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ASSESSING THE CONNECTION BETWEEN CROP IMPORTS AND DOMESTIC PRODUCTION IN QATAR IN THE CONTEXT OF THE NATIONAL FOOD SECURITY STRATEGY.

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Abstract— This paper provides an integrated framework for optimizing the distribution of agricultural products in Qatar, in which the goal is to balance imports and local production to satisfy total demand at minimum costs. Based on the Qatar National Food Security Strategy (QN-FSS), a new mathematical model is devised that incorporates economic, environmental, and policy constraints including the agricultural land, water, and energy resources available, as well as import diversity and resilience to disruptions. Such an integrated framework holistically targets Qatar's arid climate challenges through the utilization of agricultural technologies and sustainable practices whilst elucidating self-sufficiency rates, price differentials and import distribution through its unique analysis in the agriculture sector. The results show in situations where of 3 partners imported, the best-distributed results are always 40 percent, 30 percent, and 30 percent to achieve the minimum-cost price based on 2022, which is in accordance with QNFSS regarding imports. Whoever increasingly with more import partners, distribution result becomes price, which develops the requirement for better government coordination. Combining mathematical modeling with policy insights, this research provides important insight into optimal resource allocation and food security improvements in Qatar.
Keywords— Food Security, Agricultural Optimization, Import Diversification, Sustainable Resource Management, Qatar National Food Security Strategy

INTRODUCTION

Agriculture establishes an important foundation to various political, social, and economic systems found among nations worldwide. Its influence transcends food production and enters into other realms, such as economic stability and sustainability. As climate change and population growth press on all sides, the need to adapt the agricultural sectors to different environmental conditions continues to mount. Taking this into account and in view of the growing pressures of environmental constraints on agricultural production, strategic development in the sector has become increasingly requisite for meeting national food security and economic diversification in Qatar. Characterized by hot temperatures with modest rainfalls and a scant supply of drinkable freshwater resources, the Qatari environment gives rise to unique challenges the country is attempting to overcome through creative agricultural practices and support from a strong government.
The time of food security policy where re-assessing and redesigning were previously supervised is gradually being phased out. This revision shall on its own stand the re-calibration of values, geopolitical, economic, cultural and ecological dynamism, etc. This paper thus offers pertinent information as well as relevant strategic measures aimed at giving added value to the continuous policymaking process towards an affordable and reliable supply of sufficient, wholesome food that will induce energetic lives in nations. Building upon the crops that were brought together in the previous strategy, this study evaluates their viability in terms of local production versus imports. The balance between undergoing domestic cultivation and sourcing from world markets: Given that Qatar is predominantly a food-importing country, the importance of balancing domestic production with food imports from the world market cannot be understated. This analysis seeks to engage with crops that could have a competitive local advantage in order to minimize dependence upon international intra-nation markets; hence, establishing the economic feasibility of private sector or public sector importation of any or varied crops. Optimization of local crop production and management of imports are crucial for countries like Qatar, characterized by arid climates. There are several reasons underpinning the eminence of such approaches. The first point regarding the optimization of local crop production in arid regions enables the country to move toward self-sufficiency while reducing dependence on international markets; this has tremendous importance in the case of Qatar, which has historically depended on huge food imports. Resilient agriculture and technologies like

hydroponics and vertical farming provide a secure food source in times of adverse environmental conditions. Next, it is very relevant for an oil-rich country such as Qatar to diversify away from fossil-fuel-based economic growth into forms of more sustainable growth. Although on a small scale, agriculture can contribute to economic diversification by creating jobs, initiating technological innovations, and lessening the trade deficit created by food imports. Transporting food across long distances generates a huge footprint in emissions. By optimizing local crop production, Qatar will, thereby, reduce its carbon footprint from food imports. In addition, sustainable agricultural practices would reduce these environmental impacts of farming, particularly in this fragile desert ecosystem, by conserving water and soil resources. Fourth, with water being a very scarce resource in Qatar, efficient water management becomes a necessary tool. Optimization of crop production involves the use of drought-resistant crops, utilization of efficient irrigation systems such as drip irrigation, and recycling of wastewater from various activities. This dramatically reduces water usage, allowing this very limited resource to be freed up for those purposes considered to be of vital importance. Fifth, the heavy dependency on food imports exposes countries to the whims of international market food prices and the political stability of the producing countries. This shall lessen risk through food production by giving Qatar a better chance of ensuring a more stable and reliable food supply at a given price level.

