Diversification and sophistication of exports from Azerbaijan to China: THEIL index and Toda-Yamamoto causality test

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Abstract: This study analyzes the economic relations between Azerbaijan and China within the context of export diversification and product sophistication. The research examines trade dynamics from 1992 to 2023, measuring export concentration through THEIL and HHI indices. Methodologically, the Toda-Yamamoto causality test is employed to determine the relationship between variables. The analysis reveals that Azerbaijan's exports to China remain heavily dependent on raw materials, with the non-oil sector's share being significantly low (averaging 0.04%). Indicators from the Economic Complexity Index (ECI) confirm that Azerbaijan's export portfolio possesses low technological intensity. Against the backdrop of the "Belt and Road Initiative" and the "Middle Corridor," the paper proposes strategic recommendations for Azerbaijan to strengthen its position not only as a transit hub but also as an exporter of sophisticated products.

Keywords: Azerbaijan-China trade, Export diversification, Toda-Yamamoto test, THEIL index, Economic complexity, Middle Corridor.

Following the dissolution of the Soviet Union, the People's Republic of China became the first East Asian nation to formally recognize Azerbaijan's sovereignty. On December 27, 1991, China officially acknowledged Azerbaijan's independence and diplomatic relations between the two countries were established on April 2, 1992. This event marked the initiation of a new phase of bilateral cooperation. In 1994, Azerbaijan undertook its inaugural official visit to China as an independent state, with national leader Heydar Aliyev visiting Beijing. During this visit, Aliyev delivered a speech at the Committee for the Promotion of International Trade, emphasizing the significant potential for enhancing foreign trade relations between the two nations. Furthermore, he explored the free economic zones in Shanghai, a move that was instrumental in shaping the foundational principles of Azerbaijan-China economic and political relations. This visit significantly contributed to the acceleration of the bilateral foreign trade turnover. Under Heydar Aliyev's leadership, Azerbaijan's foreign trade with China grew by a factor of 2.2 in the period from 1994 to 1995, compared to the years 1992-1993.

Between 1992 and 2003, Azerbaijan-China relations were primarily focused on strengthening political and diplomatic ties. To support Azerbaijan's economic development, finance infrastructure projects, and improve socio-economic conditions. The People's Republic of China extended a state loan of 60 million yuan and a grant of 3 million yuan to the Azerbaijani government on June 18, 1998. Over the same period, Azerbaijan's total foreign trade turnover with China amounted to US$279.2 million.

Economic and trade relations between Azerbaijan and China began to develop significantly from 2005 onwards. Since then, several agreements on economic and technical cooperation have been signed between the two countries, primarily consisting of grants provided by the People's Republic of China to the Azerbaijani government.

The Joint Declaration signed on June 14 2005, stands as the most comprehensive and far-reaching document in Azerbaijan-China relations since Azerbaijan's independence. This

declaration encompassed China's support for Azerbaijan's accession to the World Trade Organization (WTO), the development of a regional legal framework for advancing the Europe-Caucasus-Asia (TRACECA) transport corridor, and the promotion of bilateral cooperation in key sectors such as oil and petrochemicals, light industry, mechanical engineering, agriculture, transportation, telecommunications, and infrastructure development.

Azerbaijan's 2024 application for BRICS membership reflects its strategic intent to deepen economic cooperation with China. Among BRICS founding members, China stands as Azerbaijan's second-largest trading partner after Russia. By capitalizing on China's economic strength, Azerbaijan aims to broaden export diversification, enhance transit and logistics revenues, and strengthen its position as a key player in regional trade between Asia and Europe.

As an early participant in the Belt and Road Initiative (BRI), Azerbaijan has prioritized the expansion of its transit potential within international transport corridors. Under the 2024–2026 Action Plan, the country seeks to boost transit cargo volume by 27% compared to 2022, increasing from 10.7 million tons to 13.6 million tons. This initiative is part of Azerbaijan's broader ambition to solidify its role in global supply chains, integrate more deeply into value-added trade networks, and establish itself as a regional logistics and transit hub connecting Europe and China.

To support this vision, on November 22 2022, Azerbaijan, Kazakhstan, Georgia, and Turkey signed a strategic roadmap for the Middle Corridor, covering the period 2022–2027. This agreement aims to enhance the efficiency of the Trans-Caspian International Transport Route (TITR) and optimize regional connectivity, reinforcing Azerbaijan's position as a critical bridge in global trade.

Azerbaijan has played a pivotal role in enhancing the appeal of the Middle Corridor, notably through the development of the Baku-Tbilisi-Kars railway line, which has successfully established an alternative and efficient transport infrastructure linking Asia and Europe. Furthermore, the establishment of the Alat Free Economic Zone in the Alat settlement of the Garadag district in Baku on May 22, 2020, has strengthened Azerbaijan's leadership role in regional logistics chains between Europe and Asia. The Alat Free Economic Zone not only provides favorable opportunities for Chinese investors but also enhances access to European markets by processing Chinese export-oriented raw materials, maintaining competitiveness in price and quality. The Alat Free Economic Zone acts as a platform for both Chinese investors and exporters seeking to access more competitive goods in the Chinese market. In other words, it helps create a favorable regional trade environment by encouraging investment in export-oriented enterprises aimed at gaining access to East and Southeast Asian markets.

To mitigate global geopolitical risks, prevent potential delays in supply chains, and diversify its transit options—especially strengthening its regional position in the Middle Corridor—Azerbaijan is working on expanding its transit capacities. This includes, not only relying on Georgia, but also constructing a new automobile and railway route connecting the East Zangezur Economic Zone with the Nakhchivan Autonomous Republic. In this context, a memorandum of understanding was signed between Azerbaijan and the Islamic Republic of Iran in 2022, focusing on the establishment of new communication links between the East Zangezur Economic Zone and the Nakhchivan Autonomous Republic. As a result, the Turkey segment of the Middle Corridor is taking shape, which will further expand alternative transport and logistics opportunities between China and Europe.

Strengthening ties with the Chinese economy is a central focus of Azerbaijan's trade diplomacy. This is clearly reflected in the fact that nearly half of the country's global trade offices—six out of 13—are located in China. To further broaden these commercial relations, a dedicated trade representation office has been established in the region. Over the last five years, Azerbaijan's presence has expanded through the opening of trade houses in cities like Qingdao, Changzhou, Xi'an, Chengdu, and Beijing, as well as trade sections in Shanghai, Harbin, Qinhuangdao, and Wuhan. Furthermore, specialized wine houses have been launched in Urumqi and Shanghai to serve as promotional hubs for Azerbaijani products.

Integration into the Chinese economy is a priority for Azerbaijan's economic and trade diplomacy. Notably, six out of 13 Azerbaijani trade offices are located in China. Furthermore, to expand and diversify trade relations, Azerbaijan has established a trade representation office in China. Over the past five years, Azerbaijan has opened trade houses in cities such as Qingdao, Changzhou, Xi'an, Chengdu, and Beijing, as well as trade sections in Shanghai, Harbin, Qinhuangdao, and Wuhan.

Considering China's potential role in the diversification of Azerbaijan's economy and exports, efforts to enhance Azerbaijan's integration into the Chinese market have been explored. These efforts aim to align Azerbaijan's export policy with China's future trade objectives, transitioning from the export of energy commodities to value-added processed products. Research indicates that the central focus of economic relations between Azerbaijan and China has been the implementation of the Middle Corridor project and the development of the transport infrastructure that contributes to this initiative. Furthermore, increasing Azerbaijan's transit capabilities for Chinese products has been a key topic in the discussions.

However, significant research has yet to be conducted on the integration of Azerbaijani products into the Chinese market, nor have empirical calculations been made regarding Azerbaijan's export turnover and the adequacy of its products in responding to the demands of the Chinese economy. Taking this into account, the study investigates the current position of Azerbaijani products in the Chinese market, the composition of its export basket, the level of export diversification, and the complexity of these products.

Changing Economic Goals Between China and Azerbaijan in the Context of the South Caucasus.

The foreign trade objectives of the People's Republic of China differ from the priorities of countries with small economies. For small economies in regions like the South Caucasus (Azerbaijan, Georgia, Armenia), the primary goal is to gain access to vast markets such as China and strengthen their economic presence. Conversely, China's strategy in the South Caucasus region focuses on diversifying access to Western markets through the Middle Corridor, and establishing a multimodal transport corridor as an alternative to the traditional northern and maritime routes. The focus of economic relations between Azerbaijan and China is centered on the Trans-Caspian East-West International Transport Corridor (Middle Corridor), which aligns with the aforementioned objectives.

Based on the 2005 agreement, China encouraged Azerbaijan to liberalize foreign trade, reduce tariffs, and pursue membership in the World Trade Organization. As a country with enormous and diversified production capacity, China actively promotes market openings and the establishment of competitive trade relations with its partners. However, China's main goal

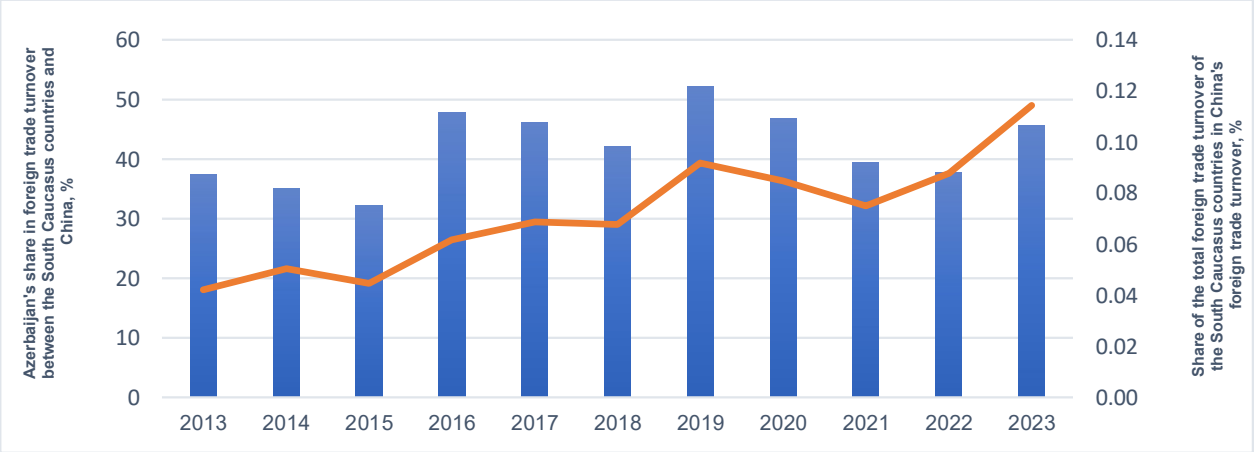
is to utilize the transport potential of South Caucasus countries to gain access to broader markets. In this context, Azerbaijan considers China's market as a primary target, while China's main priorities in the South Caucasus region are securing access to European markets and creating alternative trade routes.

Despite having a large trade turnover with Azerbaijan in the South Caucasus region, China signed a free trade agreement with Georgia on June 13, 2017. As a result, Georgia, one of the key players in the Trans-Caspian East-West International Transport Corridor, saw a significant increase in foreign trade relations with China starting in 2018. With its membership in the Belt and Road Initiative, and its transit opportunities providing access to Western markets via the Black Sea and Turkey, Georgia has become one of China's main strategic allies in the South Caucasus.

After gaining independence, Azerbaijan initially prioritized more protectionist foreign trade relations. Undoubtedly, Azerbaijan's lack of extensive production capacity has delayed its membership in regional trade alliances. However, Azerbaijan has free trade agreements with the CIS and Georgia, as well as preferential trade agreements covering a limited number of goods with Turkey and Pakistan. The National Economy Perspective Strategic Roadmap, covering the period from 2016 to 2020, emphasized Azerbaijan's intention to assess the potential of concluding a free trade agreement based on favorable trade regimes for non-oil and gas exports to the Chinese market and strengthening its position in the value chain in the medium and long term.

Among the trade relations of South Caucasus countries with East Asian countries, the highest foreign trade turnover has been recorded with the People's Republic of China. However, the share of these countries' foreign trade turnover in China's overall foreign trade structure remains below 1%, which indicates that their trade relations have limited influence in China's global trade network.

