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King Abdullah Petroleum Studies and Research Center

Saudi Vision 2030 Dynamic Input-Output Table:

Combining Macroeconomic Forecasts With the RAS Method

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About KAPSARC

The King Abdullah Petroleum Studies and Research Center (KAPSARC) is a non-profit global institution dedicated to independent research into energy economics, policy, technology and the environment across all types of energy. KAPSARC's mandate is to advance the understanding of energy challenges and opportunities facing the world today and tomorrow, through unbiased, independent, and high-caliber research for the benefit of society. KAPSARC is located in Riyadh, Saudi Arabia.

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Key Points

This paper describes in detail a framework developed for long-term projections of input-output tables (IOT).

It shows how to combine macroeconomic forecasts with the RAS method to incorporate national plans for economic transformation and diversification, such as Saudi Vision 2030.

Key economic targets of Vision 2030 are presented, as they form the basis of this particular research project.

The major advantages and drawbacks of the IOT projection methodology are discussed, along with potential improvements and further research directions.

The paper describes the use of the framework for medium-term impact analysis and the compilation of long-term scenarios.

The paper indicates how IOT projections form a solid quantitative basis to assess the progress made in achieving a more diverse and sustainable economy.

Summary

When an economy is in the midst of a transformation and diversification process, it is hard to assume that its sectoral composition and inter-industry transactions will remain unchanged. This is especially the case since substantial adjustments to a country's economic structure are at the heart of any restructuring plan. This paper introduces an approach that combines macroeconomic forecasts with the RAS method to produce long-term projections of input-output tables (IOTs), with an emphasis on key targets of Saudi Vision 2030, Saudi Arabia's blueprint for economic diversification. A significant advantage of the input-output framework is its high sectoral granularity, allowing it to capture the impacts of adjustments to final demand or government policies with respect to individual sectors. Our hybrid approach enables the introduction of different growth paths for the main variables, so that Vision 2030's transformation plan is reflected appropriately in the projected IOTs. The framework is flexible enough to accommodate sudden adjustments with relative ease, such as the introduction of new technologies or entire sectors into the economy. Saudi Vison 2030 includes a set of targets relating to economic diversification, improved energy efficiency, the introduction of new technologies, social transformation and the support of selected emerging sectors. These policies are expected to have a substantial impact on the Saudi economy, underlining the need for an adequate and flexible tool for projecting and evaluating structural adjustments in the economy.

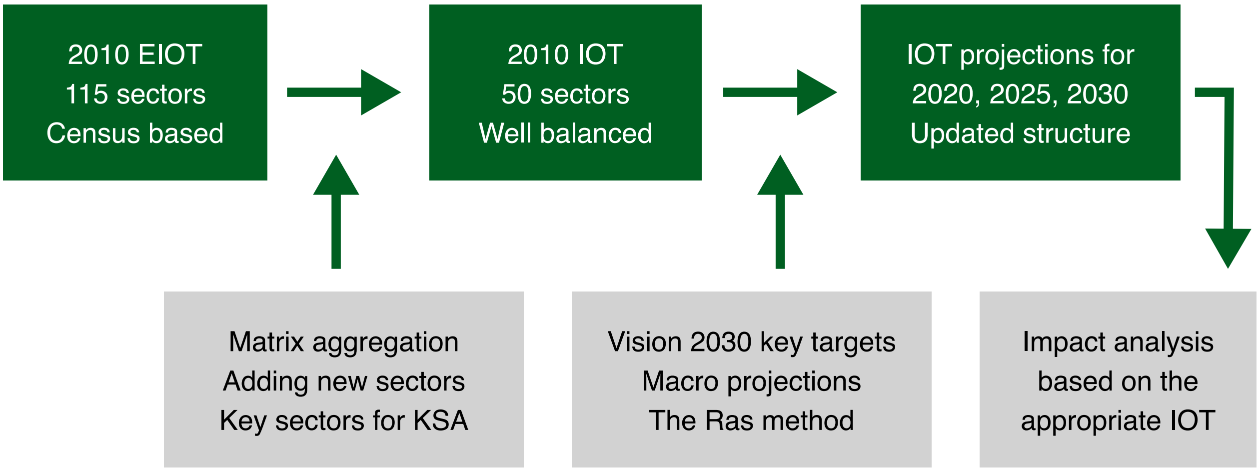
Introduction

Given the elevated oil price volatility in recent years, some Gulf Cooperation Council (GCC) countries have decided to take bold policy measures to reduce their income dependence on oil revenues, notably through economic diversification. Saudi Arabia, for example, aims to transform its hydrocarbon resource-rich economy into a sustainable and diversified one. Saudi Vision 2030, the country's blueprint for economic diversification and sustainability, contains a set of complex socio-economic transformation targets. The plan reflects the Kingdom's determination to become a global investment powerhouse and to stimulate its non-oil sector. As a result, Vision 2030 is expected to significantly change the economy's sectoral composition, with the manufacturing and service sectors becoming additional pillars of sustainable growth.

The question of how well a given input-output table (IOT) reflects the current and expected economic structure is thus a legitimate concern, especially when looking at a longer-term view. It is generally accepted that technological production processes may be considered roughly unchanged over a decade, provided that structural changes in the economy are limited, which may be the case in an advanced economy. However, if a longer time horizon is taken into account, and the economy under scrutiny is being transformed, constant inter-industry transactions can no longer be assumed. Overall, the corresponding main IOT segments, such as final demand, value added, imports and inter-industry flows, should be updated to be in line with the economy's latest or expected economic expansion and structural changes. The Vision 2030 input-output table (V2030 IOT) integrates the available historical data, yet the main focus is on long-term projections.

This methodology paper outlines a specific approach to projecting an IOT that would reflect the envisaged structural adjustments in the Saudi economy, as outlined in Vision 2030 and related government documentation. As a starting point, we take the Extended 2010 IOT compiled by Saudi Aramco (2010 EIOT), which is based on a comprehensive economic census, provides sufficient granularity and is extended to accurately represent the energy sector. This table is aggregated, and several new sectors are introduced to embody key elements of the Saudi economy and the planned transformation, with a total of 50 sectors projected. Finally, macroeconomic forecasts of final demand, value added and imports are combined with a bi-proportional scaling technique, namely the RAS method, to acquire long-term V2030 IOT projections. The IOT projections for 2020, 2025 and 2030 help policymakers answer various 'what if?' questions and assess the progress made toward achieving a more diverse and sustainable economy. The basic steps of our approach are shown in Figure 1, below.

