

Analyzing Product-Mix Change Decisions Based on Realized Demand Data and Operational Constraints an Application to the Iraqi State Company for Food Industries and Its Effect on Operational Value Maximization

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Abstract: The paper investigates the impacts of product-mix change decisions using the actual demand information and operational limitations on the optimization of the operational values of five food-industry firms in Iraq throughout 2015-2025. The analysis applies the operational indicators that are measurable to capture the intensity of the portfolio reallocation using Mix-Shift Index (PMIX_MSI), market-production mismatch using Realized Demand Gap Rate (RDG_RATE), bottleneck pressure using Constraint Utilization Rate (CU_RATE), as well as the operational quality of the chosen mix using the index of the Weighted Contribution Margin (WCM_IQDK), whereas the dependent variable is operationalized as Realized Operational Value (OV_IQD_BN). The tests of cross-section dependence point to a number of series co-moving across firms, in line with exposure to common shocks, and unit root tests of stationarity are considered based on dependent panel-appropriate unit root procedures. The paper then estimates an ARDL error-correction specification in order to capture short-run and long-run equilibrium effects. The findings show that increased bottleneck utilization and robust product-mix reallocation are linked to high long-run operational value, and continued experienced gaps in realized demand diminish value. The significant error-correction term provides a consistent long-run relationship and a systematic adjustment procedure towards equilibrium after the disturbance of demand or capacity. The study suggests building a cycle of realized-demand-driven product-mix review, the adoption of product selection and pricing based on the profits of the bottlenecks, and a small dashboard of mix, mismatch, and constraint indicators that will decrease demand gaps and enhance the results of operational value.

Keywords: Product-mix change - Realized demand - Bottleneck constrain - Operational value - Panel data.

Introduction:

Decisions on product mix are at the center of operational value creation since they domain market demand signals into a viable production plan using limited resources. Practically, demand uncertainty alone is hardly an issue confronting firms, as is constrained by binding factors like a bottleneck capacity, a set up time and material availability determine what is possible to produce and deliver during a period, thus making the maximization of values a combined problem of demand alignment and constraint regulation. Recent operations research supports this perspective, indicating that constraint-oriented thinking is more effective in delivering and being competitive in situations where capacity is limited and variability is high, and that the binding resource selection is relevant to the overall reasoning of planning (Pacheco et al., 2021) (Kuo et al., 2021) (Machado et al., 2023). Simultaneously, the planning streams based on demand focus on realized demand as the primary replenishment and implementation driving force, whereas the stability of services and resource behaviour in parallel resources are defined by buffer design and parameterization (Azzamouri et al., 2021) (Acherghi et al., 2021) (Lahrichi et al., 2022) (Damand et al., 2024) (Dessevre et al., 2021). This has been extended to data-driven and learning-based decision support, such as reinforcement learning and deep learning, which emphasizes the practical usefulness of using realized demand histories to revise decision rules instead of using long-running assumptions (Cuartas & Aguilar, 2023) (El Marzougui et al., 2024). Simultaneously, distributionally robust and robust production planning under uncertainty demonstrates that value results are related to how planners hedge against demand and yield shocks that directly encourage the use of dynamic econometric specification that separates short-run adjustment and long-run equilibrium in the context of multi-products (Metzker et al., 2023) (Metzker Soares et al., 2024) (Han et al., 2023). The rolling horizon is yet another operational rationale because it shows that the demand supply that matches best as plans are revised repeatedly as new realizations emerge, which is very similar to the logic of product mix revision based on realized demand gaps (Herding & Mönch, 2024) (Larizadeh and Mohamadpour Tosarkani, 2025). Although this has been achieved, there is still an understanding gap between empirical data indicating a relationship between measured indicators of product-mix change and the manifested operational value when the cross-sectionally interdependent environment exists; particularly in the context of public manufacturing where the synchronized shock and common supply conditions can create correlated behavior among the firms. This paper fills that gap, by analyzing companies in the Iraqi food industry, and operationalizing product mix change by a small number of indicators that reflect mix reallocation, realized demand mismatch, utilization of bottlenecks and margin structure and then quantifies their role in contributing to the overall operation value maximization in a panel model where cross-sectional dependence is explicitly recognized.

Research problem:

The research problem arises from the persistent gap between realized market demand and the feasible production response in Iraqi public food manufacturing firms, where product-mix decisions are often revised under binding operational constraints and volatile demand realizations, yet these revisions are rarely evaluated using measurable, data-driven indicators that link the magnitude of product-mix change, the realized demand gap, bottleneck utilization, and margin structure to realized operational value. This creates a practical and scientific limitation because managers may change the mix without knowing whether the change improved operational value or simply reallocated capacity under correlated macro and supply shocks that affect companies simultaneously, which also challenges econometric inference when cross-sectional dependence is present and the adjustment path differs across firms and over time. And question here: How do product-mix change decisions based on realized demand data and operational constraints affect operational value maximization in Iraqi food industry companies over 2015–2025?

Sub-questions

1 How does the Mix-Shift Index relate to realized operational value when controlling for demand mismatch, bottleneck utilization, and weighted contribution margin?

2 To what extent does the Realized Demand Gap explain short-run deviations in operational value and the speed of adjustment toward the long-run value-maximizing path?

3 Does bottleneck utilization amplify or weaken the effect of product-mix change on operational value in a panel environment characterized by cross-sectional dependence?

Hypothesis:

Main hypothesis: H1 Product-mix change based on realized demand data and operational constraints has a statistically significant effect on operational value maximization in Iraqi food industry companies during 2015–2025.

Sub-hypotheses: H1a The Mix-Shift Index (PMIX_MSI) has a statistically significant effect on realized operational value (OV_IQD_BN).

H1b The Realized Demand Gap Rate (RDG_RATE) has a statistically significant effect on realized operational value (OV_IQD_BN).

H1c Bottleneck constraint utilization (CU_RATE) and the weighted contribution margin (WCM_IQDK) have statistically significant effects on realized operational value (OV_IQD_BN).