Given these factors, careful development of local crop production and strategic food importation is needed for Qatar to achieve long-term sustainability, food security, and economic resilience. So technology, research, and development should be strongly relied upon to overcome the natural limitations of arid climate. It would also require careful planning and investment in infrastructure, education, and policy frameworks conducive to sustainable agricultural practices and efficient import strategies to support local production.

The linear programming mathematical model used to make a decision includes several variables other than the mere value of the crop, such as water and electricity usage, import diversity, and local production in Qatar. Models of this type of linear programming have been used in many papers dealing with this issue in international trade. There are quite a few different types of nonlinear programming solutions to this problem presented in the literature. One of the most salient features of the model proposal is that it is oriented toward real policies, as stated in the QNFSS. Our proposed studies investigate the intersection of international trade and local production to provide an all-around understanding of the economic and ecological dimensions of the food supply chain. This offers an understanding of how local production and imports together combine to influence the food security of Qatar. Through an integrated analysis, we intend to draw some strategic recommendations to guide the development of a resilient and adaptive food security strategy for Qatar.

This paper introduces into the existing literature of food security and attempts the development of an integrated multi-objective optimization model far beyond the traditional single-focus approaches. Prior to this study, very few authors have combined local agricultural productivity with reliance on food imports within a single framework where the economic and environmental costs as well as real-time constraints in QNFSS are given due credit. The integration of advanced agricultural technologies such as hydroponics and vertical farming, which would allow for solutions based on Qatar's climatic peculiarities, has been developed in conjunction with the model. These technologies were combined with appropriate trade strategies in order to protect the food system of Qatar from threats arising from geopolitical instability and fluctuations in the global market. This integrated approach can serve as a guide for other small, high-income, food-import-dependent nations, showing how the science of answers may assist in concrete adaptive development to improve food security.

With the changing context of global agriculture—delivered through trade patterns, technology advances, and climate change action—this approach emphasizes the importance of futuristic lens-based strategies. Qatar's increase in the impact of its food security policies about broader sustainable development should be enshrined in this sustainability agenda. As such, it would consolidate Qatar's position as an exemplar regional leader embracing and customizing such a strategy in efforts to promote food security advances in arid zones.

This paper contributes to the growing body of literature on food security in arid and semi-arid areas, particularly among the small and high-income economies highly dependent on imports. It provides a template which can be adapted by other countries of similar environmental and economic context, demonstrating just how Qatar may secure its supply of basic foodstuffs.

MATHEMATICAL MODEL FOR OPTIMIZING IMPORTS AND LOCAL PRODUCTION

This section presents a comprehensive model aimed at optimizing the allocation of agricultural imports and domestic production to satisfy overall demand efficiently. The core goal is to determine the optimal quantities of locally produced goods while considering key constraints, including the availability of greenhouse space, water resources, and energy. Additionally, the model identifies the required imports from trade partners to minimize total costs while ensuring demand is met.

The analysis focuses on a set of agricultural products. For each product, the model defines two decision variables, representing the locally produced quantity, and the amount imported from trade partner). The total demand for each product must be satisfied by the combined local production and imports.
Local production is subject to constraints such as the maximum available greenhouse area. Additionally, the production process is limited by resource availability for water and energy. Producing one unit of product requires specific resource inputs: units of area, units of water, and units of energy.
The model incorporates cost parameters to ensure economic efficiency. The objective function seeks to minimize the total cost of production and imports, which can be expressed mathematically as follows:

$$\text{Minimize} \quad \sum_{v=1..V} \left(p_v^l \cdot l_v + \sum_{c=1..C} p_{vc}^i \cdot i_{vc} \right) \qquad (1)$$

Where
p^l_v : the unit cost of local production
v: unit of product
p^i_{vc} represents the cost of importing one unit of product v
c: country

The objective described in the equation above aims to minimize the total costs associated with all products. In particular, it represents the combined costs of local production and imports for all required crops.

