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Unveiling the Dutch Disease Indexes: Principal Component Analysis in a Small Oil-rich Country

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Abstract

The Dutch disease (DD) theory is a popular approach when analyzing the economies of resource-rich countries. However, despite the extensive examination of both the original DD theory and its variations in numerous country cases, the findings remain contradictory and inconclusive, primarily due to the challenges associated with measuring DD. Building upon the notable case study of the Azerbaijani economy, this paper introduces a novel way to utilise principal component analysis (PCA) in index development, which incorporates the modelling framework of the original theory and provides a profound understanding of DD measurement. The findings of the study reveal that the fundamental variables associated with DD in the Azerbaijani economy can be effectively condensed into a small number of principal components (PCs). In addition, this research introduces not only a total Dutch disease index (TDDI), but also a resource movement index (RMI) and a spending index (SI), with the last of these demonstrating a more pronounced impact in Azerbaijan. The estimated indexes exhibit a significant and negative correlation with the manufacturing sector's share in the industry, pointing to the presence of the crowding-out mechanism of DD. Moreover, a strong positive correlation is observed with key growth indicators such as gross domestic product (GDP) and gross capital formation, underscoring the exceptional role of the oil boom in the Azerbaijani economy. These findings justify the contention that DD is present in the Azerbaijani economy. The paper also provides a composite index that can be utilised by both policymakers and scholars for measuring DD.

Keywords

Azerbaijani economy, Dutch disease, natural resource curse, oil boom, principal component analysis

1 Introduction

Index-based quantitative indicators have gained prominence as a method for assessing diverse facets of societies owing to their ability to systematically monitor and evaluate complicated patterns (Fukuda-Parr et al., 2009). Constructing a composite index entails the identification of a cohesive set of indicators or variables suitable for quantifying a particular concept or phenomenon (García-Avilés et al., 2018). These indicators are subsequently amalgamated to form a unified score or ranking (García-Avilés et al., 2018). Therefore, a composite value can offer valuable empirical information by providing a concise and comparative measure of performance or achievement across multiple variables, allowing for a comprehensive assessment of the subject under study. The selection of specific indicators and the allocation of weights to each indicator within the index may differ based on the intended purpose of the index and the contextual circumstances in which it is to be employed (Aziz et al., 2015).

The primary objective of this study is to analyse and quantify the manifestations and impacts of DD through the utilisation of index values within a specific country, with a focus on the Azerbaijani economy as a case study. DD, a concept initially modeled by Corden and Neary (1982) and Corden (1984), encompasses the adverse effects of a booming sector on the overall economy, primarily manifested through exchange rate appreciation, increased domestic production costs, and labour resource movements. While DD is a subset of the broader phenomenon known as the natural resource curse (NRC), it primarily examines the economic dimensions of resource specialisation in small, open economies.

Originating from the experience of the Netherlands in the late 1960s following a surge in natural gas

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exports, the term "Dutch disease" was proposed by The Economist (1977) to describe the adverse consequences, such as diminished competitiveness of exported goods due to currency appreciation and excessive government spending fuelled by resource revenues (referred to as the "spending effect"; van Eerd, 2010). Additionally, within a fixed capital framework, DD also provides insights into the movement of labour resources across a three-sector model comprising the booming, lagging, and non-tradeable sectors of an economy (so-called "resource movement effect"). Thus, DD has both theoretical and practical significance for developing countries heavily reliant on commodity exports, as it elucidates the structural changes that impede long-term economic development opportunities by underscoring the importance of non-resource-based manufacturing for learning-by-doing (Torvik, 2001), hedging against volatile commodity prices (Canuto et al., 2010), and promoting institutional development (Hao et al., 2021; Amiri et al., 2019). DD is above all important for commodity-exporting countries facing persistent challenges in diversifying their industrial production.

Despite the valuable contributions made by both individual country case studies and regional approaches to the literature on DD, their methodologies lack consistency and fail to provide a comprehensive and unified framework for enhancing our understanding of DD. This inconsistency is primarily attributed to the difficulties associated with measuring DD indicators and effects, which can vary across countries, as well as the modifications made to the original theory to accommodate country-specific realities. To address these challenges, the development of a composite index appears to offer a promising solution, which if successful could establish a methodological standard and facilitate a more comprehensive comprehension of the original theory.

PCA was chosen as the primary methodology to construct a composite indicator that captures the signs and effects of DD within the Azerbaijani economy between 1991 and 2021. PCA, a dimension reduction technique and multivariate statistical approach, enables the transformation of a set of correlated variables into a smaller set of uncorrelated variables known as principal components (PCs; Greenacre et al., 2022). By applying PCA to a dataset consisting of several economic variables associated with DD, it becomes feasible to capture a substantial part of the original variance with a reduced number of linear combinations. The proposed PCA-based DD indexes therefore allows for a comprehensive assessment of the multidimensional impact of resource dependence, captures the underlying patterns, reduces dimensionality, and provides an objective and interpretable representation of the phenomenon.

Although previous studies such as Kang et al. (2013), Majidzadeh and Dahmardeh (2022), and Chang et al. (2021) have utilised PCA to analyse DD, there is a noticeable gap in the literature regarding in-depth, longitudinal, and experimental studies on this topic. The Azerbaijani economy has been chosen as a case study for developing a PCA-based DD indexes, as it is believed that the country has experienced significant manifestations of this phenomenon since the early 2000s, primarily driven by the oil boom (Humbatova et al., 2019). Azerbaijan's pursuit of extractive industry-led economic growth has raised concerns among international experts regarding the potential effects of DD, a topic that gained attention in the late 1990s (Singh and Laurila, 1999). According to World Bank data, Azerbaijan stands out as the most oil-dependent country, as evidenced by the substantial presence of oil rents in its overall economy (World Bank, 2023).

