Postprint: Current Status, Problems, and Development Strategies of China' s Fertilizer and Soil Conditioner Industry from a Supply-Side Reform Perspective

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Abstract

Fertilizer, as a crucial means of production, constitutes the material foundation for sustainable agricultural development, and agricultural advancement cannot proceed without the support of the fertilizer industry. In advancing agricultural supply-side structural reform, the fertilizer industry represents an indispensable component. Currently, China' s fertilizer industry faces a series of challenges, including overcapacity in conventional fertilizers, waste of resources and energy due to irrational fertilization practices, environmental pollution, soil degradation, and issues concerning agricultural product quality and safety. The industry' s development urgently requires a breakthrough. This article, based on investigations of grassroots fertilizer markets and agricultural production, systematically elaborates on the current status and challenges of China' s fertilizer industry from the perspective of the fertilizer industry supporting agricultural supply-side structural adjustment. It proposes policy recommendations for the sustainable development of the fertilizer and soil conditioner industries, which should take advancing agricultural supply-side structural reform as the main theme, be market-oriented, and primarily aim at ensuring national food security, supplying high-quality green agricultural products, and increasing farmers' income.

Full Text

Preamble

Special Topic: Science and Technology Promoting Agricultural Supply-side Structural Reform

Thinking on the Current Status, Problems, and Development Countermeasures of China' s Fertilizer and Soil Conditioner Industry from the Perspective of Supply-side Reform

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Fertilizer, as an important means of production, constitutes the material foundation for sustainable agricultural development, and agricultural progress cannot be separated from the support of the fertilizer industry. In promoting agricultural supply-side structural reform, the fertilizer industry represents an unavoidable link. Currently, China' s fertilizer industry faces a series of challenges, including excess capacity in traditional fertilizers, resource and energy waste caused by irrational fertilization, environmental pollution, farmland degradation, and threats to agricultural product quality and safety. The industry urgently needs to break through these constraints. Based on surveys of grassroots fertilizer markets and agricultural production, this article systematically explains the current status and problems of China' s fertilizer industry from the perspective of how the fertilizer industry supports agricultural supply-side structural adjustment. It proposes that the sustainable development of the fertilizer and soil conditioner industry should follow the main thread of promoting agricultural supply-side structural reform, be market-oriented, and aim primarily to ensure national food security, supply high-quality green agricultural products, and increase farmers' income.

Keywords: fertilizer industry, current status and problems, development proposals, agricultural supply-side reform
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Introduction

Fertilizers (including new-type fertilizers such as soil conditioners, hereinafter the same) are crucial agricultural production materials that form the material basis for sustainable agricultural development—the "food" for crops. According to FAO estimates, fertilizer inputs account for approximately one-half of total agricultural production inputs. In China' s "Eight-Character Constitution for Agriculture" (soil, fertilizer, water, seed, density, protection, management, and tools), "fertilizer" ranks second, fully demonstrating its vital role. China' s ability to feed 22% of the world' s population with only 7% of the world' s arable land owes much to fertilizer contributions. Rational fertilizer application not only enhances soil fertility and improves soil structure but also increases crop yields, improves agricultural product quality, boosts farmers' income, and

ensures human and livestock safety.

However, for a long time, excessive use of chemical fertilizers and pesticides in Chinese agriculture has caused farmland ecosystem imbalances, soil compaction, acidification, salinization, shallow plow layers, and excessive pesticide and heavy metal residues, leading to declining farmland quality and increasingly serious soil pollution, which severely constrains sustainable agricultural development. As the most fundamental agricultural production material after soil itself, fertilizer' s irrational use has gradually revealed deep-seated contradictions in the agricultural industry. Currently, agriculture in many regions of China faces severe challenges of rising production costs and worsening environmental pollution.

Agricultural development cannot be separated from fertilizer industry support, and promoting agricultural supply-side structural reform makes the fertilizer industry an unavoidable link. The current fertilizer industry faces problems such as excess capacity in traditional fertilizers, and the industry urgently needs breakthroughs. Development should follow supply-side structural reform as the main thread, be market-oriented, and aim to ensure national food security, supply high-quality agricultural products, and increase farmers' income. Advancing supply-side structural reform represents a key conceptual update for China' s modern agricultural development and serves as the basis and magic weapon for fertilizer industry reform and innovation.