Figure 1. V2030 IOT projection scheme.



The next section discusses the composition and compilation of the 2010 EIOT to highlight the starting points for our projections. Section 3 focuses on the basic structure of an IOT and the algebra used to facilitate an understanding of the projection methodology, which is shown in detail in the subsequent section. The RAS method is the subject of section 5 and makes the key algorithm readily accessible to the reader. Section 6 emphasizes the benefits of using the V2030 IOT in the economic impact analysis and the opportunities arising from the long-term projection scenarios. The final section concludes the key findings and outlines future research directions. The main purpose of this paper is to detail a specific approach to long-term IOT projections. A discussion of the results of the Vision 2030 Dynamic Input-Output Table research project will follow in a separate discussion paper.

2010 EIOT Starting Point

From the perspective of economics, input-output (IO) models provide a useful quantification of linkages and interdependencies across various sectors of a national economy. They are very useful for understanding the implications of government policies and measures for a particular industry or sector. They are also used by governmental economic development agencies to evaluate and adjust the local supply chain capacity to meet the demand for inputs by domestic industries. Input-output analyses can also help policymakers to identify important industries that have large multiplier effects, which can substantially boost overall economic growth when they are expanding.

An IOT compilation requires well-assembled and structured data (Leontief 1936, 1951). There is a considerable body of literature devoted to assembling the basic data used in the input-output framework, from surveys to analyses of primary and secondary economic data sources (Jaszi 1986; Kymn 1990; Webb 1995; Lawson et al. 2002; Moyer et al. 2004a, 2004b). Basic information is often derived from social accounting data, which is routinely collected on a national or regional level through periodic censuses or other surveys.

Most countries structure relevant information about economic activity in the System of National Accounts (SNA), the internationally agreed set of recommendations on how to compile measures of economic activity. The SNA describes a coherent, consistent and integrated set of macroeconomic accounts in the context of a set of internationally agreed concepts, definitions, classifications and accounting rules. It was produced by and is released under the auspices of the United Nations, the European Commission, the OECD, the International Monetary Fund and the World Bank Group (United Nations 2008).

The starting point in this study is the 2010 Extended Input-Output Table (2010 EIOT), which includes three distinct segments: inter-industry transactions, final demand and value added. This structure is in line with the standard Eurostat IOT methodology (United Nations 1968, 1993, 1999, 2004). This section shows the data collection and compilation of the 2010 EIOT, as conducted by Saudi Aramco.

The 2010 EIOT is based on supply and use tables (SUTs) estimated from the primary data obtained through censuses and surveys conducted by Saudi Arabia’s statistical authorities. Data reallocation is applied to the SUTs to build a symmetric IOT with an equal number of rows and columns. Most of the entries in the IOT are measured directly, except for financial services and some minor services, which are measured indirectly to avoid double counting.

As a starting point for the 2010 EIOT compilation, the SUTs for Saudi Arabia, containing 59 sectors, were applied, while the detailed industrial census surveyed some 83 industries. Some additional industries and envisaged future sectors were taken into account, using coefficients derived from other countries’ industrial data, along with IOTs with a similar set of activities and economic structure. The 2010 EIOT reached 115 sectors after all the steps described below were completed.

Specific industries were further disaggregated based on the analytical requirements of Saudi Aramco. Activities of strategic importance and substantial energy-intensity met its selection criteria for the disaggregation of an existing sector. For example, oil and gas mining activity was disaggregated into production and drilling, lifting crude and gas, lifting non-associated gas, gas-oil separation package, gas treatment, gas liquids fractionation, workover and well maintenance. Other industries were disaggregated to enable a more detailed industry analysis and to improve the accuracy of Aramco's estimates.

The 2010 EIOT incorporates the significance of energy and its relationship to other industries in the economy. This is achieved by adding granularity to existing activities and by adding additional sectors as per the above-mentioned criteria. For example, petroleum refining is subdivided into five disaggregated activities: crude distillation, secondary processing, deep conversion, refined aromatics and distribution and marketing. Instead of representing petrochemicals as a single industry, the 2010 EIOT disaggregates the petrochemicals sector into basic, intermediate and specialty chemicals and is further broken down into the products of 15 industries. The power and water (desalinized) industries are subdivided into seven and five separate activities, respectively, to enable a comprehensive analysis of utility generation based on fuels used. Because the transportation sector consumes most liquid fuels, it is subdivided into road, pipeline, rail, water and air transport to increase the granularity and accuracy of demand estimation. Other inter-industry flows of inputs between energy-intensive sectors provide valuable insights into the structure of the Saudi economy. The 2010 EIOT has 115 sectors and follows the International Standard Industrial Classification of All Economic Activities (ISIC) (United Nations 1968, 1993, 1999, 2004).

