF	GVC. S	GVCB.S	GVCF.S
LVA	248896.4	102972.5	145923.9	31.46%	13.01%	18.44%
LUX	249307.4	167595	81712.38	41.74%	28.06%	13.68%
MEX	4642.36	2505.93	2136.43	38.19%	20.62%	17.58%
NLD	9320.69	6053.52	3267.17	42.29%	27.47%	14.82%
NZL	80586.3	68836.33	11749.97	71.24%	60.85%	10.39%
NOR	142676	110127	32549	35.83%	27.66%	8.17%
POL	191165.6	122785	68380.56	45.04%	28.93%	16.11%
PRT	11982.82	6760.4	5222.42	25.46%	14.36%	11.10%
SVK	51624.6	20784.42	30840.18	42.17%	16.98%	25.19%
SVN	98562.78	60546.97	38015.81	44.06%	27.06%	16.99%
ESP	29158.96	19750.29	9408.67	37.05%	25.09%	11.95%
SWE	41949.05	32054.11	9894.94	58.58%	44.76%	13.82%
CHE	13539.37	9130.91	4408.47	47.54%	32.06%	15.48%
TUR	133544.7	79391.68	54153.03	33.74%	20.06%	13.68%
GBR	71485.89	40802.32	30683.57	37.00%	21.12%	15.88%
USA	132586.1	85711.68	46874.41	37.35%	24.14%	13.20%
ARG	56836.15	31821.25	25014.9	31.89%	17.85%	14.04%
BGR	193587.9	89143.93	104443.9	31.11%	14.32%	16.78%
BRA	544435.7	183703.4	360732.3	27.38%	9.24%	18.14%
BRN	15837.12	5789.49	10047.63	22.52%	8.23%	14.29%
CHN	59919.28	23218.9	36700.38	26.79%	10.38%	16.41%
COL	2427.92	586.94	1840.98	46.06%	11.13%	34.92%
CRI	14317.3	10064.29	4253.01	45.26%	31.81%	13.44%
CYP	4889.75	3714.58	1175.17	39.87%	30.29%	9.58%
HKG	568912	277404.6	291507.3	28.49%	13.89%	14.60%
HRV	6074.15	4000.17	2073.98	31.01%	20.42%	10.59%
IDN	4044.42	2813.77	1230.64	36.53%	25.41%	11.11%
IND	119085.3	66006.49	53078.83	27.59%	15.29%	12.30%
KHM	56474.36	22852.2	33622.16	31.85%	12.89%	18.96%
KAZ	57774.03	37590.83	20183.2	34.53%	22.47%	12.06%
LAO	22358.05	6865.61	15492.44	43.32%	13.30%	30.02%
LTU	2093.51	866.58	1226.93	40.77%	16.88%	23.89%
MLT	81873.05	57162.65	24710.4	46.02%	32.13%	13.89%
MYS	8894.82	7920.13	974.69	56.88%	50.65%	6.23%
MAR	13374.03	9070.02	4304.01	37.81%	25.64%	12.17%

Country	GVC	GVCB	GVCF	GVC. S	GVCB.S	GVCF.S
MMR	5604.11	2854.61	2749.5	32.91%	16.77%	16.15%
PER	15291.31	5866.64	9424.68	35.95%	13.79%	22.16%
PHL	27312.69	14606.57	12706.12	32.66%	17.47%	15.20%
ROU	24515.29	13149.54	11365.75	36.38%	19.52%	16.87%
RUS	125275.7	38882.31	86393.43	37.81%	11.74%	26.07%
SAU	71625.56	16576.84	55048.72	36.41%	8.43%	27.99%
SGP	181654.6	143472	38182.56	52.64%	41.57%	11.06%
THA	33183.71	19464.18	13719.53	37.63%	22.07%	15.56%
TUN	153693.7	109655.4	44038.25	48.44%	34.56%	13.88%
TWN	114208.3	87797.48	26410.87	41.91%	32.22%	9.69%
VNM	6740.39	4872.22	1868.17	42.99%	31.08%	11.92%
ZAF	103574.3	87168.08	16406.23	56.44%	47.50%	8.94%
IRN	**34537.28**	**10847.8**	**23689.44**	**35.49%**	**11.15%**	**24.34%**
ROW	377568.8	146447.2	231121.6	32.91%	12.77%	20.15%
WLD	6471179	3597901	2873278	35.75%	19.88%	15.87%

Source: Research calculations based on the ICIO table for the year 2016, considering Iran and Feás (2023).

