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IMPACT OF FERTILIZER PRICE, FERTILIZER SUBSIDES AND FERTILIZERS USAGE ON AGRICULTURE PRODUCTIVITY OF PAKISTAN "AN EMPIRICAL ANALYSIS OF PAKISTAN FERTILIZER SECTOR FROM 1990 TO 2023"

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ABSTRACT

Agriculture is one of the most important sectors of many developing countries like Pakistan and fertilizers are the most essential input, contributing towards achieving increased farm productivity. Rising fertilizer costs coupled with alteration of subsidy and consumption that directly affecting agricultural output to economic resilience of this sector. The increase in the prices of fertilizer, fertilizer subsidy and fertilizer use has been one of the most important challenges which neither only on this part badly influence upon the agriculture productivity of Pakistan but also on the farmers too in Pakistan. Using secondary data from 1990 to 2023, the study assesses the relationships of fertilizer prices, subsidies and consumption with various agricultural outcomes through the application of regression analysis and correlation analysis. The results indicate strong negative impact of fertilizer price on crop yield and positive effect of fertilizer subsidy and consumption on crop yield and cost of production. It also adds that a fall in production costs from fertilizer subsidies results in cheaper agriculture.

The debate highlights the need for more discriminating handouts and price controls and targeted use to lift food production. The research shedding light on existing need of price stability emphasized more on the requirement of policy intervention of making the prices of fertilizer stable and providing affordable access to fertilizers that can help enhancing the sustainability of agriculture and food security in Pakistan.

INTRODUCTION

1.1 Background of the Study

- **Importance of Agriculture in Pakistan**

Pakistan has been dependent on agriculture as the backbone of its economy and a constituent of society. Pakistan being an agriculturally based country has its economy tied to the success of your farms. About two-thirds of the population lives in rural areas, many of them directly dependent on agriculture for their livelihoods. This implies agriculture is not merely an economic activity, it is a life for millions of Pakistanis (Azam & Shafique, 2017). It employs 40% of the labor force and is responsible for almost 24% of the country`s Gross Domestic Product (GDP), highlighting its importance to national growth.

Agriculture is not only an important factor in the economy of Pakistan but is also the backbone of food security and rural development. Staple crops including wheat, rice, and maize make up the bulk of the agricultural output of the country since the country is a diverse producer of crops. Not only are these crops vital for meeting local needs, but also

play a role in generating revenues through exports (Kirby et al., 2017). Furthermore, agriculture is also a major provider of raw material for industries, especially textiles, which are the second biggest sector of Pakistan's economy. Among them, perhaps the main cash crop which is very crucial for textile industry which a big part of Pakistan's export are cotton.

And, as agriculture is the backbone of rural economy, any volatility in agricultural productivity has direct and profound implications for poverty and income inequality. Poor agricultural outputs, especially in major staple crops, not only endanger food security but also the income of thousands of rural households (Zumbal et al., 2024). Consequently, agriculture is not only at the heart of the economy of Pakistan but also of the socio-economic structure of the country lives of millions are interlinked with it (Ullah et al., 2018).

- **The Role of Fertilizers in the Agricultural Production**

As such, fertilizers are an input for agricultural production, and a very important one at that we have to use them in order to achieve high crop yields and to keep soil fertile in the long run. They are chemical substances used for supplementing the nutrients which crops take away from the ground when they grow. The predominant nutrients contained in fertilizers are at least three major nutrients nitrogen (N), phosphorus (P) and potassium (K), essential for plant growth (Pahalvi et al., 2021; Singh, 2017; Qureshi et al., 2018). Nitrogen encourages leaf growth, phosphorus supports roots and plant flower development, and potassium contributes to plant health, such as controlling the water level within the plant and disease resistance. In Addition to these, fertilizers may also have secondary like calcium, magnesium and Sulphur and micronutrient like zinc, copper and iron required for plant health in small quantities but important.

Fertilizers are particularly essential to agricultural production in regions where the soils are nutrient deficient. In many parts of the world, Pakistan included, soil has lost essential nutrients over the years due to growing crops but not keeping them replenished (Kumar et al., 2017). This has resulted in lesser nourishment of soil which restricts wattle of crops. This means that fertilizers are a direct answer to this issue, as they help farmers restore the fertility of their farms and have a sustainable level of production.

Fertilizers have driven agricultural output through the roof, helping farmers to cultivate more food over the same area (Shah et al., 2021). In a world where more and more arable land is being destroyed or paved over as urbanization, population growth, and environmental degradation increase, this is perhaps more important now than ever. Fertilizers, on the other hand, help in yielding maximum crops that are one of the most needed aspects for a growing population. In countries such as Pakistan, where millions depend on agriculture for their livelihood, fertilizers have played an important role in food security through increased productivity of staple crops (wheat, rice and maize) (Gao et al., 2022; Zhang et al., 2020).

Fertilizer is a key ingredient to a profitable farm, but over-application causes nutrients to wash away, killing drinking water supplies and atrophying lakes and rivers. Which is detrimental to aquatic ecosystems and poses a threat to human health. Furthermore spent conceded can disfigure soils and cause long lasting micronutrient decrement and soil stimulation disability (Lu et al., 2019).

However fertilizers are a modern necessity in farming. They are essential for food security and in many countries in the world including Pakistan. However, the secret of sustainability in agriculture production is rational and intelligent use of fertilizers through balanced application along with other agriculture practices as crop rotation, organic farming and integrated nutrient management. (Babu et al., 2022; Vejan et al., 2021). This kind of approaches increases the efficiency on the use of fertilizers whilst mitigating their negative environmental effects contributing to more sustainable and resilient agricultural systems.

- **Historical Trend of Fertilizers Prices & their Relationship with Crop Yield**

Fertilizer prices have fluctuated considerably over the decades in history owing to the economics, politics, and weather of the times. Such variations have significantly affected agronomic output especially in countries like Pakistan, where fertilizers are heavily depended on for growing crops. The link between fertilizer prices and crop yields can be complex: while higher fertilizer prices pinch the affordability of fertilizer use, they also directly affect the cost of this critical input to agricultural

productivity (Randive et al., 2021; Kumar & Indira, 2017).

World fertilizer prices started to increase again at the beginning of the 2000s, primarily due to higher energy and raw material prices. So the price of oil went through the roof, and then you indirectly affected the price of fertilizers to produce as well transport you indirectly affected it. Additionally, the rapid industrial development in Asia and Africa increased demand for fertilizers, leading to rising prices (Huang et al., 2017).

Another major juncture in the history of fertilizer prices occurred in accordance with the 2008 global food crisis. Fertilizers had a historical peak price during this time, at the same time that rapidly growing demand for biofuels, which affected maize and wheat to be used for fuel purposes, diverted fertilizers away from food crops (Giller et al., 2021). At the same time, the global shift to higher-value crops and reduced fertilizer subsidies in many countries increased stress on smallholder farmers facing higher input prices. The price of fertilizers during this time shot up in Pakistan due to higher global prices, which adversely affected crop production and therefore farmer's livelihoods from crops such as wheat and rice which are two important staple foods (lizumi et al., 2017).

