Technological Change and Corporate Strategies in the Fertiliser Industry

Anthony Bartzokas
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ABSTRACT

A major restructuring process is taking place in the international fertiliser industry driven by the introduction of stricter environmental regulation in Advanced Countries and the expansion of local production capabilities in Developing Countries. The paper will analyse patterns of corporate adjustment in the fertiliser industry. The emphasis is on the unique characteristics of the fertiliser industry as the producer of a final product and a supplier of intermediate inputs to agriculture. These producer-user linkages will be examined in the context of Advanced and Developing Countries. It will be argued that the fertiliser industry has incorporated the specific characteristics of these linkages in its adjustment processes in both Developed and Developing Countries – but in very different ways. This analysis suggests significant implications for the design of policies, which could facilitate the introduction of cleaner production techniques in the fertiliser industry and the adoption of environmental-friendly production techniques in agriculture.

Keywords: Fertiliser Industry; Environmental Regulation; Corporate Strategy
INTRODUCTION

The fertiliser industry is a mature and pollution-intensive process industry. Major innovations have been introduced in the past and the current allocation of investment on research and innovation is limited. The development of the fertiliser industry took place in the Developed Countries of Western Europe, North America, and Japan until the late 1960s. The market shares of Advanced Countries and especially those of European Union (EU) Member States in this sector have been declining in the last 20 years. The manufacturing of some products and downstream processing of many raw materials have been transferred to Developing Countries.

A closer consideration of these trends reveals some interesting insights that will bring the environmental dimension into the picture. First, the European fertiliser industry went through a significant restructuring process and the remaining firms have managed to retain their position in the European and international market in some areas of final products. Second, final products are being produced by different production processes and that implies different structures of input requirements and value-added shares. The production of nitrogen fertilisers, for example, is an energy-intensive manufacturing process that depends on the supply of natural gas while the production of phosphate fertilisers uses phosphate rock imported from Developing Countries with high transport costs. Third, the final product of the industry is an input to agriculture. That makes the environmental implications of fertiliser production much wider, compared to other sectors and the link between producers (fertiliser firms) and users (farmers) an interesting one.

This paper will analyse patterns of corporate adjustment in the fertiliser industry. The emphasis is on the unique characteristics of the fertiliser industry as the producer of a final product and a supplier of intermediate inputs to agriculture. The producer-user linkages will be examined in the context of Advanced and Developing Countries. It will be argued that the fertiliser industry has incorporated the specific characteristics of these linkages in its adjustment processes in both Developed and Developing Countries but in very different ways. This analysis suggests significant implications for the design of policies, which could facilitate the introduction of cleaner production techniques in the fertiliser industry and the adoption of environmental-friendly production techniques in agriculture.
ENIRONMENTAL REGULATION AND COMPETITIVENESS

The theoretical and empirical literature on the interface between environmental regulation and competitiveness has shown a very mixed picture. Looking at the firm level, it has proved very difficult to establish causal links between environmental and economic performance. It is therefore necessary to take account of the interaction of environmental regulation with other factors, which influence corporate decisions. At the industry level, there is evidence of a shift of pollution-intensive industries to less regulated countries in the South. There is also evidence that competitiveness has increased in a number of these industries in Developing Countries while it has declined in the Advanced Industrialised Countries. However, as with firm level studies, it has been difficult to establish causal linkages. It is also the case that there has not been a generalised shift of all pollution-intensive industries to the South. Developed Countries continue to be competitive in a number of pollution-intensive industries. This raises the question of what kinds of industries have been able to maintain their competitive position in the North, despite more stringent environmental regulation. Studies of national competitiveness are useful in highlighting two broader considerations. The first is the importance of taking into account general equilibrium effects in arriving at any overall evaluation of the impact of environmental regulation. Although this is not the focus of this study, it is important to bear in mind that a negative impact on competitiveness in a specific industry does not necessarily reduce overall economic performance. Second, it is important to remember that if one defines competitiveness in terms of an economy’s success in delivering a rising standard of living, this should include those improvements in the environment that result from regulation, which contribute to the population’s overall welfare. [2]

The approach adopted in this paper rejects monocausal explanations of competitiveness and environmental regulation. A major conclusion to be drawn from this review of the literature is that the relationship between environmental regulation and competitiveness is a complex one. This contrasts both with those studies that tend to concentrate on the national level and those based on the experience of individual firms. Mono-causal explanations, which attribute changes in competitiveness solely to differences in environmental regulation, do not adequately capture this. They cannot explain why relocation occurs in some pollution-intensive industries and not in others, or why some countries with relatively strict environmental regulation have been able to maintain their competitiveness in such industries. What is required is a framework, which allows the impact
of changes in regulation to be analysed in the context of other factors affecting competitiveness and the structural features of the industry concerned.

The adoption of new technologies at the firm level is a result of many different factors. When it comes to pollution problems, the development of environmentally-conscious technologies is taking place in both production processes and product-specific technologies. Given the diversity of industries in terms of production processes, products, and hence pollution sources, the incentives structure and other considerations at the firms level are difficult to generalise. In this paper, we suggest that a better understanding of technological trends at the sectoral level is a necessary precondition for the better understanding of the impact of environmental regulation on technological change. There are a number of reasons why the specific focus chosen for the research is at the level of the industry. First of all, the dynamic of competition takes place within an industry. The behaviour of an individual firm, its competitive strategies, investment decisions and locational choices need to be understood in the context of the competition which it faces. Thus the structure of an industry and the nature of competition within it are key factors determining its evolution.

Second, the responses of firms to environmental regulation are critically dependent on the competitive characteristics of the industries within which they operate. Indeed, technological developments and production processes are industry specific. The environmental impact of an industry and the way in which it changes over time depends on the technological trajectory of the industry. Generally speaking, the impact of end-of-pipe technologies on the production process is limited compared with that of cleaner technologies. This implies that firms will face less uncertainty and irreversibility when they make a decision on investment in end-of-pipe technologies. Therefore, most of the firms would prefer first adopting end-of-pipe technologies, which is simply to be added to the existing facilities, rather than altering the production process or the main product. However, there are limits in the extent to which the adoption of end-of-pipe technologies is appropriate in dealing with environmental problems. That is because it will be very costly to further reduce pollution emissions at the end of the production process, especially when their concentration is already small but not necessarily small enough to be safe to the environment. In order to achieve drastic reductions in emissions, more fundamental changes will be necessary in the production process and/or the composition of the product. Furthermore, with the application of end-of-pipe technologies the benefits of raw material and energy savings will not occur, and technological spillovers to the main production process will be limited. That is, innovation offsets will be difficult to obtain. Eventually, firms would need to develop cleaner technologies by introducing an integrated assessment of their production processes and products. [3]
Third, in order to understand how environmental regulation leads to changes in technology and how these affect competitiveness, it is also necessary to look at specific industries. Macro studies in the past have failed to come to very clear conclusions concerning the impact of environmental regulation on competitiveness, technological change and industrial location. On the other hand, examples of specific firms that have relocated production or gained competitive advantages as a result of environmental regulation can be dismissed as ‘anecdotal’. Firm level case studies therefore are never likely to produce conclusive evidence on either the negative impact or the advantages of environmental regulation. An industry study cannot be dismissed so easily as being anecdotal, while at the same time offering more specific insights than can be obtained from often quite aggregate macro studies. Finally, it is important to look at linkages between different stages in the production process because often these have very different implications in terms of pollution generated and value added created. This again leads to an industry focus and can be usefully explored through a commodity chain approach. An additional advantage of the sectoral approach is that it provides the opportunity for a closer look at environmental problems in various stages of the production process of different groups of final products.
FERTILISERS PRODUCTION PROCESS AND THE ENVIRONMENT

Mineral fertilisers are made from naturally occurring raw materials containing nutrients, which have normally been transformed into a more plant-available form by industrial processing. While the chemical components of finished products are relatively simple, the manufacturing technologies are highly developed and production plants are very capital-intensive. Fertilisers are produced as straight or multi-nutrient products, and the production processes vary in accordance with the nutrients produced. Fertilisers are grouped by nutrients provided. As competition in the fertiliser industry has become increasingly international, manufacturers have diversified their production in many different directions aiming at better quality and increasing value-added for the customer. Fixed nitrogen (N), water-soluble phosphorus (P) and water-soluble potassium (K) are the primary fertiliser nutrients. Sulfur (S) is considered the most important secondary nutrient. The various steps involved in the manufacture of finished fertiliser products, from raw materials through intermediate products, are shown in Table 1.
Table 1: Products of the fertiliser industry

<table>
<thead>
<tr>
<th>NUTRIENTS</th>
<th>SOURCE</th>
<th>INTERMEDIATES</th>
<th>FERTILISER PRODUCTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nitrogen (N)</td>
<td>Nitrogen from air (Hydrogen from natural gas)</td>
<td>Ammonia</td>
<td>Urea</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Nitric Acid</td>
<td>Ammonium Nitrate</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Calcium Ammonium Nitrate</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Nitrogen Solutions</td>
</tr>
<tr>
<td></td>
<td>Ammonium Sulphate</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Phosphorus (P)</td>
<td>Phosphate rock</td>
<td>Phosphoric Acid</td>
<td>Ammonium Phosphates</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Superphosphates</td>
</tr>
<tr>
<td>Potash (K)</td>
<td>Potash</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sulphur (S)</td>
<td>Sulphur source</td>
<td>Sulphuric Acid</td>
<td></td>
</tr>
<tr>
<td>Various inputs</td>
<td></td>
<td></td>
<td>Multi-Nutrient Fertilisers (NPK, NK, PK)</td>
</tr>
</tbody>
</table>

Source: [4]

The majority of multi-nutrient fertilisers are complex fertilisers. Complex NPK fertilisers are usually manufactured by producing ammonium phosphates, to which potassium salts are added prior to granulation or prilling. PK fertilisers, on the other hand, are generally produced as compounds by the steam granulation of superphosphates (SSP or TSP) with potassium salts.[5]

Blend fertilisers are obtained by the mechanical mixing of several fertilisers and granular potash to give the desired analysis. Most producers of multi-nutrient fertilisers in Europe are producing nitrate-based fertilisers, namely, NP or NPK fertilisers. These fertilisers are being produced with either the mixed-acid or the nitrophosphate production process. The mixed acid process involves processing of raw materials with mixed acid and the granulation or prilling process.[6] The nitrophosphate route involves the dissolution of the phosphate rock in nitric acid and uses all the nutrient components in an integrated process without solid wastes and with minimal gaseous and
liquid emissions.[7] Since the process is not dependent on sulphur, no sulphur oxides are emitted. Furthermore, the process produces no phosphogypsum and no gypsum wastewater. Also, as by-products are upgraded to commercial products, there is no solid waste.