Diagram 1: Share of the total foreign trade turnover of the South Caucasus countries in China's foreign trade turnover



Data source: Comtrade and Export Complexity Index

A significant feature observed in the export structure of South Caucasus countries is the high dependency on resources and product concentration. Specifically, the characteristic of these countries' exports to China is that they are primarily composed of raw materials and products from the resource sector. For the other two countries in the region, alongside Azerbaijan, the main drivers of export are resource-based goods. These goods include crude oil and oil products, copper ores and waste, molybdenum ores and concentrates, unprocessed aluminum, and other low-value metals. The share of these products in the total export structure of South Caucasus countries exceeds 60%, which demonstrates the deepening resource dependency and low diversification in the export models of these countries.

Over the past decades, Azerbaijan has been the largest economy in the South Caucasus region in terms of GDP and serves as one of the key trade partners of the People's Republic of China in the region. The structural analysis of foreign trade turnover indicates that the dominant direction of these trade relations is the share of goods exported from China to Azerbaijan. Azerbaijan's exports to China are primarily composed of crude oil and chemical industry products.

The foundation of trade relations between the two countries was established in 1992. The subsequent growth in foreign trade turnover is primarily associated with the expansion of China's exports to Azerbaijan. While Azerbaijan is the sole supplier of crude oil and chemical products to China in the South Caucasus, its export potential in the non-oil sector remains limited.

Import transformation of the Chinese economy

Since 2013, the Belt and Road Initiative (BRI), launched under China's leadership, has encompassed railway and highway infrastructure along resource-rich corridors. This initiative consists of two primary components: The Silk Road Economic Belt and the 21st Century Maritime Silk Road. However, over the past decade, the BRI has expanded from Latin America to the Pacific Ocean, with the number of countries signing cooperation agreements with China under the initiative surpassing 150 by mid-2023.

According to calculations by the International Trade Centre, before the launch of the BRI, the average annual exports of developing economies that later joined the initiative amounted to approximately $445 billion between 2008 and 2012. Following the expansion of BRI membership, exports from these economies increased to $798 billion between 2018 and 2022, reflecting a significant rise compared to the previous five-year period.

Moreover, a similar comparative analysis has been conducted to assess the transformation of the export composition of developing economies that joined the BRI. Between 2008 and 2012, mineral products—particularly crude oil and petroleum products derived from bituminous minerals—accounted for 53% of these countries' export composition, while manufactured goods comprised 42%, and agricultural, fishery, and food products made up 6%. The export structure of these economies remained relatively stable over the following decade. Specifically, during the 2018–2022 period, the share of mineral products in total exports declined by 4 percentage points to 49%, the share of manufactured goods increased by 1 percentage point to 43%, and the share of agricultural, fishery, and food products rose by 1 percentage point to 7%.

Crude oil remains the dominant export commodity from BRI-participating developing economies to China. According to estimates by the International Trade Centre, these countries' average annual crude oil exports amounted to $159 billion between 2008 and 2012, increasing to $236 billion during the 2018–2022 period. Consequently, while crude oil accounted for 36% of their total exports before the BRI's implementation, this share declined to 30% in the subsequent five-year period.

According to the International Trade Centre's study on the export potential of developing economies participating in the Belt and Road Initiative (BRI) to China, raw materials accounted for 51% of China's total imports before the launch of the BRI. However, this figure declined to 47% during the 2018–2022 period. Meanwhile, the share of semi-finished products in China's import structure increased from 23% in 2008–2012 to 27% in 2018–2022.

Overall, these figures indicate the continued significance of mineral products for the Chinese economy. Nevertheless, the report's projections suggest that over the next decade, the share of mineral products in China's imports will decline, while the share of semi-finished and fully manufactured goods is expected to increase.

The findings of Bin Xu's study *"The Sophistication of Exports: Is China Special?"* and the research by Jarreau and Poncet on export sophistication and economic growth in China empirically substantiate the increasing share of high-value-added and technologically complex products in China's export structure. These studies further highlight that more than 50% of the components used in the production of these sophisticated goods are sourced through imports. The deepening of processing stages and the growing complexity of exported goods have consequently shifted China's import demand from raw materials toward intermediate goods. Moreover, projections by the International Trade Centre affirm that this structural transformation will continue over the next decade, further increasing the share of semi-processed inputs in China's import portfolio.

Azerbaijan's export targets and strategy

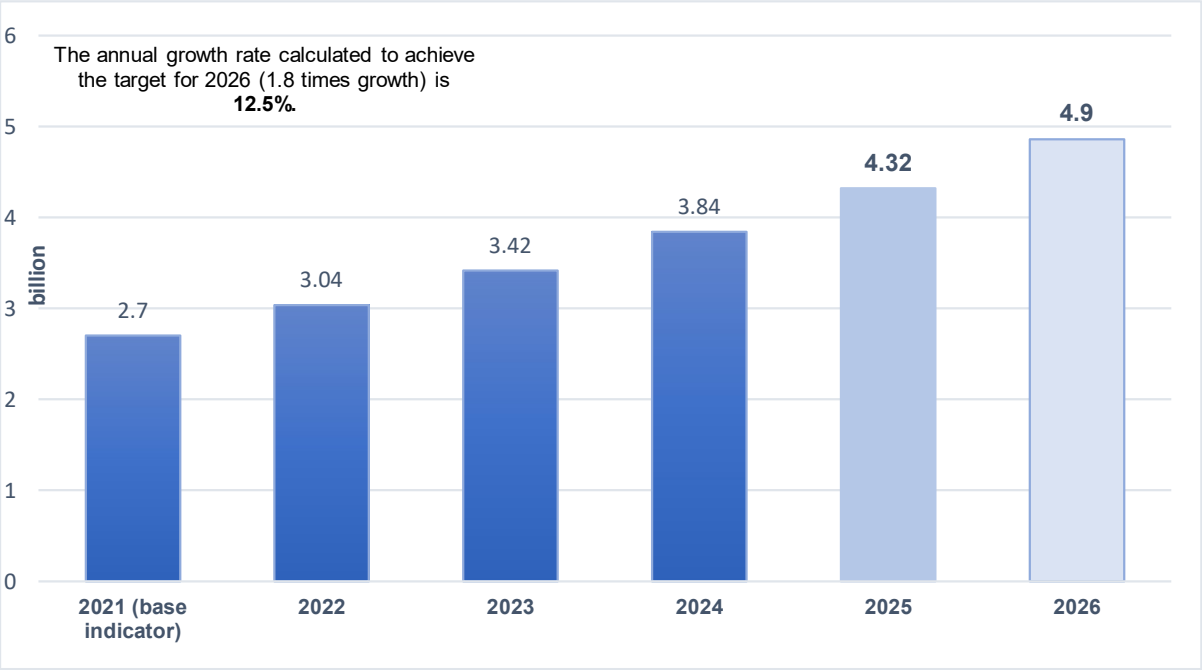
Azerbaijan possesses the largest economy in the South Caucasus, primarily due to its substantial energy resources. The monetization of energy revenues through monetary and fiscal channels has enabled the country's non-oil and gas sector to surpass those of other regional economies in scale. However, the economy remains highly dependent on revenues generated from crude oil, petroleum products, and natural gas exports, posing a significant risk to macroeconomic stability and long-term economic resilience.

Despite the prioritization of an "import substitution" policy in the Strategic Roadmap on the National Economy and Key Sectors, adopted in 2016, the Azerbaijan 2030: National Priorities for Socio-Economic Development strategy, approved in 2021, shifted focus towards an "export-oriented growth" model through integration into global value chains. Collectively, both strategic frameworks aim to reduce the dominance of hydrocarbon revenues while fostering an increase in earnings from non-oil and gas exports and enhancing product diversification.

The economic vulnerabilities stemming from resource dependency and limited diversification were starkly highlighted by the exchange rate devaluations of 2015–2016,

which posed a considerable threat to Azerbaijan's macroeconomic stability. In response, the Strategic Roadmap for the National Economy set an ambitious target of increasing non-oil and gas exports to $450 per capita by 2025, aiming to mitigate external shocks through export diversification. However, the structural disruptions induced by the COVID-19 pandemic in 2020 necessitated a recalibration of economic priorities. Consequently, the Azerbaijan 2030: National Priorities for Socio-Economic Development strategy redefined the country's export trajectory, setting a revised target of $4.9 billion in non-oil and gas exports by 2026. This strategic shift underscores the government's commitment to enhancing economic resilience through deeper integration into global value chains and a more diversified export base

Diagram 2: Azerbaijan's economic growth targets until 2026



Data source: Azerbaijan's economic growth targets until 2026

The Azerbaijan 2030: National Priorities for Socio-Economic Development strategy outlines clear objectives for achieving economic growth; however, it lacks explicit indicators for export diversification. While the strategy highlights an export-led growth model for the country's economic development, it emphasizes the need for measures to promote the export of high value-added goods without specifying concrete actions or performance metrics.

Analysis of the total trade turnover between Azerbaijan and China

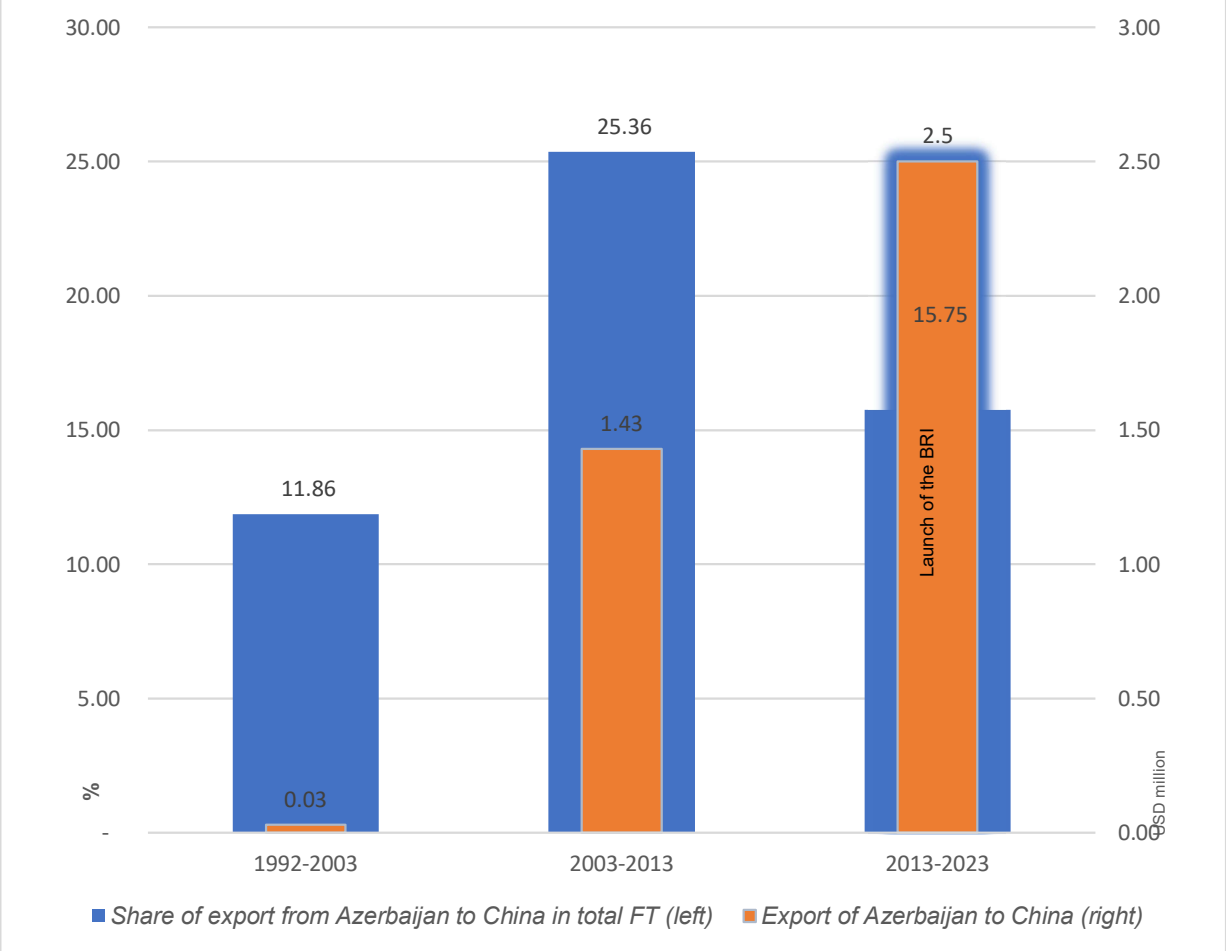
The low level of diversification in Azerbaijan's overall exports is also reflected in its trade relations with China. Over the past 31 years, the foreign trade turnover between Azerbaijan and China followed a positive trend. The main driving force behind this has been the increasing pace of exports from China to Azerbaijan. Due to the low diversification of Azerbaijan's exports, however, these trade relations exhibit a volatile nature. Between 1992

and 2023, Azerbaijan imported a wide range of goods from China, covering various sectors of the economy.

