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ECO-EFFICIENCY AND DECOUPLING ANALYSIS OF AGRICULTURE SECTOR: A CASE STUDY OF PAKISTAN

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Abstract

According to this study, the agriculture industry of Pakistan's eco-efficiency trend and decoupling status between 2001 and 2018 will be examined. As a result, the agricultural sector's impact on resources and the environment has been evaluated. Cropped area, fertilizer use, pesticide imports, and tractor output are proxies for resource use. Agricultural emissions are used as an environmental proxy. Farm output and emissions were estimated based on the World Bank and FAO data. However, there are some other indicators in the Pakistan Economic Survey 2019-20. Therefore, eco-efficiency and the Tapio Decoupling Elasticity Index, two novel approaches, were used in the analysis. Across the board, the results of the eco-efficiency studies show a rise in eco-efficiency. Despite this, the results of the decoupling research show that the indicators used in the study reveal scattered decoupling states throughout separate periods. Signs of severe decoupling, expensive negative decoupling, and weak decoupling are seen regularly. Increasing Pakistan's agricultural eco-efficiency and decoupling may be possible via new technology, modern farming practices, and sound resource management. However, farmers' education and awareness campaigns might be crucial to get the most out of available resources.

Keywords: *Eco-efficiency, Decoupling analysis, Tapio Model*

1. INTRODUCTION:

To feed an ever-increasing global population, agriculture must reduce its environmental effect and conserve natural resources. Agriculture may cause water, soil, and air pollution. Optimal farming practices may assist the environment while lowering soil and flood risks.

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Pakistan, like many developing nations, relies heavily on agriculture. Agriculture contributes significantly to Pakistan's GDP. According to Pakistan's economic forecast, agriculture gained 2.67 per cent in 2019-20, up from 0.58 per cent in 2018. This industry contributes 19.3% of Pakistan's GDP in 2019-20. It generates GDP and employs 35.89% of the workforce (PBS Labor force survey 2017-18). Besides these benefits, this sector provides most people with food and shelter (mostly living in rural areas). In addition, it benefits from being a major exporter and supplier of raw commodities. However, it does it at the expense of resources and the environment. Between 2001 and 2017, the rise was 6.69 per cent, from 57,632 to 159083 tonnes. Productivity has increased owing to higher harvests, favourable government policies, and access to certified seeds, agricultural loans, fertilizers, and pesticides (Pakistan Economic Survey, 2020). Farmland rose by 5.63 per cent and tractor production land by 0.39 per cent between 2001 and 2017. Fertilizer and pesticide usage grew by 3.44 per cent and 5.88 per cent, respectively, from 2,966,000 tonnes in 2001 to 4,763,000 tonnes in 2017-18. It went from 100,819 gigagrams in 2001 to 167,626 gigagrams in 2017-18. The population of Pakistan is expanding at a 2.4% yearly rate.

Rising demand for agricultural products reflects the nation's growing population. This would enhance agricultural activity and hence resource consumption. As we all know, the world's resources are decreasing. Agriculture, for example, may have substantial environmental repercussions, making sustainability difficult. Resources are vital for current and future populations, according to the 2011 UNEP IRP Report. Land, water, energy, and minerals from the soil are natural resources. Global attempts to promote economic development have boosted their usage. Many of these resources are now scarce, and many more will be in the future. No matter how these resources are used, they have detrimental environmental repercussions. Intentional alterations to natural systems include a land cover and resource extraction. Inadvertent ecological impacts include air and water pollution. Decoupling is vital for sustainability since it considers both resource quantity and environmental effect. Among the consequences are disruptions of critical ecological services.

Any nation is seeking to strengthen its agricultural business, regardless of its level of development. The operations' scale promotes resource utilization. Increasing economic production improves people's lives but requires resource utilization. So (e.g. Land utilization, water consumption, Fertilizers, pesticides, capital equipment etc.). These resources impair an economy's socioeconomic status when utilized. Using natural resources for profit pollutes the

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air (e.g. agricultural-related emissions etc.). Unresolved aid and environmental issues may hinder future green economies (e.g. sustainable development). Also, excessive resource use and environmental destruction will make future generations' requirements challenging to meet. Two competing schools of thought have extensively studied these activities' economic and ecological impacts. Resources are used more efficiently, resulting in the waste of harmful substances to the environment and halting development—a positive outlook. The gloomy school of thinking is avoided, many believe, by improving and deploying green technologies.

Achieving this balance is difficult due to a lack of resources and a severe environmental effect.

Eco-efficiency and decoupling are efficient in reducing resource use and environmental impact. So eco-efficiency has piqued the attention of sustainable development experts. Eco-efficiency methods currently play a vital role in reducing natural resource use and negative ecological consequences while preserving or increasing economic production. This technique's attractiveness may now be applied at numerous economic levels, including sectoral, regional, and macroeconomic. Researchers have used this technique at the sectoral, regional, and national levels (J.Van Caneghem et al. 2010, Xing Zhou et al. 2017, Yusen Lou et al. 2017). This paradoxical phenomenon is known as the Jevons' Paradox by some (Frye-Levine, 2012). A new decoupling notion is established to examine the linkages between environmental and economic benefits. Since its conception, decoupling theory has been adopted by many academic institutions and organizations, resulting in an abundance of literature. Wang et al. 2015, Zhang 2000, Yin et al. (2014) (OECD, 2002). Environment, resource use, and economic activity output are all decoupled. The EKC hypothesis, factor 5, and factor 4 are studied by Zhang et al. Zhang et al. A general understanding of the relative or absolute decoupling between economic development and environmental dynamics led to the EKC concept (G.M. Grossman et al. 1995, Ali; Khanand & ul Mustafa. 2022). Resources are decoupled in factors 4 and 5. (Aoki-Suzuki, 2013). Academics are currently studying water decoupling. M.Y. Recaldeet al. (2014) and P. Kalimeris (2014) evaluated other environmental contaminants (e.g. SO2, solid waste, wastewater, etc.) Amann et al. 2013 and Jorgenson et al. Figure 1 depicts the ecological, economic, and social effects. Notable decoupling of resources and impact.