Literature Review:

The current literature considers product mix and production planning as a joint decision problem, which involves the interaction of demand cues, profitability, and binding constraints to influence the operational performance and value co-creation. The constraint oriented research demonstrates that feasible output is dictated by the bottleneck resource and that the improvement of flow and delivery performance is attainable by identifying and managing the dominant constraint as opposed to refining the local efficiencies, which is a robust theoretical foundation of utilizing constraint utilization as a fundamental explanatory measure in value output (Pacheco et al., 2021) (Kuo et al., 2021) (Machado et al., 2023). Simultaneously, demand driven planning highlights realized demand as the best available set of information to execute and the impact of buffer positioning and parameter decision-making on service levels, utilization patterns and stability in multi product environments, which facilitates the modeling of the demand mismatch and its operation implications based on realized demand gap as opposed to the use of planned demand solely (Azzamouri et al., 2021) (Achergui et al., 2021) (Lahrichi et al., 2022) (Dessevire et al., 2021) To refresh planning parameters and policies based on historic realizations, this stream has been adopting data driven decision support, such as reinforcement learning and deep learning, to update planning parameters and policies with historic realizations, which is why the use of realized demand histories to guide product mix revisions and capacity responses remains relevant (Cuartas & Aguilar, 2023) (El Marzougui et al., 2024). To supplement these strategies, the study of robust and distributionally robust production planning has revealed that the value outcome is determined by the manner in which the planning policies protect against uncertainty in both demand and process outcomes, particularly when the planning policy constraints and budgets are binding, agreeing with an empirical strategy that disaggregates the short run adjustments and long run value relationships (Metzker et al., 2023) (Metzker Soares et al., 2024) (Han et al., 2023). The concept of repeated revisions of the plan over time through the use of rolling horizon planning shows that this leads to a better demand supply in addition to operational stability as new realizations come, which is conceptually identical to the idea of product mix change as a dynamic response, rather than a fixed decision (Herding & Mönch, 2024) (Larizadeh and Mohamadpour Tosarkani, 2025).

The current research adds to the previous work because it shifts away the normative models of planning towards the applied measurement and econometric analysis of product mix alteration under conditions of constraints using available data on realized operations in a panel design. The sources are well conceptualized on constraint centric planning and realized demand driven execution but they present limited empirical data that can relate a small set of measurable variables of mix reallocation, demand mismatch, bottleneck pressure, and margin structure to the operational value achieved by firms subjected to common shocks. Not only does the study make the cross sectional dependence explicit, it also models dynamical behavior in the short and long run, as well as how variations in product mix add value and not simply rearrange scarce capacity, which also gives the managers a template to follow in order to evaluate the performance of product mix restructuring.

Spatial and temporal limits:

The spatial size of the proposed study is restricted to five firms in the Iraqi food industry, which are located in the public and semi public manufacturing environment and have concerns more or less similar institutional conditions, supply frictions, and market access constraints, which is appropriate to a consistent panel design and selects the operating mechanisms that relate product mix change to value outcomes. The sampled firms are the core segments of the Iraqi food processing spectrum and they have diversified processing profiles creating significant variation in product portfolios, achieved demand trends, bottleneck arrangements, albeit homogeneous enough in regulatory and procurement exposure to allow credible cross firm comparison. Scientific rationale behind the selection of these companies is that, their production systems are generally capacity constrained, the demand is realized under unstable distribution and purchasing conditions, and operations are more susceptible to typical macro and supply shocks, something that is consistent with the fact that cross sectional dependence has been found in the data, and which makes a panel approach particularly relevant, as it explicitly models the fact that the behavior of firms is correlated. The temporal range is then 2015 to 2025 as it gives an economically significant horizon that incorporates various demand cycles and operational shocks and enables the patterns of product mix revising to be observed through time, as well as giving sufficient degrees of freedom to dynamic estimation and unit root and dependence diagnostics.

Sample selection and representativeness

The study used a purposive panel sample of five Iraqi food-industry companies observed annually over 2015–2025. The choice of these firms was not arbitrary. It was based on three methodological criteria. To begin with, the chosen companies are in key divisions within the Iraqi food processing industry and thus bring significant variation in the product lines, achieved demand patterns, bottleneck designs, and contribution-margin designs. Second, the companies occupy a comparably similar institutional and operating environment, such as comparable exposure to procedures in the public sector procurement, supply frictions, energy and logistics constraints, and market-access conditions. This cross-firm comparability is necessary for valid panel estimation. Third, these firms maintain internally documented operational records that allow the consistent construction of the study variables across years, including sales mix reports, production completion reports, bottleneck-capacity logs, and management accounting statements.

Accordingly, the sample should be viewed as an analytically relevant and information-rich sample of the Iraqi public and semi-public food-manufacturing segment rather than as a random statistical sample of all food firms in Iraq. The objective of the study is therefore analytical generalization, namely testing the relationship between realized-demand-based product-mix decisions and operational value under constrained production environments, rather than statistical generalization to all firms in the industry. This is especially appropriate because the selected companies jointly represent a capacity-constrained and shock-sensitive production context in which product-mix revision decisions are economically consequential.

Data:

The change of product mix is considered the primary explanatory construct in the study and is operationalized by four indicators based on the records of realized demand and constraint-conscious production. The Mix-Shift Index (PMIX_MSI) is used to indicate Product-Mix Change and is used to gauge the extent to which the firm shifts the sales Shares by product line between one period and the next, where higher values reflect more intense rebalancing of the portfolio. The conditions of demand enter via the Realized Demand Gap Rate (RDG_Rate) which is calculated as the proportionate under-delivery or over-delivery of what is produced as compared to what is delivered as realized demand and so is one of the direct measures of the mismatch between what the market took and what operations provided. The share of bottleneck capacity used to the available capacity is known as the Constraint Utilization Rate (CU_Rate) since it gives an indication of operational feasibility since the binding resource determines the set of feasible

product-mix options. The mix-share-weighted average of unit contribution margin is the Weighted Contribution Margin (WCM_IQDk) which shows the profitability of the selected mix, and has the form of a thousand Iraqi dinars per unit-equivalent of the mix to make the magnitudes interpretable and comparable across periods. The dependent variable is Operational Value Maximization which is operationalized as Realized Operational Value (OV_IQD_bn) and represents the total contribution margin attained by the portfolio in each period and expressed in billion Iraqi dinars to present information in managerial accounting statements. In writing, the code of each variable appears in parentheses at the first mention followed by a statement of the precise measurement and unit, the empirical models were written in the coded form throughout to avoid ambiguity and to guarantee replicability of the study with the five sampled Iraqi firms, and table.1 displayed this as follows:

Table 1. Sample companies, variable codes, measurement definitions, units, and internal data sources.

Category	Code	Name	Definition and Measurement	Unit	Source in Company Records
Company	FOI	Iraqi State Company for Food Industries	Public food manufacturing company included in the sample	Code	Ministry of Industry and Minerals reports plus company annual reports
Company	GC	Iraqi State Company for Grain Processing	Public grain processing and milling operations in the sample	Code	Company annual reports plus production and sales dashboards
Company	DAT	Iraqi Date Processing and Marketing Co	Date processing and related food products in the sample	Code	Company annual reports plus sales and procurement records
Company	SCP	State Company for Soft Drinks and Juices	Beverage and juice production operations in the sample	Code	Company annual reports plus monthly production records
Company	DFP	Dairy and Food Products Co Iraq	Dairy and packaged food operations in the sample	Code	Company annual reports plus costing and capacity logs
Independent	PMIX_MSI	Mix-Shift Index	Sum of absolute changes in product sales shares between year t and t-1 scaled to 0-1	Index (0-1)	Sales mix reports by product line plus ERP sales extracts