Trade relations between the two countries began in 1992. Over the past 31 years, the foreign trade turnover between Azerbaijan and China followed an upward trend. The main factor behind this positive development has been the rapid growth of exports from China to Azerbaijan. During this period, Azerbaijan's exports to China have been volatile, primarily consisting of crude oil, oil products, and inorganic chemical products.

Between 1992 and 2023, the total foreign trade turnover between China and Azerbaijan amounted to $22 billion. China's exports accounted for US$18 billion of the total trade volume, while Azerbaijan's exports amounted to US$4 billion. Over this period, Azerbaijan's average annual exports to China stood at US$124.8 million, whereas its average annual imports from China reached US$562.6 million.

Diagram 3: Azerbaijan's exports to China and the share of exports in foreign trade turnover, %



Data source: State Statistics Committee

Azerbaijan's exports to the People's Republic of China first surpassed the two-million US$ threshold in 1995, with raw cotton accounting for 98.5% of total exports that year. The entry of domestic chemical industry products into the Chinese market began in 1997. By 2000, Azerbaijan was exporting goods from 10 different sectors to China, increasing trade volume to US$4.9 million. Overall, Azerbaijan's exports to China have consistently exhibited low diversification.

Over the past 28 years, crude oil has constituted the dominant share of Azerbaijan's exports to China, with the first shipment recorded in 2003. That year, exports more than doubled compared to 2002, reaching US$20 million, primarily due to crude oil exports. From 2003 to 2023, the trade trajectory of crude oil has played a decisive role in shaping Azerbaijan's export flows and has directly contributed to the increase in China's import volume

Table 1: Azerbaijan's oil products exports to China, million US$

Years	Total export	Oil products			Specific weight of petroleum products in total exports
		Crude oil	Kerosene fuel	Petroleum coke	
2012	183,8	159,8	1,6	-	87,8
2013	88,6	47,8	1,01	-	55,0
2014	63,9	-	1,9	-	3,0
2015	53,2	-	0,9	-	1,5
2016	382,02	349,7	0,2	-	91,5
2017	443,8	418,2	0,3	-	94,3
2018	113,6	75,5	1,3	-	67,6
2019	752,2	714,1	0,7	-	95,0
2020	432,8	386,3	0,5	1,5	89,7
2021	141,1	102,6	0,09	4,5	76,0
2022	72,8	-	0,9	38,5	54,1
2023	78,7	-	0,8	46,5	60,0

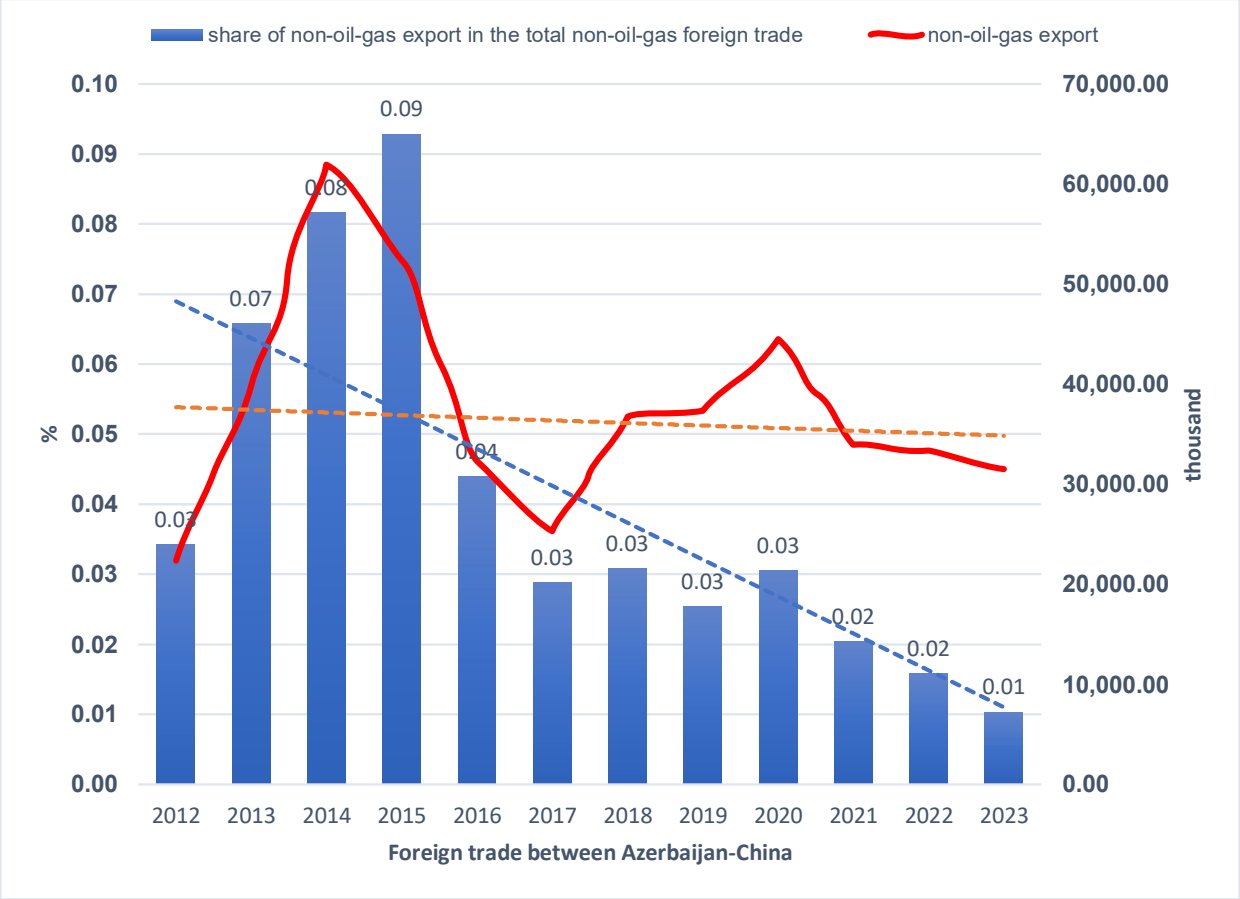
Data source: State Statistics Committee of Azerbaijan

Despite the substantial overall trade volume between Azerbaijan and China, non-oil and gas trade remains relatively low. A significant portion of Azerbaijan's non-oil and gas exports to China consists of chemical industry products. Between 2013 and 2023, the total non-oil and gas trade turnover between the two countries amounted to US$14.6 billion, which is US$2.2 billion lower than the total trade volume.

According to statistics from the last decade, Azerbaijan's non-oil and gas exports to China averaged US$39 million US$ annually, demonstrating a downward trend. During this period, the share of non-oil and gas exports in the bilateral trade turnover averaged merely 0.04%. This marginal contribution is primarily attributable to the substantial volume of imports from China, which significantly outweighs Azerbaijan's non-oil and gas export levelAzerbaijan's non-oil and gas exports to China have exhibited a declining trend over the past decade. As illustrated in Table 2, between 2012 and 2023, the export of plastics and articles thereof, chemical products, as well as alcoholic and non-alcoholic beverages, remained relatively consistent. In contrast, the export frequency of other non-oil and gas products, such as iodine, licorice extract, and leather products, was comparatively lower. Moreover, no sustained pattern was observed in the export of other non-oil and gas goods during this period.

Table 2 further highlights that Azerbaijan's export composition to the Chinese market is characterized not only by a strong concentration in oil and petroleum products but also by the limited diversification of non-oil and gas exports. Overall, Azerbaijan's non-oil and gas exports to China lack stability, reflecting inconsistencies in both product variety and trade continuity.

Diagram 4: Share of non-oil and gas exports in total non-oil and gas foreign trade



Data source: Author's calculation based on data from the State Statistics Committee

Table 2: Non-oil and gas goods by export frequency

		Non-oil-gas products, thousand US dollars						
		Export intensity by time interval						
		1	0.9	1	0.73	1	0.82	
Years	**Non-minerals**	**Plastics and articles thereof (Polyethylene in primary form with a specific gravity of less than 0.94)**	**Organic chemicals (especially iodine)**	**Inorganic chemicals (especially iodine)**	**Leather**	**Alcoholic and non-alcoholic beverages**	**Licorice juice and extract**	**Share of non-oil and gas products in total exports, %**
2012	22 341	12 392,1	3 235	1 833,9	-	111,3	-	78,7%
2013	39 864	27 987	2 569	4 075,5	900	101,2	-	89,4%
2014	61 931	44 542	3 343	2 523,3	7 426,3	35	2 202,7	93,4%
2015	52 376	44 164	2 352	778,14	2 736,9	46	1904	99,2%
2016	32 291	23 760,59	1 638	1 834,77	1 289,21	316	425	90,6%
2017	25 299	19 350	860	3 465,12	126	629,8	425	98,2%
2018	36 772	27 232,39	757	589,06	966	437,6	398,52	82,6%
2019	37 301	28 769,38	500	232,3	681,8	569,3	768,55	84,5%
2020	44 469	38 506,29	1 071	1 285,93	-	536,7	631,75	94,5%
2021	33 933	28 248,50	-	744,5	127	533,9	923,86	90,1%
2022	33 385	28 877	846	1 120,19	-	166,5	-	92,9%
2023	31 482	20 223,64	5 652	570,1	-	183,5	868,15	87,3%

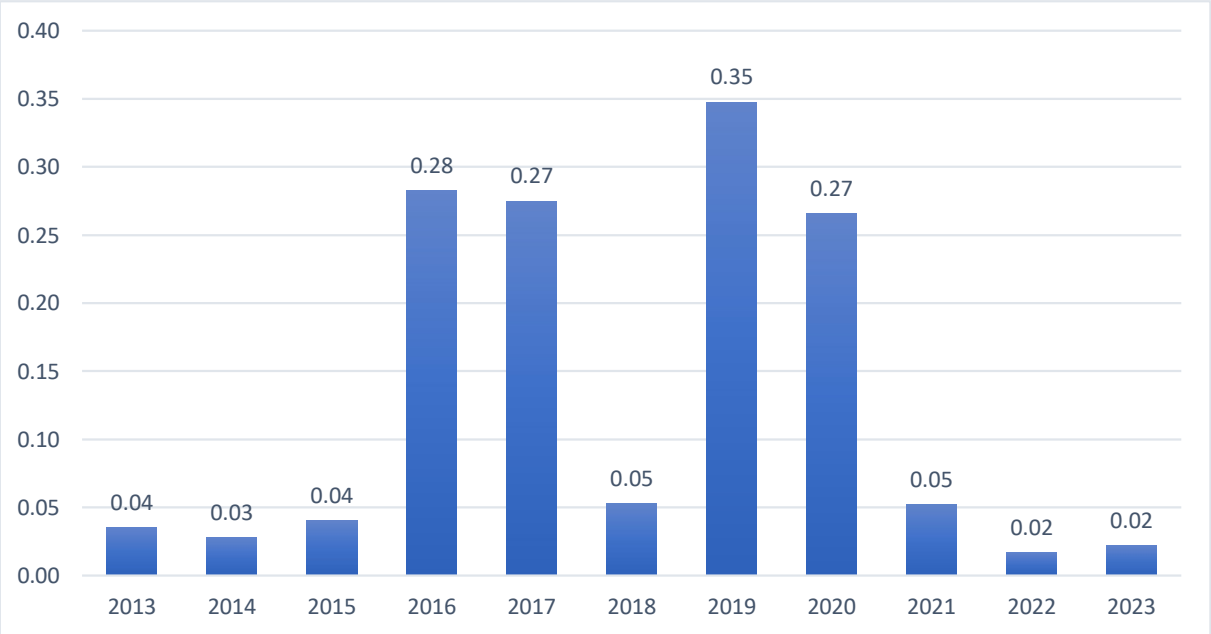
Data source: State Statistics Committee of Azerbaijan

Critical Challenges in Azerbaijan's Exports to China

Limited trade dynamism. Although the People's Republic of China has demonstrated a positive growth trend in its exports to Azerbaijan, a similar upward trajectory is not evident in Azerbaijan's exports to China. In general, the intensity and dynamism of Azerbaijani goods within the Chinese market are relatively low. This is primarily attributable to the absence of a consistent and sustainable export momentum for "Made in Azerbaijan" products. According to relevant trade statistics, there is a marked fluctuation in both the export of oil and petroleum products, as well as non-oil exports. Specifically, non-oil exports from Azerbaijan to China exhibited an average annual growth rate of 30.9% from 2012 to 2014, followed by a decline of 25.1% between 2015 and 2017, a subsequent increase of 22% from 2018 to 2020, and a decline of 10.3% from 2021 to 2023. Notably, the sharp drop in crude oil prices in 2015, compounded by the global demand contraction and disruptions in value and supply chains triggered by the COVID-19 pandemic in 2020, led to a contraction in the national economy of Azerbaijan, a decrease in the competitiveness of industrial goods, and the loss of traditional markets.