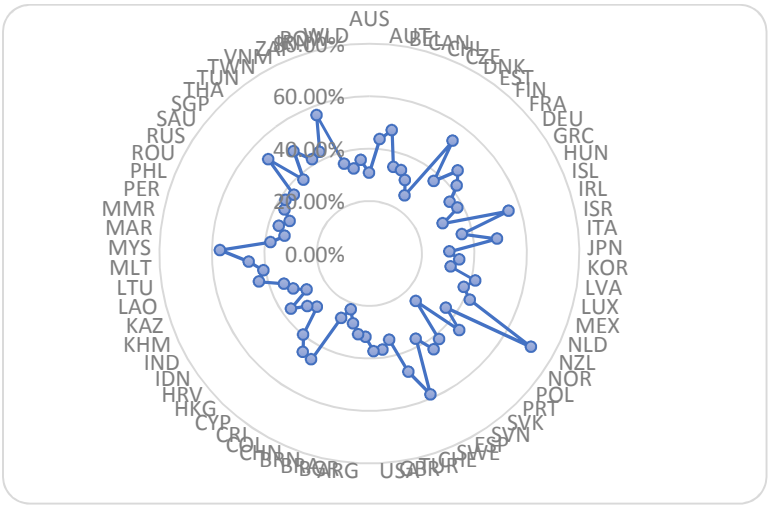

Fig 1. Share of GVC of Countries in Their Gross Exports.
Source: Research calculations based on the ICIO table for the year 2016, considering Iran.

The significance of this chart lies in illustrating the dynamics of Iran's participation and position, along with selected countries, in the global value chain. It highlights that countries with similar levels of participation may operate in different positions within the global value chain or, conversely, countries in similar positions may have varying levels of participation. This chart emphasizes the importance of the global value chain for the economies of countries.

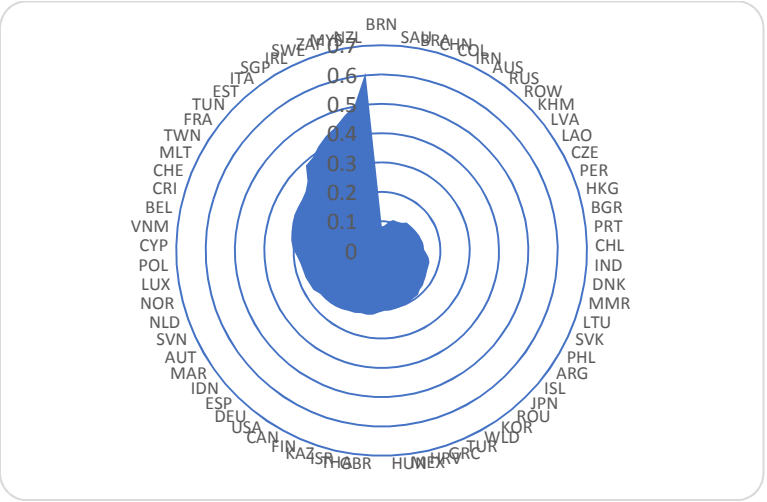

Fig 2. Share of the Backward Component of GVC of Countries in Their GVC. Source: Research calculations based on the ICIO table for the year 2016, considering Iran.