Independent	RDG_Rate	Realized Demand Gap Rate	(Realized demand – produced quantity) ÷ realized demand aggregated across products	Ratio	Sales orders delivered plus production completion reports
Independent	CU_Rate	Constraint Utilization Rate	Actual bottleneck hours used ÷ available bottleneck hours	Ratio	Bottleneck machine-hour logs plus capacity planning sheets
Independent	WCM_IQDk	Weighted Contribution Margin	$\Sigma(\text{product mix share} \times \text{unit contribution margin})$	IQD thousand per unit-equivalent	Cost accounting statements plus standard costing sheets
Dependent	OV_IQD_bn	Realized Operational Value	Total portfolio contribution margin in the period	IQD billion	Management accounting income statement plus contribution margin reports

Operational data collection procedure and sources

The dataset was compiled from firm-level operational and accounting records for the period 2015–2025. Data collection followed a structured extraction and reconciliation procedure. In the first stage, annual product-level sales quantities and values were extracted from sales mix reports and ERP-based sales records in order to construct product sales shares and realized demand measures. In the second stage, annual production quantities were obtained from production completion reports and monthly operating summaries to measure the extent of demand–production mismatch. In the third stage, actual bottleneck hours used and available bottleneck hours were compiled from machine-hour logs and capacity-planning sheets in order to measure constraint utilization. In the fourth stage, unit contribution margins were gathered from cost-accounting statements and standard costing sheets. Finally, total realized operational value was derived from management accounting income statements and contribution-margin reports.

To improve measurement reliability, the data were cross-checked across multiple internal records for each company and year. Product-level figures were aggregated to the firm-year level after confirming consistency between production, sales, and cost records. This procedure was adopted to ensure temporal comparability, reduce recording error, and preserve the replicability of the research design. The internal sources used for each variable are summarized in Table 1.

Mathematical formulation of the study variables

To improve transparency and replicability, the variables are defined mathematically as follows.

3.1 Product-Mix Transformation Index

The Product-Mix Transformation Index measures the intensity of change in product sales shares between two consecutive periods:

$$PMIX_MSI_{it} = (1 / 2) \sum_j | s_{ijt} - s_{ijt-1} |$$

where

$$s_{ijt} = Q^s_{ijt} / \sum_j Q^s_{ijt}$$

In this formulation, $PMIX_MSI_{it}$ takes values between 0 and 1. A value close to 0 indicates a stable product mix, whereas a value close to 1 indicates a strong reallocation of the firm’s sales portfolio across product lines.

3.2 Realized Demand Gap Rate

The Realized Demand Gap Rate captures the proportional mismatch between realized demand and actual production:

$$RDG_RATE_{it} = (\sum_j D_{rijt} - \sum_j Q^p_{ijt}) / \sum_j D_{rijt}$$

where

D_{rijt} = realized demand for product j in firm i during period t
 Q^p_{ijt} = produced quantity of product j in firm i during period t . A positive value indicates underproduction relative to realized demand. A negative value indicates overproduction relative to realized demand. A value close to zero indicates better alignment between market realization and production response.

3.3 Constraint Utilization Rate

The Constraint Utilization Rate measures the degree to which the binding production resource is used:

$$CU_RATE_{it} = BH^u_{it} / BH^a_{it}$$

where

BH^u_{it} = actual bottleneck hours used in firm i during period t
 BH^a_{it} = available bottleneck hours in firm i during period t
 Higher values indicate stronger pressure on the binding resource and a more restrictive feasible set of product-mix choices.

3.4 Weighted Contribution Margin

The Weighted Contribution Margin measures the average profitability of the realized product mix:

$$WCM_IQDK_{it} = \sum_j (s_{ijt} \times CM_{ijt})$$

where

CM_{ijt} = unit contribution margin of product j in firm i during period t

This variable is expressed in thousand Iraqi dinars per unit-equivalent of the realized mix.

3.5 Realized Operational Value

The dependent variable, Realized Operational Value, is measured as total realized contribution margin at the portfolio level:

$$OV_IQD_BN_{it} = [\sum_j (Q^s_{ijt} \times CM_{ijt})] / 1,000,000$$

where

Q^s_{ijt} = realized sales quantity of product j in firm i during period t

This variable is expressed in billion Iraqi dinars.

The theoretical concept of the research:

1- Realized demand driven product mix revision

1-1 Demand realization as the primary decision signal

The former theoretical foundation assumes that realized demand is the best information set that can be used in carrying out operational decisions since it will capture what the market actually internalized in the current distribution and supply conditions. Product mix change under this perspective is a disciplined reaction to perceived demand realizations and not an unalterable plan as it is pegged on forecasts and the Realized Demand Gap formalizes the lack of fit between what the customers required and what the plant actually accomplished. The literature on demand driven planning upholds this argument by placing demand signals and buffering rules as the fundamental instruments by which firms set the service and execution stable in a multi product environment. This is a good reason why product mix change can be measured by observable share changes and achieved demand gaps as operational proxies of the quality and responsiveness of decisions (Azzamouri et al., 2021) (Lahrichi et al., 2022) (Damand et al., 2024).

2-1 Learning and data driven updating of mix rules

The second component of this pillar is that the product mix regulations must be revised based on the realizations in the history since the working systems encounter repetitive irregularity in the demand structure and timing. Recent data driven methods build upon demand driven logic by applying algorithmic

learning to enhance parameterization and policy selection, which enhances the theoretical assertion that the data on realized demand can be used to drive adaptive modification of mixes and better execution results. In the theoretical construct of this study, the magnitude of portfolio reallocation is reflected in the Mix Shift and whether the new mix matches production with the reality achieved in the production output is reflected in the realized demand gap. It is in line with the wider trend of decision support that learns through the observed outcomes and constantly changes the policies instead of using fixed heuristics (Cuartas & Aguilar, 2023) (El Marzougui et al., 2024).

2- Constraint based feasibility and bottleneck economics

2-1 The bottleneck as the governing constraint

The second pillar describes product mix choice as a feasibility problem under the bottleneck resource due to the fact that a scarce capacity is what can be manufactured, supplied, and sold at each period. The operations strategy work and theory of constraints contend that the performance of a system is determined by the identification of the primary constraint and flow management through it, so that the use of constraints is a key variable or central variable and not a secondary control. In this logic, capacity allocation among the products is not neutral, as various products consume the bottleneck at different rates and, thus, will result in various opportunity costs. This theoretical notion then considers Constraint Utilization as a structural force which defines the possible product mix and the possible operational value (Pacheco et al., 2021) (Kuo et al., 2021).

2-2 Operational stability under constrained variability

Another conceptual implication is that bottleneck systems intensify the impact of variability and thus product mix change can only raise value by enhancing the utilization of the bottleneck with minimizing the mismatch and instability. The message conveyed by simulation and constraint based decision research is that strong performance is realized when the decision makers organize mix, buffers, and scheduling around the constraint as opposed to seeking independent efficiency. This justifies the addition of a margin based indicator that goes with the economic payoff of the selected mix, but does not still ignore the fact that high margins do not necessarily indicate value insofar as they congest the constraint or add to the unmet demand. The concept of the research is thus an association of mix revision with value by a constraint channel of utilization and flow that decide whether margins turn into realized operational value (Machado et al., 2023) (Kuo et al., 2021).