The dynamics of the past decade indicate that trade intensity in Azerbaijan's exports to China remains low. According to the index results, between 2013 and 2023, Azerbaijan and China have not been significant partners in global trade relative to their respective shares. In other words, Azerbaijan allocates a relatively small portion of its total exports to China, while China also assigns limited importance to Azerbaijan in its overall imports.

Diagram 5: Trade intensity index between Azerbaijan and China[28]



Data source: Author's calculations derived from World Bank data

28 TII index of less than 1 indicates that trade relations between Azerbaijan and China are relatively weak compared to other countries and that these countries have a low position in world trade. This situation also indicates that the economic structures and trade priorities of the two countries have not yet been fully consolidated in world markets. In some cases, this may reflect a situation where economic relations are not yet developed or are strategically focused on certain product groups. Low trade intensity may also indicate weak economic diplomacy, logistical and infrastructure deficiencies, or political and economic obstacles.

Inadequate Export Diversification. There is substantial scholarly research regarding the weak diversification of Azerbaijan's exports. Based on the findings of Mohsen Bahmani-Oskooee and Rustam Jamilov, the relationship between Azerbaijan's trade balance and exchange rate fluctuations has been examined through the S-curve effect, highlighting the sensitivity of Azerbaijan's non-oil sector to exchange rate policies. Overall, the need to minimize risks such as devaluation through increased export diversification has been emphasized. Additionally, several scientific articles by Vugar Bayramov underline Azerbaijan's dependence on resources and the low level of diversification in its exports.

Empirical research confirms that the weak diversification of Azerbaijan's exports is evident in its trade relations with China. The significant share of crude oil, oil products, and certain non-oil exports, with a frequency of over 75%, substantiates this conclusion. The following sections of the paper will mathematically analyze Azerbaijan's export diversification index towards China.

Due to the weak diversification of its exports, Azerbaijan's actual export commodities are unable to solidify their presence in both medium- and long-distance markets. In other words, the real export performance of the nation is consistently below its potential indicators. According to research conducted by the International Trade Centre (ITC), a significant portion of Azerbaijan's non-oil and gas exports to the Chinese market remains far below their potential levels. For instance, despite existing demand for products such as copper ores and concentrates, unrefined gold, and cathodes of refined copper, no export operations have materialized. The analysis conducted by the International Trade Centre (ITC) evaluates Azerbaijan's export potential in conjunction with China's import capacity, tariff structures, and a range of other pertinent factors.

Concentration of raw and semi-finished products. A significant portion of Azerbaijan's exports to international trade partners consists of raw and intermediate products. Specifically, crude oil and oil products, as well as chemicals and plastic industry goods, fall within the category of raw and intermediate products. These intermediate goods are typically used in the export of low- and medium-complexity products.

According to the data presented in Diagram 6, the concentration of intermediate products in Azerbaijan's exports during the periods of 2013–2015 and 2022–2023 remained relatively low, primarily due to the decline in the export volume of crude oil and oil products. Moreover, given that a significant portion of non-oil and gas sector products fall under the semi-finished category, no fundamental changes in the overall export structure have been observed.

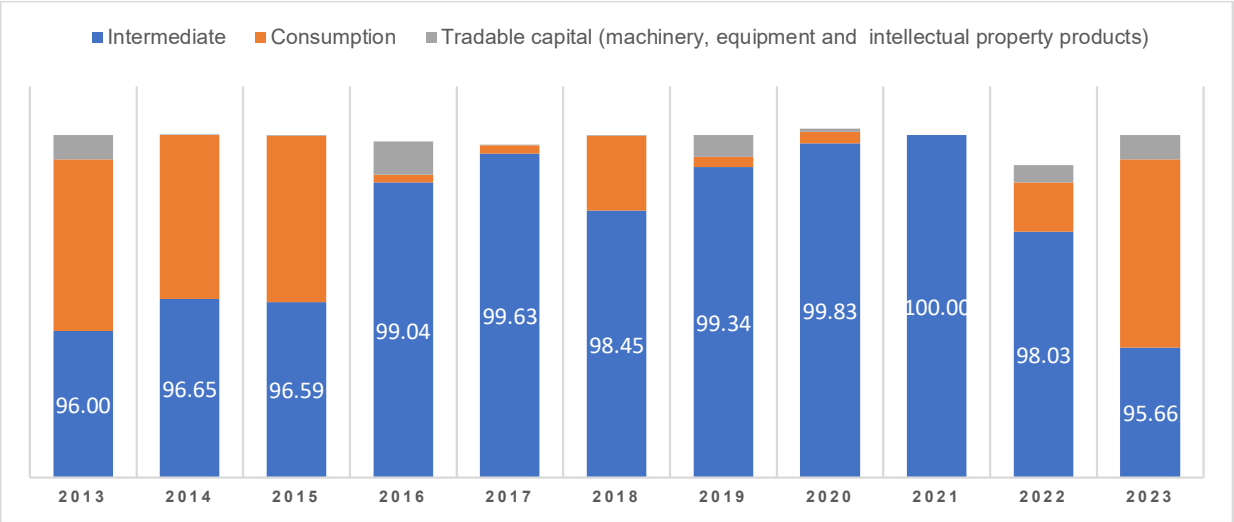
Overall, the analysis of export composition reveals that the low diversification and complexity of semi-finished products stand as one of the key structural factors limiting Azerbaijan's sustainable and resilient export potential to the Chinese market. In this context, increasing the share of high-value-added intermediate goods in the export portfolio and integrating the non-oil sector into more complex production chains is strategically crucial for enhancing economic resilience and strengthening market positions.

Table 3: Potential exports of Azerbaijan's key non-oil and gas goods to Chinese markets

Product	Export potential	Actual exports	Unrealized potential remaining	China's imports	Azerbaijan's exports	China's average applied tariff to Azerbaijan %
Gold, unwrought, for non-monetary purposes	9,2 mn	0	9,2 mn	44 bn	183 mn	0
Methanol	8,4 mn	176 k	8,2 mn	3.4 bn	96 mn	5.5
Copper ores & concentrates	2.7 mn	0	2.7 mn	52 bn	19 mn	0
Copper cathodes	1.2 mn	0	1.2 mn	30 bn	11 mn	2.0
Aluminium, unwrought	1.4 mn	0	1.4 mn	2.6 bn	53 mn	5.0
Polypropylene, in primary forms	3.1 mn	137 k	3 mn	3.3 bn	104 mn	6.5
Cotton, not carded/combed	3.5 mn	327 k	3.1 mn	4.2 bn	159 mn	20.0
Spirits obtained by distilling grape wine	599 k	14 k	586 k	1.5 bn	7.1 mn	10.0
Aluminium alloys, unwrought	849 k	0	849 k	2.4 bn	37 mn	7.0
Propylene copolymers, in primary forms	1.8 mn	132 k	1.7 mn	2 bn	57 mn	6.5
Single yarn, >=85% cotton	356 k	0	356 k	2 bn	7.7 mn	5.0
Fruits, fresh, n.e.s.	6.8 mn	0	6.8 mn	1.2 bn	158 mn	20.89
Plates of aluminium alloys, rectangular	569 k	0	569 k	1.1 bn	50 mn	6.0
Cement clinkers	553 k	0	553 k	568 mn	35 mn	5.0
Float & polished glass, in non-wired sheets, n.e.s.	345 k	0	345 k	507 mn	13 mn	10.0
Cotton seeds	398 k	0	398 k	158 mn	4.5 mn	7.40
Single yarn, >=85% cotton, uncombed fibres	339 k	0	339 k	168 mn	18 mn	5.0
Peaches & nectarines, fresh	394 k	0	394 k	84 mn	34 mn	10.0
Plates of aluminium, rectangular	420 k	0	420 k	58 mn	32 mn	6.0
Hazelnuts, shelled	1.3 mn	0	1.3 mn	26 mn	118 mn	10.0

Data source: International Trade Cente

Diagram 6: Structure of Azerbaijan's export basket to China



Data source: Author's calculation based on data from the State Statistics Committee

Low Product Complexity in the Export Composition. According to the "Atlas Economic Complexity" index data for the period 1995–2021, the complexity level of Azerbaijan's exported products has shown a downward trend. This is primarily attributed to the reliance of semi-finished goods within the export composition on fluctuating oil and natural gas prices, limited integration within global value chains, a constrained capacity for generating added value, and a relatively low degree of sophistication. In 2022, Azerbaijan ranked 131st out of 145 countries in terms of product complexity, as per the "Atlas Economic Complexity" index. This ranking reflects the absence of advanced processing in the majority of Azerbaijan's export products, the limited capacity to generate added value, the exclusion from high-tech manufacturing processes, and the minimal application of innovative components. These factors underscore that Azerbaijan's export structure remains largely dependent on raw materials and minimally processed goods, creating inherent limitations in terms of competitiveness in international markets and the sustainability of long-term economic resilience.

An evaluation of Azerbaijan's key exports to China from 2012 to 2023, based on the "Atlas Economic Complexity" index's product sophistication ranking (Table 4), reveals that the majority of these products occupy lower positions in the index. Moreover, the complexity of Azerbaijan's exports has further diminished in comparison to previous years. Among these, copper bars and profiles rank higher in terms of sophistication, whereas crude oil occupies the lowest tier in the index. Notably, exports of copper bars and profiles to China were only recorded during the 2018–2019 period, while crude oil consistently dominates as the leading export product in terms of both frequency and share. Thus, Azerbaijan's capacity to supply the Chinese market with products of higher complexity remains markedly limited.

The downward trend in the complexity of Azerbaijan's exports, as illustrated in Diagram 7, is further reinforced by the data presented in Table 4. Undoubtedly, this existing trend represents a significant threat to the diversification of Azerbaijan's exports. The substantial deviation from the median indicators of global economies diminishes Azerbaijan's

potential as a supplier of contemporary products in both medium and long-term periods. In other words, opportunities to integrate into the raw material and semi-finished goods chains for products advanced by other countries are weakening.

Table 4: Assessment of the level of complexity of Azerbaijan's exports to the Chinese market by main products in 2012-2023

Rank (1-1224)	HS Code	Product	Product Complexity Index (PCI)
904	2710	Petroleum oils and oils obtained from bituminous minerals, other than crude;	-0.66
991	2713	Petroleum coke, petroleum bitumen and other residues of petroleum oils or of oils obtained from bituminous minerals	-0.932
1216	2709	Petroleum oils and oils obtained from bituminous minerals, crude	-2.53
949	2810	Oxides of boron; boric acids	-0.814
534	3901	Polymers of ethylene, in primary forms	0.267
967	5211	Woven fabrics of cotton, containing less than 85 percent by weight of cotton, mixed mainly or solely with man-made fibers, weighing more than 200 g/m2	-0.864
716	2905	Acyclic alcohols and their halogenated, sulfonated, nitrated or nitrosated derivatives	-0.194
1081	4104	Tanned or crust hides and skins of bovine (including buffalo) or equine animals, without hair on, whether or not split, but not further prepared	-1.28
571	1806	Chocolate and other food preparations containing cocoa	0.186
833	2204	Wine of fresh grapes, including fortified wines; grape must other than that of heading 2009	-0.494
1009	2402	Cigars, cheroots, cigarillos and cigarettes, of tobacco or of tobacco substitutes	-1.01
1034	1302	Vegetable saps and extracts; pectic substances, pectinates and pectates; agar-agar and other mucilages and thickeners, whether or not modified, derived from vegetable products	-1.1
490	7407	Copper bars, rods and profiles	0.365

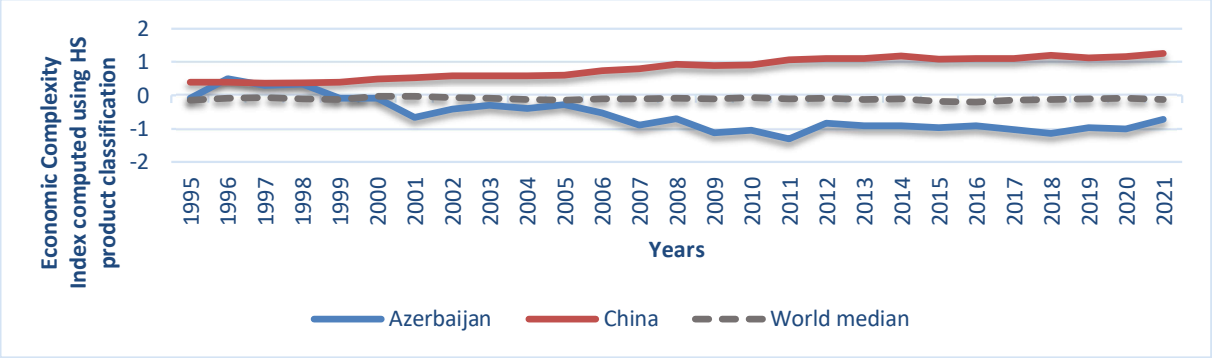
Data source: The Atlas of Economic Complexity is part of Harvard's Growth Lab Viz Hub

In comparison to Azerbaijan's trade structure, the high level of diversification and complexity (sophistication) in the Chinese economy is clearly observable in the presented diagram. The positive dynamics observed in high-tech products and those based on complex value chain integration have led to increased demand for new types of semi-finished products in China, making it one of the key directions for industrial development. Particularly, sectors such as technology, electronics, and automation serve as the main determinants of this rising demand, stimulating the expansion of high-value-added production.