China' s fertilizer industry has reached a critical period of transformation and development. Only by promoting supply-side reform can the industry adjust its structure, resolve excess capacity, enhance core competitiveness, and move toward green, efficient, and ecological new-type fertilizers. The advanced stage of fertilizer industry development should be a hybrid of production and service types, driving industrial chain upgrading and value increment to meet the demands of agricultural supply-side reform and sustainable agricultural development.

1.1.1 Nitrogen Fertilizer

Recent data indicate that China' s annual synthetic ammonia production capacity reaches 83.5 million tons, accounting for 37% of global capacity. Urea, a high-concentration nitrogen fertilizer, has become the main product, with an annual capacity of 95 million tons, representing 60.7% of China' s total nitrogen fertilizer capacity and 44% of global nitrogen fertilizer capacity. Other nitrogen fertilizer products such as ammonium bicarbonate, ammonium nitrate, ammonium chloride, and compound fertilizers (nitrogen content) account for 39.3% of China' s total nitrogen fertilizer capacity.

Currently, China has nearly 600 nitrogen fertilizer production enterprises, with small and medium-sized enterprises comprising a considerable proportion. These small and medium enterprises typically employ backward production processes with high energy consumption, and their production and environmental costs exceed international counterparts, resulting in weak product

competitiveness and low industrial efficiency. From January to October 2016, China' s nitrogen fertilizer enterprises suffered net losses exceeding 9 billion yuan, with a profit margin of -5.12% and an overall operating rate of approximately 60%. The nitrogen fertilizer industry exhibits structural overcapacity, particularly in urea production enterprises.

Faced with severe market conditions and the technical demand for fertilizer reduction and efficiency improvement, controlling total nitrogen capacity, cutting inefficient and high-consumption capacity, strengthening technological innovation, and developing new nitrogen fertilizer efficiency-enhancing products represent inevitable choices for nitrogen fertilizer industry transformation and upgrading.

1.1.2 Phosphate Fertilizer

China' s phosphate fertilizer industry began in the 1950s, with main products being superphosphate and calcium magnesium phosphate fertilizer. Since the reform and opening-up, especially in the late 1990s, China has accelerated development of high-concentration phosphorus compound fertilizers such as diammonium phosphate, NPK compound fertilizer, and nitrophosphate fertilizer. In 2016, China' s phosphate fertilizer output reached 16.55 million tons, accounting for 37.4% of world phosphate fertilizer output, with high-concentration phosphorus compound fertilizers comprising 90% of total output.

Overall, China' s phosphate fertilizer industry suffers from serious overcapacity, with small and medium enterprises employing backward production processes and prominent energy consumption and pollution problems. The key to phosphate fertilizer industry development lies in energy saving, consumption reduction, and emission reduction in production, as well as quality and efficiency improvement in products, thereby enhancing phosphorus resource utilization efficiency.

1.1.3 Potash Fertilizer

China' s potash fertilizer production began in the 1980s. Due to scarce potassium mineral resources, potash fertilizer output has increased slowly. By 2012, China' s potash fertilizer output was 3.774 million tons, far lower than nitrogen and phosphate fertilizer output. In 2016, national resource-based potash fertilizer output reached 5.783 million tons (K_2O), and processed potassium sulfate output reached 1.478 million tons (K_2O), while product diversification emerged. Currently, China' s commercial potash fertilizer varieties mainly include potassium chloride, potassium sulfate, potassium magnesium sulfate, potassium nitrate, potassium dihydrogen phosphate, potassium silicon (calcium), humic acid potassium, etc.

Presently, mainland China has over 160 potash fertilizer enterprises, with potash fertilizer sales accounting for approximately 25% of global sales. Among them, 134 are processing enterprises, including 32 large-scale enterprises whose total

potash capacity accounts for 65% of national capacity. With the implementation of fertilizer reduction and efficiency improvement technologies and changes in agricultural management systems, potash fertilizer consumption structure has changed, making structural innovation in potash fertilizer varieties inevitable.