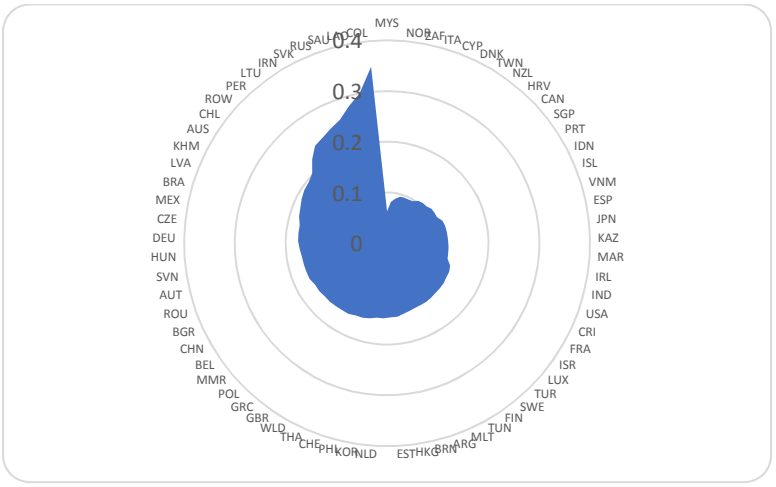

Fig 3. Share of the Forward Component of GVC in Their GVC.
Source: Research calculations based on the ICIO table for the year 2016, considering Iran.

The global value chain criteria for BRICS member countries, Shanghai Cooperation Organization (SCO), OECD, OPEC, ASEAN, member countries of the European Union, and the whole world are provided in Table 2. According to this, in the gross exports of the whole world, the value chain of BRICS member countries is about $952 billion, constituting approximately 30.15% of their gross exports. From this amount, the role of vertical specialization (its backward component) is much less than its forward component. However, in the member countries of the Shanghai Cooperation Organization, the value of their global value chain in the world is approximately $1,153 billion, which is almost more than the backward component in their gross exports. OECD member countries have about $8,716 billion in GVC, where vertical specialization or, in other words, the share of their backward component in their gross exports is much higher than the forward component compared to BRICS and Shanghai Cooperation Organization countries. This indicates that these countries play a fundamental role in the world production structure. The member countries of the European Union have a global value chain of $5,993 billion, which, like OECD

member countries, the role of their backward component in the world is more than their forward component. According to calculations, Iran's role is almost different from these groups of countries in the world, and from the breakdown of Iran's global value chain, which is about $34.5 billion, the forward component plays a more prominent role in Iran's gross exports due to its resource focus in the energy and crude oil and natural gas sectors. This observation shows that Iran's position in the global value chain is firstly very insignificant and secondly different from the style of production and industrial countries present in the global value chain. Thirdly, the main role of presence in the forward component of the global value chain is also due to the presence and supply of energy, mineral resources, and chemical products, which will be discussed further.

If we calculate the above calculations with a country-oriented and bilateral export approach for Iran, the results of Table 3 and Chart 7 are obtained. According to these calculations, in the gross exports of the whole world, the value chain of BRICS countries is about $6.3 billion, which constitutes approximately 34.9% of their gross exports. From this amount, the role of backward component and its forward component aren’t equal and forward component is greater. However, in the member countries of the Shanghai Cooperation Organization, the value of their global value chain with Iran is approximately 6 billion dollars, which is almost like the BRICS member countries, the share of the forward component is more than the backward. OECD member countries have about $14.2 billion worth of GVC with Iran, with the role of the forward component in their gross exports to Iran similar to that of BRICS member countries and the Shanghai Cooperation Organization, which is significantly dominant in the global value chain. European Union member countries have $11.1 billion worth of global value chain with Iran, where, like OECD member countries, their role as the forward component in their global value chain with Iran exceeds that of the backward component. According to calculations, the total global role in the value chain with Iran in the world is approximately $34.5 billion, with the forward component mainly related to energy activities.