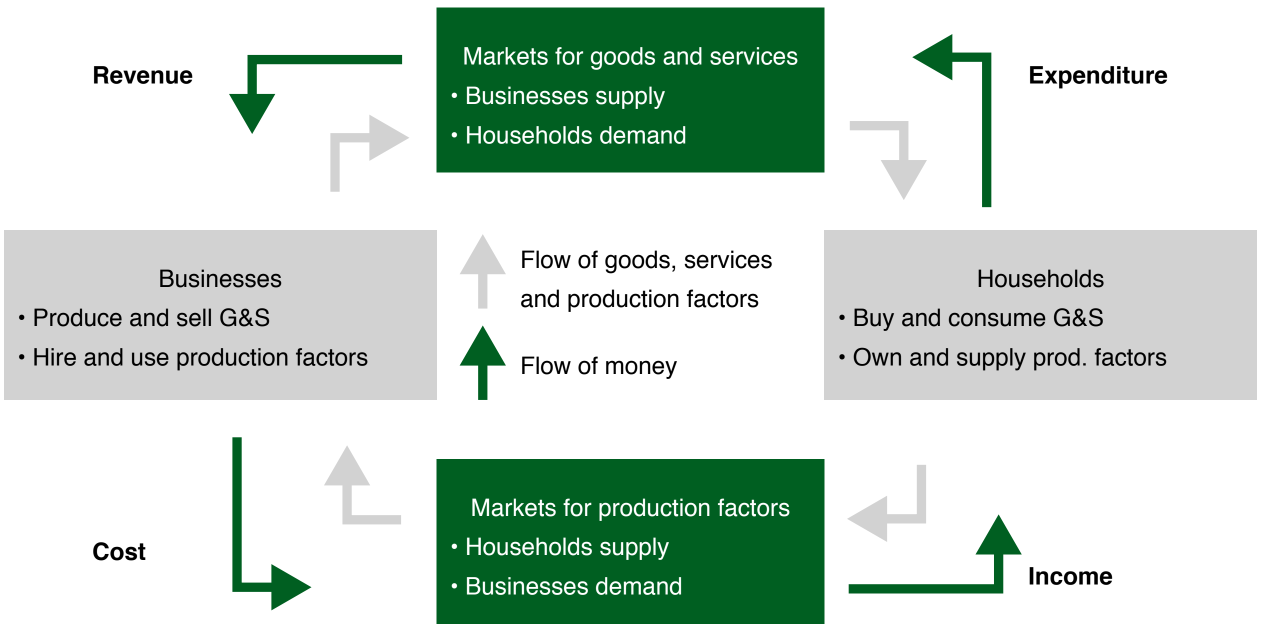
The 2010 EIOT is compiled product-by-product, resulting in transaction homogeneity. Assumptions regarding technology and relationships within and between products and industries are applied to accurately reflect the structure of the economy and the inter-industry flow of inputs. First, product-by-product mapping is used to create a symmetric IOT, based on the assumption that each product is produced in a specific way irrespective of its industry. Second, it is also assumed that the organization of each industry is fixed irrespective of the product mix. Under the assumption that production units are homogeneous, secondary production, comprising subsidiary, by-products and joint products, is relocated to industries where these are primary products.

The IOT followed a fixed sales structure where each product has its own specific structure irrespective of the industry in which it is produced. Adjustments were made to assign comparable and non-comparable imports accordingly. The product-by-product imports are finally aggregated and represented in a simplified manner as a single row in the 2010 EIOT. There are alternative approaches in the literature to compiling the Z matrix (Ten Raa et. al 2003, 2007; Kop Jansen and Ten Raa 1990), depending on whether aggregation is based on products or industries.

IOT Structure and Algebra

The SNA can be understood as a circular flow of various types of resources in the economy and shown in various levels of detail. In its basic form, businesses produce goods and services on the one hand, and households purchase and consume these products on the other. Households also possess and supply factors of production, such as labor and capital, and receive income from businesses for these factors in the form of wages and rents. To balance the flow of funds, the overall household income equals the overall value of their purchases. According to this basic idea of the circular flow of expenditure and income, the total value of final production can be measured either by the value of all final goods and services (G&S) purchased by households, or by the payments of businesses for the rental of production factors, as shown in Figure 2.

Figure 2. Circular flow diagram, including households and businesses.



This basic model could be extended to show more structured supply and demand, or other markets may be taken into account, yet the principle would remain the same. Further on, we will consider a more detailed view of the final demand breakdown, which includes not only households but also the government, investors and foreign entities. On the payment side, wages, taxes, and the use of capital and profits will appear among outlays of the businesses. At the same time, it is important to keep in mind the limitations of any methodology. The main drawback of the IOT framework is that it does not explicitly address price relations and their developments. As prices are essentially linked to resource constraints, IOT simulations provide optimal outcomes in conditions with sufficient resources. The missing price information could be overcome by constructing an IOT time series that would allow additional econometric applications.

The value added segment of the IOT framework captures payments from businesses for hiring the factors of production and government services, while the final demand segment reflects the value of all final goods and services purchased by households, the government, investors and foreign entities. The inter-industry flows represent the intermediate inputs and outputs purchased and sold between industries used in the production process. Total output equals the sum of intermediate output and final demand (the selling perspective of a particular sector), while total input equals the sum of intermediate input, imports and value added (the purchasing perspective of a particular sector). Finally, to maintain a balance of overall resource flows, total input and total output equal one another for each industry.

All of these typical IOT segments are shown in Table 1. The transaction matrix Z represents flows of intermediate inputs and outputs between all sectors, having $n \; x \; n$ dimensions for an IOT with n sectors. The row sums of the transaction matrix form the vector of the intermediate outputs u, while the column sums form the vector of intermediate inputs v, both of which are provided on an industry-to-industry basis. Required inputs from abroad are represented by the vector of imports m. All other domestic production inputs, in the form of employee compensation, government taxes, capital use and profits for business owners, are shown in the value added matrix L, which is added up column-wise to the value added vector l.

All the final goods and services are represented by the final demand matrix F. These are purchased by households for consumption, by the government, by business owners for investment and also exported abroad. The row sums of the final demand matrix form the vector of final demand, denoted as f. The intermediate input, imports and value added sum up to the total input x, while intermediate output and final demand add up to the total output, also denoted x. These two equal for each sector to close the circular economic system.

Table 1. IOT scheme with typical segments.