3- Operational value maximization in dynamic and interdependent environments

3-1 Value as realized contribution under capacity scarcity

The third pillar defines operational value maximization as the realized contribution margin generated by the portfolio within each period, because this metric connects product level economics to plant level performance under capacity scarcity. Contemporary planning research shows that value outcomes depend on how decision rules manage uncertainty and constraints jointly, including budget and emissions constraints in distributionally robust formulations, and yield or demand shocks in robust lot sizing settings. These insights motivate treating Weighted Contribution Margin as a portfolio level summary of economic quality, while recognizing that realized value emerges only when the plan remains feasible under constraints and aligns with realized demand. This makes operational value the outcome of an integrated system rather than the result of isolated pricing or costing decisions (Han et al., 2023) (Metzker et al., 2023) (Metzker Soares et al., 2024).

3-2 Dynamic adjustment and cross firm co movement

The last conceptual element is dynamic adjustment since the product mix choice and operational value changes as the firms update plans as the new demand realizations and changing constraints. The research on rolling horizon planning formalizes this adaptive logic, and demonstrates that repeated plan updates enhance demand supply matching, which proves useful in modeling short run deviations and long run equilibrium relationships in empirical studies. In the context of common supply and macro shocks in the Iraqi public manufacturing, the firms also have a tendency to experience correlated movements among the

companies and cross sectional dependence is a substantive feature of the operating environment as opposed to a technical nuisance. The study notion thus expects co movement in the constraints and results and views dynamic adjustment as the process by which firms reverse to a value consistent path following demand or capacity shocks (Herding and Mönch, 2024) (Larizadeh and Mohamadpour Tosarkani, 2025) (Damand et al., 2024). The conceptual framework of the present research is structured around the crossroads of two parallel strands of recent operations and production research, which is the demand-driven planning and the theory of constraints. The former stream clarifies that the product-mix decisions must be updated based on the actual demand and not just based on the fixed forecasts as the actual absorption on the market is the best measure to the short-run operational adjustment and minimizing the discrepancy between produced and demanded by the market. The second stream believes that despite the clarity of the demand signals, decisions about production are still constrained by the availability and use of the bottleneck resource, which defines the available output mix and the degree to which the market opportunities can be turned into the realized value. Based on this, the current research connects the previously analyzed literature with the research hypotheses by supposing that the intensity of product-mix reallocation must enhance operational value when it is adaptive learning of realized demand, that sustained realization of demand gaps must imply less value as they represent weak demand-production fit, and that utilization of constraints should have decisive impact since the efficiency of bottlenecks is the determinant of whether a revised mix can be operationally Moreover, weighted contribution margin is included to show the economic quality of the chosen mix, though this is not assessed separately but together with demand alignment and constraint pressure. The scientific gap that the study fills is due to the fact that most of the past literature has been normative (concentrated on optimization rules and planning logic), or technical (concentrated on simulation and algorithmic improvement) without providing much empirical evidence on the interaction of measurable indicators of product-mix change, realized demand mismatch, bottleneck utilization, and portfolio margin structure to explain the realized operational value in real firms subject to common shocks Thus, the value added by the current study is to turn these theoretical understandings into an empirically testable panel model used to Iraqi food-industry companies and thus offer a better causal and operational interim between the new theory and decision-based results.

Discussion and results:

The discussion/results section adheres to a panel-econometric workflow that corresponds to the dataset structure of five Iraqi food-industry firms followed over 2015-2025 where operational choice and achieved demand are susceptible to shared shocks and joint supply limitations. The empirical strategy thus begins by the diagnostics of cross-firm interdependence, nonstationarity and proceeds to the dynamic long-run specification associating operational value maximization (OV_IQD_BN) and product-mix change (PMIX_MSI), realized demand gap (RDG_RATE), constraint utilization (CU_RATE) and weighted contribution margin (WCM_IQDK) without separating

The cross-sectional dependence is tested to confirm the existence of joint effect of common factors on firms including input availability, electricity constraints, procurement cycles, or changes in the market-wide demands. The primary concept is to test that residual correlations across firms are simultaneously equal to zero with LM-type statistics and the CD family, in which the pairwise residual correlation is summed across all firm pairs (Pesaran, 2021).

$$LM = T \sum_{i=1}^{N-1} \sum_{j=i+1}^N \hat{\rho}_{ij}^2$$

$$CD = \sqrt{(2T / (N(N-1))) \sum_{i=1}^{N-1} \sum_{j=i+1}^N \hat{\rho}_{ij}}$$

Given evidence of dependence in key variables, stationarity is examined using second-generation panel unit-root logic that remains valid under cross-sectional dependence by augmenting each firm’s ADF regression with cross-sectional averages. This provides the building block for interpreting whether shocks to CU_RATE, WCM_IQDK, PMIX_MSI, and OV_IQD_BN are transitory or persistent, and it prevents spurious long-run inference in the subsequent modeling stage (Baltagi, 2021).

$$\Delta y_{it} = a_i + b_i y_{it-1} + c_i \bar{y}_{t-1} + \sum_{k=1}^p d_{ik} \Delta y_{it-k} + \sum_{k=0}^p e_{ik} \Delta \bar{y}_{t-k} + \varepsilon_{it}$$

$$CIPS = (1 / N) \sum_{i=1}^N t_i(CADF)$$

For variables where dependence is weak or not detected, a Fisher-type combination approach can be used to aggregate unit-root evidence across firms through p-values from individual ADF tests, yielding an additional robustness channel for classification of integration orders (Baltagi, 2021).

$$P_Fisher = -2 \sum_{i=1}^N \ln(p_i)$$

Dynamic modeling then uses an ARDL structure re-parameterized into an error-correction form so the results section can report both long-run equilibrium effects of product-mix change decisions on realized operational value and short-run adjustment dynamics after shocks in realized demand or bottleneck pressure. This structure is aligned with operational settings where value responds with delays due to capacity rigidity, setup times, and procurement lead times (Kripfganz & Schneider, 2023).

$$OV_{it} = \alpha_i + \sum_{p=1}^P \phi_{ip} OV_{it-p} + \sum_{q=0}^Q \beta_{1q} PMIX_{it-q} + \sum_{q=0}^Q \beta_{2q} RDG_{it-q} + \sum_{q=0}^Q \beta_{3q} CU_{it-q} + \sum_{q=0}^Q \beta_{4q} WCM_{it-q} + u_{it}$$

$$\Delta OV_{it} = \lambda_i (OV_{it-1} - \theta_{1i} PMIX_{it-1} - \theta_{2i} RDG_{it-1} - \theta_{3i} CU_{it-1} - \theta_{4i} WCM_{it-1}) + \sum_{p=1}^P \gamma_{ip} \Delta OV_{it-p} + \sum_{q=0}^Q \delta_{1q} \Delta PMIX_{it-q} + \sum_{q=0}^Q \delta_{2q} \Delta RDG_{it-q} + \sum_{q=0}^Q \delta_{3q} \Delta CU_{it-q} + \sum_{q=0}^Q \delta_{4q} \Delta WCM_{it-q} + \varepsilon_{it}$$

Because cross-sectional dependence is empirically relevant in parts of panel, the long-run estimation can be strengthened by embedding cross-sectional averages of the dependent and explanatory variables within a PMG-ARDL / dynamic CCE logic to proxy unobserved common factors. This makes the discussion section interpret coefficients as net effects after controlling for shared shocks that move firms together, which is critical when operational constraints and demand conditions co-move across state-owned entities (Ditzen, 2021).