Table 2. Global value chain of Iran and some regions in the world (million $)

	EXGR	GVC	GVCB	GVCF	GVCB %	GVCF %	GVC %
BRICS*	3158417	952290	398979	553311	12.63	17.52	30.15
SOC**	1153968	362054	165699	196356	14.36	17.02	31.37
OECD	8716433	3382023	2067163	1314861	23.72	15.08	38.80
NAFTA	821117	292244	194878	97366	23.73	11.86	35.59
ASEAN	875591	362104	231511	130593	26.44	14.91	41.36
EUR27***	5993807	2415360	1459247	956113	24.35	15.95	40.30
IRN	97326	34537	10848	23689	11.15	24.34	35.49
WLD	18100997	6471179	3597901	2873277	19.88	15.87	35.75

*BRICS member countries include: Brazil, Russia, India, China, and South Africa. The countries that are expected to join this group from 2024 onwards have not been considered in the calculations. These countries include Saudi Arabia, Argentina, the United Arab Emirates, and Ethiopia, with Iran being included in bilateral trade in this context. *Shanghai Cooperation Organization (SCO) member countries include: China, India, Kazakhstan, and Russia, which were explicitly mentioned in the ICIO table. However, Pakistan, Tajikistan, and Uzbekistan were not explicitly mentioned in the ICIO table, so they were not considered in the calculations.
***Except for the United Kingdom.

Source: Research calculations based on the ICIO table for the year 2016, considering Iran and Feás (2023).

Table 3. Iran's Global Value Chain in bilateral Exports in Some Regions (million $)

	EXGR	GVC	GVCB	GVCF	GVC	GVCB	GVCF
BRICS*	18043.43	6310.52	2191.03	4119.51	34.97%	12.14%	22.83%
SOC**	17576.54	6014.85	2137.93	3876.93	34.22%	12.16%	22.06%
OECD***	28325.11	14165.45	3416.4	10749.05	50.01%	12.06%	37.95%
NAFTA	157.49	46.75	15.84	30.91	29.68%	10.06%	19.63%
ASEAN	1560.48	259.83	189.88	69.95	16.65%	12.17%	4.48%
EUR27	22165.33	11156.54	2691.53	8465.02	50.33%	12.14%	38.19%
WLD	97326.21	34537.23	10847.85	23689.41	35.49%	11.15%	24.34%

*BRICS member countries include: Brazil, Russia, India, China, and South Africa. The countries that are expected to join this group from 2024 onwards have not been considered in the calculations. These countries include Saudi Arabia, Argentina, the United Arab Emirates, and Ethiopia, with Iran being included in bilateral trade in this context.

**Shanghai Cooperation Organization (SCO) member countries include: China, India, Kazakhstan, and Russia, which were explicitly mentioned in the ICIO table. However, Pakistan, Tajikistan, and Uzbekistan were not explicitly mentioned in the ICIO table, so they were not considered in the calculations.

***Except for the United Kingdom.

Source: Research calculations based on the ICIO table for the year 2016, considering Iran and Feás (2023).