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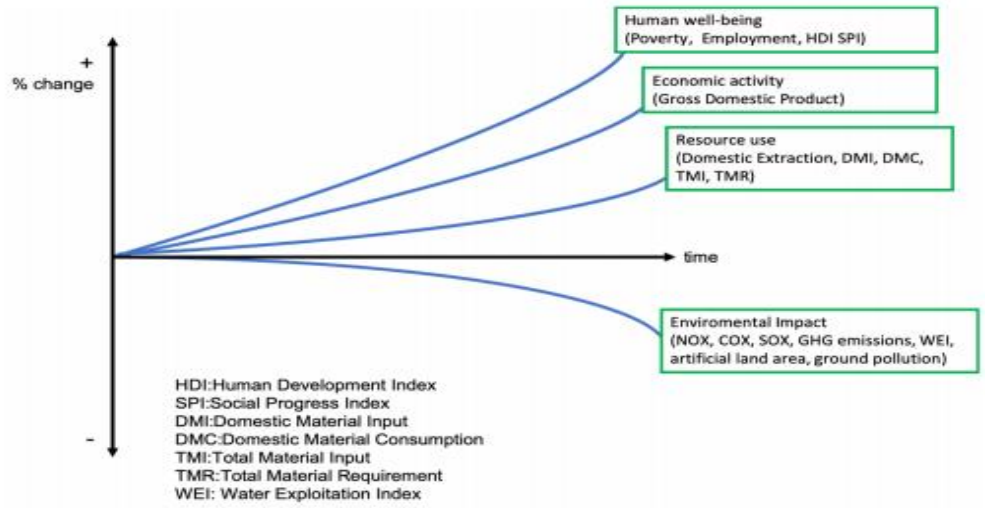
Figure 1: This figure is taken by (UNEP, 2011).



Scholars have also considered both absolute and relative decoupling in their research (Bithas K. and Kalimeris P., 2014). Absolute decoupling occurs when drops in resource consumption outstrip gains in economic output, while relative decoupling happens when resource consumption rises exceed economic production increases.

Before decoupling, the Environment Kuznets model was commonly employed. According to this theory, environmental forces rise initially and fall as money increases in value. As a result, economic growth and ecological quality should have an inverted U-shape connection, with relative decoupling indications appearing over the long run. Confirmation of this theory may be found in studies by Munir (2014), Alam (2010), Sher Khan (2016, 2019), Awan, Abro, & ul Mustafa. (2021), Ali et al. (2016), Hye, ul Mustafa, & Mahmood (2010) and Khan (2019). Some scientists believe that EKC is important in decoupling, whereas others disagree. The Kuznets curve hypothesis was not shown to be true in this investigation (Stern, 2004). Although the Kuznets curve theory may be used in local studies with acceptable results, it cannot be applied to global research, according to Borghesi S. et al. (2003). Several critics have argued that it is unnecessary to develop sophisticated techniques and measurements to investigate the relationship between economic growth and environmental impact. For example, OECD (2002, 2005) and Tapio (2005a) introduced the decoupling factor and elasticity index, respectively, in 2005a These decoupling indicators are often used by environmental scientists. The first OECD indicator used an intensity change rate transformation (OECD, 2002). Despite the ease with which this index item may be analyzed, it does not give a reliable economic or environmental development measure. Tapio elasticity

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was calculated by considering elasticity and emission routes and ecological change. Decoupling signs are organized into eight separate states, each exhibiting a particular decoupling relationship.

The decoupling theory has become a contentious issue among scientists in recent years. Both proponents and opponents of the idea exist. Others doubted the theory's ability to analyze economic growth, environmental impact, and energy use. It was shown that decoupling affluence growth from energy consumption had a lesser effect than the current energy use and affluence gauges used in this article, according to Ward, J.D. et al. (2016). According to model forecasts and historical facts, as Ward J.D. et al. (2016) determined, economic growth and energy usage are closely connected. The results predicted a decline in economic growth from fossil fuel-intensive carbon dioxide emissions.

According to the previous study given here, decoupling in today's economy may be successfully implemented. Analysis of determinants of economic efficiency in Flemish sectors by J.Van Caneghem et al. (2010) found that Flemish industries are decoupling from economic growth in absolute and relative terms. D. Freitas L.C. et al. set out to examine the decoupling, decomposition, and decoupling in Brazil. The energy structure and carbon intensity decreased CO2 emissions between 2004 and 2009. Furthermore, in 2009, they claimed a complete decoupling. Ex-President Obama's (2017) book, The Irreversible Momentum of Clean Energy, emphasized the need of decoupling energy sector emissions from economic growth. Former U.S. President Barack Obama claimed that during his administration (2008-2015), energy sector emissions decreased by 9.5% while GDP expanded by over 10%. For further information, see Deutch (2017).

Pakistan has the fifth largest population globally, which necessitates a significant need for agricultural products. However, agricultural production has a detrimental impact on the environment and uses many natural resources. The agriculture industry has a particularly damaging effect on resource efficiency; thus, finding ways to reduce this impact. This technique would help future generations save resources while still serving the fundamental demands of the present age. In the long run, this sets the scene for growth. To find a solution to this problem, this study will use eco-efficiency and decoupling theory.

As a result, the study's goal is to examine Pakistan's economy's agricultural sector's resource consumption and environmental effect on the country's eco-efficiency trend. In addition, this

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study examines the potential of eco-efficiency and decoupling strategies in Pakistan. In addition, the study's goal is to make policy suggestions based on empirical analysis and the study's limitations, utilizing the approach described above.

Two publications (Khan, S. & Majeed, M.T., 2019) and (Yousuf, Z.; Nassani, A; Bushra, U., 2020) has been published in Pakistan on eco-efficiency and decoupling methodologies in the literature. Khan, S. and Majeed, M.T. (2019) conducted a study on eco-efficiency and the decoupling of environmental impact from economic growth between 1990 and 2014. Decoupling environmental impact from resource consumption was explored by (Khan, S.) (Yousuf, Z.; Nassani, A. & Bushra, U., 2020). According to our findings, many countries, including China, use similar strategies at the regional and sectoral levels. Because of this, comparable approaches are being used in Pakistan to evaluate the environmental efficiency and decoupling status of the country's agriculture industry.