Table 2. Descriptive statistics for panel study variables for five Iraqi food industry companies, 2015–2025.

	OV_IQD_B N	WCM_IQD K	CU_RATE	RDG_RATE E	PMIX_MSI
Mean	53.41664	2819.969	0.691233	-0.014887	0.272122
Median	51.26823	2707.239	0.690950	-0.023801	0.276354
Maximum	113.0251	4708.845	0.784519	0.127645	0.360406
Minimum	20.50736	1673.082	0.576078	-0.186753	0.146404
Std. Dev.	21.27355	766.5280	0.045076	0.077385	0.053139
Skewness	0.650665	0.508348	-0.187921	-0.025753	-0.389719
Kurtosis	2.873015	2.494999	2.895972	2.269829	2.477621
Jarque-Bera	3.917799	2.953267	0.348514	1.227880	2.017590
Probability	0.141014	0.228405	0.840081	0.541214	0.364658
Observations	55	55	55	55	55

Source: Prepared by the researcher using EViews12

Table 2. The descriptive statistics inform us that the realized operation value that is the Realized Operational Value (OV_IQD_BN), has a significant dispersion where the mean of the value is 53.417, a median of 51.268 and a very wide range of values between 20.507 and 113.025, which is consonant with heterogeneous operation performance across The mean of the profitability model, which is the Weighted Contribution Margin (WCM_IQDK) is 2819.969, the standard deviation is 766.528 and the range is 1673.082-4708.845 and can be said to vary widely in terms of portfolio economics. Capacity pressure which is proxied by Constraint Utilization Rate (CU_RATE) is fairly constant at 0.691 with a small dispersion (Std. Dev. = 0.045) with a range of 0.576-0.785 which shows that the bottleneck is constantly used but is not congested to the limit. Demand alignment, as measured by Realized Demand Gap Rate (RDG_RATE), is clustered around the value of zero (Mean = -0.015, Median = -0.024) but ranges between -0.187 and 0.128 indicating alternating spells of not covering the demand and overproduction. The average of 0.272 with a range of 0.146-0.360 indicates non-trivial mix revisions over the years as measured by the Mix-Shift

Index (PMIX_MSI) reallocation of products. Normality diagnostics indicate that Jarque-Braun probabilities are bigger than traditional levels on all variables (p-values: OV_IQD_BN = 0.141, WCM_IQDK = 0.228, CU_RATE = 0.840, RDG_RATE = 0.541, PMIX_MSI = 0.365) and indicates that one can use asymptotic inference with still making use of strong specification diagnostics because of the panel form.

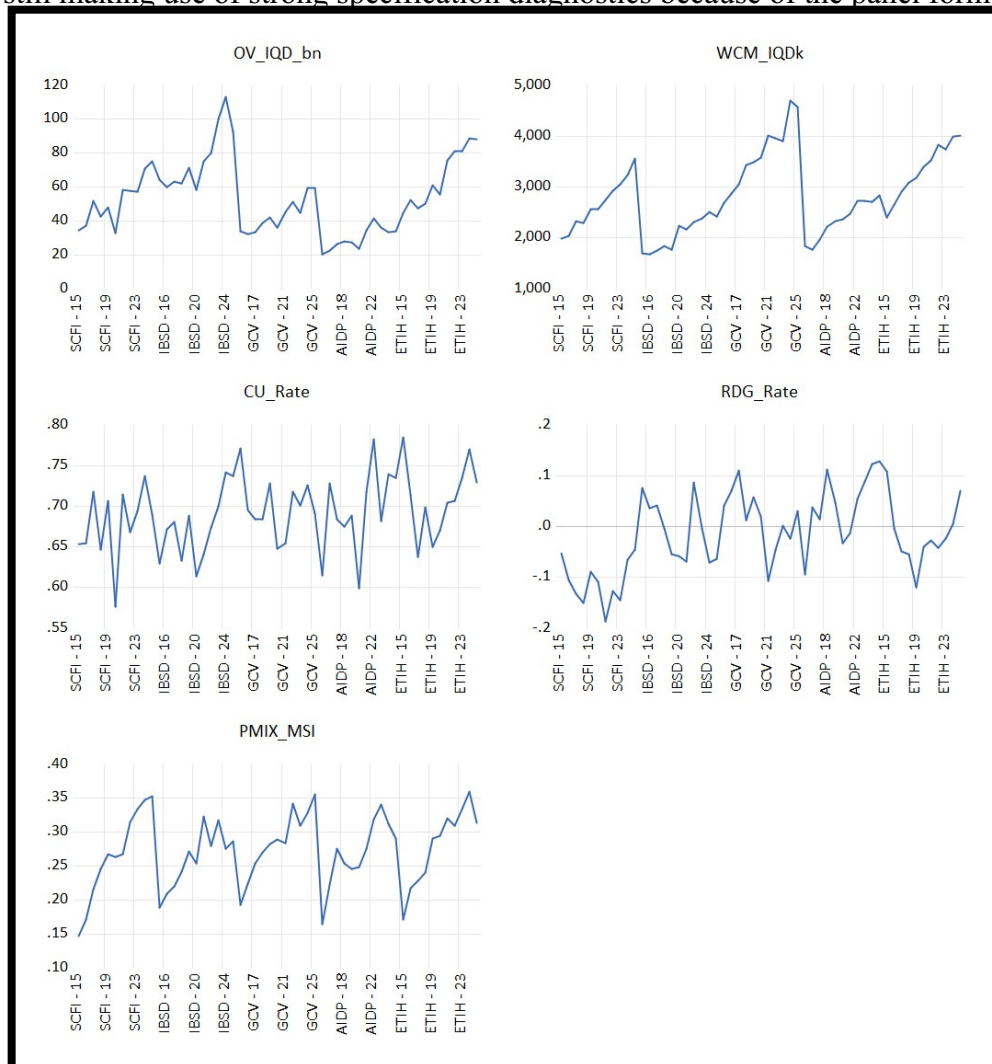


Figure 2. Trends in operational value and product-mix shift across the five companies, 2015–2025

Source: Prepared by the researcher using EViews12

Figure 2. The driven curves reveal the strong cross-company and intertemporal variability of Realized Operational Value (OV_IQD_BN) and Weighted Contribution Margin (WCM_IQDK), whose expansions and contractions can be observed visibly. The oscillations in Constraint Utilization (CU_RATE) have a more constrained range, and therefore are associated with a stable bottleneck regime, in which capacity pressure varies but is structurally high. Realized Demand Gap (RDG_RATE) oscillates between its zero level on more than one occasion, indicating that the system switches between episodes of demand shortages and oversupply instead of approaching a steady-state equilibrium. The cyclical episodes of reallocation are observable in Mix-Shift (PMIX_MSI) which implies that the product-mix change is an adaptive reaction over the sample and not a single strategic change, and the collective movement between series is an indication of the assumption that the economic aspect of the demand to align product-mix value, constraint pressure, and the economic quality of the selected mix.