1.2.1 Enhanced-Efficiency Fertilizers

Enhanced-efficiency fertilizers with new efficiency-enhancing carriers have been industrialized in many enterprises due to low costs and simple process modifications. Currently, China' s enhanced-efficiency fertilizer annual capacity reaches 12 million tons, with four national chemical industry standards— "Humic Acid Urea," "Seaweed Acid Urea," "Seaweed Acid Fertilizers," and "Humic Acid Compound Fertilizers"—officially implemented on April 1, 2017, marking the gradual formation of enhanced-efficiency fertilizers as a new industry with standardized production.

1.2.2 Slow/Controlled-Release Fertilizers

By the end of 2016, China had 36 slow/controlled-release fertilizer products with valid registration certificates. The development potential of low-cost slow/controlled-release fertilizers matching crop nutrient demand patterns cannot be ignored. Since 2014, China' s demonstration and promotion scale of slow/controlled-release fertilizers has continuously expanded, with crop types and experimental demonstration sites basically covering China' s main regions and crops. Products involve sulfur-coated, resin-coated, fertilizer-coated-fertilizer, chemical inhibitor, matrix composite, organic polymer, and other types.

1.2.3 Water-Soluble Fertilizers

From current development trends, with the implementation of China' s water-fertilizer integration action plan, water-fertilizer integration promotion area will reach 150 million mu by 2020, which will drive the rapid development of water-soluble fertilizers. Currently, China's water-soluble fertilizer development shows diversification, with accelerated enterprise growth and intensified product competition, but homogenization and low-quality products are numerous, with profits gradually declining. The functionalization of water-soluble fertilizer products will become an inevitable development trend.

1.2.4 Microbial Fertilizers

Soil ecological degradation often leads to frequent soil-borne diseases. Microbial fertilizers and bio-organic fertilizers have shown obvious effects in preventing soil-borne diseases, driving corresponding product research and industrial development. Currently, China' s total microbial fertilizer capacity reaches approximately 15 million tons/year. Officially registered microbial fertilizers include microbial agents, bio-organic fertilizers, compound microbial fertilizers, organic

material decomposing agents, rhizobium agents, photosynthetic bacterial agents, microbial fertilizers, endomycorrhizal agents, and bioremediation agents. Future efforts should strengthen basic theoretical and applied technology research on microbial fertilizers to solve problems such as unstable effects.

1.2.5 Soil Conditioners

With the promulgation of the "Soil Ten Articles," China' s soil degradation remediation and soil pollution control industries have enormous growth potential, with various soil conditioners and remediation materials ushering in a new development period. In recent years, soil conditioner products have developed rapidly in China. By the end of 2016, over 100 soil conditioners had been registered in China. Classified by use, common soil conditioners mainly include five categories: improving soil structure, reducing soil salinization hazards, adjusting soil pH, improving soil moisture conditions, and remediating heavy metal and pesticide contaminated soil. Main raw material sources include natural non-metallic minerals, industrial by-products, and agricultural product processing by-products.

Main Problems in China' s Fertilizer Industry

Traditional Fertilizer Overcapacity and Severe Homogenization

Taking national urea capacity as an example, according to the China Nitrogen Fertilizer Industry Association, China' s urea capacity reached 95 million tons in 2016 (excluding imports/exports and industrial use). Based on 1.8 billion mu of cultivated land nationwide with an average multiple cropping index of 200%, the current urea capacity can supply 26.4 kg per mu per cropping season, not even counting the application of ammonium bicarbonate, ammonium sulfate, ammonium chloride, ammonium nitrate, synthetic ammonia, etc. This demonstrates serious overcapacity in China' s agricultural fertilizers.

Taking Anhui Province as another example, according to the Anhui Province Chemical Fertilizer Industry Association, by the end of 2016, the province's total main fertilizer capacity (urea, compound fertilizer, and phosphate ammonium) reached 12.71895 million mu, with an average of 83.7 kg available fertilizer per mu. With such enormous capacity, product formulations show few significant differences. Between different enterprises and even within the same enterprise' s similar products, formulations are often similar. Some enterprises, to capture market share, produce over a dozen formulations of the same nutrient content product. Such huge capacity and product homogenization are the main reasons for declining fertilizer market prices in recent years.