Some of the potential semi-finished products presented in Table 3 could significantly contribute to the growth trajectory of China's complex value chain integration, enhancing its production and trade structure. In this context, the limited diversification and complexity levels

of medium-stage industrial products in Azerbaijan's export portfolio are considered one of the key challenges hindering the country's deeper integration into global value chains.

Diagram 7: Economic Complexity Index computed using SITC product classification



Data Source: Atlas of Economic Complexity - Country Complexity Rankings

Model and Statistical Data

Considering the literature review and the specific characteristics of the national economy, the impact of China-Azerbaijan foreign trade relations on Azerbaijan's overall exports, as well as the influence of several fundamental factors on Azerbaijan's exports to China, has been assessed using the following equation:

$$AzExp_{total} = \alpha_0 + \alpha_1 ExpChina_t + \alpha_2 ImpChina_t + \alpha_3 ChinaGrowth_{t,\ (demand\ factor)} + \alpha_4 Reer_t + \varepsilon_{1t} \quad (1)$$

$$ChinaExp_{total} = \beta_0 + \beta_1 ImpofAz_t + \beta_2 ChinaGrowth_{t,\ (demand\ factor)} + \beta_4 Reer_t + \varepsilon_{2t} \quad (2)$$

Here, $AzExptotal$ represents Azerbaijan's total exports, $ExpChina_t$ denotes Azerbaijan's exports to China, $ImpChina_t$ refers to Azerbaijan's imports from China, $ChinaGrowth_t$ is the economic growth index of China, $Reer_t$ is the real effective exchange rate, $ImpofAz_t$ indicates Azerbaijan's imports, and μ_t is the error term. The coefficients β_1, β_2, β_3 and β_4 correspond to the variables in the model. As can be seen from the equation, the analysis will be conducted based on two models.

The primary objective of the conducted evaluation is to determine whether there exists a causal relationship between Azerbaijan's total exports and foreign trade with China (1), as well as between Azerbaijan's exports to China and its imports (2). Considering the scope of the research, the analysis focuses on Azerbaijan's foreign trade relations with China and the factors affecting its exports to China. Since a strong correlation was observed between Azerbaijan's exports and monthly Brent crude oil prices, the latter was excluded from the model. The evaluation was conducted using monthly data for the period from 2010 to 2023, with all variables first seasonally adjusted using the Census (X-11) method, followed by subsequent analysis. All indicators are based on data from official sourc

Table 5: Indicators used in the assessment

Variable	The characteristic of the model.	Simvol	Source
Azerbaijan`s total exports	Given the substantial share of oil and oil products in Azerbaijan's exports to China, the model employs the country's total exports. The primary aim of the model is to determine the causal relationship between Azerbaijan's total exports and its trade turnover (both exports and imports) with China.	$AzExp_{total}$	State Statistics Committee of Azerbaijan
Azerbaijan`s imports	The model includes this variable in order to measure the impact on Azerbaijan's exports to China.	*ImpAz*	State Statistics Committee of Azerbaijan
Azerbaijan`s exports to China	The variable has been included in the model both as an independent and dependent variable to establish the causal relationship.	*ExpChina*	State Statistics Committee of Azerbaijan
Azerbaijan`s imports from China	It has been included to establish the causal relationship between Azerbaijan's total exports and exports to China.	*ImpChina*	State Statistics Committee of Azerbaijan
Economic growth of China	It has been included as a demand factor in the model.	*Chinagrowth*	National Bureau of Statistics of China
Azerbaijan and China weighted real exchange rate	The exchange rate factor has been included in the model to assess its impact on the foreign trade turnover between Azerbaijan and China.	*ChinaREER*	Central Bank of Azerbaijan
Dummy variables	The model accounts for the impacts of periods such as the COVID-19 pandemic observed in 2020 and the devaluations recorded in 2015 to assess their effects.	*Dummy*	

Table 6 presents the descriptive statistics of all variables. Based on the test results, the p-value of the Jarque-Bera test statistic is greater than 0.05, and thus, the null hypothesis (H0) was not rejected. For all other variables, the p-values were less than 0.05, leading to the rejection of H0 and concluding that the variables do not follow a normal distribution. Therefore, taking the natural logarithm of the variables and continuing the analysis will allow for more robust results from both statistical and econometric perspectives.

Table 6: Descriptive Statistics of Variables

	$AzExp_{total}$	*ImpAz*	*ExpChina*	*ImpChina*	*ChinaREER*	*Chinagrowth*
Mean	11507844	5560196.	133128.5	571891.3	76.13626	112.9612
Median	9929567.	5158166.	54463.07	424434.4	72.83329	110.8757
Maximum	38146684	17285345	752162.6	3022811.	102.8761	136.5771
Minimum	657076.2	364000.2	1593.800	24382.05	53.49289	80.08526
Std. Dev.	8084601	3582873.	176301.5	531295.3	17.24399	14.85771
Skewness	0.907587	0.641622	1.916350	1.977186	0.245640	-0.125400
Kurtosis	3.513697	3.001307	6.115442	7.668477	1.362767	2.242215
Jarque-Bera	24.91121	11.52703	170.7690	262.0222	20.45321	4.459965
Probability	0.000004	0.003140	0.000000	0.000000	0.000036	0.107530

In Table 7, a negative relationship is observed between Azerbaijan's total exports and exports to China, while a positive relationship exists with imports. Furthermore, a positive correlation is noted between total trade with China (exports and imports), while a negative relationship is observed between imports from China and China's economic growth. A positive relationship is found between Azerbaijan's exports and the weighted real effective exchange rate of China, whereas a negative relationship is observed with exports to China.

Table 7: Model 1.

	AzExptotal	**ExpChina**	**ImpChina**	**Chinagrowth**	**ChinaREER**
AzExptotal	1	-0.21	0.47	-0.34	0.54
ExpChina	-0.21	1	0.22	-0.43	-0.35
ImpChina	0.47	0.22	1	-0.54	-0.39
Chinagrowth	-0.34	-0.43	-0.54	1	0.08
ChinaREER	0.54	-0.35	-0.39	0.08	1

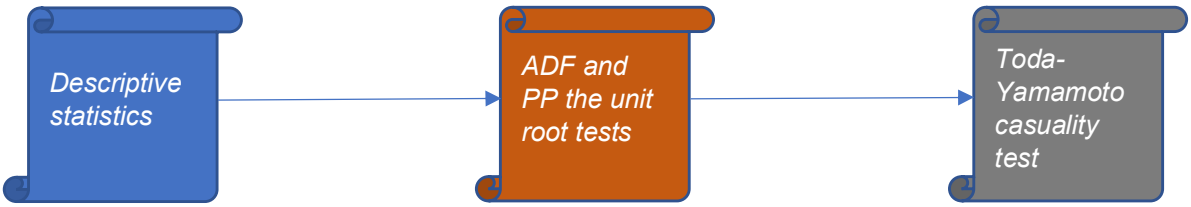
Table 8: Model 2.

Symbols	ExpChina	ImpAz	Chinagrowth	ChinaREER
ExpChina	1	0.05	-0.43	-0.35
ImpAz	0.05	1	-0.28	-0.23
Chinagrowth	-0.43	-0.29	1	0.08
ChinaREER	-0.35	-0.23	0.08	1

Methodology

This section provides an overview of the econometric techniques employed in the study. As depicted in Figure 1, the first step involves the presentation of descriptive statistics of the variables to assess their properties, normality, and overall suitability for the analysis. Following this, the stationarity of the variables is tested using the Augmented Dickey-Fuller (ADF) (1981) and Phillips-Perron (PP) (1988) unit root tests. Upon confirming the stationarity of the variables, the Toda-Yamamoto (TY) causality test is conducted to examine the causal relationships among the variables under consideration.

Picture 1: Econometric methodology sequence



Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) unit root tests

The stationarity of the variables plays a critical role in the context of the present study. In the theoretical literature, there are various unit root tests available to assess whether the given variables exhibit a unit root, and these tests continue to evolve and develop over time. Unit root tests are fundamental in the specification of causality models. For the purposes of this research, both the Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) unit root tests will be employed. The regression model for the ADF test, applied to the selected variables in this study, is outlined as follows:

Augmented Dickey-Fuller (ADF)	*None*	$\Delta\ LnAzExp_{total} = \varphi\ LnAzExp_{total\ t-1} + \varepsilon_t$;
		$\Delta\ LnChinaREER = \varphi\ LnChinaREER_{t-1} + \varepsilon_t$
	Intercept	$\Delta\ LnExpChina = \beta_0 + \varphi\ LnExpChina_{t-1} + \varepsilon_t$;
		$\Delta\ LnChinagrowth = \beta_0 + \varphi\ LnChinagrowth_{t-1} + \varepsilon_t$
	Intercept and trend	$\Delta\ LnImpChina = \beta_0 + b_t + \varphi\ LnImpChina_{t-1} + \varepsilon_t$
		$\Delta\ LnImpAz = \beta_0 + b_t + \varphi\ \Delta\ LnImpAz_{t-1} + \varepsilon_t$

In each regression model of the ADF test, if the test statistic calculated based on a single lag of the dependent variable's level exceeds the critical values, the null hypothesis is rejected. The second most commonly used unit root test in theoretical literature and empirical research is the Phillips-Perron (1988) unit root test. The regression model for the PP unit root test is presented below:

$$\boldsymbol{Y_t = \lambda + \acute{a}y_{t-1} + u_t}$$

$$\boldsymbol{Y_t = \lambda + \delta\ (t - 1/2\xi) + \acute{a}y_{t-1} + u_t}$$

As in the ADF unit root test, in the PP test, if the test statistic calculated based on a single lag of the variables exceeds the critical values in absolute terms, the null hypothesis (H_0) will be rejected.

As an alternative to large-scale macro-econometric models, the Vector Autoregressive (VAR) model was first introduced by Sims (1960). VAR analysis is widely employed by applied researchers to examine the validity of economic theories and to provide policy recommendations. After analyzing variables that are stationary at the first difference using the VAR model, the traditional F-statistic is commonly used in Granger causality tests. However, the distinct feature of the Toda-Yamamoto (TY, 1995) test is its ability to investigate short-term causality relationships even when one of the variables has a unit root while the other remains stationary (Mert, Çağlar).