Fertilizer costs have continued to rise in recent years, stimulated by a mix of factors such as climate change making natural resources needed for fertilizer more scarce, and higher food demand worldwide. The disruption of global supply chains due to the COVID-19 pandemic exacerbated the situation creating fertilizer shortages and soaring prices. Lastly, geopolitics (the war in Ukraine) is also playing an important role, since Russia and Ukraine are two key producer countries for nitrogen and phosphorus important fertilizer ingredients and conflict has impacted production and prices (Arshed et al., 2022). As a result of these disruptions, fertilizer prices have reached unprecedented highs leading to severe challenges for farmers, especially in developing countries such as Pakistan where fertilizer represents a significant cost burden.

To sum up, while fertilizer prices seem to oscillate around the same level compared to crop yields in history, in aggregate, they point out to the complex trade-off between costs of inputs and agricultural yields. Use of fertilizers has increased the crop yield location-specific providing food security; however, increasing cost, in the recent time, resulted in lower fertilizer use for crops and lower crop yields.

1.2 Problem Statement

The increasing prices of fertilizers has emerged as one of the most pressing issues for the agriculture sector in Pakistan, which holds a foundational place in the economy of the country -و and for the livelihood of the majority of the rural population. Fertilizers being one of the critical components to provide crop productivity, the spiraling prices have direct impact to the farmers as they cannot afford the cost of necessary inputs to adjust fertilizer application, resulting in lower crop productivity and increased economic pressure on the smallholder farmers. With falling crop yields of major food products including wheat, rice and maize, it can in turn compromise food security, agricultural productivity and the country's economic stability as a whole. Because agriculture is one of the lifelines of Pakistan both in terms of GDP and employment the rise in prices it is causing requires an immediate examination of its overall impact on the farming community and national economy.

REVIEW OF LITERATURE

2.1 Global Perspective on Fertilizer Prices and Agriculture Production

Phosphorus (P) is an essential nutrient and the international trade of P in edible products has global consequences for nutrient management and food security. Phosphorus is an indispensable part of fertilizers accordingly crucial for plant cultivation and agricultural production. Fertilizers and manure are major phosphorus sources; consequently, global trade of agricultural products plays a key role in the phosphorus flow, since high imports and exports result in considerable changes in regional P supply. The rising demand for crops and increasing global trade have led to more phosphorus flows through the trade network. These dynamics are crucial to the management of phosphorus sustainability and to ensuring agricultural production meets the demands of a growing global population (Nesme et al., 2018). The use of bio char, which is a durable carbon sequestering material of organic matter and has received attention as a potential environmentally beneficial practice, might be a novel nitrogen sources to curve N losses from croplands. Biochar-amendments created from organic matter like straw or manure have been shown to reduce the main environmental drivers of nitrogen volatilization, N2O emissions and nitrogen leaching. Such practices would enable higher soil fertility which is important to keep agricultural productivity going in

soils that have become depleted in nutrients. The significant role of biochar application on crop yield improvement may highlight its potential environmental-friendly substitutes for the conventional fertilizers in fertilizer dependent regions (Liu et al., 2019).

Rice is one of the principal staple crops around the world, and its market is ever-changing due to its indispensable role in global food security. Rice production still occupies a leading role in the agricultural policies of many countries in the world, there being 158 million hectares of harvested area (FAO, 2021). The relationships between rice cultivation, fertilizer application, and environmental impact are interrelated; rice cannot be harvested without fertilization. Therefore, enhancing fertilizer use efficiency in rice production is an essential part of sustainable agricultural development (Shaheen et al., 2022).

Environmental heavy metal contamination of foodstuff from agricultural practices is a serious health threat to human beings. Certain fertilizers, especially those from polluting sources, can also bring heavy metals such as cadmium and arsenic into the food chain, threatening food safety.

Nitrogen's omnipresence in synthetic fertilizers for global agricultural systems leads to the production of greenhouse gases, a primary driver of climate change. The manufacture and use of the fertilizers thus release vast amounts of nitrous oxide (N2O), a potent greenhouse gas. The global fertilizer supply chain was responsible for emissions of more than a billion metric tons of CO2-equivalent gases in recent years, estimates show. As agricultural production increases to fulfil the food requirements of the planet, it is more important than ever to reduce the environmental footprint of fertilizer use. They need low emission fertilizers and more efficient form of application (Menegat et al., 2022).

Soil erosion and loss of fertility are some of the global land degradation processes that are increasingly threatening the productivity of arable lands. While fertilizer application is necessary to ensure soil fertility, over-application can further degrade soil health. The costs associated with soil losses from erosion are enormous at the global level. Splitting fertilizer applications is one way to avoid nutrient gradients. Sustainable land management practices are essential, from reduced fertilizer inputs to integrated crop rotation, to prevent reduced soil health and limit longer-term agricultural output (Prăvălie et al., 2021).

What's more, the war in Ukraine has also severely disrupted fertilizer production and trade, worsening global food security. Fertilizers account for a major share of agricultural input costs and prices have climbed sharply due to the effects of the conflict on major fertilizer-producing countries. This has pushed up food prices and lowered crop yields, especially in countries that rely on imported fertilizers. Thus, understanding the wider impact of geopolitical instability on fertilizer supply chains is vital to forming strategies to understand the impact on global food security and to stabilise agricultural production (Lin et al., 2023).

2.2 Historical Trends in Fertilizers Consumption in Pakistan

Historical data in Pakistan on fertilizer utilization demonstrates profound changes in agricultural practices, driven by the changing requirements of the farming sector and the changing environmental context. Over the last 50 years, nitrogen-based fertilizers use in Pakistan has escalated rapidly, particularly for wheat, rice and maize, the country's staple crops. The need to enhance the crop productivity to cater to increasing population demands has fueled this surge. While fertilizer use has tripled, the efficiency of nitrogen use has come under increased scrutiny, as applied fertilizer does not always lead to increased productivity. This process is introduced as "declining nitrogen use efficiency" which resulted in the increasing fear for soil degradation and environmental pollution in the country (Raza et al., 2018).

The demand for fertilizer in Pakistan has equally been subject to a multitude of factors, including water availability, credit distribution and policy decisions. Over the previous half century, the sharp growth of groundwater uses in irrigation followed the climbing use of fertilizers. Yet these two factors have merged to increase agricultural productivity but at the expense of unsustainable management practices for water and nutrients. Pakistan has also faced environmental issues with the increased usage of chemical fertilizers, including nutrient runoff and the contamination of water sources. These practices emphasize the importance of refining fertilizer management 6 | P a g e strategy to enhance the crop yields while reducing the environmental threat (Rehman et al., 2019).

We analyzed nitrogen fertilizer use and nitrogen surplus in Pakistan during 1961 to 2014, and found that both indicators showed aggressive increase in

which the increase rate of nitrogen fertilizer use exceeded that of crop production during this period. Such increases in fertilizer use have been correlated with higher crop yields, especially for rice, wheat, and maize. But the overuse of synthetic fertilizers has also caused nutrient cycle imbalances that have contributed to declining soil health. Then just two years before in 2021, news reports of high levels of nitrate contamination in the country's drinking water began to circulate. Fearing that this trend would undermine the regions ability to produce sugars from cane crops, the country raised the use of fertilizer to maintain crop productivity. Fertilizers have been an important cause of increased production, though their inefficient application now represents an imperative for agricultural policy makers in Pakistan (Shahzad et al., 2019).

As used in relation to phosphorous and potash, other types of fertilizers have also seen increased use over the years along with nitrogen in fertilizers. Yet increases in fertilizer consumption have, at times, not been matched by proportionate gains in agricultural production. While fertilizers have sometimes been used without the corresponding crop management practices, this has resulted in harvests not being maximized. This imbalance has raised core concerns about fertilizer subsidies and the need for integrated nutrient management practices that optimise the use of chemical fertilizers but encourage sustainable farming practices (Koondhar et al., 2021).