The Research Questions

The following questions need to be answered to meet the study's goal.

1. In Pakistan's agricultural industry, what is the current eco-efficiency trend?
2. Agricultural decoupling in Pakistan: where are we now?
3. Decoupling and eco-efficiency approaches have a bright future ahead of them.
4. How may Pakistan's agricultural industry be made more environmentally efficient and decoupled?

The following is a breakdown of the remaining research initiatives. An in-depth review of an existing global and national literature on the use of eco-efficiency and decoupling concepts may be found in Section 2. There's also a tiny quantity of information about Pakistan's agriculture industry. Section 3 explains the study's theoretical and empirical techniques in great depth. For this study, the variables used to choose them are also defined and shown in numbers. Tapio's Decoupling Index and Eco-efficiency approach were used in the study's results and analysis in Section 4. (described in Section 3). Finally, after a thorough examination of the data and a literature review, the conclusions and policy recommendations presented in Section 5 come to a close.

LITERATURE REVIEW

Since people worldwide are becoming more concerned about climate change, economic activity's influence on the environment has come back into attention. High levels of economic

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output led to a more significant depletion of natural resources and, therefore, environmental harm. The idea is that sustainable development may be achieved by isolating economic activity from environmental and resource implications. What is the link between economic activity, resource consumption, and environmental strain on Pakistan's agricultural sector? The Tapio decoupling Index and eco-efficiency have been intensively examined internationally and nationally.

Efficient environmental management may be achieved by reducing environmental impact and resource consumption while increasing the firm's value, according to Schaltegger and Sturm in 1989. This issue was examined further in WBCDS's essay Changing Course (Schmidheiny 1992). At the same time as meeting human requirements at competitive costs, eco-efficiency is accomplished when the environmental impact and resource intensity are reduced to an amount that is at least following Earth's estimated carrying capacity. World Business Council for Sustainable Development (WBCSD). During the European Environmental Agency's fifth anniversary in 1998, the concepts of eco-efficiency and resource productivity were explained, and indicators for eco-efficiency and resource productivity were discussed, along with some experiences in applying these ideas. An examination of how well and how difficult it would be for the EEA to help establish and promote appropriate indicators and best practices was also conducted. Twenty-nine years spanning 1980-2008 was examined by Camarero et al. (2013) using secondary time series data to investigate the convergence of eco-efficiency in a group of 22 OECD member countries. A proxy has been used for CO2, SO2, and NO2. As a result of data envelopment analysis, Phillips and Sul Econometrica, and Phillips and Sul Econometrica, eco-efficiency have increased over time, except for NO2, with Switzerland demonstrating the most significant levels of eco-efficiency. Although Turkey, Hungary, the United States and Canada were among the most polluting countries in this study. Using Rattanapan, C. and colleagues (2012), eco-efficiency indicators for glove rubber goods were developed utilizing the eco-efficiency theory and material flow analysis.

Economic and environmental indicators may be seen in this study's results. According to the research results, eco-efficiency indicators may be used to identify more efficient techniques to increase productivity and recycling while lowering energy and material intensity. Research on eco-efficiency conducted by Lahouel B.B. 2015 on 17 French enterprises between 2011 and 2012 decomposed eco-efficiency into resource and ecological efficiency. According to data development analysis, only three of the 17 organizations evaluated were found to be eco-

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efficient, and environmental efficiency is the key factor of eco-efficiency. Furthermore, when a corporation grows, its eco-efficiency score tends to decline. To gauge Kymenlaakso's eco-efficiency on a regional scale, Seppala J et al. 2005 worked with other researchers to generate economic and environmental indicators. They developed and categorized environmental impact, total impact, and pressure indicators based on total material input, direct material input, and the region's total material requirement. However, they started with the region's most significant industries' GDP, output, and absolute value-added. Various environmental indicators are also discussed, as are their merits and downsides. In Japan, environmental management accounting and eco-efficiency were studied by Burritt, R.L. (2006) and other scholars.

According to a global literature study, decoupling the economy is doable and practicable, although additional research may be necessary (Nicholas 2014, Jackson 2015 and Kallis 2011). By using strategies like decoupling and eco-efficiency, policymakers may better understand sustainability and, as a result, better economic policies. A national and international literature review shows that the decoupling approach has been widely used to promote sustainable development in China and the West. However, according to a study, there are just a few examples of decoupling techniques being employed in Pakistan's national literature (e.g., Khan and Majeed 2019). Previous Pakistani research focused on just one CO2 indicator and one aspect of sustainability concerning environmental damages and economic gains. Based on the literature described above, we may conclude that little effort has been made in Pakistan on decoupling and eco-efficiency. More research is needed into decoupling economic activity from resource consumption and environmental impact using decoupling theory and eco-efficiency theory. In addition, regional and sectoral decoupling and eco-efficiency may be explored utilizing these concepts. Consequently, in an attempt to bridge this knowledge gap, we've concentrated our study on agriculture. Researchers and environmental policymakers alike will gain from this study's analysis of resource efficiency and decoupling elasticity in the ecological study region and its exploration and flagging of prospective future research subjects.

For example, Khan and Majeed (2019), who analyzed environmental effects and Pakistan's GDP using time series data from 1990 to 2004, observed four unique decoupling statuses. The most prominent of which was a costly negative decoupling. He found that although energy intensity and emission intensity favour decoupling, energy structure and GDP

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constrain it. He found this. He concluded that decoupling is beneficial to both parties. As a result, there is no decoupling effect on the population. In addition, the data reveal that a mix of variables, such as population, GDP, and the design of a country's energy infrastructure, lead-carbon emissions to be produced. The decoupling index analyzed Pakistan's UNSD targets by Yousuf et al. (2020). The Tapio decoupling index examined the relationship between water, food, energy, and fossil-carbon emissions in this study. They used data from 1970 to 2016 to compile their analysis. Several empirical investigations have shown the connection between fossil-carbon-based greenhouse gas emissions and water, food, and energy supplies. As Anwar et al. (2015) point out, Pakistan's agriculture industry affects the country's GDP and other economic indicators. They discovered an agricultural sector that had a positive association with GDP. According to their recommendations, Pakistan's agriculture and GDP should be supported by a well-thought-out plan (GDP).