Inputs (purchases) / Outputs (sales)	**Sector (1)**	**Sector (2)**	**…**	**Sector (n-1)**	**Sector (n)**	**INTERMEDIATE OUTPUT**	**Household consumption**	**Government purchases**	**Investment expenditure**	**Exports**	**FINAL DEMAND**	**TOTAL OUTPUT**
Sector (1)	**Z**					u (1)	**F**				f (1)	x (1)
Sector (2)						u (2)					f (2)	x (2)
…						…					…	…
Sector (n-1)						u (n-1)					f (n-1)	x (n-1)
Sector (n)						u (n)					f (n)	x (n)
INTERMEDIATE INPUT	v (1)	v (2)	…	v (n-1)	v (n)							
Imports	m (1)	m (1)	…	m (n-1)	m (n)							
Taxes less subsidies on products												
INTERMEDIATE CONSUMPTION												
Compensation of employees	**L**											
Other taxes less subsidies on production												
Consumption of fixed capital												
Net operating surplus												
VALUE ADDED AT BASIC PRICES	l (1)	l (2)	…	l (n-1)	l (n)							
TOTAL INPUT	x (1)	x (2)	…	x (n-1)	x (n)							

The resulting IOT can be used to understand the inter-industry flows, the structure of final demand and, to some extent, the production technology of each sector in the economy (Stone 1961; Miller and Blair 2009). Assume an economy with n sectors, thus an $n \ x \ n$ transaction matrix Z, with z_{ij} representing inter-industry sales of sector i to all sectors j, including itself for i=j. These transactions are also called intermediate sales. If the total output of each sector i is denoted as x_i and final demand as f_i, then the way sector i distributes its overall production through sales to all other sectors and final demand can be formalized as

$$x_i = z_{i1} + \ z_{i2} + \cdots + z_{ii} + \cdots + z_{in} + f_i = \sum_{j=1}^{n} z_{ij} + f_i \ , \ \ i = 1 \dots n,$$

or in matrix notation as

$$x = Z\sigma + f,$$

with

$$x = \begin{bmatrix} x_1 \\ \vdots \\ x_n \end{bmatrix}, \; Z = \begin{bmatrix} z_{11} & \cdots & z_{1n} \\ \vdots & \ddots & \vdots \\ z_{n1} & \cdots & z_{nn} \end{bmatrix}, \; f = \begin{bmatrix} f_1 \\ \vdots \\ f_n \end{bmatrix},$$

and σ representing an appropriate unit vector. This implies that the intermediate output of a particular sector, which is sold to all other industries to be used in their production processes, is the row sum of the corresponding transaction matrix elements

$$u_i = z_{i1} + z_{i2} + \cdots + z_{in} = \sum_{j=1}^{n} z_{ij}\ , \; i = 1 \dots n\ ,$$

while the intermediate input, which is purchased by a particular sector from all other industries, is represented by the column sum of the inter-industry transactions matrix

$$v_j = z_{1j} + z_{2j} + \cdots + z_{nj} = \sum_{i=1}^{n} z_{ij}\ , \; j = 1 \dots n\ ,$$

providing in matrix notation

$$u = Z\sigma \text{ and } v = \sigma' Z.$$

In the basic input-output model, the matrix of technical coefficients A, also called the direct requirements (or technical coefficients) matrix, is derived directly from the inter-industry transaction matrix Z and total output x. The total output vector has to be transformed into a diagonal matrix $\hat{x}$ (diagonalized), so that the resulting A matrix has appropriate dimensions as

$$A = Z\hat{x}^{-1}.$$

The individual technical coefficient (or input-output coefficient) $a_{ij}=z_{ij}/x_j$ measures a fixed proportion between input and output in a particular sector. As a consequence, economies of scale are omitted in a short-term IOT analysis, as the concept relies on constant returns to scale. Within this structure, the input-output model relates the economy's total output and final demand in the following manner

$$x = Ax + f,$$

with f standing for final demand. This formula can be rewritten as

$$x = (I - A)^{-1} f.$$

The above equation is essential for input-output analysis, with final demand being directly linked to the total output of the economy. The matrix inverse is often referred to as the total requirements matrix or the Leontief inverse matrix and denoted as L, with

$$x = (I - A)^{-1} f = Lf.$$

The technical coefficient matrix A is often a good summary of the inter-industry flows, enabling an easy and clear prediction of the economy's production capacity as the final demand evolves with the algebraic link. The Leontief inverse matrix L is better suited for investigating the overall impact on the economy as a result of changing the final demand for a single sector or a group of industries. The column-sums of the L matrix represent simple output multipliers that include both the direct and indirect effects of the change in final demand.

Vision 2030 IOT Projection

Updating the IOT involves acquiring the transactions and the technical coefficients matrix for the target year. It is usually in the interests of researchers and policymakers to understand the disaggregated effects of an overall change in economic output. If two or more sets of input-output data are available, it is possible to split the overall change in output between two periods into incremental adjustments, due to the shifts in technology and final demand. However, collecting information for IOT compilation is very time consuming and expensive. As a general practice, a base year IOT (2010 for Saudi Arabia) is compiled and the projections are acquired through an updating procedure. Well-documented approaches and algorithms are available for updating IOT segments over a given time horizon. Typical reasons behind long-term adjustments in the transaction matrix are as follows:

- Technological changes, including the introduction of more efficient methods of production, improvements in human capital and better organization of the production process.
- Significant increases in demand for particular types of goods or services, implying a rise in supply and resulting in economies of scale and changes in input-output proportions.
- The introduction of entirely new goods and services, leading to substitution effects and adjustments in the production scheme.
- Changes in the relative costs of inputs, implying shifts in the input pattern, such as the energy mix composition, depending on the relative prices of energy sources.
- Adjustments in the use of imported and domestically produced inputs, goods and services that can precipitate the emergence or disappearance of entire industries.

IOT updates were usually based on available historical datasets for final demand and value added. Though we take on board available historical data up to 2018, this study aims to provide long-term projections. Our approach combines macroeconomic forecasts, expert judgment for individual sectors and a bi-proportional scaling algorithm, namely the RAS method. This allows us to project to 2030 and to incorporate the key transformation targets of Saudi Vision 2030 and related government documentation. Examples of the key economic targets of Vision 2030 considered in this exercise are listed below:

- Increase the contribution of the private sector to gross domestic product (GDP).
- Increase the local content of the oil and gas sectors.
- Raise the share of non-oil exports in non-oil GDP.
- Improve the country’s ranking in global logistics performance measures.
- Boost the capacity to welcome Umrah pilgrims.
- Promote household spending on entertainment activities in the Kingdom.
- Increase the country’s renewable energy capacity.
- Increase the government’s non-oil revenue.