Enterprises Fail to Grasp Key Points of Agricultural Supply-Side Structural Reform, with Misaligned Technological Innovation

Currently, China has many fertilizer categories, but few are efficient, green, and high-quality. Enterprises have not grasped the key points of agricultural

supply-side structural reform, focusing only on high yield as the primary factor while neglecting fertilizers' supporting role in increasing supply of high-quality agricultural products and enhancing sustainable agricultural development capacity. Enterprises show strong willingness for technological innovation, but with misaligned innovation purposes.

China' s fertilizer production basically meets domestic demand, and the market has shifted from a seller' s to a buyer' s market. Consequently, many fertilizer enterprises are actively innovating, with new-type fertilizers emerging endlessly. Most fertilizer enterprises and scientific researchers are committed to developing new technologies and products, launching technologically advanced products with good application effects that contribute to the healthy development of China' s fertilizer industry and agricultural progress. However, a few enterprises misuse concepts for marketing purposes—replacing innovation with "selling points" to launch so-called new products and technologies. This is manifested in: some enterprises establish various soil testing and formula compound fertilizer names to reduce production costs but actually "test soil without formulating," ignoring actual soil testing results and basic fertilizer functions; some violate basic crop nutrition principles, "seeking novelty" while neglecting farmland ecological safety and agricultural product safety, arbitrarily formulating nutrient ratios and adding non-nutrient components, exaggerating fertilizer functions; others use substances harmful to soil environments and not easily degradable as fertilizer additives or coating materials, sharply increasing potential environmental risks. For example, some products simply mix 2-3 existing basic products without substantive innovation, merely changing fertilizer form yet claiming to be new-type fertilizers; or pursue nominal and packaging innovations without technical or substantive breakthroughs.

Confusing Product Packaging and Labeling, Misusing Concepts, Misleading Farmers

Fertilizer products in the market sometimes mislabel nutrients or misuse concepts. Some label non-existent nutrients like "nitrogen fixation factors" or "nanoparticles" ; some falsely claim honors like awards, major inventions, American technology, or inscriptions by leaders or scientists; some exaggerate effects, claiming fertilizers are "all-powerful divine fertilizers" ; some hype high-tech concepts—for instance, various urea products on the market claim to be "energy-concentrated," "polypeptide," "triamine," "element X," "glacier extracts," etc., when in fact urea refers to only one chemical compound that cannot be called "urea" after adding any other components. These misused concepts often mislead farmers and growers in rational fertilizer use.

Insufficiently Rigorous Standards for New-Type Fertilizers, Not Representing Whole Industry Interests

Many new-type fertilizers lack necessary standard constraints. Although national and industry standards for slow-release fertilizers and commercial organic fertilizers have been implemented, they often only represent products from dif-

ferent production processes. With new-type fertilizer development and market demand, standard revision issues will become increasingly prominent. For example, three national and industry standards currently exist for slow-release fertilizers, reducing operability and convenience; the current organic fertilizer standard lacks constraints on harmful components like antibiotics and salts; water-soluble fertilizer nutrient content standards are set too high, limiting formulation flexibility and practicality and increasing costs; national standards for soil conditioners still need to be formulated. New-type fertilizers have high technological content, but this advantage often fails to be realized due to lax, unrealistic, or missing standards.

Increased Fertilizer Law Violations and Damage Disputes, with Inadequate Fertilizer-Specific Regulations

In recent years, fertilizer dispute cases have occurred frequently. For example, compound fertilizers labeled with 45% NPK content (total nitrogen, potassium, and phosphorus) actually contained less than 20%. Such exaggerated claims inevitably lead to improper fertilizer use, insufficient crop nutrients, and yield losses. Some fertilizers use inferior raw materials, causing crop poisoning. Some new-type fertilizers' quality and effects lack long-term testing in agricultural production, causing market disputes. Many fertilizer dispute cases exposed by media in recent years reflect the harm caused by fertilizer law violations.

