The American Antitrust Institute

# THE FERTILIZER OLIGOPOLY: THE CASE FOR GLOBAL ANTITRUST ENFORCEMENT

**C. Robert Taylor and Diana L. Moss**

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**ABSTRACT**

Fertilizers are a critical input in the agricultural sector where industrial farming is heavily dependent on external inputs of nitrogen, phosphorus, and potassium or potash. A history of supra-competitive pricing by the few, large global producers of fertilizer inputs – coupled with characteristics that make the market conducive to anticompetitive coordination (i.e., collusion) – raise significant competitive concerns. This working paper qualitatively and quantitatively analyzes the exercise of market power by members of the U.S. and Canadian government sanctioned export associations, *PhosChem* and *Canpotex,* from 1998-2012. The first part of the paper provides relevant background on the role of fertilizer in industrial food production systems, examines the structure of the global fertilizer industry, and reviews limited antitrust immunity for export associations under the U.S. Webb-Pomerene Act. The latter half of the paper examines indicators that large global fertilizer producers have acted collusively to exercise market power. One part of this analysis focuses on anecdotal evidence of collusion and the disruption in pricing recently induced by the exercise of countervailing market power by powerful fertilizer buyers. A second part of the analysis relies on economic modeling and estimation of dynamic Lerner indices – a well-known measure of market power. The overall analysis supports the notion that fertilizer producers have likely acted in a coordinated fashion to raise prices, to the detriment of competitors and consumers. The paper concludes with a number of major observations that emphasize the need for concerted, organized competition enforcement action.

Keywords:

fertilizer, agriculture, production, manufacturing, industry studies, pricing, market structure, firm behavior, concentration, competition, anticompetitive coordination, collusion, cartel, monopoly, oligopoly, econometrics, antitrust, international business, multinational firms, government policy and regulation, antitrust law

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C30 - Multiple or Simultaneous Equation Models; Multiple Variables: General
C51 - Econometric Modeling: Model Construction and Estimation
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D4 - Market Structure and Pricing
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D43 - Oligopoly and Other Forms of Market Imperfection
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Q13 - Agricultural Markets and Marketing; Cooperatives; Agribusiness
Q18 - Agricultural Policy; Food Policy
Q56 - Environment and Development; Environment and Trade; Sustainability; Environmental Accounts and Accounting; Environmental Equity; Population Growth

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## PREFACE

The American Antitrust Institute (AAI) is an independent non-profit organization based in Washington D.C. with a mission to increase the role of competition, assure that competition works in the interests of consumers, and challenge abuses of concentrated economic power in the American and world economy. Through its education, research and advocacy work, the AAI provides valuable legal and economic information, analysis, and perspective on U.S. and international antitrust law, litigation, and legislation, with a particular focus on the effects of anticompetitive practices on consumers. Our website is www.antitrustinstitute.org.

This important and highly relevant monograph by C. Robert Taylor and Diana L. Moss examines the troubling competitive problems in the U.S. and global fertilizer markets. It provides a background picture, valuable qualitative and quantitative analysis and evidence, and a call for antitrust enforcement action regarding potential anticompetitive coordination among global fertilizer producers that has harmed both competition and consumers. We believe the analysis will be helpful to government officials, the industry, the media and public interest activists in the face of further current and anticipated movements in the direction of economic concentration and abusive firm conduct in fertilizer markets. Reform will not be easy. Re-examination of the legal status of export cartels will be needed and the efforts of multiple jurisdictions may be required, in the face of strong political and economic interests.

C. Robert Taylor is Alfa Eminent Scholar of Agricultural Policy, Auburn University and member of the Advisory Board of the AAI. Professor Taylor is an economist with particular expertise in agricultural commodity and input markets. Diana L. Moss is Vice President, AAI. An economist, Dr. Moss specializes in antitrust and regulation with a focus on energy, agriculture, transportation, and healthcare, among other areas. Although this monograph has been read in draft form by several experts inside and outside AAI (and their comments taken into account), it of course represents Professor Taylor's and Dr. Moss's own work and does not necessarily reflect the views of any individual members of the Board of Directors or the Advisory Board. Having said that, we all salute Professor Taylor for his long-term focus and fine work on this industry and Dr. Moss for helping bring the pieces together under the auspices of the AAI.

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# THE FERTILIZER OLIGOPOLY: THE CASE FOR GLOBAL ANTITRUST ENFORCEMENT

**C. Robert Taylor and Diana L. Moss**[1]

## I. INTRODUCTION

Fertilizers are a critical input in the agricultural sector. Industrial farming in much of the world is heavily dependent on external inputs of nitrogen, phosphorus, and potassium or potash. Following an industry shakeout from 1998 to 2004, fertilizer prices increased dramatically in 2008. High prices persisted for several quarters, dipped in 2009, and have since returned to supra-competitive 2008 levels. The fertilizer industry has, and continues to be, marked by considerable excess capacity. At the same time, large buyers of fertilizer such as China and India are becoming increasingly powerful, putting downward pressure on high prices. Earlier in 2013, the decision of key eastern European potash producers to refuse to deal with such buyers or cut their prices has caused significant disturbance among global producers, with falling profits industry-wide.

The foregoing pattern raises a number of questions about the dynamics of supra-competitive fertilizer price increases and profits. Price setting appears to have been the dominant strategy in 2008, shifting to supply cutbacks in 2011 in order to strengthen and maintain prices, particularly with major customers. This was followed by apparent defections from tacit or explicit agreements among global potash producers in mid-2013. Such defections and the subsequent

[1] C. Robert Taylor is Alfa Eminent Scholar of Agricultural Policy, Auburn University and Diana L. Moss is Vice President, American Antitrust Institute. Constructive suggestions by John Connor, Steve Martin, Phil Nelson, James Francisco, and Bert Foer are gratefully acknowledged. Many thanks also to AAI research fellows Jipil Choi and Marcus Epstein for valuable assistance. The AAI is an independent Washington D.C.-based non-profit education, research, and advocacy organization. AAI's mission is to increase the role of competition, ensure that competition works in the interests of consumers, and challenge abuses of concentrated economic power in the American and world economies. See www.antitrustinstitute.org for more information.

breakdown in any tacit or explicit agreement among producers should be a strong signal that anticompetitive coordination has been at play. In such situations, economic analysis also explores the possibility of non-cooperative oligopoly behavior. An analysis of collusive behavior would also examine the possibility of regional cartels or a global "super" cartel among fertilizer producers, or the more complex interaction between cabals, government sanctioned export cartels, and governments themselves. Regardless of the explanation, high fertilizer prices inflict damage on growers of crops and livestock worldwide and, ultimately, consumers themselves through higher food prices.

Collusive agreements between fertilizer producers on prices and market shares pepper the history of the global commercial fertilizer industry dating back to the 1880s. The underlying structure of the current global industry remains conducive to anticompetitive coordination – a landscape that undoubtedly prompted Wall Street Journal commentators to observe that fertilizer markets are so manipulated, "they might make a Saudi prince blush,"[2] and "the global price sets a benchmark so American farmers pay essentially what the cartels dictate."[3] Indeed, the global industry is dominated by two government-sanctioned export associations in the U.S. (*PhosChem*) and Canada (*Canpotex*); a privately traded monopoly sanctioned and likely controlled by the Moroccan government (Office Chérifien des Phosphates (OCP)); and a cabal of three potash companies in the former Soviet Union (Belaruskali, Silvinit, and Uralkali, operating through their marketing cartel, Belarusian Potash Company (BPC)).[4] Governmental involvement amplifies the

[2] Tom Philpott, *The WSJ on fertilizer markets so manipulated, they might make a Saudi prince blush*, GRIST (May 31, 2008, 2:23 AM), http://grist.org/article/industrial-ag-onistes/.

[3] Lauren Etter, *Lofty Prices for Fertilizer Put Farmers in a Squeeze*, WALL ST. J. (May 27, 2008), http://online.wsj.com/article/SB121184502828121269.html.

[4] The current web page for Belarusian Potash Company (BPC) states that it is a "sole supplier of potash fertilizers manufactured by JSC (The Republic of Belarus) and JSC Uralkali (the Russian Federation)." BELARUSIAN POTASH COMPANY, http://www.belpc.by/en (last visited Aug. 14, 2013).

problematic nature of the competitive problem in fertilizer markets. Reports indicate that the Belarusian government "skims" Belaruskali's high profits, a response that is not fundamentally different from the Canadian government's support for maintaining *Canpotex* because high prices generate commensurately high tax revenues.[5]

Frederic Jenny and Eleanor Fox note that sanctioned export-cartel exemptions and the implicitly sanctioned Russian potash cabal are flagrant manifestations of a "beggar thy neighbor" approach to competition law.[6] Supra-competitive fertilizer prices initially harm farmers and quickly translate into higher food prices throughout the world. Because this problem raises related strategic, food sustainability, and environmental issues for the U.S. and other countries, it transcends traditional competition policy concerns. Despite strong evidence of potentially anticompetitive behavior and consumer harm, however, antitrust authorities throughout the world have done little on the enforcement front.

This working paper qualitatively and quantitatively analyzes the exercise of market power by members of *PhosChem* and *Canpotex* from 1998-2012. It begins in Section II by explaining the importance of fertilizer in industrial food production systems. Section III examines the structure of the global fertilizer industry. Section IV discusses limited antitrust immunity for export associations under the U.S. Webb-Pomerene Act of 1918 (Webb-Pomerene). Section V examines qualitative evidence of anticompetitive behavior in fertilizer markets, including data on prices,

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[5] Rob Gillies, *Potash Corp criticizes government report*, SEATTLE TIMES (Oct. 5, 2010), http://seattletimes.com/html/businesstechnology/2013080821_apcncanadapotashcorpbhp.html. PotashCorp notes the contribution of government involvement (which favors "production over profitability") to price volatility for phosphate. POTASHCORP ANNUAL REPORT FOR 2011 at 22. For example, in their hostile takeover offer for PotashCorp, mining giant BHP Billiton stated that it would break up the cartel. The Canadian government blocked the takeover, noting that a breakup of Canpotex was unacceptable because it would lower tax revenues.

[6] Eleanor Fox, *Antitrust Challenges of Deep Globalization*, AM. ANTITRUST INST., June 2011, *available at* http://www.antitrustinstitute.org/sites/default/files/Fox percent20Presentation.pdf. *See also* F. Jenny, *Export Cartels in Primary Products: the Potash Case in Perspective,* in TRADE, COMPETITION AND THE PRICING OF COMMODITIES (S. J. Evenett & F. Jenny eds., 2012); Frederic Jenny, Global potash trade & competition, Econ. Times, (Nov. 25, 2010), http://articles.economictimes.indiatimes.com/2010-11-25/news/29382665_1_potash-saskatchewan-bhp-billiton.

profits, and excess capacity; anecdotal evidence of the exercise of market power, evidence of market segmentation, and the influence of increasingly powerful buyers. Section VI employs economic modeling and econometric estimation to explore recent price spikes and the extraordinary profits earned by fertilizer producers using dynamic Lerner indices – a well-known measure of market power. Section VII considers the state of antitrust enforcement "inaction" involving fertilizer and Section VIII concludes with a number of major observations, all of which highlight the need for concerted, organized competition enforcement action.

Overall, the analysis strongly supports the notion that global fertilizer producers have likely acted in a coordinated fashion to raise prices, to the detriment of competitors and consumers. The accretion of buyer power by large users such as India and China and the associated pushback on high fertilizer prices are a recent development that requires monitoring. These developments have yet to fully play out. Their impact on disrupting coordinated global potash prices in 2013 could be temporary while producers regroup to establish the terms of any tacit or explicit agreement. On the other hand, the exercise of buyer power by larger users could signal a fundamental change in fertilizer market dynamics. Under either scenario, the disruption caused by powerful buyers is in itself strong evidence that fertilizer markets have been cartelized and are long overdue for investigation by global antitrust enforcers.

## II. BACKGROUND ON FERTILIZER

### A. The Availability and Control of Fertilizer

Industrialized food production systems throughout the world rely heavily on external inputs of plant nutrients, namely nitrogen, phosphorus ($P_2O_5$), and potash, ($K_2O$). Fertilizer is typically applied as a nitrogen-phosphorus-potash blend. U.S. expenditures on nitrogen-phosphorus-potash commercial fertilizer were over $25 billion in 2012, and over $200 billion worldwide.[7] The U.S. imports 57 percent of its nitrogen and 86 percent of potash, but is a net exporter of phosphorus, accounting for 35 percent of world exports.

Most commercial nitrogen is manufactured from natural gas, while phosphorus and potassium are produced from mined raw material. Production of nitrogen fertilizer is concentrated in regions with relatively low natural gas prices. About 35 percent of supply availability is located in East Asia, followed by Eastern Europe and Central Asia, and South Asia.[8] Based on estimates from the U.S. Geological Survey (USGS), world reserves of potash are located primarily in Canada (46 percent) and the former Soviet Union (43 percent).[9] Reserves will last only a few centuries at present extraction rates and could occur much sooner with substantial use of plant material for biofuel production.[10] Reserves of phosphate rock used to manufacture phosphorus fertilizer are located primarily in the Morocco and the Western Sahara (75 percent) and China (five percent).[11] Reserves in the U.S. (two percent) will be depleted in only 25-30 years at present extraction rates,

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[7] Computed from demand data published by FAO, FOOD & AGRIC. ORG., CURRENT WORLD FERTILIZER TRENDS AND OUTLOOK TO 2016 30-32 (2012), ftp://ftp.fao.org/ag/agp/docs/cwfto16.pdf, and prices farmers paid published by USDA, U. S. Dep't. of Agric., Econ. Research Serv., *Fertilizer Use and Price, Table 7—Average U.S. farm prices of selected fertilizers*, 1960-2013 (Jul. 12, 2013), http://www.ers.usda.gov/datafiles/fertilizer_use_and_price/fertilizer_prices/table7.xls.

[8] FOOD & AGRIC. ORG., CURRENT WORLD FERTILIZER TRENDS AND OUTLOOK TO 2011/12 31-33 (2008), ftp://ftp.fao.org/agl/agll/docs/cwfto11.pdf.

[9] U.S. DEP'T. OF THE INTERIOR & U.S. GEOLOGICAL SURVEY, MINERAL COMMODITY SUMMARIES 123 (Jan. 2013), http://minerals.usgs.gov/minerals/pubs/mcs/2013/mcs2013.pdf [hereinafter *Mineral Commodity Summaries*].. In this report, the term "economic reserves" is used loosely, but is consistent with USGS definitions given in their annual mineral reports. USGS reserve estimates "encompass those parts of the resources that have a reasonable potential for becoming economically available within planning horizons beyond those that assume proven technology and current economics. The reserve base includes those resources that are currently economic, marginally economic, and some of those that are currently subeconomic." *Id.,* at 194.

[10] C. Robert. Taylor & Rodrigo Rodriguez-Kabana, *Phosphorus: A Strategic Barrier to the National Biofuels Action Plan for Energy Independence*, BIOENERGY POL'Y BRIEF, BPB 040109, Apr. 2009, *available at* http://www.ag.auburn.edu/biopolicy/. *See also* Dana Cordell, et al., *The story of phosphorus,* 19 GLOBAL ENVTL. CHANGE 292 (2009).

[11] *See Mineral Commodity Summaries, supra* note 9, at 118-19 (showing OCP controls 70 percent of reserves of phosphate rock).

and relatively inexpensive reserves may last only 10-15 years. "Peak" phosphorus is predicted to occur in the next decade.

At present, governments control 57 percent of nitrogen, 47 percent of phosphorus, and 19 percent of potash. PotashCorp began as a Crown corporation owned by the government of Saskatchewan, becoming a publicly traded corporation in 1989. Belaruskali is controlled in part by the Belarusian government and OCP is a privately traded monopoly sanctioned by the Moroccan government. Governments have strong ties to PotashCorp, OCP, Belaruskali and others. These ties could enhance government control of reserves – from 19 percent to over 80 percent for potash and 47 percent to over 80 percent for phosphorus rock, based on current market shares. The concentrated location of reserves, some of which are in politically unstable areas, makes fertilizer a very complex socioeconomic and political issue, termed by some experts as a "geostrategic ticking time bomb."[12]

### B. The Role of Fertilizer in Industrial Farming and Sustainability

Adoption of nitrogen-phosphorus-potash fertilizers played a dominant role in the "green revolution" that transformed agrarian agricultural systems into industrial farming. Dramatic increases in crop yields attributable to application of commercial fertilizer lowered food costs and freed up labor for employment in non-agricultural industries. Industrial farming has met the food needs of many, but problems are looming. For example, industrial farming as commonly practiced is not sustainable because it relies almost exclusively on phosphorous and potash fertilizer obtained by mining phosphate rock and potash deposits. As noted above, resources of plant

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[12] David A. Vaccari, *Phosphorus Famine: The Threat to Our Food Supply*, SCIENTIFIC AM. (June 3, 2009), http://www.scientificamerican.com/article.cfm?id=phosphorus-a-looming-crisis. *See also* Hilmar Schmundt, *Essential Element Becoming Scarce: Experts Warn of Impending Phosphorus Crisis*, DER SPIEGEL ONLINE INT'L (Apr. 21, 2010), http://www.spiegel.de/international/world/essential-element-becoming-scarce-experts-warn-of-impending-phosphorus-crisis-a http://articles.economictimes.indiatimes.com/2010-11-25/news/29382665_1_potash-saskatchewan-bhp-billiton -690450.html.

nutrients are finite and, at present extraction rates, economic sources may be depleted in the next century, if not sooner.[13] The potential severity of a phosphorus shortage, for example, could cause a shift in the global economy from one that revolves around ownership of oil reserves to one based on who owns and controls phosphorus reserves.[14]

A number of factors contribute to the limitations on a sustainable approach to fertilizer use in industrial farming. First, there are serious environmental concerns related to the mining of phosphorus and potash. For example, radioactive waste is a byproduct of the mining process and must be transported and stored. Second, nitrogen-phosphorus-potash nutrients from natural or manufactured sources do not substitute for each other in plant growth. Rather, all are necessary to biosynthesize basic building blocks of plants, animals, and other life forms so therefore are complimentary inputs to crop production at current usage rates. The relationship between nitrogen-phosphorus-potash presents challenges for each type of fertilizer input. Conserving nitrogen, for example, might entail switching from a food production system that is largely monoculture with high external inputs of nitrogen to a more sustainable system based on specific crop rotations. However, such a switch would likely decrease yields and increase food prices, at least in the short term.

Third, obtaining plant nutrients from recycling or non-mined alternative sources is limited. For example, potash fertilizer can be manufactured from seawater, but is not economically viable with current technology. Of the three major nutrients, phosphorus manufactured from mined phosphate rock seems the most limiting for the continuation of industrial farming. Theoretically, phosphorus can be recycled since it only changes form and location. However, with industrial

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[13] *See, e.g.*, *Mineral Commodity Summaries,* note 8 (compiling the annual production and reserve statistics by the USGS.

[14] Arno Rosemarin & Ian Caldwell, *The Precarious Global Geopolitics of Phosphorus*, STOCKHOLD ENV'T. INST. (2007), *available at* http://www.ecosanres.org/icss/proceedings/presentations/76--RosemarinAugust252007.pdf.

farming much of the phosphorus is not recycled back to the fields receiving the nutrients from commercial sources; rather it is flushed into the environment as animal and human waste.[15]

Of particular concern is the role of fertilizer in meat and poultry production, most of which now occurs in what are known as concentrated (confined) animal feeding operations (CAFOs). Many CAFOs are distant from major areas where food and feed crops are grown. They are also located on land not well suited to crop production, thus limiting recycling.[16] Feed is brought into these regions from outside areas and supplemented with phosphorus – thereby adding to the phosphorus content of animal waste. Much of this waste is disposed of near where it is generated, leading to substantial buildup in nearby fields. Excess nutrients applied near many CAFOs (especially phosphorus) may contaminate drinking water supplies and cause water quality deterioration in streams and rivers. Safely separating nitrogen-phosphorus-potash from undesirable compounds and transporting it back to farm fields is generally uneconomical at present, as is cleansing wastewater for safe application to fields.

It is unlikely that supra-competitive pricing of fertilizer will appreciably affect use of commercial fertilizers under current economic and technological conditions, or induce significant recycling of nutrients from human and animal wastes. Inelastic demand for phosphorus and potash fertilizer is a contributory factor and recycling is cost prohibitive in many situations.[17] Since industrial farming, with its reliance on mined phosphorus and potash, cannot be sustained, the

[15] Plant nutrients from humans are flushed in with heavy metals, drugs, growth hormones, and many other compounds.

[16] For example, poultry production is concentrated in a few areas of Arkansas, Georgia and Alabama.

[17] *See* Harry Vroomen & Bruce Larson, *A Direct Approach for Estimating Nitrogen, Phosphorus, and Land Demands at the Regional Level*, USDA TECHNICAL BULL. *at* 1786 (1991); Hoy F. Carman, *The Demand for Nitrogen, Phosphorus and Potash Fertilizer Nutrients in the Western United States*, 4 W. J. AGRIC. ECON. 23 (1979).

impact of fertilizer pricing on reserves and on recycling of plant nutrients merits consideration in a competitive analysis of the industry.

## III. STRUCTURE OF GLOBAL AND REGIONAL FERTILIZER MARKETS

The world's fertilizer industry has a history of cartels tracing back to the 1880s.[18] A 1949 report by the Federal Trade Commission (FTC), for example, documents cartels in nitrogen, phosphorus, and potash from before World War I to just after World War II.[19] Connor identifies 83 known hard-core international fertilizer cartel episodes over the period 1902 to 2010, comprising 20 percent of primary industry cartels and 12 percent of identified international cartels. Twenty fertilizer cartels were detected from 1990-2010.[20] Numerous conditions make the fertilizer industry conducive to cartelization, for individual nutrients and all three nutrients together. These factors include: inelastic demand, high barriers to entry, easy explicit and tacit communication between members, and corporate and government control of limited reserves. Observed sustained high profit margins, excess capacity, and the concomitant movement of nitrogen, phosphorus, and potash prices are also consistent with cartel behavior.

### A. Measures of Market Concentration

Figure 1 shows production capacities of the ten largest fertilizer companies. Market shares based on production capacities can be used to calculate Herfindahl-Hirschman Indices (HHI) of

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[18] For an historical perspective on fertilizer cartels, *see* MIRKO LAMER, THE WORLD FERTILIZER ECONOMY, (1957); GEORGE WARD STOCKING & MYRON WEBSTER WATKINS, CARTELS IN ACTION: CASE STUDIES IN INTERNATIONAL BUSINESS DIPLOMACY (1946).

[19] FEDERAL TRADE COMMISSION, ANNUAL REPORT 18-21 (1949).

[20] The median overcharge by hard-core fertilizer cartel members was almost 41 percent, above the 30 percent overcharge for all industries from 1702-2010. John M. Connor, *Price Effects of International Cartels in Markets for Primary Products*, *in* TRADE, COMPETITION AND THE PRICING OF COMMODITIES 74 (Simon J. Evenett & Frederic Jenny eds. (2012).

market concentration for regional and global markets. The HHIs in Table 1 reveal that markets are extremely concentrated.[21]

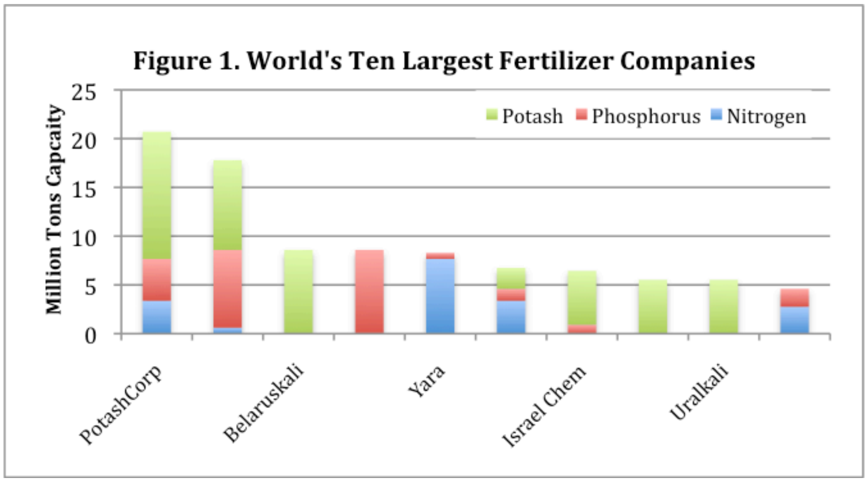
| **Table 1. Regional and World HHI's Based on Annual Capacity of Fertilizer, 2011** | | | |
|---|---|---|---|
| **Regional HHI's** | **Nitrogen** | **Phosphorus** | **Potash** |
| North America | 2,107 | 3,163 | 4,604 |
| South America | 3,712 | 5,593 | 5,760 |
| Asia and Parts of the Pacific Rim | 2,508 | 3,711 | 7,365 |
| Europe | 9,721 | 6,069 | 3,401 |
| Africa and the Middle East | 3,382 | 10,000 | 10,000 |
| **World HHI** | **964** | **1,447** | **1,486** |
| **World HHI (combining capacities of *PhosChem* and *Canpotex* members, and combining Belaruskali, Silvinit and Uralkali)** | **1,163** | **2,534** | **2,688** |
| Source: *Agrium Fact Book 2011-2012,* AGRIUM, http://www.agrium.com/includes/2011_Agrium_Fact_Book_v15_w_links.pdf. | | | |

However, the HHIs potentially understate the oligopolistic structure of markets, for a number of reasons. First, underlying market shares do not account for government sanctioned export cartels, state backed monopolies, cabals, and joint ownership.[22] Second, because many of the smaller firms do not appear to be engaged in significant trade, an HHI based on world trade flows (for which data is limited) would be higher than the world HHI's shown in Table 1. Third, the classical HHI does not account for the involvement of many companies in the market not for just one nutrient, but all three major nutrients, which may enhance and reinforce market power.