**The problem with cadmium**

Varieties of production processes with different raw materials are being used in the manufacture of phosphoric acid. The thermal process uses phosphorus as its raw material. Because of the amount of energy that is needed, this process has been abandoned. The wet processes use phosphate rock decomposed with an acid. Currently, they are the only economic alternative ways to produce phosphoric acid, accounting for 95 per cent of world production. There are three possible subgroups of wet processes depending on the acid which is used for the acidulation, namely, nitric, hydrochloric or sulphuric. In Europe, normally the sulphuric acid route is used in the production of fertilisers. Around five tonnes of phosphogypsum are generated per tonne of phosphoric acid expressed as P₂O₅. [8] The disposal of phosphogypsum poses a serious problem, especially with the large-scale phosphoric acid production units of over 1000t/d capacity, which are now being built. This phosphogypsum contains some of the trace elements from the phosphate rock, including cadmium and some radioactive elements. Although it was previously a common practice for phosphoric acid plants situated on coasts to pump gypsum into the sea, where it rapidly dissolves, recent restrictions on the disposal of phosphogypsum into the sea have been introduced, subject to restrictions on the cadmium content of the gypsum. [9]

During the processing of phosphate rock, cadmium is partitioned between wastes from the beneficiation process of phosphate rock and phosphogypsum from the further processing into phosphoric acid. The percentage of the elements that is transferred from the phosphate rock to the phosphogypsum depends on the type of process and the rock used. The cadmium level in product fertilisers is increasingly causing concern in Industrialised Countries. [10] While the EU Directive on cadmium emissions to water in 1988 explicitly recognised the desirability of reducing inputs of cadmium to soils as part of an overall strategy for reducing environmental contamination by cadmium, it also acknowledged that there was still no feasible process to remove cadmium from phosphate rock and that exports of rock phosphate represented a significant source of revenue for a number of Developing Countries in Africa. The European Commission recently decided not to formalise a negotiated agreement or a regulation for the time being, but to assess the risk to humans from cadmium in fertilisers more carefully before taking any regulatory action.[11]
Leaching of nitrates from agriculture

Recently there has been a growing concern that mineral fertilisers used in agriculture have adverse effects on the environment. Agriculture is the main source of nitrate in drinking water, either directly to surface waters through surface run-off or through land drains or by infiltration to groundwater. Most of this nitrate originates from agricultural inputs. Nitrate occurs naturally in soils and becomes vulnerable to loss when supply exceeds crop requirement, particularly if the imbalance develops at times when water is draining through or over the soil. The fertiliser industry, in co-operation with fertiliser spreader manufacturers, performs regular tests to ascertain the most appropriate form and properties for fertiliser granules and prills in order to achieve optimal spreading. The industry also offers farmers the special service of checking, and if necessary recalibrating, fertiliser spreading equipment. [12]

The essential legislation about nitrate in water in the EU is the 1980 Drinking Water Directive. This set legal maximum allowable concentrations in drinking water for many chemical and biological determinants, including nitrate. The 50 mg/l nitrate level became binding on all member states in 1985. [13] By the late 1980s, several member states were pushing further EU legislation to tackle the main sources of nutrient input to waters. Consequently, in December 1991 the Council of the EU adopted a directive, often known as the Nitrates Directive, concerning the protection of waters against pollution caused by nitrates from agricultural sources. This directive recognises that while the use of nitrogen-containing fertilisers and manure is necessary for the EU agriculture, any over-use of fertilisers and manure constitutes an environmental risk. It emphasises that common action is needed to control the problem arising from intensive livestock production, and that agricultural policy must take greater account of environmental policy.

Basically, two types of measures could be considered to deal with this problem. The first one is improvements in fertiliser products. Complex and compound fertilisers account for 83 per cent of all phosphorus, 67 per cent of all potassium, and 25 per cent of all nitrogen consumed in the EU. They are normally classified according to the ratio of their nutrient content, in the order N, P₂O₅ or P, and K₂O or K. Given the range of soils and crops in the EU, a wide variety of grades should be available to meet the different agronomic and environmental requirements. [14] Slow and specifically controlled release fertilisers are aimed at plant nutrient use efficiency and at minimising nutrient losses. The effectiveness of such fertilisers requires a good match between the release rate and the plant needs. Therefore, fertilisers that are designed to provide better control over the release in soils are expected to provide high-use efficiency and minimize adverse effects on the environment. The most acceptable types of slow or controlled release fertilisers in practical use are
organic nitrogen compounds and fertilisers protected physically by encapsulation with hydrophobic materials, mainly coating. The potential of these fertilisers to serve as controlled release nutrient sources has led to a steady and significant increase of their use. [15]

The second type of measures is to improve the practices of fertiliser application to the agricultural field. The leaching of excess nitrates can also be prevented by farmers’ appropriate practices of fertiliser application.[16] In many countries, new legislation or codes of good farm practices have been developed to improve nutrient efficiency and reduce the load on the environment.[17] Farmers are encouraged to make fertiliser plans for their crops, taking account of the total input of nutrients from mineral fertiliser sources. A mineral book-keeping system enables farmers to monitor the nutrient flow on their farms. Nutrient efficiency would be improved as a result of optimal dosing, coupled with an informed fertiliser choice, new application techniques and more appropriate timing. EFMA has published the Code of Best Agricultural Practice of Nitrogen for farmers. [18] The recommendations provided by the code encouraged appropriate application rate, correct timing of the application, the use of a suitable type of fertiliser and an accurate calibrated fertiliser spreader. The recommendations are aimed at achieving good crop yields while minimising the loss of nutrients by leaching or volatilisation. Farmers are also encouraged to choose a suitable type of fertiliser. Selecting the type of fertiliser to be used should include an assessment of likely environmental impact and agronomic efficiency. Both chemical form and physical characteristics are important. The choice of fertiliser and chemical form of the nutrient components depends on the chemical properties and analysis of the nutritional requirements and physiological sensitivities of the crop. [19]
THE STRUCTURE OF THE FERTILISER INDUSTRY

Considering the technical characteristics of the production process and the large quantities of the raw materials used and by-products produced, the fertiliser industry has a significant potential for environmental problems. Various forms of environmental regulation, mainly related to the manufacturing process of fertilisers, have been introduced in Europe and since the early 1980s there has been considerable concern about the impact of fertilisers used in agriculture on the environment, particularly about the level of nitrates in water supplies and the cadmium content in fertilisers. On the other hand, the European fertiliser industry is facing stagnating demand for fertilisers in the European market and increasing imports of low-cost fertilisers from foreign producers, especially those in Central and Eastern Europe (CEE), the Former Soviet Union (FSU) and North Africa. Profitability has been very low for the European producers for many years. This has led to a considerable restructuring of the industry. Production capacity and employment were reduced drastically, and a wave of mergers and acquisitions took place. In what follows, we will discuss the main trends in the international fertiliser industry and the response of European fertiliser manufacturers.

There have been significant shifts in the distribution of world fertiliser production over the past two decades. Total production of fertilisers in Developing Countries increased almost threefold between 1979 and 1998, while production declined in the Developed Countries, and fell by a half in the former centrally planned economies after 1989 (see Table 2). As a result, the share of world fertiliser production located in the Developing Countries was greater than that of the Developed Countries at the end of the millennium.
Table 2: World Fertiliser Production, 1979-1998

<table>
<thead>
<tr>
<th>Year</th>
<th>DEVELOPED COUNTRIES</th>
<th>DEVELOPING COUNTRIES</th>
<th>TRANSITION ECONOMIES</th>
<th>WORLD</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Vol (’000Mt)</td>
<td>% Share</td>
<td>Vol (’000Mt)</td>
<td>% Share</td>
</tr>
<tr>
<td>1979</td>
<td>64769</td>
<td>54.5%</td>
<td>23964</td>
<td>20.2%</td>
</tr>
<tr>
<td>1984</td>
<td>64338</td>
<td>46.1%</td>
<td>36132</td>
<td>25.9%</td>
</tr>
<tr>
<td>1989</td>
<td>61685</td>
<td>40.3%</td>
<td>48601</td>
<td>31.8%</td>
</tr>
<tr>
<td>1994</td>
<td>60831</td>
<td>44.8%</td>
<td>55110</td>
<td>40.6%</td>
</tr>
<tr>
<td>1998</td>
<td>59408</td>
<td>40.3%</td>
<td>66503</td>
<td>45.2%</td>
</tr>
</tbody>
</table>

Source: FAO Statistical Database

Production of nitrogenous fertilisers in the Developed Countries increased slightly over this period, but their share of world production declined from almost a half at the end of the 1970s to a third in the 1990s. The Developing Countries increased their share of world production at the expense of the Developed Countries in the 1980s and the transition economies in the 1990s, so that by the end of
that decade they accounted for over half of world production. Production of phosphate fertilisers in the Developed World has actually fallen during this period, particularly in the EU. Again the North’s share of world production has declined significantly, while that of the Developing Countries has increased to overtake production in the North in the late 1990s.