Additional constraints have been added to solve the model above to ensure alignment with the current Qatar National Food Strategy and these include:

$$l_v + \sum_{c=1}^{C} i_{vc} = D_v \qquad \forall v = 1, \dots, V \qquad (2)$$

$$\sum_{v=1}^{V} a_v \cdot l_v = A \qquad (3)$$

$$\sum_{v=1}^{V} w_v \cdot l_v \leq W \qquad (4)$$

$$\sum_{v=1}^{V} e_v \cdot l_v \leq E \qquad (5)$$

$$l_v, i_{vc} \geq 0 \qquad \forall v = 1, \dots, V, \; c = 1, \dots, C \qquad (6)$$

Where::
A: is land area
D: total demand
W: water used for irrigation
E; energy used to extract the water for irrigation

DATA SOURCES AND IMPLEMENTATION DETAILS

The datasets used in this study include local crop production data from the Planning and Statistics Authority (PSA) of Qatar (PSA, 2024), specifically for 12 greenhouse-grown crops. This data provides production quantities, demand, and land usage, all of which were incorporated into the model. Water requirements for each crop were estimated using global averages from the FAOSTAT database (Food and Agriculture Organization of the United Nations, 2024), while energy consumption for agricultural operations was estimated based on standard values for water extraction and pump efficiency as proposed by Plappally and Lienhard V (2012).
Local production costs were derived from selling prices provided by the Ministry of Commerce and Industry (MOCI) (Ministry of Commerce and Industry, Qatar, 2024). These prices were adjusted for subsidies by comparing local selling prices with average prices in the United States (Wamucii, 2024). Import data for 12 crops

in 2022 was sourced from the United Nations Comtrade database (United Nations, 2024), which compiles global trade statistics by product and partner. The data includes quantities and values of various imported crops. The corresponding Harmonized System (HS) Codes (International Trade Administration, U.S. Department of Commerce, 2024) for the selected crops were used to obtain the relevant data. The crops analyzed include:

- Tomatoes (HS Code: 702)
- Cucumbers (HS Code: 707)
- Green Pepper (HS Code: 70960)
- Pumpkin (HS Code: 70993)
- Cabbage (HS Code: 70511)
- Watermelons (HS Code: 80711)
- Cauliflower (HS Code: 70410)
- Potatoes (HS Code: 70190)
- Onion (HS Code: 70310)
- Eggplant (HS Code: 70930)
- Banana (HS Code: 803)
- Apples (HS Code: 80810)
- Citrus (HS Code: 805)

The QNFSS guidelines recommend sourcing crops from three to five countries, with no more than 70% of imports coming from the top two suppliers. However, the actual data indicates that Qatar imports from up to 26 countries, with a significant portion—around 80%—of imports for many crops coming from just one country. In some cases, more than 90% of imports are from the top two countries. This heavy reliance on a few suppliers poses a potential risk to Qatar's food security in the event of disruptions in those countries.

RESULTS

To begin with, the possibility of reorganizing local production fully is considered a potential as far as cost reduction is concerned. In the case of the model suggested in this case, this is equivalent to making the parameter α equal to 0, which means that the production of certain crops is free to be cut down to the extent of making it zero. The comparison is based on three, four and five trade partners as well as 70%, 60% and 50% import shares from the top two partners in turn. Then, the original state is compared where energy costs and consumer's expenditure for demand for foodstuffs is depicted as in Fig.1.
This is true especially after analyzing the problem thoroughly, where optimization of the amount of local production that needs to be imported along with the imports leads to considerable amount of reduction in expenditure. Where currently the dollar import bill stands at around two million entities $442.4 million. With optimization, however, this is expected to come down to $283.7 million, $307.1 million and $343.8 million when there are 3, 4 and 5 trade partners respectively which brings the savings or cost reductions between 35% and 22% cost among the trade partners. But at the same time the risk of cost went up because an increase in a number of trade partners meant an increase in cost because more expensive imports were in use.

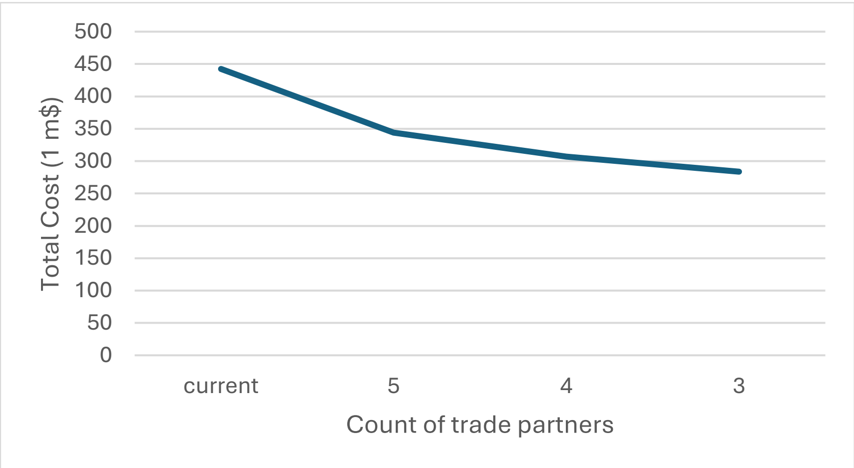

Fig. 1. The cost of meeting the total demand for 12 selected crops in Qatar is presented for two scenarios: the current state of local production and imports, and for varying numbers of trade partners with α = 0, allowing full reorganization of local production