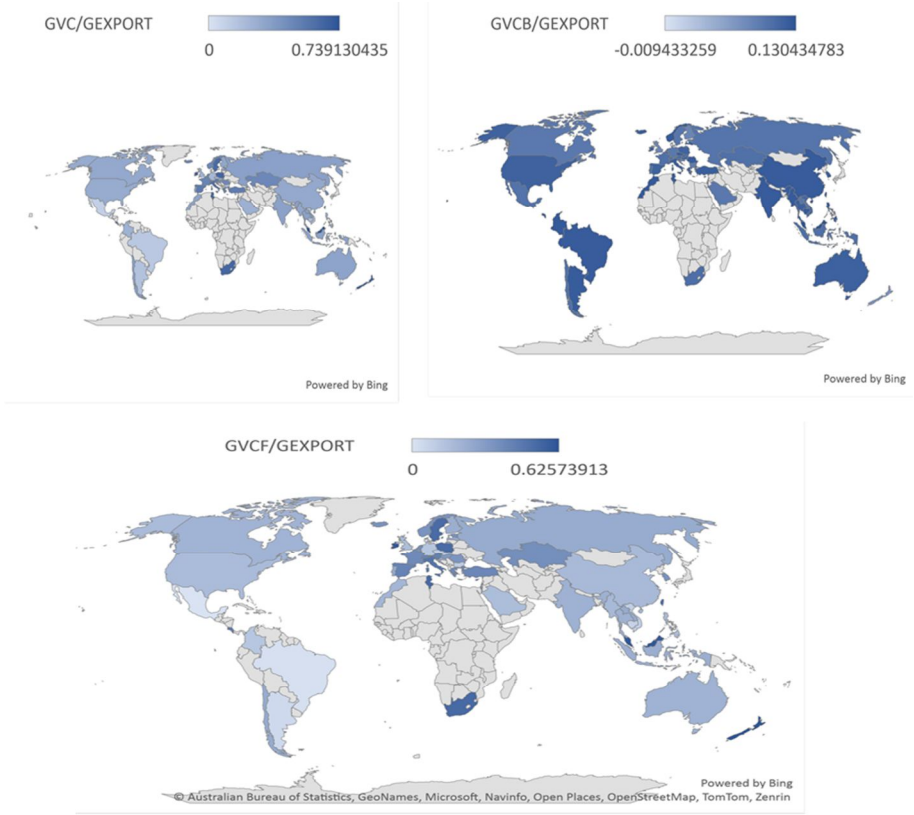

Fig 4. Global Value Chain, Backward Component and Forward Component of Iran in Bilateral Exports.

Source: Research calculations based on the ICIO table for the year 2016, considering Iran.
Note that this figure is drawn considering the countries present in the ICIO table, and countries within the ROW category are not identifiable in this figure

Table 4, presents the calculation of GVC (Global Value Chain) and its components, namely the forward and backward components, for 42 economic activities in Iran. The figures indicate that the highest GVC value among Iran's economic activities is related to the extraction of crude oil, natural gas, and mining, with an amount of 17.1 billion dollars, constituting approximately 17.58% of the gross export value of the activity. Following

this activity, the production of chemical and chemical products comes next with 5.1% of its gross exports and an amount of about 4.96 billion dollars. The production of coke and products derived from oil refining holds 1.8% of its gross exports, totaling 1.75 billion dollars. The production of basic metals contributes approximately 1.55% of its gross exports, amounting to around 1.5 billion dollars. Agriculture, hunting, forestry, with a 1.09% share of gross export value, reach about 1.058 billion dollars. The extraction of Mining and quarrying, non-energy producing products, with a 1.04% share of gross exports, is valued at around 1 billion dollars. The remaining economic activities in Iran, which represent less than one percent of their gross export value, are not included in their global value chain.

Table 4. Iran's Global Value Chain in 42 Economic Activities (million $)

CODE	GVC	GVCB	GVCF	gvc/exgr
D01T02	1058.03	283.77	774.31	1.09%
D03	21.27	17.36	3.92	0.02%
D05T06	17105.2	1003.2	16102.03	17.58%
D07T09	1013.37	52.44	960.9	1.04%
D10T12	816.72	595.57	221.14	0.84%
D13T15	409.06	280.02	129.02	0.42%
D16	14.33	5.52	8.81	0.01%
D17T18	145.96	13.73	132.19	0.15%
D19	1754.88	224.12	1530.73	1.80%
D20	4961.86	778.95	4182.93	5.10%
D21	104.83	79.32	25.54	0.11%
D22	281.5	256.1	25.4	0.29%
D23	144.56	110.86	33.61	0.15%
D24	1510.95	421.57	1089.4	1.55%
D25	108.89	73.79	35.09	0.11%
D26	49.17	27.79	21.4	0.05%
D27	103.18	92.38	10.75	0.11%
D28	95.5	38.3	57.23	0.10%
D29	88.38	62.43	25.94	0.09%
D30	10.05	7.77	2.28	0.01%