Additionally, many countries worldwide have specialized fertilizer laws. China is a major agricultural country and fertilizer producer/user, but has not yet formulated a specialized fertilizer law. The Ministry of Agriculture' s "Fertilizer Registration Management Measures" is only a departmental regulation with insufficient legal force to deter violations. In production and sales, new-type fertilizer markets have diverse products with uneven quality, with some enterprises avoiding product shortcomings and exaggerating effects. Advertising language often uses unverifiable claims like "fertilizer from the world" or "American technology" to exaggerate promotion.

Negative Effects of Excessive Fertilizer Use

Excessive fertilizer use produces negative effects mainly in four aspects: (1) **Harming soil health**: Long-term chemical nitrogen fertilizer use causes soil acidification and compaction, destroys soil aggregate structure, and reduces soil organic matter and biodiversity. Phosphate fertilizers contain heavy metals that accumulate in soil with long-term application, affecting food chain safety. Overemphasis on NPK causes soil micronutrient depletion and nutrient imbalance. Organic fertilizer made from untreated livestock manure may cause heavy metal pollution and antibiotic/salt accumulation, creating soil environmental risks. High-intensity fertilization in facility agriculture, combined with high temperature and humidity in greenhouses, causes salt accumulation in the plow layer, easily leading to secondary salinization. (2) **Increasing user burden**: Most users still have three habits: relying on traditional experience without considering fertilizer characteristics, using simple "one-shot" fertilization methods

causing over-fertilization with continuously increasing inputs but no efficiency gains; blindly listening to fertilizer dealers who often recommend based on product profit, frequently causing farmers to increase fertilizer amounts or costs; and overly believing advertisements and false "science," especially commercial capital-invested agricultural users who, lacking experience, think the more powerful and expensive the fertilizer, the better, only to discover later that excessive costs don' t significantly increase yields. (3) **Threatening agricultural product quality safety**: Excessive fertilizer use easily causes crop lodging and diseases/pests, increasing pesticide use; applying unfermented and untreated organic fertilizer may cause seedling burn and accumulation of nitrites, antibiotics, and heavy metals in agricultural products—direct factors threatening food safety. (4) **Aggravating environmental pollution**: Excessive fertilizer use increases nitrogen and phosphorus loss from farmland, polluting groundwater and causing eutrophication in rivers and lakes. Additionally, nitrogen oxides generated from ammonia volatilization and denitrification processes in soil are greenhouse gases. Long-term heavy nitrogen application in facility agriculture often makes greenhouse nitrogen oxide concentrations too high, producing acid fog that damages crops. Insufficiently decomposed organic fertilizer applied to soil surfaces emits foul odors, and when applied to poorly aerated soil, produces methane, hydrogen sulfide, and other harmful gases that pollute the environment.

Countermeasures and Suggestions for Sustainable Development

Establishing a Fertilizer Industry Based on Resolving Capacity and Ensuring Agricultural Supply Quality

Promoting fertilizer industry development with agricultural supply-side structural reform as the main thread means cultivating capacity resolution and avoiding homogenization and low quality, guided by market demand and aiming to ensure national food security, supply high-quality green agricultural products, and increase farmers' income. As the main agricultural input and primary soil input, fertilizer is shifting from meeting agricultural supply-side "quantity" demands to pursuing green, ecological, sustainable agriculture and focusing more on meeting "quality" demands. China' s fertilizer industry has reached a critical transformation period. Only supply-side reform can drive capacity resolution, structural adjustment, and core competitiveness improvement, moving toward green, efficient, and ecological directions. Traditional fertilizers, fertilization techniques, and methods, along with corresponding marketing models and agricultural services, no longer match modern agricultural development. Changing mindsets, innovating development, and adapting to supply-side reform demands are inevitable choices for the fertilizer industry. The fertilizer industry should establish development concepts of "responsibility, environmental protection, service, and win-win," based on agricultural production requirements of "resource efficiency, cost reduction, labor saving, and practicality," implementing product positioning of "efficiency, quality, greenness, and safety," thereby achieving

the goals of "solving government concerns and meeting farmer needs" and realizing fertilizer industry supply-side reform for weight reduction and efficiency improvement.