From its earlier large share of 40 per cent in world mineral fertiliser production in the mid-1950s, the EU has experienced a drop in its share of the world total output. Table 10.6 presents the allocation of world fertiliser production among the main producers. Germany and the Netherlands are among the main producers of nitrogen fertilisers. During the heavy restructuring of the industry in the early 1990s, the European fertiliser industry reduced nitrogen fertiliser capacities by 25 per cent. Western Europe’s share of the world nitrogen fertiliser production fell from 20 per cent in 1981 to 11 per cent in 1997. [20] For ammonia production its share declined from 14.9 per cent in 1980 to 8.8 percent in 1998 and for urea production from 12.3 per cent to 4.9 per cent. [21]

The main reasons for the decline in consumption is the reform of Common Agricultural Policy (CAP). This reform, implemented in 1992, abandons price support mechanisms in favour of compensation paid directly to farmers. It has had a particular impact on the arable land sector. The intervention purchase prices of cereals have dropped by almost 25 per cent, and these reductions have been compensated for by direct aid per hectare. At the same time, aid payment is contingent on the freeze of the surface area devoted to cereals, oil, and protein-yielding crops. Consequently, as the production of crops was reduced, demand for fertilisers declined by about the same proportion. [22]

Almost all of the world’s nitrogen supply is produced from ammonia. About three-quarters of world ammonia production is based on natural gas, and this proportion has increased steadily from less than 60 per cent in 1970. In 1996, the most important producers of natural gas were the FSU, accounting for 25 per cent of the world total production, and the US, which contributed 24 per cent. Western European countries produced 11 per cent of the world total. The UK produced 32 per cent of the Western European total, the Netherlands 29 per cent and Norway 19 per cent. The cost of feedstock accounts for two-thirds to three-quarters of the total cost of producing ammonia. In the case of urea production, natural gas accounts for more than 80 per cent of all input costs.[23]

About two-thirds of phosphate fertilisers are derived from phosphoric acid, which is obtained by processing phosphate rock with an acid, mainly sulphuric acid. Overall, mineral fertilisers account for approximately 80 per cent of phosphate use. While over 30 countries are currently producing phosphate rock, the top 12 producing countries account for nearly 95 per cent of the world total phosphate rock production. The main producers in 1996 were the US (31.7 per cent), China (20.5
per cent) and Morocco (14.7 per cent) (see Table 3). Within Western Europe, there are only small reserves in Finland.

Over the past two decades, there has been a distinct trend towards the processing of phosphate rock in countries with substantial natural resources of this material. In 1997, the US accounted for 43 per cent of the world phosphoric acid production, Northern Africa (Morocco and Tunisia) for 15 per cent, the FSU for 8 per cent, and Latin America and the Middle East each for 6 per cent. [24] Phosphoric acid production capacity in Western Europe has fallen by 60 per cent since 1980, with a drop in its share in world capacity from 14 per cent in 1980 to 4.7 per cent in 1998. From the mid-1980s to the mid-1990s there was little investment in new phosphoric acid plants and several plant closures in Western Europe. [25]

Potash is produced in the few countries where the ores are located. In 1996 the FSU (Russia and Belarus) accounted for 25 per cent of the world potash production, North America, mostly Canada, for 40 per cent, Western Europe for 21 per cent and Israel and Jordan together for 9 per cent. These regions thus provide 92 per cent of the total world production. [26] In Europe, the merger of two German potash companies resulted in a large reduction in production capacity. Potash mines in France will be closed by 2004, when the deposits will be exhausted. [27]

Table 3: World fertilisers production, Ammonia (N), Phosphate Rock (P) and Potash (K)

<table>
<thead>
<tr>
<th>PRODUCT AND COUNTRY</th>
<th>1992</th>
<th>%</th>
<th>1994</th>
<th>%</th>
<th>1996</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ammonia</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>China</td>
<td>18,000</td>
<td>19.3</td>
<td>20,075</td>
<td>21.2</td>
<td>24,483</td>
<td>23.4</td>
</tr>
<tr>
<td>United States</td>
<td>13,400</td>
<td>14.3</td>
<td>13,397</td>
<td>14.2</td>
<td>14,564</td>
<td>13.9</td>
</tr>
<tr>
<td>India</td>
<td>7,452</td>
<td>8.0</td>
<td>7,503</td>
<td>8.0</td>
<td>8,549</td>
<td>8.2</td>
</tr>
<tr>
<td>Russia</td>
<td>8,786</td>
<td>9.4</td>
<td>7,264</td>
<td>7.7</td>
<td>7,932</td>
<td>7.6</td>
</tr>
<tr>
<td>Canada</td>
<td>3,100</td>
<td>3.3</td>
<td>3,474</td>
<td>3.7</td>
<td>3,840</td>
<td>3.7</td>
</tr>
<tr>
<td>Indonesia</td>
<td>2,690</td>
<td>2.9</td>
<td>3,012</td>
<td>3.2</td>
<td>3,647</td>
<td>3.5</td>
</tr>
<tr>
<td>Ukraine</td>
<td>3,908</td>
<td>4.2</td>
<td>3,004</td>
<td>3.2</td>
<td>3,302</td>
<td>3.2</td>
</tr>
<tr>
<td>Germany</td>
<td>2,110</td>
<td>2.2</td>
<td>2,170</td>
<td>2.3</td>
<td>2,512</td>
<td>2.4</td>
</tr>
<tr>
<td>Netherlands</td>
<td>2,590</td>
<td>2.8</td>
<td>2,479</td>
<td>2.6</td>
<td>2,353</td>
<td>2.2</td>
</tr>
<tr>
<td>Mexico</td>
<td>2,200</td>
<td>2.4</td>
<td>2,028</td>
<td>2.1</td>
<td>2,054</td>
<td>2.0</td>
</tr>
<tr>
<td>Trinidad</td>
<td>1,570</td>
<td>1.7</td>
<td>1,649</td>
<td>1.8</td>
<td>1,801</td>
<td>1.7</td>
</tr>
<tr>
<td>Poland</td>
<td>1,490</td>
<td>1.6</td>
<td>1,607</td>
<td>1.7</td>
<td>1,796</td>
<td>1.7</td>
</tr>
<tr>
<td>-------------</td>
<td>-------</td>
<td>-----</td>
<td>-------</td>
<td>-----</td>
<td>-------</td>
<td>-----</td>
</tr>
<tr>
<td>All others</td>
<td>26,104</td>
<td>27.9</td>
<td>26,678</td>
<td>28.3</td>
<td>27,734</td>
<td>26.5</td>
</tr>
<tr>
<td>TOTAL</td>
<td>93,400</td>
<td>100.0</td>
<td>94,340</td>
<td>100.0</td>
<td>104,567</td>
<td>100.0</td>
</tr>
</tbody>
</table>

**Phosphate Rock**

<table>
<thead>
<tr>
<th></th>
<th>%</th>
<th>%</th>
<th>%</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>United States</td>
<td>47,000</td>
<td>33.8</td>
<td>41,650</td>
<td>32.6</td>
</tr>
<tr>
<td>China</td>
<td>21,400</td>
<td>15.4</td>
<td>24,761</td>
<td>19.4</td>
</tr>
<tr>
<td>Morocco</td>
<td>19,145</td>
<td>13.8</td>
<td>19,765</td>
<td>15.5</td>
</tr>
<tr>
<td>Russia</td>
<td>11,500</td>
<td>8.3</td>
<td>8,021</td>
<td>6.2</td>
</tr>
<tr>
<td>Tunisia</td>
<td>6,400</td>
<td>4.6</td>
<td>5,699</td>
<td>4.4</td>
</tr>
<tr>
<td>Jordan</td>
<td>4,300</td>
<td>3.1</td>
<td>4,216</td>
<td>3.3</td>
</tr>
<tr>
<td>Israel</td>
<td>3,600</td>
<td>2.5</td>
<td>3,961</td>
<td>3.1</td>
</tr>
<tr>
<td>Brazil</td>
<td>2,850</td>
<td>2.1</td>
<td>3,938</td>
<td>3.1</td>
</tr>
<tr>
<td>Togo</td>
<td>2,083</td>
<td>1.5</td>
<td>2,149</td>
<td>1.7</td>
</tr>
<tr>
<td>South Africa</td>
<td>3,080</td>
<td>2.2</td>
<td>2,545</td>
<td>2.0</td>
</tr>
<tr>
<td>All others</td>
<td>17,642</td>
<td>12.7</td>
<td>11,183</td>
<td>8.7</td>
</tr>
<tr>
<td>TOTAL</td>
<td>139,000</td>
<td>100.0</td>
<td>127,843</td>
<td>100.0</td>
</tr>
</tbody>
</table>

**Potash**

<table>
<thead>
<tr>
<th></th>
<th>%</th>
<th>%</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Canada</td>
<td>7,270</td>
<td>30.4</td>
<td>8,040</td>
</tr>
<tr>
<td>Germany</td>
<td>3,460</td>
<td>14.5</td>
<td>3,290</td>
</tr>
<tr>
<td>Belarus</td>
<td>3,310</td>
<td>13.8</td>
<td>3,021</td>
</tr>
<tr>
<td>Russia</td>
<td>3,470</td>
<td>14.5</td>
<td>2,498</td>
</tr>
<tr>
<td>United States</td>
<td>1,710</td>
<td>7.3</td>
<td>1,400</td>
</tr>
<tr>
<td>Israel</td>
<td>1,300</td>
<td>5.4</td>
<td>1,260</td>
</tr>
<tr>
<td>Jordan</td>
<td>794</td>
<td>3.3</td>
<td>930</td>
</tr>
<tr>
<td>All others</td>
<td>2,586</td>
<td>10.8</td>
<td>2,661</td>
</tr>
<tr>
<td>TOTAL</td>
<td>23,900</td>
<td>100.0</td>
<td>23,100</td>
</tr>
</tbody>
</table>

Source: [28]

Although not as marked as the trends in the global production of fertilisers, trade patterns have also changed in the past two decades with the share of the Developed Countries falling from almost three-quarters in 1979 to about 60 per cent in the late 1990s. Developing Countries have increased their share of world exports, but in contrast to what has happened in production, the transition
economies also gained an increased share of world fertiliser exports during the 1990s (see Table 4). The developing country share of exports has been particularly marked in the case of phosphate fertilisers where it increased from around a fifth in 1979 to between a half and two-thirds in the 1990s.