[21] The Guidelines state that markets for which post-merger concentration is less than 1,500 HHI are "unconcentrated" and mergers in such markets are unlikely to have adverse competitive effects. Markets for which post-merger concentration is between 1,500 and 2,500 HHI are "moderately concentrated" and mergers that induce changes in HHI greater than 100 points potentially raise significant competitive concerns. Markets for which post-merger concentration is greater than 2,500 HHI are "highly concentrated" and mergers that induce changes in HHI of 100 to 200 points potentially raise significant competitive concerns. Mergers that increase concentration by more than 200 HHI points in highly concentrated markets are presumed to be likely to enhance market power. *See* U.S. DEPARTMENT OF JUSTICE AND FEDERAL TRADE COMMISSION, HORIZONTAL MERGER GUIDELINES (GUIDELINES), §5.3 (August 2010), *available at* http://www.justice.gov/atr/public/guidelines/hmg-2010.pdf.

[22] Data used for Table 1 account to some extent for partial ownership. For example, the Agrium data recognize PotashCorp's ownership of 22 percent of Sinofert, 28 percent of Arab Potash, 32 percent of SQM, and 14 percent of ICL. However, the HHI does not show how such joint relationships affect behavior of the various firms.

Finally, the Cournot assumption underlying the theoretical calculation establishing the connection between an industry Lerner index and the HHI is particularly suspect given the complex structure of the fertilizer industry.




### B. The Structure of Global Markets

The structure of the world's phosphorus and potash markets, while complex, may best be viewed as duopolies with small, high cost fringe firms. The phosphorus duopoly is comprised of the U.S. export cartel, *PhosChem,* operating with limited antitrust immunity under Webb-Pomerene, and the Moroccan monopoly OCP. There are presently only two members of *PhosChem* – PotashCorp and Mosaic.[23] *PhosChem* members account for 52 percent of world phosphorus trade. PotashCorp's phosphorus sales volume traded by *PhosChem* averages 69 percent for fertilizer, 17 percent for industrial, and 14 percent for feed. The majority of Mosaic's phosphorus sales volume (85 percent) is fertilizer.[24] PotashCorp's production of phosphate products is almost evenly split among liquid fertilizer, solid (dry) fertilizer, feed grade products and industrial, while OCP's sales

[23] The Cargill family controls a majority of Mosaic stock and Board of Directors. Creation of Mosaic from the merger of IMC Global, Inc. and Cargill's crop nutrition business in 2004 came after a decade of consolidation and shutdown of high-cost fertilizer production facilities.

[24] *2011 Online overview*, POTASH CORP., http://www.potashcorp.com/industry_overview/2011/advantages/14/.

are about equally split between liquid and solid phosphorus fertilizer.[25] OCP controls 36 percent of the global raw phosphate market and 51 percent of the global phosphoric acid sales.[26] PotashCorp and Agrium obtain phosphate rock from OCP.[27]

The potash duopoly is comprised of the Canadian sanctioned export cartel, *Canpotex*, that markets potash from Saskatchewan, and a Russian cabal.[28] The three owner-members of *Canpotex* are PotashCorp, Mosaic, and Agrium, each with a fixed market share of 54 percent, 37 percent and 9 percent of export sales, respectively. *Canpotex* accounts for 61 percent of world potash trade, including trade by other potash companies in which PotashCorp has significant ownership. The Russian cabal accounts for 32 percent of trade, with a high-cost, non-integrated fringe accounting for the remaining seven percent. There are three major producers of potash in the former Soviet Union – Belaruskali, Silvinit, and Uralkali. These three producers were tightly interlinked, arguably operating effectively as a cartel, and appeared to be morphing into a single firm, until an apparent breakup between Uralkali and Belaruskali in August 2013.[29]

Many of the major phosphorus producers also manufacture nitrogen fertilizer, partly because a source of nitrogen is required to stabilize phosphorus, and partly because many fertilizer

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[25] *Id.*

[26] OCP, FACTSHEET (last visited Aug. 14, 2013), http://www.ocpgroup.ma/en/finance/ocp-in-brief/fact-sheet.

[27] PotashCorp owns phosphate mines in the U.S. and import about seven percent of the phosphate rock they process globally from OCP. Mississippi Phosphates Corporation (MPC), formerly a member of P*hosChem,* obtains all rock for their U.S. operations from OCP.

[28] *See* Jenny, *supra* note 6 (providing an excellent perspective on the potash cartel).

[29] According to news reports Russian billionaire Suleiman Kerimov and associates have controlling interests in Silvinit and Uralkali, and are in talks to merge the two companies. *Russia Uralkali, Silvinit to mine 10.6 mln T potash*, REUTERS (Mar. 18, 2011), http://www.reuters.com/article/2011/03/18/uralkali-idUSMSC00017220110318. Silvinit also has a joint trading venture with Belaruskali. Yuliya Fedorinova & Maria Kolesnikova, *Potash Export Grip Challenged in China's Bond Deal*, BLOOMBERG (Nov. 14, 2012), http://www.bloomberg.com/news/print/2012-11-14/potash-exports-grip-challenged-in-china-s-bond-deal-commodities.html.

manufacturers sell blended nitrogen-phosphorus-potash fertilizer at wholesale and retail.[30] Agrium and PotashCorp each had nitrogen sales of about $2 billion in 2012, far lower than their sales of phosphorus or potash. While global nitrogen fertilizer producers are not as closely intertwined as are phosphorus and potash producers, duopolies in phosphorus and potash potentially invite antitrust mischief. They achieve this, at a minimum, through the sharing of information and executive decision-making between *PhosChem* and *Canpotex*, and the division of markets inside and outside North America.

## IV. ANTITRUST EXEMPTIONS FOR FERTILIZER PRODUCERS IN THE U.S.

Webb-Pomerene granted certain export associations limited immunity from the U.S. antitrust laws. The original intent of the Act appears to have been to aid the war effort by permitting small American firms to join together to countervail the market power of foreign governments, as long as the collaboration did not harm domestic markets.[31] There have been less than 300 Webb-Pomerene associations over the last 95 years. At present, only six such associations exist, all of which are engaged in agricultural or natural resource industries: (1) American Cotton Exporters Association, (2) American-European Soda Ash Shipping Association, Inc., (3) American Natural Soda Ash Corporation, (4) Overseas Distribution Solutions, LLC, (5) Phosphate Chemicals Export Association, Inc. (*PhosChem*), and (6) Specialty Crop Trade Council.[32]

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[30] Diammonium phosphate (DAP), a common form of phosphorus fertilizer, has a nitrogen-phosphorus-potash analysis of 18-46-0, meaning that it contains 18 percent nitrogen, 46 percent $P_2O_5$, and 0 percent $K_2O$. Other, nonfertilizer, forms of phosphorus is used in livestock and poultry feed, food additives, and metal treatment.

[31] *See also* WILLIAM F. NOTZ & RICHARD S. HARVEY, AMERICAN FOREIGN TRADE AS PROMOTED BY THE WEBB-POMERENE AND EDGE ACTS (1921); Ryan C. Amacher, et. al., *A Note on the Webb-Pomerene law and the Webb-cartels*, 23 ANTITTRUST BULL. 371 (1978); Andrew R. Dick, *Are export cartels efficiency-enhancing or monopoly promoting? Evidence from the Webb-Pomerene Experience*, 15 RESEARCH IN L. & ECON. 89 (1992).

[32] Letter from Robert S. Highsmith Jr., Holland & Knight, to FTC Bureau of Competition (Jan. 1. 2011), *available at* http://www.ftc.gov/os/statutes/webbpomerene/2010/overseasdistrib2010.PDF.

### A. The History of Webb-Pomerene Act Export Associations

Webb-Pomerene does not apply to associations that "substantially lessen competition within the United States" or that "artificially or intentionally enhances or depresses prices within the United States."[33] Thus, the Act prohibits monopsony and domestic dumping of products, monopoly pricing, and unfair acts that extend beyond the territorial jurisdiction of the U.S.[34] Specific annual reporting and investigative authority is given to the FTC under the Act, and in the event that an association fails to comply with the recommendations of the FTC, the agency can refer its findings and recommendations to the U.S. Attorney General for appropriate action.[35]

Since the beginning, the FTC and other competition observers have noted the tension inherent in the Webb-Pomerene export association exemption. In 1916, the FTC submitted a report to Congress on Webb-Pomerene, which was subsequently included and endorsed in a 1940 report by the Temporary National Committee.[36] The FTC's recommendation emphasized the potential benefits of Webb-Pomerene to American exporters in that they "should be enabled to compete in foreign markets on nearly equal terms with foreign competitors…smaller manufacturers and producers, so far as they desire, should be enabled to share in such foreign business."[37] However, the FTC also highlighted the perils of cartels, namely that they: (1) can be used to "exploit consumers in the home market," and (2) "may be used unfairly against individual

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[33] 15 USC § 62 (2012).

[34] 15 U.S.C. § 64 (2012).

[35] Webb-Pomerene Act, Pub L No 65-126 (1918), codified at 15 USC §§61-66.

[36] TEMP. NAT'L ECON. COMM., 76TH CONG., INVESTIGATION OF CONCENTRATION OF ECONOMIC POWER, MONOGRAPH NO. 316,(S. Comm. Print 1940), *available at* http://archive.org/details/investigationofc41unit.

[37] FEDERAL TRADE COMMISSION, REPORT ON COOPERATION IN AMERICAN EXPORT TRADE 379 (1916).

American concerns in export trade that are not members of the organizations."[38] As a result, the FTC recommended that the agency be able to take enforcement action with a focus on the "public interest." This stands in contrast to the body of antitrust case law and economics that typically ties enforcement to narrower concepts like consumer surplus or welfare.[39] In the case of fertilizer (and *PhosChem* in particular), the broader concept of public interest is arguably more appropriate because of the implications of anticompetitive practices on food sustainability, and other important features of agriculture.

Florida phosphate rock producers were among the first to form Webb-Pomerene export associations in 1919, namely the Phosphate Export Association (PEA) and the Florida Hard Rock Export Association (FHREA). Following World War II, the FTC conducted an extensive investigation, culminating in a 1946 report.[40] The investigation noted that by 1930, new production abroad "sharpened" competition in Europe and the Far East, resulting in six interrelated cartel agreements, under which prices in foreign markets were fixed and imports of foreign rock to the U.S. were negligible.[41] A 1947 American Economic Association (AEA) *ad hoc* committee on Webb-Pomerene concluded that the success and persistence of export associations attested to the advantages of participating firms but that in some cases, export associations' international cartel connections were illegal.[42]

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[38] *id.*

[39] *See* C. Robert Taylor, *Efficiency, Power, and Freedom*, *in* THE ETHICS AND ECONOMICS OF AGRIFOOD COMPETITION 75 (Harvey James, ed. 2013) (giving numerous well known, but often ignored or overlooked, limitations to consumer surplus analysis).

[40] FEDERAL TRADE COMMISSION, REPORT ON INTERNATIONAL PHOSPHATE CARTELS (1946).

[41] FEDERAL TRADE COMMISSION, ANNUAL REPORT 19 (1949).

[42] *Consensus Report on the Webb-Pomerene Law*, 37 AM. ECON. REV. 848, 855 (1947).

The 1947 AEA report also concluded that the competitive position of small U.S. phosphate experts had "probably been injured rather than improved by the law."[43] This conclusion highlights, among other adverse effects, the impact of export associations such as *PhosChem* on the ability of smaller domestic manufacturers to compete, or even survive in the market. This includes small, independent firms (including farmer cooperatives) that are dependent on large integrated producers for inputs to blend nitrogen-phosphorus-potash fertilizers for wholesale or retail sales in domestic and export markets. This group was also identified by the FTC report as potentially harmed by export associations, in part, because dependency on fertilizer inputs dissuaded smaller rivals from competing on price in the sale of mixed fertilizer.[44]

Following the FTC investigation and hearings, the FHREA adjusted their operations and the PEA was dissolved, leading some experts to conclude that export associations had limited value without antitrust immunity.[45] Allegations of phosphate price-fixing reemerged in the early 1960s, with action taken by the U.S. Department of Justice (DOJ). After losing a private antitrust suit brought by the International Commodities Corporation, phosphate producers reactivated their association under Webb-Pomerene. Success was fleeting, however, as the DOJ brought suit in 1964 against the Concentrated Phosphate Export Association (CPEA), alleging that the association was fixing prices and establishing quotas.[46] Analysis of the DOJ litigation indicates that the CPEA had little to do with scale economies or cartel protection. Rather, the major interest of the members was price fixing, not only in foreign markets but also in domestic markets, and the

43 *Id.*, at 849.

44 Annual Report of the Federal Trade Commission for the Fiscal Year Ended June 30, 1949, U.S. Government Printing Office, 1949, phosphorus, at 18.

45 David A. Larson, *An Economic Analysis of the Webb-Pomerene Act*, 13 J. L. & ECON., 461, 495 (1970).

46 *Id.*

use of the association to effectuate price agreements with chief foreign rivals. The PEA, FHREA, and CPEA were precursors to *PhosChem*.

### B. The Changed Landscape – Calls for Repeal of Webb-Pomerene

Since Webb-Pomerene was passed almost a century ago, a number of significant changes have altered the features of the global market landscape. For example, Webb-Pomerene was intended to enable smaller U.S. manufacturers to share in export trade, but such firms have dropped out of *PhosChem* over the years, leaving only two giant transnational companies.[47] The Act's partial grant of antitrust immunity was also designed "for the purpose of competing effectively with foreigners." In other words, Webb-Pomerene was designed to enable U.S. firms to develop sufficient market power to countervail the market power of foreign firms. In the current global economy, many members of the six Webb-Pomerene associations are now dominant firms, and some (e.g., PotashCorp) are essentially foreign. Indeed, such firms may have more market power than foreign buyers or sellers, so the current imbalance of market power is the inverse of what prevailed when Webb-Pomerene was passed.

The exercise of market power possessed by global firms like Mosaic and PotashCorp in phosphorus and potash will, with rare exception, adversely affect competition and consumers in the domestic market. This, coupled with the consolidation of seller and buyer market power in the fertilizer industry over time begs the question: Did *PhosChem* and *Canpotex* actually countervail the market power of other international firms, or did the enhancement of market power through the formation of the export cartels induce consolidation of other fertilizer manufacturers and trigger consolidation of buyers as well?

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[47] The last domestic firm to drop out of *PhosChem* is Mississippi Phosphates, in 2005.

While the foregoing question cannot be answered in this paper, it is clear that the members of export cartels such as *PhosChem* and *Canpotex* are deeply intertwined. For example, *PhosChem* is claimed as a legal corporate subsidiary of Mosaic, and Mosaic reports PotashCorp's *PhosChem* sales in their own financials.[48] Mosaic is also entrenched in *PhosChem*, with the power to direct the activities that most significantly impact the export association's economic performance. Mosaic also has the obligation to absorb losses or right to receive benefits that could be significant to *PhosChem* because it accounts for the majority of sales volume. Among other outcomes, these complex business arrangements facilitate the potentially anticompetitive sharing of information on export prices and volumes of phosphorus fertilizer between Mosaic and PotashCorp.

Substantive economic arguments for revision or repeal of Webb-Pomerene date to the Act's inception.[49] Economic research demonstrates that the adverse economic effects of anticompetitive practices by Webb-Pomerene export associations generally far outweigh any benefits. The American Bar Association proposed in the 1990s that all countries agree to repeal statutes granting immunity to export cartels.[50] A consensus has therefore developed among the legal-economic community that export associations are generally undesirable.

To date, the FTC has issued automatic annual approvals to export associations. A lack of enforcement action by the agency is troubling, particularly in light of its authority to oversee export associations under Webb-Pomerene and the pressing competitive questions raised by

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48 Recent *PhosChem* annual reports approved by the FTC state that it is "a non stock corporation and has no stockholders." Letter from, Howard W. Fogt, Jr., Foley & Lardner, to FTC Bureau of Competition (Dec. 30, 2010), *available at* http://www.ftc.gov/os/statutes/webbpomerene/2010/phosphatechemexport2010.PDF.

49 *See, e.g.,* Eliot Jones, *The Webb-Pomerene Act*, 28 J. POL. ECON 754 (1920); Leslie Fournier, *The Purposes and Results of the Webb-Pomerene Law*, 22 Am. Econ. Rev. 18 (1932); Larson, *supra* note 45; Dick, *supra* note 31; Christian Schultz, "Export Cartels and Domestic Markets," J. INDUS. COMPETITION & TRADE, 233 (2002).

50 AM. BAR ASS'N, SECTION OF ANTITRUST LAW, SPECIAL COMMITTEE ON INTERNATIONAL ANTITRUST, REPORT (Sept. 1, 1991).

*PhosChem*. For example, have *PhosChem's* members PotashCorp and Mosaic harmed the competitive position of smaller phosphorus firms in the domestic market? Moreover, must small non-integrated fertilizer blenders in the domestic market for wholesale and retail sales refrain from domestic or foreign competition in order to obtain phosphorus inputs? Finally, can two globally dominant firms achieve any meaningful efficiency gains or countervailing power that is in the public interest, foreign or domestic? These questions deserve further scrutiny and should not be restricted to members of *PhosChem*, or even phosphorus. Rather, antitrust scrutiny should also extend to all producers and potash, nitrogen, and even sulfur.[51]

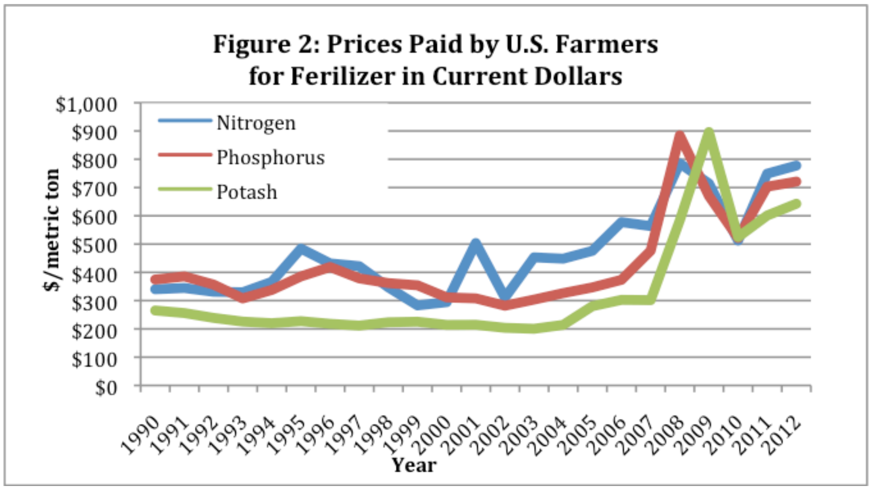
## V. INDICATORS OF ANTICOMPETITIVE CONDUCT

### A. Price Spikes, High Profits, and Excess Capacity

Real fertilizer prices were largely stable from the late 1980s until 2004. By 2008, however, nitrogen prices had doubled and phosphorus and potash prices had tripled. These rates of increase far exceed those for fertilizer manufacturing costs and other crop production costs.[52] Figure 2 shows average prices paid by U.S. farmers for fertilizer from 1990 through 2012.

[51] Sulfur is important not only because it is used in manufacture of phosphate fertilizer, but because it is a minor but important plant nutrient. Historically sulfur used in agriculture was mined, and there is an old history of sulfur cartels. Now most sulfur is obtained as a by-product of gasoline and diesel refinement. For many years, sulfur prices were very low and at times negative. However, in 2008 sulfur prices spiked to over $500/ton, over twenty times its average price over the previous ten years. Recent sulfur price gyrations suggest that market power in this industry merits analysis.

[52] *See also Fertilizer Use and Price,* USDA ECON. RESEARCH SERV., www.ers.usda.gov/data-products/fertilizer-use-and-price.aspx (last visited Aug. 1, 2013) (giving U.S. fertilizer price and consumption data).




Farmers responded to exceptionally high prices in 2008 by temporarily reducing the application of phosphorus and potash.[53] Even though real crop prices were at twenty-five year highs in 2008-2009, proportionally higher fertilizer prices led to a 33 percent and 26 percent decrease in U.S. potash and phosphorus consumption, respectively, relative to the previous crop year. A decline in consumption resulted in a rapid buildup of inventory of manufactured product held by the dominant firms. Corporate records confirm such buildups during the high price period 2008-2009.[54] The decline in consumption was likely unanticipated by fertilizer producers. In other words, price setters may have thought short-run demand for phosphorus and potash to be more inelastic than it actually was. Even so, PotashCorp reported average potash prices that were "15 percent higher than second-quarter 2008 levels," even as it experienced the "most significant deferral of demand our industry has ever seen."[55]

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[53] This is likely possible without significant loss in crop yield.

[54] See, for example, POTASHCORP, OVERVIEW OF POTASHCORP AND ITS INDUSTRY 2009 at 37 (2009), *available at* http://www.potashcorp.com/media/POT_2009_OverviewBook.pdf.

[55] Press Release, Potash Corp., Q2: PotashCorp Reports Weaker Second-Quarter Earnings (Jul. 23, 2009), available at http://www.potashcorp.com/news/409/.

A clear picture of market dynamics before and after the pivotal price spikes of 2008-2009 is critical to understanding potentially collusive behavior among fertilizer producers. As expected, a number of economic explanations surfaced in the aftermath. For example, in 2010, PotashCorp attributed soaring prices to increases in raw materials (e.g., phosphate rock, potash, sulfur, and ammonia) costs. The company explained that diammonium phosphate (DAP) prices are set by the marginal highest cost, non-integrated producer. Higher marginal costs, combined with strong agricultural demand supported by high crop prices, thus caused prices to surge. PotashCorp further explained that as trends reversed and excess capacity developed, DAP prices fell below marginal costs, a "situation that is not expected to be sustained with normalized demand."[56]

A CBC report took a different perspective, explaining that high concentration, a reduction in the amount of excess capacity in the industry, and a high level of "market discipline among leading producers to manage production in response to market demand and thus maximize prices contributed to potash prices reaching a record high in late 2008 and early 2009."[57] This scenario more accurately portrays market dynamics at the time of fertilizer price increases. However, it is crucial to note that price spikes occurred in the presence of longer-term excess capacity trends in the industry and sustained high profits before and after the spikes. The CBC reported in an analysis of BHP Billiton's hostile offer for PotashCorp that, "The [potash] industry has long been characterized as having excess capacity."[58] The International Fertilizer Industry Association (IFA) reports, for example, that effective production capacity for each major nutrient exceeded the

[56] *Id.,* at 44.

[57] CONFERENCE BOARD OF CANADA, SASKATCHEWAN IN THE SPOTLIGHT 51 (Oct. 1, 2010), available at Oct. 1, 2010, *available at* http://www.gov.sk.ca/adx/aspx/adxGetMedia.aspx?mediaId=1245&PN=Shared.

[58] Conference Board of Canada, *supra* note 57, at 8.

quantity consumed for the period 2008-2012.[59] Table 2 summarizes excess nitrogen-phosphorus-potash capacity for three major corporations, as well as world capacity utilization in 2010. Excess capacity is as high as 39 percent for phosphate rock (PotashCorp) and 63 percent for potash (Mosaic).

**Table 2. Capacity Utilization in 2010**

| Nutrient | PotashCorp | Mosaic | Agrium | World |
|---|---|---|---|---|
| Nitrogen | 80 percent urea<br>95 percent ammonia | - | 73 percent | 80 percent |
| Phosphorus | 61 percent rock<br>84 percent acid | 81 percent | 87 percent | 80 percent |
| Potash | 71 percent | 57 percent | 92 percent | 74 percent |

Sources: *2011 Annual Report*, MOSAIC, http://www.mosaicco.com/images/Mosaic_AR11.pdf, *2011 Online Annual Report*, POTASHCORP, http://www.potashcorp.com/annual_reports/2011/pdf/, *2011 Annual Report*, AGRIUM, http://www.agrium.com/includes/2011_Agrium_Annual_Report.pdf, and *Yara Fertilizer Industry Handbook* (Feb. 2012), http://www.yara.com/doc/37694_2012%20Fertilizer%20Industry%20Handbook%20wFP.pdf.