CODE	GVC	GVCB	GVCF	gvc/exgr
D31T33	49	20.97	28.01	0.05%
D35	294	233.64	60.37	0.30%
D36T39	12.98	3.73	9.26	0.01%
D41T43	53.55	9.78	43.74	0.06%
D45T47	177.79	132.66	45.12	0.18%
D49	396.89	333.86	63.02	0.41%
D50	162.58	149.85	12.75	0.17%
D51	183.51	158.54	24.93	0.19%
D52	44.63	30.7	13.92	0.05%
D53	1.68	0.13	1.53	0.00%
D55T56	229.93	217.01	12.95	0.24%
D58T60*	-285.79	-341.18	55.38	-0.29%
D61	461.7	434.99	26.7	0.47%
D64T66	24.84	11.67	13.14	0.03%
D68	71.35	0	71.34	0.07%
D69T75	56.22	26.11	30.1	0.06%
D77T82	39.95	39.79	0.14	0.04%
D84	33.8	33.72	0.05	0.03%
D85	8.61	5.18	3.42	0.01%
D86T88	4.87	3.43	1.39	0.01%
D90T93	12.87	12.72	0.12	0.01%
D94T98	22.76	9.77	12.99	0.02%

Source: Research calculations based on the ICIO table for the year 2016, considering Iran.and Feás(2023).

*The reason for the negative value of code D58T60 is the negative change in inventory for Iran in this activity.

Table 4 and Figure 5, illustrate the composition of the forward and backward components in the global value chain (GVC) for 42 economic activities in Iran. Figure 5, shows that the backward component of the global value chain for the following activities accounts for more than 50% of their own global value chain: Publishing, audiovisual and broadcasting activities, IT and other information services, Public administration and defense; compulsory social security, administrative and support service activities,

Arts, entertainment and recreation, Accommodation and food service activities, Telecommunications, Water transport, Rubber and plastics products, Electrical equipment, Air transport, Land transport and transport via pipelines, Fishing and aquaculture, Electricity, gas, steam and air conditioning supply ,Other transport equipment, Other non-metallic mineral products ,Pharmaceuticals, medicinal chemical and botanical products, Wholesale and retail trade; repair of motor vehicles, Food products, beverages and tobacco, Motor vehicles, trailers and semi-trailers, Human health and social work activities, Warehousing and support activities for transportation, Textiles, textile products, leather and footwear ,Fabricated metal products, Education, and Computer, electronic and optical equipment.

The remaining economic activities, including 17 economic activities out of 42, have their forward component in the global value chain greater than their backward component. These activities include Real estate activities, Mining and quarrying, non-energy producing products Mining support service activities, Mining and quarrying, energy producing products, Postal and courier activities, Paper products and printing, Coke and refined petroleum products, Chemical and chemical products, Construction, Agriculture, hunting, forestry, Basic metals, collection, purification, Water supply; sewerage, waste management and remediation activities ,Wood and products of wood and cork, Machinery and equipment, nec Manufacturing nec; repair and installation of machinery and equipment, Other service activities, Professional, scientific and technical activities, Financial and insurance activities.

It should be noted that the indicators calculated in this research about GVCs only state the facts, but cannot explain the causes. Investigating the causes of the results requires a new study and purpose.