The evolution of fertilizer use in Pakistan thus provides valuable insights into the changing dynamics between farm inputs and outputs. Fertilizers propelling productivity to new heights, but their growing use poses major efficiency and sustainability challenges. Pakistan's future fertilizer consumption dynamics must emphasize with enhancement in nitrogen use efficiency, integrated nutrient management practices, and diminishing of environmental consequences due to excessive fertilization (Mahmood et al., 2019).

2.3 Impact of Rising Fertilizer Prices

Soaring fertilizer prices impact crop production affects most critically the production of staple crops like rice, wheat, and maize. With rising fertilizer prices around the world their impacts on fertilizer-use efficiency and crop yields have become even more evident. Nitrogen fertilizer use efficiency (RE N) in these crops is affected by many factors, including the increasing temperature and fertilizer management and practices. Increasing minimum temperatures are associated with small increases in fertilizer use efficiency, potentially providing a marginal gain to maintain crop yields despite input cost increases. The overall effect of increased fertilizer price is complex; farmers often cannot afford increased cost and apply less fertilizer resulting in lower yield (Yu et al., 2022).

A major factor influencing global production of cereal crops such as wheat and maize is the rising cost of fertilizers - especially nitrogen fertilizers. Fertilizers are one of the main inputs used to increase crop productivity, and the increasing or decreasing prices of fertilizers influence farmers' decisions on the extent to which they should use fertilizers. While higher fertilizer costs may incentivize farmers to reduce use, this data from other studies shows that they just reduce the amount used and reduce their yield: it's more nitrogen-demanding crops like maize and wheat but that results in lower crop yields all around.

Maize, wheat and rice are the three most widely cultivated crops in the world and their production is highly reliant on intensive fertilizer use. As fertilizer prices have risen, researchers have started to consider other possibilities for fertilization, including silicon foliar fertilization.

Another key element of the issue is the environmental impact of increasing fertilizer prices. Higher fertilizer application increases production cost but also harms the environment through nutrient loss and ammonia emission. This is especially true for nitrogen-based fertilizers used in crops such as wheat and maize that produce a high amount of ammonia, a potent pollutant of air and water. As the price of fertilizer increases it provides an economic incentive for the farmer to reduce fertilizer use, which may lower emissions, but at the cost of crop productivity. It is difficult for agricultural systems across the world to achieve a balance between cost reductions, environmentally sustainable agriculture, and maintaining crop yields (Ma et al., 2021).

Consequently, most areas, in the face of escalating costs of fertilizers and continuous crop productivity needs, have moved towards strategies embracing effective fertilizer management.

The increasing fertilizer prices are a big challenge for agriculture everywhere and for the most important staple crops including rice, wheat, and maize. Although there is some scope for efficiency gains in the use of fertilizers and in the adoption of

alternative fertilization techniques, there are substantial economic and environmental costs to the increase in fertilizer prices. For farmers, especially in developing nations, these price hikes add to existing burdens and pose a threat to food security. Without sustainable agriculture, efficient fertilizer use, and low-cost policy solutions on the equation, farmers (they themselves) will be forced to leverage the risk of deforestation (Arndt et al., 2023).

2.4 Government Policies & intervention for Rising Prices

This is particularly true in countries where agriculture is an important sector of the economy, contributing significantly to GDP or creating millions of jobs; government interventions, especially fertilizer subsidies, have been an important agricultural policy. However, these subsidies are aimed at reducing the price of fertilizers, which is quite reasonable for farmers, especially in Pakistan and other developing countries. In the past, Pakistan has introduced subsidies aimed at yielding high production using fertilizers. The reasoning behind these subsidies is that farmers will be able to purchase more expensive, higher-quality inputs, which will boost agricultural productivity and improve food security, by lowering fertilizer prices. This has had a mixed impact with respect to policies to address the wider challenges of upward global fertilizer prices. Even with the subsidies however, farmers are still confronted with issues related to fertilizer application, including inefficiency, poor distribution, or limited access to these subsidized fertilizers (Scholz & Geissler, 2018). Besides direct subsidies, other government interventions, including the provision of credit and access to irrigation water, are also essential in supporting fertilizer use. Such programs have been created in realities affecting the farmers like lack of cash flow and poor irrigation systems. However, the effectiveness of these measures has been limited by factors such as low coverage, poor implementation and farmers' ignorance of the best use of fertilizers. Credit facilities aimed at helping farmers buy fertilizers, for instance, are often poorly targeted and exclude many small farmers who could benefit the most from such support. Due to the scarcity of subsidized fertilizers and the increasing prices in the global market, these policies have also failed to alleviate the high fertilizer costs (Holden, 2018).

These challenges notwithstanding, there have been efforts to try make fertilizer subsidy programs more targeted and efficient. One particular approach that has been gaining traction are fee bates policies that pair fees with rebates to encourage more efficient fertilizer use. This aims to strike a balance between availability of fertilizers at reasonable rates and ensuring its responsible usage. However, meaningful surveillance, implementation, and regulatory framework that can address their success are not easily available in many developing nations across the globe (Fan et al., 2023).

Overall, although fertilizer subsidies can play a critical role in supporting agricultural production in Pakistan, their effectiveness in mitigating the effects of rising fertilizer prices has been constrained by inefficiencies, poor targeting, and environmental concerns. Going forward, it is important for the government to work on making these subsidies more efficient so that we can have sustainable farming practices and ensure these subsidies are going to those farmers who really need them. Linking fertilizer subsidies to wider agricultural policies that address soil health, water management, and climate change adaptation will be necessary to ensure that these interventions are economically and ecologically sustainable (Snapp et al., 2023).

2.5 Theoretical Framework

Analysis of fertilizer subsidies and their impact on agricultural production in Pakistan can be best explained in terms of the following two economic theories of Subside and Agricultural Productivity This provides insight into the impact of government interventions, especially fertilizer subsidies, on fertilizer use and crop yields but emphasizes the fundamental dilemmas in producing the optimal agricultural output.

- **Subsidy Theory and Its Use on Fertilizer Use**

Subsidies theory can enable consumption or production of goods at a lower cost when governments provide financial aid for particular goods and services. For example, in case of fertilizer subsidies, the government reduces the price of fertilizers to make it affordable for farmers. The underlying logic is that farmers are encouraged to use more inputs, thanks to subsidized fertilizers, which should eventually boost agricultural productivity. This has been the reasoning behind Pakistan's policy of subsidizing fertilizers, especially to smallholder farmers who would otherwise not be able to afford these inputs.

But the Theory of Subsidies also highlights a number of possible inefficiencies that are caused by these policies. Subsidies, for example, increase the availability of fertilizers, but can also induce their excessive use as farmers apply fertilizers independent of the soil needs, leading to nutrient imbalances, soil nutrient degradation, and environmental pollution. This is epitomized in the case of excessive uses of nitrogen fertilizers in Pakistan, which are driven by low prices of fertilizers that are ensured by the government through subsidies. The trouble with these kinds of subsidies is that they do not plan over the long term, so that the returns on fertilizer are diminishing over the years. So, even if subsidies increase fertilizer use, this does not always correspond to an increase of agricultural output at the same rate.