While several studies have examined DD in the context of Azerbaijan, none of them have presented a unified and systematic approach that could also be applicable to similar countries (e.g., Russia, Kazakhstan, Mongolia). Furthermore, the lack of consensus regarding the presence of DD in the country has led politicians, government officials, and even scholars to overlook this economywide issue (Bayramov and Conway, 2010). By introducing composite index values for this phenomenon, this study aims to reduce confusion, facilitate versatile and adaptable diagnoses, and ultimately compel authorities to take action to mitigate the negative consequences of DD. Consequently, this research significantly contributes to our understanding of the rarely analysed development of a DD index and its implications for the Azerbaijani economy.

The formulated research questions that guided this study are as follows: To what extent can the TDDI, developed based on PCA, be effectively utilised to analyse the impact of natural resource dependence in a small, open economy like Azerbaijan, characterised by a significant oil boom (between 2005 and 2014), within the period spanning from 1991 to 2021? Furthermore, what level of effectiveness would be achieved by separately considering the resource movement and spending effects of DD theory to construct a concise subset of indexes representing DD?

In short, the results of the present study provide a justification for the usefulness of DD-based indexes that encompass the main indicators and effects of this elusive phenomenon in the Azerbaijani economy. Notably, both the resource movement and spending effects of DD are observable in the Azerbaijani context, aligning with the country's oil boom period from 2005 to 2014.

2 Literature review and theoretical framework

2.1 The concept of "Dutch disease index"

The DD index introduced by Gelb et al. (1988) serves as a pioneering measure to assess the deviation of the tradeable sector's share in real non-commodity GDP from the established benchmarks outlined by Chenery (1976). Essentially, the DD index mentioned above quantifies the extent to which the share of tradeable sectors in non-commodity sectors deviates from the expected norm. The authors exclude windfall sectors, which are characterised by abrupt increases in revenues and determine the discrepancy between the actual tradeable sector in the overall economy and the expected value based on historical patterns. This disparity or discrepancy is then employed as an index to gauge the presence of the DD phenomenon.

Based on the above-mentioned approach, Said et al. (1995) developed a DD index for the Egyptian economy from 1959 to 1991, focusing primarily on the performance of the non-commodity manufacturing sector. This index effectively illustrated the process of industrialisation through import substitution and non-traditional export promotion measures, the impact of liberalisation on tradeable sectors, and the influence of the real effective exchange rate (REER) and interest rates on Egypt's industrial structure.

In a similar way, Lopez (1999) constructed short-term sectoral DD indexes, focusing on manufacturing and agriculture, utilising the established benchmarks by Gelb et al. (1988) and Syrquin (1989) within the Venezuelan economy. The developed DD index effectively captured the consequences of national currency overvaluation and provided insights into the different impacts experienced by the agriculture and manufacturing sectors during the period from 1973 to 1982. Despite these valuable findings, however, Lopez (1999) expressed dissatisfaction with the limited ability of the DD index to fully explain the phenomena of de-agriculturalisation and de-industrialisation in the Venezuelan economy. It is important to note that Lopez (1999) did not incorporate more sophisticated variables to measure DD or to separately distinguish resource movement and spending effects separately. Finally, the studies by Auty (2002) and Kyle (2005) also followed the principles established by Gelb et al. (1988) and Syrquin (1989) by using an index-based approach to demonstrate the presence of DD.

In a more recent study, Chang et al. (2021) introduced the Dutch Disease Diagnosis Index, which places particular emphasis on structural shifts (e.g., the share of mining or manufacturing), trade patterns (e.g., import dependence), and the real exchange rate to detect signs of DD in different countries during specific time periods. The results include notable case studies of DD, including Russia, Canada, Brazil, and Chile, with Russia and Canada showing a more pronounced manifestation of DD, while Chile performs comparatively better in this regard.

The examination of the DD index is further illustrated in the case studies on the Iranian economy. Sadeghi Soghdel et al. (2014) employed a descriptive methodology for the DD index using a fuzzy logic approach. This led to remarkable results showing pronounced signs of DD in recent years (especially after 2006), while signs of DD declined in the 1970s and 1980s. However, it is important to note that this approach lacks cogency and methodological rigor. It cannot be considered fully consistent with the established empirical procedures commonly used in economics, especially when addressing structural matters in commodity-exporting countries.

Henceforth, the proposition of an extensive empirical and experimental framework utilising PCA to construct a DD index appears to hold considerable utility. The diagnosis of DD requires a broader perspective that includes not only structural changes but also underlying determinants such as the real exchange rate and government spending. The PCA approach overcomes the tendency of various methodologies to overlook certain facets of DD while disproportionately emphasising others. Notably, the literature concerning the conceptualisation and application of the DD index exhibits significant potential for further expansion and refinement.

2.2 Dutch disease in the Azerbaijani economy

The phenomenon of DD was initially brought to attention through early studies conducted by Rosenberg and Saavalainen (1998), Gahramanov and Fan (2002), and Mahmudov (2002), all of which emphasised the upcoming challenges stemming from inadequate political will and government capacity in managing oil wealth in Azerbaijan. Building upon this foundation, more comprehensive studies by Hasanov (2013), Guliyev (2013), and Niftiyev (2022) have provided detailed insights into the exact impact of DD-related variables on the non-resource manufacturing and agricultural sectors, revealing a strong correlation with international oil prices and resulting growth-reducing effects in Azerbaijan. Consequently, Azerbaijan stands as a prominent example of an oil-dependent country with an unbalanced industrial capacity that hinders the achievement of sustainable growth rates and rendering it susceptible to shocks in global commodity prices.