The advanced stage of fertilizer industry development should be a hybrid of production and service types, driving industrial chain upgrading and value increment to adapt to agricultural supply-side reform and meet agricultural and socio-economic sustainable development demands.

Addressing Negative Effects of Excessive Chemical Fertilizer Use

(1) **Correcting soil ecological balance**: Over-reliance on chemical fertilizers, pursuit of high yields, prevalence of continuous cropping, heavy pesticide use, and other practices have disrupted soil ecological balance and nutrient equilibrium. Therefore, we recommend developing new-type fertilizers such as biological fertilizers, functional fertilizers, and soil conditioners to correct continuous cropping obstacles, improve soil ecological balance, and reduce disease and pest occurrence.

(2) **Correcting micronutrient deficiency bottlenecks**: Develop highly active water-soluble fertilizers to promote crop growth, correct crop micronutrient deficiencies, improve crop quality, and increase yields.

(3) **Reducing ecological environment damage**: Promote advanced fertilizer production and application technologies, improve agricultural service systems, increase fertilizer use efficiency, reduce soil, atmospheric, and water pollution caused by fertilization, and protect the ecological environment.

(4) **Ensuring agricultural product quality safety**: Prevent and control crop absorption of antibiotics, heavy metals, toxic and harmful microorganisms, and other hazardous substances to ensure agricultural product quality and safety.

Supporting Innovation in New-Type Fertilizer Industries Such as Soil Pollution Remediation Conditioners

China' s soil pollution survey shows a point 超标 rate of 16.1%, with farmland soil reaching 19.4%. Remediating soil pollution and improving the environmental quality of contaminated soil will be important tasks for some time, especially farmland pollution remediation. Restoring functions of degraded and polluted soil requires full play of soil conditioners and other new-type fertilizers. Therefore, more environmentally friendly, economical, and effective soil remediation materials should be developed. Currently, new materials used in contaminated soil remediation mainly include mesoporous/functional membrane materials, plant polyphenols, and nanomaterials. These materials have unique surface structures and compositions, showing good remediation effects at low application rates. However, they share a critical drawback—difficult synthesis and high prices—necessitating the development of green, efficient, and economical new-type soil pollution remediation materials.

Standardizing Fertilizer Management and Improving Laws and Regulations

(1) **Improving standards**: For example, soil conditioners as a new-type fertilizer currently lack national standards; for slow-release fertilizers and similar types with multiple national or industry standards, unification should be pursued.

(2) **Enhancing standard feasibility**: Classify and form standard systems based on existing fertilizer standards to improve feasibility.

(3) **Valuing frontline professionals' suggestions**: Fertilizer standard formulation should incorporate suggestions and opinions from frontline professionals at grassroots agricultural technology departments.

(4) **Improving fertilizer and soil conditioner standardization technical committee establishment**: Change the current practice of establishing fertilizer and soil conditioner standardization committees in research institutions or enterprises. Instead, establish specialized committees under the Ministry of Agriculture or General Administration of Quality Supervision, creating expert pools covering fertilizer research, plant nutrition, fertilizer manufacturing and equipment technology, chemical engineering, environmental protection, and agricultural technology promotion. Encourage enterprises to propose enterprise standards meeting national industrial policies and agricultural production needs, such as energy-saving, emission-reduction, disaster-resistance, and fertilizer use efficiency-improving products.

(5) **Maintaining fair market competition**: Improve the scientific authority of relevant standards in regulating fertilizer production and operation to maintain fair competition in fertilizer markets.

(6) **Advancing fertilizer legislation and improving laws and regulations**: Accelerate the fertilizer legislation process to legally regulate fertilizer research, production, operation, promotion, and use. This is important for purifying fertilizer markets, regulating competitive behavior, maintaining healthy fertilizer industry development, and promoting sustainable agricultural development.

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Note: Figure translations are in progress. See original paper for figures.