THREE ESSAYS ON

AGRICULTURAL RESEARCH AND DEVELOPMENT,

MERGERS, AND FUTURES MARKETS

by

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Abstract

Three of the most important new trends in agriculture are the evolution of the regimes of intellectual property rights, the ever-increasing market concentration in the plant breeding industry, and the complete migration of agricultural commodity trading to an electronic platform. This dissertation explores the impact of these structural changes in order to provide a better understanding of different aspects of the sector. In the first paper, ***R&D Investments by Asymmetric Plant Breeding Firms under Changing Intellectual Property Rights***, the effect on Research and Development (R&D) investment as well as welfare impacts of three main intellectual property rights:. patents, patents with a farmer's exemption, and patents with a researcher's exemption are evaluated. In the second paper, ***Tariffs, R&D, and Two Merger Policies***, I explore how trade policy coupled with different merger policies can induce endogenous mergers when firms conduct R&D. The effect on R&D investment by firms and the welfare effect of the trade and merger policies are also studied. In the third paper, ***The Information Content of the LOB***, an empirical model is used to examine whether the bid and ask price steps beyond the best bid in the limit order book (LOB) and ask contain valuable information and contribute to price discovery in agricultural commodity futures markets.

The first paper of this dissertation, in a Cournot duopoly model, examines three major intellectual property rights in the plant breeding industry. In the symmetric variation of the model, I find that breeders invest less in R&D with a researcher's exemption if variety differentiation is low or knowledge spillover is high. I also show that farmers prefer a farmer's exemption in the short run to other IPRs but should favour a researcher's exemption or patent in the long run. Moreover, the social planner for most ranges of variety differentiation and knowledge spillover prefers the research exemption over the patent and prefers the patent to the

farmer's exemption. In the asymmetric variation of the model, I consider two sources of asymmetry i.e. asymmetry in efficiency and asymmetry in stock of knowledge for breeders separately. Both asymmetric cases give rise to the situations where the researcher's exemption can resolve the common pool problem and increase R&D investment or create free riding problems and lower R&D investment. I show that the more efficient/more endowed breeder invests more in R&D under the researcher's exemption than patents alone if variety differentiation is high and cost/knowledge endowment dispersion is low. On the other hand, the less efficient/less endowed breeder, generally, invests less in R&D under a researcher's exemption if variety differentiation or cost/knowledge endowment differences are low. Importantly, the results show that for most of the possible range of parameters where the researcher's exemption encourages R&D more than a patent, asymmetric firms voluntarily cooperate in research and a social planner intervention may not be required to increase R&D. These findings suggest new gains for society from adopting the 1991version of the UPOV convention.

The second paper of this dissertation, in an international Cournot oligopoly model, compares two different merger policies when firms are merging *endogenously* and engage in R&D. In the benchmark model, countries set optimal tariff levels but do not have merger policy. If ex-ante identical firms merge internationally, they have an ex-post cost advantage over the outsiders due to tariff savings. This gives the merger an incentive to increase its R&D investment, which increases the cost dispersion further; therefore, the merger paradox disappears when R&D is efficient. As a result, I find different equilibrium market structures depending on the efficiency of R&D. In the second part, I compare two different merger policies, one that puts emphasis on total welfare (roughly the Canadian merger policy) and another one that puts emphasis on consumer surplus (roughly the European Union's merger policy). I show that under the "welfare-increasing" merger policy, monopoly is the equilibrium market structure when R&D is very efficient. This explains why a merger, which created a monopoly, was approved in Canada. As R&D becomes less efficient, the equilibrium market structures become less concentrated under the two different merger policies. Each merger policy can be global welfare maximizing depending on the efficiency of R&D; however, the "consumer-surplus-increasing" merger policy is optimal for a wider range of parameters.

The third paper of this dissertation examines price discovery in the futures markets for agricultural commodities. I investigate whether, as a part of their trading strategies, informed traders submit limit orders instead of market orders. If so, the steps of limit order book (LOB) beyond the best bid and best ask spread (BAS) contain valuable information and contribute to price discovery of the underlying asset. I reconstruct the LOB using market depth data and apply three information share approaches to test whether the steps of the LOB beyond the BAS contribute to price discovery in agricultural commodity futures markets. This is done for five major agricultural commodities namely lean hogs, live cattle, corn, wheat, and soybeans as well as the CME E-mini S&P 500. The results show, first, a substantial market depth existing in the steps beyond the BAS, and second, a considerably high contribution to price discovery for the steps beyond the BAS, for all the products studied. The results also indicate that the information contained in the LOB steps beyond the BAS is higher for the steps closer to the top of the book than the steps farther along the book. These findings suggest that traders in futures markets actively use limit orders with price steps beyond the BAS, and especially steps closer to the top of the book and show the importance of studying the LOB when analyzing different aspects of electronic futures markets.

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Chapter 1. Introduction

Agricultural sector has gone through tremendous structural changes in recent years. Three of the most important new trends in agriculture are the evolution of the regimes of intellectual property rights, the ever-increasing market concentration in the plant breeding industry, and the complete migration of agricultural commodity trading to an electronic platform. This dissertation aims at examining the impact of these structural changes in order to provide a better understanding of different aspects of the sector. In the second chapter, the effect on Research and Development (R&D) investment as well as welfare impacts of three main intellectual property rights i.e. patent, patent with farmer's exemption, and patent with researcher's exemption are evaluated in a theoretical framework. In the third chapter, also in a theoretical framework, it is examined that how trade policy coupled with different merger policies can induce endogenous mergers when firms conduct R&D. The effect on R&D investment by firms and the welfare effect of the trade and merger policies are also studied. In the fourth chapter, an empirical model is used to examine whether the bid and ask price levels beyond the best bid and ask spread contain valuable information and contribute to price discovery in agricultural commodity markets. Chapter 5 draws concluding remarks.

The first paper of this dissertation (chapter 2), in a Cournot duopoly model, examines three major intellectual property rights in the plant breeding industry, namely patents, patents with a farmer's exemption, and patents with a researcher's exemption. Three variations of the game are examined. The first variation involves two competing symmetric plant breeding firms that undertake product R&D and produce new varieties which increase farmers' yield. The model tries to examine the effect of different IPRs, through their effect on R&D undertaken by breeders, on farmer's and breeder's surpluses. The second and third variations focus on patent and patent with research exemption to answer an important question: Does a research exemption to patent foster the R&D investment by firms through pooling the knowledge and ideas or does researcher's exemption hinder R&D investment due to creating the free-riding problem. In the asymmetric variations of the model, two sources of asymmetry for breeders are considered separately. First, it is assumed that one breeder is more efficient in conducting R&D. Second, it is assumed that there is no cost difference between the breeders, however, one breeder benefits from a head start in terms of stock of knowledge. The study derives the conditions under which the researcher's exemption can resolve the common pool problem and increase R&D investment or create free riding problems and lower R&D investment.

A few studies in the literature address different aspects of the IPRs in plant breeding industry and their results to some extent are mixed. Chapter 2 of this dissertation attempts to extend this existing literature and provide a better understanding of the implications of these protection regimes for farmers and breeders.

Moschini and Lapan (1997) find that, under patent, when the breeder's innovation is "non-drastic", farmers and consumers surplus are unaffected by R&D. On the other hand, when the innovation is "drastic", the combination of larger agricultural output and lower prices results in an unambiguous increase in consumer surplus but the effect of a drastic innovation on the farmer surplus is dependent on the elasticity of demand. Moschini et al. (2000) find that the breeder realizes the largest portion of benefit or about 44 to 75 percent. Farmers and consumers share from the benefit are 10-16 and 15-40 percent, respectively. In contrast, Flack-Zepeda et al. (2000) conclude a higher share of the surplus going to the farmers and consumers. More recently, Malla and Brewin (2015) showed considerable gains to producers when two drastic innovations (RR and Liberty Link) were developed under more competition. These papers mainly focus on the distributional effect of patents and R&D as opposed to the differences in regimes of intellectual property protection.

Galushko (2008) show that under certain conditions PBRs are as effective as patents in creating incentives for a monopolistic breeder to invest in R&D activity. However, the share of farmers in total benefits is generally smaller under patents than under PBRs. In a second model, Galushko (2008) finds that private firms and public researchers tend to maintain their exclusive rights and that knowledge sharing or cross licensing in the breeding industry is undermined under patents. Moschini and Yerokhin (2007) suggest that the researcher's exemption inevitably weakens the *ex ante* incentive for private firms to innovate, especially when there is high cost and risk related to this research. On the other hand, when the costs and risks of research are low, a researcher's exemption may be optimal in creating innovation incentives for private firms as it provides a larger pool of innovations for the subsequent inventions. A more recent study by Hervouet and Langinier (2015) finds that a relatively high royalty can eliminate self-production by farmers when only a farmer's exemption is enacted. Moreover, when a farmer's exemption and patents coexist, the self-production is not fully prevented. However, the breeder's incentive to innovate is increased. They conclude that the monopolist has the highest incentive to innovate if the IP regime is either patent or farmer's exemption with a prohibitive tax level.

Chapter 2 of this dissertation contributes to the current literature in some important ways. It extends the studies by Galushko (2008) and Hervouet and Langinier (2015) by distinguishing between the short run and the long run effects of a farmer's exemption on farmers' surplus. This enables us to show if the farmers' optimal choice of IPR in the short run is different from the long run choice. Second, the chapter incorporates the effect of a researcher's exemption to be able to compare it with a farmer's exemption. This helps assess whether farmer surplus can be greater under a researcher's exemption than that under a farmer's exemption. This also helps us, ultimately, derive the social planner's optimal IPR. Third, the models in the literature take breeding firms as either identical units or monopolistic. Previous studies have not accounted for the effect of IPR protection regimes on the plant breeding industry when firms are asymmetric. The results of chapter 2 show that relaxing previous assumptions can have important implications in the breeders' incentive to innovate and their surplus as well as their incentive to share their knowledge. The asymmetry incorporated into our model is the main driving force of the difference between our findings and previous papers. We derive the conditions necessary for asymmetric competing breeders to cooperatively conduct R&D research even when one breeder is more efficient or has access to a greater stock of knowledge. Together with the symmetric variation of our model, we conclude that breeders' and society's interest are aligned for a great range of our model parameters and that when a researcher's exemption successfully functions as an effective mechanism to encourage R&D investment, breeders may voluntarily cross license their varieties or share their knowledge. We also show that under certain conditions the researcher's exemption can lower the breeders' incentive to innovate and cause free riding. If so, the enforcement of a researcher's exemption by social planners can result in lower firm and industry level R&D.

The second paper of this dissertation (chapter 3), in an international Cournot oligopoly model, compares two different merger policies when firms are merging *endogenously* and engage in research and development (R&D). Regulators traditionally have concentrated on how mergers affect the competition in the markets; however, they have recently become interested in the research and development (R&D) aspect of these mergers. The 2010 Horizontal Merger Guideline of US specifically mentions R&D as one of the criteria in the merger approval process.

Firms, on the other hand, merge to save on tariff costs, among other reasons. Therefore, to compare different merger policies, the trade policy and R&D incentives of involved firms should be studied simultaneously.

In the benchmark model of chapter 3, countries set optimal tariff levels but do not have merger policy. If ex-ante identical firms merge internationally, they have an ex-post cost advantage over the outsiders due to tariff savings. This gives the merger an incentive to increase its R&D investment, which increases the cost dispersion further; therefore, the merger paradox, where each firm wants to be an outsider, disappears when R&D is efficient. In the second part, two different merger policies are compared, one that puts emphasis on welfare (roughly the Canadian merger policy) and another one that puts emphasis on consumer surplus (roughly the European Union's merger policy). This results show that under the "welfare-increasing" merger policy, monopoly is the equilibrium market structure when R&D is very efficient. This explains why a merger, which created a monopoly, was approved in Canada. As R&D becomes less efficient, the equilibrium market structures become less concentrated under the two different merger policies. Each merger policy can be global welfare maximizing depending on the efficiency of R&D; however, the "consumer-surplus-increasing" merger policy is optimal for a wider range of parameters.

Chapter 3 of this dissertation contributes to three different aspects of the existing literature. The first one is the literature combining the competition policies and trade policies (e.g. Ross 1988, Horn and Levinsohn 2001, Yano 2001). None of these papers model how firms endogenously (and voluntarily) merge, rather they allow the countries to determine the number of firms in the market as the competition policy. In addition, these papers do not take into account the international mergers that are observed in today's global economies. The closest paper to ours is Horn and Levinsohn (2001) since both papers use Cournot competition, Nash level trade policies, and a partial equilibrium setting. Our model is different in the sense that we allow firms to merge endogenously and internationally, and to engage in cost reducing R&D. Our merger policies are also different since we compare two different merger policies. We show that trade liberalization occurs as an equilibrium phenomena depending on the efficiency level of R&D, among other results. In a recent paper, Breinlich et al. (2015) study how mergers in a domestic country affect the consumer surplus in the foreign (and domestic) country. They are mainly interested in whether the merger policy of a country is too lenient or too tough for the foreign consumers. They do not have R&D nor optimal tariffs. Unlike them, we allow for international mergers, and compare welfare-increasing merger policy and consumer-surplus-increasing merger policy.

Chapter 3 also falls into the literature that use endogenous mergers. Horn and Persson (2001a), endogenized the mergers as a cooperative coalition game by allowing firms to freely communicate and signing binding contracts. We follow Horn and Persson (2001a) to determine the equilibrium market structures in the first stage of our game. Horn and Persson (2001b) study an endogenous formation model when two firms in two countries face bilateral trade costs. They study neither merger policy nor optimal tariffs since they have trade costs in the model. Using Horn and Persson's endogenous merger formation model, Ulus and Yildiz (2012) study a differentiated goods oligopoly where firms compete in prices. We study a Cournot oligopoly setup, our firms engage in R&D investment, and our focus is on the use of trade and merger policy. Qiu and Zhou (2006a) explain that endogenous mergers occur if there is cost asymmetry and negative demand shock. Our firms are ex-ante identical but the mergers cause cost-asymmetry among firms due to tariffs. This cost asymmetry affects the mergers in equilibrium.

Chapter 3 of this dissertation also contributes to the R&D literature. The relation between mergers and R&D has been studied by Stenbacka (1991), Kabiraj and Mukherjee (2000), Davidson and Ferrett (2007), and Matsushima et al. (2013). None of these papers studies the international aspect of the mergers, which bring new insights, as follows. The nature of the mergers, international or national, determines whether there will be cost dispersion among firms due to tariff. We show that the international merger, not facing tariff, increases its R&D investment compared to the outsider firm(s) facing tariff. One implication of this observation is on the "merger paradox" (Salant et al. (1983). The merged firm, with its increased R&D, has a cost advantage which increases its profits more than the outsider firm(s). This mitigates or eliminates the "merger paradox."

In the third paper of this dissertation (chapter 4), the electronic markets for agricultural commodities are studied. Agricultural commodity futures were traditionally traded in the open outcry pit, however, over the past decade there has been a major shift to trading on the electronic platform. Grain and livestock futures contracts trading electronically weighed less than five percent of overall trade in 2006 and grew to over eighty and ninety percent, respectively, in 2011 (Irwin and Sanders 2012). Today the Chicago Mercantile Exchange (CME) Group, the largest futures contracts open interest exchange, has completely migrated its agricultural futures trading to the electronic platform, and pit trading for these commodities futures contract is non-existent. The electronic system differs significantly from the traditional open outcry system. One major difference is the presence of the limit order book (LOB) in the electronic system, which contains actual bid and ask prices and their corresponding volumes at different levels. Literature recognizes price discovery as a fundamental function of electronic markets and defines it as the incorporation of information to prices through the actions of traders. Recent finance literature has found evidence that, as a part of their trading strategies, informed traders may submit limit orders instead of market orders. If informed traders use limit orders, their information is presumably reflected in the book. If, however, informed traders use market orders, the orders in the book may not contain any of their private information. Therefore, the levels of limit order book (LOB) beyond the best bid and best ask spread (BAS) may contain valuable information and contribute to price discovery of the underlying asset. Several studies on the type of orders used by informed traders and the extent to which prices in the LOB carry information about the efficient price have been conducted, however the results are mixed (some examples are Harris and Panchapagesan 2005, Kaniel and Liu 2006, and Madhavan et al. 2005). In addition, only few of those studies analyze futures markets and none of them examine agricultural commodities. Cao et al. (2009) measure the information share of the levels of the LOB beyond BAS for 100 active Australian stocks and find that the levels beyond BAS contribute to price discovery by about 22%.

This is the first attempt to examine the informativeness of the LOB beyond (BAS) for agricultural commodities. Chapter 4 of this dissertation reconstructs the LOB using market depth data and applies three information share approaches (i.e. Hasbrouck (1995) information share, Gonzalo and Granger (1995) Permanent-Transitory shares, and Lien and Shrestha (2009) modified information share) to test whether the levels of LOB beyond BAS contribute to price discovery in agricultural commodity futures markets. This is done for five major agricultural commodities namely lean hogs, live cattle, corn, wheat, and soybeans as well as the CME E-mini S&P 500 to examine the informativeness of the LOB across the agricultural commodities and compare them with the stock markets. The chapter's findings can be informative in analyzing different aspects of electronic markets for agricultural commodities.

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Chapter 2. R&D Investments by Asymmetric Plant Breeding Firms under Changing Intellectual Property Rights

Abstract

In a Cournot duopoly model, we examine three major intellectual property rights in the plant breeding industry, namely patents, patents with a farmer's exemption, and patents with a researcher's exemption. In the symmetric variation of the model, we find that breeders invest less in R&D with a researcher's exemption if variety differentiation is low or knowledge spillover is high. We also show that farmers prefer a farmer's exemption in the short run to other IPRs but should favor a researcher's exemption or patent in the long run. Moreover, the social planner for most ranges of variety differentiation and knowledge spillover prefers the research exemption over the patent and prefers the patent to the farmer's exemption. In our asymmetric variation of the model, we consider two sources of asymmetry for breeders separately. First, we assume that one breeder is more efficient in conducting R&D. Second, we assume there is no cost difference between the breeders, however, one breeder benefits from a head start in terms of stock of knowledge. Both asymmetric cases give rise to the situations where the researcher's exemption can resolve the tragedy of the anticommons and increase R&D investment or create free riding problems and lower R&D investment. We show that the more efficient/more endowed breeder invests more in R&D under the researcher's exemption than patents if variety differentiation is high and cost/knowledge endowment dispersion is low. On the other hand, the less efficient/less endowed breeder, generally, invests less in R&D under a researcher's exemption if variety differentiation or cost/knowledge endowment differences are low. Importantly, the results show that for most of the possible range of parameters where the researcher's exemption encourages R&D more than a patent, asymmetric firms voluntarily cooperate in research and a social planner

intervention may not be required to increase R&D. These findings suggest new gains for society from adopting the 1991version of the UPOV convention.

Keywords: Plant breeding, farmer's exemption, researcher's exemption, IPRs, game theory, asymmetric firms, knowledge spillover, product differentiation, Cournot oligopoly.

2.1. Introduction

The self-pollinating nature of some crops makes crop research output non-excludable and thus R&D investment in plant breeding industry considerably different from other sectors. In normal self-pollinating grain production, a portion of the crop can be saved and used again for seed without significant yield losses. This farmer saved seed can present a serious problem for the economics of plant breeding. The development of a new variety can take up to ten years and cost "several million dollars (Acquaah 2007)." Less than five percent of a wheat crop is required for seed. A farmer who buys seed and plants it can sell ninety five percent of his subsequent crop as seed at a price of just over five percent of his original seed cost and make a profit, eroding the price for the original supplier. If the breeder charges the first farmer for the seed, nothing stops that farmer from growing a crop for seed and selling it to neighbors the following year. A survey conducted in eighteen countries in 2005 revealed that farmer saved-seed might have resulted in an annual loss of some seven billion dollars to the seed trade (GRAIN, 2007).

Innovations in hybrid seeds present a market solution to the issue of seed saving because of the very high yield loss in seeds collected after planting a hybrid for some species of plants. So there is a steady demand for new seeds for hybrids. Other species are less viable as hybrids and are still saved and used for reproduction by farmers. For instance, 66% of the U.S. and 80% of Canadian wheat seeds come from seed saving (Curtiss and Nilsson, 2012). The problem in capturing the benefits from these saved seeds contributes to underinvestment in breeding. Innovators in the plant breeding industry, without a regulated market, due to this non-excludability feature, are not able to capture any benefits from an innovation outcome. The private sector, as a result, has no incentive to invest in R&D in such an industry so breeding has to be funded by the public sector (Galushko, 2008).

Most countries have some form of public investment in seed breeding or regulation to help create incentives in the private sector. International agreements on plant breeders' rights (PBRs) and intellectual property rights (IPRs) have attempted to address the problems faced by trading nations as they try to change the nature of knowledge from non-rival to rival and provide some return to breeding investment. Different IPRs and their level of strength can result in significantly different implications. These implications need to be explored before adopting any new policies.

The International Union for the Protection of New Varieties of Plants (UPOV) was initiated to protect intellectual property rights in plant breeding. Seventy four countries have joined the UPOV convention as of April 2016 (UPOV, 2016). Intellectual property laws, however, are not harmonized and there remain differences in the regimes of protection which are adopted by different members of UPOV. Some countries follow the 1978 Act under which farmer's and researcher's exemptions are allowed (e.g. Argentina, Norway, Brazil, and New Zealand) and plant breeder rights (PBRs) are the protection regime used. In other countries the 1991 Act is implemented which is more restrictive in farmer's and researcher's exemptions (e.g. U.S., Canada, France, and Australia) and patents and PBRs coexist. The two acts are similar in the way that both regimes provide the owner with exclusive commercial rights for a limited period of time. However under 1978 Act, there are two exemptions to the intellectual property right. Under the farmer's exemption, farmers have a privilege that allows them to save the seed they have grown for subsequent reproduction which makes this system less effective than patents in creating incentives to innovate for breeders. Some empirical studies provided support for this claim such as Carew and Devadoss (2003), Alston and Venner (2002), and Perrin et al. (1983). Specifically, under UPOV-91, the researcher's exemption does not include the "essentially derived" varieties or the varieties which carry the essential characteristics of the initial protected varieties. Moreover, under UPOV-78, saving and replanting seeds was an automatic right for farmers; whereas under UPOV-91, this automatic right is eliminated, but can be granted by the member states (GRAIN, 1996).

In the U.S., patents provide plant breeders with the power to prevent farmers from self-production of seeds with certain traits. In some countries, taxes or royalties are used to compensate plant breeders for the loss incurred as a result of farmers saving seeds. The advocates of the farmer's exemption argue that farmers should be given the right to save seed and replant it because the newly developed varieties are partly a product of the efforts of generations of farmers and not only the outcome of the latest breeders' research. The critics of the exemption suggest that if farmers need to buy the varieties every period, the created incentive to innovate may lead to new varieties with high productivity or efficiency which ultimately gives the farmers higher profits.

Another important exemption to IPRs is the experimental use of registered varieties a.k.a. a researcher's exemption and this has been introduced to avoid limiting innovators access to the stock of knowledge while they are developing other new varieties (Moschini & Yerokhin, 2007). Due to the cumulative nature of innovation in the seed breeding industry, Scotchmer (1991) suggests that too strong IPRs can limit the access of knowledge in research aiming at new innovation generating the “common pool problem” or “the tragedy of the anticommons” named by Heller and Eisenberg (1998). Lindner (1999) indicates that developing a new transgenic plant can require fifteen to fifty identifiable tangible components as research inputs. These components can be the property of different breeding firms. The researcher’s exemption may solve some common pool problems by connecting the building blocks of research. However, it might create a free riding problem when firms try to benefit from the R&D of other firms. This problem can be even more serious when firms have different level of efficiency or stock of knowledge and the innovation products are closer substitutes. In such cases, the less efficient/endowed firm might tend to minimize its cost by free riding on the R&D investment of the more efficient/endowed firm and lower its R&D investment. Moreover, the more efficient firm may have less incentive to invest in costly R&D which helps its competitor. Therefore, the overall effect of a research exemption may be a lower level of R&D by firms and the industry.

Today, the private sector plays a crucial role in the plant breeding industry and in the food security of the global economy. For example, the area planted to field corn in the US, Canada and the EU, is dominated by hybrids developed in the private sector (Heisey et al., 2002). The interactions among researchers, the type and enforcement of IPRs, and competitive forces in the market are the driving factors of the economic outcomes in the plant breeding industry (Lindner, 2004). For these reasons, protecting intellectual property is vital in creating incentives for investment in R&D by the private sector. Too strong protection regimes, on the other hand, might cause inefficiency and undermine the flow of new innovations and discoveries by limiting the access of proprietary knowledge in research. Even though most UPOV members have implemented the 1991 Act, some countries have only recently upgraded their IPR regime to the newest version such as France (May 27, 2012) and Canada (July 19, 2015), and many other countries remained with the 1978 Act. A study which carefully examines the effects of each IPR regime on investment in plant breeding innovation and on the welfare of plant breeders and farmers can shed light on the choice of optimal policy and seems to be lacking in the literature. Wright (1983) puts it this way:

"Many studies concentrate on patents, but any assumption of their superiority over other incentives has been founded on intuition rather than on formal analysis."

2.1.1. Objectives

We develop a duopolistic model with product competition and study the effect of different IPRs on firm and industry level R&D as well as on farmers and breeders surplus. Our general model is characterized by many homogenous farmers who buy the breeders' varieties to maximize their profits and two breeders who invest in R&D which increases the varieties productivity and sell their varieties to the farmers assuming Cournot competition. The first variation of the general model is a symmetric duopoly version where breeders have an identical initial endowment of knowledge and cost structure. Here the focus is to answer to the question of how the industry level R&D is affected by the choice of IPRs, and how IPRs rank in terms of their impact on farmers and breeders surplus in the short run and long run. In this variation, a social planner decides on the choice of IPR regime to maximize the summation of farmer and breeder surplus. This variation includes four stages to capture the short run and the long run effects of a farmer's exemption on the incentive of breeders to invest in R&D. In stage zero of this game, the social planner chooses the IPR. In stage one, breeders produce new varieties, given their initial stock of knowledge, and sell them to the farmers in a Cournot style duopoly market. In the same stage, breeders invest in R&D which increases the yield of varieties and consequently the derived demand for the new varieties by the farmers. If the IPR adopted by the social planner is a researcher's exemption, breeders are allowed to utilize one another's product of R&D subject to a spillover parameter. If the IPR is a farmer's exemption, farmers who purchased a new variety from either breeder, save the variety for replanting in stage two. In stage two, breeders compete in the Cournot completion style and sell their new varieties to the farmers. If the IPR regime is a farmer's exemption, the portion of the farmers who did not purchase a variety from the breeders in stage one buy the new varieties in stage two. The game ends here if the IPR is either a patent or a researcher's exemption. However, if a farmer's exemption is enacted, farmers who bought the new varieties in stage two, replant using saved seeds in stage three.

The results show that a farmer's exemption can decrease farmers' welfare in the long run by deteriorating the breeders' incentive to invest in R&D. In addition, a researcher's exemption to patent may solve the common pool problem when varieties are not close substitutes. On the other hand, it might create a free riding problem and lower the breeders' incentive to undertake R&D when varieties are not differentiated enough.

In the second and third variations of the game, we focus on patent and researcher's exemption. Breeders are assumed to be asymmetric either in cost structure or in initial stock of knowledge. The game is in two stages in these variations. In the first stage, breeders invest in demand increasing R&D. In the second stage, breeders sell their new varieties to the farmers in assuming Cournot competition. Asymmetric firms decide whether a patent or a researcher's exemption is in place. The equilibrium IPR is the one under which both breeders have higher profits than under the alternative IPRs. In the first asymmetric variation, firms are assumed to have different efficiency in conducting R&D and one firm incurs lower R&D unit cost. In the second asymmetric variation, firms are similarly efficient but one firm benefits from a larger starting stock of knowledge, or starts with a higher demand for their varieties. We show that a researcher's exemption to patents can be both increasing or decreasing firm and industry level R&D for both asymmetric variations. One of our most important findings, perhaps, is that where the researcher's exemption *is* encouraging higher R&D, asymmetric firms may voluntarily cooperate in conducting research and a research exemption policy may not need to be enforced by the social planner. Results of the three variations of our model seem to advocate the implementation of the 1991 Act.

2.1.2. This Study in the Context of Previous Work

One of the first theoretical studies to examine the effect of plant breeding R&D on welfare, when IPRs are enacted, was conducted by Moschini and Lapan (1997). They modeled plant breeding R&D as a "drastic" or "non-drastic" innovation for an input sold to competitive farmers. Patents, in their model, enable the breeder to charge farmers a price above the breeder`s marginal cost. They conclude that when the innovation is non-drastic, farmers and consumers surplus are unaffected by R&D. On the other hand, when the innovation is drastic, the combination of larger agricultural output and lower prices results in an unambiguous increase in consumer surplus. The effect of a drastic innovation on the farmer surplus is dependent on the elasticity of demand. Moschini et al. (2000) extended this model to an open economy and applied the model to the case of Roundup Ready (RR) soybeans. They found that the breeder realized the largest portion of benefit or about 44 to 75 percent. Farmers and consumers share from the benefit were 10-16 and 15-40 percent, respectively. Flack-Zepeda et al. (2000) used a similar approach to study the benefits of Bt cotton and Herbicide-Tolerant (HT) soybeans. Unlike, Moschini et al. (2000), they found a higher share of the surplus going to the farmers and consumers. Malla and Brewin (2015) also showed considerable gains to producers when two drastic innovations (RR and Liberty Link) were developed under more competition. These papers mainly focus on the distributional effect of patents and R&D as opposed to the differences in regimes of intellectual property protection.

Study by Galushko (2008) is the closest model to our paper. She developed a model that compares the incentive for innovation and the distribution of benefits from research under protection of PBRs with a farmer's exemption or patent. In that study, the research industry is modeled as a monopolistic seed company investing in R&D. The company develops a new variety and sells it to heterogeneous farmers. The results show that under certain conditions PBRs are as effective as patents in creating incentives for the breeder to invest in R&D activity. However, the share of farmers in total benefits is generally smaller under patents than under PBRs. In a second model, Galushko (2008) examines the effect of IPRs on the incentive of private and public researchers to share their research input. She finds that private firms and public researchers tend to maintain their exclusive rights and that knowledge sharing or cross licensing in the breeding industry is undermined under patents. She suggests that patents have generally reduced germplasm and have limited the flow of information to downstream research in the wheat and canola breeding industries and thus they can be a policy concern.

Another theoretical paper was developed by Moschini and Yerokhin (2007) to examine the impact of a researcher's exemption to patent on the incentive of plant breeders to innovate. In their Bertrand model, there exist two firms that initially have access to the same germplasm or stock of knowledge. Each firm then engages in R&D activity and innovates a new seed with some probability. Only the best product is sold in the market. If a firm does not improve its product, it cannot proceed to the next innovation stage under a patent. It can only participate in the next innovation stage if the rival firm's innovation succeeds and there is researcher's exemption. Their results suggest that the researcher's exemption inevitably weakens the *ex ante* incentive for private firms to innovate, especially when there is high cost and risk related to this research. On the other hand, when the costs and risks of research are low, a researcher's exemption may be optimal in creating innovation incentives for private firms as it provides a larger pool of innovations for the subsequent inventions.

A more recent study by Hervouet and Langinier (2015) examines the effect of a farmer's exemption on the price of new varieties and on the breeders incentive for varietal development. They model the breeding industry as a monopolistic firm. They also assume that when farmers save seed, they pay a tax to the breeder to compensate her for the loss. They consider different scenarios where only the patent or farmer's exemption is enacted or where a mix of the two policies is implemented. They find that a relatively high tax can eliminate self-production by farmers when only a farmer's exemption is enacted. Moreover, when a farmer's exemption and patents coexist, the self-production is not fully prevented. However, the breeder's incentive to innovate is increased. They conclude that the monopolist has the highest incentive to innovate if the IP regime is either patent or farmer's exemption with a prohibitive tax level.

Our paper contributes to the current literature in some important ways. We extend the studies by Galushko (2008) and Hervouet and Langinier (2015) by distinguishing between the short run and the long run effects of a farmer's exemption on farmers surplus. This enables us to show if the farmers' optimal choice of IPR in the short run is different from the long run choice. Second, we incorporate the effect of a researcher's exemption to be able to compare it with a farmer's exemption. This helps assess whether farmer surplus can be greater under a researcher's exemption than that under a farmer's exemption. This also helps us, ultimately, derive the social planner's optimal IPR.[1]

Third, the models in the literature take breeding firms as either identical units or a monopolist. This seems to be a strong assumption in the imperfectly oligopolistic agricultural biotechnology industry. Firms can be asymmetric in different aspects. One source of difference can arise from the production cost of firms especially if they engage in private cost reducing R&D activities. Some firms, perhaps, incur lower costs in their varietal development process than others. Another important source of asymmetry in the plant breeding industry is the quality of germplasm that each firm possesses. At any point in time, firms can have access to significantly different stocks of knowledge; especially if the information is kept private and the leakage is small. Previous studies have not accounted for the effect of IPR protection regimes on the plant breeding industry when firms are asymmetric. When asymmetries exist in the industry at the time of implementing policy, each policy can have a considerably different impact on the performance of different firms. Specifically, different policies can give advantages to some firms and disadvantages to others.[2]

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[1] Our study, where a farmer's exemption is enacted, is related to the literature of durable goods, pioneered by Coase (1972). Under a farmer's exemption, the saved-seed presents a durable feature to the developed variety. Using the durable goods theory, Perrin and Fulginity (2004) compared the monopolist's pricing of a non-durable crop trait such as hybrid or a variety protected by patent and a durable crop trait such as the case of varieties protected by a farmer's exemption. They find that the price which the monopolist can charge under a farmer's exemption is about a quarter of that under a patent. They do not incorporate the effect of R&D in varietal development in their study. Our model is different in the way that breeder R&D investments increase the demand for their product. Thus, Coase's conjecture where the monopolistic firm necessarily charges a lower price or the competitive price in the absence of a credible commitment, does not hold here. However, inter-temporal competition or the fact that, due to farmer's exemption, breeders' demand is reduced every period applies to our model.

[2] A different form of asymmetry is discussed in the paper by Wright (1983) where he compares three different alternatives to create incentive to innovate namely patents, contracts, and prizes in a competitive economy. He suggests that if *ex ante* informational asymmetry about costs and benefits of research between the innovators and the administrator exists, the common pool problem can make contracts or centralized research incentives the optimal policy over decentralized alternatives of prizes and patent. Especially if researchers are relatively highly responsive

We show that relaxing previous assumptions can have important implications in the breeders' incentive to innovate and their surplus as well as their incentive to share their knowledge. The asymmetry incorporated into our model is the main driving force of the difference between our findings and previous papers. We derive the conditions necessary for asymmetric competing breeders to cooperatively conduct R&D research even when one breeder is more efficient or has access to a greater stock of knowledge. Together with the symmetric variation of our model, we conclude that breeders' and society's interest are aligned for a great range of our model parameters and that when a researcher's exemption successfully functions as an effective mechanism to encourage R&D investment, breeders may voluntarily cross license their varieties or share their knowledge. We also show that under certain conditions the researcher's exemption can lower the breeders' incentive to innovate and cause free riding. If so, the enforcement of a researcher's exemption by social planners can result in lower firm and industry level R&D.

This study attempts to examine the effect of different IPR protection regimes on breeders and farmers as well as the breeders' incentive to invest in R&D activity in presence of asymmetry among the firms. To do so, we design a Cournot competition game and explore the impact of different protection regimes on the level of R&D expenditure from breeders and on the welfare of the creators and buyers of biotechnology products. Table 1 briefly describes how we introduce the effect of IPRs protection regimes on the demand for new varieties and on varietal development.

Insert Table 2.1 here

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to the incentives. Any of the three alternatives, however, can be the optimal choice from the point of view of a welfare maximizing social planner under different situations depending on his model's parameters.

As shown in Table 1, under a farmer's exemption (case FE), if farmers buy the newly developed seed, they save it and use it in the subsequent period. Therefore, the fulfilled demand of stage one is deducted from demand of period two. Under a researcher's exemption (case RE), farmers are not allowed to save seed. However, researchers can use one another's ideas in order to come up with new varieties. Under a patent with no exemption (case NE), neither farmers nor researchers are given the exemptions.

The rest of the paper is organized as follows. We first develop our general model in section 2. Then we develop three variations to this benchmark model in section 3. In subsection 3.1, we assume breeders are symmetric and we compare three different IPR regimes, namely patents, patents with a farmer's exemption, and patents with a researcher's exemption. In subsection 3.2 and 3.3 we focus on patents and the researcher's exemption. In subsection 3.2, we assume cost dispersion exists between the breeding firms and in subsection 3.3 it is assumed that one firm starts the game with a higher stock of knowledge. Finally, in section 4, we present our discussion and concluding remarks.

2.2. Benchmark Model

Consider an industry with two firms which produce differentiated products and sell them to many perfectly competitive homogeneous farmers. We denote the firms with *h* and *l* and assume that firm *l* may have access to a smaller stock of knowledge or lower quality germplasm at the beginning of the game and firm *h* may have access to a larger stock of knowledge or it is the same as *l* but firm *h* is more efficient than firm *l*. The analysis for a general production function proves very difficult. Therefore, the representative farmer's production function is assumed to be in quasilinear quadratic form as follows.

$$y(x_o, x_h, x_l) = x_o + A_h x_h + A_l x_l - \frac{1}{2}(x_h^2 + x_l^2 + 2\theta x_h x_l) \qquad [2.1]$$

This production function gives rise to a linear demand system and allows a partial equilibrium analysis. In eq. 1, y is the farmer's yield, x_o represents a competitive numeraire factor and may be interpreted as a conventionally bred variety, and x_h and x_l stand for firm *h*'s and firm *l*'s products, respectively. Moreover, *A* is endogenously determined in the model and captures the effect of R&D undertaken by breeders on the farmer's productivity by increasing their yield in terms of the numeraire. *A* can also be interpreted as the amount of the numeraire that the representative farmer would be willing to replace by the first marginal unit of a particular variety. The production function for technology is explained in later paragraphs. Finally, θ denotes the degree of differentiation between inputs x_l and x_h and, to assure concavity of y, it is assumed to range from *zero* when they are independent for the farmer and each firm is a monopoly for their own seed and *one* when they are homogenous when $A_h = A_l$. We also exclude the possibility of production of identical varieties by the two breeders to assure an interior solution; that is $0 \leq \theta < 1$. The intuition behind a farmer's production function with both varieties is that because each variety has its strengths and weaknesses, by applying variety complementation, farmers plant multiple varieties (in larger fields) or a blend of various varieties (in smaller fields) to obtain consistent performance (Klein et al., 2012). The selection of varieties, however, is an important decision that has consequences for the growers' profits. Yield is considered to be the most important consideration in selecting varieties to most farmers. Other characteristics, such as disease and insect resistance, herbicide tolerance, winter hardiness, maturity, and straw strength are also important considerations when selecting varieties. Therefore, we assume a mix of the two varieties can be selected and purchased by farmers for variety complementation. It is also assumed that the share of each variety in the farmer's input basket depends on the variety's yield and price. This means that if a brand starts to yield higher, farmers can substitute away from the other brand towards the brand with higher yield.