METHODOLOGY

This section will talk about the research techniques and conceptual Framework and the variables and their antecedents. Analytical data gleaned from secondary sources are employed in this study, which operates the quantitative research method. Quantitative research is used as a result of this. It's easy to compare and reproduce outcomes in quantitative research, 2). The value of a topic may be assessed objectively, 3). the observer is a distinct individual from what is observed (see also paragraphs 4). Qualitative approaches tend to be subjective, so quantitative methods are favoured for assessing the validity and reliability of research, 5). Quantifying a description is relatively simple (A Tehrani et al., 2015). This portion of the study explains the empirical models for Eco-efficiency and the Tapio Decoupling Elasticity Index.

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Eco-efficiency Technique: The efficiency with which economic resources are used in economic activity, as assessed by eco-efficiency, is the major driving factor behind sustainable development. This may be seen in a variety of ways. For example, Figge F. et al. profit .'s or output is compared to the damage or hardship they have caused (2014). The World Business Council for Sustainable Development (WBCSD) adopted a new direction when it was created in 1992. Economical and environmentally friendly, efficient eco-products and services [Schmidheiny S. (1992), Carrillo-Hermosilla el and coworkers, 2009] are what we call "green." ability to create more goods and services with less environmental impact in a particular location or sector (Camarero, M. el et. 2012). Commonly used methods of measuring this include the ratio of environmental inputs (such as arable land and Fertilizer) to useable outcomes (such as emissions from agricultural operations). This empirical inquiry uses the following equation to define eco-efficiency:

$$\text{Eco} - \text{efficiency} = \frac{Agriculture\ Output}{Environmental\ performance}$$

The agricultural production of Pakistan is measured. On the other hand, environmental performance assesses the burden of ecological inputs and their negative impact on the environment. These represent ecological inputs, including fertilizer use, pesticide imports, and tractor manufacture. These indicators are qualitative and quantitative. We will not include qualitative aspects of sustainable development like social and cultural indicators since this research is only focused on quantitative measures like natural resource consumption indicators (such as land-use change, fossil fuel energy use, renewable energy use, and so on). Two sustainable development indicators were chosen based on data quality and availability, measurability, and policy relevance: resource efficiency and environmental efficiency. Resource efficiency is improved by using less Fertilizer, pesticides, and land. The ecological efficiency calculation includes farm CO2 emissions. It is easy for policymakers and the general public to understand the environmental strains on Pakistan's agriculture business.

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Decoupling technique analysis: The decoupling technique is the second empirical analysis method employed in this paper. Environmental load and environmental impact were the two methodologies formerly used by academics to quantify the decoupling between agricultural production and environmental strain. Models based on the decoupling factor, created by the Organization for Economic Co-operation and Development (OECD), and the Tapio Elasticity Index, are available (TEI). This percentage change is calculated by dividing the percentage change into environmental factors by the percentage change in economic output variables. Many others, including P. Tapio (2005, 2007). How does it work mathematically?

$$\alpha = \frac{\%\Delta R}{\%\Delta AP} = \frac{\frac{Ri}{Ri-1} - 1}{\frac{APi}{APi-1} - 1}$$

In this context, the elastic decoupling index is referred to as. Based on agricultural, environmental load (Land utilized for crop production, fertilizer intake, pesticide import and equipment production (e.g. tractor)) and adverse environmental impact (farm-related emissions). As a unit of measurement, a year is used in this study. Ri and Ri 1 indicate the ecological implications of years I and I-1. The A.P. growth rate is the percentage change in agricultural production between the start and end of the period. The Agriculture Production Index (API) and Agriculture Production Index (API 1) are listed here. Table 1 shows the eight different states of decoupling based on the value, as illustrated in the figure. When it is between 8 and 12, a phenomenon called coupling may be seen. Due to the "coupling effect" (both burden and harmful impact), there will be a more vital link between environmental factors and crop yields. Expanding (in which agricultural output and environmental influence increase) and recessive coupling are subcategories of this link (where agriculture production and environmental effects decrease).

There are three forms of decoupling in the human body: strong decoupling, mild decoupling, and receding. If the Tapio elasticity value () is less than 0, agricultural production, resource consumption, and environmental impact are all decoupled to an excessive degree. As agricultural output rises, resource consumption and ecological impact decrease, and the Tapio elasticity value () range from zero to 0.8 (i.e. zero to eight), moderate decoupling will be seen. If the Tapio elasticity value () is greater than or equal to 1.2, the recessive decoupling will be seen. Negative decoupling, like positive decoupling, comes in various strengths and costs. As agricultural production and environmental impact (resource consumption burden

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and adverse environmental impact) increase, the enlarged negative decoupling will be noticed if the Tapio elasticity () is more significant than 1.2. When the Tapio elasticity value () is less than 0, positive decoupling occurs when agricultural production increases while environmental impact (consumption of resources and damage to the environment) decreases. Weak Negative Decoupling will be detected if the elasticity value () is less than zero and agricultural production (resource consumption burdens and unfavourable environmental impacts) decreases. Studying the different degrees of decoupling is made more accessible by using the conceptual Framework shown in Figure 2.