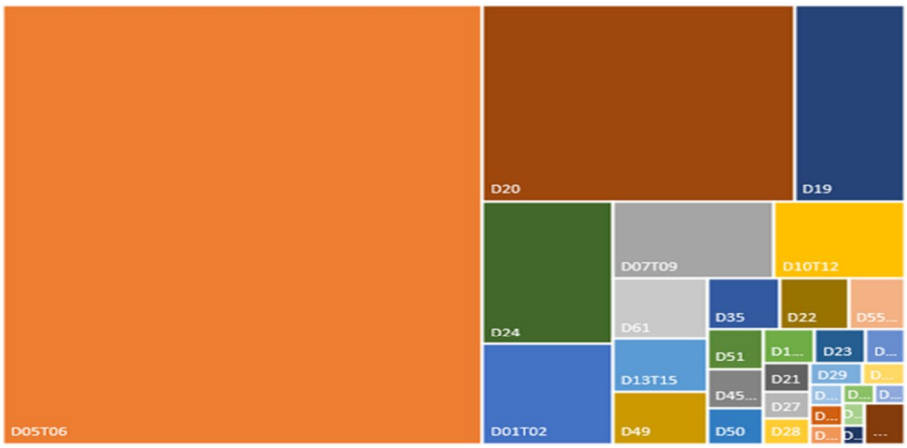

Fig 5. Composition of Iran's Global Value Chain in 42 Economic Activities. Source: Research calculations based on the ICIO table for the year 2016, considering Iran.

6. Conclusions and policy suggestions

In this paper, we utilize the 2016 ICIO table, including Iran and adopting a source-based and country perspective on gross exports. Following the approach outlined by Borin and Mancini (2023), we calculate the overall participation in the Global Value Chain GVC).The statistics indicate that the average participation or share of GVC in Iran's gross global exports (35.49%) is slightly less than the global economic average (35.75%), despite the utilization of oil and mineral resources. In other words, among the 68 countries listed in the ICIO table, Iran has lower participation in the global economy than 44 world countries. However, this participation in the Global Value Chain has a separate implication for Iran, suggesting that this upstream position is not necessarily due to Iran's high-skill activities, but mainly stems from the characteristic of Iran as a raw material exporter, which needs attention.

Iran's position in the global value chain has been more affected than the previous components of the global value chain. From the perspective of the previous components, Iran has less participation in the global value chain

than only a few countries, including Colombia, Laos, Russia, Saudi Arabia, and Slovakia, and has a higher share in bilateral gross exports than the rest of the world countries listed in the table. However, from the perspective of the latter components, this pattern contradicts, and Iran falls into the category of countries with the lowest position in the global value chain.

Calculating GVC and its backward and forward components for 42 economic activities in Iran shows that the highest amount of GVC among Iran's economic activities is related to the extraction of crude oil and natural gas and mining, with a value of 17.1 billion dollars, allocating approximately 17.58% of the value of gross export activity to itself. After this activity, the Chemical and chemical products follows with 5.1% of its gross exports and about 4.96 billion dollars, Coke and refined petroleum products with 1.8% of its gross exports and a value of about 1.75 billion dollars, the Basic metals with 1.55% of its gross exports and a value of about 1.5 billion dollars, Agriculture, hunting, forestry with 1.09% of its gross export value and about 1.058 billion dollars, and the Mining and quarrying, non-energy producing products with 1.04% of its gross exports and about 1 billion dollars in value. The remaining economic activities in Iran account for less than one percent of their gross export value in the global value chain.

According to the results of the study, the following proposal is presented: The real and primary question for Iran's economy at present is not about entering GVCs. The real question for Iran's economy is how it can deepen its production capacities to gain a larger share of the value added from its gross exports in the global value chain across various activities and products. To achieve this, it is necessary to pursue the path of industrial development, agriculture, and service sector expansion.

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Authors' contributions

All authors had contribution in preparing this paper.

Conflicts of interest

The authors declare no conflict of interest

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Appendix A.