Breeder interactions take place in two periods. In the first period, breeders produce new varieties using the stock of knowledge which is private and owned independently by them and sell them in the market assuming a Cournot competition. Over the same period, breeders conduct research to improve the productivity of their varieties which are sold in the subsequent period. In the second period, firms supply the improved varieties in the market and compete again in a Cournot fashion. Farmers choose between the seeds based on their productivity and price. The choice of farmers and breeders would be different under different IP protection regimes. Under a protection policy with a farmer's exemption, noted as FE hereafter, farmers who buy a variety from either breeding firm are assumed to save the seed for replanting it in the second period. Thus the breeders lose the portion of demand which was met in the first period by either of them. It is implied that the improvement of the varieties from the first period to the second is incremental and the increase in the seed productivity is not large enough relative to the price to justify purchasing the improved seed in the second period by the farmers who already bought a breeder's seed in the first period.

When the protection policy with a researcher's exemption (RE), is enacted, breeders must share their innovation product when trying to introduce a new variety for the second period. Therefore, spillover of knowledge is assumed to happen in this case (and only this case). Farmers must buy the varieties from the breeders in each period and seed saving by farmers is not allowed.

Finally, under patents with no exemptions (NE), farmers are not allowed to save seed for replanting and breeders do not share their knowledge and thus own it privately in the second period as well as in the first period.

With the above specification for the production function of the farmers, the derived inverse demand functions for the breeders' varieties in stage one and two are respectively:

$$w_{i,1} = A(G_i) - x_{i,1} - \theta x_{j,1} \qquad ; i, j \in \{h, l\}, i \neq j \tag{2.2}$$

$$w_{i,2} = A\big(G_i, e_j, e_i\big) - x_{i,2} - \theta x_{j,2} - \psi\big(x_{i,1} + x_{j,1}\big) \qquad ; i, j \in \{h, l\}, i \neq j \tag{2.3}$$

Where ψ is equal to *one* when the protection policy is FE and *zero* otherwise. In addition, G_i denotes the stock of knowledge owned by firm *i*. In the demand equations, $w_{i,1}$ and $w_{i,2}$ stand for the price which firm *i* charges farmers for their variety in stage 1 and 2, respectively. Finally, e_i is the R&D expenditure undertaken by firm *i*. In the stage two demand equation for firm *h*, e_l is a determining factor only when the regime of protection is RE. A firms' initial stock of knowledge and their investments in R&D activity is assumed to shift the farmers demand for varieties. A more or less similar approach was applied previously by Kabiraj and Roy (2004). They modeled the effect of R&D investments on consumers demand for final goods and assumed firms' R&D investments increase the quality of goods and consequently consumers utility. This is captured by an outward shift in the demand curve.

The production function for technology which increases the variety productivity represented in the farmer's production function and accordingly the farmer's demand for the variety is now described. The magnitude of the increase in the productivity of firm *i*'s variety (*i.e.* A_i) is a function of the initial stock of knowledge and firm *i*'s R&D investment which is assumed to be in linear form for simplicity. If the protection regime is RE, firm *i*'s *effective* R&D investment is also a function of firm *j*'s R&D investment subject to a spillover parameter, $0 \leq \beta \leq 1$, and stage two and one stock functions respectively are:

$$A_{i,2} = e_i + G_i + \beta e_j \quad ; i, j \in \{h, l\}, i \neq j \qquad [2.4]$$

$$A_{i,1} = G_i \quad ; i \in \{h, l\} \qquad [2.5]$$

The spillover parameter, β, is equal to *zero* for protection regimes other than RE. The R&D spillover is introduced in the paper by Kamein *et al.* (1992) in the same manner[3]. In their paper, however, the R&D investment is undertaken to decrease the firms' unit cost of production. They argue that the R&D process is modeled this way to describe the type of R&D process which involves many possible paths and trial and error. If the firms share information completely, they can avoid duplication of efforts whereas when information is kept and used privately each firm has to try the same trial and error process[4]. On the other hand, with high spillover, when varieties are not very differentiated, each firm has a lower incentive to invest in costly R&D which strengthens the competitor and firms try to free ride instead.

Let the cost function for firm i's varietal improvement be given by[5]:

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[3] Spence (1984) modeled knowledge accumulation resulted from cost reducing R&D investments, by a firm itself as well as by other firms through spillover, using a similar approach.

[4] The trial and error process to develop improved varieties seems to be a reasonable description of R&D conducted in the agricultural biotechnology industry. Malla and Gray (2005) describe a certain type of R&D process in plant breeding as firms using research trials to search for the highest yielding off-spring. This results in developing an improved variety with higher expected yield.

[5] The cost function assumed in equation [2.6] implies decreasing return to scale. This property is also implied in the cost function (Eq. 16) assumed in Kabiraj and Roy (2004) for R&D production (Eq. 15). With a more general specification such as $E_i = k_0 + k_{1i} e_i^2$; $i \in \{h, l\}$, if the scalar $k_0 > 0$ is small enough, it does not change our results qualitatively.

$$E_i = k_i e_i^2 \qquad ; i \in \{h, l\} \qquad [2.6]$$

where E_i is the cost associated with varietal development incurred by firm i and e is how much firms spend on R&D projects and k is a scalar. The cost other than R&D associated with producing the seed is assumed to be zero.

We can now have a complete description of the game. Our game is set as follows. In stage zero, the social planner sets an IPR which maximizes the welfare. This is the IPR which results in highest farmer surplus plus breeder surplus. In stage one, firms produce a new variety using their available stock of knowledge or germplasm. Assume this privately owned germplasm is the results of each firm's R&D activity at the time before implementing a new intellectual property protection policy. Firms can be, therefore, asymmetric in terms of the stock of knowledge or the quality of germplasm they have access to at stage one, or they can be asymmetric in terms of cost of undertaking R&D which could be due to one firm having a proprietary knowledge and is more efficient in conducting further R&D. Farmers buy the new varieties from the breeding firms and their demand for the new seeds depends on the productivity of firms' innovated varieties. Different levels of productivity for the varieties is represented in different intercepts of the demand curves which is endogenously determined in the model. In stage one, breeding firms also engage in a costly R&D activity and invest in production innovation. These decisions determine demand for each firm's product in stage two. We add stage three under the FE to account for the surplus that farmers receive by buying the variety in stage two and saving it for reproduction in the subsequent stage. The model is solved in the standard Cournot style and by means of backward induction.

The amount the breeding firms invest in R&D activity and how much they produce differ under different types of protection regimes. Under FE, the firms in stage two lose the portion of farmers' demand which was fulfilled in stage one by either firm *h* or *l*, since it is assumed that the farmers save some seed to plant it in the subsequent period and once they bought seed, they would not upgrade it to a newer variety.

Under RE, in stage two, firms not only use their own germplasm and R&D investment but also can benefit from the one another's innovation for use in developing new varieties. Knowledge spillover is the result of this sharing and it can be as small as zero, which means firms cannot make any use from the one another's innovation. On the other hand , with the maximum spillover, they make total use of all innovation and this means the demand for varieties shifts outward the most.

Under patent and with no privileges, firms have access only to their own innovation product and farmers are not permitted to save seed for replanting.

Based on the inverse demand equations described above for the breeders and their cost functions, the profit maximization problem for breeders in can be written as:

$$\max_{x\geq 0, e\geq 0} \pi_i = \sum_{t=1,2} w_{i,t} x_{i,t} - k_i e_i^2 \qquad ; i \in \{h, l\} \qquad [2.7]$$

Where *t* refers to stage one and two when breeders sell their varieties to the farmers. There is also a net payment by firm *j* to utilise the proprietary knowledge of firm *i* and this is non-zero for RE and zero for other regimes. A Subgame Perfect Nash Equilibrium is determined by simultaneously solving the profit maximization problems for firms under each policy. Given the above specification of the functions, optimal levels of R&D investment, price charged and quantity produced by each firm, and consumer and producer surplus under different types of protection regimes are derived. We show the detailed derivation process for this general model under NE in the appendix. The variations of the general model can be thought of as special cases of the general model and can be solved with a similar approach and thus are not shown.

2.3. Derivation of Equilibria

In subsection 3.1 through 3.3, we characterize the optimal levels of the amount spent on R&D and the quantity of varieties produced by breeders. We solve the model using backward induction. We solve the level of production at stage two for the firms given their level of R&D and quantity produced at stage one. Then we use these values to find the optimal levels of R&D investment and quantities produced at stage one. Finally, we plug the optimal values found for stage one back into the optimal equations of stage two to have derived the endogenous variables in terms of the model's parameters.

2.3.1. The Symmetric Model

We start with a symmetric model where breeders are assumed to have the same level of efficiency and initial endowment of knowledge. For simplicity and without losing generality, let us make the following assumptions:

Assumption 3.1.1. Breeders R&D cost function is given by $E_i = e_i^2$, $i \in \{h, l\}$; that is $k = 1$

Assumption 3.1.2. Breeders initial stock of knowledge is $G_i = 1$, $i \in \{h, l\}$

In the symmetric model, we assume four stages for the game. In stage zero, the social planner chooses an IPR to maximize the summation of breeder and farmer surplus. In stage one, breeders produce new varieties and sell them to farmers based on their initial stock of knowledge and compete in the Cournot style. Breeders also conduct R&D in stage one to stimulate their variety demand in stage two. In stage two, breeders sell their new varieties to farmers, again, assuming Cournot competition. The game ends at stage two if the IPR is either NE or RE. Under FE, farmers who buy a new variety in stage one can save it to replant in stage two and farmers who purchased the new varieties in stage two, can save it for replanting in stage three with no penalty.[6]

With symmetric breeders, we can simplify the demand for new varieties to

$$w_{i,1} = 1 - x_{i,1} - \theta x_{j,1} \qquad ; i,j \in \{h,l\}, i \neq j \tag{2.8}$$

$$w_{i,2} = 1 + \beta e_j + e_i - x_{i,2} - \theta x_{j,2} - \psi\left(x_{i,1} + x_{j,1}\right) \qquad ; i,j \in \{h,l\}, i \neq j \tag{2.9}$$

In addition, profits can be written as

$$\max_{x \geq 0, e \geq 0} \pi_i = \sum_{t=1,2} w_{i,t} x_{i,t} - e_i^2 \qquad ; i,j \in \{h,l\}, i \neq j \tag{2.10}$$

With the above demand and profit functions, optimal quantities and R&D investments by firms are given by

$$x_{i,1}^{FE} = \frac{\theta^6 + 4\theta^5 - 6\theta^4 - 28\theta^3 + 8\theta^2 + 48\theta + 12}{\theta^7 + 6\theta^6 + 4\theta^5 - 40\theta^4 - 64\theta^3 + 64\theta^2 + 132\theta + 24} \qquad ; i,j \in \{h,l\}, i \neq j \tag{2.11}$$

[6] If farmers who buy a new seed in stage one can replant it in both stage two and three for free under FE, the main conclusions derived in this model remain the same.

$$x_{i,1}^{z} = \frac{1}{\theta + 2} \qquad ; i, j \in \{h, l\}, i \neq j, z \in \{NE, RE\} \qquad [2.12]$$

$$x_{i,2}^{FE} = \frac{\theta(\theta - 2)(\theta + 2)(\theta^3 + 2\theta^2 - 4\theta - 6)}{\theta^7 + 6\theta^6 + 4\theta^5 - 40\theta^4 - 64\theta^3 + 64\theta^2 + 132\theta + 24} \qquad ; i, j \in \{h, l\}, i \neq j \qquad [2.13]$$

$$x_{i,2}^{NE} = \frac{(\theta - 2)(\theta + 2)}{\theta^3 + 2\theta^2 - 4\theta - 6} \qquad ; i, j \in \{h, l\}, i \neq j \qquad [2.14]$$

$$x_{i,2}^{RE} = \frac{-(\theta - 2)(\theta + 2)}{\beta\theta(\beta + 1) - 2\beta - \theta^3 - 2\theta^2 + 4\theta + 6} \qquad ; i, j \in \{h, l\}, i \neq j \qquad [2.15]$$

$$e_{i}^{FE} = \frac{-2\theta(\theta^3 + 2\theta^2 - 4\theta - 6)}{\theta^7 + 6\theta^6 + 4\theta^5 - 40\theta^4 - 64\theta^3 + 64\theta^2 + 132\theta + 24} \qquad ; i, j \in \{h, l\}, i \neq j \qquad [2.16]$$

$$e_{i}^{NE} = \frac{-2}{\theta^3 + 2\theta^2 - 4\theta - 6} \qquad ; i, j \in \{h, l\}, i \neq j \qquad [2.17]$$

$$e_{i}^{RE} = \frac{2 - \beta\theta}{\beta\theta(\beta + 1) - 2\beta - \theta^3 - 2\theta^2 + 4\theta + 6} \qquad ; i, j \in \{h, l\}, i \neq j \qquad [2.18]$$

Farmer surplus in the short run under various IPRs is given by:

$$FS_{SR}^{FE} = \frac{(\theta^6 + 4\theta^5 - 6\theta^4 - 28\theta^3 + 8\theta^2 + 48\theta + 12)(2\theta^7 + 11\theta^6 + 2\theta^5 - 74\theta^4 - 84\theta^3 + 120\theta^2 + 192\theta + 36)}{(\theta^7 + 6\theta^6 + 4\theta^5 - 40\theta^4 - 64\theta^3 + 64\theta^2 + 132\theta + 24)^2} \qquad [2.19]$$

$$FS_{SR}^{z} = \frac{\theta + 1}{(\theta^2 + 2)^2}, z \in \{NE, RE\} \quad [2.20]$$

Farmers surplus in the long run under various IPRs is given by:

$$FS_{LR}^{FE} = \frac{\theta(\theta - 2)(\theta + 2)(\theta^3 + 2\theta^2 - 4\theta - 6)(2\theta^7 + 11\theta^6 + 6\theta^5 - 76\theta^4 - 122\theta^3 + 128\theta^2 + 264\theta + 48)}{(\theta^7 + 6\theta^6 + 4\theta^5 - 40\theta^4 - 64\theta^3 + 64\theta^2 + 132\theta + 24)^2} \quad [2.21]$$

$$FS_{LR}^{NE} = \frac{(\theta + 1)(\theta - 2)^2(\theta + 2)^2}{(\theta^3 + 2\theta^2 - 4\theta - 6)^2} \quad [2.22]$$

$$FS_{LR}^{RE} = \frac{(\theta + 1)(\theta - 2)^2(\theta + 2)^2}{(\beta(\beta\theta + \theta - 2) - \theta^3 - 2\theta^2 + 4\theta + 6)^2} \quad [2.23]$$

Breeders surplus under various IPRs is given by:

$$BS^{FE} = \frac{4(\theta^{12} + 7\theta^{11} - 96\theta^9 - 128\theta^8 + 476\theta^7 + 894\theta^6 - 948\theta^5 - 2296\theta^4 + 336\theta^3 + 2040\theta^2 + 720\theta + 72)}{(\theta^7 + 6\theta^6 + 4\theta^5 - 40\theta^4 - 64\theta^3 + 64\theta^2 + 132\theta + 24)^2} \quad [2.24]$$

$$BS^{NE} = \frac{4(\theta^6 + 4\theta^5 - 4\theta^4 - 30\theta^3 - 14\theta^2 + 48\theta + 42)}{(\theta + 2)^2(\theta^3 + 2\theta^2 - 4\theta - 6)^2} \quad [2.25]$$

$$BS^{RE} = \frac{2(\beta^4\theta^2 + \beta^3(2\theta^2 - 4\theta) + \beta^2(-3\theta^4 - 8\theta^3 + 5\theta^2 + 8\theta + 4) - 2\beta(\theta^4 - 2\theta^3 - 16\theta^2 - 6\theta + 12) + 2(\theta^6 + 4\theta^5 - 4\theta^4 - 30\theta^3 - 14\theta^2 + 48\theta + 42))}{(\theta + 2)^2(\beta(\beta\theta + \theta - 2) - \theta^3 - 2\theta^2 + 4\theta + 6)^2} \quad [2.26]$$

The above equations give rise to the following propositions. All proofs are delegated to the appendix.

Proposition 2.1 – When firms are symmetric, R&D investment under these IPRs can be characterized as:

Breeders tend to invest less in R&D under RE than NE when variety differentiation is low or knowledge spillover is high.

Firms undertake less R&D under FE than NE or RE for all levels of variety differentiation and knowledge spillover.

Part *i* of proposition 2.1 points at two potential disadvantages of RE: firstly, when varieties produced are not very different, breeders are less willing to share knowledge since it generates a stronger competitor; secondly, when knowledge spillover is high, along with the first disadvantage, firms try to reduce costly R&D and free ride on other firms' R&D investment. Part ii refers to the intuitive problem with FE that is drained demand as a result of farmer's exemption decreases breeders incentive to undertake R&D.

The next step is to examine how IPRs rank in terms of farmer surplus. Farmer surplus is calculated by the standard approach with one exception: under FE, buyers of the new varieties in each period benefit from the varieties for two periods, the surplus net of price for the purchasing period plus the surplus without payment in the subsequent period. Their payment in the subsequent period is zero. Moreover, we examine the farmer surplus obtained from varieties purchased in stage one separately from that gained by buying the varieties in stage two. The reason for this is that R&D investment undertaken in stage one only affects the varieties produced in stage two. Therefore, FE in stage one does not negatively affect the farmer surplus by lowering the R&D investment in the same stage. This can be viewed as the short run. The FE regime, however, lowers the R&D investment undertaken in stage one used in the production of new varieties in stage two. This negatively affects farmer surplus gained by utilizing the new varieties in stage two. This can be thought of as the long run effect.

From binary comparisons of farmer surplus (FS) under different IPRs, in the short run (SR) and in the long run (LR), we can prove proposition 2.2.

Proposition 2.2 – When firms are symmetric, farmer surplus under IPRs has the following ranking:

in the short run, $FS_{SR}^{NE} = FS_{SR}^{RE} < FS_{SR}^{FE}$

in the long run, $FS_{LR}^{FE} < FS_{LR}^{NE} \leq FS_{LR}^{RE}$.

Proposition 2.2 shows that, even though farmers might enjoy a higher surplus in the short run under FE, in the long run and through decreases in R&D investment by breeders, this policy results in the lowest farmer surplus. Figure 2.1 depicts the farmers all-time optimal IPR. It shows that if knowledge spillover is relatively high and varieties are differentiated enough, the long run positive effect of increases in R&D under RE can overcome the short run loss in the consumer surplus, making RE the farmer’s optimal policy in both the short and long run.

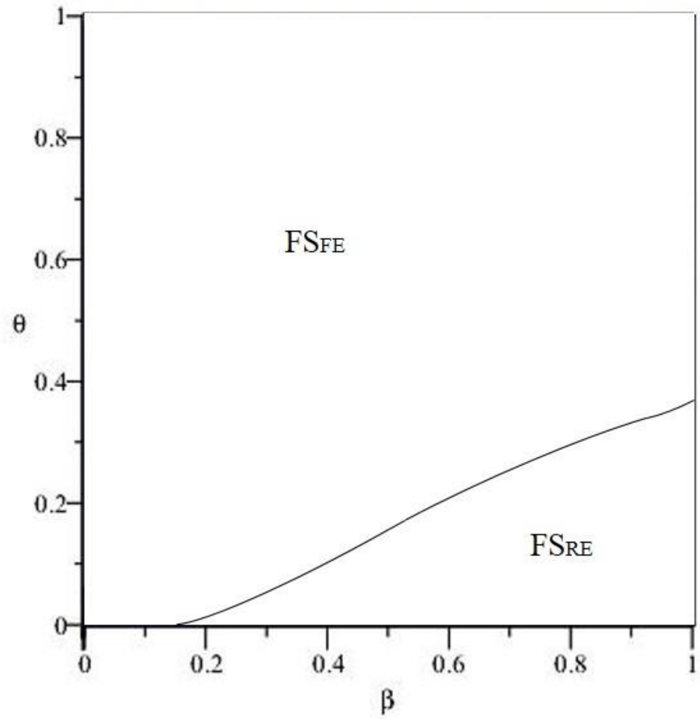

Figure 2.1 Farmers all-time optimal IPR

We now consider breeders surplus (BS). Binary comparisons of the breeder's profits under different IPRs result in the following proposition:

Proposition 2.3 – when firms are symmetric, IPRs in terms of the breeder's profit are ranked as

$$BS^{FE} < BS^{NE} \leq BS^{RE}$$

Note in proposition 3 that symmetric breeders are better off under RE than NE for all range of model parameters. This shows than even when R&D investment is lower under RE than under NE, (when varieties are similar and knowledge spillover is high) the increase in breeders profit due to knowledge sharing overcomes the loss of lower R&D investment by each firm.

The social planner chooses the IPR which maximizes the total surplus; the sum of farmers and breeders surplus. Figure 2.2 shows the social planner's optimal IPR. It shows that except for a small range of the model parameters, when differentiation of the varieties and knowledge spillover are very low, RE is the optimal IPR. It is also easy to show that while total surplus under NE is less than that under RE for all levels of variety differentiation and knowledge spillover, it is higher under NE than FE when the variety differentiation parameter is below 0.7482527209. In other words, for a greater range of parameters NE is preferred to FE by the social planner. This is shown by the dotted line in the figure.

So far it is assumed that firms are symmetric. This helped answer the important question of how IPRs affect breeders and farmers surplus. We now relax this assumption to examine how breeders are affected by research exemptions when they are asymmetric. Two important forces are at play. On the one hand, research exemptions may eliminate the tragedy of the anticommons and increase R&D investment and welfare of breeders and farmers. On the other hand, it may reduce a firm's incentive to invest in R&D due to the free-riding effect. We examine this issue in the next sub-sections.

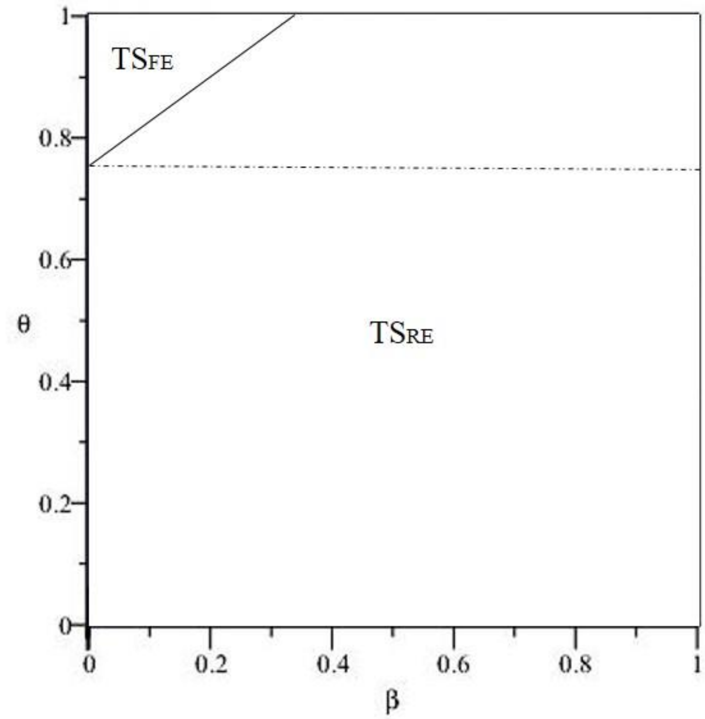

Figure 2.2   Social Planner Optimal IPR

2.3.2. Firms Are Asymmetric in Efficiency

It may seem intuitive that in an oligopoly market structure with product competition, firms which are more efficient or enjoy a head start prefer no research exemption to knowledge sharing. However, with product differentiation which naturally emerges in the plant breeding industry, the choice of IPR might not be straightforward. That is, if varieties' characteristics are different enough, breeders have higher market power over their product and in the presence of a knowledge spillover, larger and more efficient firms may even prefer RE over NE. In this subsection and next, we try to derive the conditions that can give rise to this phenomenon. In addition, proposition 1 showed that firms tend to free ride on other firms R&D investment when knowledge spillover is high and as a result they invest less under RE. We assume knowledge spillover is maximum i.e. $\beta = 1$ and investigate whether there is a possibility where asymmetric firms invest more under RE than NE.

The focus in subsection 2.3.2 and 2.3.3 is on the effect of the researcher's exemption on breeders' R&D investment. Thus, the two policies of NE and RE are examined. This can be done by a shorter version of our symmetric model. The game in this case has two stages, a first stage when breeders invest in R&D to improve the quality of their varieties, and a second stage when breeders sell their product to farmers under Cournot competition. In subsection 2.3.2, it is assumed that firms benefit from an equal stock of knowledge (or germplasm) but are asymmetric in terms of their efficiency in conducting R&D investments. In subsection 2.3.3, on the other hand, firms are assumed to have the same R&D cost structure but one firm enjoys a head start or enters the game with a greater stock of knowledge. Games are solved by backward induction. Given R&D levels, quantities are determined. Then quantities are used to derive the optimal levels of R&D by each breeder. Finally, the derived R&D functions are plugged into the equations for quantities to find their optimal functions.

Cost dispersion is assumed to be the source of asymmetry between the firms. Let firm *h*'s unit cost of conducting R&D be the same as before, i.e. 1, however, let firm *l* incur a *k* unit cost when investing in each unit of R&D where *k* is a scalar and is greater than 1. This means that firm *h* is more efficient in undertaking R&D than firm *l*. Under this assumption, our general model of breeders demand and profit changes to:

$$w_i = 1 + \beta e_j + e_i - x_i - \theta x_j \qquad ; i, j \in \{h, l\}, i \neq j \tag{2.27}$$

$$\max_{x \geq 0, e \geq 0} \pi_h = w_h x_h - e_h^2 \tag{2.28}$$

$$\max_{x\geq 0, e\geq 0} \pi_l = w_l x_l - k e_l^2 \qquad [2.29]$$

β is zero for the NE case and it is equal to one for RE. With the above demand and profit functions, optimal quantities and R&D investments by firms are given by:

$$x_h^{NE} = \frac{(\theta-2)(\theta+2)(k\theta^3 - 2k\theta^2 - 4k\theta + 8k - 2)}{k\theta^6 - 12k\theta^4 + 44k\theta^2 - 4\theta^2 - 48k + 12} \qquad [2.30]$$

$$x_l^{NE} = \frac{k(\theta-2)(\theta+2)(\theta^3 - 2\theta^2 - 4\theta + 6)}{k\theta^6 - 12k\theta^4 + 44k\theta^2 - 4\theta^2 - 48k + 12} \qquad [2.31]$$

$$x_i^{RE} = \frac{k(\theta+2)}{k\theta^2 + 4k\theta + 3k - 1} \qquad ; i, j \in \{h, l\} \qquad [2.32]$$

$$e_h^{NE} = \frac{-2(k\theta^3 - 2k\theta^2 - 4k\theta + 8k - 2)}{k\theta^6 - 12k\theta^4 + 44k\theta^2 - 4\theta^2 - 48k + 12} \qquad [2.33]$$

$$e_l^{NE} = \frac{-2(\theta^3 - 2\theta^2 - 4\theta + 6)}{k\theta^6 - 12k\theta^4 + 44k\theta^2 - 4\theta^2 - 48k + 12} \qquad [2.34]$$

$$e_h^{RE} = \frac{k}{k\theta^2 + 4k\theta + 3k - 1} \qquad [2.35]$$

$$e_l^{RE} = \frac{1}{k\theta^2 + 4k\theta + 3k - 1} \qquad [2.36]$$

Breeder profits are given by:

$$BS_h^{NE} = \frac{(\theta^2 - 2)(\theta^2 - 6)(k\theta^3 - 2k\theta^2 - 4k\theta + 8k - 2)^2}{(k\theta^6 - 12k\theta^4 + 44k\theta^2 - 4\theta^2 - 48k + 12)^2} \quad [2.37]$$

$$BS_l^{NE} = \frac{k(\theta^3 - 2\theta^2 - 4\theta + 6)^2(k\theta^4 - 8k\theta^2 + 16k - 4)}{(k\theta^6 - 12k\theta^4 + 44k\theta^2 - 4\theta^2 - 48k + 12)^2} \quad [2.38]$$

$$BS_h^{RE} = \frac{k^2(\theta + 1)(\theta + 3)}{(k\theta^2 + 4k\theta + 3k - 1)^2} \quad [2.39]$$

$$BS_l^{RE} = \frac{k(k\theta^2 + 4k\theta + 4k - 1)}{(k\theta^2 + 4k\theta + 3k - 1)^2} \quad [2.40]$$

Proposition 2.4 –

The more efficient firm invests more in R&D under RE than NE if variety differentiation is high and cost dispersion is low.

The less efficient firm invests less in R&D under RE than NE if variety differentiation is low or if variety differentiation is moderate and cost dispersion is low.

Figure 2.3 illustrates proposition 2.4 and it shows some important features of the difference between NE and RE in terms of firm level as well as industry level R&D. The figure is divided into four areas. Part *I* and *II* show the range of parameters for which industry level R&D is higher under RE than NE. Part *III* and *IV* are the opposite. Area *I* represent the region where firm *h* invests more under RE than NE. This means that not only can RE increase the less efficient firm's R&D investment but also encourage the more efficient firm to undertake more R&D investment when varieties are highly differentiated. Firm *h* loses its incentive as the cost dispersion (i.e. *k*) increases. Part *II* is even more interesting. It shows the level of parameters where firm *h* invests less under RE than NE, however, this decrease is overcome by the increase in R&D by firm *l* resulting in a higher industry level R&D under RE than NE. Part *I* and *II* can be considered as the range of parameters for which RE can eliminate the tragedy of the anticommons effect of IPRs. Part *III* and *IV* refer to the range of parameters for which RE would decrease the incentive to invest in industry level R&D. More importantly, part *IV* is where R&D investment by firm *l* is higher under NE than under RE which reflects the free riding effect or the tragedy of the commons.

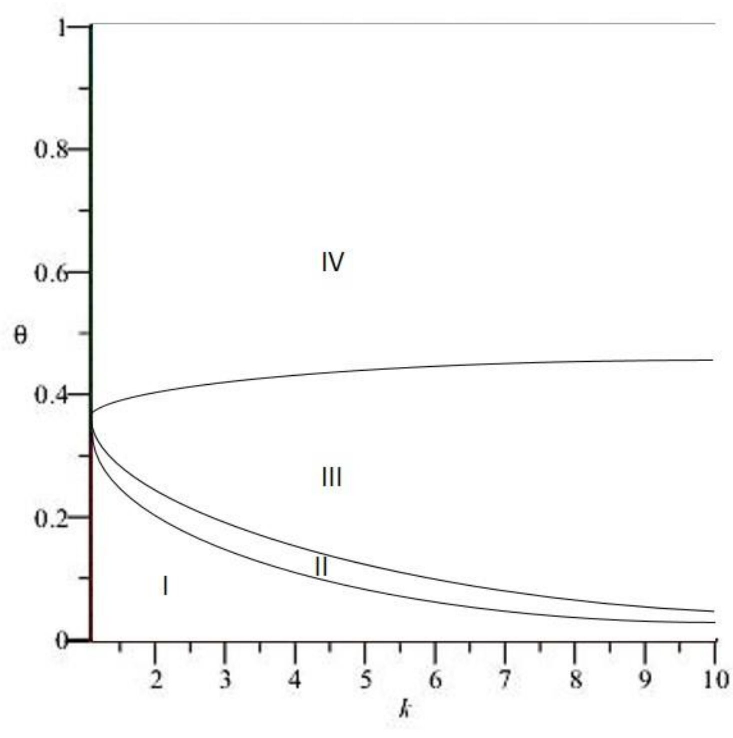

Figure 2.3 R&D comparison under NE and RE.

We observed that for a range of model parameters, RE can increase firm and industry level R&D. To determine if, in the absence of a social planner, firms agree to follow a researcher's exemption policy, we compare their profit under each case. It is assumed that a firm will voluntarily accept a policy if it's profit is greater under that policy than under the alternative. It is easy to show that firm *l* prefers RE for the total range of model parameters. A possible agreement, therefore, depends on the profit of firm *h* under the two policies. If the range of parameters where RE overcomes the tragedy of the anticommons coincides with that of the firms' interest, RE need not necessarily be enforced by a social planner since firms cooperate in conducting R&D to increase their profits. Figure 2.4 emphasizes this point. It is basically figure 3 but with the area where firm *h* prefers RE over NE. It shows that firm *h* prefers RE to NE if variety differentiation is high or cost dispersion is low.

Figure 2.4. shows that where RE can help increase R&D, asymmetric firms voluntarily adopt it. This suggests that if anything, the policy concerned with RE may be towards approving it where it is not deteriorating R&D activity. For example, in figure 2.4, firms agree on collaborating in R&D in area *IV*. However, the form of this collaboration is two firms with highly similar varieties and with less overall R&D investment where the more efficient firm does the main R&D activity and the less efficient firm free rides. Even this case can be beneficial to the society if it prevents unfruitful and repeated R&D investments. Here R&D is mainly undertaken by the more efficient firm and yet farmers benefit from two different varieties. This result may be controversial in the sense that it shows a researcher's exemption need not necessarily be enforced where firms' interest and that of the society are aligned. In subsection 2.3.3, we check whether these results hold when firms are similarly efficient in conducting R&D, however one firm has a larger starting stock of knowledge.

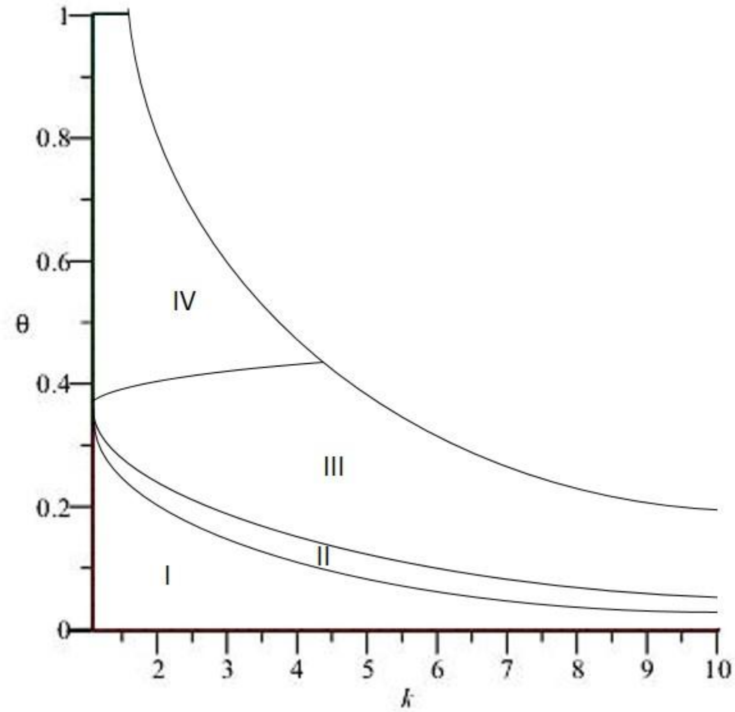

Figure 2.4   R&D levels and firms selected IPR.

2.3.3 Firms Are Asymmetric in their Stock of Knowledge

In this subsection, we assume one of the firms, say firm *h*, starts the game with a greater stock of knowledge (e.g. higher quality germplasm), and investigate how RE compares to NE in terms of firm and industry level R&D. The firms' cost structures in this variation of the model are assumed to be identical and the only source of asymmetry is the stock of knowledge. We assume that the firms' stock of knowledge have the following relationship.

$$G_h = \tau . G_l \qquad [2.41]$$

where τ is a scalar which represents the asymmetry in the firms' initial stock of knowledge. We set G_l equal to one in eq. [2.41] and thus τ is assumed to be greater than one and it is the stock of knowledge of firm h at the beginning of the game. We also assume that if the varieties are not completely independent (i.e. $\theta > 0$), τ is less than the level of asymmetry for which quantity produced by the less endowed firm drops to zero, denoted by $\breve{\tau}$, as indicated in the following assumption.

Assumption 2.3.3. Breeders asymmetry in stocks for all $0 < \theta < 1$ is below the level which creates a monopoly market structure given by:

$$\breve{\tau} = \frac{2(\theta^2 - 3)}{\theta(\theta^2 - 4)}$$

With the above assumptions, our general model of breeders demand and profit turns to:

$$w_l = 1 + \beta e_h + e_l - x_l - \theta x_h \qquad [2.42]$$

$$w_h = \tau + \beta e_l + e_h - x_h - \theta x_l \qquad [2.43]$$

$$\max_{x\geq 0, e\geq 0} \pi_i = w_i x_i - e_i^2 \qquad ; i,j \in \{h,l\} \qquad [2.44]$$

Similar to the previous case, β is zero for the NE case and it is equal to one for RE. With the above demand and profit functions, optimal quantities and R&D investments by firms are given by

$$x_h^{NE} = -\frac{(\theta - 2)(\theta + 2)(2\tau\theta^2 - \theta^3 - 6\tau + 4\theta)}{(\theta^3 - 2\theta^2 - 4\theta + 6)(\theta^3 + 2\theta^2 - 4\theta - 6)} \qquad [2.45]$$

$$x_l^{NE} = \frac{(\theta - 2)(\theta + 2)(\tau\theta^3 - 4\tau\theta - 2\theta^2 + 6)}{(\theta^3 - 2\theta^2 - 4\theta + 6)(\theta^3 + 2\theta^2 - 4\theta - 6)} \qquad [2.46]$$

$$x_h^{RE} = -\frac{2\tau\theta - \theta^2 + 3\tau - 2\theta + 1}{(\theta - 2)(\theta^2 + 4\theta + 2)} \quad [2.47]$$

$$x_l^{RE} = \frac{\tau\theta^2 + 2\tau\theta - \tau - 2\theta - 3}{(\theta - 2)(\theta^2 + 4\theta + 2)} \quad [2.48]$$

$$e_h^{NE} = \frac{2(2\tau\theta^2 - \theta^3 - 6\tau + 4\theta)}{(\theta^3 - 2\theta^2 - 4\theta + 6)(\theta^3 + 2\theta^2 - 4\theta - 6)} \quad [2.49]$$

$$e_l^{NE} = -\frac{2(\tau\theta^3 - 4\tau\theta - 2\theta^2 + 6)}{(\theta^3 - 2\theta^2 - 4\theta + 6)(\theta^3 + 2\theta^2 - 4\theta - 6)} \quad [2.50]$$

$$e_h^{RE} = -\frac{2\tau\theta - \theta^2 + 3\tau - 2\theta + 1}{(\theta - 2)(\theta + 2)(\theta^2 + 4\theta + 2)} \quad [2.51]$$

$$e_l^{RE} = \frac{\tau\theta^2 + 2\tau\theta - \tau - 2\theta - 3}{(\theta - 2)(\theta + 2)(\theta^2 + 4\theta + 2)} \quad [2.52]$$

Breeder profits are given by:

$$BS_h^{NE} = \frac{(\theta^2 - 2)(\theta^2 - 6)(2\tau\theta^2 - \theta^3 - 6\tau + 4\theta)^2}{(\theta^3 - 2\theta^2 - 4\theta + 6)^2(\theta^3 + 2\theta^2 - 4\theta - 6)^2} \quad [2.53]$$

$$BS_l^{NE} = \frac{(\theta^2 - 2)(\theta^2 - 6)(\tau\theta^3 - 4\tau\theta - 2\theta^2 + 6)^2}{(\theta^3 - 2\theta^2 - 4\theta + 6)^2(\theta^3 + 2\theta^2 - 4\theta - 6)^2} \quad [2.54]$$

$$BS_h^{RE} = \frac{(\theta + 1)(\theta + 3)(2\tau\theta - \theta^2 + 3\tau - 2\theta + 1)^2}{(\theta - 2)^2(\theta + 2)^2(\theta^2 + 4\theta + 2)^2} \quad [2.55]$$

$$BS_l^{RE} = \frac{(\theta + 1)(\theta + 3)(\tau\theta^2 + 2\tau\theta - \tau - 2\theta - 3)^2}{(\theta - 2)^2(\theta + 2)^2(\theta^2 + 4\theta + 2)^2} \quad [2.56]$$

Proposition 2.5 –

The firm with a larger stock of knowledge invests more in R&D under RE than NE if variety differentiation is high and head start dispersion is low.