The following section describes the main building blocks of the projection methodology. Macroeconomic projections of overall economic growth, aggregate demand, value added and imports are required to be applied as main inputs in the RAS method (Miller and Blair 2009). An economic prediction model for the aggregate economy is viewed as an external tool that supplies the main assumptions for the IOT projections. This combination of external macroeconomic assumptions and a bi-proportional scaling algorithm is usually referred to as a hybrid updating method. It is used with various modifications by the United States Department of Commerce and Eurostat.

We will use a simplified IOT shown in Table 2, below, to illustrate the projection process. It is a well-balanced IOT that includes common sections such as inter-industry flows (yellow), imports (orange), value added (green) and final demand (blue). For each industry, the total output is the sum of intermediate output and final demand, and the total input is the sum of intermediate input, imports, and value added. The overall sums of intermediate input and intermediate output across all industries are equal, while the total input and total output equal for each industry. All sections of this initial IOT will be updated in subsequent revisions. Projections of final demand, value added and imports are mainly based on macroeconomic forecasts and key transformation targets. The corresponding projections of both total and intermediate inputs and outputs are based on Leontief inverse matrix calculations. Finally, the inter-industry flows are updated by applying the RAS method.

Table 2. Initial IOT with commonly used segments, which are updated in the projection process.

Inputs / Outputs	Industry 1	Industry 2	Industry 3	Industry 4	Industry 5	INTER. OUTPUT	Consum. expend.	Capital formation	Exports	FINAL DEMAND	TOTAL OUTPUT
Industry 1	36	68	5	24	8	142	213	20	747	980	1,121
Industry 2	6	20	7	17	23	73	28	4	129	161	234
Industry 3	2	1	28	26	2	58	16	76	9	101	159
Industry 4	22	11	18	80	33	165	162	203	38	403	568
Industry 5	18	11	18	96	157	300	441	113	17	570	870
INTER. INPUT	84	111	77	244	222	738	860	415	941	2,215	2,953
Imports	20	15	30	33	35	133					
INTER. CONS.	104	127	107	276	258	871					
Compensation of employees	168	13	16	75	312	584					
Other taxes less subsidies	5	2	1	1	2	11					
Consumption of fixed capital	40	16	15	43	21	135					
Net operating surplus	805	77	20	172	278	1,353					
VALUE ADDED	1,018	108	53	292	613	2,082					
TOTAL INPUT	1,121	234	159	568	870	2,953					

Although the projections of aggregate final demand, value added and imports are sufficient to proceed with the hybrid updating methodology, the availability of disaggregated sector forecasts can significantly improve the overall accuracy and sensitivity of the IOT's projections. A higher granularity for the main inputs also strengthens the coherence and reasoning of the economic story. Some components of aggregate demand can change substantially, given the ambitious targets of Vision 2030 in selected economic areas. Our hybrid approach enables the introduction of different growth paths for final demand, value added and imports for each sector, so that Vision 2030's transformation plan is reflected appropriately in the projected IOT. At the same time, the IOT framework and the combination of macroeconomic forecasts with the RAS method provide an ideal setup. It is flexible enough to accommodate sudden adjustments with relative ease, such as the introduction of new technologies or entire sectors. Macroeconomic forecasts for the main inputs may result from a fully-fledged economic model, user-supplied expert views, or a combination of both. The hybrid updating approach we use is described in the following steps.

In the first step, the technical coefficient matrix A^0 and the Leontief inverse matrix L^0 are computed for the base year 2010. Both the inter-industry flows matrix Z^0 and the total output x^0 are available in the 2010 IOT, thus

$$A^0 = Z^0(\hat{x}^0)^{-1}$$

and

$$L^0 = (I - A^0)^{-1}.$$

The base year's intermediate output u^0, final demand f^0, intermediate input v^0, imports m^0 and value added l^0 are also provided by the 2010 IOT. To proceed to the V2030 IOT, all the above-mentioned inputs have to be projected up to the target year 2030. We start with the projected final demand f^1, value added l^1 and imports m^1, as they can all be extrapolated based on straightforward economic models, combined with expert judgement, to accommodate the Vision 2030 growth targets for individual sectors. It is crucial to treat imports separately, as increasing local content is one of the key objectives of the envisaged economic shift. In general, the economic relations underpinning the IOT framework are well aligned with the basic accounting principles of the SNA, such as

$$Total\ output = Total\ input = x,$$

thus in more detail

$$\sum u + \sum f = \sum v + \sum m + \sum l = x,$$

with the overall sum of intermediate output and intermediate input being equal

$$\sum u = \sum v,$$

follows

$$\sum l = \sum f - \sum m\ .$$

The left-hand side stands for gross national income or the total factor payments in the economy, such as employee compensation, fixed capital consumption, net operating surpluses and taxes less subsidies. These are payments (and income) for work, the use of capital and government services. The right-hand side represents the gross national product in terms of the overall expenditure on household consumption and investment, government purchases and the total value of exports less imports. These represent purchases made by households, businesses, government and foreign entities, minus purchases of foreign production.

The next step is to take the 2010 Leontief inverse matrix L^0 and apply it to the 2030 projection of final demand f^1 in order to acquire the projected total output x^1 in 2030. At this stage, we combine the 2010 technology scheme with the expected 2030 final demand. The new final demand incorporates shifted sector proportions, as we anticipate that selected sectors would expand at a much higher rate than the overall economy, while we expect others to grow at a more subdued rate or to even shrink. To reduce this intertemporal mismatch, we use five-year windows and produce updated IOTs for 2020, 2025 and 2030. For each timeframe, the Leontief inverse matrix for year t is applied to a $t+5$ forecast of the main inputs.

$$x^1 = L^0 f^1.$$

The RAS method also requires the projected 2030 intermediate output u^1 along with the 2030 intermediate input v^1. These are derived from the total output projection x^1, which is equal to the total input for each industry and overall. For the intermediate output, produced and sold by and among sectors, we subtract the final demand from the total output

$$u^1 = x^1 - f^1.$$

For the intermediate input, purchased by sectors from one another, we reduce the total output by the value added and imports

$$v^1 = x^1 - l^1 - m^1.$$

Before proceeding with the RAS method, we have to check the consistency of the projected main inputs, as they might come from different sources and types of models. The first consistency check is the alignment of the expenditure and income approaches, as shown in the circular flow diagram (Figure 2).