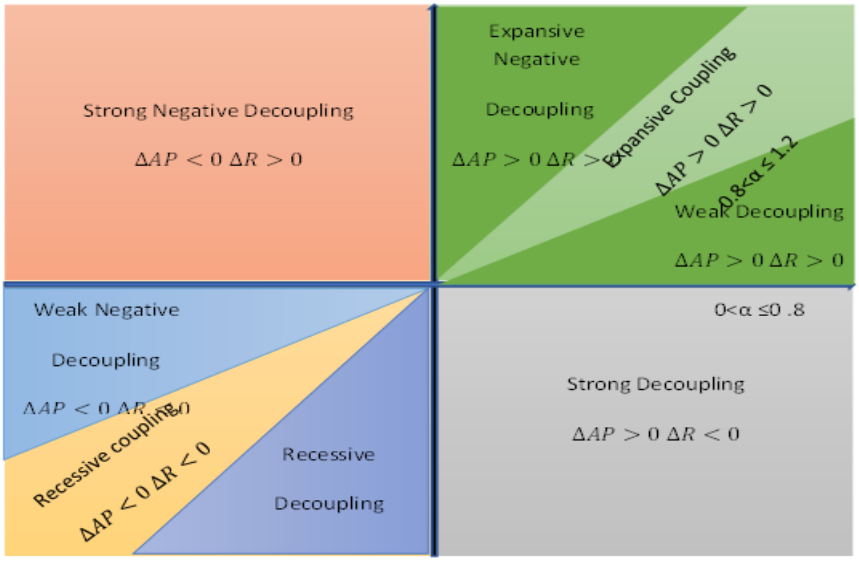

Figure 2: This picture is based on the original Framework of (Tapio, 2005).

Data Sources and variables

As previously mentioned, the years 2001 to 2018 comprise the scope of our investigation. As of the year 2000, the base year is used. Information about each variable may be found in Table 1, which lists the variables' symbols, units of measurement, and data sources.

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Table 1: **Variable description and data source**

Variable	Symbol	Unit	Data Source
Agriculture Production	AP	Metric Tons	World Bank Development Indicators
Cropped Land	CL	Hectares	Pakistan Economic Survey 2019-20
Fertilizers	F	N/Tonnes	Pakistan Economic Survey 2019-20
Pesticide	P	Tonnes	Pakistan Economic Survey 2019-20
Tracter Productions	TP	Nos	Pakistan Economic Survey 2019-20
Emissions (CO2 Eq)	E	Gigogram	FAO Organization

Source: Prepared by Author

RESULT AND DISCUSSIONS

Agricultural production climbed by 6.69 per cent year on average from 57,632 metric tonnes in 2001 to 159083 metric tonnes in 2017-18. All of these factors lead to an increase in the price of agricultural products: low-cost loans from banks, low-cost Fertilizers and pesticides, and favourable government laws (Pakistan Economic Survey 2017-18). Growing crops required a yearly rise in land usage of 0.39 per cent, whereas tractor production required an annual increase in land use of 5.63%, rising from 32,553 hectares in 2001 to 52,551 hectares in 2017-18. More than 4.7 million metric tonnes of Fertilizer and pesticides were utilized in 2017-18, with an average annual growth rate of 3.44% and 5.88% for these products, respectively An average of 3.05 per cent per year was added to agricultural emissions between 2001 and 2017-18 from 100,819 kilograms to 167,626. Annual agricultural development is shown in Figure 3 in connection to several resource consumption and environmental strain indicators based on relative size (such as cultivated area, fertilizer Offtakes and pesticides use, and tractor production and agriculture-related emissions). Starting with the base year of 2001, each variable's value is multiplied by a hundred so that the overall figure includes signals of different units or magnitudes. From 2001 to 2018, the eco-efficiency and decoupling of Pakistani agriculture from resource usage and environmental impact were examined using the technique provided in Section 3. What we learned may be found here.

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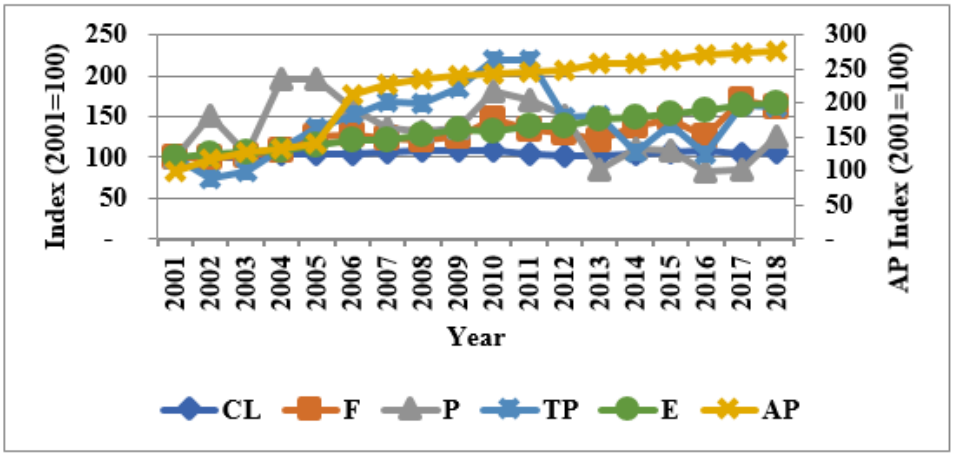
Figure 3: Trend Analysis of different indicators over 2001-2018.



Source: Prepared by Author

Eco-efficiency Result: Table 2 displays data on eco-efficiency indicators. Figure 4 shows that Pakistan's agricultural business is becoming more environmentally friendly, yet tractor production connected to resource use has grown significantly. This study showed that ploughing and harvesting crops utilizing tractor technology are more efficient than using conventional methods.

Table 2: Eco-efficiency results 2001-2018.

Year	CL[a]	F[b]	P[c]	TP[d]	E[e]
2001	0.001	0.004	0.587	0.384	0.125
2002	0.003	0.02	1.813	2.371	0.572
2003	0.003	0.022	3.011	2.471	0.645
2004	0.003	0.023	1.764	2.026	0.681
2005	0.003	0.021	1.844	1.738	0.696
2006	0.003	0.021	2.374	1.624	0.704
2007	0.005	0.033	4.188	2.238	1.004
2008	0.005	0.036	4.677	2.427	1.056
2009	0.006	0.036	4.685	2.231	1.048
2010	0.006	0.032	3.613	1.929	1.02
2011	0.006	0.036	3.872	1.958	1.049
2012	0.006	0.037	4.414	2.95	1.019
2013	0.006	0.039	7.987	2.923	1.024
2014	0.006	0.036	6.291	4.291	1.008
2015	0.006	0.034	6.408	3.236	0.986
2016	0.006	0.041	8.695	4.462	0.983
2017	0.007	0.031	8.648	2.924	0.989
2018	0.007	0.033	5.947	2.996	0.961

Source: Calculated by Author

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Eco-efficiency analysis – Resources.