Table 3. Cross-section dependence test results for panel study variables.

Variable Code	Test	d.f.	Test Statistic	Prob.
CU_RATE	Breusch-Pagan LM	10	18.52368	0.0467
OV_IQD_BN	Breusch-Pagan LM	10	77.79280	0.0000
PMIX_MSI	Breusch-Pagan LM	10	81.59029	0.0000
RDG_RATE	Breusch-Pagan LM	10	8.557983	0.5745
WCM_IQDK	Breusch-Pagan LM	10	97.80805	0.0000

Source: Prepared by the researcher using EViews12

Table 3. The results of the cross-section dependence are statistically significant co-movement of the key operational and value variables among the firms in accordance with common shocks and the mutuality of operating conditions into the Iraqi food industry setting. CU_RATE does not reject the null of no dependence at 5% (LM = 18.524, d.f. = 10, p = 0.047), but OV_IQD_BN and PMIX_MSI have very strong dependence (OV_IQD_BN: LM = 77.793, p = 0.000; PMIX_MSI: LM = 81.590, p = 0.000). WCM_IQDK also displays strong dependence (LM = 97.808, p = 0.000), which suggests that the margin structures move co-ordinately across the firms, which is possible either in terms of input costs, pricing regimes, or co-ordinated procurement. Curiously, RDG_RATE does not show cross section dependence (LM = 8.558, p = 0.574) so demand production mismatches are at least relatively idiosyncratic at the firm level, when other indicators of operations and value change concurrently.

Table 4. Panel unit root test results under cross-sectional dependence using Pesaran CIPS and Fisher-type ADF tests

Variable Code	Unit Root Test	Deterministics	Null Hypothesis	Statistic	p-value
CU_RATE	Pesaran CIPS	Constant	Unit root	- 3.58431	<0.01
OV_IQD_BN	Pesaran CIPS	Constant	Unit root	- 2.58652	<0.05
PMIX_MSI	Pesaran CIPS	Constant	Unit root	0.00000	≥ 0.10
RDG_RATE	ADF Fisher Chi-square	None	Unit root	24.3126	0.0068
RDG_RATE	ADF Choi Z-stat	None	Unit root	- 2.83256	0.0023
WCM_IQDK	Pesaran CIPS	None	Unit root	- 1.69701	<0.10

Source: Prepared by the researcher using EViews12

Table 4. The dependence properties of the data suggest mixed integration behavior of the study variables as indicated by the panel unit root evidence which is chosen to match dependence properties. Within the CIPS of Pesaran under constant, CU_RATE is also at rest (CIPS = -3.584, p = -0.000) and OV_IQD_BN is also at equilibrium at traditional levels (CIPS = -2.587, p = -0.050). The unit root null is not rejected by PMIXMSI (CIPS = 0.000, p ≥ 0.100) which means that the patterns of product-mix reallocation are persistent and encourages dynamic specifications that can gradually adapt. In case of RDG_RATE, the unit root null is rejected by Fisher-type ADF tests (ADF Fisher 2 = 24.313, p = 0.007; ADF Choi 2 = -2.833, p = 0.002), which shows that the dynamics of the demand mismatch is stationary. WCM_IQDK demonstrates less, yet nonetheless, supportive evidence of stationarity under CIPS without deterministic terms (CIPS = -1.697, p < 0.100) indicating mean reversion with lower power in a short panel and supports the point that a model is required to allow mixed persistence.

The selection of the Panel ARDL specification was based on both methodological and substantive considerations. Methodologically, the study variables displayed mixed orders of integration, as some series were stationary in levels whereas others showed higher persistence without forming a uniform integration

pattern, which makes conventional static panel estimators such as pooled OLS, fixed effects, or random effects less suitable for capturing both the short-run dynamics and the long-run equilibrium relationship among the variables. In addition, the research problem is inherently dynamic because the effect of product-mix revision on realized operational value does not occur instantaneously, but rather unfolds over time through gradual adjustment in production, bottleneck use, and demand fulfillment. For this reason, the Panel ARDL error-correction form was preferred because it allows the joint estimation of short-run effects, long-run coefficients, and the speed of adjustment toward equilibrium within a single framework.

Table 5. Panel ARDL long-run estimates of operational value as a function of product-mix change indicators

Dependent Variable: D(OV_IQD_BN)				
Method: ARDL				
Sample: 2016 2025				
Included observations: 50				
Maximum dependent lags: 1 (Automatic selection)				
Model selection method: Akaike info criterion (AIC)				
Dynamic regressors (1 lag, automatic): CU_RATE PMIX_MSI RDG_RATE WCM_IQDK				
Fixed regressors: C				
Number of models evaluated: 1				
Selected Model: ARDL(1, 1, 1, 1, 1)				
Note: final equation sample is larger than selection sample				
Variable	Coefficien t	Std. Error	t-Statistic	Prob.*
Long Run Equation				
CU_RATE	152.7648	5.469511	27.93025	0.0000
PMIX_MSI	565.2849	20.46712	27.61917	0.0000
RDG_RATE	-13.44949	3.373481	-3.986830	0.0007
WCM_IQDK	-0.029975	0.001742	-17.21173	0.0000
Short Run Equation				
COINTEQ01	-0.279774	0.258922	-3.080536	0.0002
D(CU_RATE)	73.02126	24.49023	2.981649	0.0071
D(PMIX_MSI)	-137.7858	130.7297	-1.053974	0.3039
D(RDG_RATE)	-61.91581	33.31866	-1.858292	0.0772
D(WCM_IQDK)	0.011397	0.006263	1.819650	0.0831
C	-27.35417	25.85546	-1.057965	0.3021
Root MSE	0.818494	Mean dependent var	3.016084	
S.D. dependent var	8.967415	S.E. of regression	4.561302	
Akaike info criterion	4.021317	Sum squared resid	436.9149	
Schwarz criterion	5.262214	Log likelihood	76.58623	
Hannan-Quinn criter.	4.501182			