$$\sum f^1 = \sum l^1 + \sum m^1,$$

to ensure that the expenditure on final demand (household consumption, investment, government purchases and exports) equals the payments for value added (wages, profits and taxes) and imported production. This condition holds for sectors where projections are based on a reasonably good econometric model that secures consistency between income and expenditure. For sectors where projections are mostly based on expert judgement, the scope for discrepancies is larger. We corrected the mismatch between income and expenditure on an ad-hoc basis where necessary, as the IOT has to be perfectly balanced. Consequently, the sums of projected overall intermediate output and overall intermediate input are equal:

$$\sum u^1 = \sum v^1.$$

The second consistency check ensures that there are no negative numbers in either of the intermediate vectors. Negative figures in both vectors are converted to the value of a marginally positive adjustment factor. After such an adjustment, the vector with a larger sum is rescaled so that the sums of both vectors are equal. In our case only a few limited modifications were needed, as the consistency of the original macroeconomic forecast was quite high.

Now all the required inputs are ready to enter the RAS method, namely the total output x^1, the intermediate output u^1 and the intermediate input v^1 for the target year 2030. At this stage, the 2010 transaction matrix Z^0 is inconsistent with the 2030 main inputs, as the row sums of Z^0 do not equal the 2030 intermediate output u^1, and the column sums do not equal the projected intermediate input v^1 for each industry. These two summation conditions must be met to acquire a well-balanced V2030 IOT with all the properties desired. The RAS method is, in essence, an optimization approach that improves the two summation conditions iteratively, so that the overall distance of the new transaction matrix Z^1 to the original is minimal.

The simplified IOT with the updated main inputs is shown below, including the initial forecasts of final demand, value added and imports in blue, based on external macroeconomic models and expert judgement. The green segments, representing both the total and intermediate input and output, are based on IOT algebra and the Leontief inverse matrix. Finally, the inter-industry transaction matrix in yellow will be balanced by applying the RAS method.

Table 3. Updated main inputs and the still unbalanced Z matrix.

Inputs / Outputs	**Industry 1**	**Industry 2**	**Industry 3**	**Industry 4**	**Industry 5**	**INTER. OUTPUT**	**Consum. expend.**	**Capital formation**	**Exports**	**FINAL DEMAND**	**TOTAL OUTPUT**
Industry 1	36	68	5	24	8	178	245	23	859	1,127	1,305
Industry 2	6	20	7	17	23	93	33	5	155	193	286
Industry 3	2	1	28	26	2	76	21	98	12	132	208
Industry 4	22	11	18	80	33	209	194	243	46	483	692
Industry 5	18	11	18	96	157	375	507	130	19	656	1,031
INTER. INPUT	112	138	101	301	279	930	1,000	499	1,092	2,591	3,522
Imports	23	18	37	37	39	154					
INTER. CONS.	135	156	138	338	317	1,085					
Compensation of employees	193	16	22	94	368	684					
Other taxes less subsidies	6	3	1	2	2	13					
Consumption of fixed capital	46	19	20	52	24	161					
Net operating surplus	925	92	26	207	320	1,578					
VALUE ADDED	1,170	130	69	354	714	2,437					
TOTAL INPUT	1,305	286	208	692	1,031	3,522					

Once the 2030 transaction matrix Z^1 has been balanced by the RAS algorithm to a satisfactory degree, the computation of the remaining analytical matrices of interest is straightforward, as all the required components are available. It is now possible to proceed with a comparative analysis of the economic structure in 2010 and that expected in 2030. This is done by using the projected matrix of technical coefficients A^1, the 2030 Leontief inverse matrix L^1, and the corresponding simple output multipliers.

It is obvious that the sources for and quality of the economic projections of final demand, value added and imports may vary. Furthermore, their consistency and perceived relevance can be substantially elevated by focusing on the sectoral sub-components of these projections for the target year, especially if there is a clear link to planned government policies such as Vision 2030. Improvements can be achieved by implementing sophisticated economic models, along with well-informed and well-justified expert evaluations of possible future developments. Generally, appropriate econometric models boost the consistency of forecasts, while expert intervention is needed for sectors with elevated growth potential that are subject to extended government support. For instance, the expected boom in renewable energy, a target of Vision 2030, would be difficult to imitate using a standard macro model, as the value of this sector will likely multiply over the coming years.

One of the transformation targets of Vision 2030 is reducing import intensity. The table below shows a hypothetical scenario in which this target is actioned. The growth in imports between $t=0$ and $t=1$ is set below the expansion of value added for selected sectors. Domestic intermediate inputs are correspondingly increased to compensate for the reduction in import intensity, implying an increase in domestic content overall. The illustrative assumptions about value added and import growth are summarized in Table 4.

Table 4. Value added and import growth - illustrative exercise.

Change between t=0 and t=1	Industry 1	Industry 2	Industry 3	Industry 4	Industry 5	Overall
Imports (% change)	15.0	15.0	25.0	15.0	10.0	15.9
Value added (% change)	15.0	20.6	31.5	21.3	16.5	17.0
Growth differential (pp)	0.0	5.6	6.5	6.3	6.5	1.1

Imports grow at a slower pace than value added in industries 2 to 5, by some 6 percentage points. This results in a 15.9 % increase in overall imports between $t=0$ and $t=1$, while the overall economy is assumed to grow by 17 %. The growth differential will lead to a reduction in imports and, consequently, to an overall increase in domestic content.

The RAS Method

Cross-sectoral relations may undergo substantial adjustments over time, mainly as a result of technological progress, changes in the demand structure and adjustments in government policies. As a result, the overall economic structure may shift significantly over the long term, requiring a modification of the IOT's transaction scheme to accurately reflect the transformed flows. Given the large number of sectors in our study, coupled with the detailed specification of economic transformation goals, we decided to apply a bi-proportional scaling technique, namely the RAS method. The main advantages of this approach are as follows:

> A granular IOT with a large number of sectors can be projected, as forecasts of intermediate input and output, final demand and value added can be provided sector by sector.