Notably, the QNFSS strategy improves food security and reduces costs. That would be the result of a more balanced import strategy, making it more resilient against market disruptions because of lower reliance on expensive trade partners. Such a position will create a more sustainable and cost-efficient equilibrium, which could support both food security and economic efficiency.

The model focuses on cost minimization and, as seen previously, local production loses diversity. For this case study -with α = 0-the computational experiments give a local production that is specialized in a single crop: cauliflower which meets the entire demand.

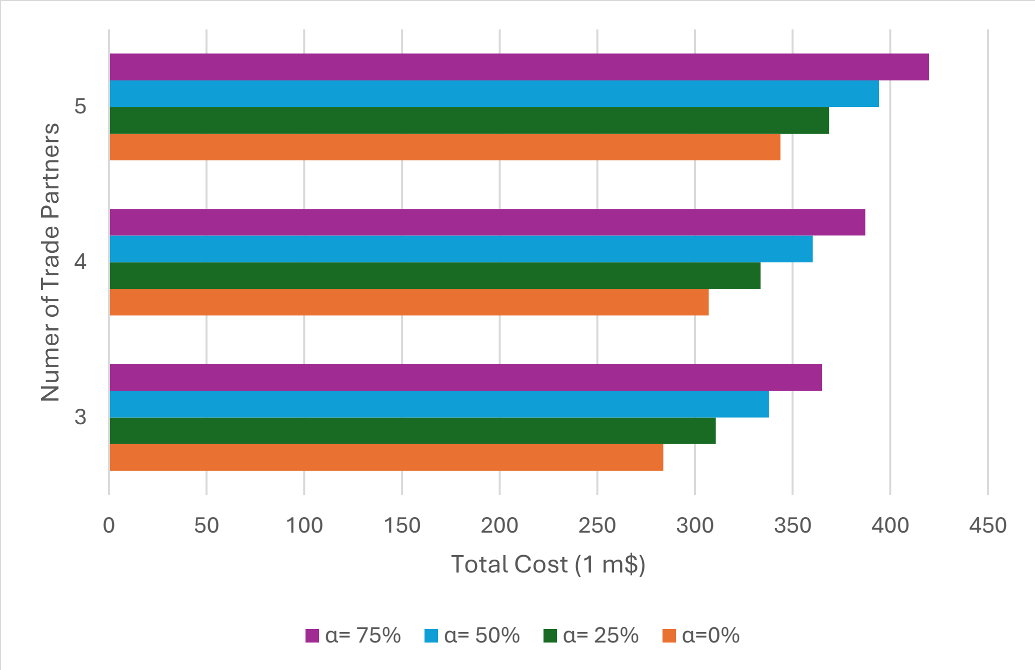

Fig. 2 Cost of meeting Qatar's demand for 12 crops with varying trade partners and reorganization levels (α values).

The effect of allowing different levels of change of local production is shown in Fig. 2 for values of α of between 0% and 75%. First, it can be observed from this figure that the potential costs decrease by allowing a higher level of change to current production. What is important to observe is that even in the case where 75% of local production is maintained, the potential annual savings are, however, not negligible and vary between $80-20 million a year depending on the utilized number of trading partners. Regarding the optimized distribution of local production, it is critical to note that is highly insensitive of the number of trading partners.