Table A1. List of country in ICIO 2016 with added Iran

Row	Country	Code	Row	Country	Code	Row	Country	Code
1	Australia	AUS	25	Mexico	MEX	49	Hong Kong	HKG
2	Austria	AUT	26	Netherlands	NLD	50	Kazakhstan	KAZ
3	Belgium	BEL	27	New Zealand	NZL	51	Laos	LAO
4	Canada	CAN	28	Norway	NOR	52	Malaysia	MYS
5	Chile	CHL	29	Poland	POL	53	Malta	MLT
6	Colombia	COL	30	Portugal	PRT	54	Morocco	MAR
7	Costa Rica	CRI	31	Slovakia	SVK	55	Myanmar	MMR
8	Czech Republic	CZE	32	Slovenia	SVN	56	Peru	PER
9	Denmark	DNK	33	Spain	ESP	57	Philippines	PHL
10	Estonia	EST	34	Sweden	SWE	58	Romania	ROU
11	Finland	FIN	35	Switzerland	CHE	59	Russia	RUS
12	France	FRA	36	Turkey	TUR	60	Saudi Arabia	SAU
13	Germany	DEU	37	United Kingdom	GBR	61	Singapore	SGP
14	Greece	GRC	38	United States	USA	62	South Africa	ZAF

Row	Country	Code	Row	Country	Code	Row	Country	Code
				of America				
15	Hungary	HUN	39	Argentina	ARG	63	Taiwan	TWN
16	Iceland	ISL	40	Brazil	BRA	64	Thailand	THA
17	Ireland	IRL	41	Brunei	BRN	65	Tunisia	TUN
18	Israel	ISR	42	Bulgaria	BGR	66	Vietnam	VNM
19	Italy	ITA	43	Cambodia	KHM	67	Iran	IRN
20	Japan	JPN	44	China	CHN	68	Rest of the World	ROW
21	South Korea	KOR	45	Croatia	HRV	69	Mexico 1	
22	Latvia	LVA	46	Cyprus	CYP	70	Mexico 2	
23	Lithuania	LTU	47	India	IND	71	China 1	
24	Luxembourg	LUX	48	Indonesia	IDN	72	China 2	

Source: OECD, Inter-Country Input-Output (ICIO) Tables, 2021 edition adjusted with Iran.

Table A2. List of Activities in ICIO 2016 with added Iran

ROW	CODE	ACTIVITIES
1	D01T02	Agriculture, hunting, forestry
2	D03	Fishing and aquaculture
3	D05T06	Mining and quarrying, energy producing products
4	D07T09	Mining and quarrying, non-energy producing products and Mining support service activities
5	D10T12	Food products, beverages and tobacco
6	D13T15	Textiles, textile products, leather and footwear
7	D16	Wood and products of wood and cork
8	D17T18	Paper products and printing
9	D19	Coke and refined petroleum products
10	D20	Chemical and chemical products
11	D21	Pharmaceuticals, medicinal chemical and botanical products
12	D22	Rubber and plastics products
13	D23	Other non-metallic mineral products
14	D24	Basic metals
15	D25	Fabricated metal products
16	D26	Computer, electronic and optical equipment
17	D27	Electrical equipment

ROW	CODE	ACTIVITIES
18	D28	Machinery and equipment, nec
19	D29	Motor vehicles, trailers and semi-trailers
20	D30	Other transport equipment
21	D31T33	Manufacturing nec; repair and installation of machinery and equipment
22	D35	Electricity, gas, steam and air conditioning supply
23	D36T39	Water supply; sewerage, waste management and remediation activities
24	D41T43	Construction
25	D45T47	Wholesale and retail trade; repair of motor vehicles
26	D49	Land transport and transport via pipelines
27	D50	Water transport
28	D51	Air transport
29	D52	Warehousing and support activities for transportation
30	D53	Postal and courier activities
31	D55T56	Accommodation and food service activities
32	D58T60 & 62 T63	Publishing, audiovisual and broadcasting activities and IT and other information services
33	D61	Telecommunications
34	D64T66	Financial and insurance activities
35	D68	Real estate activities
36	D69T75	Professional, scientific and technical activities
37	D77T82	Administrative and support services
38	D84	Public administration and defence; compulsory social security
39	D85	Education
40	D86T88	Human health and social work activities
41	D90T93	Arts, entertainment and recreation
42	D94T98	Other service activities and Activities of households as employers; undifferentiated goods- and services-producing activities of households for own use

Source: OECD, Inter-Country Input-Output (ICIO) Tables, 2021 edition adjusted with Iran.