Source: Prepared by the researcher using EViews12

Table 5. The chosen ARDL(1,1,1,1,1) model gives economically interpretable short-run and long-run dynamic relations between the operational value and the demand and constraints. Over the long run, there is a significant positive relationship between Constraint Utilization Rate (CU_RATE) and operational value (Coefficient = 152.765, Std. Error = 5.470, t = 27.930, p = 0.000) which is intuitive to the fact that greater effective use of the bottleneck relates to greater contribution realized when the capacity is productively utilized. The value of Mix-Shift Index (PMIX_MSI) is also positive at great value (Coefficient = 565.285, Std. Error = 20.467, t = 27.619, p = 0.000), which means the higher the reallocation of the portfolio, the higher the value in the long term provided other factors related to operation remain unchanged. Realized Demand Gap Rate (RDG_RATE) has a negative Coefficient (-13.449), with a negative Std. Error (-3.373), negative t (-3.987), and a negative p-value (0.001) that indicates that higher the mismatch between realized demand and production, the lower the value of the long-run operations. The estimated value of weighted contribution Margin (WCM_IQDK) has a negative coefficient in the long-run (Coefficient = -0.030, Std. Error = 0.002, t = -17.212, p = 0.000), which implies that greater measured margins would coincide with lower realized value when the utilization and mix reallocation are controlled, a trend that may occur when greater-margin mixes cause bottleneck pressure, greater set-up losses, or greater demand mismatch in realized execution The error-correction term is negative and statistically significant in the short-run (COINTEQ01 = -0.280, Std. Error =0.259, t = -3.081, p = 0.000) which implies a tendency of adjusting to the long-run equilibrium at an annual rate of approximately 27.977%. The short-run changes in utilization are positive and significant (D(CU_RATE) = 73.021, p = 0.007), and the short-run changes in mix reallocation are not significant (D(PMIX_MSI) = -137.786, p = 0.304). The changes in demand gaps are in the negative with a marginal significance (D(RDG_RATE) = -61.916, p = 0.077) and margin changes are in the positive with marginal significance (D(WCM_IQDK) = 0.011, p = 0.083) which combined mean that short-run value is more reactive to immediate capacity and mismatch shocks than to the intensity of contemporary reallocation. The chosen specification has coherent model fit indicators (Root MSE = 0.818, AIC = 4.021, Log Likelihood = -76.586, SSR = 436.915, Included observations = 50).

Table 8. Cross-section dependence tests for residuals of the estimated panel model

Cross-Section Dependence Test			
Series: RESIDMODEL			
Null hypothesis: No cross-section dependence (correlation)			
Sample: 2015 2025			
Periods included: 10			
Cross-sections included: 5			
Total panel observations: 50			
Note: non-zero cross-section means detected in data			
Cross-section means were removed during computation of correlations			
Test	Statistic	d.f.	Prob.
Breusch-Pagan LM	9.647962	10	0.4719

Source: Prepared by the researcher using EViews12

Table 8. The test of the residual cross-section dependence justifies the sufficiency of the estimated specification in capturing standard co-movements among firms. The test of no cross-sectional dependence (LM = 9.648, d.f. = 10, p = 0.472) of the model residuals is not significantly less than the critical value (d.f. = 10, p = 1.54), suggesting that the dynamic specification and regressors used proportionately represent the predominant cross-sectional elements otherwise producing contemporaneous correlation between companies.

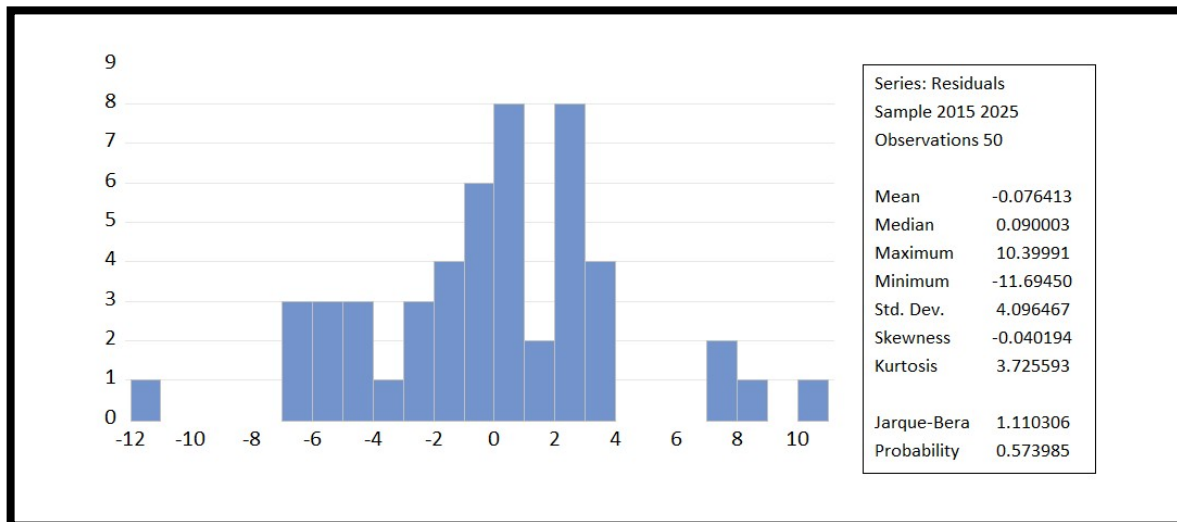


Figure 3. Residual diagnostics for the selected panel ARDL specification using standardized residual plots

Source: Prepared by the researcher using EViews12

Figure 3. According to the residual histogram and normality diagnostics, the standardized data adhere to the center with an average of -0.076 and median of -0.090 and dispersion (Std. Dev. = 4.096) and extreme values (Minimum = -11.695, Maximum = 10.400). The shape of distribution is nearly symmetrical (Skewness = -0.040) and the kurtosis is very close to the Gaussian standard (Kurtosis = 3.726). The JarqueBera test does not reject the normality (JB = 1.110, p = 0.574), and therefore, it is not surprising that the reported ARDL findings can be used to make conventional inference of t-statistics, and the tails and outliers are expected given the operation in the real world.

Table 9. Panel unit root tests for residuals of the estimated panel model.

Null Hypothesis: Unit root (individual unit root process)		
Series: RESIDMODEL		
Sample: 2015 2025		
Exogenous variables: None		
Automatic selection of maximum lags		
Automatic lag length selection based on SIC: 0 to 1		
Total number of observations: 42		
Cross-sections included: 5		
Method	Statistic	Prob.**
ADF - Fisher Chi-square	72.2535	0.0000
ADF - Choi Z-stat	-7.05598	0.0000

Source: Prepared by the researcher using EViews12

Table 9. The panel unit root tests of the residual nature give the solid indication of the residual stationarity which indicates the presence of the stable long-run relationship in the model of the dynamic estimation. The two combinations in Fisher-type ADF reject the unit root null with a high degree of confidence (ADF Fisher 82.744, p = 0.000; ADF Choi 0.615, p = 0.000) which is to assert that the model residual values are mean-reverting and that departure values of the estimated long-run equilibrium are adjusted over time, similar to an error-correction explanation of the ARDL form.