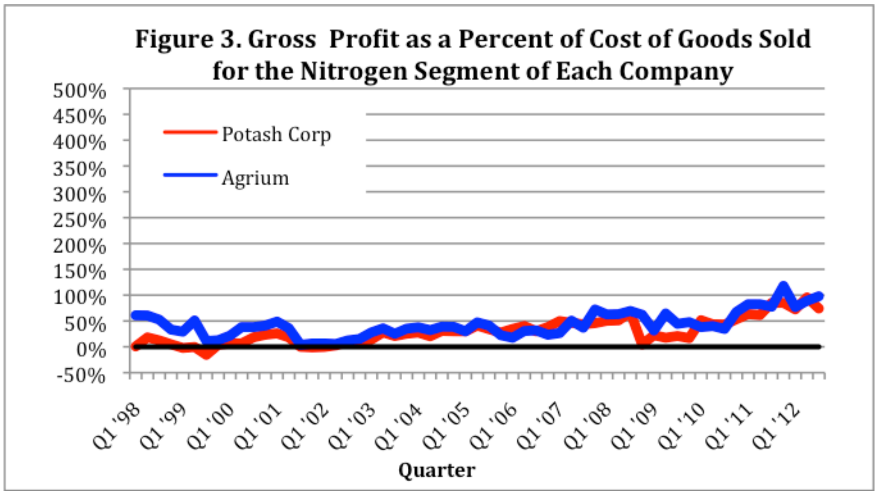
Record profits for *PhosChem* and *Canpotex* members persisted even in the presence of excess capacity. Figures 3-5 show nitrogen, phosphorus, and potash gross operating profits as a percent of cost of goods sold for PotashCorp, Mosaic, and Agrium, Inc.[60] Nitrogen, phosphorus and potash gross profit margins were high and sustained leading up to the price spike in 2008-2009. Profits for each company are remarkably similar for the same business segments, as are the prices charged by each. Gross profits for all three firms average 65 percent over the 15-year period, and almost 100 percent since the beginning of the price run-up in 2008. Nitrogen profits are somewhat lower than phosphorus and potash.[61] Profits on sales of potash sales by the three

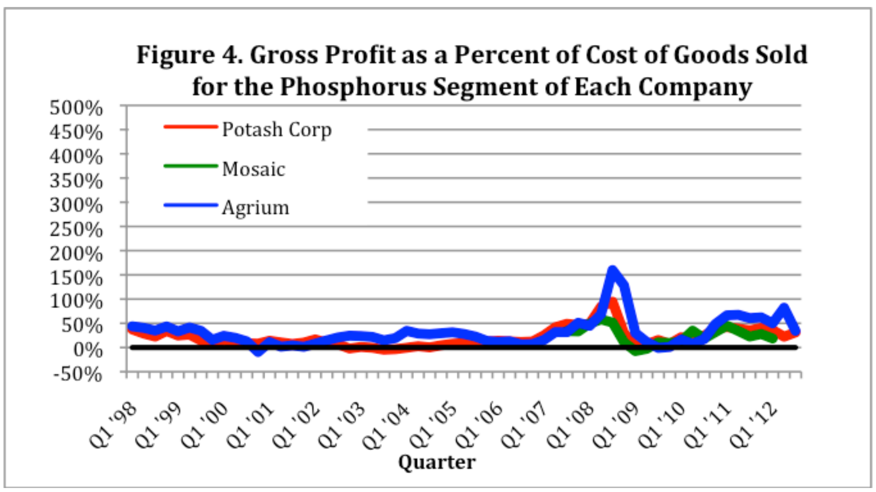
[59] Patrick Heffer & Michel Prud'homme, *Short-Term Fertilizer Outlook 2011-2012*, INT'L FERTILIZER INDUS. ASS'N (Mar. 2012), *available at* http://www.fertilizer.org/ifacontent/download/70142/1025273/.

[60] Operating profits are measured as net sales less cost of goods sold. The three charts have the same vertical scale to make them directly comparable across nutrients.

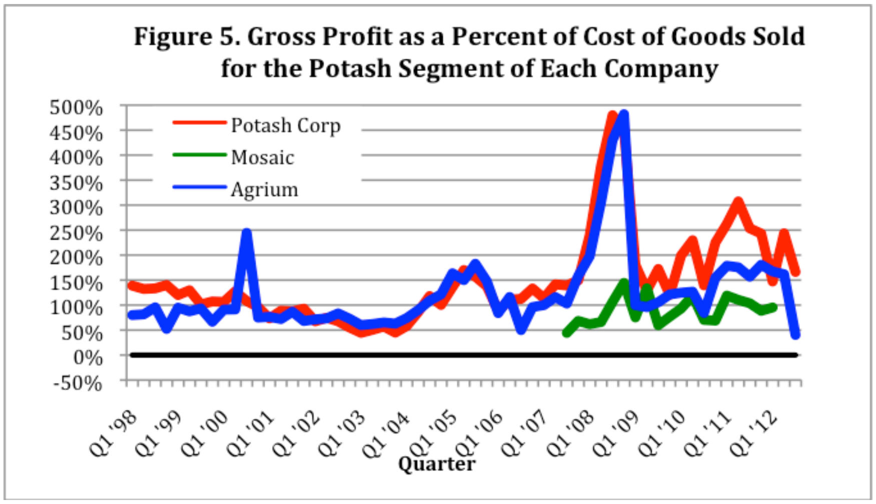
[61] Depreciation, depletion and amortization charges are only about 10 percent of the average cost of goods sold.

*Canpotex* members average 196 percent over 2008-2009 (peaking at 480 percent in mid-2008), and 156 percent since. Profits from phosphorus sales by the two members of *PhosChem* average almost 40 percent over 2008-2009.[62]




62 Limited public data suggest that profits of the Russian potash cabal and phosphorus producer OCP and were in line with profits shown in Figure 10-11.




The foregoing discussion of prices, profits, and excess capacity suggests that fertilizer producers exercise market power through some combination of setting prices and controlling production. Dominant fertilizer manufacturers may well have attempted to maintain collusive prices for several quarters by reducing production to match consumption, rather than to competitively lower prices to induce higher sales volume. The decrease in prices 2009 to 2010 may have served not just to restore sales quantities, but also to dissuade smaller firms from expanding or new firms from entering the market. Production cutbacks and extended mine shutdown could well have been designed to boost prices after they dipped. Later empirical analysis of price-cost margins supports the notion that dominant producers engaged in coordinated price setting in fertilizer markets.

### B. Anecdotal Evidence of Market Power

The classical model of a dominant firm (or combination of large, low-cost firms), with a high cost fringe, might apply in the fertilizer industry. In this model, the price-setting dominant firm allows small, price-taking, high-cost fringe firms to have their small share of the market; the dominant firm then behaves as a monopolist given the price-taking fringe. Public statements suggest a tightening of the relationship between dominant companies leading up the price spike.

For example, the Director General of Silvinit noted a close relationship with other Russian producers in 2005: "We have old and friendly connections with potassium manufacturers from Belarus and we still are pretty good partners…Quite often we have visiting groups from Belaruskali as well as do visit our Byelorussian colleagues ourselves."[63] Uralkali reported that in the summer of 2006, representatives of their management visited Mosaic as part of an exchange program of mutual visits among potash producers in Canada, Russia, and Belarus. In the previous year, a similar visit revealed a friendly attitude to Russian colleagues and the comment that "…We were shown everything we wanted to see."[64]

Especially aggressive pricing in the summer of 2007 appears to have started with the solidification of relations between Belaruskali, Silvinit and Uralkali – which collectively account for 50 percent of world potash exports. In 2008, BPC explained that the company did not want to "compete with Russian companies" and, by inviting Silvinit to join the BPC on equal terms, hoped to be the "strongest and most powerful company that will set to a great degree the rules of the game in the world's potash fertilizer market, which means billions of dollars."[65] Indeed, a 2010 CBC report notes that less than ten years ago, "Russian producers started to push up against capacity and realized it was in their interest to behave like oligopolists…The tendency for concentration in the Russia/Belarus supply structure makes this behavior just as likely going forward."[66] The precise relationship between Belaruskali, Uralkali, and Silvinit, however, is still

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[63] *Petr Kondrashev: "In three years Silvinit will increase its production capacities by a million tons"*, THE CHEMICAL JOURNAL (May 2005), http://www.tcj.ru/en/2005/5/i_silvinit.pdf.

[64] Press Release, Uralkali, Visit by Uralkali Management Team to Canadian company Mosaic (Jul. 3, 2006), http://www.uralkali.com/press_center/company_news/item656/index.php?print=Y.

[65] *Belarusian Potash Company is still interested in Russia's Silvinit becoming a stockholder, director general says*, NAVINY (Jan. 31, 2008), http://naviny.by/rubrics/english/2008/01/31/ic_news_259_284897/.

[66] Conference Board of Canada, *supra* note 57, at 20.

unclear. Reports indicate that Uralkali merged with Silvinit in June 2012 and that Belaruskali and Uralkali, via their marketing cartel BPC, had reached a marketing and sales allocation agreement for 2013-2015, under which Belarusian fertilizers would have a 48.3 percent share in 2013, increasing to 49 percent in 2014, and 50 percent in 2015.[67]

Fertilizer producers themselves acknowledge directly or indirectly coordination with rivals and the dynamics of supra-competitive pricing. For example, PotashCorp statements support the notion of price setting and following the price leadership of BPC and others. A 2011 PotashCorp report recognizes fellow producer BPC's price announcements for large and small buyers.[68] And Agrium's 2011 annual report clearly notes "… potential changes to anti-trust laws, or interpretations thereof, that could negatively impact our international marketing operations through Canpotex."[69]

Despite any strain in a tacit or overt agreement among producers induced by the chaotic period around 2008-2009, price setting appears to continue.[70] Industry new reports note that "… phosphate prices are still negotiated the old-fashioned way in closed meetings between buyers and sellers."[71] And it appears that producers remain confident that the sensitivity of consumption to changes in price remains low. For example, a PotashCorp executive noted in 2011 that fertilizer

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[67] *Belaruskali: Russian potash co downplays India's bid,* HINDU BUS. LINE, (Sep. 26, 2011), http://www.thehindubusinessline.com/industry-and-economy/agri-biz/belaruskali-russian-potash-co-downplays-indias-bid/article2487590.ece and http://www.tumblr.com/tagged/belaruskali.

[68] PotashCorp, *Q1 Market Analysis Report* 40 (Mar. 18, 2011).

[69] AGRIUM, 2011 ANNUAL REPORT, at 10.

[70] Some try to explain the cutback in fertilizer consumption to the global recession beginning in 2008. However, farm prices and the demand for fertilizer remained strong as supported by econometric demand analyses reported in a later section of this report.

[71] *Phosphate: Morocco's White Gold*, BLOOMBERG BUS. WEEK (Nov. 4, 2010), http://www.businessweek.com/magazine/content/10_46/b4203080895976.htm.

costs constitute a "miniscule" percentage of total returns and concluded that "…you start looking at the incentive here. We're a long way from any type of demand destruction."[72]

Dramatic price increases since 2004, and the price spikes of 2008 in particular, thus raise the question of whether market behavior resembles a competitive industry, separate phosphorus and potash duopolies, or more globalized cartelization of fertilizer markets. Simultaneous price movements for nitrogen, phosphorus and potash and similar profit changes suggest a super cartel, embracing all of the major nutrients as well as the government sanctioned export cartels, *Canpotex* and *PhosChem*.

### C. Market Segmentation

Segmentation of the North American and offshore markets likely accompanied the 2008-2009 fertilizer price increases. Figure 6 shows the difference between nominal North American and offshore net prices for potash fertilizer. From 1998-2004, the North American average price is four percent below the offshore price. From 2008-2012, the North American average price is 25 percent higher than the offshore price.[73] Mosaic acknowledged the domestic-international price differential in 2011 (up to a $200 gap at the Saskatchewan mine) and emphasized the expected role of bellwether contracts from India and China to "correct" the difference.[74]

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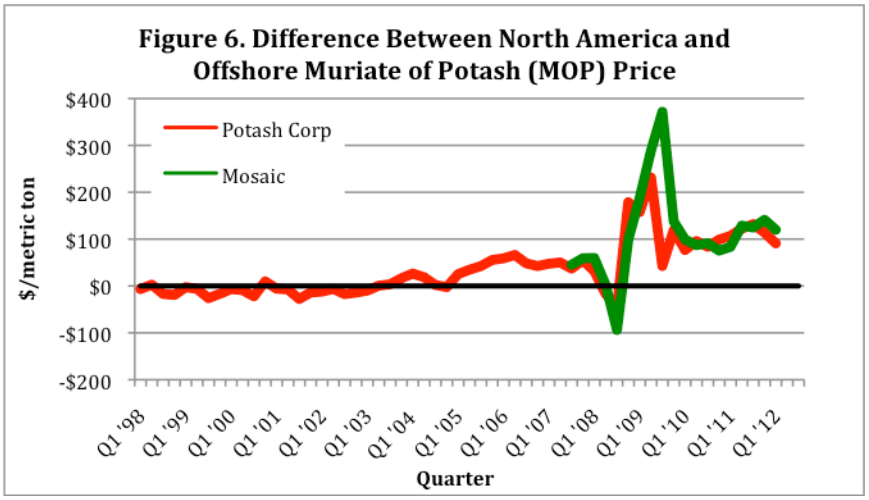
[72] *Potash of Saskatchewan's CEO Discusses Q4 2010 Results - Earnings Call Transcript* (Jan. 27, 2011, 1:00 PM) http://seekingalpha.com/article/249234-potash-of-saskatchewan-s-ceo-discusses-q4-2010-results-earnings-call-transcript?part=qanda.

[73] Mosaic and PotashCorp financials do not report average prices in different markets for phosphorus.

[74] *Mosaic Company CEO Discusses Q2 2011 Results - Earnings Call Transcript* (Jan. 5, 2011), http://seekingalpha.com/article/245073-mosaic-company-ceo-discusses-q2-2011-results-earnings-call-transcript?part=qanda.




Because potash fertilizer is a homogeneous product with essentially the same attributes regardless of where it is produced, transportation cost differences in a competitive market should be a primary determinant of regional price differences.[75] However, most of the potash fertilizer used in North America is produced nearby in Canada, which should narrow or even reverse the North American-offshore price gap. Moreover, the gap existed for ten quarters prior to 2011, with a smaller gap dating back to 2005. In a competitive market, any such gap would be expected to close in far less time than seven years. Together with comparative price data, these observations suggest market segmentation and price discrimination, resulting in higher than the supra-competitive pricing in the U.S. than what is observed abroad.

### D. Development of Powerful Buyers

Major fertilizer customers such as India and China have developed into powerful buyers, a shift that could have potentially important implications for the pricing and output strategies of large sellers. China has not been a major factor in world trade in phosphorus until recently, with a

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[75] Mosaic financials clearly identify North American and International potash prices as being F.O.B. the plant for MOP (Muriate of Potash, commonly known as potassium chloride), a homogeneous product. Potash Corp reports "net realized" price for potash fertilizer. Thus, differences evident from Figure 6 cannot be explained by product or transportation cost differences.

strengthening in exports, for which it has large reserves. The Chinese imposed high export taxes on phosphorus (35-135 percent) and nitrogen (up to 150 percent) when prices spiked in 2008, likely to preserve reserves for sustainability and strategic reasons. Among other implications, this policy raises sustainability issues for other countries, including the U.S. In contrast to phosphorus, China does not have adequate access to potash to ensure domestic food security. In the past decade, it has had only limited success in acquiring access to potash reserves, either through outright purchase or through acquisition of stock in publicly traded manufacturers. A recent loan by China Investment Corp., for example, carries a 12.5 percent stake in Uralkali.[76] This arrangement will give China better access to needed potash and strengthen their price negotiating power. So unique is the Chinese position that a CBC report explained they would be the only suitor (to PotashCorp) with an incentive to run the mines "full out" and could justify a "takeover premium" to prevent BHP from exercising market power (similar to *Canpotex* and BPC)."[77]

India has historically imposed price controls on fertilizer. The difference between the total delivered price at the farm gate and the maximum retail price is made up for by a government subsidy to farmers, manufacturers, or importers.[78] Prices of phosphate and potash were deregulated in April 2010. However, some sources report that the Indian government is considering re-imposing price control for phosphate and potash fertilizers, and rumored to be

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[76] Yuliya Fedorinova and Maria Kolesnikova, *Potash Export Grip Challenged in China's Bond Deal: Commodities*, BLOOMBERG (Nov. 14, 2012), http://www.bloomberg.com/news/print/2012-11-14/potash-exports-grip-challenged-in-china-s-bond-deal-commodities.html.

[77] Conference Board of Canada, *supra* note 57, at 37 and 51.

[78] Gov't of India, Dep't of Fertilizers, *Fertilizer Policy*, http://fert.nic.in/page/fertilizer-policy (last visited Aug. 14, 2013).

considering cutting subsidies.[79] Whether this is a government response to fertilizer prices rising shortly after deregulation, or internal policy to increase food production, or both, is unclear.

Reports indicate that fertilizer contracts for India and China are now negotiated by a single entity, or only a few entities for each country.[80] As a precursor to recent events, reports in 2011 suggest potash "supply management" preceding contract negotiations with major Indian and Chinese buyers. In mid-2011, Mosaic explained that *Canpotex's* "cupboard is bare" and that they would not resume negotiations with Indian buyers until later than normal.[81] More recently, Russian producer Phosagro recently announced that it had "no plans to renew a contract to supply India, the world's largest phosphate consumer, because it is offering too low a price."[82]

The exercise of countervailing power by China and India may be responsible in part for the significant market disruption in mid-2013. For example, Russian producer Uralkali pulled out of the BPC cartel marketing agreement with fellow producer Belaruskali in a move that appeared to be a defection from broader "price over volume" strategy among major producers.[83] In the wake of these dynamics, Uralkali claimed that it would lower potash prices, prompting some

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[79] Aman Malik, *Government mulls price control on non-urea fertilizers*, LIVEMINT (Feb. 19, 2013. 10:42 PM), http://www.livemint.com/Politics/RpL9JEzaekpmt2v4UJBu5M/Government-mulls-price-control-on-nonurea-fertilizers.html.

[80] Reports characterize Chinese and Indian potash buyers as "wily in their challenge to the current pricing structure." Alessandro Bruno, *Potash Corp's Bid for ICL an Attempt to Alter the Potash Game*, PROEDGEWIRE (Feb. 27, 2013), http://www.proedgewire.com/potash-phosphate-intel/potash-corps-bid-for-icl-an-attempt-to-alter-the-potash-game/.

[81] Christopher Donville, *Potash Group's 'Cupboard Is Bare' for India, Mosaic Says*, BLOOMBERG (Jul. 19, 2011), http://www.bloomberg.com/news/print/2011-07-18/canpotex-s-potash-cupboard-is-bare-mosaic-s-prokopanko-says.html.

[82] *Phosagro Pulls Out of Fertilizer Deliveries to India*, MOSCOW TIMES (July 16, 2013) http://www.themoscowtimes.com/business/article/phosagro-pulls-out-of-fertilizer-deliveries-to-india/483171.html.

[83] Garry White, *Potash to slump as Uralkali's new strategy ushers out the era of cartels*, THETELEGRAPH (Aug. 4, 2013), http://www.telegraph.co.uk/finance/commodities/10221572/Potash-to-slump-as-Uralkalis-new-strategy-ushers-out-the-era-of-cartels.html.

analysts to opine that cartel pricing for potash was "over."[84] Defections from – and resulting breakdowns in – anticompetitive agreements, however, are commonplace and could be a temporary adjustment while major producers regroup to address powerful buyer strategies and to penalize defectors from cartel agreements. At the same time, contracting developments in China and India may suggest an evolution toward bilateral oligopoly where price may fluctuate between a low monopsony outcome and a high monopoly outcome. The fertilizer industry – known for decades as having stable prices – may thus exhibit higher price variability moving forward. This variability, however, may not extend to the U.S. or serve to narrow the existing North American-offshore price gap. The three major producers have a significant presence in wholesale and retail fertilizer markets in the U.S., where it is unlikely that farmers will develop the ability to effectively exercise buyer power.[85]

## VI. MODELING MARKET POWER

### A. Factors Facilitating Coordination

The economics literature elucidates a number of structural conditions that tend to make industry more conducive to collusion. These include: (1) communication between firms, (2) conditions of mutual monitoring, (3) number of sellers, (4) relative sizes of sellers, (5) conditions of entry, (6) ease of expansion by smaller firms, (7) cost structure of sellers, (8) structure of the buyer side of the market, (9) industry conditions, (10) nature of the product, and (11) industry history and sociology.

[84] Rod Nickel, *Major potash producers may abandon tactics that would keep prices high*, DENVERPOST (Feb. 13, 2013), http://www.allvoices.com/news/14026546-major-potash-producers-may-abandon-tactics-that-would-keep-prices-high.

[85] Agrium's acquisition of Viterra will give them a dominant position in the retail fertilizer market in Canada and the U.S.

The foregoing factors are "contributory (so-called 'plus') factors to whether a group of oligopolists will be able to maintain an understanding among themselves and thereby jointly to exercise market power."[86] The world's fertilizer industry is characterized by these "plus" factors. Indeed, the world's fertilizer industry has been characterized by cartels during much of its history.[87] Between the two World Wars, collective agreements among fertilizer producers flourished and production and trade in nitrogen, potash and phosphate rock was united. Some analysts estimate that by 1939, about 90 percent of phosphate rock exports and about 79 percent of production was cartelized – the only important outsider being the USSR."[88] Although some cartels broke up during World War II, it remains that the industry has both a history of and current corporate sociology of collusion.

### 1. Communication and Monitoring

"Exchange programs of mutual visits" among government-sanctioned cartels such as *Canpotex* and *PhosChem* and trade associations facilitate communication between firms. For example, in North America, Mosaic and PotashCorp are the dominant phosphorus and potash producers, respectively. The firms dominate both export associations, thus providing a means of communicating not just about individual nutrients but about all nutrients and blended fertilizer prices. So-called "exchange programs" also provide a vehicle for mutual monitoring, made easier

[86] Lawrence J. White, *Market Power: How Does It Arise? How Is It Measured?, in* THE OXFORD HANDBOOK IN MANAGERIAL ECONOMICS (C. R. Thomas and W. F. Shughart II (eds.), forthcoming 2013) (manuscript at 19), available at http://web-docs.stern.nyu.edu/old_web/economics/docs/workingpapers/2012/White_MarketPowerRiseandMeasure.pdf.

[87] The 1957 book by Lamer lays out the history of international fertilizer cartels in great detail, including the part played by Webb-Pomerene Act export cartels. MIRKO LAMER, THE WORLD FERTILIZER ECONOMY (1957).

[88] *Id.,* at 190.

by a high level of product standardization.[89] The ease of monitoring rival behavior is supported by the availability of public information on fertilizer usage and prices by USDA and FAO, and statistics produced by trade associations and market intelligence firms.[90] Annual reports issued by the major players and other industry sources provide detailed information on rivals, including production costs and size.[91] Both Mosaic and PotashCorp provide cost comparisons with non-integrated phosphorus producers, other dominant rivals, and new mines.[92]

### 2. Market Structure and Entry

The third through seventh factors concern relative sizes of sellers and buyers, and conditions of entry and expansion in fertilizer markets. Entry barriers to phosphorus and potash production are extremely high because dominant firms or governments such as China, Morocco, and Canada control most known reserves. Environmental regulations for mining phosphorus and potash also create significant barriers to entry, as does access to financing, which is a bottleneck for new producers.[93] Relatively few, large, similarly sized sellers dominate the industry: PotashCorp, Mosaic, Agrium, OCP, and the Russian cabal. Dominant firms are

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[89] Press Release, Uralkali, Visit by Uralkali Management Team to Canadian company Mosaic, (Jul. 3, 2006), http://www.uralkali.com/press_center/company_news/item656/index.php?print=Y.

[90] Trade associations include: International Fertilizer Industry Association[90] (IFA) and The Fertilizer Institute (TFI) http://www.tfi.org/statistics. International Plant Nutrition Institute (IPNI) provides detailed data through Agristats. http://www.ipni.net/article/IPNI-3157. The nature and timeliness of the data Agristats (http://www.agristats.com) supplies to fertilizer companies is not clear from public information.

[91] See, for example, Potash Corp, *Overview of PotashCorp and Its Industry 2008,* at 55, http://www.potashcorp.com/media/POT_2008_OverviewBook.pdf (citing the data of Fertecon, now part of Informa Economics).

[92] MOSAIC, 2010 ANNUAL REPORT, at. 9. See also, e.g., PotashCorp, *Global Potash Overview* (Mar. 16, 2010), http://www.potashcorp.com/slideshow/167/ and http://www.potashcorp.com/annual_reports/2011/graph_gallery/23.

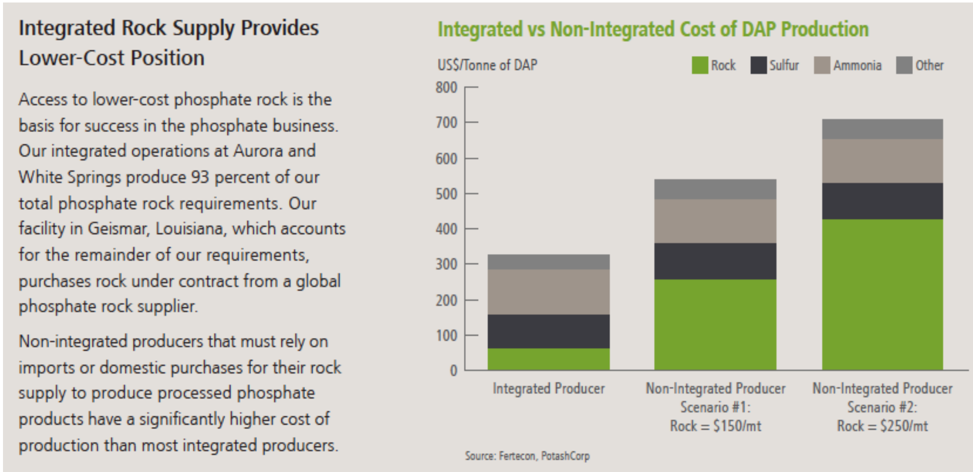
[93] Rabobank, *Playing the Potash Field,* Rabobank Industry Note #321 (Jun. 2012), at2, http://www.miningclub.com/upload/archivos/mercado_mundial_potasio_139.pdf , at 2. Conference Board of Canada, *supra* note 57, at 44.

vertically integrated, largely controlling the known reserves of phosphate rock and potash. Historically, the buyers of fertilizer throughout the world have been many, which aids collusion. As noted earlier, however, this may be changing as India and China contract for fertilizer needs through a smaller number of entities.