Recent studies consistently provide support for the presence of DD and de-industrialisation in the Azerbaijani economy, as evidenced by the growing number of empirical and academic investigations highlighting the urgent need for further research on the extent and impact of DD in Azerbaijan. Notably, Taguchi and Abdullaev (2023) employed country-fixed effects within the framework of Rodrik's (2016) hypothesis on premature de-industrialisation, finding evidence of DD and de-industrialisation in various post-Soviet countries, including Azerbaijan. While Humbatova et al. (2023) have recently presented more optimistic views on the role of the oil sector in Azerbaijan's economic development, they also acknowledge the presence of DD, given the reliance on transfers from the State Oil Fund of the Republic of Azerbaijan (SOFAZ) as a crucial determinant of macroeconomic stability. Furthermore, Aliyev et al. (2023) reveal a significant direct impact of oil prices on inflationary pressures, primarily through the money supply channel.

The use of a mixed-methods approach in one recent study further demonstrated that specific non-oil industries in Azerbaijan, such as chlorine, soda, and sulfuric acid, have experienced de-industrialisation due to DD (Niftiyev, 2022). Various obstacles, such as exchange rate appreciation (Majidli, 2022), deficiencies in fiscal policy management of oil wealth (Ahmadov, 2022), and slow and ineffective industrial diversification (Guliyev, 2022), further confirm the undeniable presence of DD. In essence, recent studies underscore the crucial role of oil prices in shaping the Azerbaijani economy, influencing overall GDP, growth rates, and oil production (Sarkhanov, 2022). Consequently, the research trend on this subject is expected to persist in the foreseeable future.

2.3 Theoretical framework

The research design and variables for creating the DD indexes in this study were chosen based on the theoretical modelling of Corden and Neary (1982) and Corden (1984), who propose a three-sector model of an economy consisting of booming, lagging, and non-tradeable sectors. Booming sectors experience significant output growth due to technological advancements, resource discoveries, or price increases. Lagging sectors typically include non-commodity manufacturing industries, while non-tradeable sectors encompass domestically price-determined services. Additional assumptions, summarised by Mironov and Petronevich (2015), include a production function reliant on labour and sector-specific fixed capital, mobile and fully employed labour, varying labour-to-capital ratios across sectors, and domestic demand determining household consumption.

Fig. 1 provides an overview of the DD theory, emphasising the resource movement and spending effects. Resource movement entails the shift of labour resources from lagging sectors to booming sectors. This movement results in direct de-industrialisation when output declines in lagging sectors. The reason for the direct de-industrialisation or resource movement effect could be the increased demand and higher wages in booming sectors. Meanwhile, indirect de-industrialisation happens when output declines in lagging sector due to the shift of labour towards non-tradeable sectors. In line with Corden's findings in 1984, the transition of labour resources from lagging sectors to non-tradeable sectors can coincide with the reallocation of resources from lagging sectors to booming sectors. This implies that in certain scenarios, both indirect de-industrialisation and direct de-industrialisation may transpire concurrently.

The key assumption underlying resource movement effect is the anticipation of increased labour demand in labour-intensive booming sectors. Conversely, the spending effect involves government or factor owner spending, leading to wage increases in non-tradeable sectors and subsequent domestic inflation. In this respect, the Balassa-Samuelson effect (whereby countries with higher productivity in the tradable goods sector also tend to have higher prices for non-tradable goods) could be present following domestic inflation via real appreciation. The Balassa-Samuelson effect leads to higher wages in the tradable goods sector, typically in developed countries. To attract labour, producers of non-tradable goods and services must increase wages despite lower productivity, causing higher prices for

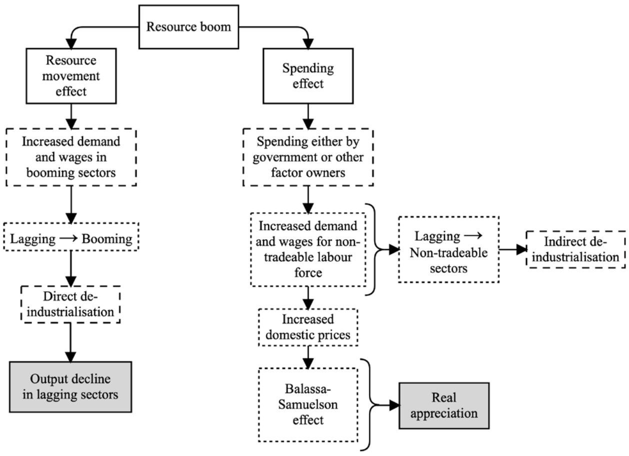

Fig. 1 Theoretical framework of the current study

non-tradable goods and services. Notably, Azerbaijan exhibits a pronounced spending effect due to substantial government expenditures, appreciation of the REER, and domestic inflation, while the capital-intensive nature of the oil industry limits direct de-industrialisation (Hasanov, 2013).

3 Data and methodology

To obtain longitudinal and comprehensive perspectives with which to construct a DD index, the main data source for this study was time series data from State Statistical Committee of the Republic of Azerbaijan (SSCRA), Statistical Yearbooks of World Bank (SYWB), SOFAZ, International Monetary Fund (IMF), and World bank. The annual data spanned from 1991 until 2021. While most of the recent statistics related to wages, employment and economic output came from SSCRA (i.e., 1999–2021), the data points for the 1990s were collected from the SWYB, and some variables such as oil rents were collected from the online World Bank (2023) database. Additional information about the variables, their measurement and descriptions can be found on Table A1 in Appendix section. Meanwhile, Table A2 in Appendix provides the descriptive statistics of all variables. All missing data were filled with linearly interpolated data points. Outlier values were examined using boxplot visualisation to prepare the dataset for the PCA procedure, as classical PCA is a sensitive technique for outliers (Sapra, 2010). REER had two outlier values for 1991 and 1992; manufacturing's share in GDP had three outlier values for 1991, 1992, and 1993; manufacturing trade balance had outlier values for 1992 and 1993; wages of mining industry in terms of non-tradeable sectors had two outliers for 2016 and 2017. All outliers were replaced by linear imputation method based on the suggestions of Akouemo and Povinelli (2014).