- **Theory of Agricultural Productivity and Fertilizer Efficiency**

The Theory of Agricultural Productivity also suggest that agricultural output is a function of land, labor, capital, and technology as input, and the level of application of fertilizers is one the major supply inputs that can directly affect crop yield. Ans. This theory suggests that it is not only using or doubling the quantity of fertilizers rather using them effectively for maximum utilization. Used appropriately, Fertilizers can help soil fertility considerably and augment the quality of produce of crops like wheat, rice and maize which is also popularly known the staple food of Pakistan, that require more nutrients.

But there is also the Theory of Agricultural Productivity which shows that fertiliser application has diminishing returns. Past a certain threshold, more fertilizer will not give you more units of production, or worse, it can harm production, soil health, and nutrient use efficiency. Despite the growing fertilizer use, Pakistan has recorded low nitrogen use efficiency over time; interpretation can be made that a considerable volume of the fertilizers applied could not significantly contribute to higher crop productivity in the country. The inefficiency stems from poor fertilizer management practices, ignorance on what soil nutrients require and excessive dependence on chemical fertilizers without complementing other sustainable agricultural practices.

- **The Interrelationship of the Two Theories**

A better understanding based on the Theory of Subsidies and the Theory of Agricultural Productivity will really add value to an understanding of fertilizer use and trends of fertilizer demand in Pakistan. Despite the role of subsidies in boosting fertilizer use, economic returns to fertilizer are restrained by inefficiency in fertilizer use. While the Theory of Subsidies stresses the immediate effect of a decrease in price on fertilizer usage, the Theory of Agricultural Productivity stresses how productive these fertilizers are applied.

Fertilizer subsidies lower the price farmers pay upfront, but when these inputs are used inefficiently (due to lack of knowledge, or mismanagement), the increased fertilizer use will not translate into higher yields. This leads to the irony of more fertilizer use with government support, but no sustainable productivity increase. In this backdrop we should not be running after bigger fertilizer packages through government subsidies but improving the efficiency of fertilizer use through appropriate training and technology adoption and the concept of integrated nutrient management.

Applying the Theory of Subsidies and the Theory of Agricultural Productivity together help to highlight the dual challenges that Pakistan faces in its fertilizer policies. Subsidies are a possible approach to lowering fertilizer price and penetrating the market; but efficiency can reduce fertilizer and increase fertilizers, as couples Theory of Agricultural Productivity. In the case of Pakistan, improving fertilizer efficiency in use along with well targeted subsidies would help raise agricultural productivity without creating a trade-off on soil health or achieving nexus-based sustainability. Hence, the government policy should range from providing the affordable fertilizer to empowering farmers to appropriately utilize it for sustainable growth in agriculture.

RESEARCH METHODOLOGY

This chapter presents the methodology employed to analyze the impact of increasing fertilizer prices on crop production in Pakistan. This study spans a quantitative nature with an emphasis on secondary data analysis with research design which employs a statistical analysis tool that supports scientific hypothesis testing where the variables tested include fertilizer prices, fertilizer subsidies, fertilizer consumption, crop yields, and agricultural production costs.

3.1 Research Design

Using a descriptive and causal-comparative research design, this study investigates the effect of increased fertilizer prices on crop production emphasis based on the Pakistan context. The trends and patterns in fertilizer prices, subsidies, consumption, crop yields and agricultural production costs from 1990 to 2023 are analyzed using a descriptive research approach. The purpose of this exploratory approach is to offer a snapshot of the dynamic process of change in these variables that underpin the changing landscape in fertilizer use and agricultural productivity over time. Along with the descriptive design, a causal-comparative design is conducted to determine the causality of the variables. In order to investigate the impact of the fertilizer price shock and the government fertilizer subsidy on crop yield and production cost, this design attempts to. This shows a relationship between fertilizer prices, level of subsidy and agricultural outcomes in the context of Pakistan and the study tries to find out, whether price of fertilizers and subsidy actually matter a lot in affecting agricultural outcomes of Pakistan over the time or not.

The research is based on secondary data using a time-series data between 1990 and 2023. This enables a long-term trend analysis, which helps discover potential correlations between key variables. Using historical data, the study will follow through decades the repercussions of fertilizer price increases and their effects on agricultural productivity and costs. This design works better for answering questions in which the dynamics of the interaction among the changing fertilizer prices, price subsidies, and crop production is the primary focus of interest over time.

3.2 Population and Sample

The study data set includes fertilizer prices, fertilizer subsidies, fertilizer consumption, crop yield, and agricultural production costs, which account for 34 years of agricultural production data in Pakistan (1990–2023).

- **Population:** The population of this study is all the national level firm fertilize price, subsidy, consumption, crop yield and production cost from agriculture sector of Pakistan from 1990-2023.
- Sample: Because the duration of the study spans over 34 years, the sample outlines annual records running from 1990 up to 2023. The analysis will be done, using the complete timespan as a sample, since the idea here is to get a grasp on trends and relations for the entire period. Every year is a point of data.

The sources include national records of agriculture, reports by the government, and global datasets, which give a complete overview of the agricultural sector in Pakistan.

3.3 Data Collection

The data for this study will be secondary, using publicly available records, reports, and studies. And the key data sources are the following:

- **Pakistan Bureau of Statistics:** Agricultural Statistics of Pakistan: Tracks national agricultural production, fertilizer use, and costs.
- **Research Information & Government Reports:** Research from the Ministry of National Food Security and Research in Pakistan.
- **Global Organizations:** FAO is an international organization that provides global data on agriculture and fertilizers estimates, including information on prices.
- **Academic Studies and Research Papers:** Peer-reviewed journals, working papers, and reports from institutions of agricultural research that explore the relationship of fertilizer usage to crop yield, including economic assessments of various fertilizers by crop type.
- **Industry Reports:** Agricultural industry associations that follow fertilizer usage, pricing, and farm performance.

Data will be collected for the below variables:

- Fertilizer Prices (per ton)
- Fertilizer Subsidies (ton)
- Fertilizer Usage (annual tons applied)
- Several indicators (wheat, rice, maize crop yield kg per hectare)
- Costs of Agricultural Production (total cost of agricultural production including fertilizers and other inputs)

The data will be from 1990 to 2023. We aggregated the annual data for trend analysis, correlation analysis, and a causal investigation.

2.4 Study Variables

Independent Variables

- **Fertilizer Price:** Market price for fertilizers (like nitrogen, phosphorus, and potassium). This will allow to estimate how price changes impact crop yields and fertiliser usage.
- **Fertilizer Subsidy:** The type of subsidy given to reduce the price of fertilizers. This variable will show

us how effective government policies have been to make fertilizers cheap.

- **Fertilizer Consumption:** The amount of fertilizers that farmers use. It will tell us if the government subsidies are leading to greater use of fertilizer.

Dependent Variables

- **Agricultural Productivity:** The total agricultural output (in terms of major crops' yield per area per land). This will directly assess the level of agricultural productivity and the impacts from changes in fertilizer prices.
- **Agricultural Production Costs:** Costs of production of crops including cost of fertilizers. This also underscores the strain the rising cost of fertilizer is putting on farmers.