To conduct the Toda-Yamamoto (TY, 1995) test, it is recommended to estimate a VAR model of order *(k + dmax).* Here, k represents the optimal lag length that satisfies stability conditions, while *dmax* denotes the maximum order of integration of the variables included in the model. For example, if *x ~ I(0) and y ~ I(1), then dmax = 1; if x ~ I(1)* and *y ~ I(2)*, then *dmax = 2*; and if *x ~ I(0)* and *y ~ I(2)*, then *dmax = 2*. The prior determination of *k* and *dmax* is crucial for the implementation of the TY (1995) test, as the accuracy of causality analysis depends on the correct specification of these two parameters. The Toda-Yamamoto (1995) causality test equation for any given variables x and y is formulated as follows:

$$y_t = \delta_0 + \sum_{i=1}^{k+dmax} \alpha_i * y_{t-i} + \sum_{i=1}^{k+dmax} \theta_i * x_{t-i} + e_{1t}$$

$$x_t = \delta_1 + \sum_{i=1}^{k+dmax} \gamma_i * x_{t-i} + \sum_{i=1}^{k+dmax} \varphi_i * y_{t-i} + e_{2t}$$

Here, it is assumed that the error terms e_{1t} and e_{2t} are free from autocorrelation.

$$\begin{bmatrix} Azexp \\ Expchina \\ ImpChina \\ Chinagrowth \\ ChinaREER \end{bmatrix} = \begin{bmatrix} \alpha_1 \\ \alpha_2 \\ \alpha_3 \\ \alpha_4 \\ \alpha_5 \end{bmatrix} + \sum_{i=1}^{k} \begin{bmatrix} \beta_{1i} & \theta_{1i} & \lambda_{1i} & \nu_{1i} & \kappa_{1i} \\ \beta_{2i} & \theta_{2i} & \lambda_{2i} & \nu_{2i} & \kappa_{2i} \\ \beta_{3i} & \theta_{3i} & \lambda_{3i} & \nu_{3i} & \kappa_{3i} \\ \beta_{4i} & \theta_{4i} & \lambda_{4i} & \nu_{4i} & \kappa_{4i} \\ \beta_{5i} & \theta_{5i} & \lambda_{5i} & \nu_{5i} & \kappa_{5i} \end{bmatrix} \begin{bmatrix} Azexp_{t-i} \\ Expchina_{t-i} \\ ImpChina_{t-i} \\ Chinagrowth_{t-i} \\ ChinaREER_{t-i} \end{bmatrix} +$$

$$\sum_{i=1}^{k+d_{max}} \begin{bmatrix} \varphi_{1j} & \theta_{1j} & \omega_{1j} & \varkappa_{1j} & \gamma_{1j} \\ \varphi_{2j} & \theta_{2j} & \omega_{2j} & \varkappa_{2j} & \gamma_{2j} \\ \varphi_{3j} & \theta_{3j} & \omega_{3j} & \varkappa_{3j} & \gamma_{3j} \\ \varphi_{4j} & \theta_{4j} & \omega_{4j} & \varkappa_{4j} & \gamma_{4j} \\ \varphi_{5j} & \theta_{5j} & \omega_{5j} & \varkappa_{5j} & \gamma_{5j} \end{bmatrix} \begin{bmatrix} Azexp_{t-j} \\ Expchina_{t-j} \\ ImpChin_{t-j} \\ Chinagrowth_{t-j} \\ ChinaREER_{t-j} \end{bmatrix} + \begin{bmatrix} \varepsilon_1 \\ \varepsilon_2 \\ \varepsilon_3 \\ \varepsilon_4 \\ \varepsilon_5 \end{bmatrix} \textit{(1)}$$

$$\begin{bmatrix} Expchina \\ ImpAz \\ Chinagrowth \\ ChinaREER \end{bmatrix} = \begin{bmatrix} \alpha_1 \\ \alpha_2 \\ \alpha_3 \\ \alpha_4 \end{bmatrix} + \sum_{i=1}^{k} \begin{bmatrix} \beta_{1i} & \theta_{1i} & \lambda_{1i} & \nu_{1i} \\ \beta_{2i} & \theta_{2i} & \lambda_{2i} & \nu_{2i} \\ \beta_{3i} & \theta_{3i} & \lambda_{3i} & \nu_{3i} \\ \beta_{4i} & \theta_{4i} & \lambda_{4i} & \nu_{4i} \end{bmatrix} \begin{bmatrix} Expchina_{t-i} \\ ImpA_{t-i} \\ Chinagrowth_{t-i} \\ ChinaREER_{t-i} \end{bmatrix} +$$

$$\sum_{i=1}^{k+d_{max}} \begin{bmatrix} \varphi_{1j} & \theta_{1j} & \omega_{1j} & \gamma_{1j} \\ \varphi_{2j} & \theta_{2j} & \omega_{2j} & \gamma_{2j} \\ \varphi_{3j} & \theta_{3j} & \omega_{3j} & \gamma_{3j} \\ \varphi_{4j} & \theta_{4j} & \omega_{4j} & \gamma_{4j} \end{bmatrix} \begin{bmatrix} Expchin_{t-j} \\ ImpAz_{t-j} \\ Chinagrowth_{t-j} \\ ChinaREER_{t-j} \end{bmatrix} + \begin{bmatrix} \varepsilon_1 \\ \varepsilon_2 \\ \varepsilon_3 \\ \varepsilon_4 \end{bmatrix} \textit{(2)}$$

To conduct the Granger causality test within the VAR model, the Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) unit root tests were performed. According to the ADF test results, Azerbaijan's exports and imports, Azerbaijan's imports from China, the real effective exchange rate between the national currencies of Azerbaijan and China, and China's economic growth indicator were found to be first-order stationary in both the constant-only and constant-with-trend models. However, Azerbaijan's exports to China were identified as having a unit root at level in both specifications, implying that this variable is *I(0)* based on the ADF test results. Overall, since the stationarity condition at the first difference was not satisfied, conducting the Granger causality test within the VAR framework was not feasible. As previously mentioned, since the TY (1995) test allows for causality analysis between variables integrated at *I(0)* and *I(1)* levels, the necessary conditions for its application were met. Similarly, the PP test results indicated that Azerbaijan's exports and imports, Azerbaijan's imports from China, the weighted real effective exchange rate between China and Azerbaijan, and China's economic growth indicator were first-order stationary in both constant-only and constant-with-trend models, whereas Azerbaijan's exports to China were identified as non-stationary at level in both specifications. Consequently, based on both the ADF and PP unit

root test results, the model exhibited integration properties at both *I(0)* and *I(1)* levels, confirming the appropriateness of applying the TY (1995) causality test.

Table 9: Model 1. Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) unit root tests

Variable		ADF test				PP test			
		Constant		Constant and Trend		Constant		Constant and Trend	
		t-statistic	p-value	t-statistic	p-value	t-statistic	p-value	t-statistic	p-value
LnAzExptotal	Level	-1.137008	0.7006	-1.248203	0.8965	-1.329571	0.6153	-1.416136	0.8530
LnExpChina		-3.770848***	0.0039	-3.767020***	0.0207	-3.871091	0.0028	-3.891817***	0.0144
LnImpChina		-0.256027	0.9274	-1.847624	0.6770	0.088927	0.9640	-1.582271	0.7961
LnChinagrowth		-1.468826	0.5470	-1.999274	0.5971	-1.303103	0.6277	-1.731499	0.7330
LnChinaREER		-1.405113	0.5788	-0.529271	0.9813	-1.334221	0.6131	-0.166690	0.9933
ΔLnAzExptotal	First dif.	-15.99762***	0.0000	-15.99463***	0.0000	-15.98762***	0.0000	-16.03101***	0.0000
ΔLnExpChina		-14.89277***	0.0000	-14.87806***	0.0000	-14.89277***	0.0000	-14.87885***	0.0000
ΔLnImpChina		-14.18368***	0.0000	-14.16580***	0.0000	-14.44945***	0.0000	-14.57123***	0.0000
ΔLnChinagrowth		-4.156255***	0.0010	-4.295102***	0.0041	-10.76848***	0.0000	-10.90159***	0.0000
ΔLnChinaREER		-9.149616***	0.0000	-9.302263***	0.0000	-8.974680***	0.0000	-9.047265***	0.0000

*Notes: *** and ** denotes statistical significance at 1%, 5% level respectively.*

Table 10: Model 2. Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) unit root tests

Variable		ADF test				PP test			
		Constant		Constant and Trend		Constant		Constant and Trend	
		t-statistic	p-value	t-statistic	p-value	t-statistic	p-value	t-statistic	p-value
LnExpChina	Level	-3.770848***	0.0039	-3.767020***	0.0207	-3.871091	0.0028	-3.891817***	0.0144
LnImpAz		-2.086539	0.2504	-2.761205	0.2139	-1.938166	0.3142	-2.797226	0.2005
LnChinagrowth		-1.468826	0.5470	-1.999274	0.5971	-1.303103	0.6277	-1.731499	0.7330
LnChinaREER		-1.405113	0.5788	-0.529271	0.9813	-1.334221	0.6131	-0.166690	0.9933
ΔLnExpChina	First dif.	-14.89277***	0.0000	-14.87806***	0.0000	-14.89277***	0.0000	-14.87885***	0.0000
ΔLnImpAz		-15.18764	0.0000	-15.15106	0.0000	-15.20264	0.0000	0.0000	0.0000
ΔLnChinagrowth		-4.156255***	0.0010	-4.295102***	0.0041	-10.76848***	0.0000	-10.90159***	0.0000
ΔLnChinaREER		-9.149616***	0.0000	-9.302263***	0.0000	-8.974680***	0.0000	-9.047265***	0.0000

*Notes: *** and ** denotes statistical significance at 1%, 5% level respectively*

According to the results of the ADF and PP unit root tests, the integration orders *I(0)* and *I(1)* do not allow for the implementation of the Granger causality test within the VAR framework. Therefore, to conduct causality analysis with variables integrated at *I(0)* and *I(1)* levels, the Toda-Yamamoto (1995) test will be applied. As highlighted in the theoretical literature, before performing the TY (1995) test, it is necessary to determine the optimal lag length (k) and the maximum order of integration *(dmax).* For this purpose, the VAR model was employed to select the appropriate lag length. In both models, the lag selection criteria, including the likelihood ratio (LR) test statistic, final prediction error (FPE), Akaike information criterion (AIC), Schwarz information criterion (SC), and Hannan-Quinn information criterion (HQ), were utilized. For the first model, LR, FPE, and AIC criteria suggested an optimal lag length of two, whereas SC and HQ criteria recommended one lag. In the second model, all selection criteria unanimously suggested an optimal lag length of one.

Table 11: Model 1. Length of the lag.

Lag	LogL	LR	FPE	AIC	SC	HQ
0	1032.614	NA	2.02e-12	-12.73728	-12.35126	-12.58052
1	1104.906	136.3992	1.12e-12	-13.33215	-12.46359*	-12.97943*
2	1130.126	45.99889*	1.12e-12*	-13.33491*	-11.98382	-12.78625
3	1138.376	14.52897	1.38e-12	-13.12423	-11.29060	-12.37961
4	1147.625	15.70604	1.69e-12	-12.92610	-10.60995	-11.98554
5	1155.238	12.44855	2.13e-12	-12.70740	-9.908709	-11.57088
6	1161.605	10.01153	2.72e-12	-12.47302	-9.191804	-11.14055
7	1168.732	10.75683	3.47e-12	-12.24820	-8.484446	-10.71978
8	1175.778	10.19254	4.45e-12	-12.02236	-7.776080	-10.29799

Table 12: Model 2. Length of the lag.

Lag	LogL	LR	FPE	AIC	SC	HQ
0	849.8939	NA	2.81e-10	-10.64018	-10.56297	-10.60882
1	891.4223	80.44484*	2.04e-10*	-10.96129*	-10.57526*	-10.80453*
2	898.1442	12.68299	2.29e-10	-10.84458	-10.14974	-10.56241
3	906.0324	14.48635	2.54e-10	-10.74255	-9.738879	-10.33497
4	912.3554	11.29403	2.88e-10	-10.62082	-9.308336	-10.08784
5	915.5143	5.483337	3.39e-10	-10.45930	-8.837991	-9.800904
6	918.8866	5.684117	3.99e-10	-10.30046	-8.370332	-9.516656
7	923.2218	7.089088	4.65e-10	-10.15373	-7.914785	-9.244521
8	924.7409	2.407532	5.63e-10	-9.971583	-7.423814	-8.936961

The optimal lag length must satisfy not only the VAR stability condition but also the autocorrelation (LM test) and homoscedasticity (White test) assumptions. Even if the selected lag length meets the given criteria, the VAR model will not be considered valid unless these conditions are fulfilled. If these assumptions are not satisfied, the lag length of the model must be adjusted accordingly (Mert, Çağlar). During the VAR diagnostics, the minimum value of the information criteria (SC, HQ) was set at one. In the first model, when the lag length was set to one, the null hypothesis (H_0) of the LM test was not rejected at the second lag ($P = 0.0417 > 0.01$). However, the null hypothesis of homoscedasticity was rejected ($P = 0.00 < 0.01$). When the lag length was set to two, as suggested by the LR, FPE, and AIC criteria, the LM test failed to reject the null hypothesis (H_0) at the third lag ($P = 0.7792 > 0.01$), but the null hypothesis of homoscedasticity was again rejected ($P = 0.00 < 0.01$). Ultimately, both conditions were satisfied at the fifth lag length, where the LM test failed to reject the null hypothesis (H_0) at the sixth lag ($P = 0.9996 > 0.01$), and the null hypothesis of homoscedasticity was not rejected ($P = 0.1873 > 0.01$). For the second model, despite the initial suggestion of a lag length of one, the null hypothesis (H_0) was not rejected for both the LM test ($P = 0.8071 > 0.01$) and the heteroscedasticity test ($P = 0.0415 > 0.01$) at the sixth lag length.