PCA analysis followed these steps: first, the rotation criteria were selected following the guidelines of Brown (2009). To put it another way, all PCA were conducted via direct oblimin as an oblique method to see if the component correlations exceed 0.320 threshold or not. If they were below the indicated value, instead of direct oblimin, varimax (an orthogonal method) was applied. This procedure allowed for a comprehensive analysis of the data, considering both oblique and orthogonal factors and selecting the most appropriate rotation method based on the observed component correlations. Second, Kaiser-Meyer-Olkin measure of sampling adequacy (KMO value) and Bartlett's test of sphericity were examined to determine if the dataset can be analysed within PCA procedure. As a threshold value for KMO, OECD et al. (2008) suggested at least 0.600. Then, the significance of Bartlett's test of sphericity was examined. Third, PCA results were evaluated based on the values of commonalities, extraction values, scree plot, variance explained, and rotated factor loadings. All assessments were made based on the proposals by OECD et al. (2008) and Sarstedt and Mooi (2014). Lastly, the PCA results were stored as individual variables to create a composite index of annual manifestations of DD.

All the analyses were conducted on SPSS software, version 23.00.

4 Results

This section presents the PCA results for TDDI, RMI, and SI in the Azerbaijani economy from 1991 to 2021. In the preliminary explanatory PCA, it was observed that all component correlations were below 0.320. Consequently, the varimax rotation technique, as suggested by Brown (2009), was chosen as the primary method for obtaining the rotated component loadings. Since the variables were measured at different scales, the correlation matrix was used as the main analysis technique during the extraction phase, as recommended by Brown (2009). Finally, regression analysis was utilised as the primary method to store the values of the PCA-based annual indexes.

The reference to the "2nd Phase" in the tables presented within the results section signifies the outcomes obtained after removing non-significant loadings in the PCA, particularly focusing on the first principal component. "Significant loadings" refers to loadings that exceed a threshold of +/– 0.300, as explained by Brown (2009).

4.1 PCA results

The preliminary PCA results show that the KMO values are high, ranging from 0.700 to 0.803, indicating the suitability of the present dataset for PCA analysis (Table 1). In addition, all Bartlett's Sphericity Test results are statistically significant, further supporting the suitability of PCA for the data. The average communality values are notably high, with the highest reaching 0.906 and the lowest at 0.777. Then, using the scree plot (criterion: eigenvalue of 1 as threshold), the dataset was reduced to 4 and 2 principal components for the TDDI, while RMI and SI were reduced to 3 and 2 principal components, respectively.

Table 2 summarises the percentage of variance explained by each PCs and the cumulative variance before and after rotation (indicated by the values after the arrow, which are the sums of squared loadings). After eliminating

Table 1 Quality indicators of the applied principal component analysis

Total Dutch Disease Index		
1st Phase	Kaiser-Meyer-Olkin (KMO)	0.783
	Bartlett's Test of Sphericity	815.29***(*df* = 136)
	Average communalities	0.906
	Scree plot	4
2nd Phase	Kaiser-Meyer-Olkin (KMO)	0.792
	Bartlett's Test of Sphericity	506.41***(*df* = 55)
	Average communalities	0.856
	Scree plot	2
Resource Movement Index		
1st Phase	Kaiser-Meyer-Olkin (KMO)	0.725
	Bartlett's Test of Sphericity	512.87***(*df* = 78)
	Average communalities	0.849
	Scree plot	3
2nd Phase	Kaiser-Meyer-Olkin (KMO)	0.803
	Bartlett's Test of Sphericity	336.15***(*df* = 36)
	Average communalities	0.848
	Scree plot	2
Spending Index		
1st Phase	Kaiser-Meyer-Olkin (KMO)	0.700
	Bartlett's Test of Sphericity	286.49***(*df* = 36)
	Average communalities	0.777
	Scree plot	2
2nd Phase	Kaiser-Meyer-Olkin (KMO)	0.745
	Bartlett's Test of Sphericity	238.18***(*df* = 28)
	Average communalities	0.806
	Scree plot	2

Notes: *df* denotes "degrees of freedom"; *** indicates statistical significance at the 1% level.

Table 2 Explained variances of the principal components within total Dutch disease index, resource movement index, and spending index

Components	% of var.	% of cum. var.
Total Dutch Disease Index—1st phase		
1	59.07 →34.55	59.07→34.55
2	17.17→31.32	76.23→65.87
3	8.35→14.31	84.58→80.18
4	6.07→10.48	90.66→90.66
Total Dutch Disease Index—2nd phase		
1	69.76→59.33	69.76→59.33
2	15.80→26.23	85.56→85.56
Resource movement index—1st phase		
1	54.74→38.17	54.74→38.17
2	21.32→25.83	76.06→64.20
3	8.83→20.88	84.89→84.86
Resource movement index—2nd phase		
1	66.55→46.06	66.55→46.06
2	18.20→38.69	84.75→84.75
Spending index—1st phase		
1	58.64→51.02	58.64→51.02
2	19.04→26.66	77.68→77.68
Spending index—2nd phase		
1	65.40→41.87	65.40→41.87
2	15.19→38.73	80.59→80.59

Notes: "var." denotes variance; "cum." denotes cumulative variance; the arrow sign shows the results of the changed explained variance resulting from the rotation process.

nonsignificant loadings in the second phase of PCA, the explanatory power of the TDDI (measured by the first PC) increased from 34.55% to 59.33%, whereas it decreased slightly (from 31.32% to 26.23%) in the second PC. Similar trends were observed for the RMI, with improvements in both explained individual and cumulative variance after the elimination of nonsignificant loadings. However, in the case of the SI, the explanatory power of the individual variance of the first PC was higher in the first phase of PCA.