Table 4: Exports of Manufactured Fertiliser, 1979-99

<table>
<thead>
<tr>
<th>Year</th>
<th>DEVELOPED COUNTRIES</th>
<th>DEVELOPING COUNTRIES</th>
<th>TRANSITION ECONOMIES</th>
<th>WORLD</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$ mn.</td>
<td>%</td>
<td>$ mn.</td>
<td>%</td>
</tr>
<tr>
<td>1979</td>
<td>6018</td>
<td>74.1%</td>
<td>947</td>
<td>11.7%</td>
</tr>
<tr>
<td>1984</td>
<td>7037</td>
<td>67.1%</td>
<td>1553</td>
<td>14.8%</td>
</tr>
<tr>
<td>1989</td>
<td>8779</td>
<td>65.3%</td>
<td>2449</td>
<td>18.2%</td>
</tr>
<tr>
<td>1994</td>
<td>8209</td>
<td>62.4%</td>
<td>2477</td>
<td>18.8%</td>
</tr>
<tr>
<td>1998</td>
<td>8269</td>
<td>58.8%</td>
<td>2705</td>
<td>19.2%</td>
</tr>
<tr>
<td>1999</td>
<td>8369</td>
<td>60.3%</td>
<td>2556</td>
<td>18.4%</td>
</tr>
</tbody>
</table>

Source: FAO Statistical Database

About 90 per cent of world ammonia production is processed or used locally, and the remaining 10 per cent is exported. The major exporters in 1997 were Russia and Ukraine (using Russian gas for production), accounting for 49 per cent of world exports, Trinidad for 19 per cent and the Middle East for 18 per cent. The major net importers were the US (46 per cent) and Western Europe (31 per cent).

Total nitrogen fertiliser exports from CEE and the FSU increased from 18 per cent of the world total in 1980 to about 33 per cent in 1996. [29] The significant decline in fertiliser consumption in the CEE countries and the FSU in recent years has led to a sharp increase in the quantity of low-priced nitrogen fertilisers imported into the EU. The share of imports in European nitrogen consumption reached 23.5 per cent in 1998, and the CEE and the FSU countries accounted for 71.4 per cent of total nitrogen imports.[30] Other important sources of imports to the EU are Libya and Morocco.

Previously the main form of phosphate was phosphate rock, which was mostly processed in Developed Countries. Over the last 20 years, as vertically integrated industries have developed at
the site of rock mines, the role of phosphate rock as an intermediate input for the phosphate industry in the international market, declined sharply from 53 million tonnes in 1979 to 31 million tonnes in 1996. Currently only 25 per cent of phosphate rock is exported from the countries of origin, and two countries, Morocco and the US, account for nearly half of the exports. [31] Because of this trend, the international trade of processed phosphate, including ammonium phosphate, triple superphosphate and phosphoric acid, has increased substantially in recent decades, at the expense of phosphate rock. From the mid-1970s to the early 1980s, most of the increase in processed phosphate trade was in the form of phosphoric acid. A more recent trend has been the increase in trade of ammonium phosphate, which currently accounts for approximately 60 per cent of the world phosphate trade, compared with 46 per cent in the mid-1980s. While Morocco supplied 41 per cent of the world exports of phosphoric acid, Tunisia for 15 per cent and the US for 11 per cent, the US provided 60 per cent of the world exports in ammonium phosphate, the FSU for 17 per cent, and Morocco and Tunisia for 11 per cent in 1996.[32] The major suppliers of phosphate fertilisers to Western Europe were Russia, Morocco, and Tunisia. [33]

World trade in potash, mostly in potassium chloride, also called muriate of potash, has increased slightly during the past decade. From 1994 to 1996, North America, mostly Canada, accounted for 47 per cent of world exports, the FSU for 22 per cent, Western Europe, mainly Germany, for 19 per cent, and Israel and Jordan for 12 per cent. [34] It is expected that the European potash industry will continue to maintain the capacity to fully meet potash demands in Europe. [35] Fertiliser exports from Western European countries mainly consist of NPK, by-product sulphate of ammonia, and some nitrates and urea. The main markets are China, Thailand, and the Americas. In 1968, net exports amounted to over 2 million tonnes, whereas in 1996 net imports increased to more than 1.4 million tonnes of nitrogen. The trade balance indicates that Western Europe has changed from being a net exporter of nitrogen fertiliser from the 1960s to the early 1980s, to being a net importer in the 1990s. In other words, the trade balance deteriorated by 3.4 million tonnes of nitrogen. The market of Phosphate fertilisers has been another area of increasing trade deficit for the EU in recent years. [36]
CORPORATE STRATEGIES IN THE EUROPEAN UNION

The European fertiliser industry employed about 110,000 people in 1983, but in 1992 the number of employees was reduced to 40,000. In the 10-year period leading up to 1990, the number of ammonia plants decreased from 74 to 41, and production capacity declined by 12 per cent. The number of phosphoric acid plants was halved during the 1980s, and capacity was reduced by 35 per cent. The level of concentration of ownership control increased and it was estimated in 1992 that eight major companies owned 80 per cent of European fertiliser production capacity. [37] Low growth or even negative growth in consumption was expected, and competition with imports of fertilisers based on cheap raw materials had been intensified, particularly for upstream products such as ammonia, nitric acid, and phosphoric acid. In this difficult market environment, the European fertiliser industry went through major structural changes with mergers and acquisitions of companies.

In an attempt to obtain detailed information on corporate strategies and adjustment patterns in this restructuring process, we conducted interviews with six major firms, namely, Norsk Hydro, Kemira, Agrolinz, Badische Anilin & Soda Fabrik (BASF), DSM, and Imperial Chemical Industries (ICI). Based on our fieldwork, we suggest that we can identify three different corporate strategies in the restructuring process of the European fertiliser industry. The exit strategy: firms like ICI, Hoechst, and Enichem have decided to exit the fertiliser industry. These firms are relatively large and produce various kinds of chemical products other than fertilisers. These firms consider that their core competence is not in sectors based on the availability of cheap natural resources, including fossil fuels and mineral ores. Believing that the trend of declining profitability of the fertiliser business will continue, they have chosen a strategy of moving out of bulk chemicals to fine and speciality chemicals, which would require more intensive research and development.

Second, the regional orientation strategy: companies that are following this strategy include Agrolinz, BASF, DSM, Grande Paroisse, IFI, and Fertiberia. Facing fierce competition from imports from Russia and Central Europe in the case of nitrogen fertilisers, and from the North African countries such as Morocco and Tunisia in the case of phosphoric acid, their strategy is basically to secure their own local markets within Europe. There are two types of firms included in this category. On the one hand, there are large, diversified firms like BASF and DSM. Their corporate characteristics are close to those of the firms which have already withdrawn from the
fertiliser business. On the other hand, there are also relatively small, specialised firms like Agrolinz. Close relationships with local farmers are regarded as very important for pursuing this strategy in regional markets within Europe.

The third type of corporate strategy is global expansion. Norsk Hydro and Kemira have decided to go beyond the European market, which has reached maturity. One of the characteristics of these firms is that they have their own natural resource bases. Norsk Hydro possesses oil and natural gas resources, and Kemira has its own reserves of phosphate rock with low cadmium content. With their core competence in areas related to the processing of natural resources, they are pursuing vertical integration in the fertiliser business. These firms have started to make foreign direct investment in the upstream segment in an attempt to secure access to cheap raw materials, including natural gas and phosphate rock, in the Caribbean and the Middle East. At the same time, they are also shifting to production in high-demand Developing Countries, such as South Asia and China.

In addition, we would like to consider how environmental issues have influenced corporate strategies in the European fertiliser industry. Among the various sources of environmental pollution we identify major issues, including energy consumption and its related emissions of carbon dioxide, emissions of nitrogen oxides, disposal of phosphogypsum, cadmium content in fertilisers and leaching of nitrates to waters. [38] The production technologies that are used today have reached maturity and remained essentially unchanged since the late 1960s. Most subsequent innovations have focused on optimising energy and intermediate inputs needed for the manufacturing of relatively simple fertilisers. Technologies have been more or less standardised, and R&D activities are relatively limited.

In the nitrogen sector, especially in the upstream segments of the fertiliser business, for example, ammonia, the production technologies have been well established, and many specialised engineering firms can readily provide these technologies in the world market. The key is high efficiency in energy and material use for manufacturing, and it has been relatively easy to enter the fertiliser business. In this technological trend, the investment made from the mid-1970s to late 1980s was aimed at modernising old plants with more efficient processes. Since energy saving could lead to reductions in emissions such as NO\textsubscript{X} and CO\textsubscript{2}, it was possible to achieve both economic and environmental objectives with the same technological measure. However, as efficiency in energy consumption is approaching the theoretical limit, the scope for further technological progress is expected to be very limited.

Regarding reductions in NO\textsubscript{X} emissions from the production of nitric acid, various types of technologies are well established and readily available from engineering firms. Although
investment for pollution abatement normally does not produce direct economic benefits, the scale of costs required is not significant. For a new 1000 t/d plant, the capital cost of an integrated SCR unit is estimated to be around 1.5 per cent of the total, and a typical reduction in NOX emissions from 1000 ppmv to 150 ppmv using an SCR unit will add 1.1 per cent to the operating cost of the nitric acid plants. Therefore, the overall impact of NOX regulations on firm competitiveness would be relatively small. The major issue facing the nitrogen sector thus would be increasing imports based on cheap natural gas from CEE and the FSU.

In the phosphate sector, one of the most serious issues regarding process waste is phosphogypsum, which contains heavy metals such as cadmium. As we have discussed, at present there still remain technological and economic difficulties in removing cadmium from phosphate rock or phosphoric acid. One effect of environmental regulations on cadmium in phosphogypsum as well as in phosphate fertilisers is the shift in raw material use from phosphate rock with high cadmium content to that with low cadmium content. While some firms have already switched the source of phosphate rock from Togo to other countries such as Jordan and Morocco, this option may not always be possible, as the supply of phosphate rock with low cadmium content is limited.

A more significant effect of stringent regulations on phosphogypsum is firms’ withdrawal from the production of phosphoric acid. In fact, there have been several plant closures in Western Europe, and phosphoric acid production capacity and output have fallen by 60 per cent since 1980. More than 60 plants were operating in 1980 and the total production capacity was approximately 4.9 million tonnes P2O5 per year. In 1997, the number of operating plants was 11 and the total capacity has declined to about 1.9 million tonnes P2O5 per year. In 1977, there were 11 phosphoric acid plants in the UK. Now there are none. On the other hand, the average plant size has increased from 80,000 tonnes P2O5 per year to 176,000 tonnes P2O5 per year, suggesting that the decline in production capacity was mainly due to the closure of smaller units. [39]

With regard to the same issue of the cadmium content, we should underline the difference in implications between regulations on process wastes, i.e. phosphogypsum, and those on products, i.e. fertilisers. Since regulations in Europe on cadmium in phosphogypsum do not directly influence production processes of phosphoric acid in other countries, these regulations would create an advantage to exporting countries like Morocco. On the other hand, in the case of regulations on cadmium in phosphate fertilisers, the maximum concentration of cadmium, say, 60 mg cadmium per kg P2O5, has to be achieved by any fertiliser, whether it is produced within Europe or imported from outside. One consequence is that exporting countries, trying to comply with regulations on product quality, might shift the cadmium content from fertiliser products to phosphogypsum wastes.
(‘pollution shift’). While clean phosphoric acid with little cadmium content would be exported to Europe, phosphogypsum with most of the cadmium originally contained in phosphate rock would be dumped in the exporting countries.