The firm with a smaller stock of knowledge invests less in R&D under RE than NE if variety differentiation and head start dispersion are low.

Proposition 2.5 draws a similar conclusion to the previous case. Part *i* derives the range of the model parameters for which firm *h* might invest more in R&D under RE than NE or the possibility that RE increases the incentive of the firm with the larger stock of knowledge to invest in R&D. Part ii of the proposition, however, refers to the range of parameters for which firm *l* invests less under RE than NE and free rides. Different cases of proposition 5 are presented in figure 2.5. Apart from the $\check{\tau}$ constraint, the area of the figure is restricted to the part for which firm *h*'s profit is higher under RE than NE that is where firm *h* volunteers to share knowledge with firm *l*.

Similar to the previous subsection, figure 2.5 is divided to four areas. *I* and *II* are the areas for which industry level R&D is higher under RE than NE. Parts *III* and *IV* show the opposite. Area *I* shows the range of the model parameters for which RE increases firm *h*'s incentive to invest in R&D. Area *IV* shows the range for which firm *l* invests less in R&D under RE than NE. In other words, firm *l* free rides on firm *h*'s R&D investment in the presence of an exemption for research. The graph, however, shows that when RE increases the industry level and to some extent the firm level of R&D, firms voluntarily cooperate in research even when firm *l* free rides on firm *h*'s R&D investment. Outside this area, the researcher's exemption may result in a reduction in the firm and industry level R&D. This case, like the case where firms are different in efficiency, suggests that the implementation of a research exemption by policy makers requires caution.

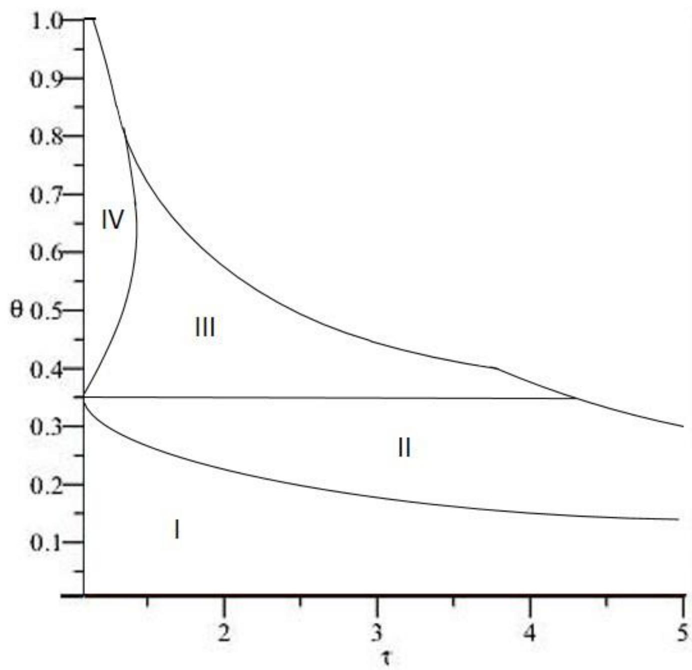

Figure 2.5 R&D comparison under NE and RE and firms selected IPR.

2.4. Conclusion

The durability and non-excludability features of some research products, like seeds in agriculture, make the problem of capturing the innovation benefits and thus creating incentives to innovate different from other sectors. Different policies have been introduced to solve this problem. Previous researchers have examined the effect of these policies on plant breeders' incentives to innovate and based on different objectives have drawn different policy implications. In the previous studies, the industry was modeled as either a monopolist or a few identical firms. This overlooks the impact of these policies on different types of firms when there are some levels of asymmetry among them. With the presence of asymmetry, some policies might be favorable to a group of firms and harmful to other firms. If asymmetry is introduced to the analysis, one can examine how IPRs affect breeders' incentive to innovate and surplus when they are not identical units. This is particularly important to understand if the IPR which is placed to protect innovators represents the interest of the most efficient firms.

Another controversial aspect of IPRs is the farmer's exemption provision. If farmer surplus is modeled in the short run and long run separately, one might explain how farmers may favor a farmer's exemption in the short run. However, using a reasonable range of starting conditions, we find that farmers should prefer a different IPR in the long run due to the undermining effect of a farmer's exemption on the incentive of breeders for varietal improvement. We assumed a specific type of production function for farmers to obtain linear factor demands which might appear a restrictive assumption to some readers. A general function proved too difficult to analyze. Even with this setting, we believe we obtain novel results in understanding the effect of IPRs on the breeder's incentive to innovate, breeder and farmer surplus, and especially on the effectiveness of a researcher's exemption in creating higher incentives to invest in R&D by asymmetric firms.

Considering the ongoing debate on the effect of IPRs on farmer surplus and the fact that many countries are still skeptical about joining the UPOV convention or in upgrading to the UPOV-91 Act, this study sheds more light on the issue and expands the analysis to some aspects of IPRs which were not deeply examined previously. Our results agree with the critics of farmer's exemption in that farmer saved-seeds undermine the incentive to innovate by breeders to the extent that farmers can be worse off in the long run. We also found that the free riding effect seems to be a greater problem concerning researcher's exemption than the tragedy of the anticommons. Our analysis shows that when a researcher's exemption *is* effective in encouraging higher R&D investment, it is voluntarily practiced by asymmetric breeders. Under UPOV-91, breeders can choose if they want to share their knowledge or cross license their innovation products and it is up to the member states whether a farmer's exemption is granted to farmers or not. Overall, our results suggest new gains from the UPOV-91 convention that were ignored in previous studies.

Table 2.1 The Three Policies

Policy	Demand in Stage 2	R&D Investment
Farmer's Exemption (case FE)	Firms lose the part of the market demand which was fulfilled in stage 1 by either firms	Firms conduct research independently; R&D spillover is zero
Patent with No Exemption (case NE)	No loss in demand; buyers who purchased seed in stage 1 must buy seed in stage 2	Firms conduct research independently; R&D spillover is zero
Researcher's Exemption (case RE)	No loss in demand; buyers who purchased seed in stage 1 must buy seed in stage 2	Firms share their stock of knowledge to develop new varieties; R&D spillover exists and can go up to a maximum level.

Appendix 2.1. Farmers and Breeders Optimization Problem and Proofs to the Propositions

The benchmark model derivation -

The problem facing the representative farmer is as follows.

$$\min_{x\geq 0} \; x_0 + \sum_{i=h,l} w_i x_i \qquad [2.56]$$

$$s.t.\; x_o + A_h x_h + A_l x_l - \tfrac{1}{2}(x_h^2 + x_l^2 + 2\theta x_h x_l) = y^*$$

The Lagrangian for the problem is

$$\mathcal{Z} = \; x_0 + \sum_{i=h,l} w_i x_i + \mu[y^* - \left(x_o + A_h x_h + A_l x_l - \tfrac{1}{2}(x_h^2 + x_l^2 + 2\theta x_h x_l)\right)] \qquad [2.57]$$

The first order conditions for the farmer's problem is given by:

$$FOCs: \begin{cases} \mathcal{Z}_{x_h} = w_h - \mu(A_h - x_h - \theta x_l) = 0 \\ \mathcal{Z}_{x_l} = w_l - \mu(A_l - x_l - \theta x_h) = 0 \\ Z_{x_0} = 1 - \mu = 0 \\ \mathcal{Z}_\mu = [y^* - \left(x_o + A_h x_h + A_l x_l - \tfrac{1}{2}(x_h^2 + x_l^2 + 2\theta x_h x_l)\right) = 0 \end{cases} \qquad [2.58]$$

Solving the above FOCs results in the system of linear demands for varieties presented in equations [2.2] and [2.3].

Checking the second order condition for a minimum, we find

$$|\bar{H}| = \begin{vmatrix} 0 & A_h - x_h - \theta x_l & A_l - x_l - \theta x_h & 1 \\ A_h - x_h - \theta x_l & 1 & \theta & 0 \\ A_l - x_l - \theta x_h & \theta & 1 & 0 \\ 1 & 0 & 0 & 0 \end{vmatrix} = \theta^2 - 1 < 0 \text{ for } 0 \leq \theta < 1 \qquad [2.59]$$

which satisfies the sufficient condition for a minimum.

With the derived farmers' demand for the new varieties, breeders face a maximization problem given by

$$\max_{x\geq 0, e\geq 0} \pi_i = \sum_{t=1,2} w_{i,t} x_{i,t} - k_i e_i^2 \qquad ; i \in \{h, l\} \qquad [2.60]$$

The first order conditions for the breeders' problem in stage two, given their R&D investment in stage one, is as follows:

$$FOCs: G_i + e_i - 2x_{i,2} - \theta x_{j,2} = 0 \qquad ; i, j \in \{h, l\}, i \neq j \qquad [2.61]$$

By solving the above FOCs simultaneously, we get the quantities of stage two as functions of R&D of stage one, given by:

$$x_{i,2} = -\frac{2(G_i + e_i) - \theta\left(G_j + e_j\right)}{(\theta - 2)(\theta + 2)} \qquad ; i, j \in \{h, l\}, i \neq j \qquad [2.62]$$

The next step is to plug the above optimal quantities into the breeders profit function and derive FOCs for R&D investments:

$$FOCs: = \frac{2(4(G_i + e_i) - k_i e_i(\theta^4 - 8\theta^2 + 16) - 2\theta(G_j + e_j)}{(\theta - 2)^2(\theta + 2)^2} = 0 \qquad ; i, j \in \{h, l\}, i \neq j \qquad [2.63]$$

By solving the above FOCs simultaneously, we get the optimal level of R&D investments by breeders given by

$$e_i = \frac{2\left(2G_i(1+k_j(\theta^2-4)) - \theta k_j G_j(\theta^2-4)\right)}{k_i k_j(\theta^6 - 12\theta^4 + 48\theta^2 - 64) - 4(\left(k_i+k_j\right)(\theta^2-4)+1)} \qquad ; i,j \in \{h,l\}, i \neq j \qquad [2.64]$$

Moreover, FOCs for $x_{i,1}$ are

$$FOCs: G_i - 2x_{i,1} - \theta x_{j,1} = 0 \qquad ; i,j \in \{h,l\}, i \neq j \qquad [2.65]$$

And the optimal quantities of breeders' varieties in stage one can be derived by solving the above FOCs simultaneously:

$$x_{i,1} = \frac{\theta G_j - 2G_i}{(\theta-2)(\theta+2)} \qquad ; i,j \in \{h,l\}, i \neq j \qquad [2.66]$$

Finally, the optimal levels of quantities produced by the breeders in stage two can be obtained by plugging the optimal R&D into their equations:

$$x_{i,2} = -\frac{k_i(\theta-2)(\theta+2)\left(2G_i(1+k_j(\theta^2-4)) - \theta k_j G_j(\theta^2-4)\right)}{k_i k_j(\theta^6 - 12\theta^4 + 48\theta^2 - 64) - 4(\left(k_i+k_j\right)(\theta^2-4)+1)} \qquad ; i,j \in \{h,l\}, i \neq j \qquad [2.67]$$

Thus, the optimal quantities are derived as functions of the model parameters. It can be easily shown that the second order conditions for the maximization problems above are satisfied. In addition, the non-negativity condition requires that if $G_i > G_j$, the following relation must hold

$$\frac{G_i}{G_j} < \breve{\tau} = \frac{2(k_i(\theta^2 - 4) + 1)}{k_i \theta (\theta^2 - 4)} \quad [2.68]$$

Proposition 2.1 Proof – first consider part i. The binary comparison of the equilibrium R&D under NE and RE results in

$e_i^{NE} - e_i^{RE} = \frac{\beta(\theta^4 + 2\theta^3 - 4\theta^2 - 2\theta(\beta+4) + 4)}{(\theta^3 + 2\theta^2 - 4\theta - 6)(\beta\theta(\beta+1) - 2\beta - \theta^3 - 2\theta^2 + 4\theta + 6)}$ [2.69]; with the following conditions:

$$e_i^{NE} - e_i^{RE} > 0 \text{ iff } \frac{\theta^4 + 2\theta^3 - 4\theta^2 - 8\theta + 4}{2\theta} < \beta \leq 1 \text{ or } 0.3593040860 < \theta < 1$$

$$e_i^{NE} - e_i^{RE} \leq 0 \text{ iff } 0 \leq \beta \leq \frac{\theta^4 + 2\theta^3 - 4\theta^2 - 8\theta + 4}{2\theta} \text{ and } 0 \leq \theta \leq 0.3593040860$$

Now consider part ii.

$e_i^{FE} - e_i^{NE} = \frac{4(\theta^6 + 4\theta^5 - 6\theta^4 - 28\theta^3 + 8\theta^2 + 48\theta + 12)}{(\theta^7 + 6\theta^6 + 4\theta^5 - 40\theta^4 - 64\theta^3 + 64\theta^2 + 132\theta + 24)(\theta^3 + 2\theta^2 - 4\theta - 6)}$ [2.70]; this is negative for all $0 \leq \theta < 1$.

$$e_i^{FE} - e_i^{RE} =$$

$$\frac{\beta\theta^8 + 6\beta\theta^7 - 4\theta^6(1-\beta) - 2\theta^5(\beta^2 + 21\beta + 8) - 4\theta^4(\beta^2 + 16\beta - 6) + 8\theta^3(\beta^2 + 10\beta + 14) + 4\theta^2(3\beta^2 + 32\beta - 8) - 48(4\theta + 1)}{(\theta^7 + 6\theta^6 + 4\theta^5 - 40\theta^4 - 64\theta^3 + 64\theta^2 + 132\theta + 24)(\beta\theta(\beta+1) - 2\beta - \theta^3 - 2\theta^2 + 4\theta + 6)}$$

[2.71]; this is negative for all $0 \leq \beta \leq 1$ and $0 \leq \theta < 1$. ■

Proposition 2.2 Proof – first consider part i.

$$FS_{SR}^{FE} - FS_{SR}^{NE} =$$

$$\frac{\theta^{15} + 14\theta^{14} + 62\theta^{13} + 12\theta^{12} - 676\theta^{11} - 1580\theta^{10} + 1344\theta^9 + 9376\theta^8 + 7400\theta^7 - 17296\theta^6 - 33920\theta^5 - 5248\theta^4 + 34608\theta^3 + 33504\theta^2 + 10944\theta + 1152}{(\theta^7 + 6\theta^6 + 4\theta^5 - 40\theta^4 - 64\theta^3 + 64\theta^2 + 132\theta + 24)^2(\theta+2)^2}$$

[2.72]; this is greater than zero for all $0 \leq \theta < 1$.

Now consider part ii.

$FS_{LR}^{FE} - FS_{LR}^{NE} = [(\theta-2)(\theta+2)(\theta^{17} + 10\theta^{16} + 20\theta^{15} - 116\theta^{14} - 512\theta^{13} + 192\theta^{12} + 3864\theta^{11} + 3104\theta^{10} - 137728\theta^{9} - 200096\theta^{8} + 233328\theta^{7} + 516480\theta^{6} - 118240\theta^{5} - 624320\theta^{4} - 147840\theta^{3} + 289920\theta^{2} + 172800\theta + 2304)]/[(\theta^{7} + 6\theta^{6} + 4\theta^{5} - 40\theta^{4} - 64\theta^{3} + 64\theta^{2} + 132\theta + 24)^{2}(\theta^{3} + 2\theta^{2} - 4\theta - 6)^{2}]$ [2.73]; this is negative for all $0 \leq \theta \leq 1$.

$FS_{LR}^{FE} - FS_{LR}^{RE} = [(\theta-2)(\theta+2)(\beta^{4}\theta^{3}(2\theta^{10} + 15\theta^{9} + 20\theta^{8} - 120\theta^{7} - 364\theta^{6} + 152\theta^{5} + 1464\theta^{4} + 796\theta^{3} - 1728\theta^{2} - 1776\theta - 288) + \beta^{3}\theta^{2}(4\theta^{11} + 22\theta^{10} - 20\theta^{9} - 320\theta^{8} - 248\theta^{7} + 1760\theta^{6} + 2320\theta^{5} - 4264\theta^{4} - 6640\theta^{3} + 3360\theta^{2} + 65280\theta + 1152) + \beta^{2}\theta(-4\theta^{14} - 38\theta^{13} - 82\theta^{12} + 311\theta^{11} + 1516\theta^{10} + 292\theta^{9} - 7692\theta^{8} - 9472\theta^{7} + 13208\theta^{6} + 29948\theta^{5} + 4352\theta^{4} - 25472\theta^{3} - 23712\theta^{2} - 9408\theta - 1152) + \beta\theta(-4\theta^{14} - 30\theta^{13} - 8\theta^{12} + 472\theta^{11} + 940\theta^{10} - 2664\theta^{9} - 8752\theta^{8} + 5176\theta^{7} + 35008\theta^{6} + 6784\theta^{5} - 65392\theta^{4} - 40608\theta^{3} + 43968\theta^{2} + 43776\theta + 6912) + \theta^{17} + 10\theta^{16} + 20\theta^{15} - 116\theta^{14} - 512\theta^{13} + 192\theta^{12} + 3864\theta^{11} + 3104\theta^{10} - 137728\theta^{9} - 200096\theta^{8} + 233328\theta^{7} + 516480\theta^{6} - 118280\theta^{5} - 624320\theta^{4} - 147840\theta^{3} + 289920\theta^{2} + 172800\theta + 2304]/[(\theta^{7} + 6\theta^{6} + 4\theta^{5} - 40\theta^{4} - 64\theta^{3} + 64\theta^{2} + 132\theta + 24)^{2}(\beta\theta(\beta+1) - 2\beta - \theta^{3} - 2\theta^{2} + 4\theta + 6)^{2}]$ [2.74]; this is negative for all $0 \leq \beta \leq 1$ and $0 \leq \theta < 1$.

$FS_{LR}^{NE} - FS_{LR}^{RE} = \frac{(\theta+1)(\theta+2)^{2}(\theta-2)^{2}\beta(\beta\theta+\theta-2)(\beta\theta(\beta+1)-2\beta-2\theta^{3}-4\theta^{2}+8\theta+12)}{(\theta^{3}+2\theta^{2}-4\theta-6)^{2}(\beta\theta(\beta+1)-2\beta-\theta^{3}-2\theta^{2}+4\theta+6)^{2}}$ [2.75]; this is negative for all $0 < \beta \leq 1$ and $0 \leq \theta < 1$. ■

Proposition 2.3 Proof – First, consider breeders' industry profits under NE and RE. Their difference is given by:

$BS^{NE} - BS^{RE} = 2\beta[\beta^3\theta^2(\theta^4 - 8\theta^2 + 12) + \beta^2\theta(2\theta^5 - 4\theta^4 - 16\theta^3 + 32\theta^2 + 24\theta - 48) + \beta(-\theta^8 + 21\theta^6 + 12\theta^5 - 100\theta^4 - 64\theta^3 + 112\theta^2 + 96\theta + 48) - 2\theta^8 - 4\theta^7 + 16\theta^6 + 12\theta^5 - 64\theta^4 + 64\theta^3 + 192\theta^2 - 192\theta - 288]/[(\theta^3 + 2\theta^2 - 4\theta - 6)^2(\beta\theta(\beta + 1) - 2\beta - \theta^3 - 2\theta^2 + 4\theta + 6)^2]$ [2.76]; this is negative for all $0 < \beta \leq 1$ and $0 \leq \theta < 1$.

Next, consider breeders' profits under FE and NE.

$BS^{FE} - BS^{NE} = -4[(\theta^2 - 2)(\theta^2 - 6)(\theta^{15} + 16\theta^{14} + 86\theta^{13} + 86\theta^{12} - 832\theta^{11} - 2760\theta^{10} + 552\theta^9 + 14968\theta^8 + 16632\theta^7 - 25832\theta^6 - 60512\theta^5 - 10624\theta^4 + 58416\theta^3 + 51360\theta^2 + 13824\theta + 1152)]/[(\theta^7 + 6\theta^6 + 4\theta^5 - 40\theta^4 - 64\theta^3 + 64\theta^2 + 132\theta + 24)^2(\theta^3 + 2\theta^2 - 4\theta - 6)^2(\theta + 2)^2]$ [2.77]; this is negative for all $0 \leq \theta < 1$.

Finally, consider breeders' profits under FE and RE.

$BS^{FE} - BS^{RE} = 2[(\beta^4\theta^4(\theta^{12} + 10\theta^{11} + 20\theta^{10} - 114\theta^9 - 432\theta^8 - 120\theta^7 - 364\theta^6 + 152\theta^5 + 1464\theta^4 + 796\theta^3 - 1728\theta^2 - 1776\theta - 288) + \beta^3\theta^2(4\theta^{11} + 22\theta^{10} - 20\theta^9 - 320\theta^8 - 248\theta^7 + 1760\theta^6 + 2320\theta^5 - 4264\theta^4 - 6640\theta^3 + 3360\theta^2 + 6528\theta + 1152) + \beta^2\theta(-4\theta^{14} - 38\theta^{13} - 82\theta^{12} + 311\theta^{11} + 1516\theta^{10} + 292\theta^9 - 7692\theta^8 - 9472\theta^7 + 13208\theta^6 + 29948\theta^5 + 4352\theta^4 - 25472\theta^3 - 23712\theta^2 - 9408\theta - 1152) + \beta\theta(-4\theta^{14} - 30\theta^{13} - 8\theta^{12} + 472\theta^{11} + 940\theta^{10} - 2664\theta^9 - 8752\theta^8 + 5176\theta^7 + 35008\theta^6 + 6784\theta^5 - 65392\theta^4 - 40608\theta^3 + 43968\theta^2 + 43776\theta + 6912) + \theta^{17} + 10\theta^{16} + 20\theta^{15} - 116\theta^{14} - 512\theta^{13} + 192\theta^{12} + 3864\theta^{11} + 3104\theta^{10} - 13728\theta^9 - 20096\theta^8 + 23328\theta^7 + 51648\theta^6 - 11828\theta^5 - 62432\theta^4 - 14784\theta^3 + 28992\theta^2 + 17280\theta + 2304]/[(\theta^7 + 6\theta^6 + 4\theta^5 - 40\theta^4 - 64\theta^3 + 64\theta^2 + 132\theta + 24)^2(\beta\theta(\beta + 1) - 2\beta - \theta^3 - 2\theta^2 + 4\theta + 6)^2(\theta + 2)^2]$ [2.78]; this is negative for all $0 \leq \beta \leq 1$ and $0 \leq \theta < 1$. ■

Proposition 2.4 Proof – Consider part i first. Comparing R&D undertaken by firm *h* under NE and RE, we can derive the following:

$$e_h^{NE} - e_h^{RE} = -\frac{k^2\theta\left(\theta^5+2\theta^4-8\theta^3-18\theta^2+16\theta+40\right)-k\left(2\theta^3+4\theta^2+8\theta+16\right)+4}{(k\theta^2+4k\theta+3k-1)(k\theta^6-12k\theta^4+44k\theta^2-4\theta^2-48k+12)}$$ [2.79]; with the

following conditions:

$e_h^{NE} - e_h^{RE} > 0$ iff $0.3593040860 < \theta < 1$ or

$$k > \frac{\theta^3 + 2\theta^2 + 4\theta + 8 + (-3\theta^6 - 4\theta^5 + 44\theta^4 + 104\theta^3 - 16\theta^2 - 96\theta + 64)^{\frac{1}{2}}}{\theta(\theta^5 + 2\theta^4 - 8\theta^3 - 18\theta^2 + 16\theta + 40)}$$

$e_h^{NE} - e_h^{RE} \leq 0$ iff $0 \leq \theta \leq 0.3593040860$ and

$$1 < k \leq \frac{\theta^3+2\theta^2+4\theta+8+\left(-3\theta^6-4\theta^5+44\theta^4+104\theta^3-16\theta^2-96\theta+64\right)^{\frac{1}{2}}}{\theta(\theta^5+2\theta^4-8\theta^3-18\theta^2+16\theta+40)}.$$

Now let's consider part ii.

$$e_l^{NE} - e_l^{RE} = -\frac{k(\theta^6+2\theta^5-8\theta^4-18\theta^3+12\theta^2+24\theta-12)-2\theta(\theta^2-4)}{(k\theta^2+4k\theta+3k-1)(k\theta^6-12k\theta^4+44k\theta^2-4\theta^2-48k+12)}$$ [2.80]; with the

following conditions:

$e_l^{NE} - e_l^{RE} > 0$ iff

aa) $0.4833419210 < \theta < 1$ or

ab) $0.3593040860 < \theta < 0.4833419210$ and $1 < k < \frac{2\theta(\theta^2-4)}{\theta^6+2\theta^5-8\theta^4-18\theta^3+12\theta^2+24\theta-12)}$

$e_l^{NE} - e_l^{RE} \leq 0$ iff

ba) $0 < \theta \leq 0.3593040860$ or

bb) $0.3593040860 < \theta < 0.4833419210$ and $k \geq \frac{2\theta(\theta^2-4)}{\theta^6+2\theta^5-8\theta^4-18\theta^3+12\theta^2+24\theta-12)}$. ■

Proposition 2.5 Proof – Consider part i first. Comparing R&D undertaken by firm *h* under NE and RE, we can derive the following:

$$e_h^{NE} - e_h^{RE} =$$

$$\frac{\tau(2\theta^7+7\theta^6-8\theta^5-56\theta^4-32\theta^3+112\theta^2+120\theta-12)-\theta^8-4\theta^7+5\theta^6+36\theta^5+12\theta^4-80\theta^3-52\theta^2+8\theta-36}{(\theta-2)(\theta+2)(\theta^2+4\theta+2)(\theta^3-2\theta^2-4\theta+6)(\theta^3+2\theta^2-4\theta-6)} \quad [2.81]$$

; with the following conditions:

$e_h^{NE} - e_h^{RE} > 0$ iff $\theta > 0.3593040860$ or $\frac{\theta^8+4\theta^7-5\theta^6-36\theta^5-12\theta^4+80\theta^3+52\theta^2-8\theta+36}{2\theta^7+7\theta^6-8\theta^5-56\theta^4-32\theta^3+112\theta^2+120\theta-12} < \tau < \breve{\tau}$

$e_h^{NE} - e_h^{RE} \leq 0$ iff $\theta \leq 0.3593040860$ and

$1 < \tau \leq \frac{\theta^8+4\theta^7-5\theta^6-36\theta^5-12\theta^4+80\theta^3+52\theta^2-8\theta+36}{2\theta^7+7\theta^6-8\theta^5-56\theta^4-32\theta^3+112\theta^2+120\theta-12}$.

Now let’s consider part ii.

$$e_l^{NE} - e_l^{RE} =$$

$$-\frac{\tau(\theta^8+4\theta^7-5\theta^6-36\theta^5-12\theta^4+80\theta^3+52\theta^2-8\theta+36)-2\theta^7-7\theta^6+8\theta^5+56\theta^4+32\theta^3-112\theta^2-120\theta+12}{(\theta-2)(\theta+2)(\theta^2+4\theta+2)(\theta^3-2\theta^2-4\theta+6)(\theta^3+2\theta^2-4\theta-6)} \quad [2.82]$$

; with the following conditions:

$e_l^{NE} - e_l^{RE} < 0$ iff $\theta < 0.3593040860$ or $\frac{2\theta^7+7\theta^6-8\theta^5-56\theta^4-32\theta^3+112\theta^2+120\theta-12}{\theta^8+4\theta^7-5\theta^6-36\theta^5-12\theta^4+80\theta^3+52\theta^2-8\theta+36} < \tau < \breve{\tau}$

$e_l^{NE} - e_l^{RE} \geq 0$ iff $\theta \geq 0.3593040860$ and $1 < \tau \leq \frac{2\theta^7+7\theta^6-8\theta^5-56\theta^4-32\theta^3+112\theta^2+120\theta-12}{\theta^8+4\theta^7-5\theta^6-36\theta^5-12\theta^4+80\theta^3+52\theta^2-8\theta+36}$. ■

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Chapter 3. Tariffs, R&D, and Two Merger Policies

Abstract

In an international Cournot oligopoly model, we compare two different merger policies when firms are merging *endogenously* and engage in research and development (R&D). In the benchmark model, countries set optimal tariff levels but do not have merger policy. If ex-ante identical firms merge internationally, they have an ex-post cost advantage over the outsiders due to tariff savings. This gives the merger an incentive to increase its R&D investment, which increases the cost dispersion further; therefore, the merger paradox, where each firm wants to be an outsider, disappears when R&D is efficient. As a result, we find different equilibrium market structures depending on the efficiency of R&D. In the second part, we compare two different merger policies, one that puts emphasis on welfare (roughly the Canadian merger policy) and another one that puts emphasis on consumer surplus (roughly the European Union's merger policy). We show that under the "welfare-increasing" merger policy, monopoly is the equilibrium market structure when R&D is very efficient. This explains why a merger, which created a monopoly, was approved in Canada. As R&D becomes less efficient, the equilibrium market structures become less concentrated under the two different merger policies. Each merger policy can be global welfare maximizing depending on the efficiency of R&D; however, the "consumer-surplus-increasing" merger policy is optimal for a wider range of parameters.

Keywords: Competition Policy, Merger Policy, R&D, Endogenous Mergers, Tariff, Trade Policy, Cournot oligopoly, Merger Paradox.

3.1. Introduction

Regulators traditionally have concentrated on how mergers affect the competition in the markets; however, they have recently become interested in the research and development (R&D) aspect of these mergers. The 2010 Horizontal Merger Guideline of US specifically mentions R&D as one of the criteria in the merger approval process. Firms, on the other hand, merge to save on tariff costs, among other reasons. Therefore, to compare different merger policies, the trade policy and R&D incentives of involved firms should be studied simultaneously.

In this paper, we develop a model in which trade and merger policies are used simultaneously by each country, and firms are allowed to merge endogenously and engage in R&D. Our focus is to compare two different merger policies. The first one is similar to the Canadian merger policy, where the merger is approved by regulators provided that it is welfare increasing compared to status-quo even if it creates a monopoly.[7] The second one is similar to the European Union's merger policy, where the merger is approved if it is consumer-surplus-increasing compared to status-quo. In our paper, we show how these two merger policies affect the equilibrium market structure, and when they are global-welfare maximizing.

We develop a symmetric model of an oligopolistic industry with two firms in the home market and another two in the foreign market. The ex-ante identical firms produce a homogenous product. They undertake costly R&D activities to reduce their marginal cost. The firms choose to merge with other firm(s) a la Horn and Persson's (2001a) cooperative endogenous merger formation model. If firms form an international merger, they do not incur tariff. The order of the interaction for the benchmark model is as follows. In the first stage of this game, endogenous

[7] The famous *Super Propane* merger was allowed in Canada even though it was creating monopolies in some local markets due to its welfare-increasing nature. (Ross and Winter 2005).

mergers are decided (monopolies are not allowed).[8] In the second stage, each country chooses their Nash level tariffs. In the third and fourth stage, firms choose R&D and then Cournot quantities simultaneously.[9] To check robustness, in a variant of this model, we also allow countries to set the optimal tariff rate for the status-quo at the beginning of the game, and hold it fixed throughout the game (i.e., tariff commitment).[10] The equilibrium market structure (EMS) depends on the efficiency level of R&D. Asymmetric duopoly, where there is a three-firm merger and an outsider firm, is the EMS when R&D is efficient. We show that the three-firm merger, which has a marginal cost advantage due to not paying tariffs, increases its R&D investment. This increases the cost dispersion between the merger and the outsider further, especially when R&D is efficient. As a result, the merger paradox, where each firm wants to be an outsider, disappears.[11] This makes the asymmetric international duopoly the equilibrium when R&D is efficient. When R&D is inefficient, symmetric duopoly with two international mergers is the EMS. Countries use Nash level tariffs in the off-path equilibrium so the "threat" of using the Nash level tariffs makes firms form cross-border mergers. In other words, trade liberalization occurs as an equilibrium phenomena in this model.

In the second part of the paper, we introduce merger policy to the model. As we discussed above, we compare two merger policies. The first merger policy is where the focus is on welfare. We call it a "welfare-increasing" merger policy (roughly the Canadian merger

[8] We do not allow monopolies in the benchmark model to be consistent with the literature (e.g. Horn and Persson 2001b and UIus and Yildiz 2012). We allow monopoly when we introduce merger policies to the model.
[9] We note that, in a complete information setting, agents rationally forecast the actions that will be taken in later stages by sequential rationality.
[10] The qualitative results are the same for both models. We also allow different order for the game; namely, R&D was chosen first, then the optimal Nash level tariffs. The qualitative results have not changed for that model neither.
[11] Salant et al (1983) shows that the outsider firm is better off in Cournot markets when other firms merge due to less competition. As a result, each firm wants the other firms to merge, and hence, a free-riding incentive is present. This is called "merger paradox."

policy). The order of interaction in this game is as follows. In the first stage, firms decide whether to merge and if so with which firm(s) a la Horn and Persson. In the second stage, regulation agencies accept the merger if it is welfare-increasing compared to status-quo, which is equivalent to no merger. Firms pay a small penalty if the merger is not approved. An international merger has to be approved by both regulators, and a national merger has to be approved by only the domestic regulator. In the third stage, each country, after observing the market structure, determines its Nash level tariffs simultaneously. In the fourth stage, firms decide the level of cost-reducing R&D. In the last stage, firms produce a homogenous product and sell it in Cournot fashion. To check robustness, in a variant of the model, we allow countries to set the optimal tariff at the beginning of the game, and hold it fixed throughout the game. Our qualitative results have not changed.

We show that under the welfare-increasing merger policy, monopoly is the EMS when R&D is highly efficient. Per firm output is higher in monopoly compared to status-quo where there are four identical firms. Hence, the monopoly invests more on R&D than any other firm under status-quo. This limits the increase in the market price and the decrease in consumer surplus. The increase in producer surplus compensates the loss of consumer surplus and the tariff revenue. Hence, the welfare is higher when R&D is highly efficient compared to status-quo.

We also show that as R&D becomes less efficient, the EMS becomes monopoly, asymmetric duopoly, symmetric (international) duopoly, triopoly with one international merger, or the status-quo, respectively. In other words, the market becomes less concentrated as R&D becomes inefficient.

Next, we study the second merger policy where the focus is on consumer surplus. We call this a "consumer-surplus-increasing" merger policy, and this is roughly the European Union's merger policy. The game is the same as above except that a merger is accepted by regulators only if it is consumer-surplus-increasing compared to status-quo. We show that as R&D becomes less efficient, the EMS changes from symmetric (international) duopoly to triopoly with one international merger, and then to status-quo. As expected, monopoly cannot be EMS in this case.

When one country uses the "welfare-increasing" merger policy and another uses the "consumer-surplus-increasing" merger policy, the EMS is the same as if the two countries are using the "consumer-surplus-increasing" merger policy.

The results of the paper give us a testable empirical prediction. Industries with efficient R&D must have international mergers while industries with inefficient R&D will have no (or fewer) mergers.[12]

We also examine global welfare in this paper. The global welfare maximizing market structure is symmetric (international) duopoly (hence free trade) when R&D is efficient, and triopoly with one international merger when R&D is inefficient (more liberal trade compared to status-quo). Both merger policies can be global welfare maximizing for some parameter space; however, consumer-surplus-increasing merger policy is the global welfare maximizing policy for a wider range of parameters. The interaction of the firms' private merger incentives and the merger policy provide this seemingly surprising result. The consumer-surplus-increasing merger policy selects the market structures that increase consumer surplus compared to the status-quo. Among those market structures, firms choose the producer surplus increasing market structure given the private incentives. As a result, the welfare is higher for both consumers and producers

[12] We assume no variable and/or fixed cost savings from mergers.

compared to the status-quo. Therefore, it is more likely to be the global welfare increasing merger policy.

Our paper contributes to three different aspects of the existing literature. The first one is the literature combining the competition policies and trade policies (e.g. Ross 1988, Horn and Levinsohn 2001, Yano 2001). None of these papers model how firms endogenously (and voluntarily) merge, rather they allow the countries to determine the number of firms in the market as the competition policy.[13] In addition, these papers do not take into account the international mergers that are observed in today's global economies. The closest paper to ours is Horn and Levinsohn (2001) since both papers use Cournot competition, Nash level trade policies, and a partial equilibrium setting. Our model is different in the sense that we allow firms to merge endogenously and internationally, and to engage in cost reducing R&D. Our merger policies are also different since we compare two different merger policies. We show that trade liberalization occurs as an equilibrium phenomena depending on the efficiency level of R&D, among other results. In a recent paper, Breinlich et al. (2015) study how mergers in a domestic country affect the consumer surplus in the foreign (and domestic) country. They are mainly interested in whether the merger policy of a country is too lenient or too tough for the foreign consumers. They do not have R&D nor optimal tariffs. Unlike them, we allow for international mergers, and compare welfare-increasing merger policy and consumer-surplus-increasing merger policy.

Our paper also falls into the literature that use endogenous mergers. Horn and Persson (2001a), endogenized the mergers as a cooperative coalition game by allowing firms to freely

[13] Breinlich et al. (2017), criticize the modelling of the competition policy in these papers as regulation agencies cannot determine the number of firms in a free market.

communicate and signing binding contracts. We follow Horn and Persson (2001a) to determine the equilibrium market structures in the first stage of our game. Horn and Persson (2001b) study an endogenous formation model when two firms in two countries face bilateral trade costs. They study neither merger policy nor optimal tariffs since they have trade costs in the model. Using Horn and Persson's endogenous merger formation model, Ulus and Yildiz (2012) study a differentiated goods oligopoly where firms compete in prices. We study a Cournot oligopoly setup, our firms engage in R&D investment, and our focus is on the use of trade and merger policy. Qiu and Zhou (2006a) explain that endogenous mergers occur if there is cost asymmetry and negative demand shock.[14] Our firms are ex-ante identical but the mergers cause cost-asymmetry among firms due to tariffs. This cost asymmetry affects the mergers in equilibrium.[15]

Our paper also contributes to the R&D literature. The relation between mergers and R&D has been studied by Stenbacka (1991), Kabiraj and Mukherjee (2000), Davidson and Ferrett (2007), and Matsushima et al. (2013). None of these papers studies the international aspect of the mergers, which bring new insights, as follows. The nature of the mergers, international or national, determines whether there will be cost dispersion among firms due to tariff.[16] We show that the international merger, not facing tariff, increases its R&D investment compared to the outsider firm(s) facing tariff. One implication of this observation is on the "merger paradox" (Salant et al. (1983). The merged firm, with its increased R&D, has a cost advantage which

[14] Qiu and Zhou (2006b) also study an endogenous merger where firms are randomly chosen and decide whether to form mergers with another firm.