Cropped Land (CL): The CL eco-efficiency is the amount of agricultural product produced per unit of cultivated land. At a growth rate of 27 per cent per year, the Eco-efficiency of cropped land (CL) has improved from 0.01 to 0.007 metric tonnes per hector. The above reasons contribute to this increase in the agricultural output: technology and new equipment, supportive government policies, higher water availability, better supply of certified seeds, pesticides, and farm finance (Pakistan Agriculture Survey 2017-18).

Together with readily available water and high-quality seeds, Fertilizer is critical to increasing agricultural productivity. Using fertilizer efficacy as a yardstick, the amount of crop produced per tonne of Fertilizer may be calculated for a given farm operation. As shown in Figure 4, the Eco-efficiency of Fertilizer has increased from 0.004 to 0.033 metric tonnes per tonne on average year over the study period. Throughout the study period, fertilizer consumption increased by an average of 3.44 per cent every year. Government subsidies, such as those for natural gas subsidies used to manufacture fertilizer production feed, LNG subsidies used to generate urea at Fatimafert and Agritech, and support for urea imports, have increased the availability of Fertilizer and increased the demand for that Fertilizer. (Pakistan Agriculture Survey 2017-18).

A particular quantity of agricultural output may be reaped from one tonne of pesticide. Pesticide's Eco-efficiency has increased by an average of 25 per cent each year during the study period from 0.587 to 5.947 metric tonnes per tonne. As a result, imports of pesticides grew at an annual average rate of 5.88 per cent over the study period. Because of this, it is feasible to enhance agricultural productivity while decreasing dangerous Persistent Organic Pollutants (POPs) to the environment and human health.

Tractor Production: With the addition of a single Tractor to the manufacturing line, how much extra agricultural output would have been generated? It is seen from the figure-4 that the Eco-efficiency of tractor manufacturing has observed an annual average increase rate of 35 per cent over the research period from 0.384 to 2.996 metric tonne per tractor. The average yearly growth rate of tractor production over the research period was 5.63 per cent. Tractor availability and other farm-related equipment play a crucial role in enhancing the output capacity of the agriculture sector (Pakistan Agriculture Survey 2017-18). (Pakistan Agriculture Survey 2017-18).

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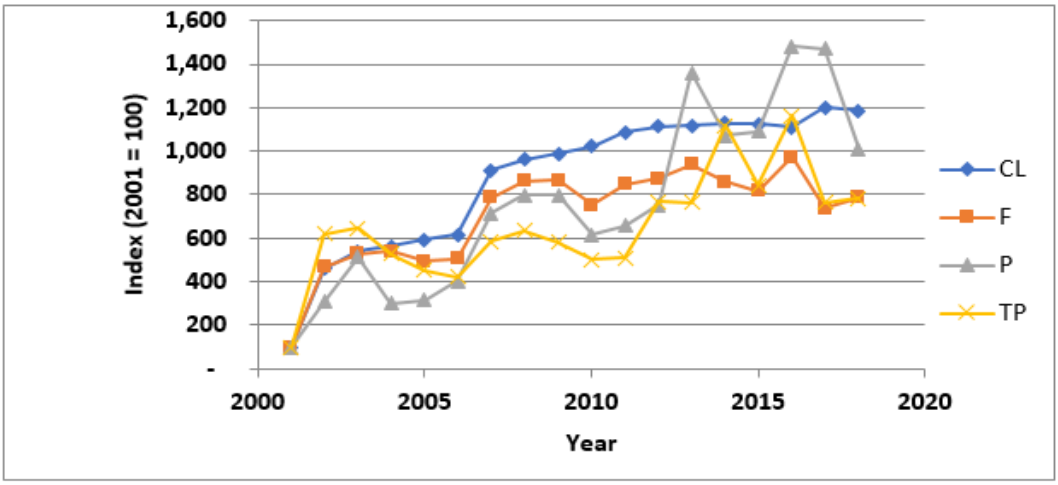

Source: Prepared by Author

Figure 4: Eco-efficiency Trend - Resources

Eco-efficiency analysis – Environmental Impact.

Agricultural Emissions (E): This calculator estimates how much food may be produced in the agriculture sector for every gigajoule of carbon dioxide emitted. As shown in figure 5, emissions Eco-efficiency increased from 0.125 to 0.91 metric tonnes per kilogram at a 25 per cent annual average growth rate. Emissions increased by an average of 3.05 per cent every year over the study period.

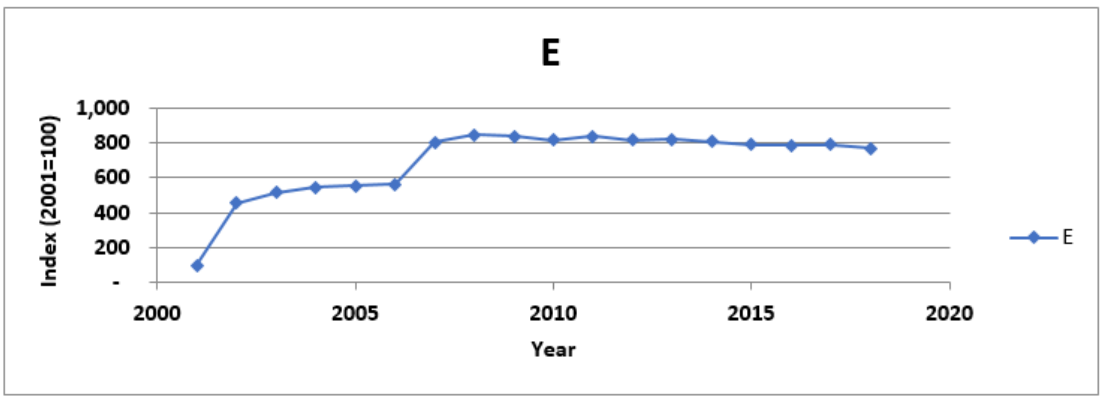

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Figure 5: Eco-efficiency Trend – Environmental Impact.