Tables 3, 4, and 5 show the rotated component loadings obtained from PCA. Examining the TDDI, it becomes evident that in the first phase of the PCA, all variables, except for certain employment and wage variables (e.g., EMP_SER_MIN, WG_MIN_MAN), have significant loadings on the first PC of the TDDI (Table 3). However, during the subsequent phase, nonsignificant loadings were eliminated, resulting in a more efficient dimension reduction for the TDDI. Notably, all loadings on the first PC became significant in the second phase of the PCA, where variables such as manufacturing trade balance, manufacturing share of GDP, and oil rents had negative correlations with the other variables. On the other hand, government spending, CPI, transfers from SOFAZ to the state budget, and oil extraction had the highest positive loadings on the first PC. Furthermore, the limited impact of the three-sector approach on employment and wages on the TDDI components suggests a lower relevance of the resource movement effect in Azerbaijan, which is consistent with the results of Hasanov (2013).

Table 4 presents the rotated component loadings of the RMI in two phases. Roughly as with the TDDI results, when focusing solely on the RMI, it is evident that variables related to service sector employment relative to manufacturing and mining and wage variables only exhibit marginal loadings on the first PC. The first PC of the reduced-form RMI exhibits a higher number of significant loadings, with the most pronounced positive loadings observed for the manufacturing trade balance, mining wages relative to manufacturing, and oil extraction. Conversely, the most

Table 3 Rotated component loadings of total Dutch disease index

	1st phase				2nd phase	
Components → Variables ↓	1	2	3	4	1	2
MIN_GDP	0.94	−0.01	0.30	−0.10	0.49	0.82
EMP_MIN_MAN	0.93	0.23	0.15	0.02	0.67	0.70
OIL_P	0.89	0.38	0.01	0.03	0.72	0.63
OIL_EXT	0.81	0.50	0.15	0.11	0.84	0.48
MAN_GDP	−0.78	−0.22	−0.33	−0.37	−0.75	−0.45
REER	0.72	0.31	0.09	0.43	0.81	0.30
GAS_EXT	0.33	0.88	0.17	0.11		
EMP_SER_MIN	0.19	0.87	0.28	0.08		
EMP_SER_MAN	−0.24	0.86	0.31	0.15		
TRANS	0.46	0.79	−0.10	0.23	0.89	0.04
GOV_SPEN	0.49	0.78	0.05	0.32	0.93	0.06
CPI	0.41	0.71	0.52	0.20	0.91	0.04
MAN_TR_BAL	−0.54	−0.68	−0.43	−0.09	−0.91	−0.20
WG_MIN_MAN	0.13	0.16	0.93	0.10		
WG_MIN_NT	0.31	0.38	0.74	0.27		
WG_NT_MAN	−0.22	−0.18	−0.16	−0.85		
OIL_RENTS	0.55	−0.27	−0.27	−0.62	−0.30	0.87

Notes: in the table, cells highlighted in light green indicate positive and significant loadings; cells highlighted in red indicate negative and significant loadings; for the abbreviations used in the table, please refer to Table A1, Appendix section.

Table 4 Rotated component loadings of resource movement index

	1st phase			2nd phase	
Components → Variables ↓	1	2	3	1	2
MIN_GDP	0.95	−0.06	0.21	0.39	0.87
EMP_MIN_MAN	0.93	0.16	0.17	0.52	0.81
OIL_P	0.90	0.39	0.06	0.54	0.77
OIL_EXT	0.82	0.44	0.22	0.71	0.63
MAN_GDP	−0.76	−0.17	−0.52	−0.70	−0.55
OIL_RENTS	0.61	−0.31	−0.57	−0.42	0.80
EMP_SER_MAN	−0.20	0.88	0.31		
EMP_SERV_MIN	0.26	0.88	0.25		
GAS_EXT	0.39	0.87	0.20	−0.90	−0.33
MAN_TR_BAL	−0.59	−0.65	−0.41	0.86	0.14
WG_MIN_MAN	0.15	0.19	0.78	0.85	0.07
WG_MIN_NT	0.35	0.37	0.76		
WG_NT_MAN	−0.15	−0.17	−0.67		

Notes: in the table, cells highlighted in light green indicate positive and significant loadings; cells highlighted in red indicate negative and significant loadings; for the abbreviations used in the table, please refer to Table A1, Appendix section.

Table 5 Rotated component loadings of spending index

	1st phase		2nd phase	
Components → Variables ↓	1	2	1	2
OIL_P	0.95	−0.26	0.92	0.14
GOV_SPEN	0.90	0.35	0.72	0.64
TRANS	0.86	0.29	0.69	0.58
REER	0.84	0.02	0.93	0.14
CPI	0.79	0.46	0.56	0.74
EMP_SERV_MIN	0.69	0.54	0.37	0.86
WG_NT_MAN	−0.43	−0.41	−0.45	−0.33
OIL_RENTS	0.16	−0.87		
EMP_SER_MAN	0.35	0.83	0.01	0.95

Notes: in the table, cells highlighted in light green indicate positive and significant loadings; cells highlighted in red indicate negative and significant loadings; for the abbreviations used in the table, please refer to Table A1, Appendix section.

significant negative loadings on the first PC arise from natural gas extraction, manufacturing as a share of GDP, and oil rents. This suggests that the dynamics of the booming sector in Azerbaijan are predominantly tied to oil rather than natural gas. Furthermore, the profitability of oil, as indicated by oil rents, has experienced a decline over time, coinciding with the growth of Azerbaijan's GDP and the decrease in oil prices. Interestingly, however, oil rents exhibit a significant and positive loading on the second PC, indicating a strong and positive correlation with the mining industry's share of GDP, mining employment relative to manufacturing, and other related factors.