Table 13: Model 1 and 2 - Diagnostic check

Specification	***Stat./p-values***		***Conclusion***
	Model 1	**Model 2**	
Breusch-Godfrey (autocorrelation)	7.776884/ 0.9996	11.03839/ 0.8071 > 0.01	No higher-order autocorrelation
Breusch-Pagan (heteroscedasticity)	784.2371/ 0.1873	535.0256/ 0.0415 > 0.01	No heteroscedasticity
Stability	No root lies outside the unit circle. VAR satisfies the stability condition.	No root lies outside the unit circle. VAR satisfies the stability condition.	Models are stable

Table 14: Model 1 – results of Toda-Yamamoto causality

Direction of Causality	χ^2	*Probability*	*Hipotez*
LnExpChina → LnAzExptotal	1.451451	0.9186	The hypothesis H0 is not rejected.
LnAzExptotal → LnExpChina	4.099698	0.5352	The hypothesis H0 is not rejected.
LnImpChina → LnAzExptotal	17.13652*	0.0042	The hypothesis H0 is rejected
LnAzExptotal → LnImpChina	7.283230	0.2004	The hypothesis H0 is not rejected.
LnChinagrowth → LnAzExptotal	15.93607*	0.0070	The hypothesis H0 is rejected
LnAzExptotal → LnChinagrowth	19.65473*	0.0015	The hypothesis H0 is rejected
LnCHINAREEM → LnAzExptotal	10.07876***	0.0730	The hypothesis H0 is rejected
LnAzExptotal → LnCHINAREEM	8.027243	0.1547	The hypothesis H0 is not rejected.
LnImpChina → LnExpChina	0.365584	0.9962	The hypothesis H0 is not rejected.
LnExpChina → LnImpChina	2.421201	0.7883	The hypothesis H0 is not rejected.
LnChinagrowth → LnExpChina	1.414012	0.9228	The hypothesis H0 is not rejected.
LnExpChina → LnChinagrowth	8.955537	0.1109	The hypothesis H0 is not rejected.
LnCHINAREEM → LnExpChina	2.525512	0.7726	The hypothesis H0 is not rejected.
LnExpChina → LnCHINAREEM	2.323488	0.8028	The hypothesis H0 is not rejected.
LnImpChina → LnChinagrowth	3.470423	0.6279	The hypothesis H0 is not rejected.
LnChinagrowth → LnImpChina	8.557055	0.1281	The hypothesis H0 is not rejected.
LnCHINAREEM → LnImpChina	7.567958	0.1817	The hypothesis H0 is not rejected.
LnImpChina → LnCHINAREEM	24.91513*	0.0001	The hypothesis H0 is rejected.
LnCHINAREEM → LnChinagrowth	2.525512	0.7726	The hypothesis H0 is not rejected.
LnChinagrowth → LnCHINAREEM	2.137840	0.8298	The hypothesis H0 is not rejected.

*Notes: *, ** and *** denotes statistical significance at 1%, 5% and 10% level respectively.*

At the end of the study, the causal relationship between the variables in Model 1 and Model 2 was examined using the Toda-Yamamoto (1995) method, and the results were detailed in the corresponding tables. The analysis revealed a unidirectional causality from Azerbaijan's imports from China and the China-weighted real effective exchange rate to Azerbaijan's total exports. Additionally, a bidirectional causality was identified between China's demand-driven

economic growth and Azerbaijan's total exports. The share of intermediate goods imported from China in Azerbaijan's non-oil and gas manufacturing exports indicates the presence of supply chain dependencies. On the other hand, the financing of Azerbaijan's imports from China is facilitated through foreign currency inflows generated by total exports. China's economic growth plays a crucial role not only in the expansion of its own economy but also in shaping global demand. Moreover, as the world's largest crude oil importer, China significantly influences global energy price dynamics. In this regard, a causal relationship at a 1% significance level was found between China's economic growth indicator and Azerbaijan's total exports. The real effective exchange rate between Azerbaijan and China is influenced by the exchange rate dynamics of the Azerbaijani manat against the Chinese yuan, as well as inflation trends in both countries. Given the relative stability of the manat against the US dollar, the movements of other currencies against the dollar also impact the trajectory of the manat. Consequently, the real exchange rate between Azerbaijan and China has positively contributed to Azerbaijan's non-oil and gas exports. Furthermore, Azerbaijan's demand for foreign currency due to imports from China has influenced the movement dynamics of the real exchange rate between the two countries. In this context, the null hypothesis (H_0) regarding the causal relationship from Azerbaijan's imports from China to the real exchange rate was rejected at a 1% significance level.

Table 15: Model 2 – results of Toda-Yamamoto causality

Direction of Causality	$\chi 2$	Probability	Hipotez
LnImpAz → LnExpChina	8.162951	0.2264	The hypothesis H0 is not rejected.
LnExpChina → LnImpAz	5.897996	0.4347	The hypothesis H0 is not rejected.
LnChinagrowth → LnExpChina	4.090084	0.6645	The hypothesis H0 is not rejected.
LnExpChina → LnChinagrowth	11.31092***	0.0792	The hypothesis H0 is rejected.
LnCHINAREEM → LnExpChina	2.035382	0.9164	The hypothesis H0 is not rejected.
LnExpChina → LnCHINAREEM	2.292436	0.8909	The hypothesis H0 is not rejected.
LnChinagrowth → LnImpAz	3.035216	0.8044	The hypothesis H0 is not rejected.
LnImpAz→ LnChinagrowth	13.74200**	0.0327	The hypothesis H0 is rejected.
LnCHINAREEM → LnImpAz	5.294625	0.5066	The hypothesis H0 is not rejected.
LnImpaz → LnCHINAREEM	19.10386*	0.0040	The hypothesis H0 is rejected.
LnCHINAREEM → LnChinagrowth	4.075061	0.6665	The hypothesis H0 is not rejected.
LnChinagrowth → LnCHINAREEM	3.875215	0.6936	The hypothesis H0 is not rejected.

*Notes: *, ** and *** denotes statistical significance at 1%, 5% and 10% level respectively.*

In the second model examined using the Toda-Yamamoto method, no causal relationship was found from other indicators to Azerbaijan's exports to China. However, a unidirectional causality at the 1% and 10% significance levels was identified from Azerbaijan's

imports and from Azerbaijan's exports to China to China's economic growth, driven by demand factors. According to the results of the second model, a significant portion of Azerbaijan's exports to China consists of oil and oil products, as well as chemicals and plastic industrial products, which positively contribute to China's manufacturing sector. Furthermore, the analysis shows that both Azerbaijan's imports from China and other countries have an impact on China's economic growth.

The level of diversification of Azerbaijan's exports to China. Mathematical methodology and solution of HHI product concentration and Theil index

Within the scope of this research, the unequal distribution of Azerbaijan's export revenues and the goods listed in its export portfolio can be effectively observed through the use of share-based analysis. The low level of diversification within the export basket, both in terms of goods and revenue sources, emerges as a fundamental factor hindering the sustained growth of export dynamics. Moreover, the fluctuating trajectory of export revenues introduces significant macroeconomic volatility. The analysis of Azerbaijan's export diversification level towards China reveals that the trajectory of revenues, primarily influenced by energy commodities, exhibits notable volatility within the relevant sectors, reflecting a pattern of instability.

The data presented in the aforementioned table and graphs, which reveal a significant concentration of goods within the total export turnover, provides a basis for forecasting a low level of diversification. However, the assessment of export diversification will be carried out utilizing the Theil index, based on the methodology proposed by Cadot et al. (2011). The Theil index serves as a statistical measure for both diversification and inequality, and is extensively employed in analyses of economic concentration, income inequality, and export diversity. The concentration of export products, as employed by UNCTADstat, aligns conceptually with the Theil index. Importantly, the Theil index not only quantifies the degree of diversification but also offers a critical framework for evaluating the sophistication level of exports.

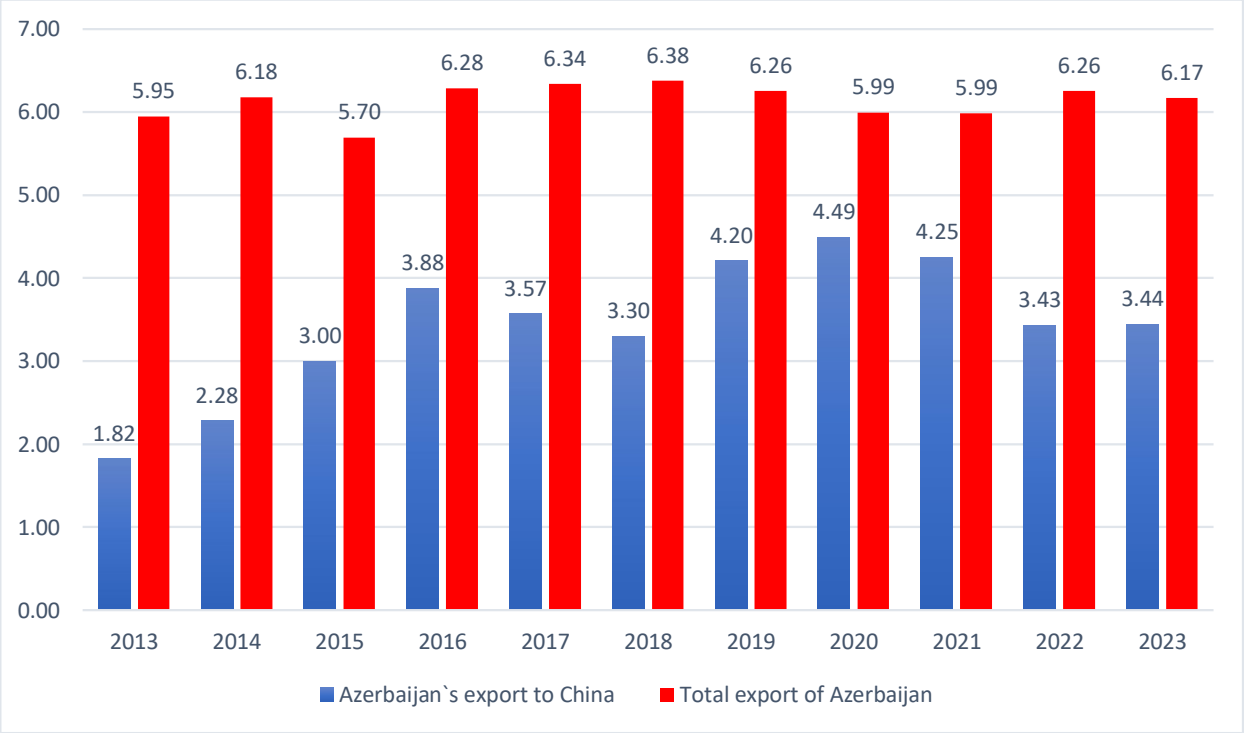
$$\boldsymbol{THEIL} = \frac{1}{N}\sum_{i=1}^{N}\left(\frac{x_i}{\bar{X}}\ ln\frac{x_i}{\bar{X}}\right); \boldsymbol{HHI_j} = \frac{\sqrt{\sum_{i=1}^{N}\left(\frac{X_{i,j}}{X_j}\right)^2}}{1-\sqrt{\frac{1}{N}}} - 1$$

Here, *N represents the number of export products, x_i denotes the export value of the i-th product, $\bar{x}$ is the average dollar value of all products and Xj refers to total exports*. The export concentration levels across global countries, covering the period from 1962 to 2014, were calculated based on the results of structural transformation and diversification, as analyzed by experts from the International Monetary Fund in the context of low-income countries.