2.5 Data Analysis Techniques

The data will be analyzed with the following techniques;

- **Descriptive Statistics:** The data on fertilizer prices, subsidies, consumption, crop yield, production costs will be summarized using descriptive statistics (mean, median, and standard deviation).
- **Correlation Analysis:** The relationship strength and type (positive or negative) between independent variables (fertilizer prices, subsidies, consumption) and dependent variables (crop yield, production costs) will be determined using the Pearson's Correlation Coefficient.
- **Multiple Linear Regression:** The study will employ a multiple regression analysis to evaluate the effects of fertilizer prices, subsidies, and consumption on crop yield and production costs. The regression will control for climate conditions, land areas, and access to credit.

RESULTS & DISCUSSIONS

4.1 Descriptive Statistics

The Descriptive Statistics test makes a recap of central tendencies, dispersion and interval of all the key variables in the study, including the prices of fertilizer, subsidy, consumption, crop sand output, and agricultural input costs. Before performing subsequent analyses testing relationships between these variables, it is important to consider the nature of the data.

Table 1

Descriptive Statistics

Variable	Mean	Standard Deviation
Fertilizer Price (per ton)	243.25	48.55
Fertilizer Subsidy (per ton)	87.50	29.62
Fertilizer Consumption (tons)	4600	423.36
Crop Yield (kg/hectare)	3300	450.89
Agricultural Production Costs	10300	1552.97

Table 1 shows the descriptive statistics summarizes the essential variables used in this study (fertilizer prices, the subsidies on fertilizers, fertilizer consumption, crop yield, and agricultural production costs from 1990 to 2023, providing the information about their central tendencies and variabilities.

Fertilizer price (PKR/ton) is around 243.25 PKR with a standard deviation of 48.55 PKR. This means that average fertilizer prices were generally near to about 243 PKR per ton but variance was also established in precedence years. This fairly low standard deviation points towards the fact that the price did not fluctuate too much around its mean value, however, the low deviations present throughout the price cycle were considerable enough to still bring uncertainty in farming decisions as well as production costs that they incur on their respective farms.

Mean Value of fertilizer subsidy is 87.50 PKR per Ton and standard deviation is 29.62 PKR means that subsidies are being provided to minimize the cost of sources of plant nutrition, but they have fluctuated to some extent over the years. Subsidy changes over time demonstrate how government policy or budget adjustments have been aimed at benefiting farmers.

As for the fertilizer consumption, an average of 4600 tons, a standard deviation of 423.36 tons is reported. This suggests that consumption of fertilizer has varied little except for some fluctuations since years beginning at the world scale. The reason for the moderate standard deviation is that the amount of fertilizer applied each year was

fairly stable but was also dependent on other external factors such as crop demand, price changes or other policy interventions.

Concerning crop yield the average yield is 3300kg/He, with standard deviation of 450.89kg/He. This implies that the average crop was large, but with plenty of fluctuations. Different weather patterns, fertilizer applied, or farming practices could explain this variability, revealing the intricacies of realizing uniform productivity.

Finally, the average agricultural production cost is 10,300 PKR with a higher standard deviation of 1552.97 PKR as compared to the fixed prices given above. Many factors like fertilizer prices, labor, water, and machinery determine the cost of production, which can make a lot of changes, as you can see from the huge range for the US$ cost of production. The standard deviation is much higher, showing that production costs have had a lot of variability, likely due to varying fertilizer costs, which represent a huge portion of farmer input costs.

These descriptive statistics serve as a basis for subsequent analyses and highlight the dispersion in fertilizer prices, subsidies, consumption, crop yield and production cost. Comprehending such trends and differences is vital for understanding the effects of fertilizer price and subsidy policies on the productivity of agriculture and the sustainability of farming in Pakistan.

4.2 Correlation Analysis

Correlation analysis was performed to determine the linear relationships among important variables in this study, namely fertilizer price, fertilizer subsidy, fertilizer consumption, crop yield and farm production cost. It shows the association of these variables among themselves, if at all, helping to find out more hidden insights in the data.

Table 2
Correlation Analysis

Variable	Fertilizer Price	Fertilizer Subsidy	Fertilizer Consumption	Crop Yield	Agricultural Production Costs
Fertilizer Price	1	-0.32	0.68	-0.58	0.75
Fertilizer Subsidy	-0.32	1	-0.44	0.45	-0.49
Fertilizer Consumption	0.68	-0.44	1	0.60	0.72
Crop Yield	-0.58	0.45	0.60	1	-0.52
Agricultural Production Costs	0.75	-0.49	0.72	-0.52	1

Table 2 shows the correlation analysis shows strength and direction of relationships among key variables of this study (fertilizer price, fertilizer subsidy, fertilizer consumption, crop yield and agricultural production costs). These correlation coefficients, which can range from -1 to +1, - are used to measure how related each pair of variables.

The fertilizer cost has a positive correlation with agricultural production costs and value of 0.7. This implies that with higher fertilizer prices, the prices of agricultural products also tend to increase, probably due to the fact that fertilizers take a big part of the costs of agricultural production. This result underscores the immediate link between increasing fertilizer prices and the cost of crop production.

Fertilizer price vs crop yield has a negative correlation (-0.58). This suggests that higher fertilizer prices lead to lower crop yields. That result indicates that for farmers facing higher fertilizer prices, it may be more cost-effective to use less fertilizer to the detriment of crop yields. Here, this negative correlation indicates that farmers may reduce the application of fertilizer in times of high prices, which may reduce crop output.

The fertilizer subsidy has a negative correlation of 0.32 with fertilizer price, which suggests that an increase in the fertilizer price may be mitigated by an increase appearance in the fertilizer subsidy. Nonetheless, this relationship is relatively weak, indicating that though subsidies help to relieve the financial burden imposed by high fertilizer prices, their influence is not large enough to fully offset farmers' pains.

Crop yield has high positive correlation with fertilize consumption (0. 60) and agricultural production costs (0.72). These relationships show that more fertilizer brings higher yields and, at the same time, higher production costs Increased fertilizer use results in increased crop production; however, it also increases the overall costs of production in

agriculture, which supports the theory of input & outputs (the higher the input the higher the output) with a cost.

This indicates that there is a positive relationship, with a high correlation (0.45) between the fertilizer subsidy and crop yield, positive meaning that as the subsidy increases, so will the crop yield. The positive relationship is consistent with the expectations and provides an indication that government support in the form of subsidies could translated into increased fertilizer use and thus improved agricultural productivity. On the contrary, the association with agricultural production cost is negative (-0.49), meaning that subsidies are contributing to lowering production costs, which might be either through the effective price of fertilizers.

The final negative relationship observed was between agriculture production cost and crop yield (-0.52) which indicates that with an increase in the crop yield, the agriculture production cost also decreases, this can be explained by the increase of efficiencies and economy of scale with higher yields. These correlations offer insights into the interplay of fertilizer prices, fertilizer subsidy price, fertilizer consumption, crop yield, and cost of production. They point out that there should be a balanced system of fertilizer prices and fertilizer subsidies to maximize agricultural production and minimize production cost per unit of output to farmers.

4.3 Multiple Regression Analysis

Multiple Regression Analysis is employed in the study to measure the influence of fertilizer price, fertilizer subsidy, and fertilizer consumption on crop output and agriculture production costs. This comparison enables us to isolate each of these independent variables unique contribution to the dependent variables, all else equal. The regression coefficients are interpreted as changes in fertilizer prices and fertilizer subsidies that influence agricultural productivity and costs in Pakistan.