Large fertilizer producers also have similar cost structures, with substantially lower costs than smaller, non-integrated rivals. Such fringe firms are, as mentioned previously, dependent on the dominant firms for raw materials necessary for phosphorus and potash fertilizer production, or for mixing product for wholesale and retail sales. Expansion by smaller firms is thus limited by access to raw materials and retail markets. Cost comparisons for DAP shown in Figure 7 reveals a significant difference in price paid for phosphoric rock by large versus small firms that is not due to other material or manufacturing costs. It is not clear whether the non-integrated producers pay substantially more for phosphate rock (or acid) because it must be imported long distances (e.g. Mississippi Phosphates importing from Morocco), they must obtain rock from inefficient mines; or they are paying supra-competitive prices from integrated producers. The cost advantage held by PotashCorp and Mosaic in domestic and foreign markets comes largely from control of domestic reserves of phosphoric rock, as opposed to efficiencies in production.[94]

[94] Apparently, PotashCorp and Mosaic do not sell rock or phosphoric acid to smaller domestic non-integrated phosphorus fertilizer manufacturers. Some other domestic phosphorus manufacturers presently import rock or acid from other sources, (principally OCP) for delivery in Gulf ports near where PotashCorp and Mosaic mines are located.

**Figure 7. DAP Production Cost Comparison**




### 3. Industry Conditions

A final set of factors that can facilitate coordination among rivals involves industry conditions. The fertilizer industry is relatively stable and growing at a predictable pace, making the maintenance of an anticompetitive agreement relatively easy. Demand for major plant nutrients is predictable and highly inelastic, although short-run (one or two crop years) demand for phosphorus and potash is more price elastic than in the long-term. Maintenance of anticompetitive agreements is also facilitated by the fact that the industry is comprised largely of a small, close-knit group of executives and closed trade associations.

## B. Empirically Estimating Market Power

Analysis and measurement of market power in extractive industries is conceptually and empirically complicated by the presence of competitive user cost, often referred to as Hotelling rent.[95] Pindyck emphasized that the (static) Lerner index of monopoly power was misleading and would overstate monopoly power in an extractive industry because it did not account for

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[95] Based on analysis of data from 14 non-ferrous metal mining and refining industries, Margaret Slade reject the hypothesis that firms in exhaustible resource industries are as far-sighted as predicted by the classical (competitive user cost) exhaustible resource model. Margaret Slade, *Competing Models of Firm Profitability*, 22 INT. J. IND. ORGAN. 289 (2004).

Hotelling rent as a competitive departure from static profit maximization.[96] Pindyck thus proposed a simple generalization of the Lerner index for markets in which price and production are intertemporally determined, such as extractive industries. Ellis and Halvorsen further refined Pindyck's theoretical model and empirically applied it to estimation of market power in the nickel industry.[97]

Pindyck's dynamic or instantaneous measure of monopoly power is:

(1) $LD_t = [\, P_t - FMC_t \,] \,/\, P_t$

where $LD_t$ is the dynamic Lerner index at time t, $P_t$ is product price, and $FMC_t$ is full marginal cost at time t. Following Pindyck, the full marginal cost is, defined as,

(2) $FMC_t = MC_t + MUC_t$

where $MC_t$ is the current (static) marginal cost, and $MUC_t$ is marginal user cost, defined to be the present value of all future additional costs of production caused by the marginal unit extracted currently. A firm facing declining average costs may incur a loss if price is equated with marginal cost. A Lerner index computed with marginal cost will therefore potentially *overstate* market power in a declining cost industry.

Empirical measurement of market power is complicated under circumstances when excess capacity results from the exercise of market power. While average cost may be declining over the observed range of fertilizer production, we expect the U-shaped average cost curve to turn up when capacity is reached. However, this segment of the cost curve will not be observed to the extent that supra-competitive pricing (i.e., by restricting production) leads to production along the downward sloping segment of the average cost curve. Such excess capacity means that no

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96 Robert S. Pindyck, *The Measurement of Monopoly Power in Dynamic Markets*, 28 J. L. & ECON. 193 (1985).

97 Gregory M. Ellis & Robert Halvorsen, *Estimation of Market Power in a Nonrenewable Resource Industry*, 110 J. POL'Y ECON. 883 (2002).

empirical data points will be on the upward sloping part of an average cost function. Because the estimated average cost curves are declining over most, if not all of the observed range of variability, estimates of the dynamic Lerner index using actual AC (instead of MC) are also presented. In contrast to the use of MC, however, when excess capacity results from supra-competitive pricing, the Lerner index computed from AC will potentially *underestimate* the degree of market power.

### C. Cost Functions and Product Supply Relations

Data used in this analysis exhibit sufficient variation in quarterly sales and a few key input prices to permit direct estimation of a total cost function. A stylized quadratic total cost function is specified to allow for the effects of production (or sales quantity) on current costs, future costs, and the fixed proportion nature of fertilizer production:

(3) $TC_t = \alpha_1 + \alpha_2 Q_t + \alpha_3 Q_t^2 + \alpha_4 Z_{t-1} + \alpha_5 Q_t R_t$

where $TC_t$ is the total cost of goods sold, t is a time index, $Q_t$ is the quantity sold in t, and $R_t$ is a exogenous unit input cost (or set of input costs). $Z_t$ is the cumulative production defined as the sum of the quantities from the beginning of the observation period through t. Any effects of cumulative production prior to the first empirical observation (t = 1) are implicit in the intercept, $\alpha_1$.

The chemistry of fertilizer manufacturing is essentially to combine inputs in fixed proportions. Consequently, specification of total cost function (1) uses the product $Q_t R_{t,}$ which can be interpreted as the part of total production cost attributable to the input R. Factors such as labor and mining equipment could introduce nonlinearities into a cost function. The lack of firm and product specific data on numerous inputs – or the lack of sufficient variation in other input prices (e.g., wage rates) – does not allow for more sophisticated cost functions. Nevertheless, the linear and quadratic terms for $Q_t$ in (3) are considered to allow for possible nonlinearity in the total cost function.

The cost of goods sold shown in corporate financials includes allocation of certain fixed costs based on sales.[98] Specification of (3) to include the term $\alpha_4 Z_{t-1}$ means that AC, but not MC, is influenced by cumulative production. There is a high and rising real cost of exploration, permitting, development, and other capital investment for mine expansion and for development of a new mine for phosphorus and potash. To the extent that fixed costs dominate expansion, it is plausible that AC but not MC would rise with cumulative production, $Z_t$. An alternative specification of (3) would include the term $\alpha_6 Z_{t-1} Q_t$ in lieu of or in addition to $\alpha_4 Z_{t-1}$. These alternative mathematical forms of (3) allow both AC and MC to change with cumulative production. Dynamic Lerner indices and market power are estimated with all three of these specifications. Although there are small differences – depending on nutrient and company – statistical results weakly favored specification shown in equation (3). In any case, specification of this term does not appreciably affect empirical conclusions. For convenience, the coefficient $\alpha_4$ is at times referred to as the "Hotelling" coefficient, even though it does not precisely measure Hotelling rent.

In keeping with the Ellis and Halvorsen approach, MUC measures the marginal cost of any increase in the future incremental cost of production resulting from extraction in a given period. While the derivation under this approach employs an optimal control theory model, here we simplify derivation of MUC for a competitive firm by considering the present value of cost over the expected economic life of the mine. Given total cost function (3), the present value of the total cost function over the entirety of the planning horizon is,"

(4) $PVCT_t = TC_t + \beta TC_{t+1} + \beta^2 TC_{t+2} + \ldots + \beta^T TC_T$

98 In other words, corporate financials allocate unallocable fixed costs.

where $PVTC_t$ is the net present value of the total cost of the firm over the planning horizon, T, and $\beta$ is the discount factor.

Full marginal cost ($FMC_t$) therefore is given by,

(5) $(\delta PVTC_t / \delta q_t) = (\delta TC_t / \delta q_t) + \beta(\delta TC_{t+1} / \delta Z_t)(\delta Z_t / \delta q_t) + \ldots + \beta^T(\delta TC_T / \delta Z_{T-1})(\delta Z_{T-1} / \delta q_t)$

where the first term on the right hand side of (5) is current marginal cost, $MC_t$, and the remaining terms comprise $MUC_t$. Noting that:

$(\delta Z_t / \delta q_t) = (\delta Z_{t+1} / \delta q_t) = \ldots = (\delta Z_T / \delta q_t) = 1$, and that $\alpha_5 = (\delta TC_{t+1} / \delta Z_t)$,

equation (5) reduces to:

(6) $(\delta PVTC_t / \delta q_t) = MC_t + \beta\alpha_4 + \beta^2\alpha_4 + \ldots + \beta^T\alpha_4$

which can be rewritten as:

(7) $(\delta PVTC_t / \delta q_t) = MC_t + \beta\alpha_4(1- \beta^T) / (1- \beta)$

Thus:

(8) $FMC_t = MC_t + MUC_t = (\delta PVTC_t / \delta q_t)$

Estimates of the coefficients, $\alpha$, in the total cost equation (3) provide estimates of the dynamic Lerner index, (1), for each t:

(9) $LD_t = [ P_t - (\alpha_2 + 2\alpha_3 Q_t + \alpha_5 R_t) - \beta\alpha_4( 1- \beta^T) /( 1- \beta)] / P_t$

Ellis and Halvorsen simultaneously estimated a cost function with a supply relation that includes a market power markup term given by:

(10) $P_t = FMC_t - (\delta P^*_t / \delta q_t)Q_t$

where $(\delta P^*_t/\delta q_t)$ is the slope of the "perceived" demand, $P^*_t$. Ellis and Halvorsen, Breshahan, and others specified a model that allows the degree of market power to vary over time. With a polynomial in time, g(t), we replace $(\delta P^*_t/\delta q_t)$ in (10) to obtain:

$$(11) \qquad P_t = FMC_t - g(t)\, Q_t = [(\alpha_2 + 2\alpha_3 Q_t + \alpha_5 R_t) + \beta\alpha_4(1-\beta^T) / (1-\beta)] - g(t)\, Q_t$$

Equation (11) is referred to as a supply "relation," as distinguished from a true supply function, because it is based on a *perceived* demand function. A g(t) significantly different from zero means that firm behavior is not competitive.

Specification of g(t) as a (smooth) polynomial function, as implemented by Ellis and Halvorsen, presumes that any changes in market power occur smoothly over time. Events in the global fertilizer industry suggest, however, that changes in the exercise of market power may have been smooth through 2007. But the tripling of prices in 2008 suggests a dramatic shift in market power and perhaps the emergence of a global super cartel involving not just the major industry producers, but also multiple plant nutrients, especially phosphorus and potash. Fertilizer producers' explanation, whether real or pretext, that demand changes during this period were due to high agricultural prices suggest the addition of an agricultural price index as a shifter of market power. The substantial fall in prices that began late in 2009 also suggests non-smooth changes in market power.

To allow for non-smooth changes in market power, g(t), is augmented to allow for the firm's perception of the slope of the demand function, g(.), to discretely change during critical times periods (represented by binary variables) as well as smoothly change with agricultural prices. Thus, (11) is augmented as follows:

$$(12) \qquad P_t = FMC_t - g(t)\, Q_t = [(\alpha_2 + 2\alpha_3 Q_t + \alpha_5 R_t) + \beta\alpha_4(1-\beta^T) / (1-\beta)] - g(t, D_{it}, PF_t)\, Q_t$$

where $D_{it}$ a set of i binary (dummy) variables to measure possible discrete changes during critical time periods, and $PF_t$ is an index of agricultural prices.

Switching regressions have also been employed or suggested for empirical analysis of oligopoly behavior when cooperative periods may have broken down.[99] While conceptually appealing, application of switching regression to the fertilizer markets does not seem viable because the period during which potential anticompetitive coordination is apparent lasts only a few quarters. Thus, there are inadequate observations to estimate a switching regression model and several binary variables, as suggested above, are therefore employed.

We use an econometric approach similar to Ellis and Halvorsen in that (3) and (12) are simultaneously estimated. But here, the two equations for each nutrient produced are included in a simultaneous system for all nutrients produced by the firm. For companies that produce all three nutrients, this results in a system of six equations. The system is estimated using Zellner's seemingly unrelated regression technique to account for possible correlation of error terms appended on the equations and for cross-equation parameter restrictions. An alternative approach involves a two-step estimation procedure. In the first step, the total cost function (3) is estimated using OLS. This gives estimates of the parameters in (3) and thus estimates of $MC_t$ and $MUC_t$, which are substituted into (12) to give:

$$(13)\quad P_t = \{(\hat{a}_2 + 2\hat{a}_3 Q_t + \hat{a}_5 R_t) + \beta\alpha_4(1-\beta^T) / (1-\beta)\} - g(t, D_{it}, PF_t)\, Q_t$$

where $\hat{a}_k$ are estimates of $\alpha_k$ obtained from the single equation estimate of the total cost function, (3). In the second step, parameters characterizing the market power term, g(.) in equation (13) are estimated with OLS.

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[99] Timothy F. Bresnahan, *Empirical Studies of Industries with Market Power*, in 2 HANDBOOK OF INDUSTRIAL ORGANIZATION (Richard Schmalensee & Robert D. Willig, eds. 1989).

It is plausible that this two-step process mimics the corporate decision process better than the simultaneous approach because decision makers in the fertilizer industry likely have much better information about their cost structure than they do about the exercise of market power. With simultaneous estimation of two equations with common parameters, misspecification of one equation may distort estimates of both equations, thereby leading to inaccurate conclusions about the exercise of market power. However, the two-step procedure is also subject to specification and estimations biases that are unknown a priori.

Preliminary estimates of the total cost function (3) generally reveal AC declining over the observed range of variation in quantity for each nutrient and each firm. As noted earlier, to the extent that this is a declining cost industry, use of marginal cost ($MC_t$) may overestimate market power in the dynamic Lerner index. Some applications of the static Lerner index use AC because MC is unavailable or there are inadequate data to directly estimate MC (from TC or AC equations). Declining AC over the observed range of data may be an artifact of excess capacity attributable to oligopoly rather than competitive behavior. Given the nature of the fertilizer production process and short-term fixed mines and plants, one would expect AC to turn up sharply when production capacity is reached or neared. Absent observations in this range, the potential of MC to overestimate market power cannot be definitively resolved. Consequently, models are estimated with actual AC replacing estimated MC in equation (12) or (13). Dynamic Lerner indices are computed using both actual AC and estimated MC.

Supply relation (12) or (13), as well as the dynamic Lerner indices, include a discount term $\beta(1- \beta^T) / (1- \beta)$. This term cannot be econometrically estimated (identified) separate from other coefficients in the model. For estimation purposes, a five percent real (annual) discount rate is assumed. Based on numerous references in company and USGS reports about the expected life of the known phosphate rock and potash deposits, a life (T in the equations) of 40 years for phosphorus and 100 years for potash is assumed. As a practical statistical matter, these assumptions are not highly critical in econometric estimation, as scaling the discount factor up or down would have the opposite effect on parameters characterizing g(.). However, the assumptions are critical determinants of MUC.

Comparison of estimates from the two approaches using both MC and AC specifications sheds light on the robustness of estimates of market power. Since market power estimates and associated significance levels are not appreciably different across the two approaches, results from the simultaneous approach are used in the main text.

### D. Financial Data and Empirical Estimates of Market Power

PotashCorp, Mosaic, and Agrium publicly report quarterly price, cost, and quantity data for each of their nitrogen, phosphorus, and potash segments.[100] Consistent quarterly financials for PotashCorp and Agrium cover 15 years, while Mosaic covers five years.[101] This provides an unusually rich data set for analysis of market power, permitting econometric estimation of not only (current) marginal cost, but also the marginal user cost. Prices and costs are expressed in current dollars using the GDP implicit price deflator.

[100] A common difficulty in market power analyses is that reported financials might not provide managerial or economic costs information appropriate for market power analysis. Franklin M. Fisher, John. J. McGowan. *On The Misuse of Accounting Rates of Return to Infer Monopoly Profits*, 73 AM. ECON. REV. 82, 82 (1983); Peter Davis & Eliana Garces, QUANTITATIVE TECHNIQUES FOR COMPETITION AND ANTITRUST ANALYSIS 125(2010) Mosaic, which was formed in 2004, realigned their financial reporting in 2009, and reconstructed segment financials back through 2007. Their stated reason was to align reporting with "how our chief operating decision maker began viewing and evaluating our operations." Thus their segment financials, as well as similar reporting by PotashCorp and Agrium, seem appropriate for economic analysis.

[101] This analysis did not rely on Mosaic financials for 2005-2006, as they were based on different accounting procedures than the financials later reconstructed by Mosaic back to 2007.

System estimates of equations (1) and (12) for all nutrients manufactured by PotashCorp, Mosaic, and Agrium are presented in Appendix A.[102] Estimated total cost equations (1) generally explain about 70 percent of the variability in cost, while estimated supply relationships (12) explain over 95 percent of the variation in price. The alternative estimation approaches proposed in the earlier discussion produce similar results, so only the system estimates are presented.

Most of the variables included in the market power component of the system models are highly significant. A function quadratic in t generally fits best, and most of the quarterly binary variables for Q1 2008 through Q2 2009 are significant. The general pattern for estimated coefficients on the binary variables reveal growing market power starting in Q1 2008, rising until late 2008, and then declining through Q2 2009. Coefficients on polynomial terms must be interpreted as a set. In interpreting the estimated market power terms in g(.), it is important to note that a significant negative sign reveals a "positive" market power effect. Furthermore, coefficients on binary variables must be interpreted relative to this smooth quadratic trend and not relative to zero (pure competition).

Critical to implementation of the dynamic Lerner index and thus critical to assessment of oligopoly behavior is the $MUC_t$, which in this case is based on the estimated Hotelling rent coefficient, $\alpha_4$. Estimated values of this coefficient are summarized in Table 3.

**Table 3. Estimated values of the Hotelling rent coefficient, $\alpha_4$**

| Company/Model | Phosphorus | Potash |
|---|---|---|
| Potash Corp–AC | 1.36 | 1.32 |
| Potash Corp–MC | 2.67 | 1.36 |
| Agrium–AC | 1.78 | 1.60 |
| Agrium–AC | 2.36 | 1.54 |
| Mosaic–AC | 1.31 | 1.54 |
| Mosaic–MC | 2.46 | 3.40 |

[102] Appendices are available from the authors upon request.

All of the estimated Hotelling rent coefficients in Table 3 are significant at a 95 percent or higher level, except for the Mosaic phosphorus equations, which are significant at a 75 percent or higher level. Estimated coefficients using the MC specification tend to be somewhat higher than in the AC specification. Magnitudes of the estimates are similar for all models and for phosphorus and potash.

Results of the system estimation can be summarized in various ways. Perhaps the most informative for inferences about oligopoly and cartel behavior are simple statistical tests of whether the mean of the estimated dynamic Lerner index is equal to zero for different time periods. Test statistics are shown in Tables 4 and 5 for index values calculated using the system results (Appendix A) for the AC and MC models, respectively. Average sales are also shown in this Table.[103] Table 4 indicates values that are statistically significant at a 90 percent confidence level (in bold). Probability levels are shown below respective means. Significant positive means are highlighted in bold, while negative means are highlighted in blue. A negative mean is consistent with pricing behavior designed to drive out rivals, or it could be due to a breakdown in cartel agreements. A significant positive mean (red) is consistent with supra-competitive pricing.

[103] Sales for each company and segment did not have a distinct upward or downward trend over the observation period.

| **Table 4. Mean Dynamic Lerner Indices and Associated Probability Level for Different Time Periods based on AC Models** | | | | | | |
|---|---|---|---|---|---|---|
| | **Avg. Quarterly Sales (1,000 tons)** | **All** | **1998-2004** | **2005-2007** | **2008-2009** | **2010-2012** |
| **PotashCorp – nitrogen** | **1,279** | **0.210** | **0.102** | **0.276** | **0.221** | **0.392** |
| | | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| **Agrium – nitrogen** | **1,099** | **0.280** | **0.216** | **0.256** | **0.354** | **0.410** |
| | | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| **PotashCorp – phosphorus** | **917** | **-0.107** | **-0.246** | **-0.097** | 0.077 | **0.090** |
| | | 0.00 | 0.00 | 0.02 | 0.37 | 0.00 |
| **Mosaic – phosphorus** | **2,841** | 0.037 | | | 0.004 | **0.058** |
| | | 0.27 | | | 0.96 | 0.06 |
| **Agrium – phosphorus** | **258** | **-0.098** | **-0.247** | **-0.121** | 0.100 | **0.147** |
| | | 0.10 | 0.00 | 0.00 | 0.40 | 0.01 |
| **PotashCorp – potash** | **1,804** | **-0.088** | **-0.470** | **-0.050** | **0.460** | **0.407** |
| | | 0.11 | 0.00 | 0.04 | 0.00 | 0.00 |
| **Mosaic – potash** | **1,650** | **0.154** | | | **0.191** | **0.200** |
| | | 0.00 | | | 0.01 | 0.00 |
| **Agrium – potash** | **381** | **-0.168** | **-0.488** | **-0.223** | **0.383** | **0.275** |
| | | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |

Notes: Probability that the dynamic Lerner index is not equal to zero is given s below respective means. Means that are statistically statistical significance at a 90 percent or higher level of confidence are shown in bold. Significant negative values are shown in blue, and significant positive numbers in red. Mosaic data covered the period Q3 2007 through Q2 2012

| Table 5. Mean Dynamic Lerner Indices and Associated Probability Level for Different Time Periods based on MC Models | | | | | | |
|---|---|---|---|---|---|---|
| | **Avg. Quarterly Sales (1000 tons)** | **All** | **1998-2004** | **2005-2007** | **2008-2009** | **2010-2012** |
| **PotashCorp – nitrogen** | **1,279** | **0.295** | **0.240** | **0.300** | **0.315** | **0.407** |
| | | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| **Agrium – nitrogen** | **1,099** | **0.194** | **0.087** | **0.201** | **0.313** | **0.360** |
| | | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| **PotashCorp – phosphorus** | **917** | **0.205** | **0.073** | **0.144** | **0.439** | **0.427** |
| | | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| **Mosaic – phosphorus** | **2,841** | **-0.024** | | | -0.070 | 0.011 |
| | | 0.63 | | | 0.55 | 0.67 |
| **Agrium – phosphorus** | **258** | -0.016 | **-0.232** | -0.076 | **0.287** | **0.356** |
| | | 0.66 | 0.00 | 0.12 | 0.01 | 0.00 |
| **PotashCorp – potash** | **1,804** | 0.060 | **-0.314** | **0.051** | **0.637** | **0.567** |
| | | 0.27 | 0.00 | 0.03 | 0.00 | 0.00 |
| **Mosaic – potash** | **1,650** | 0.042 | | | 0.121 | **0.062** |
| | | 0.55 | | | 0.32 | 0.06 |
| **Agrium – potash** | **381** | **-0.109** | **-0.500** | **-0.189** | **0.539** | **0.467** |
| | | 0.07 | 0.00 | 0.00 | 0.00 | 0.00 |

Notes: Probability that the dynamic Lerner index is not equal to zero is given below respective means. Means that are statistically statistical significance at a 90 percent or higher level of confidence are shown in bold. Significant negative values are shown in blue, and significant positive numbers in red. Mosaic data covered the period Q3 2007 through Q2 2012

Results in Tables 4 and 5 establish significant supra-competitive pricing for nitrogen for the full observation period, 1998-2012. Results for phosphorus and potash are mixed for the early period, but reveal a high degree of supra-competitive pricing for 2008-2009, followed by lower, but significant supra-competitive pricing for 2010-2012. Anomalous results for Mosaic (phosphorus) are explained by cost considerations, not pricing differences. Values in Tables 4 and 5 for Mosaic are based on an estimated MUC that is statistically insignificant at classical levels and higher for Mosaic than for PotashCorp or Agrium. Furthermore, AC of phosphorus for Mosaic is higher than for PotashCorp and Agrium, perhaps because Mosaic had yet to achieve or fully achieve operating efficiencies they anticipated with the 2004 merger of IMC Global and Cargill's crop nutrition. Deleting the insignificant MUC from the Lerner calculation reveals significant positive exercise of market power by Mosaic for 2008-2012.

The overall average of the dynamic Lerner index for all three companies and three nutrients is 0.29 over the 2008-2012 period. This means that profits for members of *Canpotex* and *PhosChem* are 29 percent above the cost of goods sold (or above marginal cost), after accounting for the marginal user cost associated with an extractive industry. The dynamic Lerner index for PotashCorp, Mosaic, and Agrium across the three nutrients analyzed averages about 0.40 over 2010-2012, indicating that a very high degree of market power markup remains in the industry. In contrast, the conventional (static) Lerner index based on AC and ignoring MUC averages 0.39 over 2008-2012 for the members of *Canpotex* and *PhosChem.* Both static and dynamic Lerner indices indicate a higher degree of supra-competitive pricing for potash than for nitrogen and phosphorus. Figures 8 through 15 show the estimated market power markup, which is the numerator in the dynamic Lerner index.  A negative market power markup (bar below the zero line) means that FMC exceeds price. These figures also show estimated MUC and MC. For phosphorus and potash, MUC is fairly large relative to MC.

The composite picture that emerges from Figures 8-15 is one in which market power is increasingly exercised over time, with some ebb and flow. Similar trends for all three nutrients clearly establish a high interconnectedness of oligopoly behavior in global markets for the three nutrients.