The recent focus of environmental regulations related to fertiliser application has been on the leaching of nitrates to surface and ground waters. Increasing requirements of environmental regulation has enlarged the scope for new product innovation. The solution to the problem of excessive leaching of nitrates is product differentiation in the composition of NPK fertilisers and sophistication of products such as speciality fertilisers, which are adjusted to specific conditions such as soil, temperature, and moisture. In addition, as precision farming at the agricultural field is emphasised, customer dependence on the fertiliser manufacturer for tailor-made fertilisers, instructions about fertiliser spreading and monitoring of fields with satellite systems is increasing. Consequently, the linkage between farmers and manufacturers is likely to become closer and that would make it difficult in practice for farmers to switch from one fertiliser supplier to another. That would in effect create entry or mobility barriers against other fertiliser manufacturers.
FERTILISER INDUSTRY IN DEVELOPING COUNTRIES

During the past few decades fertiliser consumption has increasingly shifted towards developing regions. The main forces held responsible for this shift are the introduction of environmental legislation restricting the use of fertilisers in many Developed Countries and a significant growth in fertiliser demand in Developing Regions as a result of an unprecedented growth in population in most of these regions, particularly Asia. While fertiliser production started to move towards Developing Countries, export-oriented production also increasingly gained importance. Resource-oriented producers are found in those regions endowed with large reserves of natural phosphates, such as North Africa and the Middle East. Countries in these regions are developing downstream phosphate production capacity near their phosphate mines responding to the potential to exploit their abundant reserves of natural phosphates by adding value to their processed phosphates. This trend is likely to continue as the integration of mining and phosphate processing, practised in these countries, offers obvious advantages as a result of reduced transport costs by shipping highly concentrated processed fertilisers instead of phosphate rock, and economies of scale in processing as a result of vertically integrating the manufacturing process allowing for large-scale, export-oriented production.

In this section, we present the main findings of our case studies on environmental regulation and fertiliser production in two Developing Countries with large fertiliser industry, which are undergoing restructuring process driven by import penetration and market liberalisation (China and Turkey).[40] In addition, we will examine in more detail the case of Morocco, one of the leading producers of phosphate rock and the main supplier of the European fertiliser industry.[41] Finally, in our concluding remarks, we draw some policy conclusions based on our findings regarding the impact of environmental regulation on industrial restructuring and competitiveness.

Environmental regulation and the Chinese fertiliser industry

Although there are many general environmental laws in China, environmental management is mainly based on the regulations issued by State Environmental Protection Administration (SEPA). Compared to environmental laws with general provisions, SEPA regulations have more details for implementation as guidelines. A series of environmental policies and regulations suited to its national conditions, such as Environmental Impact Assessment and the Pollution Levy/Charge
system, have been implemented across the country. China has many environmental laws, regulations and standards, however enforcement is the essential problem. In the future, environmental regulation will become stricter, due to the worsening environmental conditions and the increasing environmental awareness of the population.

Since 1991, all provinces, autonomous regions and municipalities directly under the Central Government (NEPA) have carried out a pollution charge system. The Government introduced a fine, which has been standardized across the country and depends on the amount and concentration of discharged pollution. The pollution permit system is based on the volume control of pollutants, taking the improvement of environmental quality as its target; it specifies the category, quantity and the discharge course of the pollutants discharged by the enterprises, which get verified ‘permits’ for pollutants. The registration of the pollutant discharge is the base of the implementation of the pollutant discharge ‘permit’ system. The system is the quantitative specification for the pollution discharge of production units according to the existing regulations and the local situation. The registration for the pollutant discharge is universal and it must be implemented in all the pollution discharge units. The pollution permits system for air pollution control and other aspects are on trial. Indeed, a new policy on Total Emissions Amount Control is being prepared by SEPA, which is actually an extension of the pollution permit system.[42]

The main pollutants of the chemical fertiliser industry in China are described mainly as wastewater and air emissions. Limited solid waste is being produced. [43] Normally, the affected polluted areas are around the manufacturing plants. Most of the air emissions could be re-used by adding new equipment, except for dust. Coal-based plants have some additional TSP and SO2 emission problems. Natural gas and other resource-based plants have smaller problems, compared with coal-based factories. Wastewater results in extensive organic pollution of water.

The indirect environmental consequences of fertiliser products, i.e. the consequences of using chemical fertiliser, are also significant. The impact is very wide, including aquatic body pollution, decreasing soil fertility, land degradation, soil erosion, deforestation, wetland disappearance and others. The use of chemicals has contributed largely to the aquatic body eutrophication in rural China. According to researchers studying the lake Taihu and the lake Dianchi, for example, the contribution of fertiliser application to eutrophication is over 50 per cent of the total pollution effect. According to FAO, chemical fertiliser used per hectare in China was 2.6 times bigger than the world average and 3.4 times the average for Developing Countries.[44]

Chemical fertiliser firms in China are mainly small-scale nitrogen chemical plants. In every one or two counties, a small nitrogen fertiliser plant operates for the needs of local agriculture (see also.
Table 5). Small-scale chemical fertiliser plants contribute 64.5 per cent of total production. Thus, small fertiliser plants are extremely important for China. In the past, the small-scale plants only produced NH₄HCO₃ as well as a limited amount of urea. In recent years, the Chinese Government has invested in small-scale urea and ammonia phosphate plants. Up until 1996, 77 small-scale urea plants and ammonia phosphate plants were set up with a total capacity of 3.2 million tons urea and 2.47 million tons of ammonia phosphate.

Table 5: Size of China’s Chemical Fertiliser Plants

<table>
<thead>
<tr>
<th>SIZE</th>
<th>PRODUCTION CAPACITY OF PLANTS (THOUSAND TONS)</th>
<th>NUMBER OF ENTERPRISES</th>
<th>PERCENTAGE OF TOTAL CHEMICAL FERTILISER INDUSTRY ENTERPRISES %</th>
<th>ESTIMATED PROPORTION OF TOTAL PRODUCTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Large</td>
<td>About and over 300</td>
<td>22</td>
<td>1.59</td>
<td>1/4</td>
</tr>
<tr>
<td>Medium</td>
<td>Mainly 40-80</td>
<td>55</td>
<td>4.78</td>
<td>1/4</td>
</tr>
<tr>
<td>Small</td>
<td>Less 25</td>
<td>1057</td>
<td>93.63</td>
<td>1/2</td>
</tr>
</tbody>
</table>

Of which, over 70% are very small plants with capacity lower than 15,000 tons.

Source: [45]

Small-scale factories produce low-grade nitrogen and phosphates using locally developed technologies. The use of ammonia for the production of nitrogen fertilisers involves a simple technology based on anthracite coal deposits. This production process has been widely adopted in small plants. However, it is highly polluting and energy inefficient. [46] Although the volume of production of China is ranked first in the world, the productivity of Chinese fertiliser plants is very low. The overall labour productivity is only half that of Western Countries, but energy consumption is almost double that of Western Countries. The equipment for small-scale chemical fertiliser plants is mainly made in China, but the equipment of large and medium plants is imported. The age of machinery in existing plants varies: some were made in the 1990s with new technologies, but some were made back in the 1960s. The details are given in Table 6.
Table 6: Chemical Fertiliser Production Equipment

<table>
<thead>
<tr>
<th></th>
<th>LOCALLY-PRODUCED EQUIPMENT</th>
<th>IMPORTED EQUIPMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Total No. of Production Units</td>
<td>Made in 1990s</td>
</tr>
<tr>
<td>Urea Production Units</td>
<td>133</td>
<td>68.4%</td>
</tr>
<tr>
<td>Nitramines Production Units</td>
<td>45</td>
<td>8.9%</td>
</tr>
<tr>
<td>Phosphate Production Units</td>
<td>1966</td>
<td>23.9%</td>
</tr>
<tr>
<td>Potash Production Units</td>
<td>75</td>
<td>65%</td>
</tr>
</tbody>
</table>

Source: [47]

The equipment for large-scale fertiliser plants is mainly imported from the US and Europe. The following technologies of chemical fertiliser production are already widely diffused in China: US Kellogg with lower energy consumption, US Brown with deep cooling and energy saving, UK ICI-AMV and the German Wood-AMV technology. The role of local equipment suppliers before the 1990s was limited to the support of imported equipment. Since the early 1990s some Chinese equipment and technology has been used as well, but the amount is very limited. The motives behind management decisions for the adoption of cleaner technologies need further clarification. Especially in the case of simple pollution abatement equipment, demand was initially created by the introduction of regulation but the combination of simple recycling and reuse as well as energy
saving has yielded significant economic benefits that created additional demand through the ‘demonstration effect’ to other managers in rural areas. [48]

The Chinese fertiliser industry is facing pressures from the introduction of environmental regulations and has to improve its environmental performance. At the same time, clean technologies could also improve the efficiency of energy and materials consumption at the firm level. The State Economic and Trade Commission (SETC) also considers the introduction of incentives to encourage the adoption of environmental technologies. As environmental problems are becoming increasingly important, clean technology has a big potential and it will be used more and more in the future. Among the clean technologies, energy-saving applications is the most important case.

In order to promote cleaner production, SETC is also issuing some policies to encourage firms to shift to cleaner production. In the future, as in the case of the large fertiliser plants, new technology will be used, especially when it comes to low cost and high-efficiency technology. Some of these technologies will be produced domestically. In the case of new plants, production capacity should be larger than 20,000-30,000 tons of ammonia to reach economies of scale, according to SETC’s estimates. More and more technological innovations will be focused on small and medium chemical fertiliser plants, particularly in an attempt to increase the installed capacity of small plants from 40,000 tons of ammonia to 60,000 and from 60,000 to 80,000 tons. The capacity of 110,000-130,000 tons of urea per plant is also a direction of development.