According to the THEIL index, Azerbaijan's export basket to China exhibits a low level of diversification and moderate concentration. In the methodology of the index, an increase in the number of products reduces the concentration level. However, a significant factor here is the presence of seasonal, non-continuous, fluctuating, and low-value products in Azerbaijan's exports to the Asian market throughout the years. Despite the low export frequency of non-traditional and variable products from 2013 to 2024, their inclusion in the composition has a

positive impact on the diversification level of exports. Overall, if non-traditional products are excluded, Azerbaijan's export structure to China will exhibit high concentration.

Diagram 8: Level of diversification of Azerbaijan's total and exports to China, THEIL index

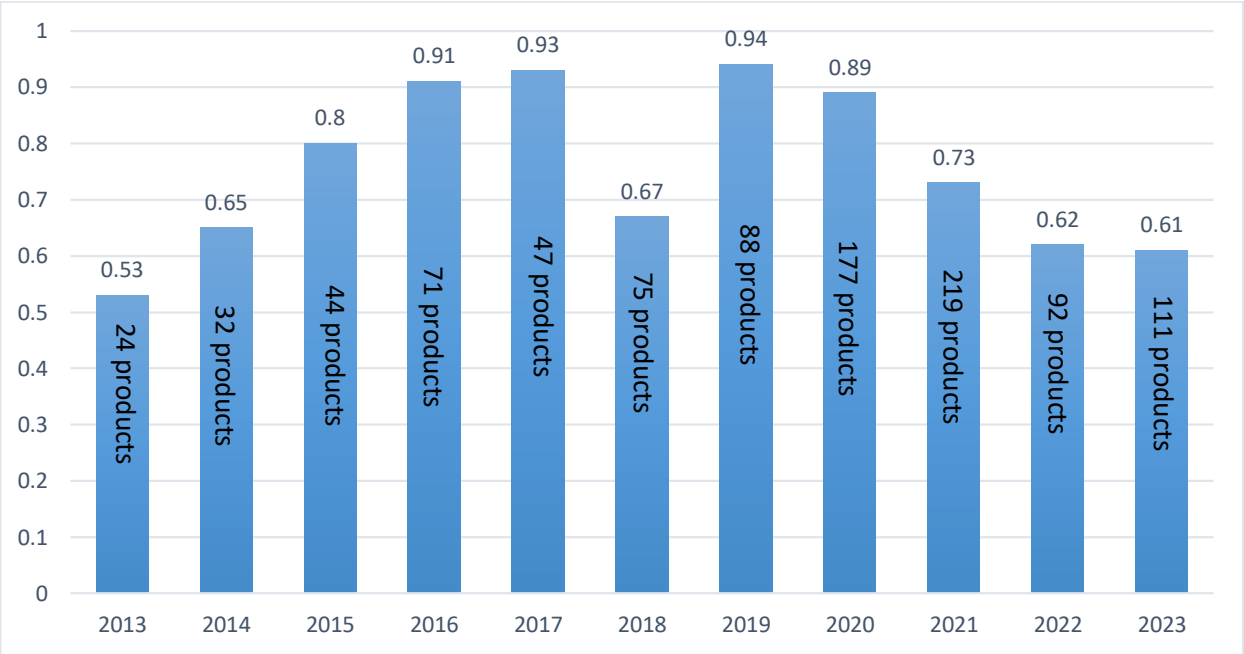


Data source: Author's calculation based on data from the State Statistics Committee of Azerbaijan

Note: According to the International Monetary Fund methodology; less than 1 – high diversification, 1-2 – medium diversification, 2-3.5 – weak diversification, 3.5-5 – medium concentration, above 5 – high concentration

The results of Azerbaijan's exports to China based on the product-centered normalized Herfindahl-Hirschman Index (HHI) show a significant similarity to the findings from the THEIL index. In the calculations covering the period from 2013 to 2023, Azerbaijan's concentration level has been notably high. Particularly, between 2015–2017 and 2019–2021, the concentration level reached its peak. An interesting observation here is related to the number of products. When analyzing the diagram, it becomes evident that in years when the number of products is relatively high (e.g., 2020 and 2021), the diversification level is weaker, while in years when the number of products is relatively low (e.g., 2013, 2014, and 2022), the concentration level is lower. This can be attributed to the higher share of continuous export products and the lower capacity of non-traditional products to generate added value. Overall, the failure of non-traditional products to become conventional over time, coupled with the low level of sophistication across all products, is clearly reflected in the results of both the THEIL and product-centered HHI indices.

Diagram 9: Level of diversification of Azerbaijan's exports to China, a normalized Herfindahl-Hirschman index of product concentration index



Data source: Author's calculation based on data from the State Statistics Committee of Azerbaijan

Note: This index ranges from zero to one, with a larger value denoting a higher concentration of exports.

Conclusion and recommendations.

The dynamic development of political relations between Azerbaijan and China, Azerbaijan's active support for China's "Belt and Road Initiative" and its integral component, the "Middle Corridor" initiative, as well as the establishment of trade representations and trade houses in China to enhance trade intensity, create a favorable foundation for strengthening economic ties between the two countries. Within the framework of the "Middle Corridor" project, which is one of the key topics in bilateral political and economic discussions, Azerbaijan plays a crucial role in developing logistics and transport infrastructure in the South Caucasus region. This initiative is aimed at facilitating the export of Chinese-manufactured goods to Western markets via Central Asian countries through Azerbaijan.

This study examines Azerbaijan's potential access to Chinese markets by leveraging its existing transport infrastructure and evaluates the current state of economic engagement in this context. The findings highlight that Azerbaijan should not confine its economic relations with China to a mere transit role but should also adopt strategic measures to enhance the presence of domestically produced goods in the Chinese market. Accordingly, the research assesses Azerbaijan's export intensity and dynamics, analyzes its competitive position in the Chinese market, and evaluates the extent of export diversification and product sophistication.

The study evaluates the current structure of Azerbaijan's exports to the People's Republic of China, assessing the level of diversification and sophistication of its export basket

while identifying key trends and challenges. Using the THEIL diversification index and the Toda-Yamamoto causality test, the paper analyzes Azerbaijan's export trajectory, revealing limited diversification and a low technological level of exports based on economic complexity indicators.

An econometric analysis was conducted to assess the impact of Azerbaijan's foreign trade relations with China on its overall export performance. The results of the Toda-Yamamoto (1995) causality test indicate that China's global energy demand directly influences Azerbaijan's total exports, particularly in crude oil and petroleum products. Furthermore, the findings suggest that imports originating from China affect Azerbaijan's exports, highlighting the role of Chinese raw materials in the country's mining and non-oil industries. However, within the second model, no statistically significant causal relationship was identified between Azerbaijan's exports to China and other economic indicators, empirically confirming the weak competitiveness of Azerbaijan's export basket in the Chinese market.

The analysis of statistical data over the past decade indicates that Azerbaijan's exports to the Chinese market have been characterized by a negative trend. The primary reason for this decline is the limited diversification of the export basket. Overall, while Azerbaijan mainly exports oil and petroleum products to China, these commodities exhibit high trade volatility. Among non-oil exports, only "polyethylene with a specific gravity of less than 0.94 in primary forms" stands out in terms of volume and sustainability.

When assessing the level of export sophistication, it becomes evident that the majority of Azerbaijan's exports to the Chinese market consist of raw and minimally processed goods. According to the Atlas of Economic Complexity indicators, Azerbaijan's export portfolio struggles to integrate into complex value chains. While Azerbaijan's key non-oil exports to China include plastic products, polyethylene, iodine, and certain agricultural commodities, these goods exhibit weak trade intensity and unstable export flows. This is partly due to the country's limited industrial capacity and, on the other hand, the absence of well-defined strategies for establishing a sustainable position in the Chinese market.

When examining Azerbaijan's transit and logistics capabilities, the country's cooperation with China within the frameworks of the Middle Corridor and the Belt and Road Initiative holds strategic significance. However, Azerbaijan's role in this corridor remains primarily focused on transit services, while specific mechanisms to support exporters have yet to be fully developed. The establishment of the Alat Free Economic Zone and the facilitation of cargo processing from China before reaching European markets represent crucial steps. Nevertheless, Azerbaijan must also enhance the depth of processing in its export activities and move beyond its current role as a mere supplier of raw materials.

References:

1. Ziyad Samadzadeh. (2009). China in the global world economy. Baku, 154–163. (in Azerbaijani)
2. Adalat Muradov, E Bagirzadeh - The Belt and Road Initiative: An Economic Assessment for Turkic Republics - - Connectivities and Common Legacies in Central Asia …, 2022
3. Adalat Muradov, Yadulla Hasanli, Nazim Hajiyev - The assesment of impact of competitiveness to economic development - - Economic and social development: Book of …, 2019
4. Bayramov, V., Safarova, G., Garajayev, M. (2023). Economic Effects of Belt and Road Initiative: The Case of Southern Caucasus and Central Asia Countries. In: Wang, L. (eds) China's Development and the Construction of the Community with a Shared Future for Mankind. Research Series on the Chinese Dream and China's Development Path. Springer, Singapore. https://doi.org/10.1007/978-981-19-7423-6_50
5. Nijat Hajizadeh - "The impact of foreign trade turnover between Azerbaijan and CIS and non-CIS countries on economic growth: Cointegration test and VECM Granger causality," The Scientific-Analytical Journal "Economic Reforms", Center for Analysis of Economic Reforms and Communication of the Republic of Azerbaijan, vol. 2024(1), pages 16-26, June. - DOI: 10.30546/2790-2196.1.10.2024.003
6. Hausmann, R., et al. (2014). The Atlas of Economic Complexity: Mapping Paths to Prosperity. MIT Press.
7. Hausmann, R., & Hidalgo, C. A. (2009). "The building blocks of economic complexity". Proceedings of the National Academy of Sciences (PNAS), 106(26).
8. Bandiera, Luca and Vasileios Tsiropoulos, "A Framework to Assess Debt Sustainability and Fiscal Risks under the Belt and Road Initiative". World Bank Group, Macroeconomics, Trade and Investment Global Practice, Policy Research Working Paper 8891, (June 2019).
9. China National Development and Reform Commission. "Vision and Actions on Jointly Building Silk Road Economic Belt and 21st-Century Maritime Silk Road (Vision and Actions)", 2015, Accessed on September 14, 2019, http://en.ndrc.gov.cn/newsrelease/201503/t20150330_669367.html.
10. Lianlei, Bai. "Azerbaijan in the Silk Road Economic Belt: A Chinese Perspective". Caucasus International, Vol. 6, No: 1, (Summer 2016): 27- 39
11. China reports active trade with BRI countries in 2024. (2025, January 16). Belt and Road Portal. https://eng.yidaiyilu.gov.cn/p/0UJQKLTA.html
12. Kalim Siddiqui. (2019) One Belt and One Road, China's Massive Infrastructure Project to Boost Trade and Economy: An Overview. International Critical Thought 9:2, pages 214-235.

13. Kanenga Haggai, “One Belt One Road Strategy in China and Economic Development in the Concerning Countries.” World Journal of Social Sciences and Humanities, vol. 2, no. 1 (2016): 10-14. doi: 10.12691/wjssh-2-1-2

14. Izimov R., Muratalieva Z. (2018) The Central Asian Track of the One Belt One Road Initiative: Opportunities and Risks. International Organisations Research Journal, vol. 13, no 3, pp. 128– 142 (in English). DOI: 10.17323/1996-7845-2018-03-08.

15. Su, Y. (2024). The current situation, problems and future direction of energy cooperation between China and Azerbaijan. Journal of Current Social Issues Studies, 1(1), 75-85. https://doi.org/10.5281/zenodo.14280239

16. UNCTAD. (2019). Technical notes on export concentration and diversification indices. UNCTADstat. Retrieved from https://unctadstat.unctad.org/EN/IndicatorsExplained/statie2019d1_en.pdf

17. Toda, H. Y., & Yamamoto, T. (1995). "Statistical analysis in vector autoregressions with possibly integrated processes". Journal of Econometrics, 66(1-2), 225-250.

18. Theil, H. (1967). Economics and Information Theory. Amsterdam: North-Holland Publishing Company.

19. Granger, C. W. J. (1969). "Investigating causal relations by econometric models and cross-spectral methods". Econometrica, 37(3).

20. Dickey, D. A., & Fuller, W. A. (1979). "Distribution of the estimators for autoregressive time series with a unit root". Journal of the American Statistical Association.

21. Phillips, P. C. B., & Perron, P. (1988). "Testing for a unit root in time series regression". Biometrika, 75(2).