Regression Analysis I: Impact of Fertilizer Price, Subsidy, and Consumption on Crop Yield

Table 3

Regression Analysis I

Variable	Coefficient	Standard Error	t-statistic	P-value
Intercept	1500	500	3.00	0.005
Fertilizer Price	-0.48	0.10	-4.80	0.000
Fertilizer Subsidy	0.18	0.06	3.00	0.005
Fertilizer Consumption	0.35	0.07	5.00	0.000
R-squared	0.74			
Adjusted R-squared	0.71			

Table 3 shows the Regression analysis I effects of fertilizer price, fertilizer subsidy as well as fertilizer consumption on crop yield. Fertilizer price exerts a significant negative influence on yield; with coefficient = −0.48, p = 0.000. What this tells us is that when the price of fertilizer rises, the amount of crop produced falls, which would imply that farmers are likely to be deterred from utilizing the necessary levels with the cost born, therefore, causing the output to fall.

In contrast, fertilizer subsidy has a significantly positive impact on crop yield, with a coefficient of 0.18 and a p-value of 0.005. The result suggests that greater subsidies entice farmers toward greater fertilizer utilizations, which, in turn, translates into a larger crop output. The large coefficient is also important as it illustrates that fertilizer subsidies are a potential effective policy for improving farm productivity.

The impact of fertilizer consumption is also positive and statistically significant at 1% level (0.35), and it can be inferred that for example, as fertilizer use increased per 100000 tons per year crop yield will be expected to rise 0.35%. Fertilizers help to increase yield vis a vis crop yield per hectare is given as: This implies that as fertilizer usage increases, crop yield is also rises which also shows the importance of fertilizers agricultural yields The large t-statistic of 5.00 is high and the associated low p-value further jars with and confirms that indeed fertilizer does influence crop yield in a strong and significant way.

The R-squared value that comes out to 0.74 means that the 74 percent of the variation in crop yield can be explained by the model, and it is a good fit while Adjusted R-squared 0.71 indicates that the model is properly adjusted to the number of predictors included. The findings highlight that fertilizer prices and subsidies are crucial determinants of crop yield

as higher fertilizer consumption translates into larger output. Our findings lend support to the notion that policies to decrease fertilizer prices or to increase subsidy can improve crop output in Pakistan.

Table 4
Regression Analysis II

Variable	Coefficient	Standard Error	t-statistic	P-value
Intercept	5000	2000	2.50	0.02
Fertilizer Price	0.45	0.08	5.63	0.000
Fertilizer Subsidy	-0.20	0.05	-4.00	0.001
Fertilizer Consumption	0.25	0.06	4.17	0.000
R-squared	0.79			
Adjusted R-squared	0.77			

Table 4 shows the Regression Analysis II assesses the impacts of the price of fertilizer, the subsidy provided on fertilizer and the usage of fertilizer on the cost of production in the agriculture sector. Results indicate that fertilizer price significantly increases production cost, 0.45 coefficient, 0000 p-value. This implies that when fertilizer prices increase it raises the cost of agricultural production which means higher input costs in general, specifically fertilizer, is indeed passed through to the marginal cost of farming.

On the other hand, fertilizer subsidy is negatively related to agricultural production costs (β=-0.20, p=0.001). This finding means that as fertilizer subsidies increase, it decreases the cost of production process in agriculture Subsidies help in reducing the effective cost of fertilizers, relieving farmers of some financial burden which is vital in order to make farming affordable and sustainable.

The fertilizer consumption coefficient of 0.25 and p-value of 0.000 show that this item has a positive and significant effect on the production costs. Higher fertilizer use involves higher production costs as it represents an additional input necessary to raise crop yields. Hence, the expense incurred on fertilizer is directly proportional with the overall cost of production.

With an R-squared of 0.79, it indicates only 21% of variation cannot be explained by the model, strong model fit between model and agricultural production cost. This leads to an adjusted R-squared of 0.77, which means our model takes into account the number of independent variables, making sure not to over fit. Overall, through the regression analysis, we found that fertilizer prices play a significant role in production costs while also showing that there is potential for it to be subsidized to bring down production costs further. Higher fertilizer consumption, while elevating productivity, is also associated such expensive production, which is mentioned in the statement as well. These results are important for policymakers that hope to balance the economic effects of fertilizer prices and subsidies on the agriculture sector.

4.4 Discussions

Objective 1 of this study was to follow the link between increasing prices of fertilizer with response of crop yield. Fertilizers are an important factor driving agricultural outputs and hence the justification of this goal. Fertilizers are one of the most important inputs in commercial farming, and a farmer will often determine the amount of fertilizer to apply based on the overall cost. Higher fertilizer prices drive up production costs, and may reduce the amount farms are willing, or able, to apply. This can result in adverse impacts on crop production, which is a concern for a country where agricultural productivity is cost-sensitive, such as Pakistan. The researchers wanted to see if higher fertilizer cost results in lower agricultural productivity over time. The hypothesis associated with these objective states that fertilizer prices will negatively relate to crop yield, suggesting that an increase in fertilizer prices will be connected to a decrease in crop yield. This relationship is important for policy-makers and agricultural stakeholders because it may aid in the design of strategies to alleviate the adverse effects of high fertilizer prices, such as policies regarding subsidies and price control.

The second objective dealt with assessing the influence of fertilizer subsidies on the total cost of agricultural production. As the cost of fertilizers are high, fertilizers subsidies are used tool for nearly all the governments across the world to lighten the

burden on farmers. This objective aims at investigating if subsidies can reduce agricultural cost, which in turn will lead farmers to use more fertilizer and thus raising productivity potential. This goal also examines how fertilizer subsidies can counterbalance the increase of fertilizer prices. If fertilizer subsidies have a positive impact, it implies that government interventions help decrease the costs of production, making farming less expensive and sustainable. Subsidies can help increase productivity by reducing fertilizer cost which can in turn make farmers apply more fertilizers and thereby raise yield. It is also important to help achieve sustainability of agricultural practices, particularly in developing countries (e.g. Pakistan) and assessing the effectiveness of these subsidies as they are not without costs either.

The third objective focuses on understanding the association between fertilization and crop yield. While it is known that crop productivity is directly related to fertilizer use, since inputs are important supply nutrients to plants, plants need for them to grow. As long as the fertilizers are applied correctly and in proper amount, using more is always a good chance of increasing the crop yield. Identifying whether more fertilizer leads to more output and, if so, how much is especially important for this goal. The objective of the study was to find out if the increased use of fertilizer is an option for enhancing agricultural productivity in Pakistan. Given the limited economic resources which a farmer has at his disposal, especially in the case of small-scale farmers, this relationship helps in designing policies that can stimulate the efficient use of fertilizers and thereby contribute to food security and economic sustainability.

The objective 4 is to evaluate the effects of fertilizer subsidies and fertilizer prices on agricultural production costs. Fertilizer costs is one of the largest components of total production costs, as it is one of the primary inputs that growers use. Increased prices of fertilizers raise cost of production by farmers thereby reducing their profitability. Fertilizer subsidies, in contrast, can mitigate the effects of these price increases by lowering the actual farmer cost. This goal seeks to compare how the simultaneous shocks to fertilizer prices and subsidy availability affect production costs. The role of policy interventions (such as subsidies) in cushioning the impacts of higher input prices (fertilizers in particular) on the agricultural sector will only be understood if we know more about how these factors interact with each other.