Compared with large fertiliser plants, pollution abatement equipment in small plants is not as widely diffused mainly because almost all the small plants are located in counties where the environmental awareness of local people is not as strong as in urban areas and capacity for the enforcement of environmental regulations is relatively low. Pollution abatement equipment installed in small fertiliser plants are simple devices for recycling and reuse of water and air emissions as well as some equipment for noise control which are required by labour protection laws. [49] In order to improve the productivity of small chemical fertiliser plants, cleaner technologies have been introduced. For small-scale chemical plants, after the adoption of cleaner technologies, the average consumption of coal as input materials, coal as fuel and electricity are respectively 1245 kg, 298 kg and 1300 kWh, an improvement of 48 kg, 43 kg and 12 kWh respectively. For small nitrogen fertiliser plants, energy consumption per tonne ammonia is 14.48 million Kcal and 0.48 million Kcal less than before. [50]

According to the State Development Planning Commission (SDPC) and former Ministry of Chemical Industry, the policy for the development of the fertiliser industry could be divided into two areas: policy for new projects and policy for existing projects. The aims of this policy are to
establish new fertiliser plant projects with large and medium scale and to introduce incremental technological innovations for small and medium-scale fertiliser plants. Imported products with lower price and higher quality are challenging the existing chemical plants. How to improve the quality of locally produced fertilisers and reduce the production cost are the main problems to be solved by managers in existing plants. Technological innovation is an important factor in any attempt to solve these problems. For existing plants, technological innovation for small-scale fertiliser plants will be stressed. As described above, China will also adjust its structure of chemical fertiliser manufacture towards large-scale plants.

Overall, nitrogen fertilisers produced in small-scale plants dominate the structure of chemical fertilisers. The Chinese Government is implementing a policy for structural change in the sector and the aim is to shift from small to bigger size plants and from the specialisation in nitrogen to a diversified production base, which will include phosphate and potash fertilisers. The performance of most of the chemical fertiliser firms is not good enough. Ownership is one of the main reasons. The Government, by either central or provincial government, owns all of the chemical fertiliser firms. At present, small-scale fertiliser plants are in a very difficult position. In the fertiliser market, imported high-quality fertilisers and large-scale domestic plants challenge them, and some of them have already been bankrupted. They are also facing pressures from the introduction of stricter environmental regulations due to increasing environmental concerns. [51]

**Environmental regulation and the Turkish fertiliser industry**

Turkey has a well-developed fertiliser industry. At present, there are six major fertiliser-producing firms in the local market, including two private firms. Due to high domestic demand and export possibilities to neighbouring countries, Turkey still needs new investment in the fertiliser industry. Local demand is expected to increase in the next five to ten years, particularly due to the Southeast Anatolia Project (SAP), which will increase demand by 25 per cent. When this project is completed, it will increase arable land in Turkey by 1.7 million hectare. By 2005, 55 per cent of the project has been planned to finish and this will add 894,000 hectares of land into agricultural production. [52]

In terms of consumption, nitrogen fertiliser is the most important among all fertiliser products. At 631,000 tons, nitrogen consumption was 53 per cent of all consumption in 1976, which increased to 1.148 million tons in 1996, corresponding to 64 per cent of all consumption. P consumption increased slightly from 522,000 tons in 1976 to 578,000 tons in 1996. The consumption of K is supplied by imports. Although the consumption of K increased 255 per cent in terms of *volume*, its 1996 level is only 74,000 tons, representing only 0.04 per cent of total fertiliser consumption. [53]
The volume of imported fertilisers is increasing, especially in the area of compound fertilisers. Our analysis of import trends at the four-digit SITC 3 level points out to an increasing market penetration by European exports in this area of fertilisers. [54]

The Turkish fertiliser industry is highly dependent on imported raw materials and energy. This is one of the main handicaps for the competitiveness of the industry. Many domestic resources, however, can be utilised and the State Planning Organisation tries to supply incentives for firms to invest in these areas. The imported energy cost is very high in Turkey compared to many Developed Countries. Local firms have been pressing the Government for cheaper energy prices. Energy prices are undermining the competitiveness and any potential for exports by Turkish fertiliser companies. In fact, energy savings appeared to be one of the main considerations for new technological investment by Turkish firms.

The overall analysis of firm management practices reveals that they do not have any formal environmental policy at the firm level. More importantly, many of them do not plan to have environmental policies either. As Turkish fertiliser firms tend to respond only to regulations, the starting point for any policy should be to transform this management culture. This, however, requires not only training of firm management in environmental issues but also increasing customer pressure that will demand environmentally-friendly products. In the case of fertilisers, farmers who have limited resources and low levels of education could be a problem. That is why the Government’s agricultural policy plays a crucial role in forcing fertiliser firms from the demand side as well as from regulation side.

At the Government level, there is significant work being done in regulating the environmental impact of the fertiliser industry. Only the solid waste issue, namely the disposal of phosphogypsum, is not dealt with from the regulation point of view. Although there is considerable success in terms of preparing regulations, as indicated by the authorities at the Ministry of the Environment (ME), there are problems regarding their enforcement. In our study, both government institutes and firms complained that the laws are not applied evenly to all local producers. On the one hand, private firms argue that state companies often do not pay fines for pollution, because they are either too poor or else politically too powerful, and the logic is that it is the same budget anyway. On the other hand, state-owned firms argue that private firms have more flexibility in being able to avoid fines because they can use other means (by securing the support of local officials or buying the land of complaining farmers) to solve disputes. As the aim is to change the attitude of firms towards the environment, the ME should make it clear that firms cannot get away with their pollution and they will be all equally punished.
Although the Government liberalised the fertiliser market in 1987 and allowed private firms to trade fertilisers, it still keeps control of its marketing and distribution organisation. This organisation is still an intermediary between farmers and fertiliser firms since its members consist of 40 per cent of all farmers in Turkey. The Government first buys fertilisers from producers at open bids, it then adds charges on top of that price and then reduces the price by the subsidy amount (40 per cent of the final price) and sells them to its members through the intermediary organisation. This system looks quite problematic, since having such an intermediary organisation increases prices.

Despite the private firms’ exaggeration of the difficulties created by state intervention, it is true that Government intervention as a fertiliser producer and distributor prevents the healthy development of the industry, particularly its technological development. Government forces state-owned firms to operate irrationally in many ways, and as these firms constitute the majority of the market it affects the whole industry. First, state-owned fertiliser firms are not allowed to invest due to political concerns although these firms want to. For example, a state-owned firm wanted to invest in a new ammonia plant in the Izmit region. It aimed to invest $150 million for a capacity of 550,000 tons of ammonia. It was calculated that this production would each year save $40 million of otherwise imported ammonia. The Turkish Government, however, did not approve this investment due to privatisation discussions. Not only long-term and short-term plans but even urgently needed investments are not approved, since none of the political parties want to commit resources to the industry.

Our case study analysed three influential ministries and three research institutes as well as five Non-Governmental Organisations (NGOs). Our observations show that although environmental issues are new in Turkey, a few very professional institutions are active in the area. While government institutions are creating the legal framework for environmental regulations and standards, NGOs are focusing more on the organisation of interest groups around the issue of increasing environmental awareness. Both streams of developments are new but promising. The Turkish case study provides some illuminating insights on the links between environmental regulation and fertiliser manufacturing in Developing Countries. The impact of environmental regulation on production cost and investment decisions is still rather limited to investment incentives and small additions of end-of-pipe equipment in existing plants. However, the regulatory framework and the existing distribution network are the main inertia for new investment in the local fertiliser industry. [55]
Phosphate fertiliser production in Morocco

Phosphate fertiliser production has been concentrated in Developed Countries, mainly in the US and Western Europe, for many years. This has been justified not only by their level of industrial development, but also by the large scale of domestic demand. However, while the US phosphate fertiliser industry was using domestic phosphate rock deposits, the European industry was dependent on imports of phosphate rock. These imports initially came from the US, as it was the only country exploiting its phosphate rock reserves on a large scale. Over the past three decades, though, the US has been losing market shares in Western Europe to emerging suppliers from Developing Countries. This trend marks the beginning of an increasing involvement of Developing Countries in the global phosphate industry. Initially this involvement was restricted to exports of phosphate rock, but they eventually expanded into the production of processed phosphates. [56]

The emergence of phosphate fertiliser production in Developing Countries has changed the geographical pattern of trade in basic materials, intermediates and finished phosphate products. For many years, phosphate rock was the main item that was being exported to processing plants in major consuming countries. Over the last two decades, however, trade in processed phosphates has increasingly replaced phosphate rock trade and the processing of natural phosphates is being reallocated near mining sites. The main destinations for phosphoric acid exports is Western Europe, where most phosphoric acid plants were closed down for economic and environmental reasons, and India, which uses phosphoric acid for its phosphate fertiliser plants. The main exporters of phosphoric acid are Morocco, Tunisia and the US. [57]

An important feature of export-oriented production in Developing Countries has been the growth of state-owned enterprises (e.g. OCP in Morocco and JPMC in Jordan). This is due to the strategic importance of the industry and the large capital outlays required for fertiliser production, which often called for considerable government assistance. Without this active support, investment opportunities may fail to be transformed into viable projects for fertiliser production in these countries. An alternative way of stimulating domestic fertiliser production has been to attract foreign direct investment in the form of joint ventures. Although investments by transnational corporations in fertiliser production in Developing Countries have been quite limited, it has been important in some countries with sufficient resource endowments to support a substantial export-oriented industry. [58]

Because Morocco owns about two-thirds of the world’s reserves of phosphate rock, its chemical industry is dominated by downstream phosphate chemicals. The main products manufactured are
phosphoric acids and phosphate-based fertilisers. Morocco is Africa’s leading producer and the world’s largest exporter of phosphate rock and phosphoric acid. In the 1960s Morocco decided to start processing an increasing part of its phosphate rock locally in order to satisfy both the domestic and export market demand for fertilisers. The Office Cherifienne des Phosphates (OCP) has implemented a series of projects in the field of the processing of phosphate rock and managed to become one of the leading world exporters of phosphoric acid. In 1997 OCP’s share of the world export market amounted to 37 per cent, while Mexico and the US between them accounted for over 30 per cent, as did Western Europe. OCP is currently undertaking an ambitious investment programme worth more than $1.39 billion, which will strengthen its phosphate processing capacity with the expansion of existing mines, through the ‘debottlenecking’ of existing units at Safi and Jorf Lasfar and the development of new plants as new joint-ventures with foreign partners.