[15] Cabral (2005), Davidson and Mukherjee (2007), Cabral (2003), and Spector (2003), broadly speaking, analyze the effect of free entry on mergers. Saggi and Yildiz (2006) study the link between merger incentives when there are two exporting countries and one importing country. Chaudhuri and Benchekroun (2012) study the effect of bilateral tariff reduction on *exogenous* mergers and social welfare. None of these papers study the effect of R&D on mergers in an endogenous merger formation, nor do the countries use an active merger policy.

[16] Ishida et al. (2011) study how entry of new firms to the market and cost dispersion affects R&D in a Cournot market. They do not study mergers.

increases its profits more than the outsider firm(s). This mitigates or eliminates the "merger paradox."

The plan of the paper is as follows. In the second section, we describe the benchmark model with trade policy of Nash level tariffs. Then, we add the "welfare-increasing" merger policy to the model. After that, we analyze the "consumer-surplus-increasing" merger policy, and when each country use a different merger policy. Finally, we derive the global welfare maximizing market structures. We discuss our results and some of our assumptions in the conclusion.

3.2. Model

Two countries are assumed to coexist, denoted by $z = F$ (foreign country), H (home country). In each country, there are two firms which produce a homogenous product.[17] The product can be exported or sold domestically. If exported, there will be a tariff equal to t_z ($z = H, F$), imposed on each unit of product by the importing country. Each firm's ($i = 1, \dots, 4$) *ex-ante* marginal costs of production is c. Assume firms *1* and *2* are located in the home country, and firms *3* and *4* are located in the foreign country. The two markets are segmented and firms compete in the Cournot fashion. Entry to this industry is restricted.

The following symmetric inverse demand system is assumed.

$$p_z(q_z) = \alpha - \sum_{i=1}^{4} q_{iz}, \qquad z = H, F \qquad [3.1]$$

[17] We follow Horn and Persson (2001b) and Ulus and Yildiz (2012) with modelling two firms in two countries.

Where p_z is the product price in the home or foreign country, q_{iz} is the quantity of product produced by firm i demanded in country z, and α is a parameter which represents the product market size. We assume $\alpha > c$ to guarantee that firms produce positive quantities.

Each firm *i* engages in R&D activity which reduces its marginal cost, denoted by e_i. Perfect appropriability and zero spillover are assumed. Thus, each firm's effective *ex post* marginal cost of selling domestically is equal to $c - e_i$, while the effective *ex post* marginal cost of exporting is $c + t_H - e_i$ for foreign firms and $c + t_F - e_i$ for home firms. The firms are risk neutral and have zero fixed costs.[18] Therefore, the following profit functions π_i can be obtained.

$$\pi_i = \begin{cases} \left(p_H - (c - e_i)\right). q_{iH} + (p_F - (c - e_i) - t_F). q_{iF} - ke_i^2 \,, & i = 1{,}2 \\ \left(p_F - (c - e_i)\right). q_{iF} + (p_H - (c - e_i) - t_H). q_{iH} - ke_i^2 \,, & i = 3{,}4 \end{cases} \qquad 3.2]$$

In the above profit functions, a quadratic cost function, ke_i^2, for R&D expenditure is assumed where *k* is a positive scalar and can be interpreted as the firm's efficiency in conducting R&D in the production process. In order to guarantee interior solutions, we make the following assumption.

ASSUMPTION 3.1

Firms are not too much efficient in conducting R&D, that is, $k > \check{k}(= 2.266)$.

[18] We assume that merger cost synergies, such as exogenous fixed cost savings as a result of mergers, are absent here. The reason is that we want to show that firms will merge even in the absence of such exogenously given synergies. The results must be robust to small cost synergies by continuity of profit functions.

Firms are allowed to merge nationally or internationally (a la Horn and Persson (2001a)). They do so to gain higher market concentration and in the case of cross-border merger(s) to save on tariff costs since an international merger does not pay any tariff.[19]

The basic game is set as follows. In the first stage, firms make their merger decisions endogenously a la Horn and Persson (2001a). In the second stage, after observing the new market structure, the countries set their Nash level tariffs simultaneously. In the third stage, firms decide the level of R&D. In the fourth stage, firms produce a homogenous product and engage in a Cournot competition. With this formulation, Nash level tariffs respond to industry level changes (market structure change) but not firm level changes (such as firm's R&D and output decisions). To check robustness, in a variant of the model, we allow countries to set the optimal Nash tariff level at the beginning, and they are not allowed to change those tariff levels (i.e., tariff commitment. Our qualitative results are the same, and we report the results of this variant of the model in various footnotes along the paper.[20]

3.2.1. Subgame Perfect Nash Equilibrium

We start solving the game from the last stage. In the last stage, we find Cournot outputs given the market structures, tariffs, and R&D investments. Then, we derive Nash level R&D,

[19] Since goods are homogenous and marginal costs are linear, an international merger can divide its production among its locations in any way it wants. This is enough to make them avoid paying tariffs (tariff-jumping argument). R&D can be done in one location and the technology can be transferred to any location without cost. One can generalize the model with non-linear costs and there will still be tariff jumping incentives for some parameter ranges but this will only complicate the model without bringing any new insights.

[20] It seems like there is no consensus in the literature about using pre-committed tariffs. Hence, we also allowed different order for the game; namely, R&D was chosen first, then the optimal Nash level tariffs. The qualitative results have not changed for that model neither. Given that the agents can rationally forecast the moves in the later stages, we doubt that the other changes in the timing of the game will change the qualitative results.

then Nash level tariffs, and finally the equilibrium market structures. Since, we will derive equilibrium market structures, first we list all possible market structures below.

Status quo (no mergers): {S} = {1,2,3,4}

Triopoly with one national merger: $\{N_1\}$ = {12,3,4} ; $\{N_2\}$ = {1,2,34}

Triopoly with one international merger: $\{I_1\}$ = {13,2,4} ; $\{I_2\}$ = {1,3,24} ; $\{I_3\}$ = {14,2,3} ; $\{I_4\}$ = {1,4,23}

Symmetric national duopoly: {NN} = {12,34}

Symmetric international duopoly: $\{II_1\}$ = {13,24} ; $\{II_2\}$ = {14,23}

Asymmetric international duopoly: $\{IN_1\}$ = {123,4} ; $\{IN_2\}$ = {124,3} ; $\{IN_3\}$ = {1,234} ; $\{IN_4\}$ = {124,3}

Monopoly: {M} = {1234}

We assume that monopoly is not allowed by the antitrust regulators. This assumption is also maintained in Horn and Persson (2001b) and Ulus and Yildiz (2012).[21]

3.2.2. Equilibrium output and R&D

In this subsection, we show how we derive the equilibrium output and R&D for the market structure $\{IN_1\}$. The equilibrium for $\{IN_2\}$, $\{IN_3\}$, and $\{IN_4\}$ are symmetric. The calculations for the other market structures are similar and delegated to the Appendix.

[21] In this sense, the benchmark model can be said to have a merger policy where monopoly is not allowed. It is well-known that monopoly will be the EMS in these models if it is allowed.

In the last stage, given that the Nash level tariff rate t_H and optimal R&D level e, the profit maximization problem is:

$$\pi_{IN} = \sum_{z=H,F} \left(\alpha - \sum_{i=IN,4} q_{iz} - (c - e_{IN}) \right) . q_{INz} - k e_{IN}^2 \qquad [3.3]$$

$$\pi_4 = \left(\alpha - \sum_{i=IN,4} q_{iF} - (c - e_4) \right) . q_{4F} + \left(\alpha - \sum_{i=IN,4} q_{iH} - (c - e_4) - t_H \right) . q_{4H} - k e_4^2 \qquad [3.4]$$

where subscript *IN* denotes the merger's variables and subscript *4* denotes the outsider firm's variables. Given the tariff level and the R&D investments, the first order conditions are:

$$FOCs: \begin{cases} \frac{\partial \pi_{IN}}{q_{INH}} = \alpha - c + e_{IN} - 2q_{INH} - q_{4H} = 0 \\ \frac{\partial \pi_4}{q_{4H}} = \alpha - c + e_4 - 2q_{4H} - q_{INH} - t_H = 0 \\ \frac{\partial \pi_{IN}}{q_{INF}} = \alpha - c + e_{IN} - 2q_{INF} - q_{4F} = 0 \\ \frac{\partial \pi_4}{q_{4F}} = \alpha - c + e_4 - 2q_{4F} - q_{INF} = 0 \end{cases} \qquad [3.5]$$

By solving them simultaneously, we get the quantities as a function of R&D and tariff:

$$q_{INH} = \frac{\alpha - c + 2e_{IN} - e_4 + t_H}{3} ; \quad q_{4H} = \frac{\alpha - c + 2e_4 - e_{IN} - 2t_H}{3} ; \qquad [3.6]$$

$$q_{INF} = \frac{\alpha - c + 2e_{IN} - e_4 + t_H}{3} ; \quad q_{4F} = \frac{\alpha - c + 2e_4 - e_{IN} - 2t_H}{3} .$$

Next step is to substitute the derived quantities above into the profit equations and derive FOCs for R&D investment levels:

$$FOCs: \begin{cases} \dfrac{\partial \pi_{IN}}{e_{IN}} = \dfrac{8(\alpha - c - e_4) - 2(9k-8)e_{IN} + 4t_H}{9} = 0 \\ \dfrac{\partial \pi_4}{e_4} = \dfrac{8(\alpha - c - e_{IN} - t_H) - 2(9k-8)e_4}{9} = 0 \end{cases} \quad [3.7]$$

By solving the equations above simultaneously, we get:

$$e_{IN} = \frac{2(2(3k-4)(\alpha-c)+3kt_H)}{(9k-4)(3k-4)}; \qquad e_4 = \frac{4\left((3k-4)(\alpha-c-t)-2t_H\right)}{(9k-4)(3k-4)} \qquad [3.8]$$

Plugging the optimal R&D investments back into the quantity and price equations, we get the optimal level of quantities, R&D, and prices for the market structure {IN}. We summarize this in Lemma 3.1 below.

Lemma 3.1: In the market structure {IN_1}, the equilibrium outcome of quantities, R&D for the asymmetric international merger and the outsider, and the prices in each market as a function of tariff are:

$$q_{INH} = \frac{(9k(3k-4)(\alpha-c-t_H)+4t_H(3k+2))}{3(9k-4)(3k-4)} \qquad q_{INF} = \frac{(9k(3k-4)(\alpha-c)+8t_H(3k-1))}{3(9k-4)(3k-4)} \qquad [3.9]$$

$$e_{IN} = \frac{2(2(3k-4)(\alpha-c)+3kt_H)}{(9k-4)(3k-4)} \qquad q_{4H} = \frac{(9k(3k-4)(\alpha-c-2t_H)-2t_H(3k+8))}{3(9k-4)(3k-4)}$$

$$q_{4F} = \frac{(9k(3k-4)(\alpha-c)-2t_H(15k-8))}{3(9k-4)(3k-4)} \qquad e_4 = \frac{4\left((3k-4)(\alpha-c-t)-2t_H\right)}{(9k-4)(3k-4)}$$

3.2.3. Nash Level Tariff and Trade Policy Equilibrium

In our model, each country, simultaneously, decides on the level of tariff that maximizes its own welfare after observing the market structure.

Let us call the tariff imposed by the two governments by t_z^m

$$z \in H, F; \qquad \text{and} \quad m \in \{S, N_1, N_2, I_1, I_2, I_3, I_4, NN, IN_1, IN_2, IN_3, IN_4\}$$

The firms do not pay tariff in {II} so it is not included in the above set.

The optimization problem facing the countries is as follows.

$$\max_{t_z^m} W_z^m = CS_z^m + PS_z^m + \mathcal{T}_z^m \qquad [3.10]$$

Where *CS*, *PS*, and $\mathcal{T}$ stand for consumer surplus, producer surplus, and tariff revenue, respectively. The welfare, denoted by W, is a function of *k*, *c*, and α. The welfare for each market structure is written in the appendix. We calculate the welfare by using the MAPLE software. In the calculations, we assumed that if two firms of country H is in a three-firm merger, then H gets two thirds of the producer surplus, and country F gets one third of the producer surplus.

In Lemma 3.2, we write down the optimal tariff for the market structure {IN}. Only the outsider firm faces tariff here.

LEMMA 3.2 The Nash level tariff in the market structure {IN_1} is:

$$t_H^{IN1} = \frac{108k(3k-4)(9k^2-11k+4)}{12393k^4-39204k^3+40644k^2-16800k+2368}(\alpha-c) \qquad [3.11]$$

We report the optimal Nash tariff levels for each market structure in the figure below. The market structure {N} is not symmetric so we report the country H and F's optimal tariff rate separately, and denote them as Nh and Nf, respectively. We note that the highest optimal tariff rate is in {S}; therefore, the optimal tariff rate will always decrease if a merger occurs. This is in line with WTO rules.

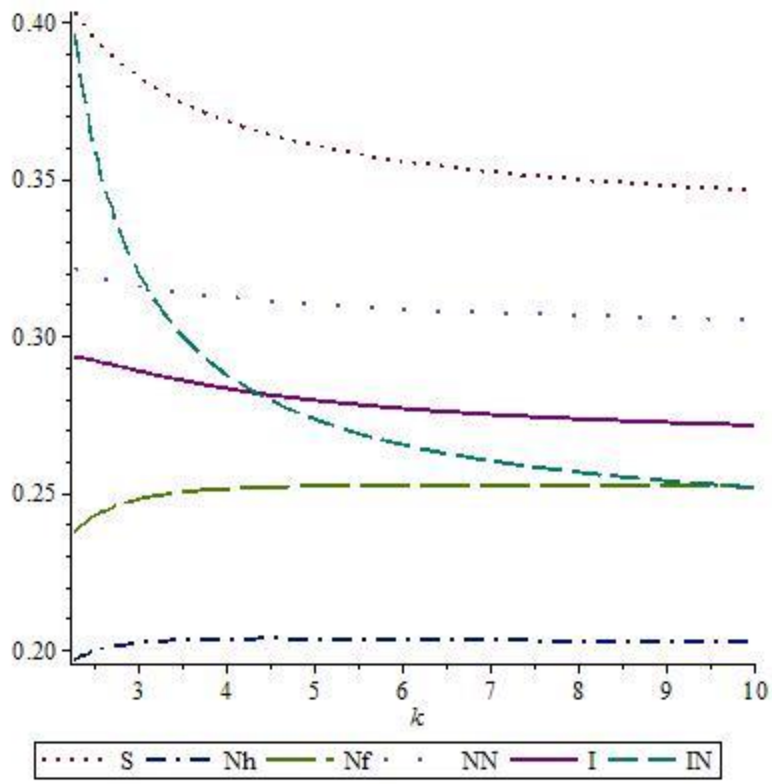


Figure 3.1   Optimal Tariff Rates for Different Market Structures

Given that we have calculated stage 4, 3, and 2, we can now move to stage 1 of our game.

3.2.4. Endogenous Merger Formation of Horn and Persson (2001a)

In Horn and Persson's (2001a) model, firms freely communicate and sign binding contracts to form mergers. Merger formation, therefore, is modeled as an endogenous cooperative coalition game, and it follows from three basic components: *(i) Decisive Owners*, *(ii) Dominance Relation*, and *(iii) Equilibrium Market Structures*.

(i) Decisive Owners: Decisive firm owners, with respect to two market structures, are those whose firm's status changes as the market moves from one structure to the other. For example, in comparing the status quo where there are four firms with the market structure under which firms 1 and 2 merge, decisive firms are only firms 1 and 2. It is as if firm 1 and firm 2 go to a room to negotiate their possible merger. Firm 3 and 4 are outside the room; hence, they cannot affect the negotiations although their profits will be affected from the merger. Therefore, they are not in the decisive group. We note that side payments are not allowed in this approach so firm 3 and firm 4 cannot alter the negotiations by paying to the negotiating parties.

Moreover, in a binary comparison of two market structures, there can be more than one decisive group. For instance, when comparing status quo and duopoly with two international mergers of say {13, 24}, there will be two separate decisive groups which are {1,3} and {2,4}.

(ii) Dominance Relation: If the summation of profits of decisive firms under one market structure is greater than that under another one, the former market structure dominates the latter one. The relation is denoted by *dom*. In the case of more than one decisive groups, the summation of firms' profits within each decisive group must be greater for one market structure than those under the other one. Then, the former market structure dominates the latter one. All market structures are binarily compared by this dominance relation.

(iii) The Equilibrium Market Structures (EMS): The set of equilibria is defined as all the market structures which are not dominated by any other market structure. In other words, under the EMS, the summation of profits of the decisive group is not lower than that under any other market structures. For example, {NN} dominates {I} if and only if the combined profit of the decisive group *i.e.* {1, 2, 3, 4} is greater under {NN} than under {I}. If that is the case, {I} is not in the core because it is dominated by at least one other structure.

In completing this approach, Horn and Persson (2001a) make one more assumption. The merger participants are free to choose any division of the profits subject to the constraint that the summation of the firms' profits is equal to the merger's profits.

Now, we are ready to give our equilibrium outcome for the subgame perfect equilibrium, which depends on *k*, the R&D efficiency parameter. When R&D is efficient, R&D's cost reducing effect plays a major role along with tariff-jumping effects in the model outcome.

We make the following assumption to ease the exposition since (α-c) appears in all equations in the cutoff values.

ASSUMPTION 3.2: (α-c)=1.

The EMS is presented in proposition 3.1.

PROPOSITION 3.1 –

Let $\bar{\bar{k}}$=3.878. The set of EMS is

(i) {IN} if $\check{k} < k < \bar{\bar{k}}$;

(ii) {II} if $k > \bar{\bar{k}}$.

The equilibrium market structure is the asymmetric international duopoly, {IN}, when R&D is efficient. The symmetric international duopoly, {II}, is the equilibrium when R&D is above the cutoff level $\bar{\bar{k}}$, that is, when R&D is inefficient.[22]

[22] If the countries set the optimal tariff rate at the beginning of the game, and cannot change it throughout the game, we still find the same result in Proposition 1 except that the cutoff value $\bar{\bar{k}}$=3.022.

In what follows, we explain the mechanism that gives this equilibrium outcome. For this, we will look into the role of R&D on the merger paradox. It is well known in the literature that there is a free-riding effect for the outsider firm since it enjoys higher profits due to the market concentration (Salant et al. 1983). We show that the efficient R&D mitigates or eliminates this effect.

PROPOSITION 3.2 Suppose countries use Nash level tariffs.

In market structure {I} compared to {S}

Each outsider invests more in R&D iff $k > 3.969$

Each outsider invests less in R&D iff $\check{k} < k \leq 3.969$.

In market structure {IN} compared to {S}

Each outsider invests more in R&D iff $k > 3.470$

Each outsider invests less in R&D iff $\check{k} < k \leq 3.470$.

In the market structure {IN}, there is marginal cost dispersion due to tariff between the merger and the outsider firm. The merger is the cost efficient firm and hence produces more. To enjoy the benefit of cost advantage, it increases its R&D even further when R&D is efficient (See figure 3.1). Then, the best response of the outsider firm is to decrease its R&D (See figure 3.2). This decreases the outsider firm's profit; hence, the outsider firm loses the free-rider effect when R&D is efficient. This is one of the main mechanisms deriving our EMS results in proposition 3.1. In fact, as R&D becomes more efficient, the profit of the merger approaches to the monopoly profit.

When R&D is inefficient, the merger paradox is in effect in {IN}; hence, each firm has an incentive to leave the three-firm merger. When one firm leaves though, it has to face a tariff cost so it is profitable to merge with the outsider to save on tariff cost. Therefore, {II} becomes the EMS.

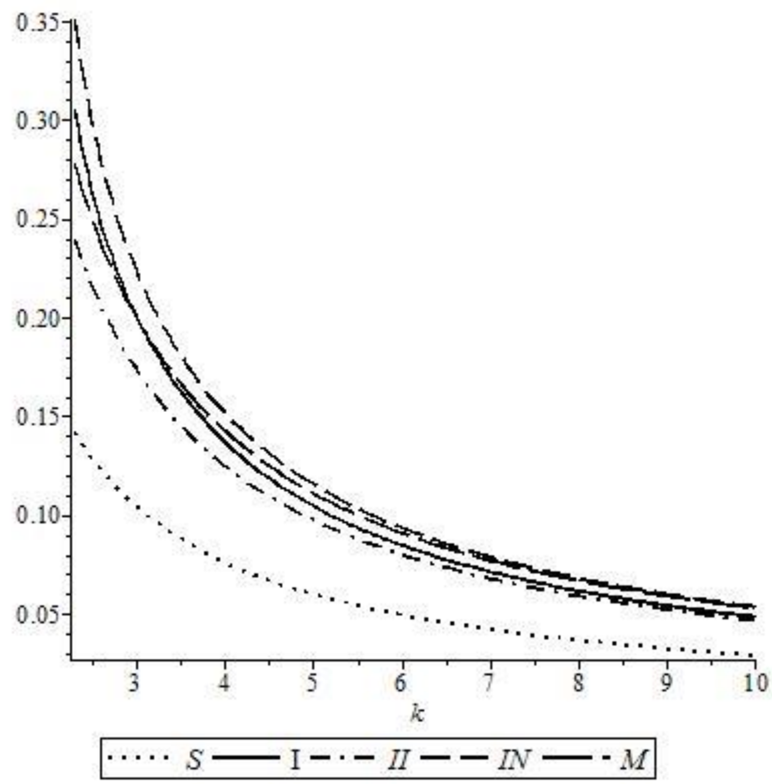


Figure 3.2 Merger's R&D level in {I}, {II}, {IN}, {M}, and firm level R&D in {S}

R&D literature (e.g., Stenbacka (1991), Kabiraj and Mukherjee (2000), Ishida (2011)) do not study the effect of international mergers on R&D and our proposition 3.2 fills this gap.

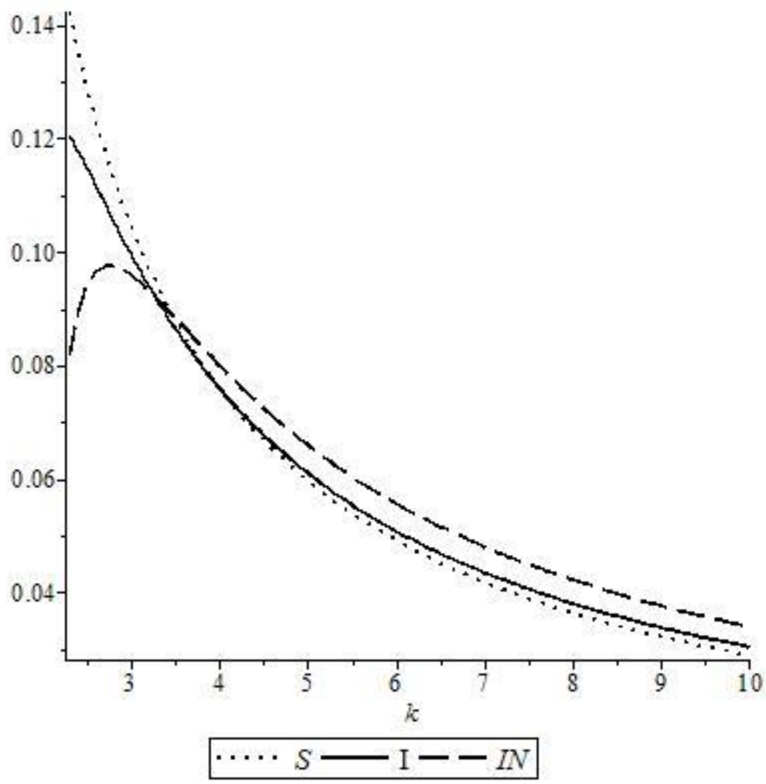


Figure 3.3 Outsider's R&D levels relative to Status Quo.

3.3. Trade and Merger Policy Equilibrium

In this section, we introduce merger policy to our model; however, merger policies are not uniform across different countries. For example, Canadian Competition Act allows even monopoly if the cost savings from the merger exceeds the loss in consumer surplus. In other words, as long as welfare is greater, the merger is approved (Ross and Winter, 2005).[23] On the other hand, in the European Union, mergers should not harm consumers by lowering consumer surplus. This is one of their main criteria for approving mergers (Ross and Winter, 2005). We add these two merger policies one by one to our model, and compare them.

[23] The famous Super Propane case in Canada was approved although the merger was creating monopoly in some local markets.

We note that regulation agencies, such as Competition Bureau in Canada, cannot determine the optimal number of firms in the market. They only evaluate whether the merger will make things better or worse than the status-quo given the law (such as Competition Act in Canada). Hence, while determining the optimal number of firms in the market are useful theoretical exercises, we believe that our approach is more relevant for real-world application.[24]

3.3.1. Welfare Increasing Merger Policy (Canadian Case)

In this subsection, we assume that regulatory agencies in each country do not authorize mergers if they decrease the country's welfare compare to the status-quo {S}. In the first stage of the game, firms form mergers a la Horn and Persson (2001a). Then, regulatory agency in each country decides whether to approve the merger if the merger is international. If it is a national merger, only the regulation agency of that country makes a decision. If it is not approved, the merging firms pay a penalty. If a merger is approved, then each country chooses their Nash level tariff. The firms choose R&D investment, and then compete a la Cournot in the markets.

Firms, rationally expecting how regulation agencies will behave, never form mergers that are denied in equilibrium. Therefore, we prove in the appendix that the only acceptable market structures are {I}, {II}, {IN}, {M}, or {S} since firms may choose not to merge. We derive the subgame perfect equilibrium, and summarize the results in Proposition 3.

PROPOSITION 3.3: *The equilibrium market structure when countries use trade and welfare-increasing merger policies is:*[25]

[24] In Horn and Levinsohn (2001), competition policy determines the optimal number of firms.
[25] In the variant of the model, where the optimal tariff is set at the {S} level throughout the game by each country, we get the same qualitative results, in the sense that only the cutoff values changes slightly except that the cutoff value for {S} and {I} change considerably; namely, {S} is the EMS if $k > 10.77$ (approximately) for that model.

{M} if $\check{k} < k < 2.628$;

{IN} if $2.628 < k < 3.248$;

{II} if $3.248 < k < 9.532$;

{I} if $9.532 < k < 21.185$;

{S} if $k > 21.185$.

When *k* is extremely efficient, {M} is the EMS. It may seem surprising that {M} results in higher welfare than {S}. The reason is that while the total industry output is higher under {S}, per firm output is higher under {M};hence, the monopoly invests more on R&D, and becomes more cost-efficient than any other firm under {S} as seen in figure 3.1. This limits the increase in product price under {M} and the decrease in consumer surplus. As a result, the welfare is higher under {M} only if R&D is extremely efficient.

When *k* is very efficient, {IN} dominates the other approved market structures (except {M} which is welfare decreasing in this range). The tariff cost asymmetry causes the merger to increase its R&D, which in turn increases the profits. This increase in profits compensates the loss in consumer surplus due to market concentration compared to {S}. Therefore, {IN} is welfare increasing.

When $3.248 < k < 9.532$, firms prefer {IN} over {II} for part of this range but {IN} is not acceptable to the country which has two firms in the merger. Hence, firms merge to form {II} which is welfare increasing compared to {S}, and approved by both countries.

When *k* is moderately efficient, $9.532 < k < 21.185$, {I} is the EMS although {II} is preferred over {I} by the firms. However, {II} is welfare decreasing compared to {S}. In {II}, although firms' profits increase and the production is more efficient due to more R&D compared to {S}, the loss in consumer surplus outweighs these gains.

When *k* is inefficient, $k > 21.185$, the other market structures are welfare decreasing compared to {S} except {I}. However, firms prefer {S} over {I} (possibly due to merger paradox); hence, {I} is not the EMS. The decrease in consumer surplus in the other market structures (other than {I}) is not compensated by profit increase and/or tariff revenue. While firms prefer {II} in this range, it is not approved by the competition regulators. Therefore, {S} is the EMS.

We note that as R&D becomes less efficient, market becomes less concentrated.

3.3.2. Consumer-Surplus-Increasing Merger Policy (The European Union Case)

In this subsection, the game is same as the welfare-increasing merger game except that mergers are accepted only if they do not decrease the consumer surplus.

Proposition 3.4: *The equilibrium market structure is:*[26]

{II} if $\check{k} < k < 2.831$;

{I} if $2.831 < k < 21.185$;

{S} if $k > 21.185$.

As expected, monopoly cannot be EMS since it always decreases consumer surplus.

[26] In the variant of the model, where the optimal tariff is set at the {S} level throughout the game by each country, we get the same qualitative results, in the sense that only the cutoff values changes slightly except that the cutoff value for {S} and {I} change considerably; namely, {S} is the EMS if k> 3.38 (approximately) for that model.

When k is efficient, R&D is very high under {II} and there is no tariff. Hence, the consumer surplus is higher than the one under {S} despite the lower market concentration. [27]

When k is moderately efficient, {I} is the equilibrium market structure. R&D is not that efficient so the efficiency gain of R&D only overcomes the loss in consumer surplus from having three firms under {I} compared to four firms under {S}.

When $k > 21.185$, {I} is preferred by the two countries, however, the firms do not have incentive to form one international merger due to merger paradox. Being an outsider is better when R&D is very inefficient. Therefore, {S} is the equilibrium.

As in the welfare-increasing merger policy case, as R&D becomes less efficient, market becomes less concentrated.

3.3.3. Two Types of Merger Policy Coexist

One question is that how the set of EMS looks like if home country (symmetrically foreign country) uses welfare-increasing merger policy while the foreign country (symmetrically home country) uses consumer surplus-increasing merger policy. From proposition 3, home country allows the market structures of {M}, {I}, {II}, {IN}, and {S} to form. From proposition 3.4, foreign country allows the market structures {I},{II}, and {S}. The outcome of this case is presented in Proposition 3.5.

[27] For $k < 2.538$, firms forming {II} have an incentive to cheat on each other since each merger prefers {I} market structure compared to {II}. Also, each country prefers {I} over {II} in terms of consumer surplus (but the other way around for welfare}. Hence, even after agreeing on {II}, each pair of firms, instead of simultaneously submitting the merger approval application, would like to submit their application first. This may result in the market structure {I}, and {II} may not arise for this range depending on the modelling assumption. We assume that if regulation agencies receive two merger applications, it will compare them both with {S} and approve both if overall the consumer surplus is increasing.

Proposition 3.5

If one country uses welfare-increasing merger policy and the other one uses consumer surplus-increasing merger policy, the set of EMS is

{II} if $\check{k} < k < 2.831$;

{I} if $2.831 < k < 21.185$;

{S} if $k > 21.185$.

The consumer-surplus-increasing merger policy is the binding policy when different merger policies are used. For the efficient k, {M} and {IN} are the EMS in the welfare increasing merger policy case; however, these are consumer surplus decreasing, and are not approved by the foreign country.[28] The proof is similar to the proof of Proposition 3 and 4 so it is not added.

Proposition 3.3, 3.4 and 3.5 imply that we have a testable empirical prediction. As R&D becomes less efficient, market becomes less concentrated. Hence, we must observe more international mergers in the industries with efficient R&D, and no (or fewer) mergers in the industries with inefficient R&D.

3.3.4. Global Welfare (Trade Policy Game)

Now, we discuss the global welfare and analyze whether the optimal global welfare is achieved under these different models. Global welfare is calculated as the sum of the two countries' welfare.

[28] {IN} is consumer surplus decreasing for both countries regardless of which country has the outsider. This is proven in the proof of Proposition 4.

PROPOSITION 3.6 – When countries impose Nash level tariffs, the market structure that maximizes the global welfare is:

{II} iff $\check{k} < k < 5.973$

{I} iff $k > 5.973$

We note that since these market structures are symmetric, they also maximize each country's welfare.

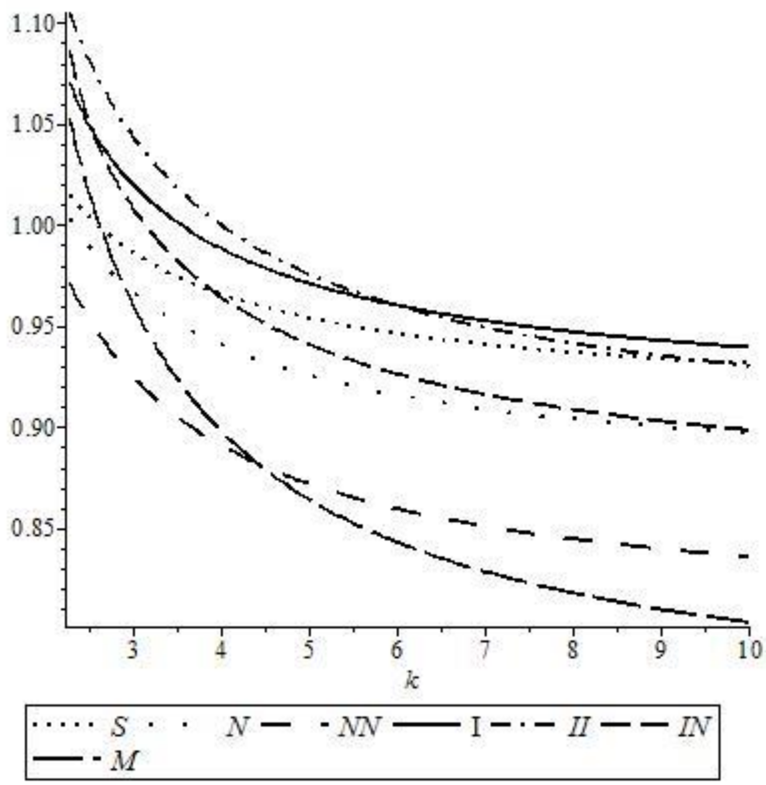


Figure 3.4 Global Welfare under different market structures.

Corollary 3.1:

The welfare increasing merger policy coincides with the global welfare when $3.248 < k < 5.973$ or $9.532 < k < 21.185$.

The consumer-surplus-increasing merger policy coincides with the global welfare when $\check{k} < k < 2.831$ or $5.973 < k < 21.185$.

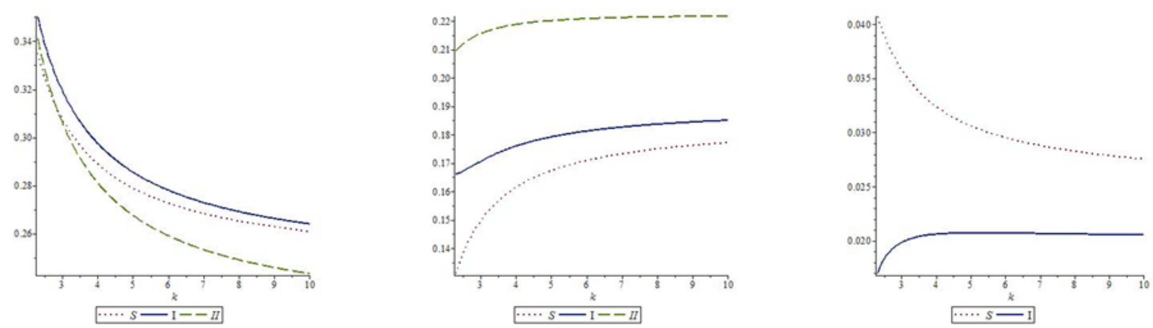
At first, one might think that "welfare-increasing" merger policy must be the global welfare increasing merger policy but consumer-surplus-increasing merger policy does a better job for a wider range of parameters. The consumer-surplus-increasing merger policy selects the market structures that increase consumer surplus compared to the status-quo. Among those market structures, firms choose the producer surplus increasing market structure given the private incentives. Given this interaction of the private incentives and the restriction of the merger policy, the welfare is higher for both consumers and producers compared to the status-quo; therefore, consumer-surplus-increasing merger policy maximizes global welfare for a wider range of parameters.

Since {I} and {II} are global welfare maximizing market structures, we compare them by decomposing their welfare into consumer surplus, producer surplus, and tariff revenue as R&D efficiency varies. {I} gives higher consumer surplus compared to {II} due to less market concentration. Figure 4a shows that the difference in consumer surplus between {I} and {II} increases as R&D becomes less efficient. {II} gives higher producer surplus compared to {I} due to more market concentration. Figure 4b shows that the difference in producer surplus between {I} and {II} decreases as R&D becomes less efficient except for a small parameter range.[29] Figure 4c shows that tariff revenue increases as R&D becomes less efficient under {I}. The

[29] The difference increases until approximately *k*=2.75, then decreases.

reason is that the merger does not invest too much in R&D when R&D is less efficient. As a result, the outsiders have a sizeable market share, and tariff revenue is relatively high for each country. When R&D is more efficient, on the other hand, the merger increases its market share at the expense of the outsiders. This results in low tariff revenue. There is no tariff revenue under {II}.

{II} is the global welfare maximizing market structure when R&D is efficient since the producer surplus difference between {I} and {II} outweighs the consumer surplus difference and tariff revenue effect. As R&D becomes less efficient, the consumer surplus difference and tariff revenue effect increase while the producer surplus difference decreases. This makes {I} the global welfare maximizing structure.



Panel (a) CS Panel (b) PS Panel (c) Tariff Revenue

Figure 3.5 Welfare Decomposition

3.4. Discussion and Conclusions

In this section, we will discuss some of the modelling assumptions and extensions. Using Horn and Persson's endogenous merger setting in the first stage of the game necessitates using two firms in each country (e.g., Horn and Persson (2001b), Ulus and Yildiz (2012)) Otherwise, the calculations would get complex. We believe that even with this setting, we get novel results and intuition such as how R&D affects mergers and the EMS.

One might add additional variations such as cost heterogeneity among firms or *exogenous* variable cost saving after merger. If the cost heterogeneity is small, our qualitative results will not change due to continuity.

Since there is no consensus on the timing of determining the Nash level tariffs, we checked robustness of our model, by assuming a fixed tariff rate set in the beginning of the game. This tariff rate is the optimal tariff rate for the status-quo market structure, and countries are not allowed to change this. We find that our qualitative results are same and only the cut-off values change.

We made another robustness check with our benchmark model. We change the stage of the games in the sense that R&D is decided first, and Nash tariffs are set afterwards. This has not changed our qualitative results. We do not expect that other changes in the timing of the game will result in any significant change since agents optimally forecast the actions in the later stages.

We note that the optimal tariff levels are less than the status-quo optimal tariff level; hence, each country obeys the WTO rules when setting the optimal tariff rate in our model.

With this paper, we fill a gap in the literature since different merger policies have not been compared to our best knowledge. Given that billions of dollars of mergers occur each year, we believe that finding an optimal merger policy has practical implications that will raise the welfare of countries.

Appendix 3.1. Firms Optimization Problem and Proofs to the Propositions

Here, we will find the equilibrium quantities, R&D, and Nash level tariffs for each market structure as we did in the main text for the market structure {IN}.

No merger {S}:

Here, we show how we derive the equilibrium output and R&D for the market structure {S}. The calculations for the other market structures are similar and summarized.