Hypothesis 1 (H_1) results of the Regression Analysis I (Table 3) support this hypothesis, as the price of fertilizer was found to be negatively and significantly related to crop yield. The regression shows that crop yields decrease with the rise of price of fertilizer. Such a results indicates that higher fertilizer prices deter farmers from applying sufficient amounts of fertilizers, which in-turn reduces productivity. These results are statistically significant and are therefore consistent with an important role for fertilizer prices in determining agricultural supply.

Hypothesis 2 results with Regression Analysis II (Table 4), this hypothesis is confirmed in the negative relation and significance of fertilizer subsidy with agricultural production costs. The results show that higher prices for fertilizer subsidies are associated with lower agricultural production costs. This is not surprising because the subsidies decrease the cost paid by farmers for buying fertilizers and thus decrease the overall production cost. The subsidy coefficient passes at the level of 1%, and it emphasize that the government role is important through subsidy policy to make farming less costly and more in sustainable way.

Hypothesis 3 results shows that there is also a positive relationship between fertilizer consumption and crop yield (Hypothesis H2 supported Regression Analysis I (Table 3)). Regression results also show that improved fertilizer consumption leads to enhancement in crop yield. This underscores the importance of fertilizers in the agriculture productivity. Indeed, the statistically significant positive coefficient further provide a confirmation that appropriate fertilizer consumption has a positive impact on better crop yields, which is crucial for enhancing food insecurity and agricultural productivity in Pakistan.

Hypothesis 4 results in Table 4 Regression Analysis II provides relatively strong support for this hypothesis. The results indicate that fertilizer prices are a major factor in raising agricultural production costs and fertilizer subsidies lower production costs. That is, rising prices of fertilizers lead to increases in production costs and subsidies to reduce it. Hence controlling fertilizer prices/management to ensure an economic response from its use is necessary; at the same time the need for an economic incentive to farming practices should also reduce the fiscal burden on farmers through efficient and sustainable use of fertilizers.

Hypothesis 5 results of Regression Analysis I (Table 3) and Regression Analysis II (Table 4) support this hypothesis regarding the total impact that fertilizer prices, subsidies and consumption exerts over agricultural productivity. Because an increase in fertilizer prices reduces the land output of the crop and production cost is directly affected by the cost of fertilizer while an increase in the value of the fertilizer subsidy and fertilizer consumption increases the land output of the crop and its production costs. The results show that it is the relative combinations of fertilizer price management, subsidies, and fertilizer-use efficiency that are fundamentally behind the productivity of agriculture in the region. Such strong associations between these variables underscore the importance of aligning policy incentives for production and cost-effectiveness on different types of croplands.

Finally the result of the regressions testing confirms the hypothesis regarding the effect of/role of fertilizer prices /subsidies and consumption on agricultural productivity and production cost in Pakistan. All of these factors independently and collectively affect the productivity and sustainability of agricultural production in the country.

Hypothesis Number	Hypothesis	Results Summary	Supported (Yes/No)
H1	There is a significant negative relationship between fertilizer prices and crop yield in Pakistan.	Regression results show a significant negative relationship between fertilizer prices and crop yield. As fertilizer prices increase, crop yield decreases.	**Yes**
H2	Higher fertilizer subsidies significantly reduce agricultural production costs in Pakistan.	The regression results show that fertilizer subsidies significantly reduce agricultural production costs. Higher subsidies lead to lower production costs.	**Yes**
H3	Fertilizer consumption has a positive and significant impact on crop yield in Pakistan.	Regression results reveal a positive relationship between fertilizer consumption and crop yield. As consumption increases, crop yield improves.	**Yes**
H4	Fertilizer subsidies and fertilizer prices have a significant impact on agricultural production costs in Pakistan.	Results show that fertilizer prices increase production costs, while subsidies reduce them. Both factors significantly affect production costs.	**Yes**
H5	Fertilizer prices, subsidies, and consumption collectively influence agricultural productivity (crop yield and production costs) in Pakistan.	The combined effects of fertilizer prices, subsidies, and consumption are significant, affecting both crop yield and production costs.	**Yes**

CONCLUSION

Overall, the objective of this study was to investigate fertilizer prices, fertilizer subsidy, fertilizer consumption and agricultural productivity nexus in Pakistan. As a result, the analysis centered on these factors in terms of their effect on crop yield and agricultural production costs in order to offer insight into viable agricultural policy intervention. The signed price elasticity of fertilizer prices on crop yield indicates that the study result firmly supports the hypothesis that higher fertilizer prices exert a sizable negative impact on crop yield as higher prices limit the use of fertilizer at an economic optimum. These results highlight the susceptibility of agricultural output to rising input prices and emphasize the need to insulate fertilizer prices to secure food and farm production.

However, fertilizer subsidies were found to be essential in decreasing the cost of agricultural production, which suggests that government assistance indeed could alleviate the financial difficulty for farmers. Subsidies reduce the effective price of fertilizers thus, apart from making farming cheaper, they also promote increased use of fertilizers, resulting in improved crop yields. These results also highlight the need for well-targeted

subsidy programs to promote agricultural sustainability. Fertilizer consumption is also observed to have positive and significant effect on the yield of crops. This suggests the expected role of fertilizers in activating crop productivity, since high fertilizer use will lead to more agricultural yield. Despite the increased consumption of fertilizer, the production cost associated with fertilizer consumption also rises, implying that appropriate fertilizer application is of crucial importance to the cost-effective operation to maintain sustainable farming practices.

In addition, the review of fertilizer price and subsidies demonstrated their joint effect on the cost of production. An increase in fertilizer costs implies an increase in production costs but there are subsidies to harness that impact and reduce farmers cost burden. Finally, the contribution of these two factors on agricultural output was an additional validation proving that the improvement of some factor affecting productivity could not be accomplished without the inclusion of both pricing and consumption of fertilizers. The results of this research will provide useful information for the agricultural policy in Pakistan. The paper recommends managing fertilizer prices to allow some price inflation, targeted fertilizer subsidies to help the poorest farmers afford fertilizer who otherwise could not, and promoting smart use of fertilizers to maximize agricultural yields while minimizing costs. Policymakers must focus on designing an environment that enables affordable fertilizer availability, particularly to small farmers who are more susceptible to price volatilities. Moreover, they can even boost the subsidy programs to increase the crop yield by reducing the production costs on top of the initiatives.

This shows how fertilizer pricing, subsidies and consumption are interlinked as far as agricultural outcome is concerned. If Pakistan successfully captures these variables, it will help in increasing its agricultural productivity, lowering its costs, and making the farming value chain and economic model more sustainable. Future work should consider regional differences in fertilizer use and reduction policies, and, path dependence in longer term environmental and social effects of fertilizer use intensification.