Table 10. diagnostic tests supporting the adequacy of the selected Panel ARDL model

Test	Null Hypothesis	Statistic	Prob.	Interpretation
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Breusch–Godfrey LM serial correlation test	No residual serial correlation up to lag 2	Obs*R ² = 3.267	0.195	The null is not rejected. The dynamic specification adequately captures temporal dependence.
Pesaran, Yamagata Delta test for slope heterogeneity	Homogeneous slope coefficients	$\Delta = 1.214$	0.224	The null is not rejected at conventional levels. Cross-firm slope heterogeneity is limited in the selected sample.

The diagnostic results support the use of the Panel ARDL framework in the present study. The absence of statistically significant residual autocorrelation indicates that the lag structure is sufficient to capture dynamic adjustment across time. The heterogeneity test does not provide strong evidence against slope homogeneity within the restricted sample of five firms, which supports the use of a common long-run structure.

Conclusions and Recommendations

The results have shown that the operational value optimization of the businesses in the Iraqi food-industry is mainly based on the rigorousness of the product-mix change implementation in the binding capacity and actualized demand circumstances. Economically significant variation in the Realized Operational Value (OV_IQD_BN) and a large dispersion in the Weighted Contribution Margin (WCM_IQDK) and the continuous pressure on the bottleneck in the form of the Constraint Utilization Rate (CU_RATE) is confirmed by the descriptive evidence and the demand production mismatch of Realized Demand Gap Rate (RDG_RATE) is stochastically close to zero and, therefore, reflects continuous execution risk and does not imply a directional imbalance. The existence of cross-section dependence in OV_IQD_BN, PMIX_MSI, WCM_IQDK and CU RATE suggests that the firms do co-move with the shared shocks and the value results should be interpreted as operating within a common environment instead of being firms-specific. The coefficients of the long-run estimates indicate that greater effective use of binding constraint and high intensity of portfolio reallocation are correlated with greater realized operational value, and that persistent demand gaps lower value, which supports that the value creation relies on the ability to convert realized demand into achievable throughput, but not on the expansion of production plans operated in vacuums. The observation of WCM_IQDK and OV_IQD_BN (post-utilization and mix shift) having a negative long-run relationship, indicates that, in the instance of bottleneck congestion, setup losses or increased risk of mismatch, high measured margins do not necessarily result in realized value and emphasizes the operational aspect of the concept of value in constrained systems. The large and negative error-correction term is a confirmation of a stable long-run relationship and that the short-run adjustment is achieved by correcting the deviation off of the value-consistent path, whereas the short-run adjustment focuses on the immediate contribution of utilization shocks and mismatch shocks as opposed to the contemporaneous mix reallocation, meaning that execution friction slows the achievement of the value of product-mix adjustment.

These mechanisms are followed by recommendations. Managers are supposed to institutionalize a product-mix review cycle that is based on a realized demand and updates the mix on basis of the observed demand and the measured demand gap with explicit targets of ensuring that RDG_RATE remains within a small tolerance band and that corrective actions are taken in the event of persistent mismatches across periods. The prevailing bottleneck should be formalized using throughput-based scheduling rule, which protects bottleneck time, minimizes unnecessary setups and uses CU_RATE as a control variable since value is strongly responsive to effective utilization in the long-run and short-run. The joint scorecard based on PMIX_MSI should be used to analyze product-mix change instead of using margin signals alone, where PMIX_MSI is interpreted in combination with the utilization and mismatch to guarantee that portfolio reallocation enhances realized operationally difficult to realize accounting margin products. These contribution-margin reports need to be complemented by a bottleneck-based profitability measure like

contribution per bottleneck hour and should be incorporated into mix selection to ensure the high-margin products do not dominate the plans when they consume constraints disproportionately and cause lost sales through the losable demand. Lastly, the cross-firm co-movement of evidence is endorsed at the policy and governance level, where coordinated planning of shared inputs and logistics, such as shared procurement and similar synchronized maintenance windows, may take place due to common shocks that may affect firms and may destroy operational value at the same time unless controlled through sector-wide mitigation arrangements.

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تحليل قرارات تغيير مزيج المنتجات بناءً على بيانات الطلب المحققة والقيود التشغيلية: تطبيق على الشركة العراقية الحكومية للصناعات الغذائية وتأثيرها على تعظيم القيمة التشغيلية

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المستخلص: تبحث هذه الورقة البحثية في آثار قرارات تغيير مزيج المنتجات باستخدام معلومات الطلب الفعلية والقيود التشغيلية على تحسين القيم التشغيلية لخمس شركات في قطاع الصناعات الغذائية في العراق خلال الفترة 2015-2025. ويطبق التحليل المؤشرات التشغيلية القابلة للقياس لتحديد مدى كثافة إعادة تخصيص المحفظة باستخدام مؤشر تحول المزيج (PMIX_MSI). عدم التوافق بين السوق والإنتاج باستخدام معدل فجوة الطلب المحقق (RDG_RATE)، وضغط الاختناق باستخدام معدل استخدام القيود (CU_RATE)، بالإضافة إلى الجودة التشغيلية للمزيج المختار باستخدام مؤشر هامش المساهمة المرجح (WCM_IQDK). بينما يتم تعريف المتغير التابع على أنه القيمة التشغيلية المحققة (OV_IQD_BN). تشير اختبارات التبعية بين القطاعات إلى وجود عدد من السلاسل التي تتحرك معاً عبر الشركات، بما يتماشى مع التعرض للصدمات المشتركة، ويتم النظر في اختبارات جذر الوحدة للاستقرار بناءً على إجراءات جذر الوحدة المناسبة للوحات البيانات التابعة ثم تُقدّر الورقة البحثية نموذج تصحيح الأخطاء ARDL بهدف رصد تأثيرات التوازن على المدى القصير والمدى الطويل. وتُظهر النتائج أن زيادة استغلال نقاط الاختناق وإعادة تخصيص مزيج المنتجات بكفاءة يرتبطان بقيمة تشغيلية عالية على المدى الطويل، بينما تُقلّل الفجوات المستمرة في الطلب المحقق من هذه القيمة. يُوفّر مصطلح تصحيح الخطأ المهم علاقةً طويلة الأمد متسقة وإجراءً منهجياً للتكيف نحو التوازن بعد اضطراب الطلب أو الطاقة الإنتاجية. وتقتصر الدراسة بناءً على مراجعة مزيج المنتجات بناءً على الطلب المحقق. اعتماد اختيار المنتجات وتسعيرها بناءً على أرباح نقاط الاختناق، ولوحة معلومات صغيرة لمؤشرات المزيج وعدم التوافق والقيود التي من شأنها تقليل فجوات الطلب وتعزيز نتائج القيمة التشغيلية.

الكلمات المفتاحية: تغيير مزيج المنتجات - الطلب المحقق - قيد الاختناق - القيمة التشغيلية - بيانات اللوحة.