The findings of the second PC in the second phase of RMI analysis align with the results of the first PC, but they exhibit a greater concentration of variance related to oil. This observation prompts a reconsideration of the extent to which individual and cumulative variance are explained by these PCs. As shown in Table 2, the first PC accounted for 46.06% of the variation in the variables, while the second PC explained 38.69%. Consequently, an average of these two PCs may offer a satisfactory approximation of the resource movement effect in DD theory in the Azerbaijani economy, which was done in the second section (Section 4.2).

Lastly, Table 5 shows the rotated component loadings of SI in two phases. The first PC of SI exhibited noteworthy and positive loadings, particularly from variables such as oil price, government spending, the share of oil revenue transfers in the state budget, and REER. The only exception was the negative loading of wages in non-tradeable sectors in terms of manufacturing on the first PC. It is intriguing that the wages of non-tradeable sectors in relation to manufacturing showed significant negative loadings on both the first and second PCs, as the rapid and extensive government spending in Azerbaijan since the beginning of the oil boom in 2005 and 2006 triggered an increased demand for labour in the service sector.

Interestingly, in the second phase of the SI estimation, the second PC had significant loadings of variables such as service sector employment in terms of mining, service sector employment in terms of manufacturing, and CPI. Considering these results together with the results of the first phase, which clearly indicate the appreciation of the REER associated with rising oil prices, we can derive a reliable estimate of the spending effect of DD in the Azerbaijani economy. See Section 4.2 for a visual representation of the index values.

4.2 Dutch disease indexes

Fig. 2 displays the PCs, namely TDDI2_1 and TDDI2_2, along with the weighted average (AVE_TDDI, comprising 66% of PC1 and 34% of PC2, as indicated by the explained variance in Table 2), which were computed in the second phase of PCA, illustrating their relationship with Azerbaijan's GDP in current USD from 1991 to 2021. The AVE_TDDI values reveal an intensification of DD effects in the economy during the period between 2002 and 2010, ranging from –0.57 to 1.10, followed by a downward trend thereafter, with a notable increase in 2018 and 2021. Fig. 2 clearly demonstrates a strong positive correlation between Azerbaijan's GDP and the total DD effects, attributed to the generation of value-added through the extractive industry.

Fig. 2 presents TDDI2_1 and TDDI2_2, two PCs of the second stage index formation. TDDI2_1 underwent its initial period of instability in the early 1990s, experiencing a notable increase from –1.59 in 1994 to –0.21 in 1998. Subsequently, TDII2_1 exhibited a gradual slowdown until 2005, followed by a significant surge to 1.41 in 2015 from its value of –0.94 in 2005. TDII2_2 shows similar trends to TDII2_1, but with greater fluctuations compared to TDII2_1.

Fig. 3 illustrates resource movement indexes alongside manufacturing's share in total industrial production from 1991 to 2021. During the period from 1991 to 2012, the average value of the first two PCs (AVE_RMI) in the second phase of estimating the RMI demonstrated a consistent positive trend, culminating in its highest value of 0.99 in 2011. In contrast, non-oil manufacturing witnessed significant declines during the same period. Subsequently, due to the downturn in commodity prices, or, in other words, during the post-boom period, the AVE_RMI decreased to 0.29 in 2016. However, a recovery from the external shock led to an increase in this value to 0.72 in 2018. Similarly, in the aftermath of the COVID-19 pandemic in 2020, the AVE_RMI began to rise once again.

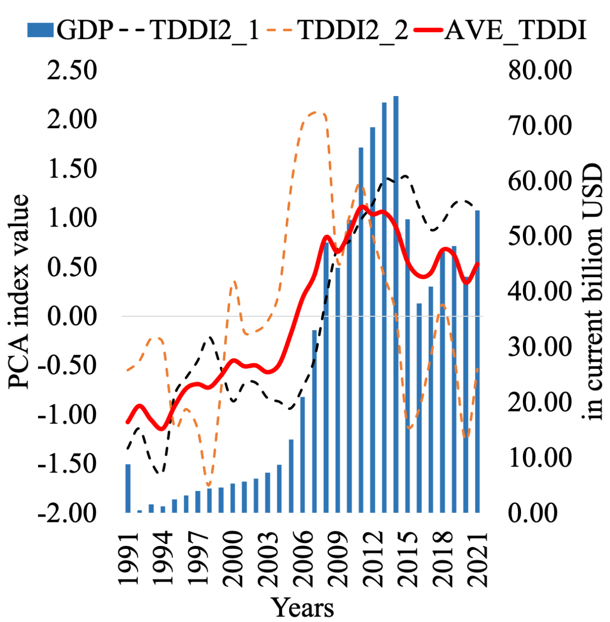

Fig. 2 Total Dutch disease index (TDDI) in the Azerbaijani economy estimated via principal component analysis (left axis, in index value) and gross domestic product (GDP) in current USD (rigt axis), 1991–2021

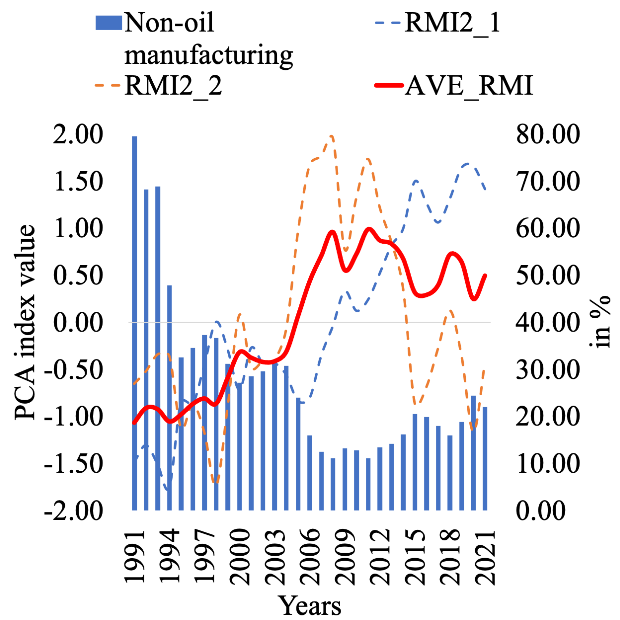

Fig. 3. Resource movement index (RMI) in the Azerbaijani economy estimated via principal component analysis (left axis, in index value) vis-à-vis non-oil manufacturing's share in total industrial production (right axis, in %), 1991–2021