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Decoupling Results: There is no longer a straight correlation between the quantity of food Pakistan produces and the number of resources it uses, as seen in Table 3. Nevertheless, the results are enlightening, as shown in the following discussion. A wide range of unique decoupling conditions has been discovered across all measurements.

Table 3: Decoupling Status Results

Year	CL	F	P	TP	E
2001	SD	END	SD	SD	WD
2002	WD	SD	END	SD	WD
2003	SD	EC	SD	END	WD
2004	EC	END	END	END	WD
2005	SD	END	WD	END	WD
2006	WD	EC	SD	EC	WD
2007	WD	WD	SD	END	WD
2008	WD	SD	SD	SD	EC
2009	WD	WD	END	END	END
2010	SD	SND	END	END	SD
2011	SD	SD	SD	SD	END
2012	SD	SD	SD	SD	WD
2013	WD	SD	SD	EC	END
2014	END	END	END	SD	END
2015	WD	END	SD	END	EC
2016	EC	SD	SD	SD	EC
2017	SD	END	END	END	END
2018	END	SD	END	SD	END

Source: Prepared by Author

Resource Decoupling Results

Cropped Land: Column 1 of Table 3 shows a slight but substantial decoupling between cropped land and agricultural output for the vast majority of the years included in this analysis. Eighteen distinct disconnected states have occurred as a result: seven strong (seven weak), two costly (two expensive), and two expensive negatives. Significant decoupling was observed, indicating that cropland and agricultural productivity may be separated. The economy has been decoupled from the agriculture sector due to a rise in agricultural productivity. Cropland utilization has reduced, but agricultural output has grown. Farmland is a valuable resource, and the costly coupling in 2004 serves as a cautionary tale. The decoupling conditions showed the underutilization of farmland from 2014 to 2018. For example, insecticides, fertilizers and tractor manufacturing are shown in Figure 6 to have grown at different rates. Agricultural output has expanded by 361 per cent per year since 2004, while the growth rate of cultivated land has decreased from 4.99 per cent per year to 1.91 per cent per year since 2018, as indicated in Figure 6 of the study.

Fertilizer: There was a substantial and expensive decoupling effect between fertilizer use and farm output in Table 3's second column across the study period. Out of 18 states, decoupling has happened in seven powerful and six expensive states. In 2003 and 2006, the

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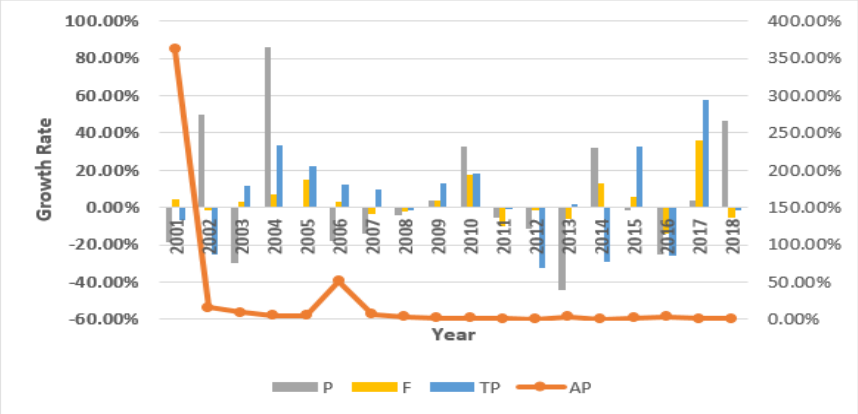
high cost of coupling was a consequence of fertilizer misuse. According to the statistics, fertilizer consumption decreased more than agricultural production during the poor decoupling periods of 2007 and 2009. Throughout the period under consideration, fluctuations in fertilizer consumption peaked in 2017 at 10% and then declined to -2.44 per cent.

Pesticides: Throughout the bulk of the study period, the decoupling effects of pesticide imports and agricultural production were extensive and costly, as seen in the third column of Table 3. It has gone through 10 strong decoupling states and seven expensive negative decoupling states out of a total of 18 stages of decoupling. There was still a weak decoupling in 2005, even though pesticide imports were down more than agricultural production was in that year. However, the yearly growth rate was 36.25 per cent in 2017 and a -5.50 per cent rate in 2018, respectively, for pesticide imports.

Tractor Production: The tractor production-to-productivity decoupling was significant and costly over most of the study period, as seen in Table 3's fourth column. From a total of 18, there have been eight severe and eight expensive negative decoupling states. According to the Expensive coupling situation between 2006 and 2013, there was an excess of tractors manufactured compared to the amount of agricultural production generated. As a result, only 1.77 per cent growth in tractors was recorded during the study period, which peaked in 2017 at 58.19%.



Source: Prepared by Author

Figure 6: Growth Rate of Resources 2001-2018.

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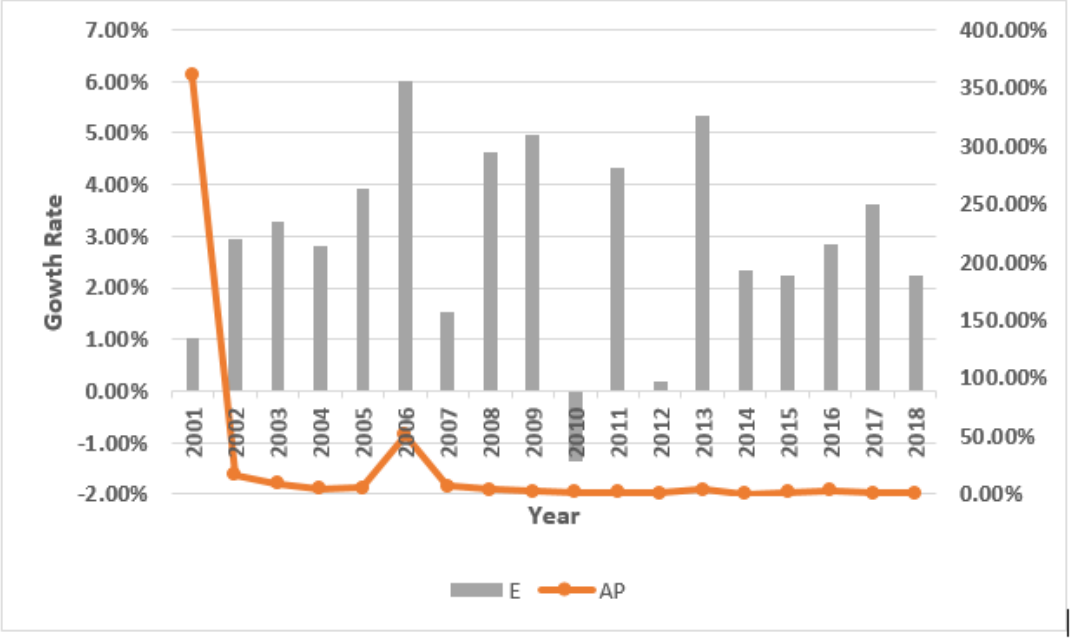
Environmental Decoupling Results