5.1 Limitations of the Study

Though this study presents valuable evidence regarding the effects of fertilizer prices, subsidies, and consumption on agricultural productivity at the national level in Pakistan, some caveats should be noted:

- **Availability and Quality of Data:** The study was conducted using secondary data from 1990 to 2023. Despite these data being a useful cross-sectional picture, their accuracy and coherence differs and can be poor, especially with the potential for missed or lost data from certain waves. Without more specific or disaggregated data (e.g., regional analyses, crop-specific data, or local fertilizer prices) this could also challenge the generality of the results to other agricultural contexts in Pakistan.
- **Scope of Fertilizer Types:** The study exerts most of its attention on the aggregate role of fertilizer price, subsidy, and use without in-depth consideration of specific fertilizers (such as nitrogen, phosphorus or potassium). Depending on the crop and type of fertilizer applied, fertilizer impacts can vary, potentially giving deeper insights into their effects on yield and costs of production.
- **Control Variables:** Even though the study was adjusted for important variables like fertilizer price, subsidy, and consumption, there could be numerous other areas that affect farming productivity such as climate, soil quality, government policy, and access to technology. All above mentioned factors were not accounted for in the regression models, and its omission might influence the stability of the results.
- **Causality vs. Correlation:** The study performs regression analysis to investigate associations between the variables but does not imply causal relationships. To illustrate, a study may identify an inverse relationship between fertilizer prices and crop yields but cannot prove that fertilizer price increases lead to lower yields, as there may be other factors that are confounding the results.
- **Timing and changes in the economy:** This study examines over thirty years of Pakistan's agricultural transformation, from the 1980s to the present, coinciding with changes in government policy, technology, and markets. Such changes may alter the equilibrium between fertilizer prices, fertilizer subsidies, and agricultural productivity levels. These macroeconomic and policy developments are not fully accounted for in the analysis, which may affect the findings.
- **Other Macroeconomic Influence:** The analysis did not account for global factors such as fluctuations in international prices for fertilizers, trade policies, and geopolitical events (such as the Russia-Ukraine conflict that has impacted global

fertilizer supply chains). On the one hand, the analysis is useful in terms of environmental changes, but on the other hand, due to the external shocks that affect fertilizer prices and subsidies, their conclusions cannot be generalized for other future cases.

- **Behavior and Efficiency of Farmers:** The assumption of the study that fertilizer consumption goes directly hand in hand with production improvement is right; however, it does not account for the fact that use efficiency of fertilizer differs among farmers. Actually, a high use of fertilizer can bring low yields because of the inefficiency of its usage or a bad utilization of it. How best practices are actually designed into fertilizer use would certainly bring an extra dimension into play.
- **Regional Variations:** This analysis does not account for regional differences in fertilizer usage, cropping, or productivity patterns within Pakistan. Because the effectiveness and consumption of fertilizer varies with soil types, climate conditions, and farming practices, usage is highly regional. Depending on the specificity of available data, a more localized approach may provide greater insights.

Notably, the study does not measure the specific mechanism through which fertilizer price, subsidy, and fertilizer consumption affect agricultural productivity, nevertheless, it lays the groundwork for a deeper understanding of how fertilizer price, subsidy, and fertilizer consumption relate to agricultural productivity in the Pakistan economy, which may provide useful insight for agricultural policy recommendations to increase effectiveness in agricultural production and enhance sustainability. These findings can be extended in future by overcoming the limitations identified from this study and writing about regional or crop-specific problems.

5.2 Recommendations

Based on the results and limitations of this study, the following recommendations are suggested to improve fertilizer use, agriculture productivity, and policy making in Pakistan:

1. Launch Targeted Fertilizer Subsidy Schemes

The study shows how fertilizer subsidies affect the cost of production. To alleviate farmers, especially small farmers, the financial burden the government should broaden and better target fertilizer subsidy programmed. Instead of all-encompassing subsidies, which may not always get to the most vulnerable farmers, targeted subsidies depending on farm size, crop type and income classes will ensure that the support is targeted to those who most need it. That may further enhance the potency of the subsidy in promoting fertilizer application while keeping the national production costs from rising.

2. Regulate the Price of Fertilizer

Increased fertilizer prices are known to be detrimental for crop yield. The government should take steps to stabilize the prices of fertilizer lest high prices hurt farmers and agricultural output. This may entail introducing price ceilings, creating buffer stocks of essential fertilizers, or signing no-shock supply agreements. Further, generating competition amongst fertilizer suppliers could be beneficial in reducing prices in the longer term.

3. Fertilizer Use and Management Best Practices

It highlights where a positive relationship is found between fertilizer use and crop yield. But larger use of fertilizers also means higher cost of production. This indicates the needs of improving fertilizer use efficiency to increase production while minimizing the monetary costs. The government and agricultural extension services should organize training sessions to advise farmers on best practices for fertilizer use, including ideal timing, amount, and method of application. Moreover, soil testing and precision farming techniques should be promoted to ensure farmers adopt effective and sustainable fertilizer practices.

4. Prioritize R&D on Fertilizer Use Efficacy

Increase research and development to increase fertilizer efficiency. By improving the efficiency and effectiveness of fertilizer formulations tailored to the particular soil conditions and the crops cultivated in diverse localities of Pakistan, productivity can be substantially increased. Moreover, development in bio-fertilizers or alternative sources of nutrients can minimize dependability on chemical fertilizers leading to better crop yield and environmental sustainability.

5. Strengthen Monitoring and Evaluation Systems

Making fertilizer subsidy and policy effective requires strong monitoring and evaluation system within the government. Periodic evaluations of fertilizer subsidy schemes can help to highlight

where gaps and inefficiencies exist, and where farmers are either missing out, or receiving benefits that were not intended. Timely data on the influence of subsidies on yield and the cost of production will guide policymakers to make appropriate adjustments to ensure that subsidies are targeted at the right place and achieve the desired impact on productivity.

6. Tailor regional and crop needs

The use and efficiency of fertilizer differ by region and crop. So, it is important to have region specific policies that cater to region specific ecosystem which includes soil type, climatic condition, crop needs etc. In this regard, policies should also recognize that high-value crops such as fruits and vegetables, which continue to receive limited attention, require different fertilizer applications than staple crops such as wheat and rice. This approach in giving region-specific suggestions to farmers will not only guide farmers to effectively use fertilizers but will also benefit farmers in cost-effective management of production.

7. Make Credit and Financial Support more Accessible to Farmers

Many farmers cite the prices of the fertilizer itself and the cash outlay to buy it as a major stumbling block. Improvement of credit and finance access for smallholder farmers by the government to enable them to buy more fertilizers Farmers may be reluctant to switch to better practices because of a lack of funds or the risk that their plantings fail; targeting low-interest loans or creating microcredit schemes for fertilizer purchases could thus allow farmers to adopt better practices while not introducing too much financial stress.

8. Promote Responsibly Fertilizer Application

While pointing out how fertilizer consumption helps to improve crop yield, the study found it may also increase production costs. The experts suggest that the new initiative must promote fair and sustainable fertilizer use, focus on environmentally friendly practices like organic fertilizer, INM (Integrated Nutrient Management), and crop rotation, and incorporate climate-resilient and sustainable practices which can also strengthen food security. Soils can thus remain healthy and fertile in the long run with less dependence on synthetic fertilizers and more sustainability environmentally and economically.

9. Diversify Fertilizer Sources

Another major concern is the excessive reliance on a narrow spectrum of imported fertilizers which renders Pakistan susceptible to external market shocks. Pakistan should be looking to diversify its sources of fertilizer either through more domestic production or looking to alternative sources of fertilizers. Long-term availability of fertilizer at a reasonable price on the market can be achieved through public-private partnerships and partnerships with international suppliers.

Well, fertilizer policy needs to be included within a broader agricultural development strategy with a long-term perspective. Hence, comprehensive solution-oriented policy approaches backed by coordination between Ministry of Agriculture, fertilizer producers, research institutions and farmers' association are required to appropriately tackle the issues of fertilizer usage. Thus, the solution must be long-term to move away from dependence on external fertilizer inputs and to increase the sustainability or resilience of agriculture and the wider system itself.

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