**Figure 8. Components of the Price of Nitrogen Fertilizer for Potash Corp**

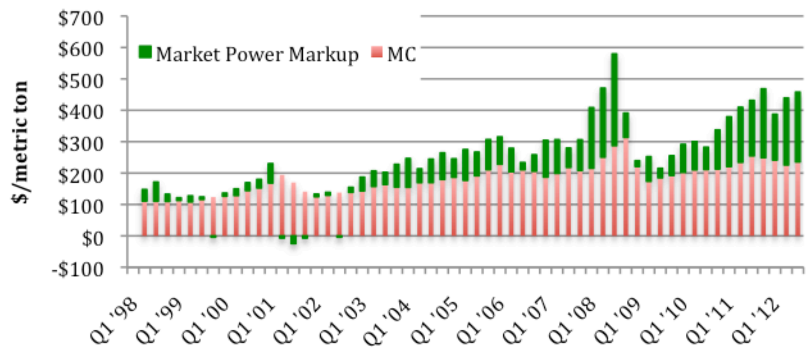



**Figure 9. Components of the Price of Nitrogen Fertilizer for Agrium**

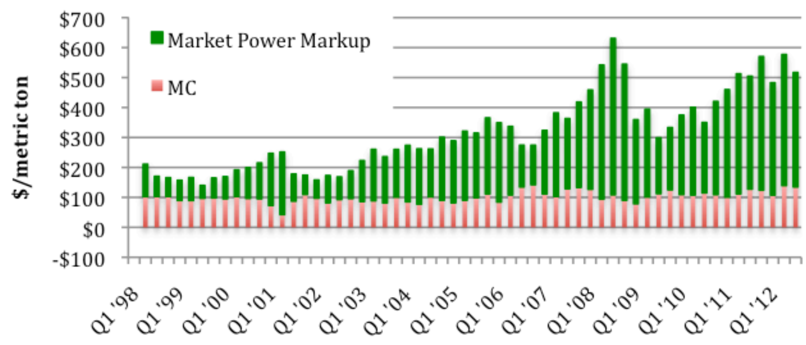



**Figure 10. Components of the Price of Phosphorus Fertilizer for Potash Corp**

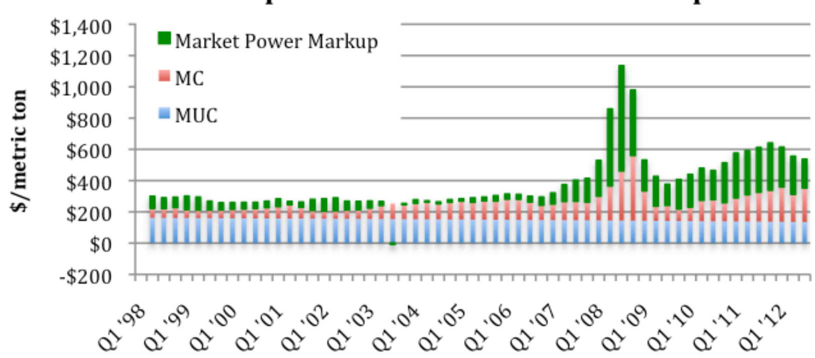


**Figure 11. Components of the Price of Potash Fertilizer for Agrium**

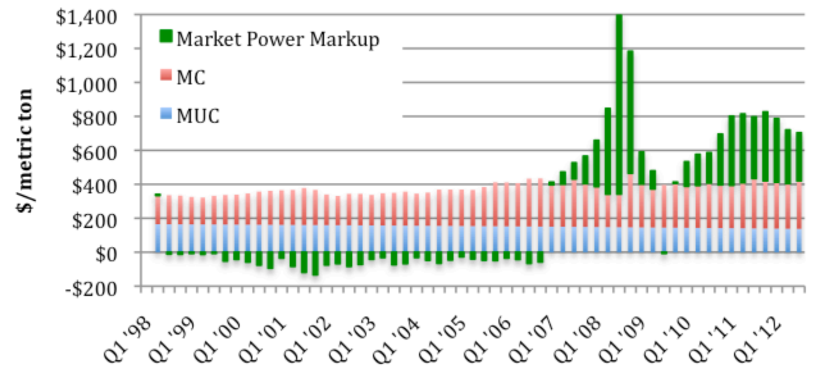



**Figure 12. Components of the Price of Phosphorus Fertilizer for Mosaic**

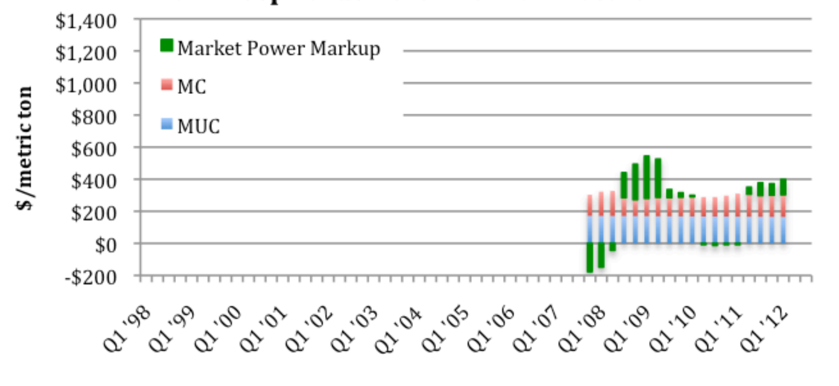
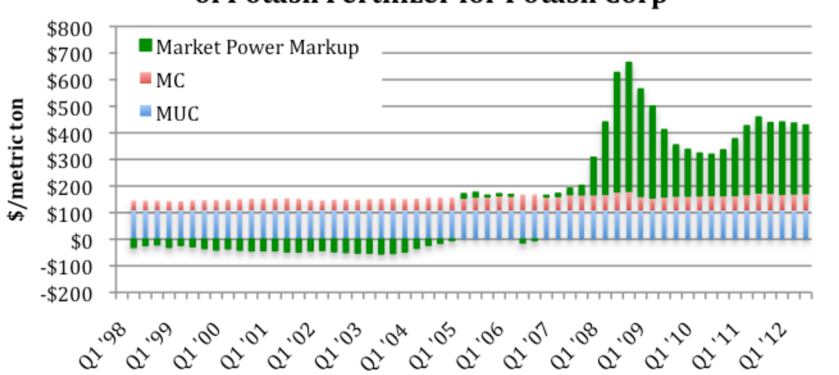
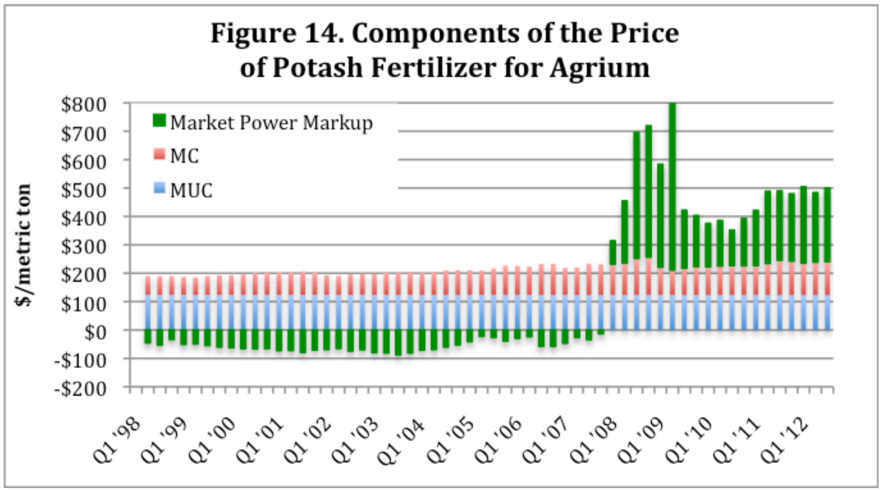
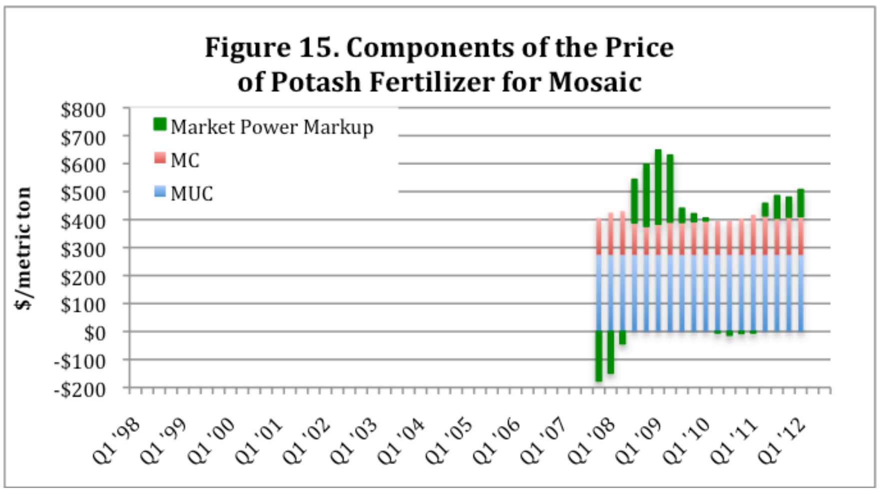



**Figure 13. Components of the Price of Potash Fertilizer for Potash Corp**



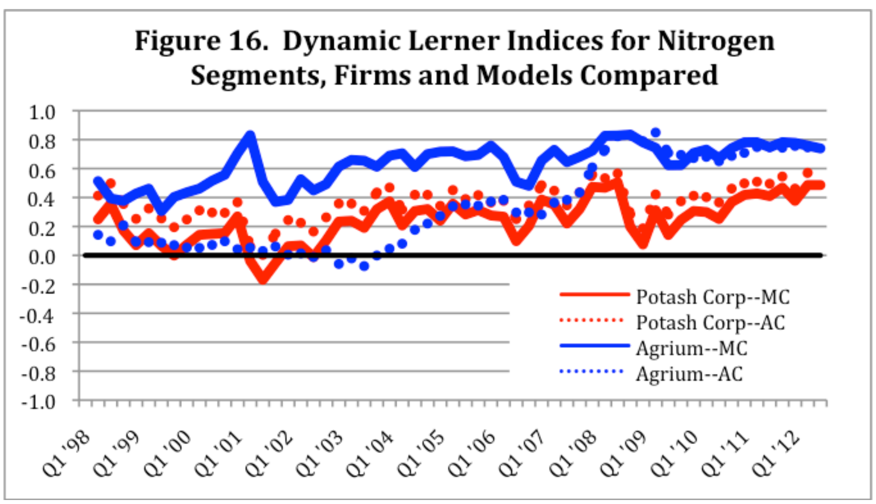


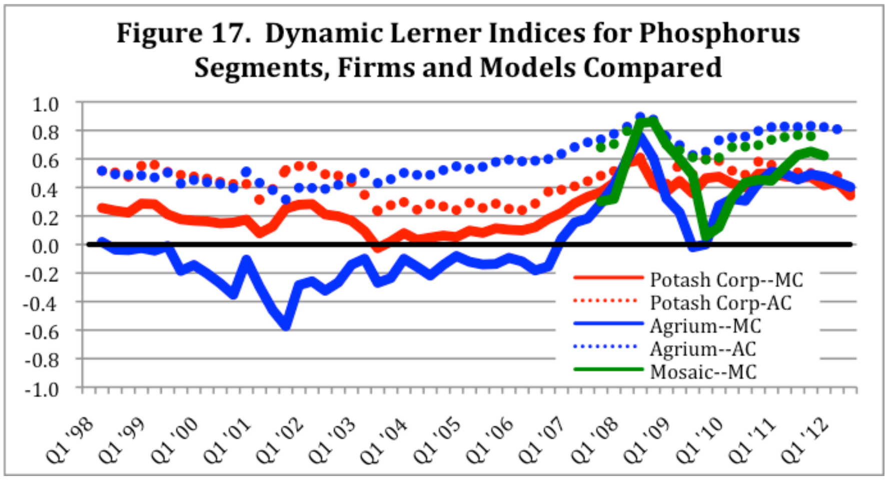



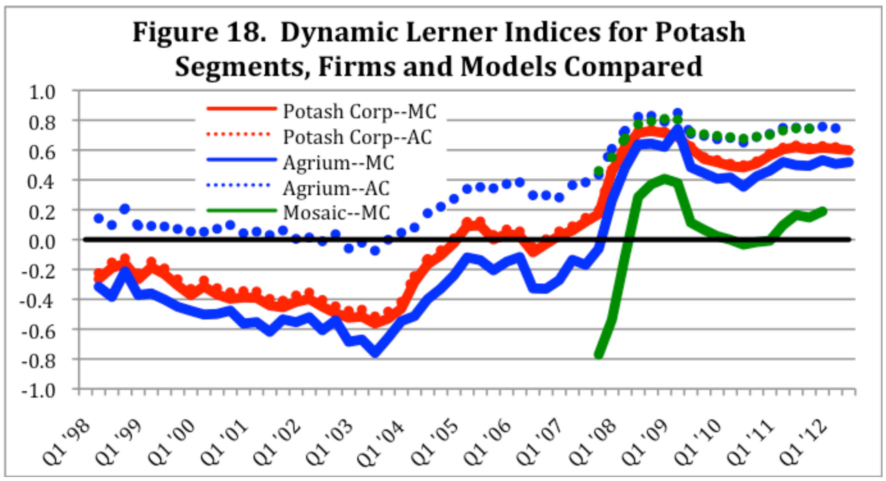

The fairly large negative market power markup for Mosaic phosphorus and potash during the first three quarters is primarily attributable to an estimated MUC that is relatively large (Table 3) but insignificant. Mosaic nevertheless obtained a short-run operating profit for these quarters for both phosphorus and potash. Full marginal cost (MUC + MC) exceeds price for Mosaic phosphorus and potash during the first three quarters of the observation period beginning mid-2007. This slight departure from the results for PotashCorp and Agrium may be explained by the formation of Mosaic in late 2004 and subsequent reorganization that did not result in operating efficiencies until later. For Mosaic potash, the estimated MUC is less than for the potash segments of PotashCorp and Mosaic. However, the estimated MUC for Mosaic phosphorus and potash is larger than for PotashCorp and Agrium, and also statistically insignificant at classical significance levels. Therefore, market power markup by Mosaic may be considerably more than the estimates charted in Figures 12 and 15 suggest. Figures 8-15 above shows MC estimated from the MC system of equations. The overall conclusion about market power markup based on estimates from the AC system of equations does not differ appreciably from the MC results.

## E. Comparison of Dynamic Lerner Indices

Figures 16-18 present estimates of dynamic Lerner indices estimates for nitrogen, phosphorus, and potash and inter-firm comparisons from the MC and AC models. Index values computed from the MC model use estimated MC and MUC from that model. Index values computed from the AC model use actual AC and estimated MUC from the AC model (not the MC model). Statistical fits of the AC and MC models are similar, so there is no compelling statistical reason to pick one model over the other and therefore both are presented.






Comparing Figures 17 and 18 reveals similarities in the exercise of market power over time in phosphorus and potash markets, respectively. The pattern for nitrogen in Figure 16 is somewhat different. The former suggests potentially anticompetitive coordination in phosphorus and potash markets – not a surprising result since PotashCorp and Mosaic dominate in *PhosChem* and *Canpotex*. Moreover, some major nitrogen producers do not produce phosphorus and potash, thus making anticompetitive coordination more difficult in the nitrogen market.

Figure 16 reveals a high degree, and fairly steady level, of market power exercised by PotashCorp and Agrium in the nitrogen market. Only a slight upward trend in power is discerned. The temporary dip in the nitrogen Lerner index in 2001 is largely due to a spike in natural gas prices. For the phosphorus market, the dynamic Lerner index is negative for Agrium in the MC model for 1998-2006. However, the index estimated form the AC model for Agrium is just the opposite. Because the overall statistical fit of the Agrium MC and Agrium AC models is essentially the same, there is no clear preference for one model over the other.

In general, Figure 17 reveals the significant exercise of market power in phosphorus markets over 1998-2006, rising to 0.80, rapidly falling in 2009, then recovering to an average of about 0.50. It is important to note that the dynamic Lerner indices and market power markups are based on an average sales price. To the extent that domestic producers are charged more for phosphorus and potash, the dynamic Lerner indices for U.S. purchasers would be higher that those shown. Estimates of dynamic Lerner indices for potash (Figure 18) suggest that PotashCorp and Agrium potentially engaged in substantial predatory pricing over the period 1998-2004. Induced consolidation, combined with strengthening of ties between the other major potash producers such as Belaruskali, Uralkali, and Silvinit, created conditions more conducive to forming and policing collusive agreements that are more consistent with the high level of market power exercised since 2007.

Dynamic Lerner indices in phosphorus and potash markets reached similar highs of about 0.80 in 2008, but do not dip as far for potash and phosphorus in 2009. This suggests that potentially collusive agreements might have broken down in 2009 more in phosphorus than in potash, perhaps due to the behavior of OCP. Table 6 summarizes market power measures averaged over 2008-2012.

| Table 6. Average Percentage Market Power Markup (MPM) based on MC, FMC, and Gross Operating Profit by Segment, 2008-2012 | | | | |
|---|---|---|---|---|
| **Company and Nutrient** | **Average Quarterly Sales (1000 tons)** | **Gross Operating Profit** | **MPM based on MC (Static Lerner Index)** | **MPM based on FMC (Dynamic Lerner Index)** |
| Potash Corp – nitrogen | 1,279 | 27.4 percent | 38.0 percent | 38.0 percent |
| Agrium – nitrogen | 1,099 | 38.6 percent | 75.7 percent | 75.7 percent |
| Potash Corp – phosphorus | 917 | 22.0 percent | 70.0 percent | 46.3 percent |
| Mosaic – phosphorus | 2,841 | 18.3 percent | 88.9 percent | 63.0 percent |
| Agrium – phosphorus | 258 | 29.0 percent | 64.7 percent | 45.0 percent |
| Potash Corp – potash | 1,804 | 68.2 percent | 86.3 percent | 61.1 percent |
| Mosaic – potash | 1,650 | 47.5 percent | 72.4 percent | 13.2 percent |
| Agrium – potash | 381 | 59.7 percent | 77.6 percent | 52.4 percent |
| **Average – nitrogen** | **2,378** | **32.6 percent** | **55.4 percent** | **55.4 percent** |
| **Average – phosphorus** | **4,016** | **19.8 percent** | **83.0 percent** | **58.0 percent** |
| **Average - potash** | **3,835** | **58.4 percent** | **79.5 percent** | **39.6 percent** |

### F. Demand Analysis

Fertilizer producers claim that substantial declines in consumption in 2008 were due to the global recession. Such declines would reflect a shift in the demand curve due to exogenous factors, as opposed to movement along the demand curve due to the exercise of market power. The analysis in this section attempts to shed some light on whether consumption changes during the price spike period are due to a shift in demand or due to a movement along a demand curve. We employ standard econometric demand analysis for this purpose. Econometric estimates of actual aggregate demand for fertilizer in the U.S. are given in Appendix B, while estimates of actual firm-level demand for nitrogen-phosphorus-potash marketed by PotashCorp, Mosaic, and Agrium appear in Appendix C. Global demand is not analyzed because credible foreign fertilizer price data are not available.

It is important to note that the market power term in the product supply relation for individual firms, $(\delta P^*_t/\delta q_t) = g(t)$ in equations (10) and (11), is the slope of the firm's perceived demand. Perceived demand can differ from actual demand analyzed here. In individual firm demand models, the term g(t) may include the net effects of various forms of oligopoly behavior. Unfortunately, adequate data are not available to analyze firm specific oligopoly behavior and how it may have changed over time.[104] As discussed earlier, price and quantity are not simultaneously determined. Rather, there is a tendency for firms to establish price, then allow quantity to adjust. This means that single equation techniques can be used to estimate quantity-dependent demand equations without the complications of simultaneously estimating supply functions or relationships.

Explanatory variables included in the demand models are the real price of fertilizer and a real price index of farm commodities. The same set of six binary variables used in the market power analysis to represent Q1 2008 through Q2 2009 are included in the firm specific demand models. Only annual data on U.S. fertilizer consumption and prices paid are available, so binary variables for the crop years ending in 2008 and 2009 are included. Estimated U.S. demand for nitrogen-phosphorus-potash is presented in Appendix Tables B-1 through B-3. Results indicate that demand for all three nutrients is highly inelastic, both in the short and long run. As expected, higher U.S. crop prices increase farmers' demand for fertilizer but the relationship between fertilizer consumption and crop prices is also very inelastic.

The binary variable for crop year 2008 is insignificant for all three nutrients, which is not surprising since much of the fertilizer for crops harvested in 2008 was applied or contracted for in 2007, before the spike in prices. However, the binary variable for crop year 2009 is significant and

[104] Data needs include price and sales by each firm in the industry, not just that for the three companies analyzed in this report.

negative for nitrogen and phosphorus but insignificant for potash. The magnitude of the estimated coefficients for the binary variable for 2009, along with other estimated coefficients, show that consumption decreases in 2009 are due in part to a downward shift in demand but also to fertilizer price and crop price changes.

Firm specific demand for nitrogen-phosphorus-potash is presented in Appendix Tables C-1 through C-7. Most of the binary variables for the six critical quarters are not statistically significant after accounting for normal quarterly variation. Only nine of the 48 combined estimated coefficients are significant at a 90 percent or higher level. Furthermore, no discernable pattern to the significant binary variables is apparent, nor is there any consistency of sign and significance of binary variables included in the cost and product supply relations given in Appendix A. Firm-specific estimates may, however, be subject to omitted variable bias to the extent that other firms' quantities are necessarily omitted due to incomplete data for the industry.

The composite picture that emerges from the foregoing analysis is that demand may have shifted downward somewhat in 2009 as a result of the weak global economy. However, much of the decline in consumption during the price spike period is due largely to movements along a demand curve explainable by fertilizer and crop price changes. This result casts significant doubt on fertilizer producers' claims that a fall in consumption in 2008-2009 was due to a weakening global economy. A doubling or tripling of prices over this period in light of the Lerner index results discussed above also provides strong support for the notion that price increases were not due largely to increasing input costs (as claimed by the industry) but the result of potentially anticompetitive conduct by dominant firms in the industry.

### G. Stages of Oligopoly Behavior in the Global Fertilizer Industry

Combined with other anecdotal evidence discussed earlier, the foregoing analysis reveals five stages of potential dynamic oligopoly or cartel behavior.

#### 1. Stage I - 1998-2004 and Stage II - 2005-2007

1998-2004 is a period of generally negative (dynamic) markups due to the exercise of market power, although the dominant, vertically integrated firms generally exhibit a short run profit. This period is potentially consistent with oligopoly behavior designed to drive out rivals, discipline cartel members, correct erroneous overinvestment in capacity, or a combination of all. Industry representatives euphemistically referred to this timeframe as a period of industry "consolidation." Following industry consolidation, prices, market power markups, and short-term profits began a gradual rise.

#### 2. Stage III – 2008

Beginning in Q1 2008, nitrogen, phosphorus, and potash prices dramatically increased. As suggested by dynamic Lerner index analysis, markups and profits are enormous. The accompanying decline in global consumption of phosphorus and potash was largely a result of price escalation. Manufacturers' inventories swelled to the point where they temporarily shutdown production. Yet prices did not decline substantially for three quarters. This combination of prices, profits and excess capacity strongly suggests the existence of anticompetitive coordination at the global level in phosphorus and potash. This potential super- cartel was likely comprised of *PhosChem, Canpotex*, the Russian cabal, the Moroccan OCP, and perhaps others.

#### 3. Stage IV – 2009 and Stage V - 2010-2012

Prices declined substantially in 2009, as did the market power markups for all three nutrients. Extremely high prices and profits in 2008 triggered substantial interest in a global search for new reserves of phosphate rock and potash deposits, particularly by potential large new entrants seeking access to capital. Dramatic price declines in 2009 are attributable to any combination of factors: a weakening of a possible "super" cartel, incumbent firms lowering prices to dissuade potential entrants, or to quiet the public outcry for an antitrust investigation. Prices generally bottomed out in late 2009, then rose significantly but not to the levels seen in 2008. The dynamic Lerner index averaged about 40 percent for all three companies and nutrients for the period 2010-2012. Even in relation to indices approaching 80 percent in 2008, these markups would be considered very high.

## VII. ANTITRUST INACTION

Farmer complaints about high fertilizer prices and alleged cartel behavior have produced limited meaningful action by governments or through private litigation. For example, Russian farmers protested to the Russian Federal Antimonopoly Service (FAS) when prices dramatically spiked in 2008.[105] The government's response was a tax on fertilizer exports, revenues from which have been used to subsidize Russian agricultural producers for 30 percent of the cost of fertilizer. Reports indicate that the subsidy will expire in 2013.[106] Despite consumer complaints, further consolidation among Russian producers appears imminent. Reports in early 2011 indicate that the Russian FAS approved the merger of Uralkali and Silvinit, a move that elicited support from

105 John Helmer, *Russian phosphate shake-out ahead*, ASIA TIMES ONLINE (Apr. 7, 2009), http://www.atimes.com/atimes/Central_Asia/KD07Ag01.html.

106 *Farmers to Pay More for Fertilizer as Voluntary Subsidy Ends*, MOSCOW TIMES (Jun. 26, 2012), http://www.themoscowtimes.com/print/article/farmers-to-pay-more-for-fertilizer-as-voluntary-subsidy-ends/461057.html. India also subsidizes fertilizer for farmers.

PotashCorp.[107] Reports in late 2011 indicate that the agency had opened a probe into Uralkali's pricing, noting that "there are signs that the prices are 'monopolistically' high.[108]

In other parts of the world competition authorities have taken some enforcement action against fertilizer producers, albeit before the tripling of fertilizer prices in 2008. For example, in 2010, the European Commission fined ten fertilizer companies $161 million for manipulating phosphorus prices from 1969 through 2004.[109] Likewise, South Africa's Competition Commission fined Sasol $22 million for taking part in a fertilizer cartel through 2004.[110] Recently, a consumer advocacy organization, Consumer Unity & Trust Society (CUTS), approached the India Competition Commission to investigate what they maintain is a global potash cartel operated by PotashCorp, Mosaic, Agrium, and the Russian producers.[111]

In the U.S., the FTC has not initiated any enforcement action against fertilizer producers involving potentially collusive agreements, or denied annual approval for *PhosChem*. Indeed, in response to a Congressional inquiry in the aftermath of the 2008 price spikes, the FTC explained that price increases were likely attributable to increased global demand for crops requiring

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107 Lauren Williamson, *Russia antitrust body approves Uralkali-Silvinit merger*, ICIS NEWS (Apr. 4, 2011, 1:18 PM), http://www.icis.com/Articles/Article.aspx?liArticleID=9449756&PrinterFriendly=true. The PotashCorp CEO noted that, "any consolidation in our industry would be a good thing."