The first PC of the RMI shows greater consistency with the realities of the Azerbaijani economy by peaking in 2020 with an index value of 1.50 (Fig. 3). It should be noted that the first PC of the RMI focused on the manufacturing trade balance and wages of the mining industry in terms of manufacturing, while the second PC focused on oil rents, oil prices, the mining share of GDP, and mining employment in terms of manufacturing (Table 4). In other words, the first PC of the RMI shows a high degree of resource movement effect from DD, while the second PC shows less evidence of it in recent years. The average value of these two PCs indicates a declining trend of resource movement effects since 2014 and some fluctuations in recent years.

Finally, Fig. 4 illustrates the SI that was estimated in the second phase of PCA. In a broader sense, the average value of SI (AVE_SI) exhibits a predominantly lower and even downward trend in terms of spending effects from 1991 to 2004. However, this trend reverses starting from 2005, with a rapid and substantial increase observed up to 1.06 in 2014. Analogous to the TDDI and RMI, the SI also experienced a decline subsequent to the pronounced drops in commodity prices in global markets in 2015. In 2016, the SI recorded a value of 0.74; nevertheless, it commenced an upward trajectory once again, culminating in a value of 1.14 in 2021.

When examining the individual components of the averaged SI, it becomes evident that SI exhibits a persistent upward trend in relation to the employment and wage aspects of DD, as SI2_2 in Fig. 4 shows. This observation suggests that SI2_2 can be considered a more accurate representation of the spending effect described in the DD theory. This finding is supported by the fact that the first component of SI incorporates limited contributions from the above variables, thereby failing to comprehensively capture the signs and effects of DD.

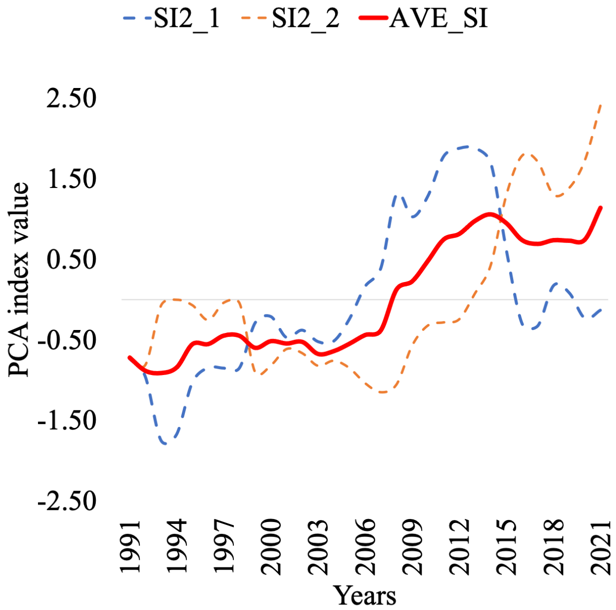

Fig. 4 Spending index (SI) of Dutch disease in the Azerbaijani economy estimated via principal component analysis, 1991–2021

To get a brief overview of how the estimated indexes are related to some economic variables of the Azerbaijani economy, a correlation analysis was performed. Table 6 reports the results. According to the findings, all DD indexes showed very high and statistically significant correlations with the variables such as gross capital formation (GCF), GDP per capita etc., suggesting that the effects of DD went hand in hand. It can also be seen that TDDI and RMI have the highest negative correlation with non-oil manufacturing output, while SI has a lower but still high correlation. These results show the relevance of the estimated PCA-based DD indexes for the Azerbaijani economy.

Table 6 Spearman's Rho correlation analysis of the Dutch disease indexes and selected indicators in Azerbaijan, 1991–2021

		1	2	3	4	5	6	7	8
1	GCF	1.00							
2	Imports	0.95	1.00						
3	GDP p.c.	0.92	0.93	1.00					
4	GNE	0.97	0.98	0.95	1.00				
5	Non-oil man.	–0.80	–0.76	–0.86	–0.77	1.00			
6	TDDI	0.91	0.88	0.95	0.90	–0.93	1.00		
7	RMI	0.86	0.82	0.90	0.83	–0.96	0.98	1.00	
8	SI	0.91	0.89	0.86	0.92	–0.75	0.87	0.80	1

Notes: All coefficients are statistically significant at 1% level; GCF denotes gross capital formation; GDP p.c. denotes gross domestic production; GNE denotes gross national expenditures; man denotes manufacturing; Variables between 1 and 4 are in current USD; Non-oil manufacturing was expressed as percentage share; TDDI, RMI, and SI are index values estimated via PCA.

5 Conclusions

DD is a controversial and elusive phenomenon when it comes to measuring and pinpointing certain dimensions (i.e., resource movement and spending effects). The main contribution of this study is to provide an experimental overview of the development of a PCA-based DD index in a small, open, and oil-rich country such as Azerbaijan for a relatively longitudinal period (between 1991 and 2021), which has not been accomplished before. As a composite index methodology, PCA reduces the dimension of datasets consisting of highly correlated and related variables, performs weighted aggregation to integrate each variable based on its contribution to variance within the dataset, and rigorously provides fewer indicators instead of multiple variables.

Based on the high KMO values, the average communalities, the explained variances, and the significant loadings on the PCs, it can be argued that PCA proves to be a fruitful approach for developing a composite index related to DD. Furthermore, by treating the resource movement and spending effects of DD separately, the study has provided RMI and SI, allowing for a more comprehensive examination of this phenomenon. The case of the Azerbaijani economy presents an intriguing context in this regard, as the obtained TDDI, RMI, and SI exhibit meaningful and expected associations with key economic indicators such as GDP per capita and non-oil manufacturing output. Notably, Azerbaijan experienced significant DD effects during the oil boom, whereby between 2005 and 2015, with the spending effect appearing to be more pronounced than the resource movement effect.