In the last stage, given that the Nash level tariff rates t_H and t_F, and optimal R&D level *e*, the profit maximization problem for firm 1 is:

$$\max_q \pi_1 = \left(\alpha - \sum_{i=1}^{4} q_{iH} - (c - e_1)\right). q_{1H} + \left(\alpha - \sum_{i=1}^{4} q_{iF} - (c - e_1) - t_F\right). q_{1F} - ke_1^2 \qquad [3.12]$$

Where subscript *1* denotes the firm *1*'s variables. The profit functions for the other firms are similar to that of firm *1* and thus not displayed. Given the tariff levels and the R&D investments, the first order conditions are:

$$FOCs: \begin{cases} \frac{\partial \pi_1}{q_{1H}} = \alpha - c + e_1 - 2q_{1H} - q_{2H} - q_{3H} - q_{4H} = 0 \\ \frac{\partial \pi_2}{q_{2H}} = \alpha - c + e_2 - 2q_{2H} - q_{1H} - q_{3H} - q_{4H} = 0 \\ \frac{\partial \pi_3}{q_{3H}} = \alpha - c + e_3 - 2q_{3H} - q_{1H} - q_{2H} - q_{4H} - t_H = 0 \\ \frac{\partial \pi_4}{q_{4H}} = \alpha - c + e_4 - 2q_{4H} - q_{1H} - q_{2H} - q_{3H} - t_H = 0 \end{cases} \qquad [3.13]$$

$$FOCs:\begin{cases}\frac{\partial\pi_1}{q_{1F}}=\alpha-c+e_1-2q_{1F}-q_{2F}-q_{3F}-q_{4F}-t_F=0\\ \frac{\partial\pi_2}{q_{2F}}=\alpha-c+e_2-2q_{2F}-q_{1F}-q_{3F}-q_{4F}-t_F=0\\ \frac{\partial\pi_3}{q_{3F}}=\alpha-c+e_3-2q_{3F}-q_{1F}-q_{2F}-q_{4F}=0\\ \frac{\partial\pi_4}{q_{4F}}=\alpha-c+e_4-2q_{4F}-q_{1F}-q_{2F}-q_{3F}=0\end{cases} \quad [3.14]$$

By solving them simultaneously, we get the quantities as a function of R&D and tariff:

$q_{1H}=\frac{1}{5}(\alpha-c+4e_1-(e_2+e_3+e_4)+2t_H)$ (15);

$q_{1F}=\frac{1}{5}(\alpha-c+4e_1-(e_2+e_3+e_4)-3t_F)$ (16);

where q_{1H} and q_{1F} are the quantity of product produced by firm *1* sold in country *H* and country *F* (firm *1*'s export), respectively.

Next step is to substitute the derived quantities above into the profit equations and derive FOCs for R&D investment levels:

$$FOCs:\begin{cases}\frac{\partial\pi_1}{e_1}=\frac{8}{25}(2(\alpha-c-e_2-e_3-e_4)+8e_1+2t_H-3t_F)-2ke_1=0\\ \frac{\partial\pi_2}{e_2}=\frac{8}{25}(2(\alpha-c-e_1-e_3-e_4)+8e_2+2t_H-3t_F)-2ke_2=0\\ \frac{\partial\pi_3}{e_3}=\frac{8}{25}(2(\alpha-c-e_1-e_2-e_4)+8e_3+2t_F-3t_H)-2ke_3=0\\ \frac{\partial\pi_4}{e_4}=\frac{8}{25}(2(\alpha-c-e_1-e_2-e_3)+8e_4+2t_F-3t_H)-2ke_4=0\end{cases} \quad [3.17]$$

By solving the equation above simultaneously, we get:

$$e_1=e_2=\frac{4(2(5k-8)(\alpha-c)+10kt_H-8t_F)}{(5k-8)(25k-8)}; \qquad e_3=e_4=\frac{4(2(5k-8)(\alpha-c)+10kt_F-8t_H)}{(5k-8)(25k-8)} \quad [3.18]$$

Plugging the optimal R&D investments back into the quantity and price equations, we get the optimal level of quantities, R&D, and prices as a function of tariff for the market structure {S}.

$$q_{1H} = \frac{\left(25k(5k-8)(\alpha-c)+2(125k^2-120k+32)t_H-4(65k-24)t_F\right)}{5(5k-8)(25k-8)};$$

$$q_{1F} = \frac{\left(25k(5k-8)(\alpha-c)-(375k^2-460k+96)t_F+16(15k-4)t_H\right)}{5(5k-8)(25k-8)}; \qquad [3.19]$$

$$p_H = \frac{5\alpha(5k-8)+100kc+2(25k-4)t_H+8t_F}{5(25k-8)};$$

$$p_F = \frac{5\alpha(5k-8)+100kc+2(25k-4)t_F+8t_H}{5(25k-8)};$$

One National Merger {N}: Two firms in the same country merge and the firms in the other country remain individual competing units. The result will be a market structure of triopoly with one national merger (*i.e.* $\{N_1\}$ or $\{N_2\}$). The profit maximization problem of the firms under $\{N_1\}$ market structure is described. By symmetry, $\{N_2\}$ would result in symmetric outcomes and is therefore not displayed.

$$\max_{q,e} \pi_N = \left(\alpha - \sum_{i=N,3,4} q_{iH} - (c - e_N)\right).q_{NH} + \left(\alpha - \sum_{i=N,3,4} q_{iF} - (c - e_N) - t_F\right).q_{NF} - ke_N^2 \qquad [3.20]$$

$$\max_{q,e} \pi_j = \left(\alpha - \sum_{i=N,3,4} q_{iF} - (c - e_j)\right) . q_{jF}$$

$$+ \left(\alpha - \sum_{i=N,3,4} q_{iH} - (c - e_j) - t_H\right) . q_{jH} - ke_j^2 , \qquad [3.21]$$

$$j = 3,4$$

Where subscript *N* means the related variable belongs to the merger under {N} market structure and variables with subscript *j* belongs to the outsider firms. Solving the profit maximization problem of the three firms, we obtain the following results.

$$e_N = \frac{3(2(2k-3)(\alpha - c) + 4kt_H - 3(2k-1)t_F)}{2(2k-3)(8k-3)} \qquad [3.22]$$

$$e_j = \frac{3(2(2k-3)(\alpha - c) + 2kt_F - (4k-3)t_H)}{2(2k-3)(8k-3)}$$

$$q_{NH} = \frac{(16k(2k-3)(\alpha - c) + 2(32k^2 - 30k + 9)t_H - 3(22k-9)t_F)}{8(2k-3)(8k-3)}$$

$$q_{NF} = \frac{(16k(2k-3)(\alpha - c) - 3(32k^2 - 38k + 9)t_F + 6(10k-3)t_H)}{8(2k-3)(8k-3)}$$

$$q_{jH} = \frac{(16k(2k-3)(\alpha - c) - 2(32k^2 - 42k + 9)t_H + 3(10k-3)t_F)}{8(2k-3)(8k-3)}$$

$$q_{jF} = \frac{(16k(2k-3)(\alpha - c) + (32k^2 - 30k + 9)t_F - 18(2k-1)t_H)}{8(2k-3)(8k-3)}$$

One International Merger {I}: Consider a triopoly market structure in which two firms from different countries merge and the other firms remain outsiders. The result will be one of the structures of $\{I_1\}$, $\{I_2\}$, … ,$\{I_4\}$. The profit maximization problem of the firms under $\{I_1\}$ market structure is described below. The other three cases are symmetric, and can be derived easily.

$$\max_{q,e} \pi_I = \sum_{z=H,F} \left(\alpha - \sum_{i=I,2,4} q_{iz} - (c - e_I) \right) . q_{Iz} - k e_I^2 \qquad [3.23]$$

$$\max_{q,e} \pi_2 = \left(\alpha - \sum_{i=I,2,4} q_{iH} - (c - e_2) \right) . q_{2H} + \left(\alpha - \sum_{i=I,2,4} q_{iF} - (c - e_2) - t_F \right) . q_{2F} - k e_2^2 \qquad [3.24]$$

$$\max_{q,e} \pi_4 = \left(\alpha - \sum_{i=I,2,4} q_{iF} - (c - e_4) \right) . q_{4F} + \left(\alpha - \sum_{i=I,2,4} q_{iH} - (c - e_4) - t_H \right) . q_{4H} - k e_4^2 \qquad [3.25]$$

Where subscript *I* means the related variable belongs to the merger under market structure {I} and variables with subscript *j* belongs to the outsider firms. We get the following results by solving the profit maximization problems of the three firms.

$$e_I = \frac{3\big((2k-3)(\alpha - c) + k(t_H + t_F)\big)}{(2k-3)(8k-3)} \qquad [3.26]$$

$$e_2 = \frac{3(2(2k-3)(\alpha - c) + 2kt_H - 3(2k-1)t_F)}{2(2k-3)(8k-3)}$$

$$e_4 = \frac{3(2(2k-3)(\alpha - c) + 2kt_F - 3(2k-1)t_H)}{2(2k-3)(8k-3)}$$

$$q_{IH} = \frac{(16k(2k-3)(\alpha - c) + (32k^2 - 30k + 9)t_H + 3(10k-3)t_F)}{8(2k-3)(8k-3)}$$

$$q_{IF} = \frac{(16k(2k-3)(\alpha - c) + (32k^2 - 30k + 9)t_F + 3(10k-3)t_H)}{8(2k-3)(8k-3)}$$

$$q_{2H} = \frac{(16k(2k-3)(\alpha - c) + (32k^2 - 30k + 9)t_H - 3(22k-9)t_F)}{8(2k-3)(8k-3)}$$

$$q_{2F} = \frac{(16k(2k-3)(\alpha - c) - 3(32k^2 - 38k + 9)t_F + 3(10k-3)t_H)}{8(2k-3)(8k-3)}$$

$$q_{4H} = \frac{(16k(2k-3)(\alpha - c) - 3(32k^2 - 38k + 9)t_H + 3(10k-3)t_F)}{8(2k-3)(8k-3)}$$

$$q_{4F} = \frac{(16k(2k-3)(\alpha - c) + (32k^2 - 30k + 9)t_F - 3(22k-9)t_H)}{8(2k-3)(8k-3)}$$

Two National Mergers {NN}: The profit maximization problem of the firms under duopoly market structure under which firms *1* and *2* and firms *3* and *4* merge can be written as follows.

$$\pi_{NH} = \left(\alpha - \sum_{i=NH,NF} q_{iH} - (c - e_{NH})\right).q_{NHH} + \left(\alpha - \sum_{i=NH,NF} q_{iF} - (c - e_{NH}) - t_F\right).q_{NHF} - ke_{NH}^2 \qquad [3.27]$$

$$\pi_{NF} = \left(\alpha - \sum_{i=NH,NF} q_{iF} - (c - e_{NF})\right).q_{NFF} + \left(\alpha - \sum_{i=NH,NF} q_{iH} - (c - e_{NF}) - t_H\right).q_{NFH} - ke_{NF}^2 \quad [3.28]$$

Where variables with subscript *NH* are related the merger between firms *1* and *2*, and variables with subscript *NF* belongs to the merger between firms *3* and *4*. Solving the profit maximization problem for the two firms results in below equations for the optimum levels of product and R&D expenditure (the two firms are symmetric and thus only firm *NH*'s variables are displayed).

$$e_{NH} = \frac{2(2(3k-4)(\alpha - c) + 3kt_H - 2(3k-2)t_F)}{(3k-4)(9k-4)} \quad [3.29]$$

$$q_{NHH} = \frac{(9k(3k-4)(\alpha - c) + (27k^2 - 24k + 8)t_H - 2(15k-8)t_F)}{3(3k-4)(9k-4)}$$

$$q_{NHF} = \frac{(9k(3k-4)(\alpha - c) - 2(27k^2 - 33k + 8)t_F + 8(3k-1)t_H)}{3(3k-4)(9k-4)}$$

Two International Mergers {II}: If two multinational firms emerge as a result of merger, we face with either market structures of $\{II_1\}$ or $\{II_2\}$. Let's consider the market structure $\{II_1\}$ which is a duopoly in which firms *1* and *3* merge and firms *2* and *4* merge, and solve their profit maximization problems. The other structure will result in symmetric outcomes.

$$\pi_i = \sum_{z=H,F} \left(\alpha - \sum_{j=II_{13},II_{24}} q_{jz} - (c - e_i)\right).q_{iz} - ke_i^2, \qquad i = II_{13}, II_{24} \quad [3.30]$$

Where II_{13} stands for the merger of firms *1* are *3*, and II_{24} represents the merger of firms *2* and *4*. Solving the first order conditions of the profit functions above, we get the following results.

$q_{iz} = \frac{3k(\alpha-c)}{9k-4}$, $i = II_{13}, II_{24}$ and $z = H, F$ [3.31]; $e_i = \frac{4(\alpha-c)}{9k-4}$, $i = II_{13}, II_{24}$ [3.32]; $p_{IIH} = p_{IIF} = \frac{3k(\alpha+2c)-4\alpha}{9k-4}$ [3.33]

Proof of Lemma 3.2:

The model's variables under different market structures are derived in Lemma 3.1 as functions of tariffs. Plugging the optimal variables back into the welfare functions, we can derive the Nash level tariffs which maximize the countries' welfare for each market structure. The countries optimization problem's solution is shown for the market structure $\{IN_1\}$. The procedure is similar to this for the other market structures and therefore they are not presented. Under $\{IN_1\}$, only the home country can impose Nash level tariff.

The welfare functions under $\{IN_1\}$ for the two countries are as follows:

$$W_H^{IN} = [k((14580k^3 - 44064k^2 + 39744k - 9216)(\alpha - c)^2 + (10206k^3 - 28512k^2 + 25056k - 6912)t_H(\alpha - c)) - (21141k^4 - 65448k^3 + 67428k^2 - 27744k + 3904)t_H^2]/54(9k-4)^2(3k-4)^2; \quad [3.34]$$

$$W_F^{IN} = [k((10206k^3 - 32400k^2 + 31968k - 9216)(\alpha - c)^2 - (7290k^3 - 21060k^2 + 19008k - 5184)t_H(\alpha - c)) + (9477k^4 - 26892k^3 + 27774k^2 - 11856k + 1760)t_H^2]/27(9k-4)^2(3k-4)^2$$

The first order condition for the home country is given by

$$\frac{\partial W_H}{t_H} = \frac{\left[\left(k\left(5103k^3-14256k^2+12528k-3456\right)(\alpha-c)-(21141k^4-65448k^3+67428k^2-27744k+3904)t_H\right]}{27(9k-4)^2(3k-4)^2} = 0; \quad [3.35]$$

Solving the FOC for t_H, we derive the Nash level tariff for the home country under the market structure {IN_1}.■

LEMMA 3.3 If governments choose tariffs simultaneously in the market structures, then the Nash level tariffs would be:

$$t_z^S = \frac{5k(625k^2 - 960k + 192)}{4(3125k^3 - 5100k^2 + 2080k - 256)}(\alpha - c) \quad [3.36]$$

$$t_z^{NN} = \frac{k(9k-8)}{27k^2 - 34k + 8}(\alpha - c) \quad [3.37]$$

$$t_z^I = \frac{2k(128k^2 - 186k + 45)}{1280k^3 - 2028k^2 + 936k - 135}(\alpha - c) \quad [3.38]$$

$$t_H^{N1} = t_F^{N2} = \frac{3k(38912k^5 - 178176k^4 + 292968k^3 - 215676k^2 + 70902k - 8505)(\alpha - c)}{389120k^6 - 1849344k^5 + 3261456k^4 - 2747088k^3 + 1171584k^2 - 243972k + 19683} \quad [3.39]$$

$$t_F^{N1} = t_H^{N2} = \frac{2k(51200k^5 - 227328k^4 + 353592k^3 - 235764k^2 + 64962k - 6075)(\alpha - c)}{389120k^6 - 1849344k^5 + 3261456k^4 - 2747088k^3 + 1171584k^2 - 243972k + 19683} \quad [3.40]$$

Proof of Lemma 3.3: It is similar to proof of Lemma 3.2. We used MAPLE to calculate the welfare for each market structure and to calculate the Nash tariff levels. Therefore, we skip the detailed proof. MAPLE code can be requested from the authors.

PROOF of Proposition 3.1

We use Horn and Persson's endogenous model; hence, first we will calculate the equilibrium profits under each market structure by using the profits calculated for stage 3 and 4, by Lemma 3.2 and Lemma 3.3. Then, by using the *dom* relation and decisive firms, we will find the EMS.

The firms' profit for all market structures after Nash tariffs are determined are as follows:

The profits of firms under no merger or {S} are:

$$\pi_i^S = \frac{k(14453125k^5 - 52625000k^4 + 69420000k^3 - 40729600k^2 + 10782720k - 1048576)}{16(3125k^3 - 5100k^2 + 2080k - 256)^2}(\alpha - c)^2, i = 1,2,3,4 \quad [3.41]$$

The profits of merger and the outsiders under $\{N_1\}$, respectively, are given by:

$$\pi_N^{N_1} = k(24645730304k^{11} - 236014534656k^{10} + 981480112128k^9 - 2336705667072k^8 + 3535403334912k^7 - 3566109941136k^6 + 2445335298432k^5 - 1139538886920k^4 + 353782661904k^3 - 69771885057k^2 + 7882332912k - 387420489)(\alpha - c)^2/(389120^6 - 1849344k^5 + 3261456k^4 - 2747088k^3 + 1171584k^2 - 243972k + 19683)^2 \quad [3.42]$$

$$\pi_j^{N_1} = k(66454552576k^{11} - 650067836928k^{10} + 2768821420032k^9 - 6771720904704k^8 + 10558287988992k^7 - 11010921982992k^6 + 7831238316768k^5 - 3796499957688k^4 + 1229486470272k^3 - 253546229889k^2 + 30019448718k - 1549681956)(\alpha - c)^2/4(389120^6 - 1849344k^5 + 3261456k^4 - 2747088k^3 + 1171584k^2 - 243972k + 19683)^2, i = 3,4 \quad [3.43]$$

The profits of firms if they form two national mergers {NN} are given by:

$$\pi_i^{NN} = \frac{k(9k-8)(1377k^4 - 3348k^3 + 2880k^2 - 1024k + 128)}{(9k-4)^2(27k^2 - 34k + 8)^2}(\alpha - c)^2, i = NH, NF \quad [3.44]$$

The merger's and the outsiders' profits under $\{I_1\}$ are as follows:

$$\pi_I^{I_1} = \frac{9k(8k-9)(4k-3)^2(32k^2 - 54k + 15)}{(2k-3)^2(1280k^3 - 2028k^2 + 936k - 135)^2}(\alpha - c)^2 \quad [3.45]$$

$$\pi_j^{I_1} = \frac{k(655360k^7 - 4435968k^6 + 12306240k^5 - 18026820k^4 + 14958756k^3 - 6984549k^2 + 1691280k - 164025)}{(2k-3)^2(1280k^3 - 2028k^2 + 936k - 135)^2}(\alpha - c)^2, j = 2,4 \quad [3.46]$$

Profit for the two cross-border mergers under {II$_1$} can be written as:

$$\pi_i^{II_1} = \frac{2k(9k-8)}{(9k-4)^2}(\alpha - c)^2, i = II_{13}, II_{24} \qquad [3.47]$$

The merger's and the outsider's profits under {IN$_1$} are, respectively:

$$\pi_{IN}^{IN_1} = \frac{2k(3k-4)^2(2394765k^5-7765308k^4+9708336k^3-5795568k^2+1637328k-175232)}{(12393k^4-39204k^3+40644k^2-16800+2368)^2}(\alpha - c)^2 \qquad [3.48]$$

$$\pi_4^{IN_1} = \frac{2k(10924065k^7-75792672k^6+212139000k^5-309277440k^4+254114064k^3-117877248k^2+28605696k-2803712)}{(12393k^4-39204k^3+40644k^2-16800+2368)^2}(\alpha - c)^2 \qquad [3.49]$$

Finally, if firms form a monopoly under {M}, the profit is:

$$\pi^M = \frac{k}{2k-1}(\alpha - c)^2. \qquad [3.50]$$

After calculating the profits, we turn our attention to the *dom* relation and decisive firms. First, consider part (i), and the following binary comparison of market structures. We will show that {IN} dominates all market structures when $\check{k} < k < 3.877711501(\alpha - c)^2$.

{IN$_1$} *dom* {S}: decisive group with respect to these two structures are {1,2,3}. From [3.41] and [3.48], $\pi_{IN}^{IN_1} - (\pi_1^S + \pi_2^S + \pi_3^S) > 0$ holds for all $k > \check{k}$.

{IN$_1$} *dom* {N$_1$}: decisive group with respect to these two structures are {1,2,3}. From [3.42], [3.43], and [3.48], $\pi_{IN}^{IN_1} - \left(\pi_N^{N_1} + \pi_3^{N_1}\right) > 0$ holds for all $k > \check{k}$.

{IN$_1$} *dom* {NN}: decisive group with respect to these two structures comprises all owners. From [3.44], [3.48], and [3.49], $\pi_{IN}^{IN_1} + \pi_4^{IN_1} - (\pi_{NH}^{NN} + \pi_{NF}^{NN}) > 0$ holds for all $k > \check{k}$.

$\{IN_1\}$ *dom* $\{I_1\}$: decisive group with respect to these two structures are {1,2,3}. From [3.45], [3.46], and [3.48], $\pi_{IN}^{IN_1} - \left(\pi_I^{I_1} + \pi_2^{I_1}\right) > 0$ holds for all $k > \check{k}$.

$\{IN_1\}$ *dom* $\{II_1\}$: decisive group with respect to these two structures comprises all owners. From [3.47], [3.48], and [3.49], we obtain the following conditions:

a) $\pi_{IN}^{IN_1} + \pi_4^{IN_1} - \left(\pi_{II_{13}}^{II_1} + \pi_{II_{24}}^{II_1}\right) > 0$ iff $\check{k} < k < 3.877711501$.

b) $\pi_{IN}^{IN_1} + \pi_4^{IN_1} - \left(\pi_{II_{13}}^{II_1} + \pi_{II_{24}}^{II_1}\right) < 0$ iff $k > 3.877711501$.

Therefore, {IN} is the EMS when $\check{k} < k < 3.877711501$.

Now consider part (ii) of the proposition. We will show that {II} dominates all other market structures when $k > 3.877711501$

$\{II_1\}$ *dom* {S}: decisive owners with respect to these two structures are two symmetric groups which are {1,3} and {2,4}. From [3.41] and [3.47], $\pi_{II_{13}}^{II_1} - (\pi_1^S + \pi_3^S) > 0$ and $\pi_{II_{24}}^{II_1} - (\pi_2^S + \pi_4^S) > 0$ holds for all $k > \check{k}$.

$\{II_1\}$ *dom* $\{N_1\}$: the decisive group comprises all firms. From [3.42], [3.43] and [3.47], $\pi_{II_{13}}^{\mathrm{II}} + \pi_{II_{24}}^{\mathrm{II}} - \left(\pi_N^{N_1} + \pi_3^{N_1} + \pi_4^{N_1}\right) > 0$ holds for all $k > \check{k}$.

$\{II_1\}$ *dom* $\{I_1\}$: decisive owners with respect to these two structures are the two outsiders, {2,4}, under $\{I_1\}$. From [3.46] and [3.47], $\pi_{II_{24}}^{II_1} - \left(\pi_2^{I_1} + \pi_4^{I_1}\right) > 0$ holds for all $k > \check{k}$.

$\{II_1\}$ *dom* {NN}: decisive group with respect to these two structures comprises all owners. From [3.44] and [3.47], we obtain the following conditions:

a) $\pi_{II_{13}}^{II_1} + \pi_{II_{24}}^{II_1} - (\pi_{NH}^{NN} + \pi_{NF}^{NN}) > 0$ iff $k > 2.792836525$,

b) $\pi_{II_{13}}^{II_1} + \pi_{II_{24}}^{II_1} - (\pi_{NH}^{NN} + \pi_{NF}^{NN}) < 0$ iff $\check{k} < k < 2.792836525$.

Notice that, from part (i) of the proposition, {NN} is dominated by {IN$_1$} for all $k > \check{k}$ and thus cannot be EMS. Therefore, and considering the dom relation of {II$_1$} and {IN$_1$} from part (i), we can conclude that {II$_1$} is the EMS if $k > 3.877711501$. ■

PROOF OF PROPOSITION 3.2

Part (i): the difference in R&D investments by an outsider firm under {I} and the same firm under {S} is given by:

$e_i^I - e_j^S = \frac{k(160000k^5 - 1069450k^4 + 2118095k^3 - 1699947k^2 + 554949k - 61560)(\alpha - c)}{(2k-3)(1280k^3 - 2028k^2 + 936k - 135)(3125k^3 - 5100k^2 + 2080k - 256)}$ for $i = 2,4$; $j = 1,2,3,4$. [3.51]

$e_i^I - e_j^S > 0$ iff $k > 3.969$

$e_i^I - e_j^S < 0$ iff $\check{k} < k \leq 3.969$.

Part (ii): the difference in R&D investments by the outsider of a merger under {IN} and the same firm under {S} is given by:

$e_4^{IN} - e_j^S = \frac{k(2318625k^5 - 13751820k^4 + 24528612k^3 - 17952128k^2 + 5531200k - 593408)(\alpha - c)}{(12393k^4 - 39204k^3 + 40644k^2 - 16800k + 2368)(3125k^3 - 5100k^2 + 2080k - 256)}$, $j = 1,2,3,4$; [3.52]

$e_4^{IN} - e_j^S > 0$ iff $k > 3.470$

$e_i^{IN} - e_j^S < 0$ iff $\check{k} < k \leq 3.470$. ■

PROOF OF PROPOSITION 3.3

We first find the set of market structures which will be approved by the merger policy, and then find the EMS among these market structures. We make binary comparisons of welfare levels between each market structure and status-quo to determine the welfare-increasing ones compared to status-quo.

{N} and {S}

$\mathcal{W}^{N,S} = W_z^N - W_z^S < 0$ $(z = H, F)$ holds for all k. Therefore, {N} is never approved by competition regulators.[30]

{NN} and {S}

$\mathcal{W}^{NN,S} = W_z^{NN} - W_z^S < 0$ $(z = H, F)$ holds for all k. Therefore, {NN} is never approved by competition regulators.

{I} and {S}

$\mathcal{W}^{I,S} = W_z^I - W_z^S > 0$ $(z = H, F)$ holds for all k. Therefore, {I} is always approved by competition regulators.

{II} and {S}

$$\mathcal{W}^{II,S} = \frac{-k(7421875k^6 - 93625000k^5 + 243270000k^4 - 252358400k^3 + 118471680k^2 - 25657344k + 2097152)(\alpha - c)^2}{8(9k-4)(3125k^3 - 5100k^2 + 2080k - 256)^2}$$

Where $\mathcal{W}^{II,S} = W_z^{II} - W_z^S, z = H, F$. The following condition is derived:

$\mathcal{W}^{II,S} > 0$ iff $\check{k} < k < 9.532$

[30] We calculated the welfares by using MAPLE. They are available from the authors.

And thus, {II} would be approved by both countries' regulators iff $\check{k} < k < 9.532$. It will be declined otherwise.

{IN} and {S} for the country with the merger bias (two of the three merger participants is located in the country)

$\mathcal{W}^{IN,S} = [-k(1920776319140625k^{13} - 23020498277437500k^{12} + 119224604061315000k^{11} - 355794523870795200k^{10} + 685601718757428240k^{9} - 903480426252666432k^{8} + 839496350648523264k^{7} - 557948236714440704k^{6} + 265761255695241216k^{5} - 89798606158905344k^{4} + 20973952512819200k^{3} - 3215567218540544k^{2} + 290878438506496k - 11759620456448)(\alpha - c)^{2}]/[24(12393k^{4} - 39204k^{3} + 40644k^{2} - 16800k + 2368)^{2}(3125k^{3} - 5100k^{2} + 2080k - 256)^{2}]$; [3.53]

where $\mathcal{W}^{IN,S} = W_z^{IN} - W_z^{S}, z = H, F$. The following conditions are derived:

$\mathcal{W}^{IN,S} > 0$ iff $\check{k} < k < 3.247600743$

And thus, {IN} would be approved by the regulators of the country hosting two of the three-merger participants iff $\hat{k} < k < 3.247600743$. It will be declined otherwise.

{IN} and {S} for the country without the merger bias (one of the three merger participants is located in the country)

$\mathcal{W}^{IN,S} = [k(109033055859375k^{13} + 195681414937500k^{12} - 7618832971515000k^{11} + 40967141001595200k^{10} - 112402203725748240k^{9} + 190325399888250432k^{8} - 214226443124120064k^{7} + 165912436513503232k^{6} - 89583888282341376k^{5} + 33614809018482688k^{4} - 8581845307359232k^{3} +$

$1420192975421440k^2 - 137268933165056k + 5879810228224)(\alpha - c)^2]/$

$[24(12393k^4 - 39204k^3 + 40644k^2 - 16800k + 2368)^2(3125k^3 - 5100k^2 + 2080k - 256)^2]$; [3.54]

Where $\mathcal{W}^{IN,S} = W_z^{IN} - W_z^S, z = H, F. \mathcal{W}^{IN,S} > 0$ holds for all k. Thus, the merger is approved by the regulators of the country hosting one of the three merger participants. Since, the merger must be approved by both countries, and from (e-iii), {IN} is approved for $\check{k} < k < 3.247600743$.

Therefore, the set of merger applications which can be approved by the competition regulators of the two countries are {I}, {II}, {IN_1}, {IN_2}, {IN_3}, and {IN_4}.

To determine the EMS among the approved market structures, we need to find the *dom* relation between {I} and {S}. This relation is as follows for, say {I_1}, which the decisive group is {1,3}. From [3.45] and [3.41], we obtain the following conditions:

i) I *dom* S iff $\pi_M^{I_1} - (\pi_1^S + \pi_3^S) > 0$ iff $\check{k} < k < 21.18540616$.

ii) S *dom* I $\pi_M^{I_1} - (\pi_1^S + \pi_3^S) < 0$ iff $k > 21.18540616$.

Hence, {I} is dominated by {S} for very inefficient *k*.

Given the dom relation between {I} and {S}, and the proof of Proposition 3.1, we can determine the EMS

{M} if $\check{k} < k < 2.627523310$;

{IN} if$2.627523310 < k < 3.247600743$;

{II} if $3.247600743 < k < 9.532$;[31]

{I} if $9.532 < k < 21.18540616$;

{S} if $k > 21.18540616$. ■

PROOF OF PROPOSITION 3.4: Analogous to proposition 3.3, first, we need to find the set of market structures which are approved according to the merger policy and then find the EMS from this set. In doing so, we make binary comparisons of consumer surplus levels between each candidate market structure and {S}.

{N} and {S}

$\mathcal{C}^{N,S} = CS_z^N - CS_z^S < 0$ $(z = H, F)$ holds for all k. Therefore, {N} is never approved by competition regulators.

{NN} and {S}

$\mathcal{C}^{NN,S} = CS_z^{NN} - CS_z^S < 0$ $(z = H, F)$ holds for all k. Therefore, {NN} is never approved by competition regulators.

{I} and {S}

$\mathcal{C}^{I,S} = CS_z^I - CS_z^S > 0$ $(z = H, F)$ holds for all k. Therefore, {I} is always approved by competition regulators. However, {I} is dominated by {S} for very inefficient k (see proposition 3.3).

{II} and {S}

[31] If $3.247600743 < k < 3.877711501$, {IN} will be denied and thus {II} will emerge.

$$\mathcal{C}^{II,S} = \frac{-k^2(76875k^3-130900k^2+59680k-8192)(1875k^3-8500k^2+9760k-2048)(\alpha-c)^2}{8(9k-4)^2(3125k^3-5100k^2+2080k-256)^2}; \text{ [3.55]}$$

where $\mathcal{C}^{II,S} = CS_z^{II} - CS_z^S, z = H, F$. The following condition is derived:

$\mathcal{C}^{II,S} > 0$ iff $\check{k} < k < 2.830838672$

and thus, {II} would be approved by both countries' regulators iff $\hat{k} < k < 2.830838672$.

{IN} and {S}

$\mathcal{C}^{IN,S} = CS_z^{IN} - CS_z^S < 0$ $(z = H, F)$ holds for all k, regardless of the merger bias. Therefore, {IN} is never approved by competition regulators.

To sum up, the set of merger applications which are approved by the competition regulators of the two countries are {I} and {II}. From proposition 3.1 (and its proof in the appendix), and with consumer surplus-increasing merger policy, we obtain the following set of EMS:

If $\check{k} < k < 2.830838672$, {II} is the equilibrium.

If $2.830838672 < k < 21.18540616$, {I} is the equilibrium market structure.

If $k > 21.18540616$, {S} is the equilibrium market structure. ■

PROOF OF PROPOSITION 3.6

The following welfare functions are derived by summing up the welfare of the two countries after the Nash tariffs. These functions are used in constructing figure 3.3 in the text and figure 3.4 below. The subscript *G* stands for global levels, and the superscript denotes the market structure:

$$W_G^S = \frac{k(875k^2-1160k+256)(40625k^3-69500k^2+30560k-4096)(\alpha-c)^2}{4(3125k^3-5100k^2+2080k-256)^2}; \text{[3.56]}$$

$$\begin{aligned} W_G^N = [k(&263502954496k^{11} - 2426328317952k^{10} + 9649423908864k^9 \\ &- 21859121700864k^8 + 31331155290624k^7 - 29835864154224k^6 \\ &+ 19271600175744k^5 - 8454324443688k^4 + 2474180183808k^3 \\ &- 461412291159k^2 + 49517074224k - 2324522934)(\alpha - c)^2] \\ &/2(389120k^6 - 1849344k^5 + 3261456k^4 - 2747088k^3 + 1171584k^2 \\ &- 243972k + 19683)^2 \end{aligned}$$

$$W_G^{NN} = \frac{k(117k^2 - 144k + 32)(45k^2 - 60k + 16)(\alpha - c)^2}{(9k - 4)(27k^2 - 34k + 8)^2}$$

$$W_G^I = \frac{k(5963776k^7 - 34947072k^6 + 83117376k^5 - 103432680k^4 + 72445752k^3 - 28526742k^2 + 5875740k - 492075)(\alpha - c)^2}{(2k - 3)^2(1280k^3 - 2028k^2 + 936k - 135)^2}$$

$$W_G^{II} = \frac{8k(\alpha - c)^2}{9k - 4}$$

$$W_G^{IN} = \frac{4k(33008391k^7 - 194658309k^6 + 463330530k^5 - 575343972k^4 + 403093152k^3 - 159675840k^2 + 33197568k - 2803712)(\alpha - c)^2}{(12393k^4 - 39204k^3 + 40644k^2 - 16800k + 2368)^2}$$

$$W_G^M = \frac{k(3k - 1)(\alpha - c)^2}{(2k - 1)^2}$$

In order to prove the proposition, we need to compare the global welfare of each market structure. Figure 3.6 depicts that {I} and {II} are the only market structures that maximize the global welfare depending on *k*.

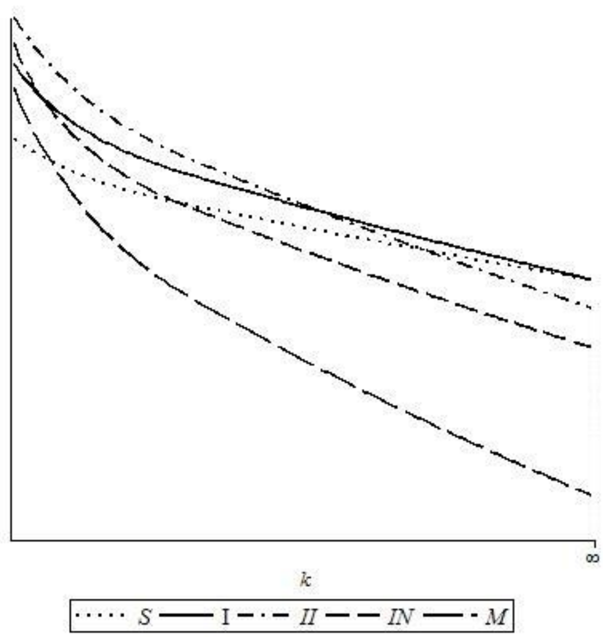


Figure 3.6 Global welfare

We compare the global welfare under {I} and {II}.

$\mathcal{W}^{II,I} = [-k(1245184k^8 - 14958592k^7 + 63192384k^6 - 132159528k^5 + 153907992k^4 - 103540518k^3 + 39641076k^2 - 7986195k + 656100)(\alpha - c)^2]/(9k - 4)(2k-3)^2(1280k^3 - 2028k^2 + 936k - 135)^2$; [3.57]

where $\mathcal{W}^{II,I} = \sum_z W^{II} - \sum_z W^{I}, z = H, F$. The following conditions are derived:

$\mathcal{W}^{II,I} > 0$ iff $\check{k} < k < 5.973$

$\mathcal{W}^{II,I} < 0$ iff $k > 5.973$

This completes the proof. ■

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Chapter 4. The Information Content of the Limit Order Book

Abstract

Price discovery is a fundamental function of electronic markets and is defined as the incorporation of information to prices through the actions of traders. Recent finance literature has found evidence that, as a part of their trading strategies, informed traders may submit limit orders instead of market orders. If so, the steps of limit order book (LOB) beyond the best bid and best ask spread (BAS) contain valuable information and contribute to price discovery of the underlying asset. This is the first attempt to examine the informativeness of the LOB beyond the BAS for agricultural commodities. We reconstruct the LOB using market depth data and apply three information share approaches to test whether the steps of LOB beyond BAS contribute to price discovery in agricultural commodity markets. This is done for five major agricultural commodities namely lean hogs, live cattle, corn, wheat, and soybeans as well as the CME E-mini S&P 500. We find that a substantial market depth exists at the steps beyond the best bid and ask prices in the futures markets. The results of the three information share measures show that the steps of the LOB beyond the BAS contribute by over 27% to price discovery of futures contracts. Across agricultural commodities, the steps of the LOB beyond the BAS have more information for grains than meats. Moreover, we find that the steps closer to the top of the book contain more information that the steps farther from the top for all the products. These findings indicate that informed traders in futures electronic markets actively use limit orders with price steps beyond the BAS and especially the steps near the top of the book. The results also show that for E-mini S&P 500, the steps closer to the top of the book contain more information at the beginning and the end of the week whereas steps farther have more information in the middle of the week. For agricultural commodities a clear pattern is not observed.

Keywords: Futures Markets, Information Share, Commodity Markets, Electronic Trading, Limit Order Book

4.1. Introduction

Agricultural commodity futures were traditionally traded in the open outcry pit, however, over the past decade there has been a major shift to trading on the electronic platform. Grain and livestock futures contracts trading electronically weighed less than five percent of overall trade in 2006 and grew to over eighty and ninety percent, respectively, in 2011 (Irwin and Sanders 2012). Today the Chicago Mercantile Exchange (CME) Group, the largest futures contracts open interest exchange, has completely migrated its agricultural futures trading to the electronic platform, and pit trading for these commodities futures contract is non-existent. The electronic system differs significantly from the traditional open outcry system. One major difference is the presence of the limit order book (LOB) in the electronic system, which contains actual bid and ask prices and their corresponding volumes at different steps (Gould et al., 2013).