108 Ilya Khrennikov, *Uralkali Faces Antitrust Probe Over Russian Potash Prices*, BLOOMBERG (Oct. 24, 2011, 8:34 AM), http://www.bloomberg.com/news/2011-10-24/uralkali-faces-antitrust-probe-over-russian-potash-prices-1-.html.

109 Gus Lubin, *Europe Busts 30-Year-Old Cartel For Manipulating Phosphate Prices*, BUS. INSIDER (Jul. 20, 2010, 12:59 PM), http://www.businessinsider.com/europe-nails-30-year-old-cartel-for-manipulating-phosphate-prices-2010-7.

110 Mark Watts, *Sasol Fined R188m for Fertilizer Cartel Involvement*, ICIS NEWS (May 6, 2009, 12:29 PM), http://www.icis.com/Articles/2009/05/06/9213543/sasol-fined-r188m-for-fertilizer-cartel-involvement.html.

111 Consumer Unity & Trust Society*, Preliminary Information Report*, Submitted by CUTS to CCI (Aug. 25, 2012), http://www.cuts-ccier.org/pdf/CUTS_Preliminary_Information_Report_Submitted_to_CCI.pdf (on global potash cartel) and Bindu D. Menon, *CUTS Approaches Competition Panel against Global Potash Cartel*, HINDU BUS. LINE (Aug. 28, 2012),
http://www.thehindubusinessline.com/news/international/article3832173.ece.

fertilizer, and other supply factors and international events.[112] Notably, the FTC found no indication that changes in North American market concentration had any significant effect on domestic or foreign fertilizer prices. While some of these factors may well have been in play during the price run-ups, the FTC's analysis sidesteps the most important question. That question is not whether changes in market concentration (e.g., due to merger) have been problematic, but whether high levels of market concentration have created a market environment conducive to collusion.

A lack of government antitrust enforcement has arguably put more pressure on private antitrust litigation to address the harm to direct and indirect purchasers resulting from collusive behavior. Perhaps one of the most successful U.S. cases is *Minn Chem Inc., v. Agrium* (*Minn-Chem*).[113] In June of 2012, the U.S. court of appeals for the Seventh Circuit in a unanimous *en banc* decision denied a motion to dismiss the case, noting that, "the inferences from these allegations is not just plausible but compelling that the cartel meant to, and did in fact, keep prices artificially high in the United States."[114] Damages from alleged price-fixing by Agrium, Mosaic, BPC, and the American subsidiary of PotashCorp in the global potash market were recently settled in *Minn-Chem* for $110 million.[115] Under the terms of the agreement, Mosaic, PotashCorp, and Agrium paid $80 million to direct purchasers and $17.5 million to indirect purchasers.[116] Russian defendants Uralkali and Silvinit settled a few months earlier for a total of $10 million to direct purchasers and $2.5

112 Letter from Donald S. Clark, Secretary, Federal Trade Commission, to the Honorable Byron L. Dorgan (Sept. 2. 2008).

113 Minn-Chem, Inc. v. Agrium, Inc., 683 F.3d 845 (7th Cir. 2012), (*en banc*) ("*Potash II*"), *cert. dismissed*, _ U.S. _ (2013).

114 Minn-Chem, Inc. v. Agrium, Inc., 683 F.3d 845, 858-859 (7th Cir. 2012).

115 *Minn-Chem, Inc. v. Agrium, Inc.*, No. 10-1712 (7th Cir. June 27, 2012) (*en banc*) ("*Potash II*").

116 Bill Donahue, *Potash Cos. Pay $97.5M To End Long-Running Cartel Case*, LAW360 (Jan. 30, 2013, 3:44 PM), http://www.law360.com/articles/411406/potash-cos-pay-97-5m-to-end-long-running-cartel-case.

million to indirect purchasers. In a not unpredictable response to the settlement, defendants either denied the antitrust claims (PotashCorp) or announced that the settlement avoided legal costs and distractions (Agrium).[117]

The successful *Minn-Chem* settlement highlights the importance of private litigation in addressing anticompetitive abuses generally, and in fertilizer in particular. However, private litigation alone cannot protect competition and consumers from the harm caused by anticompetitive conduct. We note that PotashCorp's and Agrium's markups of price over cost were as high as 480 percent over the period covered by the litigation, and their gross profits were $3.5 billion in 2008 alone. The magnitude of these overcharges highlights Connor and Lande's observation that "crime pays" because expected rewards from price fixing exceed the expected costs of cartel behavior.[118] More important, it emphasizes the importance of a complementary public-private approach to antitrust enforcement.

In sum, potentially anticompetitive coordinated conduct by fertilizer producers has generated relatively little response from government antitrust enforcers in the U.S. and abroad. Pradeep S. Mehta, Secretary General of CUTS, succinctly summarized the issues:

> "What complicates the fertilizer subsidy-food inflation dilemma are the market distortions in the international fertilizer market. When mulling over the fertilizer subsidy bills that put a drain on the Union Budget, the anti-competitive practices prevalent in the fertilizer market are often left unheeded. The world fertilizer market is not a perfectly competitive market where prices are competitively determined on the basis of demand and supply. Instead, they are reflective of the high monopoly rents of the concentrated market power

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[117] *Potash Corp. Settles 8 Antitrust Cases for $43M,* CHI. TRIB. (Jan. 30, 2013), http://articles.chicagotribune.com/2013-01-30/business/chi-potash-corp-settles-8-antitrust-cases-for-43m-20130130_1_potash-corp-global-potash-potash-prices; *Potash Antitrust Lawsuits Settled*, CAN. PRESS (Jan. 31, 2013), http://www2.canada.com/calgaryherald/news/calgarybusiness/story.html?id=257f89d0-7a58-4a0d-adc6-455bbc20815b.

[118] John M. Connor and Robert H. Lande, *Cartels as Rational Business Strategy: Crime Pays*, 34 CARDOZO L. REV. 427 (2012), available at http://www.antitrustinstitute.org/~antitrust/content/aai-working-paper-no-11-08-cartels-rational-business-strategy-new-data-demonstrates-crime-pa. Connor, *supra* note 20.

of a few players."[119]

## VIII. CONCLUSIONS

The qualitative and quantitative analysis presented in the foregoing sections tells a compelling story of the potential damage inflicted by the exercise of market power by dominant global fertilizer companies from 2008-2012. *PhosChem* and *Canpotex*, along with the Russian cabal and the Moroccan OCP, have been successful in sustaining supra-competitive prices for both phosphorus and potash fertilizer. Publicly available data are not sufficient to definitively conclude whether the exercise of market power is the result of tacit or explicit collusion, noncooperative oligopoly behavior, or the complex interactions between cabals, government sanctioned export cartels, and governments themselves. But anecdotal evidence supports the notion that producers have acted in a coordinated manner, the global fertilizer industry has a history of cartels dating back to the 1800s, and the current structure of the industry is conducive to a tacit or overt global super cartel. The analysis highlights a number of important observations and conclusions regarding competition and the fertilizer industry.

First, the scope of damage inflicted by supra-competitive pricing of fertilizer is perhaps the broadest of any essential commodity. Large inputs of mined phosphorus and potash (and nitrogen made from natural gas) are required for food production in industrial farming systems. Damages from supra-competitive pricing of fertilizer likely amount to tens of billions of dollars annually, the direct effects of which are felt by farmers and ranchers. But consumers all over the world suffer indirectly from cartelization of the fertilizer industry through higher food prices, particularly low-income and subsistence demographics. Food is a significant portion of the budget and consumers

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[119] Pradeep S. Mehta, *Hit Fertiliser Cartels With Alliances*, ECON. TIMES (Mar. 28, 2011, 4:20 AM), http://economictimes.indiatimes.com/opinion/view-point/hit-fertiliser-cartels-with-alliances/articleshow/7803720.cms.

that spent a significant proportion of their income on food when fertilizer prices were more competitive (while maintaining a barely adequate diet) may have been forced onto an insufficient diet when prices rose to supra-competitive levels. Because of these critical food availability and sustainability issues, competition policy should consider broader public interest issues rather than focus exclusively on narrow economic considerations.

Second, despite compelling evidence of enormous damages from anticompetitive pricing of fertilizer, most antitrust authorities have shown little meaningful interest in removing legal protections for coordinated conduct by producers. It is clear that the time has come for a comprehensive reassessment of the antitrust exemption for export associations such as *PhosChem* and *Canpotex* under the 1918 Webb-Pomerene Act and other foreign statutes that create immunity for fertilizer cartels from competition laws. Arguably, there is no justifiable "public good" rationale for allowing two giant transnational corporations to collaborate in export markets.

Third, despite some success, private enforcement alone cannot address the full scope of competitive harm caused by potentially collusive behavior by fertilizer producers. A complementary approach that recognizes the value of both public and private enforcement is needed. The FTC, U.S. Department of Justice, and U.S. Department of Agriculture all have some antitrust authority in agricultural markets. Yet these agencies have largely ignored repeated requests to investigate the fertilizer industry in general (and *PhosChem* in particular) and avoided enforcement action against potentially collusive behavior by export associations. This is particularly egregious in light of the fact that damages due to higher potash prices charged to domestic buyers amounts to several billion dollars over the past five years. Anecdotal evidence suggests a similar price distortion for phosphorus.[120] Evidence of higher phosphorus prices charged in domestic markets is a clear violation of Webb-Pomerene.[121] This fact pattern provides strong motivation for an FTC investigation into *PhosChem*, Mosaic, and PotashCorp in all three nutrient areas. Whether a reluctance to pursue enforcement actions against fertilizer producers or cartels is due to international political sensitivities, the immense economic and political power of dominant fertilizer producers, or insufficient resources for antitrust investigations, is unclear. But it strongly begs the question: Have the transnational fertilizer corporations become too big to prosecute?

Fourth, it is clear that corporate and political control of essential plant nutrients may be one of the most severe competition issues facing national economies today. A few transnational corporations and foreign governments now control world reserves of phosphorus and potash. Those who control inputs to food production (i.e., fertilizer, seed, technology, water and energy) control food. Reserves of phosphorus are projected to be exhausted in 25 years in the U.S. and somewhat longer in politically unstable Western Sahara and Morocco, an availability crisis that has been termed "the gravest natural resource shortage you've never heard of."[122] Greater recycling of nutrients appears many years or decades away with current technology. That technological developments may be insufficient to deter cartel pricing for some time highlights the need for antitrust enforcement action.

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120 See, for example, questions and responses in MOS's investor call in for Q2 2011. Mosaic Company CEO Discusses Q2 2011 Results - Earnings Call Transcript, Seeking Alpha (Jan. 5, 2011, 3:39 PM), http://seekingalpha.com/article/245073-mosaic-company-ceo-discusses-q2-2011-results-earnings-call-transcript?part=qanda.

121 15 U.S.C. § 62 - EXPORT TRADE AND ANTITRUST.

122 James Esler & Stuart White, *Peak Phosphorus*, FOREIGN POL'Y (Apr. 20, 2010), http://www.foreignpolicy.com/articles/2010/04/20/peak_phosphorus.

Fifth, civil and criminal penalties should be sufficiently high to deter unfair and anticompetitive behavior in international as well as domestic markets. Antitrust penalties in the U.S. and abroad are not sufficiently high to deter formation of new cartels. Rather, fines are simply a cost of doing business. Considering the long history of international fertilizer cartels, legislation should consider establishing a corporate equivalent of "repeat offender" status as well as civil fines and criminal penalties for executives that are sufficiently large to deter anticompetitive behavior.[123]

The foregoing observations highlight the fact that competition issues involving fertilizer extend well beyond traditional antitrust pricing, output, and innovation concerns. They also implicate food sustainability, human welfare, and economic and political stability. Should policy makers heed the call to address the problem, it remains imperative that competition policy be complemented constructively with broader public policy approaches. For example, a policy of encouraging development of cost-effective nutrient recycling may have triple benefits of limiting cartel pricing, making industrial farming more sustainable, and reducing environmental costs associated with fertilizer production and use. Moreover, because action by any single competition or other governmental authority may be inadequate to restore competition in fertilizer markets, a coordinated, concerted approach to enforcement will be required at both national and international levels.[124] Such an approach is more likely to deal with the reality that fertilizer producers have a history and corporate sociology of collusion and thus no longer need to explicitly communicate to continue cartel behavior. Simply breaking up export associations such as

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[123] See F. M. Scherer, COMPETITION POLICIES FOR AN INTEGRATED WORLD ECONOMY (Brookings Institution, 1994), for extensive discussion about the need for global competition policies.

[124] Persuasive arguments for international cooperation to both detect and prevent firms and governments from undermining competition in international markets are given by Margaret C. Levenstein and Valerie Y. Suslow, *The Changing International Status of Export Cartel Exemptions*, (University of Michigan_Ross School of Business Working Paper No. 897, Nov. 2004).

*PhosChem* therefore may not by itself establish competition in fertilizer markets. More creative remedial approaches may be needed.

# APPENDICES

## Appendix A:
## Estimated Cost and Product Supply Relations

Variable definitions for Appendix A Tables:

- QN = quantity of nitrogen sold (thousand metric tons)
- QP = quantity of phosphorus sold (thousand metric tons)
- QK = quantity of potash sold (thousand metric tons)
- PN = real price of nitrogen ($/metric ton)
- PP = real price of phosphorus ($/metric ton)
- PK = real price of potash ($/metric ton)
- PG = real price of natural gas
- PE = real energy CPI
- PS = real price of sulfur
- PPIFARM = real prices received index for farm commodities
- ZN = cumulative sales quantity of nitrogen from the beginning of the observation period
- ZP = cumulative sales quantity of phosphorus from the beginning of the observation period
- ZK = cumulative sales quantity of potash from the beginning of the observation period
- DiQyear = binary variable for quarter i and for stated year
- t = quarter, beginning with t = 1 for the first quarter of 1998 for PotashCorp and MOS, and t = 1 for the third quarter of 2007 for MOS.
- AR(1) = first order autoregressive error command in EViews
- Real prices are expressed in 2012 dollars based on the GDP Price Deflator

  $1-\beta)\}$ where $\beta$ is the quarterly discount factor

  $1-\beta)\}$ where $\beta$ is the quarterly discount factor

## Appendix Table A-1. Estimates of the POT_AC Model

Estimation Method: Seemingly Unrelated Regression
Date: 03/12/13 Time: 11:11
Sample: 2 59
Included observations: 58
Total system (balanced) observations 348
Linear estimation after one-step weighting matrix

| | Coefficient | Std. Error | t-Statistic | Prob. |
|---|---|---|---|---|
| C(201) | 123070.3 | 22354.42 | 5.505410 | 0.0000 |
| C(204) | 0.308154 | 0.132126 | 2.332280 | 0.0203 |
| C(205) | 14.65087 | 3.261096 | 4.492624 | 0.0000 |
| C(211) | 0.141201 | 0.044148 | 3.198379 | 0.0015 |
| C(212) | 0.000209 | 0.000806 | 0.259474 | 0.7954 |
| C(213) | -2.75E-05 | 1.52E-05 | -1.813490 | 0.0707 |
| C(215) | -0.030017 | 0.024226 | -1.239038 | 0.2163 |
| C(216) | -0.056468 | 0.025320 | -2.230209 | 0.0265 |
| C(217) | -0.102087 | 0.023329 | -4.376061 | 0.0000 |
| C(218) | 0.044181 | 0.029166 | 1.514830 | 0.1308 |
| C(219) | 0.047181 | 0.024306 | 1.941105 | 0.0532 |
| C(220) | 0.028723 | 0.025173 | 1.141021 | 0.2547 |
| C(230) | -0.001152 | 0.000312 | -3.696722 | 0.0003 |
| C(1) | 118768.6 | 11004.31 | 10.79292 | 0.0000 |
| C(4) | 0.439534 | 0.048351 | 9.090472 | 0.0000 |
| C(5) | 0.386873 | 0.067608 | 5.722259 | 0.0000 |
| C(6) | 1.356708 | 0.254263 | 5.335847 | 0.0000 |
| C(11) | 0.182287 | 0.059374 | 3.070138 | 0.0023 |
| C(12) | 0.007459 | 0.000907 | 8.221034 | 0.0000 |
| C(13) | -0.000143 | 1.74E-05 | -8.226750 | 0.0000 |
| C(15) | -0.100086 | 0.029110 | -3.438182 | 0.0007 |
| C(16) | -0.341745 | 0.030157 | -11.33202 | 0.0000 |
| C(17) | -0.468325 | 0.027787 | -16.85396 | 0.0000 |
| C(18) | -0.191393 | 0.061725 | -3.100730 | 0.0021 |
| C(19) | 0.132965 | 0.045228 | 2.939854 | 0.0035 |
| C(20) | 0.071977 | 0.036660 | 1.963383 | 0.0505 |
| C(30) | -0.001390 | 0.000381 | -3.653412 | 0.0003 |
| C(101) | -1539.943 | 7862.330 | -0.195863 | 0.8448 |
| C(104) | 0.241083 | 0.020635 | 11.68307 | 0.0000 |
| C(106) | 1.318875 | 0.098883 | 13.33770 | 0.0000 |
| C(111) | 0.021764 | 0.029940 | 0.726896 | 0.4678 |
| C(112) | 0.002870 | 0.000537 | 5.341999 | 0.0000 |
| C(113) | -8.01E-05 | 9.54E-06 | -8.393320 | 0.0000 |
| C(115) | -0.031164 | 0.012563 | -2.480735 | 0.0136 |
| C(116) | -0.071026 | 0.012113 | -5.863856 | 0.0000 |
| C(117) | -0.197728 | 0.016147 | -12.24558 | 0.0000 |
| C(118) | -0.278730 | 0.020085 | -13.87738 | 0.0000 |
| C(119) | -0.382793 | 0.071823 | -5.329683 | 0.0000 |
| C(120) | -0.183839 | 0.093241 | -1.971662 | 0.0495 |
| C(130) | -0.000115 | 0.000204 | -0.565705 | 0.5720 |

Determinant residual covariance 1.10E+35

Equation: TCN = C(201) + C(204)*PE(-1)*QN +C(205)*PG(-1)*QN

| | | | |
|---|---|---|---|
| Observations: 58 | | | |
| R-squared | 0.615402 | Mean dependent var | 279411.0 |
| Adjusted R-squared | 0.601416 | S.D. dependent var | 58570.47 |
| S.E. of regression | 36977.57 | Sum squared resid | 7.52E+10 |
| Durbin-Watson stat | 1.137917 | | |

Equation: PN = (C(201) + C(204)*PE(-1)*QN +C(205)*PG(-1)*QN)/QN - (C(211) + C(212)*T + C(213)*T*T + C(215)*D1Q2008 + C(216) *D2Q2008 + C(217)*D3Q2008 + C(218)*D4Q2008 + C(219)*D1Q2009 + C(220)*D2Q2009 + C(230)*PPIFARM) *QN

| | | | |
|---|---|---|---|
| Observations: 58 | | | |
| R-squared | 0.894270 | Mean dependent var | 289.4895 |
| Adjusted R-squared | 0.866076 | S.D. dependent var | 109.9910 |
| S.E. of regression | 40.25195 | Sum squared resid | 72909.89 |
| Durbin-Watson stat | 1.231368 | | |

Equation: TCP = C(1) + C(4)*PN(-1)*QP + C(5)*PS(-1)*QP+ C(6)*ZP(-1)

| | | | |
|---|---|---|---|
| Observations: 58 | | | |
| R-squared | 0.866733 | Mean dependent var | 289823.8 |
| Adjusted R-squared | 0.859329 | S.D. dependent var | 83797.80 |
| S.E. of regression | 31429.27 | Sum squared resid | 5.33E+10 |
| Durbin-Watson stat | 0.990151 | | |

Equation: PP= ( ((C(1) + C(4)*PN(-1)*QP + C(5)*PS(-1)*QP) + C(6)*ZP(-1)) /QP + C(6)*USERCOSTFACTORP) - (C(11) + C(12)*T + C(13)*T*T + C(15)*D1Q2008 + C(16)*D2Q2008 + C(17)*D3Q2008 + C(18) *D4Q2008 + C(19)*D1Q2009 + C(20)*D2Q2009 + C(30)*PPIFARM) *QP

| | | | |
|---|---|---|---|
| Observations: 58 | | | |
| R-squared | 0.963881 | Mean dependent var | 396.9052 |
| Adjusted R-squared | 0.953210 | S.D. dependent var | 185.1212 |
| S.E. of regression | 40.04362 | Sum squared resid | 70553.63 |
| Durbin-Watson stat | 0.784575 | | |

Equation: TCK = C(101) + C(104)*PE(-1)*QK + C(106)*ZK(-1)

| | | | |
|---|---|---|---|
| Observations: 58 | | | |
| R-squared | 0.873048 | Mean dependent var | 153330.0 |
| Adjusted R-squared | 0.868431 | S.D. dependent var | 69577.91 |
| S.E. of regression | 25237.59 | Sum squared resid | 3.50E+10 |
| Durbin-Watson stat | 0.757777 | | |

Equation: PK= ( ((C(101) + C(104)*PE(-1)*QK + C(106)*ZK(-1))/QK) + C(106)*USERCOSTFACTORK) - (C(111) + C(112)*T + C(113)*T*T + C(115)*D1Q2008 + C(116)*D2Q2008 + C(117)*D3Q2008 + C(118) *D4Q2008 + C(119)*D1Q2009 + C(120)*D2Q2009 + C(130)*PPIFARM) *QK

| | | | |
|---|---|---|---|
| Observations: 58 | | | |
| R-squared | 0.969705 | Mean dependent var | 231.0259 |
| Adjusted R-squared | 0.961626 | S.D. dependent var | 156.0276 |
| S.E. of regression | 30.56470 | Sum squared resid | 42039.05 |
| Durbin-Watson stat | 1.022119 | | |

## Appendix Table A-2. Estimates of the POT_MC Model

Estimation Method: Seemingly Unrelated Regression
Date: 03/12/13 Time: 11:13
Sample: 2 59
Included observations: 58
Total system (balanced) observations 348
Linear estimation after one-step weighting matrix

| | Coefficient | Std. Error | t-Statistic | Prob. |
|---|---|---|---|---|
| C(201) | 28983.73 | 21519.91 | 1.346833 | 0.1790 |
| C(204) | 0.769183 | 0.123623 | 6.222011 | 0.0000 |
| C(205) | 10.07193 | 3.203274 | 3.144261 | 0.0018 |
| C(211) | 0.123857 | 0.064450 | 1.921760 | 0.0556 |
| C(212) | 9.21E-05 | 0.001173 | 0.078546 | 0.9374 |
| C(213) | -2.21E-05 | 2.20E-05 | -1.004802 | 0.3158 |
| C(215) | -0.017915 | 0.035169 | -0.509395 | 0.6108 |
| C(216) | -0.050876 | 0.036772 | -1.383566 | 0.1675 |
| C(217) | -0.094184 | 0.033524 | -2.809414 | 0.0053 |
| C(218) | 0.038015 | 0.041918 | 0.906888 | 0.3652 |
| C(219) | 0.042631 | 0.035210 | 1.210764 | 0.2269 |
| C(220) | 0.029708 | 0.036555 | 0.812705 | 0.4170 |
| C(230) | -0.001180 | 0.000452 | -2.611075 | 0.0095 |
| C(1) | 111464.4 | 10676.34 | 10.44032 | 0.0000 |
| C(4) | 0.339256 | 0.053379 | 6.355555 | 0.0000 |
| C(5) | 0.348248 | 0.065667 | 5.303243 | 0.0000 |
| C(6) | 2.669381 | 0.298231 | 8.950722 | 0.0000 |
| C(11) | 0.037413 | 0.080907 | 0.462417 | 0.6441 |
| C(12) | 0.004898 | 0.001304 | 3.756607 | 0.0002 |
| C(13) | -0.000147 | 2.51E-05 | -5.839641 | 0.0000 |
| C(15) | -0.137362 | 0.042374 | -3.241679 | 0.0013 |
| C(16) | -0.416724 | 0.043995 | -9.471986 | 0.0000 |
| C(17) | -0.539955 | 0.042418 | -12.72940 | 0.0000 |
| C(18) | -0.720733 | 0.086515 | -8.330773 | 0.0000 |
| C(19) | -0.165801 | 0.063359 | -2.616847 | 0.0093 |
| C(20) | -0.102120 | 0.051380 | -1.987543 | 0.0477 |
| C(30) | -0.000647 | 0.000539 | -1.200666 | 0.2308 |
| C(101) | -7923.176 | 8197.686 | -0.966514 | 0.3345 |
| C(104) | 0.253517 | 0.026077 | 9.721858 | 0.0000 |
| C(106) | 1.356243 | 0.122252 | 11.09386 | 0.0000 |
| C(111) | -0.020242 | 0.043071 | -0.469964 | 0.6387 |
| C(112) | 0.002534 | 0.000797 | 3.180079 | 0.0016 |
| C(113) | -8.74E-05 | 1.41E-05 | -6.213667 | 0.0000 |
| C(115) | -0.033738 | 0.018646 | -1.809406 | 0.0714 |
| C(116) | -0.072601 | 0.017980 | -4.037785 | 0.0001 |
| C(117) | -0.209322 | 0.023888 | -8.762796 | 0.0000 |
| C(118) | -0.303515 | 0.029677 | -10.22728 | 0.0000 |
| C(119) | -0.811699 | 0.089450 | -9.074373 | 0.0000 |
| C(120) | -0.835919 | 0.107570 | -7.770908 | 0.0000 |
| C(130) | 0.000206 | 0.000298 | 0.690916 | 0.4901 |

| | |
|---|---|
| Determinant residual covariance | 8.59E+35 |

Equation: TCN = C(201) + C(204)*PE(-1)*QN +C(205)*PG(-1)*QN

Observations: 58

| | | | |
|---|---|---|---|
| R-squared | 0.574143 | Mean dependent var | 279411.0 |
| Adjusted R-squared | 0.558657 | S.D. dependent var | 58570.47 |
| S.E. of regression | 38910.51 | Sum squared resid | 8.33E+10 |
| Durbin-Watson stat | 1.085323 | | |