The increased impact of DD on the Azerbaijani economy, combined with the increase in GDP and the decline in non-oil production, shows that this phenomenon was not considered in the government's policy measures. First, despite the presence of a sovereign wealth fund (SWF) in the form of the State Oil Fund of the Republic of Azerbaijan, domestic inflationary pressures persisted due to the limited absorptive capacity of the national economy during the oil boom period. This observation aligns with the arguments of Davis et al. (2001), who claim that poorly integrated SWFs tend to be less transparent and efficient in terms of resource revenue management to mitigate DD effects. The lack of a government exchange rate policy has exacerbated this problem (Hasanov, 2017).

Second, the apparent resource movement effects in the Azerbaijani economy suggests that institutional and industrial policy measures may have been either ineffective or non-existent. Espinoza et al. (2013) and Alssadek and Benhin (2021) claim that without robust institutional measures, high government spending and foreign direct investment alone are unable to convert windfall revenues into productive capacity. Transparency and accountability in the management of resource revenues are important indicators of institutional quality and have a significant impact on the success of industrial policy. However, it is noteworthy that Azerbaijan has withdrawn from the Extractive Industries Transparency Initiative–EITI (2017) and has seen a decline in corruption control (Sovacool and Andrews, 2015).

Thirdly, to combat DD and reap the long-term benefits of natural resource wealth, it is imperative to improve technological advancement and infrastructure. This can be achieved by increasing investment in human capital, creating a skilled workforce that can produce high-value export goods, and diversifying the tradeable sector in Azerbaijan. Implementing a series of measures aimed at mitigating the adverse consequences of DD while maximising the long-term benefits of resource wealth is crucial for the Azerbaijani economy.

Therefore, the proposed DD indexes can be a useful policy tool for governments to diagnose the phenomenon and predict the trends and dynamics in the oil-dependent economy. Thanks to their multidimensional perspective, the DD indexes provide a unified, time- and energy-efficient method to capture the elusive nature of DD for policy making. Although the current results are limited to the Azerbaijani economy, PCA-based composite index development can be exercised in the case of other countries. The proposed methodology can therefore be improved and extended to cover a broader perspective. Further studies should apply PCA and DD theory on sub-sectoral data to gain a more granular perspective about the transmission mechanisms of DD and link them to broader theoretical considerations such as NRC.

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Appendix

Table A1 Abreviations, measurement levels, and the sources of the variables used in the study

Variable name	Abbreviation	Measurement	Source
Manufacturing's share in GDP	MAN_GDP	in %	World Bank
Mining industry's share in GDP (including construction)	MIN_GDP		
Oil rents as the share of GDP	OIL_RENT		
Transfers from the State Budget to the State Oil Fund	TRANS		World Bank Statistical Handbooks + SOFAZ Annual Reports
The share of manufacturing output in GDP	MAN_GDP		World Bank
The share of mining output in GDP	MIN_GDP		
Oil prices	OIL_P	USD per barrel	U.S. Energy Information Administration
Consumer Price Index	CPI	Index value, units, 2010=100%	International Monetary Fund
Real Effective Exchange rate	REER		Bruegel Data Sets
Manufacturing Trade Balance	MAN_TR_BAL	In millions of AZN	State Statistical Committee of the Republic of Azerbaijan + World Bank Statistical Handbook 1995
Oil extraction	OIL_EXT		
Natural gas extraction	GAS_EXT		
Government spending	GOV_SPEN		
Services employment in terms of manufacturing employment	EMP_SER_MAN	Ratio values	SSCRA + World Bank Statistical Handbook 1995
Services employment in terms of mining employment	EMP_SER_MIN		
Mining employment in terms of manufacturing employment	EMP_MIN_MAN		
Wages of mining in terms of manufacturing	WG_MIN_MAN		
Wages of non-tradeable sectors in terms of manufacturing	WG_NT_MAN		
Wages of mining in terms of non-tradeaable sectors	WG_MIN_NT		

Table A2 Descriptive statistics of the variables used in the study

Variable	Min	Max	Mean	St.Dev.	Skewness	Kurtosis
REER	40.0	140.6	94.4	24.6	0.0181	–0.1033
OIL_P	12.8	111.6	50.5	31.8	0.6075	–0.8233
OIL_RENTS	3.7	39.7	24.1	8.4	–0.1722	–0.1075
MAN_GDP	4.0	12.7	6.7	2.3	0.9299	–0.0417
MIN_GDP	27.7	66.1	47.5	11.2	–0.0239	–0.9740
CPI	0.4	171.9	80.3	49.5	0.1696	–0.8069
TRANS	7.3	58.2	30.4	17.5	0.2223	–1.5934
EMP_MIN_MAN	0.2	7.6	3.4	2.2	0.3895	–0.9741
EMP_SER_MIN	95.4	7333.9	2344.2	1603.4	1.1837	1.4659
EMP_SER_MAN	48.1	71.9	58.8	7.1	0.4531	–1.0010
OIL_EXT	9071.0	50692.0	27507.2	15096.1	0.0428	–1.7802
GAS_EXT	4995.0	32578.0	12511.2	7571.2	0.8163	–0.0928
WG_MIN_MAN	1.1	6.3	3.8	1.3	–0.5107	0.0353
WG_NT_MAN	1.0	1.7	1.3	0.2	0.5792	–0.5133
WG_MIN_NT	1.5	4.6	3.0	0.8	–0.1003	–0.3940
GOV_SPEN	–93,019,30.0	4,270,000.0	–2895991.9	3194149.0	0.0182	–0.6253