Trades in the electronic platform are conducted through a computerized system where all traders submit their orders with the number of contracts they want to trade and their intended prices. Traders can buy or sell contracts at existing market prices. If the price for which a trader intends to sell (buy) a contract is less than or equal (greater than or equal) to the price for which another trader intends to buy (sell) the contract, the trade will take place. This is also known as a market order. If, however, a trader’s bid price is lower than the lowest ask price for the contract (i.e., the best ask), the order will remain active in the exchange electronic system on the bid side until it is matched or cancelled (or expired if it is a futures contract). The bid side, thus, can be thought of as the demand side for the underlying contract. Similarly, if a trader’s ask price is higher than the highest bid price (i.e., the best bid), it remains active on the ask side until it is matched or cancelled (or expired). The ask side can be considered the supply side for the contract. The orders resting in the system are called limit orders and the system storing these orders is the LOB. At any point in time, the LOB contains all the resting orders on the demand and supply sides at different price steps. In the LOB, the best bid and best ask are the highest bid and the lowest ask prices, respectively, at that point in time which are referred to as “the top of the book”. The difference between the lowest ask and the highest bid is called “the spread” or bid-ask spread (BAS). The other bids and asks are resting in descending and ascending order beyond the best bid and best ask, respectively, in the LOB.

The information contained in the LOB has been the subject of much controversy. If informed traders use limit orders, their information is presumably reflected in the book. If, however, informed traders use market orders, the orders in the book may not contain any of their private information. Several studies on the type of orders used by informed traders and the extent to which prices in the LOB carry information about the efficient price have been conducted, however the results are mixed (some examples are Harris and Panchapagesan 2005, Kaniel and Liu 2006, and Madhavan et al. 2005). In addition, only few of those studies analyze futures markets and none of them examine agricultural commodities.

One of the most important functions of futures markets is price discovery, which is the process of incorporating market participants’ new information into market prices. Many studies have examined the contribution of related price series, such as securities trading in different markets or spot and futures prices of a commodity, to an underlying common efficient price. Hasbrouck’s (1995) Information Share (IS) and Gonzalo and Granger’s (1995) Permanent-Transitory (PT) measures have been widely used to assess the contribution of the related series to price discovery (some examples are De Jong 2002, Huang 2002, Booth et al. 2002, Chu et al.

1999, and Harris et al. 2002). Cao et al. (2009) study the information share of the steps of the LOB beyond the spread on the underlying price. By looking at 100 active Australian stocks, they find that a share of about 22 percent of the price discovery can be attributed to the steps of the LOB beyond the best bid and best ask, whereas the remaining 78 percent is contributed by the best bid and ask and the last transaction price. However, the informational content of the LOB in agricultural markets may differ considerably for a variety of reasons. Markets for futures contracts are different from spot markets because many market participants trade in futures markets for the purpose of hedging and risk management. This implies that trading algorithms which are practiced in the two markets can be different. Agricultural commodity trading in futures market can be different from trading other contracts due to differences in market characteristics such as tick size, availability of the commodity etc. Even though much research on price discovery has been done for agricultural futures markets in the traditional outcry system, none has been done for the electronic market at the microstructure level.

The objective of the research is to assess the informational content of the LOB beyond the best bid and ask (BAS) quotes in agricultural futures markets. We reconstruct the full LOB and compute both the BAS at the best quotes and the bid and ask at subsequent steps of the LOB beyond the best quotes. The informational content of the order book is then assessed by estimating the contribution of each of these series to price discovery. Cao et al. (2009) examines the contribution of the LOB to price discovery for the stock markets. This study focuses on electronic futures markets. The study, specifically, is performed using nearby contracts for five major agricultural commodities, namely soybeans, corn, wheat, live cattle, and lean hogs, as well as the popular E-mini S&P 500 from the CME Group. The products under study cover majorly traded agricultural commodities and, in order to compare the results with other actively traded futures contracts for which more research exists, the E-mini S&P 500 is also examined. Agricultural commodities are generally less traded and their market characteristics may be different from those of other products. Grain traders have access to nine steps beyond the best BAS and livestock traders have access to four steps beyond the best BAS in real time. Therefore, a better understanding of the contribution of the LOB to price movements may play a fundamental role in developing their trading algorithms and strategies.

One difficulty in assessing the information content of the LOB is that both Hasbrouck's IS and Gonzalo and Granger's PT measures use different approaches to estimating the contribution of price series to the common price, and there is no consensus in the literature favoring either estimate. While the PT measure is unique, it ignores the correlations between different price series (Hasbrouck 2000; Ballie et al. 2002). On the other hand, while IS accounts for this correlation, it is not unique as it is sensitive to the ordering of price series in the model. Lien and Shrestha (2009) propose an alternative measure, the modified information share (MIS), which uses an eigenvector factorization of the correlation matrix of residuals and thus is independent of the ordering. Here we estimate IS, PT, and MIS to assess the information content of the LOB.

4.2. Background

4.2.1. Information Contained in the LOB

The evidence on the extent to which price steps beyond the BAS carry information about the efficient price is mixed. Glosten (1994), Rock (1996), and Seppi (1997) argue that informed traders favor and actively submit market orders, suggesting that the LOB beyond the best bid and offer contains little information. However, Bloomfield et al. (2005) use an experimental market setting and find that in an electronic market, informed traders submit more limit orders than market orders. This suggests that key trader information is contained in the book. In the context of stock trading at the New York Stock Exchange (NYSE), Harris and Panchapagesan (2005) show that the imbalances in the limit buy and sell orders in the book have information regarding the short run price movements and that (NYSE) specialists benefit from it by buying for their own account when the book is heavy on the buy side and sell when it is heavy on the sell side, especially for more active stocks. Kaniel and Liu (2006) show that informed traders prefer limit orders, and that limit orders convey more information than market orders. Baruch (2005) provides a theoretical model showing that an LOB improves liquidity and information efficiency of prices. Boehmer et al. (2005) find that the deviations of transaction prices from the efficient prices became smaller after the NYSE's adoption of the LOB system. In contrast, Madhavan et al. (2005) find larger spreads and higher volatility after the Toronto Stock Exchange disseminated the top four price steps of the limit-order book in April 1990. More recently, Biais et al. (2015) and Martinez and Roşu (2011) develop theoretical models to compare algorithmic traders and humans in the informativeness of prices. Both studies suggest that algorithmic traders are advantageous compared to humans due to their quicker response to new information and that algorithmic traders use market orders to exploit their information. Hautsch and Huang (2012), on the other hand, estimate impulse response functions for thirty stocks traded at Euronext Amsterdam and find that limit orders, especially for orders posted on up to two steps beyond the market price, have a significant effect on quote adjustments. Moreover, Eisler et al. (2012) find further support on the effect of limit orders on market prices and Cont et al. (2014) argue that the order flow imbalances between supply and demand at the best bid and ask spread are the main driving force behind market price changes.

Research on agricultural markets at the microstructure level has relied on the transaction prices to study the best bid and ask. Examples of the earlier studies are Brorsen (1989), Bryant and Haigh (2004), and Hasbrouck (2004). Among the more recent studies, Frank and Garcia (2011), Shah and Brorsen (2011), and Martinez et al. (2011) used trade data to estimate BAS in measuring the cost of liquidity and comparing open outcry to electronic trading for different agricultural commodity markets. Wang et al. (2014) reconstructed the best bid and ask steps of a limit order book to study the liquidity costs in corn futures markets. Using CME Group RLC market depth data[32], Aidov (2013) and Aidov and Daigler (2015) reconstruct the five-step LOB for futures contracts of the 10-Year U.S. Treasury note, corn, light sweet crude oil (WTI), euro/U.S. dollar, yen/U.S. dollar, and gold futures to study the characteristics of the market depth in electronic futures market such as duration, symmetry, and equality of depth. They find that the steps beyond the BAS contain a large amount of depth for all the futures contracts studied. Aidov (2013) derives the market depth from the five bid and ask steps to, firstly, study the relationship between the market depth and the bid-ask spread and secondly, to examine the link between the transitory volatility and the market depth. His results indicate a negative relationship between the five-step market depth and the spread. His results also suggest a decrease in market depth following an increase in volatility. He concludes that market participants in the U.S. electronic futures market actively manage depth along the LOB. Our study extends the previous literature on agricultural commodity electronic trading in some important ways. First, we reconstruct the LOB for four other major agricultural commodities i.e. soybeans, wheat, live cattle, and lean hogs besides corn and for the E-mini S&P 500 futures contracts. Second, this is the first study

[32] RLC market depth data was discontinued in 2009 and the current format of the CME Group market depth data is FIX which is the format used in the present study. The period of study in Aidov (2013) and Aidov and Daigler (2015) for different contracts ranges from January 2008 to March, April, or October 2009, depending on when the RLC data was discontinued for the specific contract.

that examines the contribution of the LOB beyond the BAS to price discovery in agricultural commodity markets.

4.2.2. Information Share Measures

Hasbrouck's IS and Gonzalo and Granger's PT are the two most well-known information share measures used in the majority of the literature (some examples are Anand and Subrahmanyam 2008, Chen and Gau 2010, Frijns et al. 2010, Korczak and Phylaktis 2010, Anand et al. 2011, Fricke and Menkhoff 2011, Liu and An 2011, Chen and Chung 2012, Chen and Choi 2012, Rittler 2012, and Chen et al. 2013). However, some weaknesses have been identified in both measures and therefore efforts have been made to generate new measures. The IS measure is problematic because of its non-uniqueness and sensitivity to price ordering in the estimation. To overcome this problem, Hasbrouck has proposed calculating upper and lower bounds for the information shares of price series. High frequency data minimizes the correlation between price series and results in close lower and upper bounds. However, the bound widens as the contemporaneous correlation of disturbances across the price series increases, making the discrepancies between the orderings become large enough to deemed inference on the information share of prices unreasonable (Tse, 1999; Huang, 2000; Harris et al. 2002). Lien and Shrestha (2009) avoid the order-dependency problem by using an eigenvector factorization of the correlation matrix of residuals (instead of a Cholesky factorization) in their modified IS (MIS) new measure. They later extend their MIS measure for the cases where the price discovery contribution of different but related financial securities are analyzed such as price discovery in markets for different securities issued by the same firm and propose the Generalized Information Share, GIS (Lien and Shrestha 2014). Yan and Zivot (2010) and Putnins (2013) showed that the information shares calculated using IS and PT do not account for the different levels of noise in the price series. They argue that this may result in misleading measures of information share and develop a new information share metric, the Informational Leadership (IL) by combining IS and PT. The IL is, however, applicable to a two price series setting. Moreover, different level of noise arises when studying, for example, price discovery of an asset traded in different markets with different characteristics such as minimum tick size, inventory management, or other market imperfections and microstructure frictions. Another measure of price discovery was developed by Grammig and Peter (2013) to address the IS problem of non-uniqueness, particularly for longer sampling intervals. They assume a multivariate mixture distribution to develop the tail-dependent information shares (TLS). Like MIS, TLS follows from Hasbrouck (1995) contribution of a price series variance to the variance of the efficient price as the measure of the series information share by means of reduced VECM long run impact coefficients. However, the variance decomposition under TLS is performed using a VECM which is extended by the mixture parameters and estimated by a two-step process. This, unlike IS, results in an order neutral measure and is claimed to be superior to IS and PT when correlations of price innovations in the tails differ from those in the center of the distributions. Lien and Wang (2016) compare the IS upper and lower bound midpoint with the two unique, more recent, information shares of MIS and TLS. They find that TLS performs poorly for the simulated data even when the underlying assumptions of the approach are met. Moreover, their results show that MIS at most marginally improves the information share computed by the IS midpoint. They, therefore, support the use of the IS midpoint as a method of computing the information shares of different price series.

4.3. Data

4.3.1. Date and Time

We estimate the information contained in the limit order book for live cattle, lean hogs, corn, wheat, soybeans, and E-mini S&P 500 nearby futures contracts trading in the CME Group for the period of November 23, 2015 to March 31, 2016. The total number of the LOB updates for the nearby futures contracts during this period is 19,280,306 for live cattle, 14,487,393 for lean hogs, 48,400,937 for corn, 38,690,537 for wheat, 106,390,881 for soybeans, and 575,528,486 for E-mini S&P 500. The LOB is updated when a trader submits a market order, a limit order or a deletion/cancellation order. Corn, soybeans and wheat futures contracts trade in two sessions, 8:30 am to 1:20 pm CT (morning session) and 7:00 pm to 7:45 am CT (evening session). We use data from the morning session from Monday to Friday only, due to the low volume traded in the evening session and on Sunday. Live cattle and lean hogs futures contracts trade in one session only, 8:30 am to 1:05 pm CT. For the E-mini S&P 500 futures contract we use the most active daily trading hours, from 7:30 am to 3:15 pm CT, from Monday to Friday.[33] There is no trading on the CME Group on Saturdays and the two federal holidays of Jan. 18 and Feb. 15. We also remove the data for Sundays and the days for which there are extended trading halts. The latter is mostly the case for a few futures contracts with partial pre-holiday (a day prior) and post-holiday (a day after) trading with extended trading breaks. After thinning the data and restricting the data to the nearby futures contracts, we are left with total LOB updates of 6,961,908 for live cattle, 6,176,794 for lean hogs, 25,305,597 for corn, 21,285,007 for wheat, 42,625,431 for soybeans, and 386,421,232 for E-mini S&P 500.

[33] These hours correspond to 8:30 am – 4:15 pm ET. In GMT, this period is from 1:30 pm to 9:15 pm for before 13 Mar. 2016 (start of the daylight saving) and it is from 12:30 pm to 8:15 pm on and after 13 Mar. 2016. There is also a 15-minute trading halt from Monday to Friday at 3:15 pm - 3:30 pm CT.

The minimum price fluctuation (tick size) is $.00025 per pound or $10 per contract for live cattle and lean hogs, ¼ of one cent per bushel or $12.50 per contract for corn, wheat, and soybeans, and 0.25 index points or $12.50 for E-mini S&P 500. The listed contracts and their unit for each commodity are reported in Table 4.1.

Insert Table 4.1 Here

4.3.2. Roll Dates

Traders in the CME Group futures can choose to roll their futures positions from one futures contract month to the next at any time. They roll forward their futures positions before the futures contracts are very close to termination and becoming very illiquid. Traditionally, traders in the CME Group roll forward expiring futures contracts eight calendar days before the contract expiry. This is called the "roll date" and it originates in the trading floor. The eight calendar day roll period seems to be a good approximation of when traders roll their futures position to the next contract for the E-mini S&P 500. However, the period proves to be too short for the agricultural commodity futures contracts. Traders of the agricultural commodities start to roll their position considerably earlier than eight calendar days prior to expiration. We use the following rule to find the roll dates for each agricultural commodity and each contract month. We define a date as a roll date for the current contract when its aggregate volume traded for two consecutive days fall below that of the second nearest contract. If this is the case, we use the data of the second nearest contract starting the roll date.

In figures 4.1 - 4.6, the average daily volume and the average daily number of trades for the near and active contracts are plotted for the six futures markets under study. The vertical lines show the roll dates for each contracts, that is, when the highest aggregate volume traded switches from one contract to the next. It can be seen in the figures that the roll period for agricultural commodities, is considerably longer than that of E-mini S&P 500.[34]

In figure 4.1, nearby contracts for lean hogs are depicted using the aggregate volume rule. The most active contracts during the period of study for lean hogs are December 2015, February 2016, April 2016, and June 2016. Contracts expire on the 10th business day of the contract month at 12:00 pm CT. The December contract, depicted by the colour grey in the figure, is less active than the February contract and thus our data set for lean hog starts with the February contract. The total number of LOB updates for the lean hogs February futures contract during the study time period is 3,653,611 from which 2,393,517 are considered to be nearby and within the active trading sessions.

The February contract expires on February 12th. Aggregate volume for the February contract is the highest among all trading contracts until January 20th when the April contract becomes the most active contract. Similarly, the April contract expires on April 14th and it is the most active contract until March 22nd when the June contract takes over. The June contract is the nearby contract for the rest of the study period that is from March 22nd to March 31st. The total number of LOB updates for the lean hogs April and June futures contracts are 6,023,898 and 4,809,884, respectively. After thinning the data, 3,372,713 observations are left for the lean hogs nearby April contract and 410,564 observations remain for the nearby June contract.

A similar pattern to lean hogs is seemingly the case for live cattle as illustrated in figure 4.2. Contracts traded during the period of study for live cattle are December 2015, February

[34] We also considered alternative rules where we examined the daily number of trade price changes and the daily average duration of price changes to determine the roll dates. These rules almost always result in the same roll dates as the case of aggregate volume rule. In the isolated exceptions, the roll date is one day before the roll date defined by the aggregate volume rule.

2016, April 2016, and June 2016. Contracts expire on the last business day of the contract month at 12:00 pm CT. Similar to the lean hogs case, December contract, the grey series in the figure, is less active than the February contract for live cattle and thus our data starts with the February contract with a total LOB updates of 5,174,529. The February contract for live cattle expires on February 29th and it is the most active contract until January 18th. During its time as the nearby contract, the LOB for the February contract is updated 2,867,611 times during the active trading sessions.

Starting from January 18th, the April contract has the highest aggregate volume and becomes the most active contract with a total 7,168,819 LOB updates from which 3,216,374 book updates take place within active trading session when the April contract is the nearby contract. The April contract expires on April 30th, however, the June contract has the highest aggregate volume traded from March 17th. Thus, from March 17th to 31st, the June contract is considered the nearby contract. The LOB for the live cattle June futures contract is updated 6,936,958 times during the period of study and 877,923 qualify as updates of the nearby contract in active trading session.

During the period of study, corn and wheat were traded mostly for the December, March, and May contracts. For both corn and wheat, as can be seen in figures 4.3 and 4.4, the December contract had a lower aggregate volume than the March contract over this period and thus our data starts with the March contract from November 23, 2015. The March contract LOB during the study period is updated 21,762,926 and 18,328,313 times in total for corn and wheat, respectively. After thinning the data, 17,342,525 LOB updates for corn and 14,062,660 updates for wheat are considered within the nearby range. Corn and wheat contracts expire on the business day prior to the 15th calendar day of the contract month. The March contracts expiry dates for corn and wheat is March 14th. However, the roll dates for corn and wheat March contracts are, February 22nd and February 19th, respectively, when traders roll their positions to the May contract. Therefore, the data for corn nearby contract is that of the March contract from November 23rd 2015 to February 21st 2016 and is that of the May contract from February 22nd to March 31st 2016. For wheat, the nearby contract is the March contract from November 23rd 2015 to February 18th 2016 and it is the May contract from February 19th to March 31st 2016. For corn, the total number of LOB updates for the May contract is 26,638,011 during the study time period and 7,963,072 is considered nearby after thinning the data. These numbers are 20,362,224 and 7,222,347 for wheat, respectively.

Figure 4.5 illustrates the distribution of soybean trades and volumes for the period of study for January, March, and May contracts. Soybean contracts, also, expire on the business day prior to the 15th calendar day of the contract month. The January contract expires on January 14th and the March contract expires on March 14th. It can be seen in the figure that the January contract is the nearby contract from November 23rd to December 20th 2015 and the March contract is the nearby contract from December 21st 2015 to February 21st 2016. The May contract is the nearby contract from February 22nd to March 31st 2016 with the highest aggregate volume. The total number of book updates for the soybeans January, March, and May futures contracts over the period of

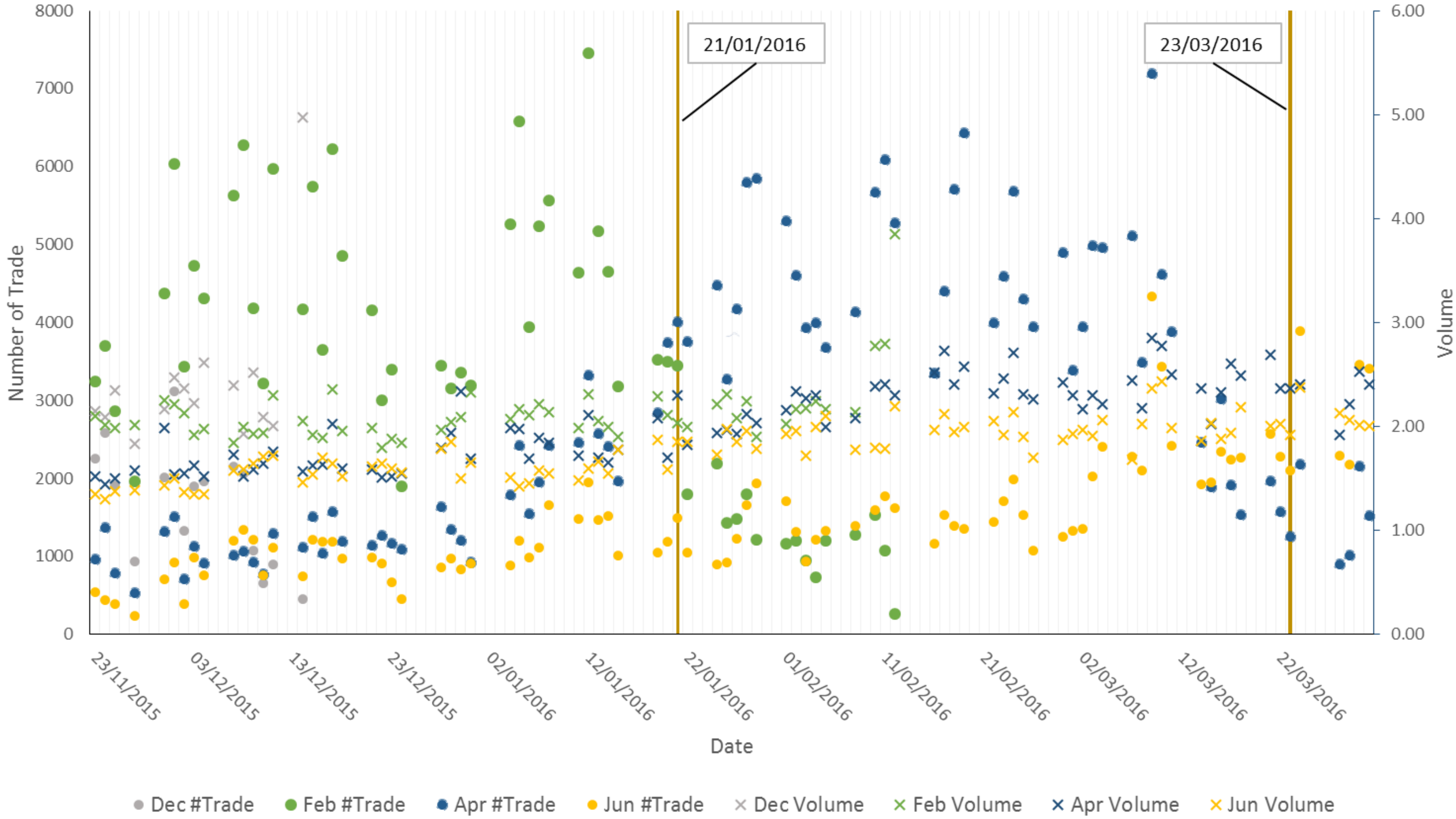

Figure 4.1 Roll dates for lean hogs

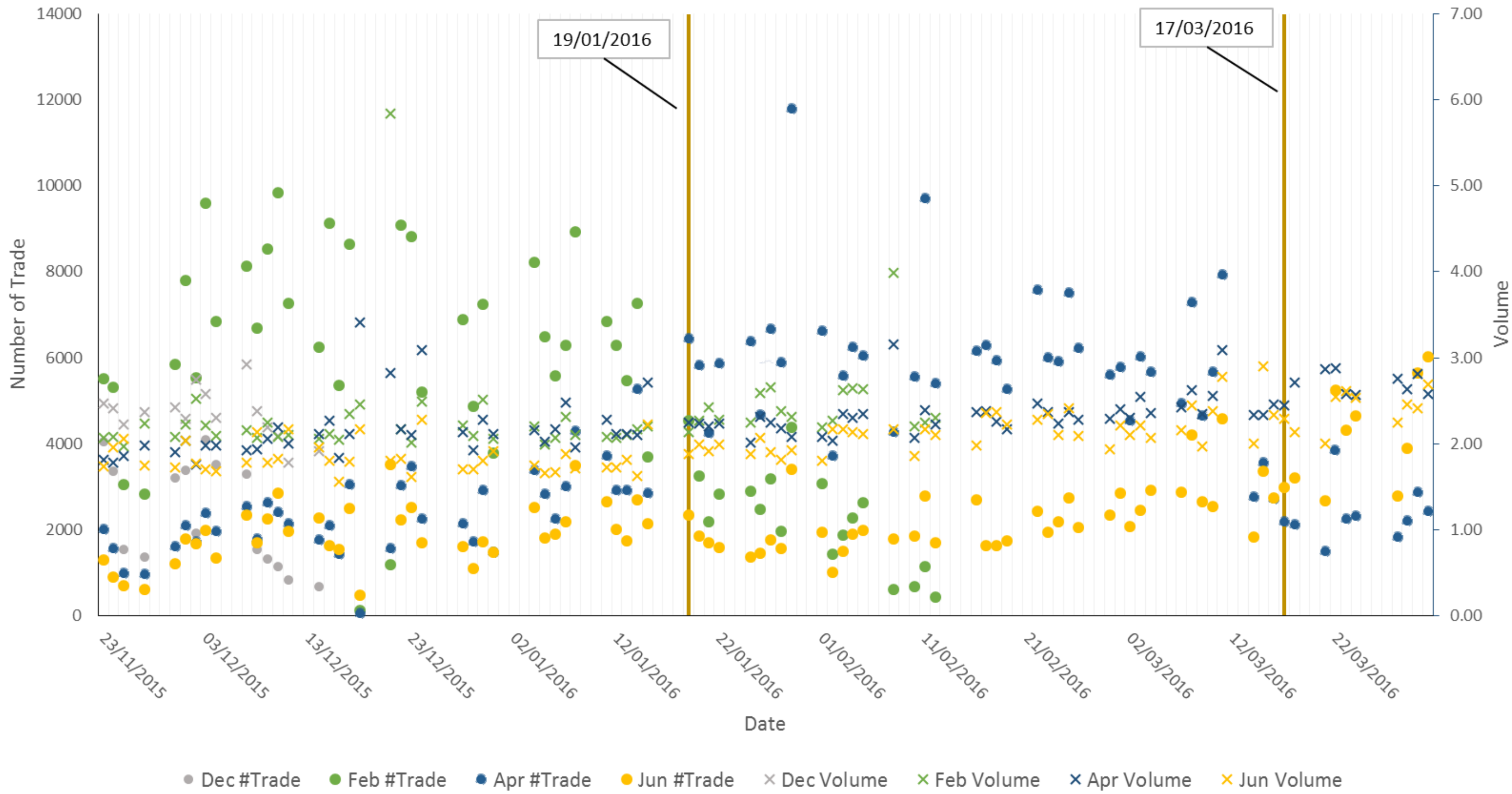

Figure 4.2 Roll dates for live cattle

study are 16,774,033, 39,302,050, and 50,314,798, respectively. From the total LOB updates after thinning the data, 10,204,153 updates are considered for the January contract, 17,958,952 for the March contract, and 14,462,326 updates for the May contract, making a total of 42,625,431 LOB updates for the nearby contracts for soybeans during the study period of time.

Figure 4.6 depicts the nearby contracts for E-mini S&P 500. For E-mini S&P 500, as can be seen in the figure, the eight calendar day rule coincides with the aggregate volume rule. The contracts traded during the period of study for E-mini S&P 500 are December, March, and June contracts with the total LOB updates of 66,993,209, 401,883,799, and 106,651,478, respectively. The December contract and the March contract expire on December 18th 2015 and March 18th 2016, respectively. The nearby contracts are the December contract from November 23rd to December 10th 2015, the March contract from December 11th 2015 to March 10th 2016, and the June contract from March 11th to March 31st 2016. After thinning the data, 42,976,237, 297,144,772, and 46,300,223 book updates are considered as the nearby contract book updates for December, March, and June futures contracts, respectively.

Table 4.2 summarizes the nearby contracts for our data for each commodities based on our roll date rule. Table 4.2 also reports the expiration date for the contracts. It can be seen in table 4.2 that traders of grains, on average, roll their position over three weeks before the expiration date of their contract. This roll period seems to be even longer for the livestock traders.

Insert Table 4.2. Here

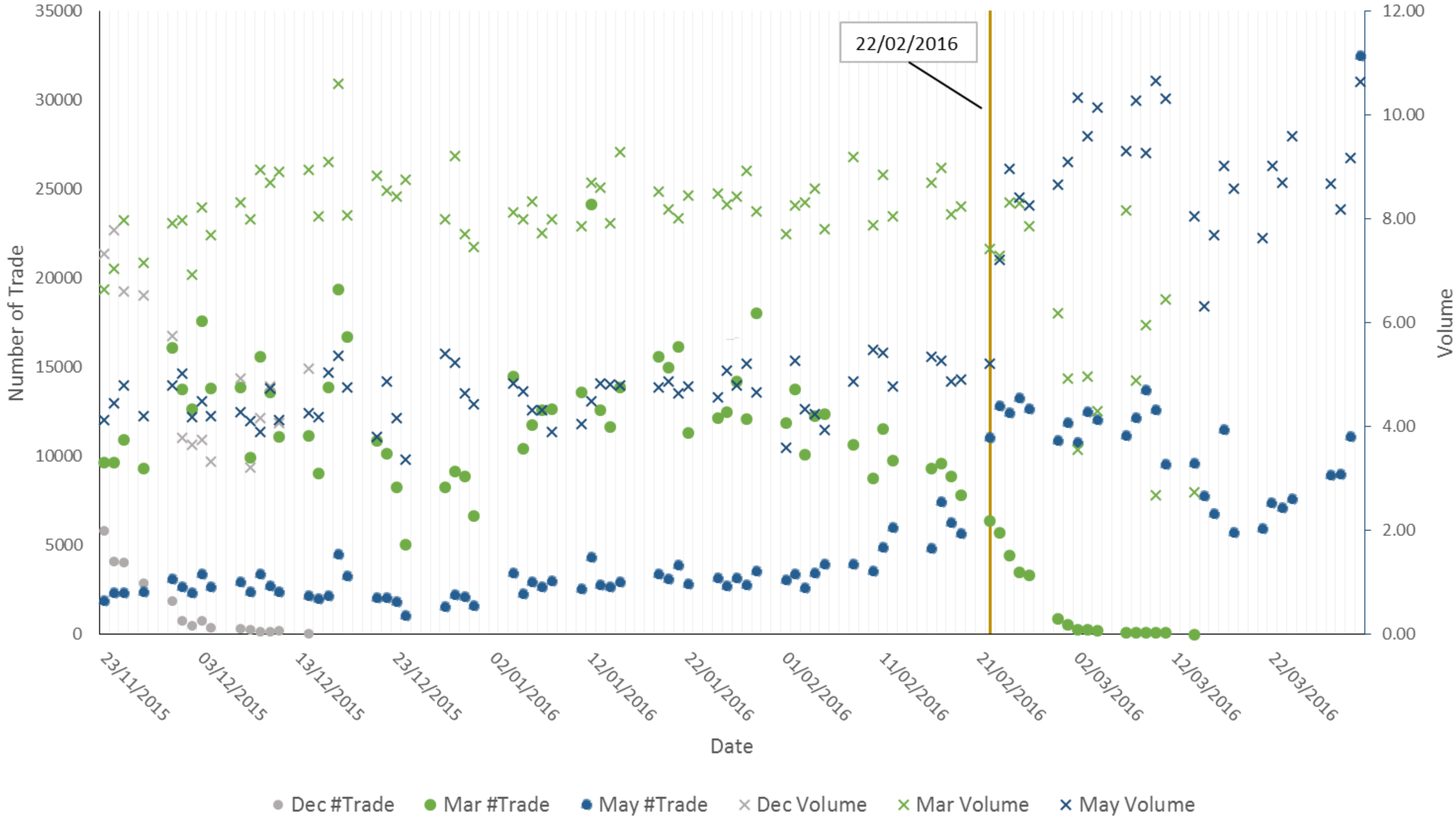

Figure 4.3 Roll dates for corn

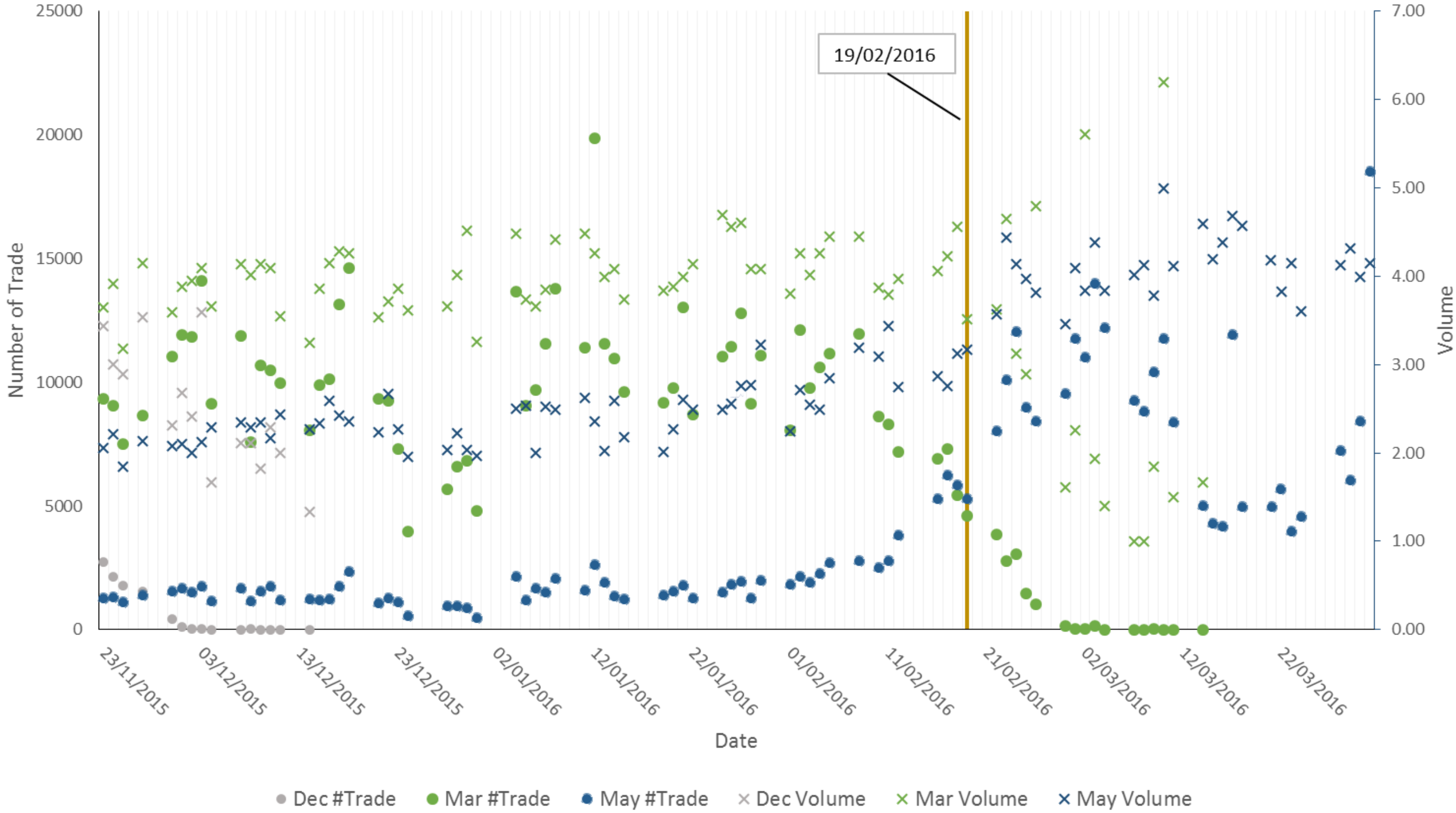

Figure 4.4 Roll dates for wheat

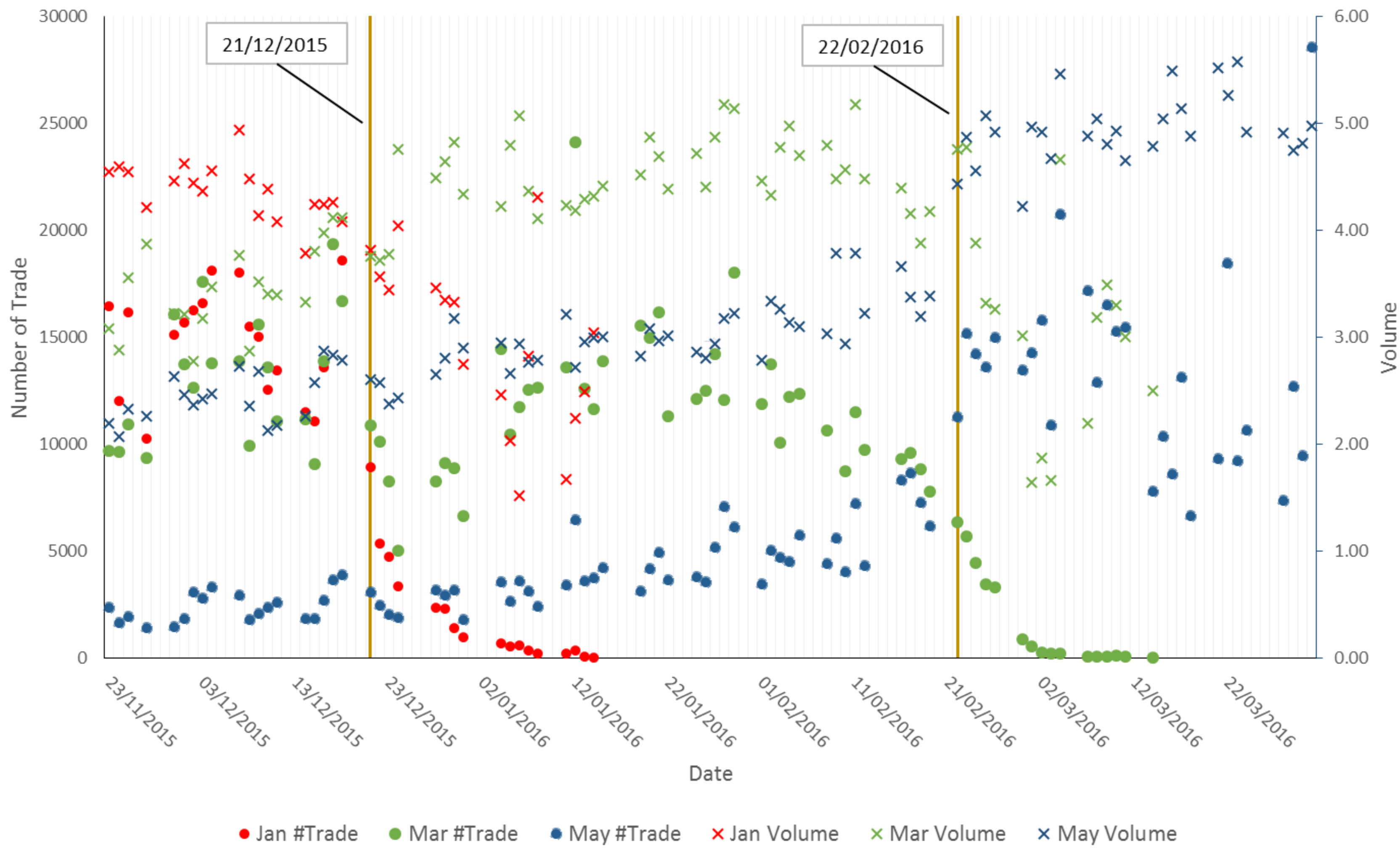

Figure 4.5 Roll dates for soybean

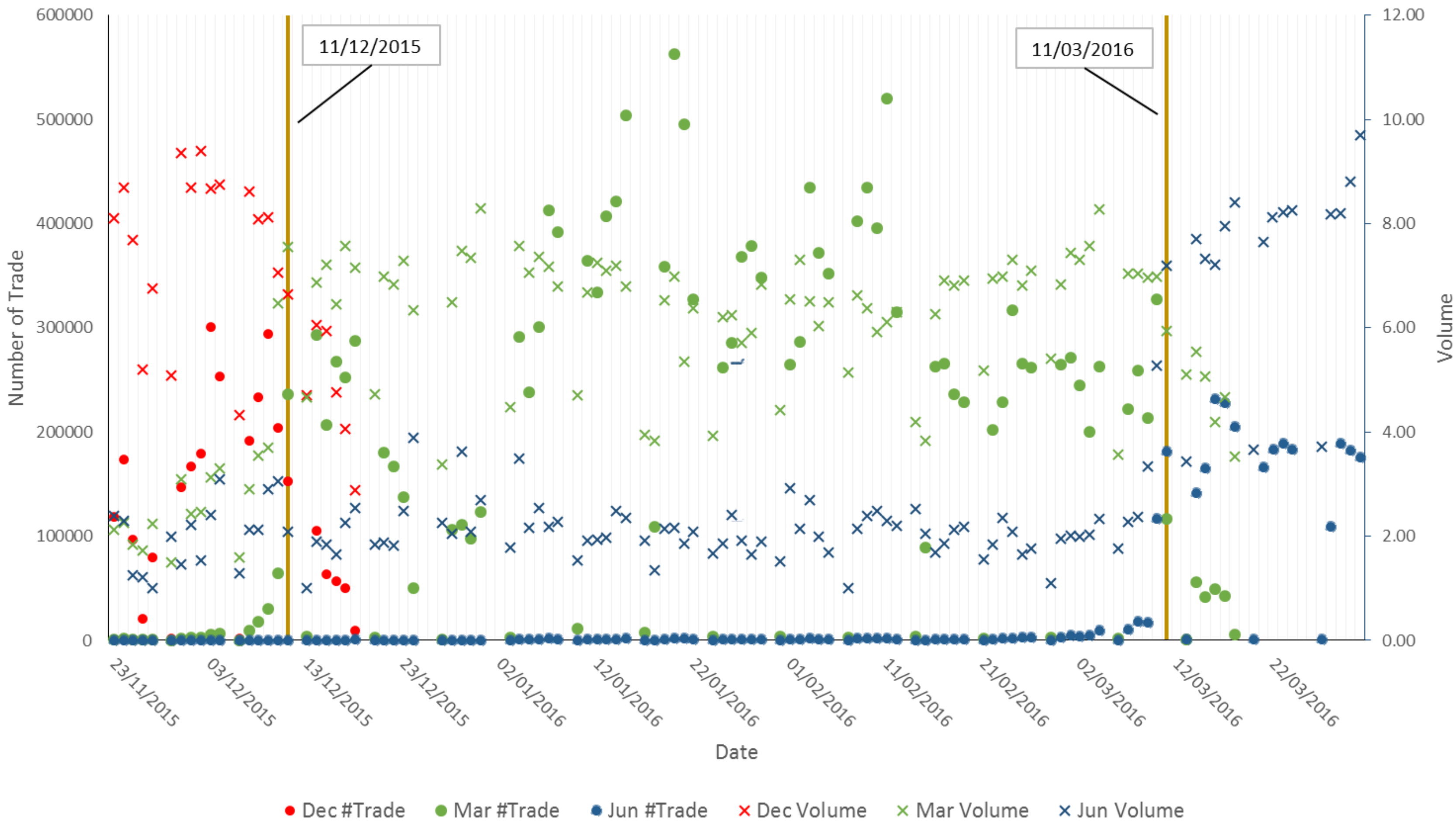

Figure 4.6 Roll dates for E-mini S&P 500

4.3.3. Reconstruction of the LOB

We use the *market depth* data files from the CME Group which provide every incremental book update required to reconstruct the LOB with Nano-second precision. Data are available to reconstruct a five-step-deep book for live cattle and lean hogs and a ten-step-deep book for corn, soybeans, wheat and E-mini S&P 500. The data are formatted using the Financial Information eXchange (FIX/BINARY) protocol which comprises of a series of messages containing information such as bids and asks with their corresponding quantities and step in the LOB, trade prices and quantities, order sending time, and changes in the LOB such as order deletions and bids, asks and quantities updates that would define a new book. Each message is processed to reconstruct the LOB (such as in figure 4.7) as follows. If a message contains information on a new market order, then there is an immediate match and a trade takes place.[35] If the trade results in a partial matching of the best bid or ask, the LOB remains the same except for the change in the number of contracts at the top of the book (figure 4.8). On the other hand, if the trade results in a full matching of the best bid or ask, all price steps beyond the best bid or ask move one step towards the top of the book and the spread widens (figure 4.9). If a message contains information on a new limit order with a better price than the best bid or ask, i.e. inside the spread, the top of the book changes and the new price becomes the best bid or ask price. In this case the spread narrows and the remaining prices on the same side move one step further down along the LOB (figure 4.10). An order can be deleted which also updates the LOB. If it is a partial deletion, the prices in the LOB remain the same and only the corresponding quantities are

[35] Futures trading in CME Group follows a price-time priority system, that is, orders matching the best bid or ask prices are executed first. If two orders have the same bid or ask prices, priority is given to the order that arrived first.

altered.[36] However, if the entire quantity on a price step is cancelled or deleted, the succeeding price steps move one step upward in the LOB (figure 4.11).