Equation: PN = ( C(204)*PE(-1) +C(205)*PG(-1) ) - (C(211) + C(212)*T + C(213)*T*T + C(215)*D1Q2008 + C(216)*D2Q2008 + C(217) *D3Q2008 + C(218)*D4Q2008 + C(219)*D1Q2009 + C(220)*D2Q2009 + C(230)*PPIFARM) *QN

Observations: 58

| | | | |
|---|---|---|---|
| R-squared | 0.836252 | Mean dependent var | 289.4895 |
| Adjusted R-squared | 0.797095 | S.D. dependent var | 109.9910 |
| S.E. of regression | 49.54546 | Sum squared resid | 112918.6 |
| Durbin-Watson stat | 1.224257 | | |

Equation: TCP = C(1) + C(4)*PN(-1)*QP + C(5)*PS(-1)*QP + C(6)*ZP(-1)

Observations: 58

| | | | |
|---|---|---|---|
| R-squared | 0.858633 | Mean dependent var | 289823.8 |
| Adjusted R-squared | 0.850780 | S.D. dependent var | 83797.80 |
| S.E. of regression | 32370.30 | Sum squared resid | 5.66E+10 |
| Durbin-Watson stat | 0.913365 | | |

Equation: PP= ( C(4)*PN(-1) + C(5)*PS(-1) + C(6) *USERCOSTFACTORP ) - (C(11) + C(12)*T + C(13)*T*T + C(15) *D1Q2008 + C(16)*D2Q2008 + C(17)*D3Q2008 + C(18)*D4Q2008 + C(19)*D1Q2009 + C(20)*D2Q2009 + C(30)*PPIFARM) *QP

Observations: 58

| | | | |
|---|---|---|---|
| R-squared | 0.965879 | Mean dependent var | 396.9052 |
| Adjusted R-squared | 0.956781 | S.D. dependent var | 185.1212 |
| S.E. of regression | 38.48536 | Sum squared resid | 66650.54 |
| Durbin-Watson stat | 0.859665 | | |

Equation: TCK = C(101) +C(104)*PE(-1)*QK + C(106)*ZK(-1)

Observations: 58

| | | | |
|---|---|---|---|
| R-squared | 0.869024 | Mean dependent var | 153330.0 |
| Adjusted R-squared | 0.864261 | S.D. dependent var | 69577.91 |
| S.E. of regression | 25634.42 | Sum squared resid | 3.61E+10 |
| Durbin-Watson stat | 0.708959 | | |

Equation: PK= ( C(104)*PE(-1) + C(106)*USERCOSTFACTORK ) - (C(111) + C(112)*T + C(113)*T*T + C(115)*D1Q2008 + C(116) *D2Q2008 + C(117)*D3Q2008 + C(118)*D4Q2008 + C(119)*D1Q2009 + C(120)*D2Q2009 + C(130)*PPIFARM) *QK

Observations: 58

| | | | |
|---|---|---|---|
| R-squared | 0.930502 | Mean dependent var | 231.0259 |
| Adjusted R-squared | 0.913884 | S.D. dependent var | 156.0276 |
| S.E. of regression | 45.78726 | Sum squared resid | 96437.77 |
| Durbin-Watson stat | 1.177165 | | |

## Appendix Table A-3. Estimates of the AGU_AC Model

Estimation Method: Seemingly Unrelated Regression
Date: 01/30/13 Time: 08:32
Sample: 2 59
Included observations: 58
Total system (balanced) observations 348
Linear estimation after one-step weighting matrix

| | Coefficient | Std. Error | t-Statistic | Prob. |
|---|---|---|---|---|
| C(201) | -1621.401 | 9256.217 | -0.175169 | 0.8611 |
| C(204) | 0.765632 | 0.076868 | 9.960369 | 0.0000 |
| C(205) | 16.93607 | 2.550389 | 6.640583 | 0.0000 |
| C(211) | 0.091593 | 0.042397 | 2.160354 | 0.0315 |
| C(212) | 0.003368 | 0.000853 | 3.948513 | 0.0001 |
| C(213) | -9.14E-05 | 1.50E-05 | -6.076239 | 0.0000 |
| C(215) | -0.118243 | 0.035265 | -3.352977 | 0.0009 |
| C(216) | -0.037608 | 0.022992 | -1.635697 | 0.1029 |
| C(217) | -0.184217 | 0.032359 | -5.692910 | 0.0000 |
| C(218) | -0.136847 | 0.039285 | -3.483481 | 0.0006 |
| C(219) | -0.030034 | 0.040144 | -0.748146 | 0.4549 |
| C(220) | -0.023432 | 0.021738 | -1.077919 | 0.2819 |
| C(230) | -0.001141 | 0.000293 | -3.897458 | 0.0001 |
| C(1) | -6740.919 | 4476.979 | -1.505685 | 0.1332 |
| C(4) | 1.516532 | 0.087846 | 17.26350 | 0.0000 |
| C(5) | 0.206732 | 0.062770 | 3.293479 | 0.0011 |
| C(6) | 1.778553 | 0.313812 | 5.667575 | 0.0000 |
| C(11) | 1.655420 | 0.387770 | 4.269077 | 0.0000 |
| C(12) | 0.029089 | 0.007099 | 4.097477 | 0.0001 |
| C(13) | -0.000507 | 0.000132 | -3.853076 | 0.0001 |
| C(15) | -0.093439 | 0.256502 | -0.364284 | 0.7159 |
| C(16) | -0.401056 | 0.212210 | -1.889898 | 0.0597 |
| C(17) | -2.644790 | 0.256969 | -10.29224 | 0.0000 |
| C(18) | -3.966023 | 0.427176 | -9.284279 | 0.0000 |
| C(19) | -0.498513 | 0.285311 | -1.747263 | 0.0816 |
| C(20) | 0.032461 | 0.220629 | 0.147129 | 0.8831 |
| C(30) | -0.012774 | 0.002671 | -4.782097 | 0.0000 |
| C(101) | -7601.540 | 3986.619 | -1.906763 | 0.0575 |
| C(104) | 0.406174 | 0.045898 | 8.849475 | 0.0000 |
| C(106) | 1.597687 | 0.142338 | 11.22464 | 0.0000 |
| C(111) | 0.049207 | 0.135051 | 0.364357 | 0.7158 |
| C(112) | 0.018136 | 0.002457 | 7.380838 | 0.0000 |
| C(113) | -0.000461 | 4.46E-05 | -10.33968 | 0.0000 |
| C(115) | -0.126631 | 0.066045 | -1.917347 | 0.0561 |
| C(116) | -0.325334 | 0.055449 | -5.867312 | 0.0000 |
| C(117) | -1.040608 | 0.075399 | -13.80136 | 0.0000 |
| C(118) | -1.401701 | 0.098021 | -14.30003 | 0.0000 |
| C(119) | -1.393705 | 0.604054 | -2.307253 | 0.0217 |
| C(120) | -4.571332 | 0.916351 | -4.988625 | 0.0000 |
| C(130) | -0.000188 | 0.000908 | -0.206907 | 0.8362 |

Determinant residual covariance 4.17E+33

Equation: TCN = C(201) + C(204)*PE(-1)*QN +C(205)*PG(-1)*QN

Observations: 58

| | | | |
|---|---|---|---|
| R-squared | 0.925351 | Mean dependent var | 237305.0 |
| Adjusted R-squared | 0.922637 | S.D. dependent var | 88961.83 |
| S.E. of regression | 24744.03 | Sum squared resid | 3.37E+10 |
| Durbin-Watson stat | 1.404464 | | |

Equation: PN = (C(201) + C(204)*PE(-1)*QN +C(205)*PG(-1)*QN)/QN - (C(211) + C(212)*T + C(213)*T*T + C(215)*D1Q2008 + C(216) *D2Q2008 + C(217)*D3Q2008 + C(218)*D4Q2008 + C(219)*D1Q2009 + C(220)*D2Q2009 + C(230)*PPIFARM) *QN

Observations: 58

| | | | |
|---|---|---|---|
| R-squared | 0.954015 | Mean dependent var | 315.6260 |
| Adjusted R-squared | 0.941753 | S.D. dependent var | 129.2847 |
| S.E. of regression | 31.20218 | Sum squared resid | 43810.91 |
| Durbin-Watson stat | 1.772320 | | |

Equation: TCP = C(1) + C(4)*PE(-1)*QP + C(5)*PS*QP+ C(6)*ZP(-1)

Observations: 58

| | | | |
|---|---|---|---|
| R-squared | 0.848220 | Mean dependent var | 86914.29 |
| Adjusted R-squared | 0.839788 | S.D. dependent var | 33149.81 |
| S.E. of regression | 13268.72 | Sum squared resid | 9.51E+09 |
| Durbin-Watson stat | 0.617991 | | |

Equation: PP= ( ((C(1) + C(4)*PE(-1)*QP + C(5)*PS*QP) + C(6)*ZP(-1))/QP + C(6)*USERCOSTFACTORP) - (C(11) + C(12)*T + C(13)*T*T + C(15) *D1Q2008 + C(16)*D2Q2008 + C(17)*D3Q2008 + C(18)*D4Q2008 + C(19)*D1Q2009 + C(20)*D2Q2009 + C(30)*PPIFARM) *QP

Observations: 58

| | | | |
|---|---|---|---|
| R-squared | 0.963474 | Mean dependent var | 458.3062 |
| Adjusted R-squared | 0.952682 | S.D. dependent var | 240.9134 |
| S.E. of regression | 52.40511 | Sum squared resid | 120837.0 |
| Durbin-Watson stat | 1.241496 | | |

Equation: TCK = C(101) + C(104)*PE(-1)*QK + C(106)*ZK(-1)

Observations: 58

| | | | |
|---|---|---|---|
| R-squared | 0.711620 | Mean dependent var | 40780.07 |
| Adjusted R-squared | 0.701134 | S.D. dependent var | 20840.28 |
| S.E. of regression | 11393.10 | Sum squared resid | 7.14E+09 |
| Durbin-Watson stat | 0.359611 | | |

Equation: PK= ( ((C(101) + C(104)*PE(-1)*QK + C(106)*ZK(-1))/QK) + C(106)*USERCOSTFACTORK) - (C(111) + C(112)*T + C(113)*T*T + C(115)*D1Q2008 + C(116)*D2Q2008 + C(117)*D3Q2008 + C(118) *D4Q2008 + C(119)*D1Q2009 + C(120)*D2Q2009 + C(130)*PPIFARM) *QK

Observations: 58

| | | | |
|---|---|---|---|
| R-squared | 0.972545 | Mean dependent var | 260.6974 |
| Adjusted R-squared | 0.965224 | S.D. dependent var | 178.0770 |
| S.E. of regression | 33.20828 | Sum squared resid | 49625.54 |
| Durbin-Watson stat | 1.083022 | | |

## Appendix Table A-4. Estimates of the AGU_MC Model

Estimation Method: Seemingly Unrelated Regression
Date: 01/30/13 Time: 08:33
Sample: 2 59
Included observations: 58
Total system (balanced) observations 348
Linear estimation after one-step weighting matrix

| | Coefficient | Std. Error | t-Statistic | Prob. |
|---|---|---|---|---|
| C(201) | -23691.82 | 7660.201 | -3.092846 | 0.0022 |
| C(204) | 0.876294 | 0.067404 | 13.00059 | 0.0000 |
| C(205) | 16.06041 | 2.456635 | 6.537566 | 0.0000 |
| C(211) | 0.123517 | 0.039645 | 3.115558 | 0.0020 |
| C(212) | 0.002677 | 0.000793 | 3.376981 | 0.0008 |
| C(213) | -7.70E-05 | 1.42E-05 | -5.427248 | 0.0000 |
| C(215) | -0.100202 | 0.032794 | -3.055453 | 0.0024 |
| C(216) | -0.036874 | 0.021081 | -1.749148 | 0.0813 |
| C(217) | -0.167751 | 0.030108 | -5.571705 | 0.0000 |
| C(218) | -0.113858 | 0.036649 | -3.106684 | 0.0021 |
| C(219) | -0.016158 | 0.036683 | -0.440484 | 0.6599 |
| C(220) | -0.030618 | 0.019930 | -1.536318 | 0.1255 |
| C(230) | -0.001216 | 0.000268 | -4.533720 | 0.0000 |
| C(1) | 3994.649 | 3609.978 | 1.106558 | 0.2693 |
| C(4) | 1.224877 | 0.103871 | 11.79231 | 0.0000 |
| C(5) | 0.248993 | 0.060101 | 4.142918 | 0.0000 |
| C(6) | 2.364486 | 0.382938 | 6.174585 | 0.0000 |
| C(11) | 1.583154 | 0.288008 | 5.496915 | 0.0000 |
| C(12) | 0.023785 | 0.005189 | 4.583779 | 0.0000 |
| C(13) | -0.000584 | 9.48E-05 | -6.160377 | 0.0000 |
| C(15) | -0.201564 | 0.185391 | -1.087237 | 0.2778 |
| C(16) | -0.384110 | 0.154996 | -2.478201 | 0.0137 |
| C(17) | -2.717202 | 0.194454 | -13.97352 | 0.0000 |
| C(18) | -4.670050 | 0.310891 | -15.02151 | 0.0000 |
| C(19) | -0.676879 | 0.204918 | -3.303163 | 0.0011 |
| C(20) | 0.013636 | 0.159251 | 0.085626 | 0.9318 |
| C(30) | -0.011570 | 0.001932 | -5.989577 | 0.0000 |
| C(101) | -11156.81 | 3591.390 | -3.106543 | 0.0021 |
| C(104) | 0.468571 | 0.055653 | 8.419551 | 0.0000 |
| C(106) | 1.538252 | 0.220050 | 6.990455 | 0.0000 |
| C(111) | -0.085106 | 0.192072 | -0.443092 | 0.6580 |
| C(112) | 0.016934 | 0.003482 | 4.863855 | 0.0000 |
| C(113) | -0.000520 | 6.29E-05 | -8.266095 | 0.0000 |
| C(115) | -0.158314 | 0.093584 | -1.691680 | 0.0917 |
| C(116) | -0.330524 | 0.078445 | -4.213458 | 0.0000 |
| C(117) | -1.096532 | 0.106811 | -10.26607 | 0.0000 |
| C(118) | -1.459250 | 0.138642 | -10.52528 | 0.0000 |
| C(119) | -4.600995 | 0.525775 | -8.750887 | 0.0000 |
| C(120) | -9.815188 | 0.656075 | -14.96047 | 0.0000 |
| C(130) | 0.001157 | 0.001277 | 0.905896 | 0.3657 |

Determinant residual covariance 4.62E+33

Equation: TCN = C(201) + C(204)*PE(-1)*QN +C(205)*PG(-1)*QN

Observations: 58

| | | | |
|---|---|---|---|
| R-squared | 0.926798 | Mean dependent var | 237305.0 |
| Adjusted R-squared | 0.924136 | S.D. dependent var | 88961.83 |
| S.E. of regression | 24503.09 | Sum squared resid | 3.30E+10 |
| Durbin-Watson stat | 1.403611 | | |

Equation: PN = ( C(204)*PE(-1) +C(205)*PG(-1) ) - (C(211) + C(212)*T + C(213)*T*T + C(215)*D1Q2008 + C(216)*D2Q2008 + C(217) *D3Q2008 + C(218)*D4Q2008 + C(219)*D1Q2009 + C(220)*D2Q2009 + C(230)*PPIFARM) *QN

Observations: 58

| | | | |
|---|---|---|---|
| R-squared | 0.958452 | Mean dependent var | 315.6260 |
| Adjusted R-squared | 0.948516 | S.D. dependent var | 129.2847 |
| S.E. of regression | 29.33469 | Sum squared resid | 39584.11 |
| Durbin-Watson stat | 1.711279 | | |

Equation: TCP = C(1) + C(4)*PE(-1)*QP + C(5)*PS*QP + C(6)*ZP(-1)

Observations: 58

| | | | |
|---|---|---|---|
| R-squared | 0.851038 | Mean dependent var | 86914.29 |
| Adjusted R-squared | 0.842762 | S.D. dependent var | 33149.81 |
| S.E. of regression | 13144.96 | Sum squared resid | 9.33E+09 |
| Durbin-Watson stat | 0.701942 | | |

Equation: PP= ( C(4)*PE(-1) + C(5)*PS + C(6)*USERCOSTFACTORP ) - (C(11) + C(12)*T + C(13)*T*T + C(15)*D1Q2008 + C(16)*D2Q2008 + C(17)*D3Q2008 + C(18)*D4Q2008 + C(19)*D1Q2009 + C(20) *D2Q2009 + C(30)*PPIFARM) *QP

Observations: 58

| | | | |
|---|---|---|---|
| R-squared | 0.971701 | Mean dependent var | 458.3062 |
| Adjusted R-squared | 0.964154 | S.D. dependent var | 240.9134 |
| S.E. of regression | 45.61218 | Sum squared resid | 93621.20 |
| Durbin-Watson stat | 1.227553 | | |

Equation: TCK = C(101) +C(104)*PE(-1)*QK + C(106)*ZK(-1)

Observations: 58

| | | | |
|---|---|---|---|
| R-squared | 0.704358 | Mean dependent var | 40780.07 |
| Adjusted R-squared | 0.693608 | S.D. dependent var | 20840.28 |
| S.E. of regression | 11535.67 | Sum squared resid | 7.32E+09 |
| Durbin-Watson stat | 0.314945 | | |

Equation: PK= ( C(104)*PE(-1) + C(106)*USERCOSTFACTORK ) - (C(111) + C(112)*T + C(113)*T*T + C(115)*D1Q2008 + C(116) *D2Q2008 + C(117)*D3Q2008 + C(118)*D4Q2008 + C(119)*D1Q2009 + C(120)*D2Q2009 + C(130)*PPIFARM) *QK

Observations: 58

| | | | |
|---|---|---|---|
| R-squared | 0.951004 | Mean dependent var | 260.6974 |
| Adjusted R-squared | 0.939288 | S.D. dependent var | 178.0770 |
| S.E. of regression | 43.87792 | Sum squared resid | 88562.51 |
| Durbin-Watson stat | 1.714351 | | |

## Appendix Table A-5. Estimates of the MOS_AC Model

Estimation Method: Seemingly Unrelated Regression
Date: 03/12/13 Time: 08:26
Sample: 2 19
Included observations: 18
Total system (balanced) observations 72
Linear estimation after one-step weighting matrix

| | Coefficient | Std. Error | t-Statistic | Prob. |
|---|---|---|---|---|
| C(1) | 208882.3 | 205754.5 | 1.015202 | 0.3153 |
| C(4) | 1.057859 | 0.241802 | 4.374902 | 0.0001 |
| C(5) | 0.854328 | 0.124821 | 6.844430 | 0.0000 |
| C(6) | 1.307564 | 1.135600 | 1.151430 | 0.2555 |
| C(11) | 0.144260 | 0.053062 | 2.718692 | 0.0092 |
| C(12) | -0.000597 | 0.000917 | -0.651530 | 0.5179 |
| C(15) | -0.015991 | 0.016449 | -0.972155 | 0.3361 |
| C(16) | -0.092072 | 0.015657 | -5.880596 | 0.0000 |
| C(17) | -0.154337 | 0.018021 | -8.564334 | 0.0000 |
| C(18) | -0.158359 | 0.036522 | -4.335956 | 0.0001 |
| C(19) | 0.132879 | 0.037764 | 3.518698 | 0.0010 |
| C(20) | 0.024351 | 0.018571 | 1.311256 | 0.1963 |
| C(30) | -0.000797 | 0.000266 | -2.995180 | 0.0044 |
| C(101) | 140526.4 | 35803.36 | 3.924951 | 0.0003 |
| C(104) | 0.512388 | 0.077295 | 6.628961 | 0.0000 |
| C(106) | 1.538404 | 0.408861 | 3.762662 | 0.0005 |
| C(111) | -0.053391 | 0.040750 | -1.310196 | 0.1966 |
| C(112) | -0.007074 | 0.001731 | -4.085943 | 0.0002 |
| C(113) | -9.97E-06 | 8.93E-05 | -0.111665 | 0.9116 |
| C(115) | -0.011177 | 0.008334 | -1.341070 | 0.1865 |
| C(116) | -0.031947 | 0.009476 | -3.371454 | 0.0015 |
| C(117) | -0.112271 | 0.010786 | -10.40882 | 0.0000 |
| C(118) | -0.151485 | 0.010200 | -14.85144 | 0.0000 |
| C(119) | -0.268547 | 0.021613 | -12.42513 | 0.0000 |
| C(120) | -0.211593 | 0.030787 | -6.872806 | 0.0000 |
| C(130) | 0.000616 | 0.000196 | 3.146394 | 0.0029 |

Determinant residual covariance 3.91E+24

Equation: TCP = C(1) + C(4)*PE(-1)*QP + C(5)*PS(-1)*QP+ C(6)*ZP(-1)
Observations: 18

| | | | |
|---|---|---|---|
| R-squared | 0.732012 | Mean dependent var | 1407172. |
| Adjusted R-squared | 0.674586 | S.D. dependent var | 380455.9 |
| S.E. of regression | 217031.4 | Sum squared resid | 6.59E+11 |
| Durbin-Watson stat | 2.017074 | | |

Equation: PP= ( ((C(1) + C(4)*PE(-1)*QP + C(5)*PS(-1)*QP) + C(6)*ZP(-1)) /QP + C(6)*USERCOSTFACTORP) - (C(11) + C(12)*T + C(15) *D1Q2008 + C(16)*D2Q2008 + C(17)*D3Q2008 + C(18)*D4Q2008 + C(19)*D1Q2009 + C(20)*D2Q2009 + C(30)*PPIFARM) *QP
Observations: 18

| | | | |
|---|---|---|---|
| R-squared | 0.961132 | Mean dependent var | 644.4817 |
| Adjusted R-squared | 0.867848 | S.D. dependent var | 222.8643 |

| | | | |
|---|---|---|---|
| S.E. of regression | 81.01713 | Sum squared resid | 32818.88 |
| Durbin-Watson stat | 2.200050 | | |

Equation: TCK = C(101) + C(104)*PE(-1)*QK + C(106)*ZK(-1)
Observations: 18

| | | | |
|---|---|---|---|
| R-squared | 0.575879 | Mean dependent var | 363773.5 |
| Adjusted R-squared | 0.519330 | S.D. dependent var | 102052.5 |
| S.E. of regression | 70753.34 | Sum squared resid | 7.51E+10 |
| Durbin-Watson stat | 1.066092 | | |

Equation: PK= ( ((C(101) + C(104)*PE(-1)*QK + C(106)*ZK(-1))/QK) + C(106)*USERCOSTFACTORK) - (C(111) + C(112)*T + C(113)*T*T + C(115)*D1Q2008 + C(116)*D2Q2008 + C(117)*D3Q2008 + C(118) *D4Q2008 + C(119)*D1Q2009 + C(120)*D2Q2009 + C(130)*PPIFARM) *QK
Observations: 18

| | | | |
|---|---|---|---|
| R-squared | 0.987420 | Mean dependent var | 449.6645 |
| Adjusted R-squared | 0.957229 | S.D. dependent var | 109.9089 |
| S.E. of regression | 22.73055 | Sum squared resid | 2583.388 |
| Durbin-Watson stat | 1.784538 | | |

## Appendix Table A-6. Estimates of the MOS_MC Model

Estimation Method: Seemingly Unrelated Regression
Date: 03/12/13 Time: 08:35
Sample: 2 19
Included observations: 18
Total system (balanced) observations 72
Linear estimation after one-step weighting matrix

| | Coefficient | Std. Error | t-Statistic | Prob. |
|---|---|---|---|---|
| C(1) | 79463.47 | 156446.2 | 0.507928 | 0.6139 |
| C(4) | 1.158791 | 0.236027 | 4.909560 | 0.0000 |
| C(5) | 0.905926 | 0.124680 | 7.265993 | 0.0000 |
| C(6) | 2.456685 | 1.556111 | 1.578733 | 0.1213 |
| C(11) | 0.142441 | 0.061959 | 2.298944 | 0.0261 |
| C(12) | -0.001025 | 0.000975 | -1.051954 | 0.2983 |
| C(15) | -0.014000 | 0.018180 | -0.770052 | 0.4452 |
| C(16) | -0.087507 | 0.017212 | -5.084042 | 0.0000 |
| C(17) | -0.150174 | 0.019381 | -7.748469 | 0.0000 |
| C(18) | -0.169359 | 0.041535 | -4.077535 | 0.0002 |
| C(19) | 0.115322 | 0.042957 | 2.684588 | 0.0101 |
| C(20) | 0.025780 | 0.020489 | 1.258278 | 0.2146 |
| C(30) | -0.000710 | 0.000294 | -2.412638 | 0.0199 |
| C(101) | 97026.41 | 39287.90 | 2.469626 | 0.0173 |
| C(104) | 0.548171 | 0.098678 | 5.555161 | 0.0000 |
| C(106) | 3.403945 | 0.500310 | 6.803672 | 0.0000 |
| C(111) | -0.163106 | 0.100177 | -1.628178 | 0.1103 |
| C(112) | -0.003684 | 0.004235 | -0.869853 | 0.3889 |
| C(113) | -0.000247 | 0.000208 | -1.190689 | 0.2399 |
| C(115) | 0.002717 | 0.022798 | 0.119183 | 0.9056 |
| C(116) | -0.009551 | 0.024720 | -0.386364 | 0.7010 |
| C(117) | -0.099861 | 0.028116 | -3.551784 | 0.0009 |
| C(118) | -0.151324 | 0.027267 | -5.549718 | 0.0000 |
| C(119) | -0.320199 | 0.054971 | -5.824882 | 0.0000 |
| C(120) | -0.358272 | 0.067176 | -5.333302 | 0.0000 |

| | | | | |
|---|---|---|---|---|
| C(130) | 0.001398 | 0.000507 | 2.757485 | 0.0083 |

Determinant residual covariance 1.55E+25

Equation: TCP = C(1) + C(4)*PE(-1)*QP + C(5)*PS(-1)*QP + C(6)*ZP(-1)
Observations: 18

| | | | |
|---|---|---|---|
| R-squared | 0.733768 | Mean dependent var | 1407172. |
| Adjusted R-squared | 0.676718 | S.D. dependent var | 380455.9 |
| S.E. of regression | 216319.3 | Sum squared resid | 6.55E+11 |
| Durbin-Watson stat | 2.004919 | | |

Equation: PP= ( C(4)*PE(-1) + C(5)*PS(-1) + C(6)*USERCOSTFACTORP ) - (C(11) + C(12)*T + C(15)*D1Q2008 + C(16)*D2Q2008 + C(17)*D3Q2008 + C(18)*D4Q2008 + C(19)*D1Q2009 + C(20)*D2Q2009 + C(30)*PPIFARM) *QP
Observations: 18

| | | | |
|---|---|---|---|
| R-squared | 0.958950 | Mean dependent var | 644.4817 |
| Adjusted R-squared | 0.883692 | S.D. dependent var | 222.8643 |
| S.E. of regression | 76.00547 | Sum squared resid | 34660.99 |
| Durbin-Watson stat | 2.206880 | | |

Equation: TCK = C(101) +C(104)*PE(-1)*QK + C(106)*ZK(-1)
Observations: 18

| | | | |
|---|---|---|---|
| R-squared | 0.562439 | Mean dependent var | 363773.5 |
| Adjusted R-squared | 0.504098 | S.D. dependent var | 102052.5 |
| S.E. of regression | 71865.69 | Sum squared resid | 7.75E+10 |
| Durbin-Watson stat | 1.000181 | | |

Equation: PK= ( C(104)*PE(-1) + C(106)*USERCOSTFACTORK ) - (C(111) + C(112)*T + C(113)*T*T + C(115)*D1Q2008 + C(116)*D2Q2008 + C(117)*D3Q2008 + C(118)*D4Q2008 + C(119)*D1Q2009 + C(120)*D2Q2009 + C(130)*PPIFARM) *QK
Observations: 18

| | | | |
|---|---|---|---|
| R-squared | 0.968804 | Mean dependent var | 449.6645 |
| Adjusted R-squared | 0.911612 | S.D. dependent var | 109.9089 |
| S.E. of regression | 32.67611 | Sum squared resid | 6406.367 |
| Durbin-Watson stat | 2.148603 | | |

## Appendix B:
## Econometric Estimates of U.S. Fertilizer Demand

Variable definitions for Appendix B Tables are given below.