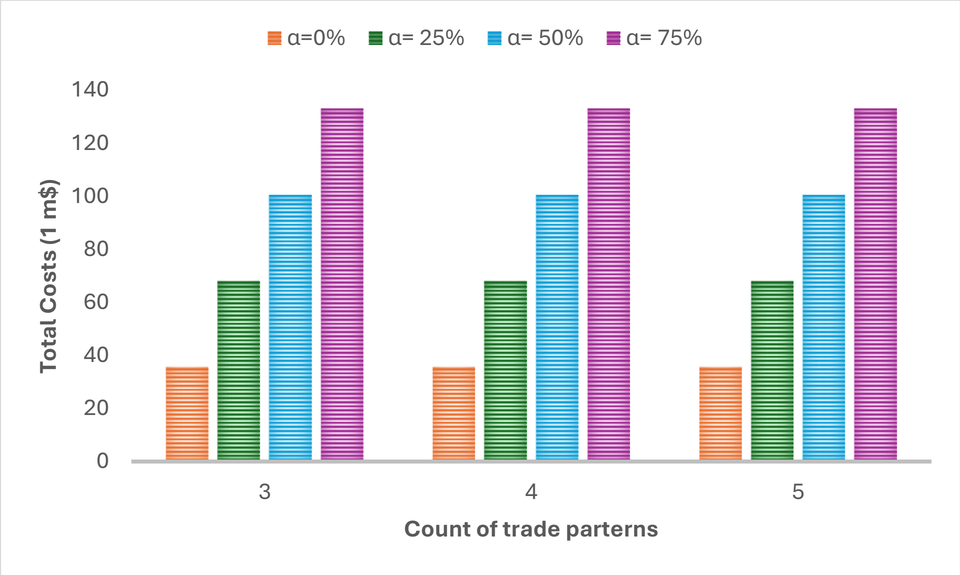

Fig. 3 Local production costs for meeting the demand of 12 crops are analyzed for different trade partner numbers and varying levels of local production reorganization, as defined by parameter α.

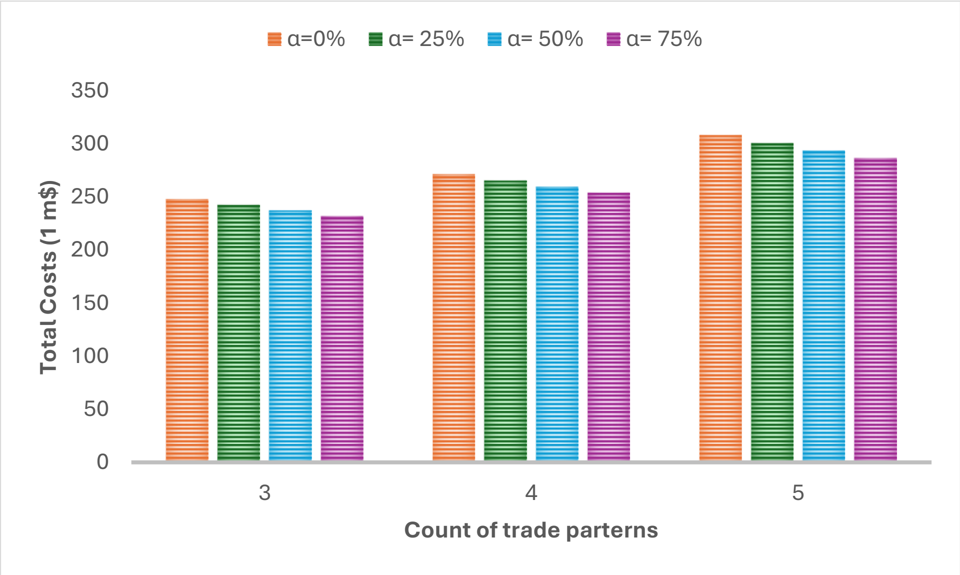

Fig 4 Import costs for meeting the demand of 12 crops are analyzed for different trade partner numbers and varying levels of local production reorganization, as defined by parameter α.

To fully understand this behavior, it is useful to examine the costs of local production and imports separately. Figures 3 and 4 provides a visual representation of this relationship. The first key observation is that the increase in total costs stems from the lack of optimization in local production. Conversely, significant savings in import costs can be achieved when the number of import partners is reduced. Notably, the QNFSS recommends using three import partners for crops with high levels of self-sufficiency. As shown in Figures 3 and 4, this strategy is effective, as the additional costs of local production in Qatar's challenging climate can be somewhat offset by an efficient import strategy.

CONCLUSIONS

In conclusion, this study points out the need to optimize the local production and imports so that the cost efficiency in satisfying Qatar's agricultural demand will be achieved. Individual cost analyses of local production and imports clearly show an increase in total costs due to sub-optimal local production strategies. However, importing costs exist that can be reduced considerably by having fewer trade partners, which results in great savings for importation. Findings also indicate that the QNFSS strategy is truly efficient as it limits imports to three trade associates for high self-sufficient crops in order to lessen inflated costs of local production in Qatar's extreme climate. Importantly, balanced and strategic measures for both local production and imports can lower overall costs while contributing to improving the security of food in Qatar and its resilience to market shocks.

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