> Detailed economic transformation targets for each sector can be incorporated with relative ease, as expert judgement is applicable sector by sector. Many sectors in our study are related to the specific objectives of Vision 2030.

> New benchmarked sectors can be included in the projected IOT, making it easier to follow the planned transition toward a more diversified economy.

> Imports can be modeled consistently according to the envisaged changes, taking into account significant government support for high value-added sectors. Increasing the share of domestic content is one of the goals of the path toward an advanced economy.

> A distinction can be made between demand-driven changes linked to overall economic expansion and structural shifts linked to technological progress, including the emergence of new sectors.
>
> (Stone 1961; Miller and Blair 2009).

For n sectors, the RAS method allows us to estimate n^2 coefficients from $3n$ exogenous projections about the future state of the economy. For 50 sectors, we estimate 2,500 IOT coefficients based on projected intermediate input and output, and total output represented by 150 data points. This iterative approach converges, minimizing the overall distance of the projected IOT from the original IOT once consistent inputs are provided (Stone 1961; Miller and Blair 2009). The inputs for the RAS algorithm are as follows:

> The *intermediate output* of each sector u_i is the row sum of inter-industry transactions $u_i=\sum_{j=1}^{n} z_{ij}$, which equals the total output of each sector x_i less final demand f_i, as the total output of each sector is $x_i=\sum_{j=1}^{n} z_{ij}+f_i$. Final demand includes household consumption, investment, government spending and exports, representing the main GDP components based on expenditure.

> The column sums of the transaction matrix represent the *intermediate input* v_j of each sector $v_j=\sum_{i=1}^{n} z_{ij}$. This is the total input x_j less purchases from the payment sector, including employee compensation, fixed capital consumption, net operating surplus and taxes less subsidies on the domestic side, and purchases of imported products on the external side. Domestic purchases by industries represent domestic value added, which constitutes a basis for GDP calculation based on the income approach.

The RAS Method

> *Total output*, including intermediate output and final demand, and total input, including intermediate input and purchases from the payment sector, are equal for each sector $x_i = x_j$.

The RAS algorithm steps that are repeated until the error in the summation conditions ($u_i = \sum_{j=1}^{n} z_{ij}$ and $v_j = \sum_{i=1}^{n} z_{ij}$) is sufficiently small are as follows:

> Take the original transaction matrix Z^0, consisting of transactions between industries z^0_{ij} at time $t=0$, and calculate the technical coefficients matrix $A^0 = Z^0 (\hat{x}^0)^{-1}$. Combine it with the target projection of total output x^1 at time $t=1$ to obtain the updated transaction matrix $Z^d = A^0 \hat{x}^1$, with the hat indicating a diagonalized vector.

> Verify how well the row sums and the column sums of the updated matrix Z^d align with the projected intermediate output u^1 and intermediate input v^1 at time $t=1$.

> If the updated intermediate input equals the projected one $v^d_j = \sum_{i=1}^{n} z^d_{ij} = v^1_j$ and the updated intermediate output equals the projected one $u^d_i = \sum_{j=1}^{n} z^d_{ij} = u^1_j$, then the updated transaction matrix Z^d is appropriate and the IOT is well balanced.

> However, this is not usually the case due to structural shifts in total output resulting from structural changes in final demand. The difference in the updated intermediate input and the projected one $\varepsilon = v^1 - v^d$ is then not equal to zero, creating space for improvement. Similarly, an existing difference in the updated intermediate output and the projected one $\delta = u^1 - u^d$ requires reduction.

> A diagonalized scaling vector $\hat{r}^d = \hat{u}^1 (\hat{u}^d)^{-1}$ can be computed, reflecting the ratio between the targeted intermediate output and the updated one.

> The coefficient matrix A^0 is then updated by multiplying it with the $\hat{r}^d$ scaling vector: $A^d = \hat{r}^d A^0$. This operation ensures that the row sums of the updated coefficient matrix A^d equal the projected intermediate output, thus $\delta = u^1 - u^d = 0$.

> However, the column sums may not be equal to the projected intermediate input at this stage, with $\varepsilon = v^1 - v^d \neq 0$. In that case, a similar diagonalized scaling vector can be obtained for intermediate input $\hat{s}^d = \hat{v}^1 (\hat{v}^d)^{-1}$, capturing the relation between the targeted and updated intermediate input.

> The coefficient matrix A^d is once again updated, this time by multiplying it with the $\hat{s}^d$ diagonalized scaling vector, $A^{dd} = A^d \hat{s}^d$. This operation ensures that the column sums of A^{dd} equal the projected intermediate input, with the summing condition for columns fulfilled $\varepsilon = v^1 - v^d = 0$.

> The steps above are repeated until both of the summation differences δ and ε are sufficiently small. When this happens, the resulting transaction matrix $Z^{dd} = A^{dd} \hat{x}^1$ meets both summation conditions closely enough and is well-balanced with respect to the projected vectors x^1, u^1 and v^1.

The name of the method, RAS, relates to the algorithm itself: $A^{dd}=\hat{r}^{d} A^{0} \hat{s}^{d}$. It is proven that the RAS algorithm converges (Miller and Blair 2009), thus reducing the summation differences in each iteration and keeping the distance between the original transaction matrix Z^{0} and the resulting transaction matrix Z^{dd} minimal. The chosen level of accuracy affects the number of iterations needed to acquire a well-balanced IOT. Our case includes 50 sectors and significant changes in final demand, value added and imports for individual sectors. Accordingly, the RAS method needed around 40-60 iterations to reduce both of the summation differences to below 0.01.

Medium-Term Impacts and Long-Term Scenarios

A significant advantage of the IOT framework is its high sectoral granularity. The impacts of adjustments to final demand or government policies can be analyzed with respect to individual sectors, taking into account the considerable differences in the overall economic impact depending on which sectors are targeted or affected. The projected V2030 IOT should serve medium-term analyses.