Agriculture emissions: The fifth column of table-3 shows that the decoupling effects of agricultural emissions and production were moderate and costly for the bulk of the study period. Six weak decoupling states and six expensive negative decoupling states have occurred out of the total of 18 conceivable transitions. Agriculture's impact on emissions was more significant in 2008, 2015, and 2016 than agriculture's impact on production. There was a wide range in the rise of emissions between 2006 and 2018, with a peak in 2006 and a low in 2018.



Source: Prepared by Author

Figure 7: Growth Rate of Environmental Related Impact.

RECOMMENDATION, LIMITATION, FUTURE SCOPE AND CONCLUSIONS

Tapio decoupling index and eco-efficiency According to this study conducted on Pakistani agriculture, I recommend the following method for increasing agricultural efficiency in resource use and emissions. When it comes to implementing policy, the priority should be improving resource efficiency and reducing the environmental impact of those resources used in agriculture. An essential role for technology in agriculture is to increase the efficiency of resources and reduce their impact on the environment. Unfortunately, there isn't much discussion of the agricultural output-increasing technology now in use throughout the globe to show how they might help achieve the sustainable agricultural production aim—starting

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with organic farming, which uses environmentally friendly production methods. Agriculture takes place on farmland of excellent grade.

A significant amount of fossil-fuel-based fertilizers and pesticides are spared as a result. In theory, urban farming might reduce the demand for farmland and minimize transportation costs and fossil fuels to convey agricultural commodities from rural to urban settings. Reduces the need for heavy machinery by using zero tillage techniques. A wide range of technologies may increase agricultural production. For example, wind and solar electricity should power agricultural machinery rather than fossil fuels. To put it another way, fossil fuels, which produce more significant greenhouse gas emissions, are reduced. Not to mention, they're cheaper than traditional energy sources like coal and oil.

The results of scientific research may be applied to the whole agricultural process in various ways. Before making any decisions on agricultural policy, it's essential to identify the factors that influence productivity, such as equipment, technological progress, water availability, and high-quality seed. Then, guidelines should be developed to promote these valuable resources' efficiency, availability, and preservation. For the fifth time, governments should focus their efforts on teaching and educating farmers about new agricultural technology and how to apply it locally. Farmers should be made aware of the benefits and options available to them via these programmes.

Limitation and scope of the study: The Tapio decoupling index and eco-efficiency were used as proxy variables for resource consumption and agriculture-related emission to test the sector's decoupling states in Pakistan's agricultural sector. These variables included offtake of fertilizers, pesticide import production, tractor production, and cropped land. In the same way, other studies have their downsides, and this one has its own. Because the survey is scheduled to begin in 2018, Agricultural emissions are another example of environmental impact being utilized as a proxy. Environmental degradation induced by agricultural output may also be proxied by nitrogen and methane emissions from agriculture. You may look at proxy variables for resource utilization in a third method by looking at things like water usage or the distribution of high-quality seeds. There was no consideration given to the effect of technology on the agriculture sector in this investigation.

We were only able to evaluate a limited number of variables to assess if agriculture in Pakistan has separated from the rest of the economy because of the lack of data and time

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restrictions. Some additional components of agriculture's methane and nitrous oxide emissions that are accessible to policy improvements include water consumption, seed distribution, and organic pollutants that stay in the soil and are difficult to remove. The agriculture industry's future eco-efficiency and decoupling evaluations may use technological elements to deliver even more compressive results. To provide a complete picture, such variables and other environmental factors might be examined as part of an investigation project. According to the literature, decoupling and efficiency theories are seldom used in Pakistan's agriculture sector. In studies conducted at the provincial, regional, or sectoral level, variables connected to resources and the environment may be improved to achieve a complete decoupling status. To get the most outstanding results, it is recommended that decoupling be used in conjunction with other econometric methodologies.

The purpose of the research was to assess the eco-efficiency and decoupling of Pakistan's agriculture industry. Time series data was used from 2001 to 2018, using 2000 as the base year. I used the Tapio Decoupling Index and eco-efficiency techniques to conduct my study. In this study, Pakistan's agriculture sector will be studied to see how well it performs in terms of environmental efficiency and decoupling. Additionally, the study looks towards the future of eco-efficiency and decoupling in Pakistan. An additional purpose of the previously stated objective study is to provide policy recommendations. The industry measures agriculture-related emissions and resource consumption as proxy variables for cropped land, fertilizer usage, pesticide imports, and tractor production.

Tractor production in Pakistan's agricultural sector has seen a significant increase in environmental efficiency, evident across all resource parameters. However, after doing a decoupling study, it was discovered that all indicators displayed a range of decoupling strengths: weak, strong, expensive, and strong throughout the inquiry. The following are some policy recommendations based on empirical research: We need to prioritize resource efficiency and conservation while minimizing the adverse effects of new technologies on our environment. Primarily, the agriculture sector should promote renewable energy sources rather than fossil fuels for energy production. As a result, agricultural practices are based on ongoing studies. Step four is to identify factors that might disrupt policy and significantly impact agricultural production, then propose possible policies in line with those results. Agriculture technology and renewable energy are also being developed and deployed to assist farmers in better understanding and utilizing these technologies and resources.

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