- QN = quantity of nitrogen consumed in the U.S. (thousand tons)
- QP = quantity of phosphorus in the U.S. (thousand tons)
- QK = quantity of potash in the U.S. (thousand tons)
- RPN = real price of nitrogen paid by U.S. producers ($/ton)
- RPP = real price of phosphorus paid by U.S. producers ($/ton)
- RPK = real price of potash paid by U.S. producers ($/ton)
- RPCROPS = real prices received index for U.S. crops
- t = time, which is crop year, beginning with t = 1 for 1980
- AR(1) = first order autoregressive error command in EViews
- Real prices are expressed in 2012 dollars based on the GDP Price Deflator

**Appendix Table B-1. U.S. Demand for nitrogen Fertilizer**

Dependent Variable: QN
Method: Least Squares
Date: 02/08/13 Time: 10:03
Sample (adjusted): 1981 2010
Included observations: 30 after adjustments
Convergence achieved after 20 iterations

| Variable | Coefficient | Std. Error | t-Statistic | Prob. |
|---|---|---|---|---|
| C | 4676.422 | 2012.884 | 2.323245 | 0.0294 |
| RPN | -2.426699 | 1.788941 | -1.356500 | 0.1881 |
| RPCROPS(-1) | 18.51712 | 8.290463 | 2.233545 | 0.0355 |
| D2008 | 259.8347 | 824.9021 | 0.314989 | 0.7556 |
| D2009 | -1576.494 | 745.1268 | -2.115739 | 0.0454 |
| T | 140.2905 | 31.68621 | 4.427494 | 0.0002 |
| AR(1) | 0.202902 | 0.231561 | 0.876238 | 0.3900 |

| | | | |
|---|---|---|---|
| R-squared | 0.648889 | Mean dependent var | 11674.01 |
| Adjusted R-squared | 0.557295 | S.D. dependent var | 904.8027 |
| S.E. of regression | 602.0204 | Akaike info criterion | 15.83942 |
| Sum squared resid | 8335858. | Schwarz criterion | 16.16637 |
| Log likelihood | -230.5913 | Hannan-Quinn criter. | 15.94402 |
| F-statistic | 7.084390 | Durbin-Watson stat | 1.776063 |
| Prob(F-statistic) | 0.000229 | | |

## Appendix Table B-2. U.S. Demand for phosphorus Fertilizer

Dependent Variable: QP
Method: Least Squares
Date: 02/08/13 Time: 10:03
Sample (adjusted): 1990 2010
Included observations: 21 after adjustments
Convergence achieved after 8 iterations

| Variable | Coefficient | Std. Error | t-Statistic | Prob. |
|---|---|---|---|---|
| C | 871.1205 | 821.4482 | 1.060469 | 0.3082 |
| RPP | -2.020861 | 1.049056 | -1.926361 | 0.0762 |
| QP(-1) | 0.332086 | 0.112216 | 2.959359 | 0.0111 |
| RPCROPS(-1) | 9.639052 | 3.819476 | 2.523659 | 0.0254 |
| D2008 | 581.9022 | 531.3249 | 1.095191 | 0.2933 |
| D2009 | -1318.851 | 273.7154 | -4.818330 | 0.0003 |
| T | 35.04520 | 11.52461 | 3.040902 | 0.0095 |
| AR(1) | -0.525359 | 0.248019 | -2.118222 | 0.0540 |

| | | | |
|---|---|---|---|
| R-squared | 0.871979 | Mean dependent var | 4363.867 |
| Adjusted R-squared | 0.803044 | S.D. dependent var | 336.6544 |
| S.E. of regression | 149.4063 | Akaike info criterion | 13.13355 |
| Sum squared resid | 290189.3 | Schwarz criterion | 13.53146 |
| Log likelihood | -129.9023 | Hannan-Quinn criter. | 13.21991 |
| F-statistic | 12.64935 | Durbin-Watson stat | 1.887551 |
| Prob(F-statistic) | 0.000069 | | |

## Appendix Table B-3. U.S. Demand for potash Fertilizer

Dependent Variable: QK
Method: Least Squares
Date: 01/31/13 Time: 15:54
Sample (adjusted): 1990 2010
Included observations: 21 after adjustments
Convergence achieved after 6 iterations

| Variable | Coefficient | Std. Error | t-Statistic | Prob. |
|---|---|---|---|---|
| RPK | -3.536667 | 1.386676 | -2.550463 | 0.0231 |
| QK(-1) | 0.218835 | 0.124443 | 1.758517 | 0.1005 |
| RPCROPS(-1) | 19.67453 | 3.634504 | 5.413265 | 0.0001 |
| D2008 | 406.5375 | 438.0145 | 0.928137 | 0.3691 |
| D2009 | -803.4787 | 671.8969 | -1.195836 | 0.2516 |
| T | 50.48998 | 12.08890 | 4.176556 | 0.0009 |
| AR(1) | -0.015995 | 0.271490 | -0.058916 | 0.9539 |

| | | | |
|---|---|---|---|
| R-squared | 0.913232 | Mean dependent var | 4966.957 |
| Adjusted R-squared | 0.876045 | S.D. dependent var | 496.4728 |
| S.E. of regression | 174.7941 | Akaike info criterion | 13.42630 |
| Sum squared resid | 427741.9 | Schwarz criterion | 13.77447 |
| Log likelihood | -133.9761 | Hannan-Quinn criter. | 13.50186 |
| Durbin-Watson stat | 2.007309 | | |

## Appendix C:
## Econometric Estimates of Firm Specific Demand

Variables names are the same as defined in Appendix A.

**Appendix Table C-1. Demand for POT's nitrogen**

Dependent Variable: QN
Method: Least Squares
Date: 02/08/13 Time: 07:50
Sample: 1 59
Included observations: 59

| Variable | Coefficient | Std. Error | t-Statistic | Prob. |
|---|---|---|---|---|
| C | 1243.784 | 239.2778 | 5.198074 | 0.0000 |
| PN | -1.179818 | 0.446829 | -2.640421 | 0.0112 |
| Q2 | 87.35982 | 66.27307 | 1.318180 | 0.1938 |
| Q3 | -72.25001 | 65.21168 | -1.107930 | 0.2735 |
| Q4 | -3.745863 | 66.40011 | -0.056414 | 0.9553 |
| D1Q2008 | 115.0721 | 180.2318 | 0.638468 | 0.5263 |
| D2Q2008 | 39.06642 | 183.9011 | 0.212432 | 0.8327 |
| D3Q2008 | 452.7794 | 200.9408 | 2.253297 | 0.0289 |
| D4Q2008 | -98.48056 | 184.6895 | -0.533222 | 0.5964 |
| D1Q2009 | -54.88870 | 175.6647 | -0.312463 | 0.7561 |
| D2Q2009 | -204.3307 | 175.3136 | -1.165515 | 0.2497 |
| PPIFARM | 2.512112 | 2.168977 | 1.158201 | 0.2526 |

| | | | |
|---|---|---|---|
| R-squared | 0.299552 | Mean dependent var | 1317.153 |
| Adjusted R-squared | 0.135617 | S.D. dependent var | 181.6863 |
| S.E. of regression | 168.9177 | Akaike info criterion | 13.27609 |
| Sum squared resid | 1341061. | Schwarz criterion | 13.69864 |
| Log likelihood | -379.6447 | Hannan-Quinn criter. | 13.44104 |
| F-statistic | 1.827265 | Durbin-Watson stat | 1.484048 |
| Prob(F-statistic) | 0.075858 | | |

**Appendix Table C-2. Demand for POT's P**

Dependent Variable: QP
Method: Least Squares
Date: 02/08/13 Time: 07:49
Sample (adjusted): 3 59
Included observations: 57 after adjustments
Convergence achieved after 10 iterations

| Variable | Coefficient | Std. Error | t-Statistic | Prob. |
|---|---|---|---|---|
| C | -5.521910 | 123.6791 | -0.044647 | 0.9646 |
| PP | -0.236173 | 0.220953 | -1.068880 | 0.2911 |
| QP(-1) | 0.756294 | 0.096051 | 7.873906 | 0.0000 |
| Q2 | 26.27139 | 40.70235 | 0.645451 | 0.5221 |
| Q3 | 123.8277 | 33.36645 | 3.711144 | 0.0006 |
| Q4 | 62.07372 | 39.33286 | 1.578164 | 0.1219 |
| D1Q2008 | -93.17048 | 92.09710 | -1.011655 | 0.3174 |
| D2Q2008 | 52.23527 | 116.7886 | 0.447264 | 0.6569 |
| D3Q2008 | 112.9626 | 162.4108 | 0.695537 | 0.4905 |
| D4Q2008 | -313.7866 | 162.9955 | -1.925124 | 0.0608 |
| D1Q2009 | 83.54320 | 104.3147 | 0.800877 | 0.4276 |
| D2Q2009 | 102.9687 | 94.30498 | 1.091869 | 0.2810 |
| PPIFARM | 1.796737 | 1.320895 | 1.360241 | 0.1808 |
| AR(1) | -0.241162 | 0.169788 | -1.420372 | 0.1627 |

| | | | |
|---|---|---|---|
| R-squared | 0.728407 | Mean dependent var | 910.9298 |
| Adjusted R-squared | 0.646297 | S.D. dependent var | 143.3549 |
| S.E. of regression | 85.25736 | Akaike info criterion | 11.93860 |
| Sum squared resid | 312559.2 | Schwarz criterion | 12.44041 |
| Log likelihood | -326.2502 | Hannan-Quinn criter. | 12.13362 |
| F-statistic | 8.871155 | Durbin-Watson stat | 2.023788 |
| Prob(F-statistic) | 0.000000 | | |

## Appendix Table C-3. Demand for POT's K

Dependent Variable: QK
Method: Least Squares
Date: 02/08/13 Time: 07:49
Sample (adjusted): 3 59
Included observations: 57 after adjustments
Convergence achieved after 12 iterations

| Variable | Coefficient | Std. Error | t-Statistic | Prob. |
|---|---|---|---|---|
| C | 43.75920 | 603.5368 | 0.072505 | 0.9425 |
| PK | -3.044827 | 1.528341 | -1.992243 | 0.0529 |
| QK(-1) | 0.151389 | 0.249130 | 0.607670 | 0.5467 |
| Q2 | 207.9113 | 161.7346 | 1.285510 | 0.2057 |
| Q3 | -213.4426 | 201.4436 | -1.059565 | 0.2954 |
| Q4 | -354.3632 | 135.2465 | -2.620129 | 0.0122 |
| D1Q2008 | 254.6122 | 341.7293 | 0.745070 | 0.4604 |
| D2Q2008 | 532.4040 | 405.2379 | 1.313806 | 0.1960 |
| D3Q2008 | 671.0330 | 607.6684 | 1.104275 | 0.2758 |
| D4Q2008 | 959.2615 | 721.0432 | 1.330380 | 0.1906 |
| D1Q2009 | -512.4239 | 594.2087 | -0.862363 | 0.3934 |
| D2Q2009 | -939.2706 | 402.6285 | -2.332847 | 0.0245 |
| PPIFARM | 11.86459 | 6.977375 | 1.700437 | 0.0964 |
| T | 17.19623 | 7.325069 | 2.347587 | 0.0237 |
| AR(1) | 0.011988 | 0.281056 | 0.042654 | 0.9662 |

| | | | |
|---|---|---|---|
| R-squared | 0.737616 | Mean dependent var | 1821.965 |
| Adjusted R-squared | 0.650155 | S.D. dependent var | 533.1100 |
| S.E. of regression | 315.3224 | Akaike info criterion | 14.56600 |
| Sum squared resid | 4175986. | Schwarz criterion | 15.10365 |
| Log likelihood | -400.1311 | Hannan-Quinn criter. | 14.77495 |
| F-statistic | 8.433623 | Durbin-Watson stat | 1.995536 |
| Prob(F-statistic) | 0.000000 | | |

## Appendix Table C-4. Demand for AGU's N

Dependent Variable: QN
Method: Least Squares
Date: 02/08/13 Time: 10:07
Sample (adjusted): 2 59
Included observations: 58 after adjustments
Convergence achieved after 8 iterations

| Variable | Coefficient | Std. Error | t-Statistic | Prob. |
|---|---|---|---|---|
| C | 1892.201 | 336.6863 | 5.620072 | 0.0000 |
| PN | 1.095779 | 0.996309 | 1.099839 | 0.2770 |
| D1Q2008 | -213.7936 | 310.3136 | -0.688960 | 0.4942 |
| D2Q2008 | 115.7009 | 333.4263 | 0.347006 | 0.7301 |
| D3Q2008 | -396.3482 | 379.6169 | -1.044074 | 0.3018 |
| D4Q2008 | -685.6254 | 360.1853 | -1.903535 | 0.0631 |
| D1Q2009 | -515.2648 | 315.3757 | -1.633813 | 0.1090 |
| D2Q2009 | -62.70756 | 303.9284 | -0.206323 | 0.8374 |
| PPIFARM | -7.378030 | 3.318033 | -2.223616 | 0.0310 |
| T | -0.580849 | 5.088277 | -0.114154 | 0.9096 |
| AR(1) | -0.349301 | 0.137863 | -2.533689 | 0.0147 |

| | | | |
|---|---|---|---|
| R-squared | 0.269587 | Mean dependent var | 1106.190 |
| Adjusted R-squared | 0.114180 | S.D. dependent var | 311.5807 |
| S.E. of regression | 293.2535 | Akaike info criterion | 14.36897 |
| Sum squared resid | 4041889. | Schwarz criterion | 14.75974 |
| Log likelihood | -405.7000 | Hannan-Quinn criter. | 14.52118 |
| F-statistic | 1.734715 | Durbin-Watson stat | 1.689891 |
| Prob(F-statistic) | 0.100672 | | |

## Appendix Table C-5. Demand for AGU's P

Dependent Variable: QP
Method: Least Squares
Date: 02/08/13 Time: 10:10
Sample (adjusted): 2 59
Included observations: 58 after adjustments
Convergence achieved after 8 iterations

| Variable | Coefficient | Std. Error | t-Statistic | Prob. |
|---|---|---|---|---|
| C | 128.4753 | 104.2724 | 1.232112 | 0.2243 |
| PP | -0.045501 | 0.113279 | -0.401669 | 0.6898 |
| Q2 | 122.3068 | 25.17439 | 4.858380 | 0.0000 |
| Q3 | 46.05056 | 22.18533 | 2.075722 | 0.0437 |
| Q4 | 73.14095 | 25.01223 | 2.924207 | 0.0054 |
| D1Q2008 | 17.34944 | 60.92005 | 0.284790 | 0.7771 |
| D2Q2008 | -31.00716 | 63.11841 | -0.491254 | 0.6256 |
| D3Q2008 | 16.15906 | 101.2124 | 0.159655 | 0.8739 |
| D4Q2008 | -105.2682 | 103.3794 | -1.018270 | 0.3140 |
| D1Q2009 | 9.138870 | 64.90491 | 0.140804 | 0.8887 |
| D2Q2009 | -51.27341 | 59.76591 | -0.857904 | 0.3955 |
| PPIFARM | 0.635514 | 1.001517 | 0.634552 | 0.5289 |
| AR(1) | -0.166105 | 0.147381 | -1.127043 | 0.2657 |

| | | | |
|---|---|---|---|
| R-squared | 0.469065 | Mean dependent var | 259.8621 |
| Adjusted R-squared | 0.327482 | S.D. dependent var | 69.61308 |
| S.E. of regression | 57.08771 | Akaike info criterion | 11.12155 |
| Sum squared resid | 146655.3 | Schwarz criterion | 11.58337 |
| Log likelihood | -309.5250 | Hannan-Quinn criter. | 11.30144 |
| F-statistic | 3.313013 | Durbin-Watson stat | 1.921689 |
| Prob(F-statistic) | 0.001702 | | |

## Appendix Table C-6. Demand for AGU's K

Dependent Variable: QK
Method: Least Squares
Date: 02/08/13 Time: 10:10
Sample (adjusted): 2 59
Included observations: 58 after adjustments
Convergence achieved after 6 iterations

| Variable | Coefficient | Std. Error | t-Statistic | Prob. |
|---|---|---|---|---|
| C | 148.6144 | 116.7057 | 1.273412 | 0.2094 |
| PK | -0.247929 | 0.144379 | -1.717207 | 0.0928 |
| Q2 | 104.6881 | 22.13130 | 4.730321 | 0.0000 |
| Q3 | -36.04707 | 24.17209 | -1.491268 | 0.1429 |
| Q4 | -1.922634 | 22.46992 | -0.085565 | 0.9322 |
| D1Q2008 | 21.10636 | 66.91349 | 0.315428 | 0.7539 |
| D2Q2008 | 77.73117 | 69.53995 | 1.117792 | 0.2696 |
| D3Q2008 | 96.01922 | 80.60657 | 1.191208 | 0.2398 |
| D4Q2008 | 26.41527 | 95.33844 | 0.277068 | 0.7830 |
| D1Q2009 | -199.6502 | 86.55761 | -2.306558 | 0.0257 |
| D2Q2009 | -274.0088 | 100.2908 | -2.732143 | 0.0090 |
| PPIFARM | 1.930100 | 0.944128 | 2.044319 | 0.0468 |
| AR(1) | 0.242068 | 0.165559 | 1.462123 | 0.1507 |

| | | | |
|---|---|---|---|
| R-squared | 0.716898 | Mean dependent var | 381.3793 |
| Adjusted R-squared | 0.641404 | S.D. dependent var | 103.8112 |
| S.E. of regression | 62.16517 | Akaike info criterion | 11.29196 |
| Sum squared resid | 173902.9 | Schwarz criterion | 11.75379 |
| Log likelihood | -314.4669 | Hannan-Quinn criter. | 11.47185 |
| F-statistic | 9.496092 | Durbin-Watson stat | 1.956167 |
| Prob(F-statistic) | 0.000000 | | |

## Appendix Table C-7. Demand for MOS's P

Dependent Variable: QP
Method: Least Squares
Date: 02/08/13 Time: 10:11
Sample (adjusted): 2 19
Included observations: 18 after adjustments
Convergence achieved after 5 iterations

| Variable | Coefficient | Std. Error | t-Statistic | Prob. |
|---|---|---|---|---|
| C | 1932.179 | 602.3462 | 3.207754 | 0.0238 |
| PP | -0.295577 | 0.713783 | -0.414100 | 0.6960 |
| Q2 | 404.8081 | 192.6421 | 2.101348 | 0.0896 |
| Q3 | -560.2357 | 158.6275 | -3.531770 | 0.0167 |
| Q4 | -461.8988 | 215.6317 | -2.142073 | 0.0851 |
| D1Q2008 | 404.3923 | 228.9694 | 1.766141 | 0.1376 |
| D2Q2008 | 965.9613 | 391.2673 | 2.468802 | 0.0566 |
| D3Q2008 | 461.8599 | 608.8898 | 0.758528 | 0.4823 |
| D4Q2008 | -1743.726 | 389.3586 | -4.478457 | 0.0065 |
| D1Q2009 | 1175.879 | 525.9092 | 2.235897 | 0.0756 |
| D2Q2009 | 143.2392 | 284.2600 | 0.503902 | 0.6357 |
| PPIFARM | 7.206069 | 4.712040 | 1.529289 | 0.1867 |
| AR(1) | -0.329903 | 0.355605 | -0.927723 | 0.3961 |

| | | | |
|---|---|---|---|
| R-squared | 0.963400 | Mean dependent var | 2807.611 |
| Adjusted R-squared | 0.875562 | S.D. dependent var | 559.2088 |
| S.E. of regression | 197.2656 | Akaike info criterion | 13.57049 |
| Sum squared resid | 194568.5 | Schwarz criterion | 14.21354 |
| Log likelihood | -109.1344 | Hannan-Quinn criter. | 13.65916 |
| F-statistic | 10.96781 | Durbin-Watson stat | 2.592914 |
| Prob(F-statistic) | 0.007905 | | |

Inverted AR Roots -.33

## Appendix Table C-8. Demand for MOS's K

Dependent Variable: QK
Method: Least Squares
Date: 02/08/13 Time: 08:19
Sample (adjusted): 2 19
Included observations: 18 after adjustments
Convergence achieved after 12 iterations

| Variable | Coefficient | Std. Error | t-Statistic | Prob. |
|---|---|---|---|---|
| C | -660.7211 | 1125.023 | -0.587296 | 0.5825 |
| PK | -1.864290 | 1.209888 | -1.540878 | 0.1840 |
| Q2 | 166.7551 | 368.7822 | 0.452178 | 0.6701 |
| Q3 | 237.0044 | 279.2831 | 0.848617 | 0.4348 |
| Q4 | 677.8835 | 415.0985 | 1.633067 | 0.1634 |
| D1Q2008 | 138.5103 | 496.8027 | 0.278803 | 0.7916 |
| D2Q2008 | 640.8225 | 494.7005 | 1.295375 | 0.2518 |
| D3Q2008 | 1283.858 | 487.5883 | 2.633078 | 0.0464 |
| D4Q2008 | -348.8224 | 717.5283 | -0.486145 | 0.6474 |
| D1Q2009 | 562.0408 | 931.1721 | 0.603584 | 0.5725 |
| D2Q2009 | -605.5224 | 572.9617 | -1.056829 | 0.3390 |
| PPIFARM | 16.26057 | 5.426743 | 2.996378 | 0.0302 |
| AR(1) | -0.335455 | 0.503602 | -0.666111 | 0.5348 |

| | | | |
|---|---|---|---|
| R-squared | 0.863707 | Mean dependent var | 1625.556 |
| Adjusted R-squared | 0.536603 | S.D. dependent var | 517.9193 |
| S.E. of regression | 352.5644 | Akaike info criterion | 14.73185 |
| Sum squared resid | 621508.4 | Schwarz criterion | 15.37490 |
| Log likelihood | -119.5867 | Hannan-Quinn criter. | 14.82052 |
| F-statistic | 2.640470 | Durbin-Watson stat | 2.116290 |
| Prob(F-statistic) | 0.146148 | | |

Inverted AR Roots -.34