	Step	Price	Quantity
Ask	5	64,050	2
	4	64,000	5
	3	63,950	40
	2	63,500	1
	1	63,250	6
	Spread ↕		
Bid	1	63,075	3
	2	62,875	27
	3	62,750	6
	4	62,700	1
	5	62,650	2

Figure 4.7 A five-step outright limit order book.

[36] Traders operating in CME Group have the option of submitting iceberg or hidden-size orders, which are limit orders that specify a "visible" portion of the order size. Once that quantity is filled the remaining portion of the order size is revealed. This might result in underestimation of the information contained in the LOB when the proportion of iceberg orders is high.

	Step	Price	Quantity
Ask	5	64,050	2
Ask	4	64,000	5
Ask	3	63,950	40
Ask	2	63,500	1
Ask	1	63,250	6
	Spread ↕		
Bid	1	63,075	3
Bid	2	62,875	27
Bid	3	62,750	6
Bid	4	62,700	1
Bid	5	62,650	2

→

	Step	Price	Quantity
Ask	5	64,050	2
Ask	4	64,000	5
Ask	3	63,950	40
Ask	2	63,500	1
Ask	1	63,250	2
	Spread ↕		
Bid	1	63,075	3
Bid	2	62,875	27
Bid	3	62,750	6
Bid	4	62,700	1
Bid	5	62,650	2

Figure 4.8 Market order arrival – buy 4 contracts at price 63,250.

	Step	Price	Quantity
Ask	5	64,050	2
Ask	4	64,000	5
Ask	3	63,950	40
Ask	2	63,500	1
Ask	1	63,250	6
	Spread ↕		
Bid	1	63,075	3
Bid	2	62,875	27
Bid	3	62,750	6
Bid	4	62,700	1
Bid	5	62,650	2

→

	Step	Price	Quantity
Ask	5	64,050	2
Ask	4	64,000	5
Ask	3	63,950	40
Ask	2	63,500	1
Ask	1	63,250	6
	Spread ↕		
Bid	1	62,875	27
Bid	2	62,750	6
Bid	3	62,700	1
Bid	4	62,650	2
Bid	5	62,600	4

Figure 4.9 Market order arrival – sell 3 contracts at price 63,075.

	Step	Price	Quantity
Ask	5	64,050	2
Ask	4	64,000	5
Ask	3	63,950	40
Ask	2	63,500	1
Ask	1	63,250	6
	Spread ↕		
Bid	1	63,075	3
Bid	2	62,875	27
Bid	3	62,750	6
Bid	4	62,700	1
Bid	5	62,650	2

→

	Step	Price	Quantity
Ask	5	64,050	2
Ask	4	64,000	5
Ask	3	63,950	40
Ask	2	63,500	1
Ask	1	63,250	6
	Spread ↕		
Bid	1	63,150	5
Bid	2	63,075	3
Bid	3	62,875	27
Bid	4	62,750	6
Bid	5	62,700	1

Figure 4.10 Limit order arrival – buy 5 contracts at price 63,150.

	Step	Price	Quantity
Ask	5	64,050	2
Ask	4	64,000	5
Ask	3	63,950	40
Ask	2	63,500	1
Ask	1	63,250	6
	Spread ↕		
Bid	1	63,075	3
Bid	2	62,875	27
Bid	3	62,750	6
Bid	4	62,700	1
Bid	5	62,650	2

→

	Step	Price	Quantity
Ask	5	64,100	7
Ask	4	64,050	2
Ask	3	63,950	40
Ask	2	63,500	1
Ask	1	63,250	6
	Spread ↕		
Bid	1	63,075	3
Bid	2	62,875	27
Bid	3	62,750	6
Bid	4	62,700	1
Bid	5	62,650	2

Figure 4.11 Book update message arrival – delete 5 contracts at price 64,000.

If the spread or the difference between any two steps on either buy or sell side of the book is greater than one tick (the minimum change in price allowed), traders can gain priority by submitting an order inside the spread or between two existing steps. In this case, the new price replaces the previous step and all following steps move one step down the LOB. For example, if a trader submits a buy order with a bid price higher than the third best bid price, the new bid becomes the third best bid, the previous best third bid moves to the fourth step, and, similarly, every step beyond it moves one step further from the top of the book.

The CME Group supports implied functionality which is the ability to combine spread and outright markets in one order book with the objective to increase liquidity.[37] An accurate picture of the LOB for futures contracts for a market with implied functionality at any point in time, therefore, is the one which comes from the consolidated limit order book (CLOB) that accounts for both the outright book and the implied limit order book (ILOB). The ILOB is reconstructed using data from the *market depth* files in the same way as described above for the outright book. Data are available to reconstruct a two order deep implied book for all six futures markets (figure 4.12). The outright and the implied books are then merged into a CLOB as follows. If the price steps in the ILOB are the same as those in the LOB, the implied quantities are added to the LOB's corresponding price steps to get the CLOB. If prices are different, however, price steps coming from LOB and ILOB are compared and sorted for each bid (descending) and ask (ascending) side to form the CLOB (figure 4.13 and figure 4.14). Even though we reconstruct and employ the consolidated, CLOB, we refer to it as LOB for simplicity in what follows.

[37] An implied price is a futures order generated based on the outright market, the spread market, or other implied orders. A first generation implied "IN" order is an implied order which is made using two individual legs in the outright market and a first generation implied "OUT" order is an implied order which drives from one individual leg in the outright market and an existing spread order. A second generation implied order is made from the combination of an implied order and an outright order or an outright spread. Higher generation implied orders can be defined analogously. In CME Group, first and second generation implied orders are derived but only the first generation implied orders are disseminated. Trades, if take place by matching two implied orders, are not disseminated and at least one leg needs to be an outright order for the resulting trade to be disseminated.

	Step	Price	Quantity
Ask	2	63,800	1
	1	63,250	2
Bid	1	63,000	2
	2	62,700	4

Figure 4.12 A two-step implied limit order book.

	Step	Price	Quantity
Ask	5	64,050	2
	4	64,000	5
	3	63,950	40
	2	63,500	1
	1	63,250	6
	Spread		
Bid	1	63,075	3
	2	62,875	27
	3	62,750	6
	4	62,700	1
	5	62,650	2

Step	Price	Quantity	
2	63,800	1	Ask
1	63,250	2	
1	63,000	2	Bid
2	62,700	4	

Figure 4.13 Merging LOB and ILOB.

	Step	Price	Quantity
Ask	5	64,000	5
	4	63,950	40
	3	63,800	1
	2	63,500	1
	1	63,250	8
	Spread ↕		
Bid	1	63,075	3
	2	63,000	2
	3	62,875	27
	4	62,750	6
	5	62,700	5

Figure 4.14   A five-step consolidated limit order book.

4.3.4. Summary Statistics of the LOB

This subsection describes the main characteristics of the full LOB and its components such as transaction price, volume, all price steps and their corresponding depth at both buy and sell sides, number of book updates, and number of orders for the nearby futures contracts of live cattle, lean hogs, corn, wheat, soybeans, and E-mini S&P 500 during Nov. 23, 2015 and Mar. 31, 2016. Table 4.3 reports the mean and standard deviation for all the contracts. Asks and bids and their corresponding quantities are reported for five steps for live cattle and lean hogs and ten steps for the rest of the products as disseminated by the CME Group.

Insert Table 4.3 Here

The LOB updates arrive at irregular times that can be as short as a Nano second. The number of observations for each product reflects the frequency of LOB updates. Table 4.3 shows that during the study time period, the LOB for E-mini S&P 500 futures contracts is updated considerably more frequently than that of agricultural commodities. Across agricultural commodities, soybeans LOB is the most dynamic book. The LOB number of updates is more or less similar for wheat and corn and for live cattle and lean hogs. Among all products, the average volume traded for corn is the highest, more than twice than that of other grains. The number of orders per trade is the highest for corn and the lowest for live cattle. On average, the BAS is about 0.27 cent for grains, 25.6 cents for E-mini S&P 500, 0.0403 cent for lean hogs, and 0.0458 cent for live cattle. Along the LOB and up to the third step, corn has a considerably higher depth than the rest of the products on average, even higher than E-mini S&P 500. After the third step, E-mini S&P 500 has a higher depth than corn. Overall, the first two steps beyond the BAS seem to have a significantly higher depth than the remaining steps for agricultural commodities. Together with more or less equal price differences for bids and asks along the book, this implies that the two steps closer to the top of the book are relatively "denser" for the agricultural commodities. For E-mini S&P 500, surprisingly, the further steps appear to have a slightly higher depth than the steps close to the top of the book. This means that traders of the agricultural futures contracts submit more limit orders at the steps closer to the top of the book whereas traders of the E-mini S&P 500 futures contracts prefer the steps further from the top of the book. Therefore, in addition to studying differences of the LOB between agricultural commodities and E-mini S&P 500 at the aggregate level, differences of the LOB at the step level can shed light on how trading in agricultural commodity markets differ from other markets.

4.3.5. Price Duration

Limit and market orders that continuously update the LOB inherently arrive in an irregular timely manner. However, regularly spaced data is needed for our underlying econometric models. Previous studies suggest taking snapshots of the LOB at regular times. For example, Hasbrouck (1995) and Cao et al. (2009) both use a one-second snapshot data for thirty

Dow stocks and one hundred most active Australian stocks, respectively. The time duration between snapshots is important because if it is too long, important information might be overlooked and if it is too short, we might create a data set with a lot of observations that are repeated with no new information and cause other problems such as heteroskedasticity (Engle and Russell, 1998). The literature is not clear on how to select an optimal duration for time intervals. We use the average duration of transaction price changes. Following Engle and Russell (1998), we denote every trade price change a price event and define a duration variable, d_i, given by:

$$d_i = t_i - t_{i-1} \quad [4.1]$$

where t_i is the time of the i^{th} transaction. We construct regularly spaced time series of the LOB for each product on the basis of how frequently their transaction price changes during the period of study. Summary statistics of the daily average durations are presented in table 4.4. As it can be seen, the price duration of one-second snapshot used in the finance literature e.g. Hasbrouck (1995) and Cao et al. (2009) is a good approximation for a product such as the E-mini S&P 500 which is highly frequently traded. However, for agricultural commodities, the trading frequency and price fluctuation is considerably lower and therefore we select a longer snapshot duration to avoid a high number of repeated observations. The price duration also varies across agricultural commodities. Table 4.4 shows the snapshot durations for each product based on the average price durations.

Insert Table 4.4. Here

Table 4.4 shows that the price events vary significantly across different agricultural commodities. For example, in the livestock group, live cattle average duration of 7.40 seconds is considerably lower than that of lean hogs, 11.97 seconds. This is in spite of the fact that, according to table 4.3, average volume for live cattle is only slightly higher than that of lean hogs and the number of contracts in all steps of the LOB on both buy and sell sides is higher for lean hogs than live cattle.[38] Figures 4.15 and 4.16 show the evolution of price for live cattle and lean hogs nearby futures contract during Nov. 23, 2015 to Mar. 31, 2016 period.

The figures are plotted over a 60-second interval. It is clear from the figures that live cattle has experienced a considerably higher fluctuation in price than lean hogs. Despite relatively lower fluctuations for each futures contract, price for different lean hogs futures contracts are considerably different from one another. Lean hogs February futures contracts were traded on average about sixty cents per pound whereas April and June contracts were traded for approximately seventy and eighty cents per pound each, respectively. For live cattle, February and April contract prices are less different. However, live cattle April contract peaked to a level of more than a hundred and forty cents per pound before the roll date. Live cattle June contract started at about ten cents less value per pound and dropped to about a hundred and twenty five cents per pound by Mar. 31, 2016.

[38] It can be argued that an average duration based on LOB events is superior to that based on price events since the purpose of this study is to determine the informativeness of the LOB. The LOB updates, however, are greatly more frequent than the price updates and such time intervals will result in a data set with many repeated prices. Thus a duration based on LOB events must be scaled up to avoid too many repeated prices. In addition, generally when LOB updates are more frequent, so are the price updates. Therefore, we chose the durations based on price events. Despite this, we repeat all our estimations and hypothesis testing for a 60-second duration for all the products to compare the outcomes. They are reported in the results section.

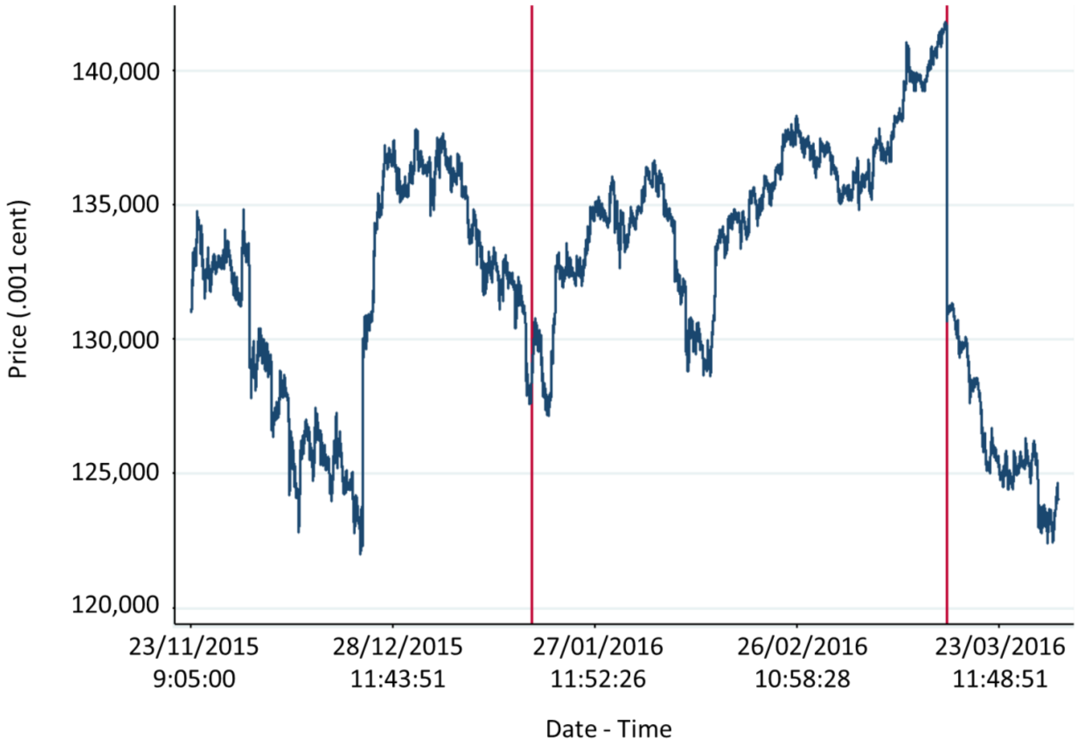

Figure 4.15 Live cattle price for the nearby contracts

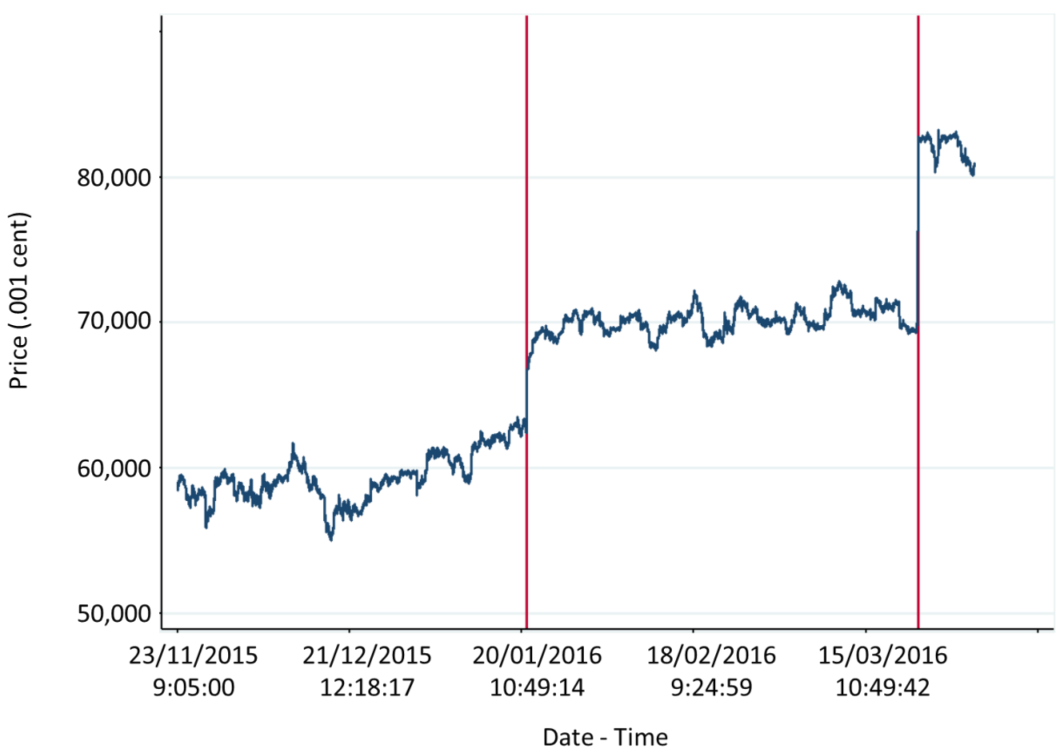

Figure 4.16 Lean hogs price for the nearby contracts

Figures 4.17, 4.18, and 4.19, depict the price movements for corn, wheat, and soybeans nearby futures contracts over the period of Nov. 23, 2015 to Mar. 31, 2016, respectively. The price points, like that of the livestock group, represent 60-second intervals. Soybean futures contracts are significantly lower in volume and quantities along the LOB than those of corn according to table 4.3. However, average price duration is 7.60 seconds for soybeans, lower than that for corn, 8.63 seconds (table 4.4). Among the grains, wheat has lower volume in trade and less quantity along the LOB as well as a relatively long price duration (11.94 seconds). Over this period, wheat futures contracts price starts from the 4.80 – 5.00 dollar bound and ends in the 4.60 – 4.80 dollar bound with a minimum of about 4.45 dollars in early March (figure 4.18). Corn also experiences a decrease in price during the same period (figure 4.17). The opposite is true for soybeans where price per contract starts from about 8.45 dollars and increases to over 9 dollars per contract by the end of March 2016 (figure 4.19).

Finally, figure 4.20 shows the price evolution of nearby contracts for E-mini S&P in 60-second intervals during the study period. The difference in the price of various contracts is less apparent for E-mini S&P 500 than that of the agricultural commodities. During this period, E-mini S&P 500 price experienced a considerable decrease of about three hundred dollars per contract. The price only recovered to close to previous peak amounts after several months.

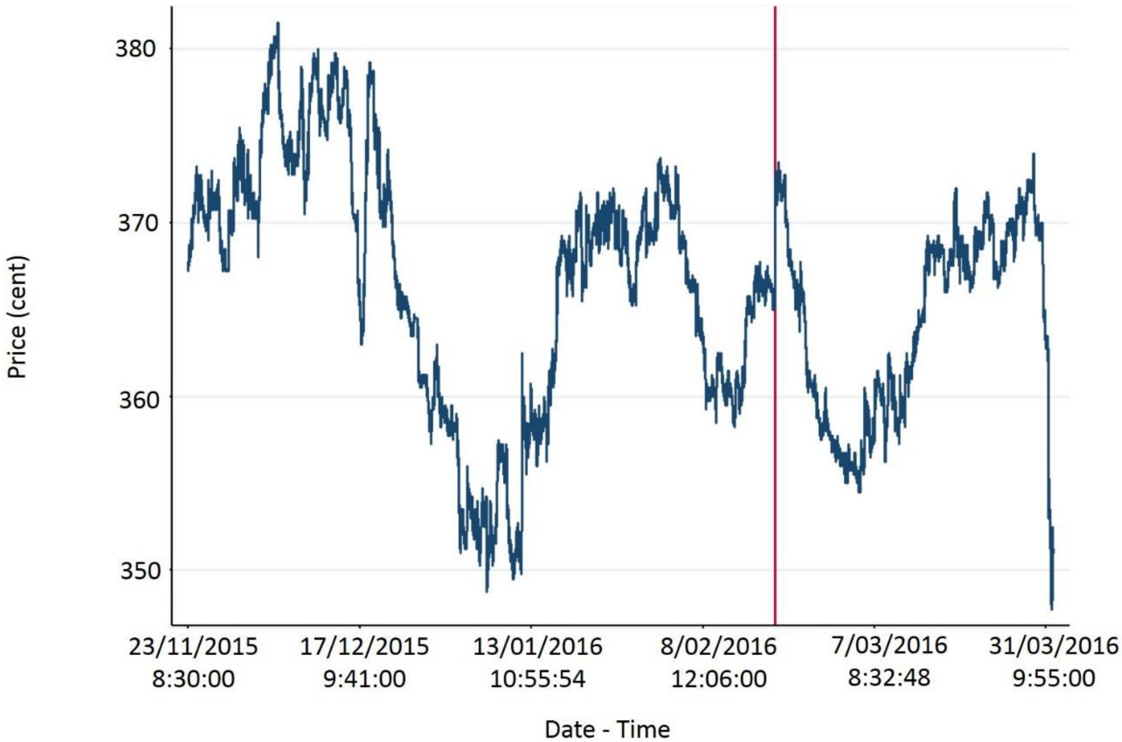

Figure 4.17 Corn price for the nearby contracts

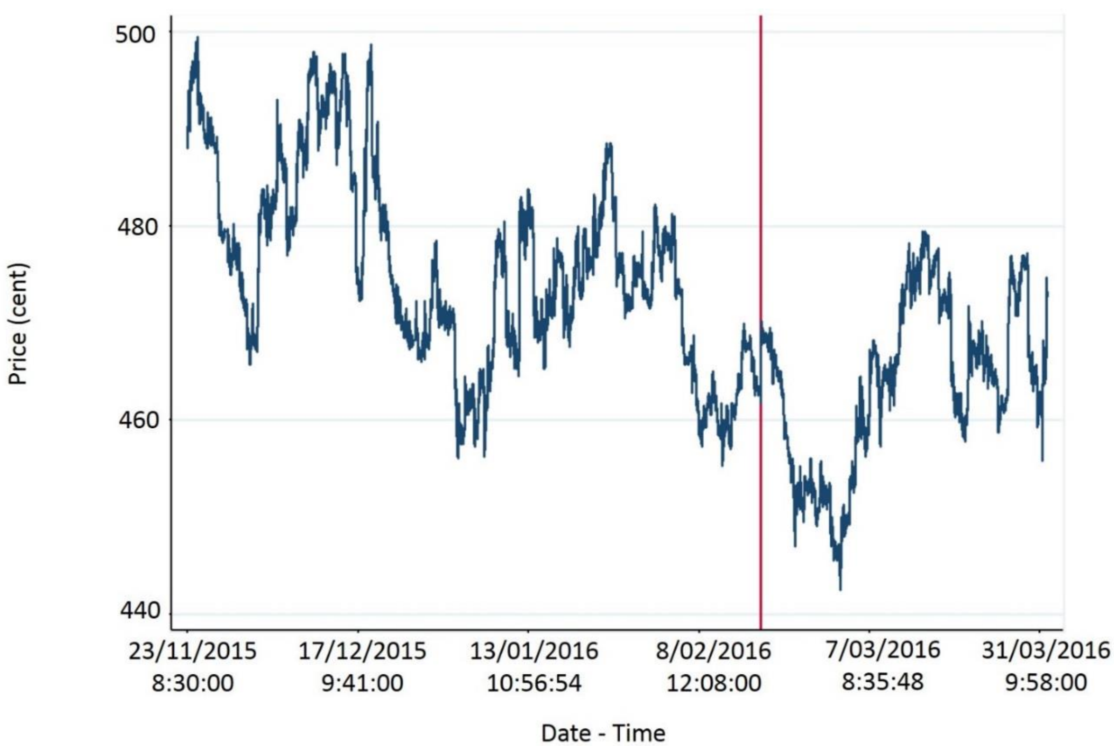

Figure 4.18 Wheat price for the nearby contracts

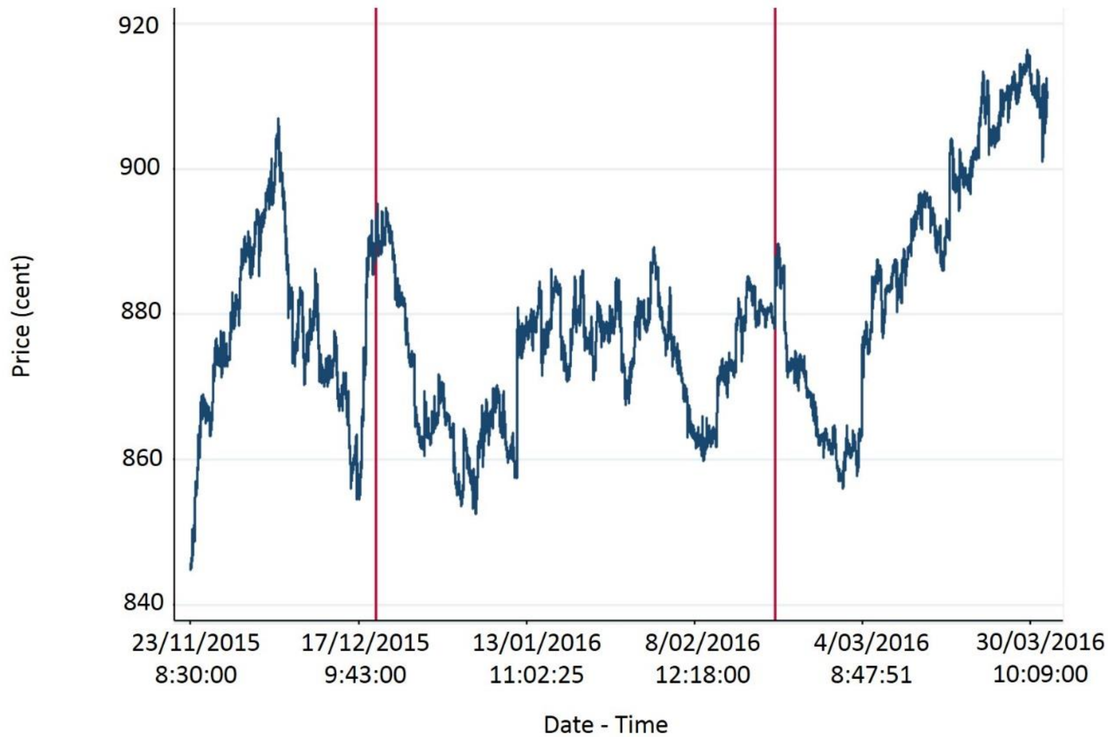

Figure 4.19 Soybeans price for the nearby contracts

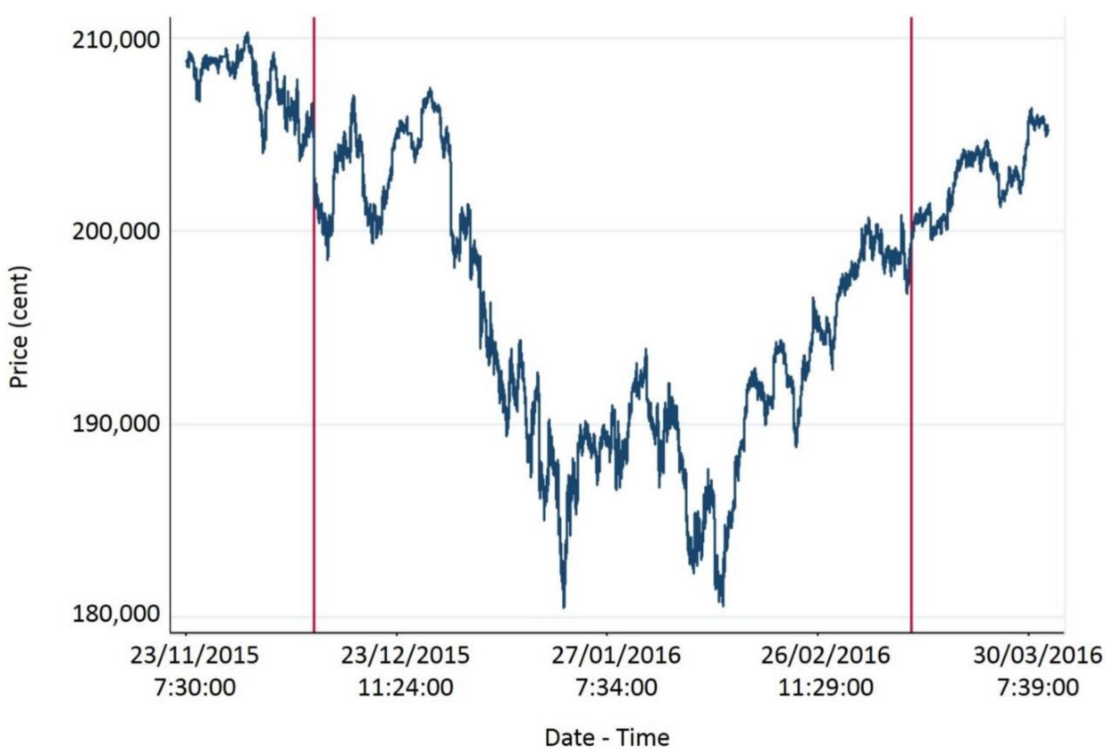

Figure 4.20 E-mini S&P 500 price for the nearby contracts

4.4. Price Discovery Measures

In this section, we introduce the three measures which are used to determine the contribution of the transaction price, the spread, and the limit order book beyond the spread to price discovery of the efficient price for all six markets under study. We first present an index to capture the summary information contained in the LOB. The index is constructed following Cao et al. (2009) and it is simply a weighted price average of the bid and ask of different steps at any point in time.

4.4.1. Measure of the LOB Summary

An LOB consists of different price steps and the associated number of futures contracts, at any point in time. The relationship between the bid price steps and the number of contracts, related to each bid price step and aggregated across all orders, can be thought of as a market demand step function. Similarly, a market supply step function derives from the relationship between the ask price steps and the related aggregate contracts. The height of a step i in the step functions is the difference between price i and price $i-1$. For instance, the height of step 4 on the demand side is the fourth best bid less the fifth best bid. The length of a step i is the summation of the contracts across all orders for price i on each demand or supply side. The mean of the best bid and ask, denoted MID, is used to compute the first step heights for both supply and demand sides. The heights and lengths of the demand and supply step functions are, then, normalized using the summation of all heights and all lengths, respectively. The following weighted price reflects the price and quantity aspects of a LOB at a given point in time:

$$WP^{n_1 n_2} = \frac{\sum_{s=n_1}^{n_2} (Q_s^b P_s^b + Q_s^a P_s^a)}{\sum_{s=n_1}^{n_2} (Q_s^b + Q_s^a)},\ n_1 \leq n_2 \qquad [4.2]$$

Where $WP^{n_1 n_2}$ is the weighted price of step n_1 to step n_2. It summarizes all the information which is contained in the LOB from step n_1 to n_2. Moreover, Q and P are quantity and price of the demand side (denoted b) or the supply side (denoted a), respectively. When $n_1 = n_2 = 1$, the weighted price becomes

$$WP^1 = \frac{Q_1^b P_1^b + Q_1^a P_1^a}{Q_1^b + Q_1^a} \quad [4.3]$$

Cao et al. (2009) use MID which is the arithmetic mean of the best bid and best ask to capture the information of the spread. MID only changes when the best bid or the best ask change whereas WP^1 changes also as a result of a change in the quantities at the best bid or ask. Vo (2007) studies the quantity at the best bid and ask prices and its relationship with the BAS for Toronto Stock Exchange stocks while Frino et al. (2008) examine the relationship for three interest rates futures contracts on the Sydney Futures Exchange (SFE). The results of both studies show a negative relationship between the two variables which implies that market participants manage both price and quantity as a part of their trading strategies. Thus we use WP^1 to capture the information contained in the spread.

The following tables and figures provide the summary statistics of the shape of the average LOB for the six markets over the studied period of time.

Insert Table 4.5 Here

The summary statistics of the shape of the average LOB shows that for the agricultural commodities the number of contracts resting on the second and third steps of the book, on both buy and sell sides, are considerably higher than that on the steps beyond the third step (table 4.5). This is comparable to the full LOB (i.e., the complete LOB before extracting the snapshots) in table 4.3 and suggests the possibility of a greater share of information for the first two steps of the LOB beyond the best bid and ask than the rest of the book. However, this is not the case for the E-mini S&P 500 for which the contracts appear to spread more or less equally over the second to tenth steps of the book. Moreover, in contrast to what Cao et al. (2009) observe in the Australian Stocks that the heights tend to be shorter for the steps close to the top of the book than the further away steps, the heights in our dataset are almost equal across all steps for all the products. This is also illustrated in figures 4.21 to 4.27.

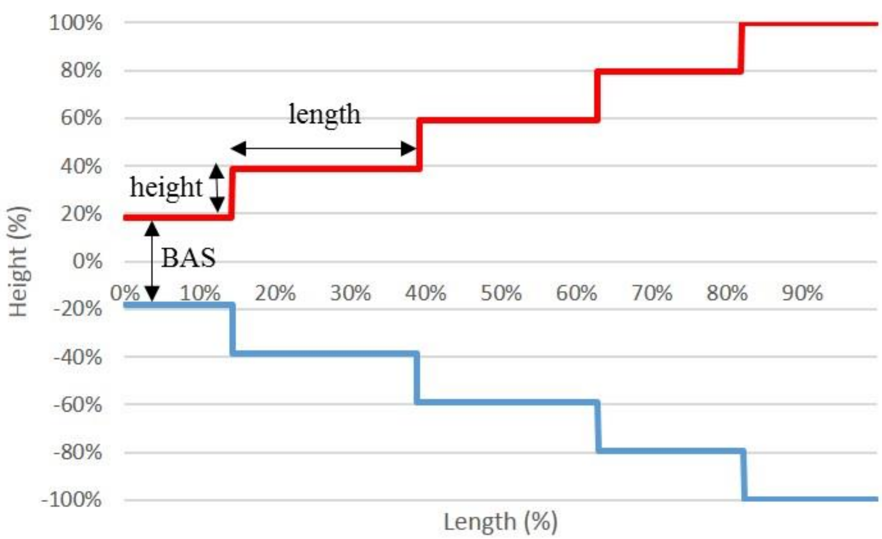

Figure 4.21 Live cattle average LOB.