In 1996, OCP started a joint venture known as EMAPHOS (Euro-Moroc-Phosphore) together with Prayon-Rupel and Germany’s phosphates company, Chemische Fabrik Budenheim. The plant is based on Prayon technology and is one of the largest of its kind worldwide. They built a production unit at Jorf Lasfar for pure phosphoric acid, with a capacity of 130,000 t/a P₂O₅. OCP is supplying the phosphoric acid for the plant from its Jorf Lasfar facilities. Budenheim takes two-thirds of the output, whilst Prayon and the US company, Solutia, take most of the remaining tonnage. Within the context of this joint venture OCP is also looking into the possibility of establishing a sodium tripolyphosphate plant at Jorf Lasfar. [59]

Another joint venture between OCP and the Indian company Chambal Fertilisers was scheduled to start up in July 1999. The joint venture is a 50:50 split between OCP and Chambal and involves the construction of a 330,000 t/a P₂O₅ merchant grade phosphoric acid plant, using Prayon technology, with associated sulphuric acid production facilities, using Monsanto’s double absorption technology. At a design capacity of 3,200 t/d the sulphuric acid unit will be the largest Monsanto unit in existence. Two-thirds of the acid produced by the plant will be taken up by Chambal. [60]

OCP employs 27,235 people including 700 engineers and other professionals. OCP has invested in the debottlenecking of the complex’s eight 500 t/d P₂O₅ lines, which are based on Rhône Poulenc’s single dehydrate process with a double gas scrubbing system. Two of them have already been completed and the end of 2000 a further two will also be completed. The increased output resulting from the debottlenecking will be used to support downstream production at Jorf Lasfar, both in already operating plants and in the new joint-venture plants. Once the debottlenecking of the remaining phosphoric acid lines is completed, OCP plans to revamp the six existing sulphuric acid units in order to meet increasing demand. [61] Some of the sulphuric acid demand may well be met
by imported product, as OCP has recently constructed receiving and storage facilities for sulphuric acid at the port of Jorf Lasfar. This forms part of OCP’s new strategy to further diversify sulphur procurement options; the company has also begun to import liquid sulphur for the first time. OCP’s current annual sulphur requirements amount to more than 2.7 million t/a, which traditionally have been met with imports of solid sulphur. Jorf Lasfar alone accounts for 1.4 million t/a, and requirements are rising as phosphoric acid production has been increasing.

The state of environmental regulation in Morocco is in sharp contrast to the situation in Europe. In Morocco, there are numerous valid laws that are being applied. However, these laws only refer to products and none of these norms belong to the category of what we would call environmental regulation of the production process. In short, we can conclude that besides hygienic norms and those related to products, which are of direct consequence to the environment, there is lack of any environmental regulation. The technical resources to monitor compliance with these norms are limited. A number of environmental laws are in the process of being promulgated. They particularly concern air quality, effluents, solid wastes and environmental impact assessments. Furthermore, the ministerial department responsible for the environment, established in 1994, has chosen a strategy of consultation with industry instead of a command-and-control strategy. Norms will be executed at a sectoral level and determined after consultation with the mediators in the sector concerned. In the case of the phosphate industry, the commission will consist of people representing the Department of Environment and people acting on behalf of OCP.

The environment has a high priority for OCP, especially when it comes to the technical standards of new investment. In setting up its mining and processing operations, including the choice of technology and equipment and during their operation, OCP always takes into account the protection of the environment. As such, a great deal of the current investment made at Safi is aimed at reducing emissions, particularly concerning improvements in primary filtration and effluent washing. The phosphogypsum produced at the Safi and Jorf Lasfar complexes is washed before it is disposed into the sea to disposal points which have been chosen to take advantage of the best currents in order to ensure material is carried away from the shoreline. Having said that, we should point out that there is no limit of the cadmium per tonne of phosphogypsum disposed into the sea. With regard to cadmium, OCP’s R&D subsidiary has also developed a decadmiation process, which it is improving with support by the World Phosphate Institute and the EU. Earlier this year, OCP signed a partnership agreement with the Moroccan Government aimed at further reducing emissions at phosphate operations, and began the construction of an air quality laboratory at Jorf Lasfar.
In the long run, the phosphate industry in Morocco will have to adjust to the internationally evolving norms and standards concerning the phosphate industry through the introduction of new technologies. OCP is being confronted with an evolution of European legislation towards increasingly restrictive specifications in terms of product quality. Examples include the norms regarding heavy metals (like cadmium), the natural radioactivity and the phosphates in detergents. If this development is going to spread among all the countries of the EU, it could seriously destabilise the market for phosphates and its downstream products, and while doing so, the economies of a large number of countries including Morocco. One other consequence is that Morocco and other phosphate exporters from Developing Countries trying to comply with regulations on product quality might shift the cadmium content from fertiliser products to phosphogypsum wastes (‘pollution shift’). While clean phosphoric acid with little cadmium content would be exported to Europe, phosphogypsum with most of the cadmium originally contained in phosphate rock would be dumped in the exporting countries.

This perspective has led to two different responses among export-oriented phosphate fertiliser producers. One of them is research into decadmiation technologies for phosphoric acid. Although several processes are shown technically applicable, their cost is the primary constraint. The most interesting project is currently under development at OCP and is jointly financed by the EU. However, due to the increased operating costs involved in decadmiation, a shortage of phosphate rock with a low cadmium content and a subsequent price increase is regarded as a requirement before any commercial decadmiation could take place at a large scale. The other response is to discontinue exports to those countries in which cadmium limits are prohibitive and look for other markets with less restrictive or even no cadmium regulation for example in Asia. This has already led to the formation of many joint ventures between newly emerging export-oriented producers such as Morocco and Jordan, and Asian countries like India, Pakistan and Japan. Some Asian countries either supply themselves with finished fertilisers, as in the case of Japan, or they secure their supply of phosphoric acid to feed their domestic production base, as in the case of India.

OCP’s intentions for the marketing of downstream products after its inauguration of further downstream phosphate capacity at Jorf Lasfar, which enhanced its ability to supply key markets at a favourable price, complicated the outlook for \( \text{P}_2\text{O}_5 \) production in Western Europe. Morocco is endowed with over three-quarters of the world’s known phosphate reserves. This is an important source of the country’s wealth. When Morocco began to develop its downstream capability, initially in the form of phosphoric acid, OCP was careful not to provoke any hostile reaction from the established Western European \( \text{P}_2\text{O}_5 \) producers, which could have jeopardised the Moroccan move
into higher added-value markets. OCP continued supplying several Western European phosphoric acid producers which had under-utilised capacity. By choosing not to undercut the Western European phosphate manufacturers in their home market, OCP acknowledged that its long-term interests would be better served by working in close collaboration with European phosphate manufacturers. Also on the side of the Western European phosphate manufacturers, there was a continuing preference for close contacts with raw material suppliers who could potentially be strong competitors in the downstream markets. [62]

These developments suggest that Western European producers, instead of trying to preserve market share at all cost, chose to specialise in sectoral niches where their competitive advantage could remain unchallenged. This essentially meant that regional production of phosphoric acid became increasingly confined to those producers that still enjoyed exceptionally favourable unit costs or managed to secure long-term preferential agreements with phosphate rock suppliers (for example the OCP-Grande Paroisse joint venture). At the same time, OCP and other North African phosphate rock producers have their own interest in ensuring that a downstream P₂O₅ sector will survive in Western Europe.
CONCLUSION AND POLICY IMPLICATIONS

The findings of the paper have a number of implications for the policy debates on trade and environment. As far as trade policy is concerned, our research suggests that it is often firms and industries that are under considerable competitive pressures for other reasons that find it most difficult to deal with stricter environmental regulation. The world fertiliser industry has gone through major changes. It started with the emergence of significant fertiliser production capacity in Developing Regions. For some of these regions, mainly Asia, this was pure necessity as they were under pressure to meet increasing domestic demand for fertilisers, which resulted from an unprecedented growth in population in these countries. The main conclusion of the Chinese and Turkish case studies in this report is that the development of fertiliser production in these countries is primarily targeting the domestic market. Other regions endowed with substantial phosphate rock reserves, like North Africa and the Middle East, responded to the potential benefits of export-oriented production of phosphates. Initially these exports were limited to phosphate rock, but as these Developing Regions created the required technological capability, they also moved downstream into the production of processed phosphates. Therefore, exportable surpluses of phosphate rock from these regions decreased in favour of processed phosphate exports.

However, the increasing importance of resource-processing fertiliser producers from Developing Countries is evolving in parallel with further specialisation of producers in Advanced Countries in specific segments of the industry (Nitrogen products and high value-added products). Individual firms have also demonstrated an increasing focus in developing further their links with the farmers. These factors provide the explanation for the survival and indeed, in some cases, further expansion of fertiliser manufacturers from Advanced Countries. They have implemented long-term restructuring strategies based on the technical characteristics of the production process of specific segments in the fertiliser industry that provided opportunities for capital deepening and for the introduction of energy-efficient environmental technologies. This investment process was supported with product innovation in better quality fertilisers and organisational innovation with the improvement of customers’ support. The introduction of environmental concerns was an integrated part of the design of new products because, apart from the enforcement of environmental regulation, these products were targeting a market with increasing concerns about the environment.
Facing stagnating demands for fertilisers and increasing pressures from cheap imports, the European fertiliser industry has been going through a significant restructuring process. At the same time, five major environmental issues have influenced technologies in the industry, namely, improvement in energy consumption in ammonia production, reduction in nitrogen oxides emissions from nitric acid production, disposal of phosphogypsum, cadmium content in fertilisers and leaching of nitrates from agricultural fields. Under the circumstances of rising competition from abroad and stagnating demand in the European fertiliser industry, there has already been an increasing focus towards the downstream segments of the sector. Overall, it seems that environmental regulations have influenced some firms in ways in which the pursuit of their corporate strategies is reinforced and strengthened. The increasing difficulties of the disposal of phosphogypsum have induced firms to withdraw from phosphoric acid production. At the same time, the requirement to limit the leaching of nitrates to waters has encouraged firms to pay particular attention to product quality and differentiation and to seek closer ties with farmers. In particular, environmental regulations on fertiliser products and their application have created close producer-user relationships between farmers and local fertiliser manufacturers, which is becoming an effective ‘mobility barrier’ against new entrants to the European fertiliser market. Firms in the European fertiliser industry are pursuing different corporate strategies. Several have already exited from this bulk chemical sector and shifted their focus to high value-added, fine and speciality chemical segments. Some others are concentrating on local markets, while there are also firms that are actively expanding their business globally. The firms that have remained in the fertiliser industry are pursuing corporate strategies of moving from the upstream to downstream segments of this sector, trying to turn environmental issues to their business advantage.