Policymakers may be interested in the impact of policies on industrial output, given the expected change in final demand. Assuming the structure of the economy remains unchanged, thus keeping the structural matrix A^0 and the Leontief inverse matrix L^0 constant and combining them with the updated level of final demand f^1, one acquires the impact in terms of total output for individual sectors

$$x^1 = (I - A^0)^{-1} f^1 = L^0 f^1.$$

Based on this outcome, further conclusions can be drawn, such as the consequences for the labor market or financing needs. A specific case assuming a unit change in final demand leads to the concept of simple output multipliers, which incorporate the direct and indirect effect on the economy corresponding to a one-unit increase in final demand. The change in total output is then calculated as

$$\Delta x = L^0 \begin{bmatrix} 1 \\ 0 \\ \vdots \\ 0 \end{bmatrix} = \begin{bmatrix} \Delta x_1 \\ \Delta x_2 \\ \vdots \\ \Delta x_n \end{bmatrix},$$

with the first element Δx_1 standing for the direct effect, expected to be greater than one to meet at least the unit increase in final demand. The remaining elements $\Delta x_2, \ldots, \Delta x_n$ represent the indirect effects through subsidiaries and are, in general, expected to be positive but less than one. The sum of the direct effect and all the indirect effects indicates the overall impact on the economy stemming from a unit change in final demand of a specific industry, usually denoted as the simple output multiplier m_j for each sector. The simple output multipliers can be acquired as column sums of the Leontief inverse matrix

$$m_j = \sum_{i=1}^{n} l_{ij}\ ,\ j = 1, 2, \ldots, n.$$

In this type of analysis, the economic structure and production technology are considered unchanged, which is a plausible assumption for a timeframe of some five to 10 years. However, the relevant timeframe might be even shorter for an economy in transition. In such a case, it is appropriate to assume that the inter-industry flows and technical coefficients may evolve as the structure of the economy adapts to technological progress and shifts in consumer preferences, among other factors. These developments may even lead to the disappearance of some industries and to the rise of others. To capture these long-term structural adjustments, our projection framework supports and facilitates the integration of alternative economic scenarios.

Various sources of structural transformation can be considered, especially for the longer term. In our study, we focus predominately on the following sources of structural transformation, as these are well defined in Vision 2030 and corresponding government documentation:

> The introduction of new technologies and best-practice production processes, including the emergence of some new sectors.

> Significant shifts in final demand reflecting changes in consumer preferences, and the substantial expansion of specific sectors.

> Adjustments in import and export patterns as a result of economic diversification and advances in the production chain toward higher value added.

As a result, a series of IOT projections could be provided, such as $Z^0, Z^1, \ldots, Z^T$, with respect to expected growth paths and technological adjustments. They would be reflected in the main macroeconomic inputs for the RAS method. Such an IOT time series would enable additional econometric techniques to be applied. Turning to our simplified example, Table 4 shows adjustments to sector-specific import ratios, implying an overall increase in local content. Because the adjustments to final demand, value added and import ratios are not uniform across sectors, the change in the simple output multipliers varies between them.

Table 5. Example of adjustments in import ratios and simple output multipliers.

Change between t=0 and t=1	Industry 1	Industry 2	Industry 3	Industry 4	Industry 5	Overall
Imports / val. added (%, t=0)	2.0	14.4	56.6	11.2	5.8	6.4
Imports / val. added (%, t=1)	2.0	13.7	53.8	10.6	5.5	6.3
Difference (pp)	0.0	-0.7	-2.8	-0.6	-0.3	-0.1
Simple output multipliers (t=0)	1.10	1.61	1.76	1.64	1.36	
Simple output multipliers (t=1)	1.12	1.63	1.78	1.66	1.39	
Change (%)	1.50	1.30	1.04	1.16	2.06	

Overall, the economic impact evaluation may be based on an appropriate matrix of technical coefficients and the corresponding Leontief inverse matrix for the selected period

$$x^t = (I - A^t)^{-1} f^t = L^t f^t.$$

Developments in simple output multipliers m_j^t are also worth exploring, especially when it is assumed that production technologies and import intensities in some sectors have changed. This allows us to assess the likely impact of planned changes in socio-economic policies with an up-to-date analytical tool. It also improves the accuracy and reliability of evaluating the progress made toward a more diversified and sustainable economy.

Conclusion

This paper has introduced our approach to projecting a set of IOTs in detail, based on macroeconomic forecasts of final demand, value added and imports. These are combined with assumptions about technological and structural changes in individual sectors backed by a socio-economic transformation plan, such as Saudi Vision 2030. Overall economic expansion, changes in final demand preferences, the introduction of new technologies and adjustments in import patterns may lead to substantial structural shifts in an economy. These changes are reflected in our projections and incorporated into a well-balanced IOT through the application of the RAS method. The method allows us to address gradual and sudden economic adjustments.

As a result, the medium-term impact analysis can be carried out on the basis of appropriate inter-industry flows and a technical coefficients matrix. Similarly, the overall response of economic output to the change in final demand is backed by the relevant Leontief inverse matrix and corresponding simple output multipliers. The framework also provides a series of projected IOTs, allowing for the construction of various long-term scenarios with respect to differing paths of economic development and technological advances.

Overall, the approach described in this study constitutes a useful framework in providing answers to ‘what if?’ questions and assessing the progress made toward achieving more diverse and sustainable economies. The results of the medium-term impact analysis and the long-term scenarios provide useful insights for policymakers into the optimal design of various policy measures, taking into account the sectoral granularity of the economy.

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Notes

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About the Project

The Vision 2030 Dynamic Input-Output Table is a joint research project between KAPSARC and Saudi Aramco. Its aim is to develop a framework for input-output table projections which reflects the anticipated structural and technological changes in the Saudi economy in the context of Vision 2030. This economic transformation plan includes a set of ambitious diversification targets, covering energy efficiency, the introduction of new technologies, adjustments in the labor market and supporting various emerging sectors. These initiatives are expected to substantially impact the Saudi economy, underlining the need for an adequate and flexible tool for projecting and evaluating such structural adjustments. The study sheds light on channels through which output is likely to be produced, distributed and consumed in the transformed and diversified economy, with a particular emphasis on the link between the energy sector and the wider economy.

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