The competitiveness of Developing Countries in the fertiliser industry depends on a different set of factors, i.e. endowments of resources, labour costs, protected markets and distribution networks and environmental regulation. It is evident from the case studies in China, Turkey and Morocco that we need to take account of all these factors for the assessment of market trends and the evolution of fertiliser production in Developing Countries. The role of Government-owned distribution networks, for example, is extremely important in these countries because it effectively determines access to the local market. [63]

Environmental regulation is only one factor in this process and in many cases its contribution is smaller than other factors. This observation has some broader policy implications when it comes to the role of international institutions and other initiatives for the enforcement of environmental regulation. It is very difficult for these initiatives to exercise significant influence on the production
processes of polluting industries in Developing Countries when these industries are targeting the domestic market. The distinction is very clear in our case studies. Morocco, with its export-oriented production capacity, is trying to respond to the stringent environmental regulation, which is being introduced in the EU. That is obvious because this is its main export market. In contrast, fertiliser firms in China and Turkey are much more reluctant to take any initiative for the introduction of cleaner technologies because they don’t foresee any risk in the domestic market that in fact is their main market.

Finally, that brings us to the challenges regarding the introduction of cleaner technologies in Developing Countries. One of the main conclusions of our fieldwork is that we could start thinking about two areas of problems and, consequently, policies to respond to these challenges. The first set of issues refers to existing production capacity. Usually these are old and heavily polluting plants, without efficient environmental management, producing for the domestic market (in most of the cases for the regional market). The introduction of cleaner technologies is limited to ‘end-of-pipe’ technical equipment and some improvements in energy efficiency. At the same time, better housekeeping and other organisational changes provide opportunities for significant improvement of environmental standards. The potential for more radical improvement is in the second area of problems, which is new investment in fertiliser production capacity. The Developing Countries case studies indicated that they are building up their production capacity in the fertiliser industry. The introduction of environmental regulation and the adoption of specific requirements for cleaner technologies in investment grants or subsidies, especially when they come from international financial institutions, have influenced the decision-making process during the implementation of new investment projects in the fertiliser industry in Turkey and, to some extent, China also.

As this paper has shown, the characteristics and sources of pollution, and consequently the environmental technologies to deal with it, are very much sector-dependent. Our sectoral studies provide detailed information about what kinds of environmental technologies are actually used and what implications their introduction has for the competitiveness of industry in Advanced and Developing Countries. We should emphasise here, however, that additional comparative research is needed that will examine how ‘sustainable development’ can be achieved by analysing the incentives to introduce cleaner technologies and the behaviour of industry at the micro and sectoral level. By considering the feasibility of incremental improvements in existing production processes, we could find out how long we can continue utilising already established production processes and what needs to be modified further with more radical innovations. This is an important consideration
for the design of a realistic policy, which could facilitate the improvement of existing production capacity and the introduction of environmentally-sound technologies in the fertiliser industry.

It should also be remembered that the purpose of environmental regulation is to prevent excessive environmental damage. Thus reduced competitiveness in a particular industry leading to a reduction in the output of that industry is not necessarily a bad thing. It may indeed be desirable to reduce the output of an industry that causes considerable environmental damage, since this can raise overall welfare when negative external effects are taken into account. This conclusion is reinforced when it is recognised that reduction in output in one industry as a result of environmental regulation leading to reduced competitiveness may, in a general equilibrium context, lead to increased output from other industries which cause less environmental damage. There is a danger that by focusing on the effects of regulation on competitiveness in particular industries, the negative impacts at the macro level will be exaggerated.
REFERENCES AND NOTES

[1] This paper was prepared as part of a three-year EU funded project on Environmental Regulation, Globalization of Production and Technological Change. It draws on four background reports: a report on the European fertiliser industry [Bartzokas, Anthony and Masaru, Yarime (1999), Environmental Regulation and Corporate Strategies in the European Fertiliser Industry, UNU/INTECH Background Report No. 21, June 1999]; the Chinese fertiliser industry [HuTao, Tom (1999b), Environmental Regulation, Globalisation of Production and Technological Change in the Fertiliser Industry: a case Study of China, UNU/INTECH Background Report No. 24, October 1999]; the Turkish fertiliser industry [Çetindamar, Delik (1999), The Impact of Environmental Regulations on the Turkish Fertiliser Industry, UNU/INTECH, Background Report No. 16, April] and the world phosphate industry [Demandt, Ivo (1999), The World Phosphate Fertiliser Industry, UNU/INTECH Background Report No. 10, July 1999]. These studies have reported the research findings of interviews with fertiliser manufacturers, industrial associations, technical experts, regulators and policy makers in Europe, China, Turkey and Morocco. Our research benefited from discussions with project partners and other colleagues in several project workshops. Special thanks to Rhys Jenkins for his comments and suggestions on earlier drafts of this paper. However, I am responsible for any remaining errors and omissions.


[7] European Fertiliser Manufacturers Association (EFMA) (1995g), Best Available Techniques for Pollution Prevention and Control in the European Fertiliser Industry, Booklet No. 7 of 8: Production of NPK Fertilisers by the Nitrophosphate Route, Brussels: EFMA.

According to industry sources, modern, sophisticated technology could provide the farmer with new opportunities to adjust the application of nutrients to the needs of crops and to the potential crop yield. Examples of measures in which the European fertiliser industry is involved include:

- Advanced advisory computer programmes for fertiliser planning, which take account of inputs from all fertiliser sources, organic as well as inorganic, application techniques, good fertiliser practice and local regulations;
- Precision farming, which uses satellite communication and detailed field and crop information to improve farm operation and nutrient efficiency by means of the site-specific application of fertilisers;
- Integrated crop management, which is a comprehensive system of modern farming husbandry that balances economic production with environmental responsibility. The system seeks to integrate improved crop nutrition, crop protection techniques, soil management, and crop rotations to maximize energy efficiency; and
- Development and promotion of soil analysis and crop deficiency diagnosis to facilitate the fine-tuning of fertiliser rates to actual crop requirements [European Fertiliser Manufacturers Association (EFMA) (1997b), The Fertiliser Industry of the European Union: The Issues of Today, the Outlook for Tomorrow, Brussels: EFMA].


[34] IFA (1999), *Fertiliser Indicators*, Paris: IFA.


[39] Poulet, Jean-Michel, *The Phosphoric Acid Production in Western Europe*, Paper presented at the IFA Production and International Trade Committee Meeting, Warsaw, Poland, 14-15 October (1997). Recent examples of plant closures include the closure of a plant of Societe Chemique Prayon-Rupel in Belgium in 1992 because its phosphogypsum landfill permit has been cancelled by the Flemish authorities, the closure of a plant of Kemira in Rotterdam in 1992, the closure of a plant of BASF in Antwerp in 1993 because of stricter regulation on phosphogypsum disposal and the closing down of a plant of Hydro Agri in Rotterdam at the end of 1999, citing the environmental regulation on phosphogypsum as a major reason for the decision.


[42] There are many regulations relevant to the fertiliser industry. Direct regulations are the following. Emission standards of waster water special for chemical industry (code: GB13458—92)
and Emission Standards of Waste Water special for Phosphate Fertiliser Industry (code: GB15581—95), which are issued by NEPA and the State Technical Supervision Bureau, see NEPA [NEPA and State Technical Supervision Bureau (1992), Water Emission Standards for Synthesis Ammonia Industry (GB13458-92) and NEPA and State Technical Supervision Bureau (1995), Water Emission Standards for Phosphate Fertiliser Industry (GB15580-95)].


[54] The market share of European companies when it comes to compound fertilisers imports in Turkey has increased from 70 per cent in 1993 to 85 per cent in 1998 (own calculations, UNCTAD COMTRADE Data Base).


[59] Lin, I. J. and Michael S. (1997), ‘A challenge for the phosphate industry: Cadmium removal’, *Phosphorus & Potassium*, (208), 27-32. For a general discussion on these trends, see Heerings, H. (1993), ‘The Role of Environmental Policies in Influencing Patterns of Investments of Transnational Corporations: Case Study of the Phosphate Fertiliser Industry’, in OECD, *Environmental Policies and Industrial Competitiveness*, 113-119. Traditional phosphate producers, e.g. Norsk Hydro, have been engaging in joint ventures in North Africa or the Middle East. The intentions of these joint ventures are of a completely different nature. Unlike the aims of joint ventures by Asian countries, the output of joint ventures by traditional phosphate producers has no guaranteed markets and is marketed on world export markets. As such these joint ventures are a way of relocating the production process to regions in which phosphate production is more cost-efficient.


[61] In 1997, a shortage of phosphoric acid due to the very high demand for acid in the company’s export markets, particularly India, led to the company running its TSP facilities at reduced capacity.

[62] An interesting example along these lines is the case of the Dutch group DSM, which wanted to form a 50:50 joint venture with OCP in September 1987. The co-operative arrangement centred on DSM’s complex at Pernis, where OCP would supply phosphate rock and DSM ammonia for the production of APs, which would have been marketed by the joint-venture company. The problem of dumping phosphogypsum with high cadmium content delayed the implementation of the scheme. By the time a compromise was reached with the Dutch Government, the Kemira proposal involving a sale to Kemira of DSM’s Dutch and UK phosphate facilities, in exchange for Kemira’s stake in the DSM Geleen ammonia plant, proved more attractive [based on field work interviews, see Demandt, Ivo (1999), *The World Phosphate Fertiliser Industry*, UNU/INTECH Background Report No. 10, July 1999].

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