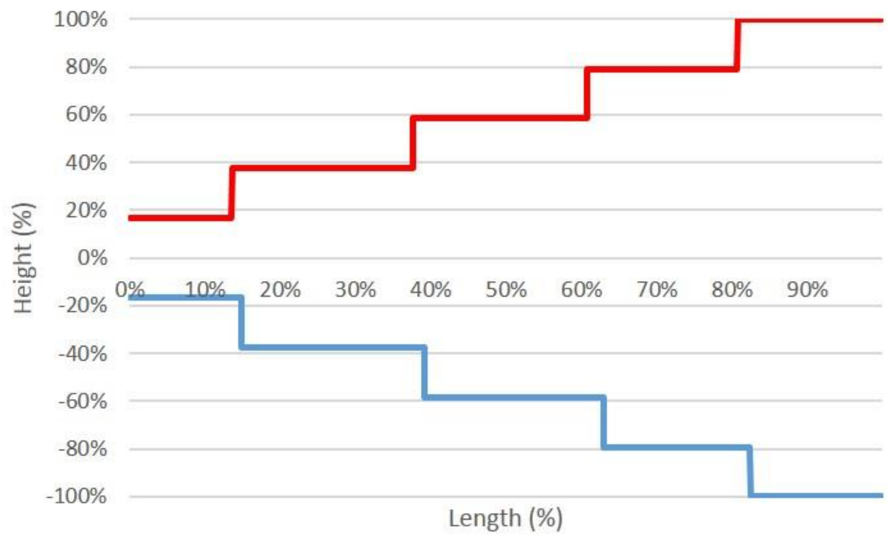

Figure 4.22 Lean hogs average LOB.

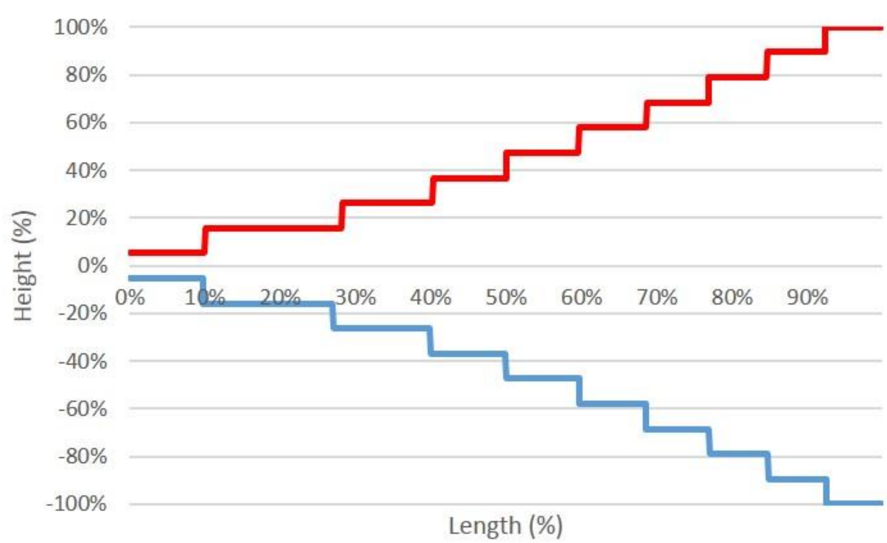

Figure 4.23 Corn average LOB.

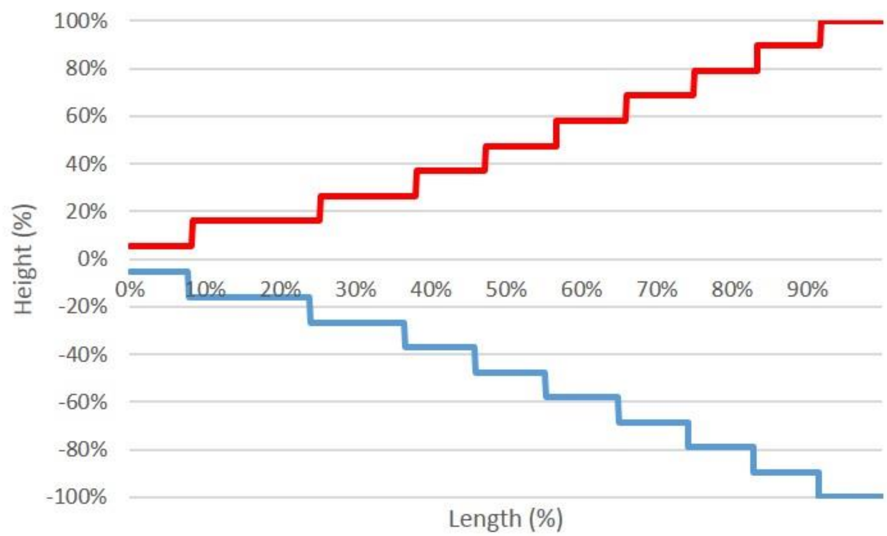

Figure 4.24 Wheat average LOB.

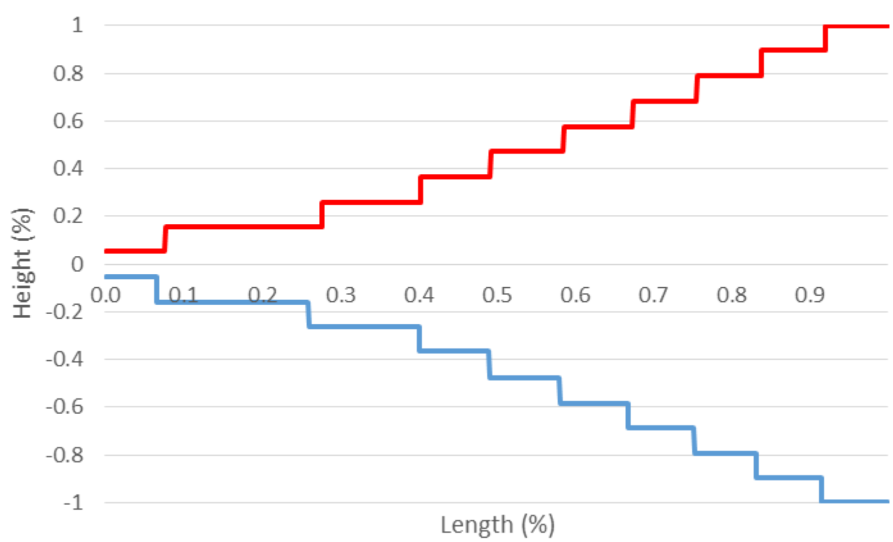

Figure 4.25 Soybeans average LOB.

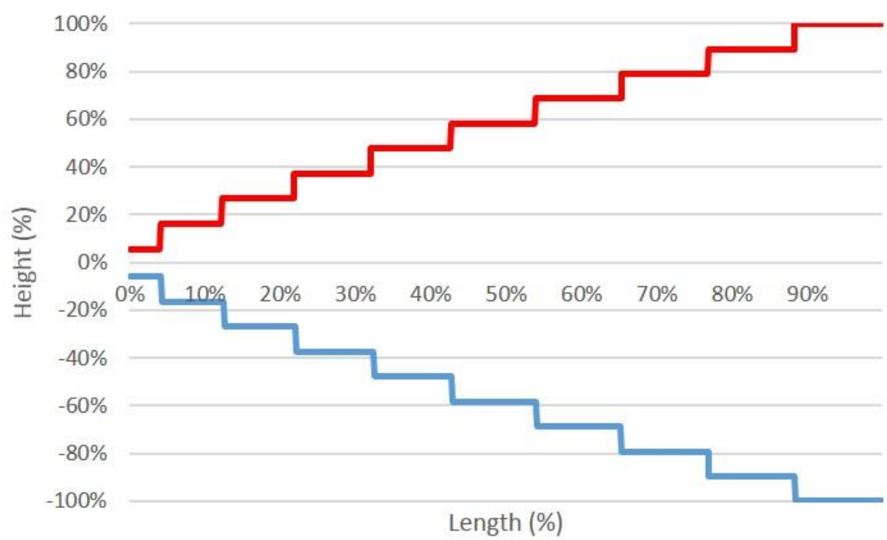

Figure 4.26   E-mini S&P 500 average LOB.

4.4.2. An Error Correction Model and Measures of Information Share

Different approaches to measure the contribution of a set of price series to price discovery in a market revolve around estimating the vector error correction model (VECM). Consider K different prices of a particular commodity in the same market. A general error correction model in matrix notation for these price series can be written as:

$$\Delta Y_t = \alpha\beta' Y_{t-1} + \sum_{l=1}^{q} A_l \Delta Y_{t-l} + \varepsilon_t \qquad [4.4]$$

where Y_t is the vector of price series such that $Y_t = (y_{1t}, y_{2t}, \dots, y_{Kt})'$, α denotes the loading matrix or the matrix of coefficients which reflect how quickly price series return to their long run equilibrium, and ε_t is a white noise error term with variance-covariance matrix Ω. Prices are allowed to be functions of previous changes in their own values as well as the other price series with a matrix of coefficients of A. These prices can be each non-stationary, however, they move as a group. That is, there exists a linear combination of the price series which is stationary. This means they are cointegrated and share a common stochastic trend. In equation [4.4], β represents the coefficients of this cointegration process, or the (non-unique) cointegrating matrix. Hasbrouck (1995) suggests the following form for β:

$$\beta'_{(K-1)\times K} = \left[\iota_{(K-1)} \colon -I_{(K-1)}\right] \qquad [4.5]$$

where ι is a vector of 1's and I is the identity matrix.

The VECM in equation [4.4] can be characterized by the following vector moving average (VMA) representation (Hasbrouck, 1995):

$$\Delta Y_t = \Psi(L)\varepsilon_t \qquad [4.6]$$

where $\Psi(L) = \Psi_0\varepsilon_t + \Psi_1\varepsilon_{t-1} + \Psi_2\varepsilon_{t-2} + \cdots$ and Ψ_i are matrices of coefficients. Equation [4.6] can be, alternatively, written as follows, which is known as Beveridge-Nelson decomposition (Beveridge and Nelson, 1981):

$$Y_t = Y_0 + \Psi(1)\sum_{i=1}^{t}\varepsilon_i + \Psi^*(L)\varepsilon_t \qquad [4.7]$$

where $\Psi(1)$ is the impact matrix in the lag operator, L, or the sum of the moving average coefficients. Therefore, $\Psi(1)\varepsilon_t$ is the long-run impact of an innovation, ε_t, in a price on each of the prices which is due to new information. The long-run impact on all prices is the same and thus $\Psi(1)$ has identical rows. We denote the common row in $\Psi(1)$ by $\psi = (\psi_1, \psi_2, \dots, \psi_K)$. The matrix $\Psi^*(L)$, which is also in the lag operator, L, is the part of the price change that is resulted from transitory shocks of bid-ask bounces, inventory adjustments, or other market imperfections.

It is assumed that the price series are integrated of order one (I(1)) and that the system consists of a single common stochastic trend (Stock and Watson, 1988). That is the system has $r = K - 1$ cointegrating vectors and the impact matrix ($\Psi(1)$) has rank one. Therefore, from the Engle-Granger representation theorem (Engle and Granger, 1987), it follows that $\beta'\Psi(1) = 0$ and $\Psi(1)\alpha = 0$ which results in a common row in $\Psi(1)$ or that the long-run impact of ε_t on each price is identical. Following De Jong (2002), equation [4.7] can be rewritten as:

$$Y_t = Y_0 + \beta_\perp \alpha'_\perp \sum_{i=1}^{t} \varepsilon_i + \Psi^*(L)\varepsilon_t \qquad [4.8]$$

where $\beta_\perp$ and $\alpha_\perp$ are orthogonal to β and α, respectively, that is $\beta'\beta_\perp = 0$ and $\alpha'\alpha_\perp = 0$ are satisfied. This equation is closely related to how Stock and Watson (1988) represent the common trend. That is, price changes have a non-stationary common factor with a permanent effect (f_t) and a stationary transient component (G_t) given by:

$$Y_t = f_t + G_t \qquad [4.9]$$

The common trend representation in Stock and Watson (1988) represented in equation [4.9] and the Beveridge-Nelson decomposition of equation [4.7] are the basis for the information share measures which follow.

4.4.2.1. Granger and Gonzalo Permanent-Transitory Effect (PT)

Gonzalo and Granger (1995) suggest that each of the prices in a system potentially contributes to the common trend or the efficient price. Therefore, the common factor is defined as a combination of prices given by:

$$f_t = \Gamma Y_t \tag{4.10}$$

where $\Gamma_{1\times K}$ is a $1 \times K$ vector of coefficients for the common factor with elements $(\gamma_1, \gamma_2, \dots, \gamma_K)$. Under this specification of the common trend, the error correction term is not allowed to Granger cause the common factor in the long run. They show that Γ is orthogonal to the vector of the error correction coefficients (i.e. α) and the common trend representation, therefore, can be written as:

$$f_t = \alpha'_{\perp} Y_t \tag{4.11}$$

Finally, the PT measure of the contribution of the j^{th} price to the efficient price is related to γ_j in Γ or $\alpha_{\perp j}$ in $\alpha_{\perp}$. That is, the PT information share only depends on γ or $\alpha_{\perp}$. Harris et al. (2002) normalize the vector coefficients of the common trend such that the sum of the price information shares equals one. Based on Harris et al. (2002), PT can be computed using:

$$PT_j = \frac{\alpha_{\perp j}}{\sum_{j=1}^{K} \alpha_{\perp j}} \tag{4.12}$$

4.4.2.2. Hasbrouck Information Share (IS)

Hasbrouck (1995) also uses the common factor representation by Stock and Watson (1988) to develop an information share in order to measure the contribution of different market prices to the efficient price discovery. The difference between IS and the previous approach is that in IS the variance of the common factor is decomposed and each price contributes to the efficient price based on how its variance contributes to the variance of the efficient price. The variance of the common factor innovations is given by

$$var(\psi\varepsilon_t) = \psi\Omega\psi' \qquad [4.13]$$

where ψ is a common row vector in the $\Psi(1)$ matrix in [4.7]. We compute the parameters in $\Psi(1)$ directly using Johansen's factorization and the estimation coefficients from the VECM in equation [4.4] by:

$$\Psi(1) = \beta_\perp \Pi \alpha'_\perp \qquad [4.14]$$

where

$$\Pi = \left(\alpha'_\perp (I - \sum_{l=1}^{q} A_l)\beta_\perp\right)^{-1} \qquad [4.15]$$

and I_K is the identity matrix.

The IS of the j^{th} price, then, can be calculated by

$$IS_j = \frac{\left(\psi_j \sigma_j\right)^2}{\psi\Omega\psi'} \qquad [4.16]$$

where σ_j is the j^{th} price's standard deviation in the variance-covariance matrix Ω.

Hasbrouck (1995) suggests that if the variance-covariance matrix of residuals (Ω) in the VECM representation (equation [4.4]) is not diagonal, that is the price innovations are significantly correlated across the price series, IS and PT can result in misleading information shares. Hasbrouck (1995) uses the Cholesky factorization of the residuals covariance matrix to eliminate the contemporaneous correlation. Based on the Cholesky factorization,

$$\Omega = MM' \qquad [4.17]$$

where M is a lower triangle matrix. The IS measure can then be written as

$$IS_j = \frac{{[\psi M]_j}^2}{\psi \Omega \psi'} \qquad [4.18]$$

Even though the IS calculated using equation [4.18] solves the correlation problem, it creates another issue that is the measure being sensitive to the ordering of prices in the system. This occurs because when correlation exists, that is the nondiagonal elements of M are nonzero, the IS measure imposes more weights on the prices that appear earlier in the system. To overcome this problem, Hasbrouck (1995) proposes calculation of upper and lower bounds for each price by placing them first and last in the system. In the multivariate cases, all permutations of the variables must be computed to find the upper and lower bounds (Hasbrouck, 2002). [39]

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[39] Baillie et al. (2002) show how PT and IS can result in similar information shares in the absence of contemporaneous correlation in residuals and under the assumption that there exists only one single common factor in the system. They show that both IS and PT measures are essentially derived from $\alpha_{\perp}$. This is true because under a single common factor, the coefficients of $\Psi(1)$ are different from those of $\alpha_{\perp}$ only by a scalar which cancels out when calculating the information share. They measure IS using the following formulas for when a price is placed first (upper bound) and last (lower bound) in the system, respectively by $IS_{j1} = \frac{\left[\sum_{j=1}^{K} \gamma_j m_{j1}\right]^2}{\Gamma \Omega \Gamma'}$ and $IS_{jK} = \frac{(\gamma_K m_{KK})^2}{\Gamma \Omega \Gamma'}$ where m_{ij} is the element in the M matrix which is on the i^{th} row and j^{th} column and γ_j are directly estimated from

Baillie et al. (2002), De Jong (2002), and Yan and Zivot (2010) show that the PT measure can be computed by:

$$PT_j = \frac{\psi_j}{\sum_{j=1}^{k} \psi_j} \qquad [4.19]$$

Therefore, we use the coefficients of the long-run impact matrix, $\Psi(1)$, computed using equation [4.14], to measure IS and PT in the equations [4.18] and [4.19], respectively.

4.2.3. Modified Information Share (MIS) and Other Information Share Metrics

Several studies have been carried out to address the drawbacks of PT and IS metrics or to extend them for more general settings. Among them Yan and Zivot (2010) show that the aforementioned measures can be misleading if different price series have different levels of noise. Different level of noise in price series of a common asset can arise if for example the minimum tick size differs in two different markets trading the asset, different inventory management in the markets, bid–ask bounce, or other microstructure frictions and market imperfections (Yan and Zivot, 2010; Putnins, 2013). Yan and Zivot (2010) argue that only the IS measure can provide information on the relative informativeness of individual price series, however, the IS measure for a series may be higher due to more information contained in that series relative to other series or it can be higher if the other series are more noisy even though the former is not necessarily containing more information. Moreover, PT which can be computed using elements of the error correction coefficient vector α in equation [4.12] (Baillie et al., 2002), measures the way in which prices adjust to lagged differences in their transitory

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the VECM model in equation [4.3] without deriving the VMA representation. Note that in their IS measure, the common row elements of Γ i.e. $(\gamma_1, \gamma_2, \dots, \gamma_K)$ are used instead of those of $\Psi(1)$.

components. In the case of two price series (Yan and Zivot, 2010; Putnins, 2013), PT of price series 1 reflects how sensitive price series 2 is, relative to price series 1, to lagged transitory shocks and vice versa. Yan and Zivot (2010) show that PT in fact reflects the dynamic responses of price series to the transitory shocks and not the permanent shocks. However, IS reflects how price series respond to both permanent and transitory shocks. Yan and Zivot (2010) propose combining IS and PT to specifically measure impounding of new information to account for, on the one hand, the information content of each series, and on the other hand, control for differences in the noise levels. That is, when there are only two price series in the system, combining the two measures can rule out the transitory shock effect on the price series to capture the long-run effect of a permanent shock only. Putnins (2013) tests the measure further and derive the informational leadership (IL) measure. This approach, however, is more appealing in bivariate systems and how successful IL measure is in ruling out the effect of the transitory shocks when there are more than two price series is unknown (Putnins, 2013).

The modified information share (MIS) was developed by Lien and Shrestha (2009) to address the problems with the previous approaches, i.e. a potential nondiagonal variance covariance matrix of residuals in PT and the order sensitivity in IS. In MIS, on the one hand, a type of factorization is used to eliminate potential contemporaneous correlations. On the other hand, instead of the variance-covariance matrix Ω which is sensitive to the ordering of price series, MIS uses the innovation correlation matrix which is invariant to different orders of price series in the system. The factorization procedure is as follows. Consider the innovation correlation matrix denoted by Φ of the VEC model in [4.4]. Consider also a diagonal matrix Λ where its elements are the eigenvalues of the correlation matrix (Φ). And the corresponding eigenvectors are given by the columns of matrix G. Finally, suppose matrix V is diagonal and its elements are the standard deviation of the innovations or the square roots of diagonal elements of Ω. Lien and Shrestha (2009) show that the innovations can be transferred to the following:

$$\varepsilon_t = F z_t \qquad [4.20]$$

where z_t is the transferred innovation with zero mean, $E[z_t] = 0$, and identity covariance matrix, $E[z_t z_t{}'] = I$. Moreover,

$$F = \left[G\Lambda^{-1/2}\mathrm{G}'\mathrm{V}^{-1}\right]^{-1} \qquad [4.21]$$

and $\Omega = \mathrm{FF}'$. This factorization results in the MIS measure given by

$$MIS_j = \frac{[\psi F]_j{}^2}{[\psi F]\Omega[\psi F]'} \qquad [4.22]$$

MIS has the desirable feature that it calculates an information share which is order invariant and it accounts for contemporaneous correlations in innovations. This is particularly important when correlation exists in the residuals. When correlation is nearly nonexistent, MIS approaches IS and PT, and when innovations are completely correlated MIS approaches $\frac{1}{K}$ or an equal share for all the K price series. Lien and Shrestha (2014) extended their MIS measure by placing the diagonal coefficients of Γ in the cointegration matrix, β (equation [4.4]), instead of 1's and using the cointegration matrix in the form of $\beta'_{(K-1)\times K} = \left[\iota_{(K-1)}\colon -\Gamma_{(K-1)}\right]$ instead of $\beta'_{(K-1)\times K} = \left[\iota_{(K-1)}\colon -I_{(K-1)}\right]$, before the factorization of innovations variance-covariance matrix using the matrix of correlations. They suggest that the generalization is suitable for the cases where the price discovery contribution of different but related financial securities are analyzed such as price discovery in markets for different security issued by the same firm and call the new measure Generalized Information Share (GIS).

Another measure of price discovery (let us denote it by TLS) was developed by Grammig and Peter (2013) to address the IS problem of non-uniqueness, particularly for longer sampling intervals. They assume a multivariate mixture distribution to develop a measure which they call "tail-dependent information shares". Like MIS, TLS follows from Hasbrouck's (1995) contribution of a price series variance to the variance of the efficient price as the measure of the series information share by means of reduced VECM long-run impact coefficients. However, the variance decomposition under TLS is performed using a VECM which is extended by the mixture parameters and estimated by a two-step process. This, unlike IS, results in an order neutral measure and is claimed to be superior to IS and PT when correlations of price innovations in the tails differ from those in the center of the distributions.

Lien and Wang (2016) conduct a research using simulated data to compare the IS upper and lower bound midpoint with the two unique, more recent, information shares of MIS and TLS. They find that TLS performs poorly for the simulated data even when the underlying assumptions of the approach are met. Moreover, their results show that MIS at most marginally improves the information share computed by the IS midpoint. They, therefore, support the use of the IS midpoint as a method of computing the information shares of different price series.

We use the two common information share metrics i.e. Hasbrouck (1995) IS and Gonzalo and Granger (1995) PT as well as Lien and Shrestha (2009) MIS metric to determine the contribution of the BAS and the LOB beyond the BAS to price discovery of the six markets under study. An extended survey on the developments in information share research and the studies using different approaches in various settings can be found in Narayan and Smyth (2015).

There is very little work done on the agricultural commodities futures market and little information available regarding the contribution of each step of a limit order book to price discovery for these commodities. We compute the three introduced measures of information share to have a better understanding of the role of a limit order book in price discovery in the agricultural commodities futures market. To make our results comparable to other markets, we also calculate the measures for the popular E-mini S&P 500. We also break down the steps beyond BAS into two price series to assess whether the information contained in the LOB is uniformly distributed or the steps closer to the BAS contain different amount of information relative to the steps farther away. The analysis aims to improve our understanding of the price discovery process in futures markets, and in particular in agricultural commodity markets.

4.5. Results

The presence of a unit root at levels and first differences for each price series is tested using the Augmented Dickey–Fuller unit root test and all price series are found to be I(1) for most days (table 4.A1). The unit root test is performed using different number of lags up to eighty with no significant change in the results. The VEC model in equation [4.4] is estimated for each day and the daily and average information share computed using equations [4.18], [4.19], and [4.22], over all days is reported for each product. The cointegration rank is tested using three statistics namely Johansen's trace statistic at the 99% confidence level, minimizing the Schwarz Bayesian information criterion (BIC), and minimizing the Hannan and Quinn information criterion (HQIC) (Gonzalo and Pitarakis, 1998; Aznar and Salvador, 2002). The rank is found to be 2 for the three-price series model and 3 for the four-price series model for almost all days. Therefore, for most days, the assumption that the system has $r = K - 1$ cointegrating vectors and the impact matrix, $\Psi(1)$, has rank one is satisfied (table 4.A2).

Moreover, all models are estimated using eighty lags for each price series.[40] Lagrange Multiplier (LM) test and autocorrelation functions were used to test for autocorrelation in the residuals and showed no significant autocorrelation in the residuals.

Tables 4.6 to 4.11 report means of each of the price discovery measures (i.e. IS, PT, and MIS) for all futures contracts for the three-variable model. The daily information share measures for the six futures contracts are reported in table 4.A3. The information shares computed for the days for which the model underlying assumptions are not fully met according to the tests i.e. I(1) price series or a single cointegration vector present in the model, as can be seen in the table, are in line with the information shares for the rest of the days and thus are included in the calculation of the average information share measures over all days. Tables 4.6 to 4.11 and 4.A3 show the information share measures for the model with three price series i.e. Price, WP^{1}, and $WP^{2\text{-}5}$ (for meats) and $WP^{2\text{-}10}$ (for grains and E-mini S&P 500). The three measures expectedly lead to different information shares, however, with an overall consistency. Daily information share measures in table 4.A3 show that for days when one measure of information share for a price series is high (low), the other two information shares also result in higher (lower) shares. For the majority of the weeks, the information share for the LOB beyond the BAS follows a V-shape pattern for E-mini S&P 500 (table 4.A3). This means that a week starts with a high information share for the LOB beyond the BAS. The information share declines for the following weekdays and reaches a minimum in the middle of the week, mainly on Wednesdays. The information

[40] The number of lags is usually determined by minimizing a criterion such as AIC or BIC. These tests were performed using a maximum number of 80 lags. Using 80 lags results in minimum AIC and BIC and thus 80 lags were added to the model. Adding more lags to the system of equations increasingly lowers the degrees of freedom and requires greater computational power. Also 80 lags cover over ten minutes of time for the agricultural commodities datasets used here given that our time intervals are greater than 7 seconds for all agricultural commodities. Moreover, Lehecka et al. (2014) show that announcement effects of major USDA reports on corn futures prices and volume disappear in ten minutes, using intraday Chicago Board of Trade data for July 2009 to May 2012.

share of the LOB beyond the BAS then increases reaching previous high levels at the end of trading weeks. For the agricultural commodities this pattern is less apparent meaning that the information contained in the steps beyond the BAS can be higher or lower for any weekday during a particular week (table 4.A3).

Based on the aggregate results in tables 4.6 to 4.11, the three measures indicate a substantial contribution of the steps beyond the BAS to price discovery for all futures contracts higher than that of Cao et al. (2009) study for the Australian stocks (22%). Considering the midpoint IS measure (IS_M), the contribution of the steps beyond the BAS for grains to price discovery is about 30% (29.49% for corn, 30.16% for soybeans, and 31.01% for wheat). IS_M suggests a slightly lower share for the steps beyond the BAS for lean hogs (26.69%), E-mini S&P 500 (26.92%), and live cattle (27.29%). The share of the steps beyond the BAS are considerably higher according to PT. The information share contained in the steps beyond the BAS based on PT, are 32.76% and 35.21% for lean hogs and live cattle, respectively. PT indicates a high information share for the steps beyond the BAS for wheat (42.26%) and soybeans (43.72%). The information share for the steps further from the top of the book is even higher for corn (52.90%) and E-mini S&P 500 (59.44%). MIS results are similar to PT information share for the steps beyond the BAS for lean hogs, live cattle, wheat, and soybeans. MIS of the steps beyond the BAS for live cattle is 34.92% and is 33.25% for lean hogs. For grains, MIS indicates a 40.10% share for the steps beyond the BAS for wheat, 40.66% for soybeans, and 42.49% for corn. For E-mini S&P 500, the MIS for the steps beyond the BAS is 45.19%.

A similar share for the steps beyond the BAS for live cattle and lean hogs is found despite the fact that during the period of study, the average price event duration is significantly lower for live cattle relative to lean hogs (7 compared to 12 seconds in table 4.4). This implies that even though the live cattle futures market is considerably more active, that is with more price changes than lean hogs, traders in both markets utilize the steps of the LOB beyond the BAS in their trading strategies to a similar extent. Moreover, according to table 4.4, lean hogs and wheat have approximately the same duration (12 seconds) but the share for the steps beyond the BAS is higher for wheat than lean hogs. In addition, live cattle duration is lower than grains whereas its share for the steps beyond the BAS for grains is higher than that of live cattle. A comparison among the agricultural commodities shows that live cattle and soybeans are the commodities with the highest number of price events whereas lean hogs and wheat have the highest price durations. Moreover, the informativeness of the LOB beyond the BAS is similar for lean hogs and live cattle and is similar for soybeans and wheat and corn. This suggests a higher level of noise in the live cattle futures market relative to the rest of the agricultural commodities.

The futures markets analyzed appear to be more homogenous with regards to the information contained in the BAS. With the exception of PT for E-mini S&P 500, the BAS contributes to the price discovery by about 30%. The BAS contains more information in price discovery for the meats group compared to the other products, according to the measures. Price contains a moderate contribution to price discovery for the grains and E-mini S&P 500 but higher information for live cattle and lean hogs (tables 4.6 - 4.11).

Tables 4.6 - 4.11 also show that the higher-lower bound for IS is considerably wide for all products despite using short intervals for taking the samples. This emphasizes the importance of a measure for price discovery which is order insensitive.

Insert Table 4.6 - 4.11 Here

As a robustness check, we calculated the information share measures for all the markets using 60-second interval data. The results are reported in the appendix, table 4.A5. The information share measures obtained from the 60-second interval data is particularly different for E-mini S&P 500 relative to our main results. Using 60-second interval data for E-mini S&P 500 increases the contribution of the BAS and decreases the information share measures for the steps beyond the BAS. This can be explained by the large number of book updates that are missed which come mainly from the steps beyond the BAS ad may carry information. For this reason, the difference between the measures derived from the main data and those derived from the data with 60-second intervals for lean hogs and wheat is small. And the measures become increasingly different for the products for which the LOB is more frequently updated such as corn.

We also calculated the information share measure using MID instead of WP^1 to compare the results with those of Cao et al. (2009). The results are reported in the appendix, table 4.A6. The results of the IS midpoint metric for E-mini S&P 500 when MID is used instead of WP^1 are similar to Cao et al. (2009) results for IS midpoint for the one hundred active Australian stocks. They find the information share of the LOB for nine steps beyond the BAS to be 22.47% on average using the midpoint Hasbrouck (1995) information share. Moreover, they find that Price has a share of 23.15% and MID's share is 54.50%. Our normalized IS midpoint results for the E-mini S&P 500 are 24.27% for Price, 50.17% for MID, and 25.56% for $WP^{2\text{-}10}$ (table 4.A6).[41] Comparing our results of the model with WP^1 in tables 4.6 - 4.11 and that of the model with MID in table 4.A6, the information share of MID appears to be considerably higher than that of

[41] The IS midpoint measure for different price series does not necessarily sum to a hundred percent. Thus, the IS midpoint for the price series is normalized to add up to a hundred percent.

WP^1 according to all three measures for all the products studied. This may be due to the lower level of noise in MID than WP^1 and not necessarily a reflection of a higher level of informativeness (Yan and Zivot, 2010; Putnins, 2013). MID is only sensitive to changes in the best bid and best ask whereas WP^1 fluctuates with a change in the corresponding quantities of best bid and ask as well. This also implies that a considerable part of the BAS updates that comes from the change in quantities at the best bid and ask is due to trades that carry noise and are not necessarily due to an inflow of information in the market. Moreover, impatient and liquidity traders submit their orders primarily at the best prevailing bid and ask (Pascual and Veredas, 2009).

By visualizing the shape of the average LOB for the six products in table 4.5 and figures 4.21 - 4.26, we observe a special shape for agricultural commodities' LOB. The number of contracts on the second and third steps seem to be considerably higher than steps further from the BAS. To study this further, we break down the steps of the LOB beyond the BAS into two variables, one with steps closer to the top of the book and one farther, to examine whether the information of the steps beyond the BAS is uniformly distributed. In order words, we examine if informed traders use steps which are closer to the top of the book rather than the steps further from the BAS to exploit their private information. For E-mini S&P 500, the contracts spread more or less equally across all steps. Therefore, in order to assess the information contained in the LOB in more detail, we construct two variables for the agricultural commodities (one for the second and third steps and one for the remaining steps) and two variables for the E-mini S&P 500 (one for the second to fifth steps and one for the remaining steps). The daily information share measures are presented in table 4.A4. The aggregate results are reported in table 4.12.

Insert Table 4.12 Here

Similar to the three-variable model, the information share measures produce different shares but are consistent across all days. The information share for the variables that are relatively lower (higher) based on one measure is lower (higher) for the other two measures as well. An important pattern again is evident for the information share of the steps beyond the BAS for E-mini S&P 500. According to table 4.12, the V-shape pattern of the whole LOB beyond the BAS that was observed in the three-variable model in table 4.8 is due to the steps closer to the BAS. And the information share of the steps closer to the BAS and the steps further away along the book have opposite patterns. In other words, when a trading week starts, the steps closer to the BAS contain higher information which decreases on the following days and increases by the end of the week before the weekend. However, the steps farther start the week with lower information, increase in information over the next weekdays and end the week with low information once again. The higher information contained in the steps closer to the top of the book offset the opposite behaviour of the steps farther and overall gives the LOB information share a V-shape pattern for each week. For agricultural commodities, the pattern of the information share appears to be more random.

Table 4.12 shows that the information share measures indicate a higher share for the steps closer to the top of the book for most of the products. From the two meats, live cattle steps closer to the BAS have relatively more information share based on the three metrics results. For lean hogs, IS_M, PT, and MIS of $WP^{2\text{-}3}$ are, respectively, 18.80, 26.05, and 26.48 percent, comparable to 17.06, 17.06, and 18.77 percent of $WP^{4\text{-}5}$. The difference is more pronounced for live cattle. IS, PT, and MIS of $WP^{2\text{-}3}$ for live cattle are, respectively, 19.83, 28.79, and 28.26 percent, as opposed to 16.04, 17.14, and 18.64 percent of $WP^{4\text{-}5}$. This means that in live cattle futures markets, despite the high number of price events and the possibility of high noise, the noise is not necessarily concentrated in the steps close to the top of the book. For grains, the measures generate mixed results but it seems that the two steps beyond the BAS are as informative as the seven steps further away. For corn, all measures suggest a slightly higher share for WP^{2-3} than WP^{4-10} whereas for soybeans the opposite is true. For E-mini S&P 500, WP^{2-5} has a significantly higher information share than WP^{6-10}, according to all three measures.

Cao et al. (2009) also examined the distribution of information across the LOB steps beyond the BAS using two variables for the 100 most active Australian stocks. They divided their LOB steps beyond the BAS into two variables one from step 2 to 4 and the other from step 5 to 10. Despite considerable higher depth in the steps closer to the BAS, they find that the contribution of the steps further from the BAS to price discovery is higher than the steps closer to the BAS. They link this phenomenon to the existence of two types of orders in the steps at or near the top of the book: orders that are used in searching for hidden orders or orders that are "faked" and canceled in a few seconds and are used to "spoof" the opposite side of the market in order to improve the price levels in the trader's favour. This "fishing" and "spoofing" may be less present in the steps further from the top of the book and thus those steps may be less noisy and more informative. We find that in the futures markets, this is not the case and the steps closer to the top of the book contain more information than the steps further from the BAS. This can be an indication that faked and hidden orders are used to a lesser degree in the futures markets. Across the agricultural commodities, soybeans might be the market with relatively higher noise present near the top of the book as opposed to corn and meats.

4.6. Conclusions

Price discovery is a fundamental function of futures markets and is defined as the incorporation of information to prices through the actions of traders. Recent finance literature has found evidence that, as a part of their trading strategies, informed traders may submit limit orders instead of market orders for a variety of reasons such as minimizing their market impact or to avoid disclosing their private information to other traders. If so, the BAS and the steps of LOB beyond BAS contain valuable information and contribute to price discovery of the underlying asset. This is the first attempt to examine the informativeness of the LOB beyond BAS for agricultural commodities.

We reconstruct the LOB for five major agricultural commodities namely live cattle, lean hogs, corn, wheat, and soybean as well as a very active futures contract namely E-mini S&P 500 using all book updates over the period of Nov. 23, 2015 to Mar. 31, 2016. We find that there is large number of contracts existing on the bids and asks beyond the best bid and ask for all the products. For agricultural commodities, most contracts exist at steps two and three compared to the BAS and the steps farther from the top of the book. For E-mini S&P 500, we find that the contracts are uniformly distributed along the LOB steps.

Three information share metrics are applied to assess whether informed traders use the steps of the LOB beyond the BAS in futures markets and especially in agricultural commodity markets in their trading strategies. Our results show a substantial contribution of the steps of the LOB beyond the BAS to price discovery in futures markets, higher than what the literature finds for stock markets (i.e. Cao et al., 2009). Across the products studied, IS indicates a 27% share for the contribution of the steps beyond the BAS to price discovery for meats and E-mini S&P 500 and about 29%-31% for the grains. PT information share suggests that the contribution of the LOB steps beyond the BAS is in the 30%-40% range for meats, the 40%-50% range for soybeans and wheat, and the 50%-60% range for corn and E-mini S&P 500. MIS information share for the LOB steps beyond the BAS is about 33%-35% for the meats, 40%-42% for the grains, and 45% for E-mini S&P 500. Moreover, the information contained in the BAS and Price is higher for the meats than the rest of the products studied.

Along the LOB steps, our results show that the steps closer to the top of the book have more information relative to the steps farther from the best bid and ask. This contrasts the finding by Cao et al. (2009) and suggests that faked and spoofing trades are less present in the futures markets relative to the stock markets. Considering the daily estimates of the information share metrics, our results show that the steps beyond the BAS but closer to the top of the book contain more information during the early and late weekdays and less information in the middle of the week, mainly Wednesdays creating a V-shaped pattern for the LOB information share for E-mini S&P 500. On the other hand, the steps beyond the BAS but farther from the top of the book have the opposite behaviour and start the week with less information, the information increases and reaches its peak in the middle of the week, and finishes the week with lower information. This means that informed traders in the E-mini S&P 500 futures markets use the steps closer to the top of the book more on the early and late days of the week and the steps farther in the middle of the week. The behaviour of the LOB steps for agricultural commodities appears to be less systematic.

Table 4.1 Listed contracts for all the futures contracts

Commodity	Listed contracts	Contract unit	Tick (cent)
Live Cattle	Feb, Apr, Jun, Aug, Oct, Dec	40,000 pounds	1000
Lean Hogs	Feb, Apr, May, Jun, Aug, Oct, Dec	40,000 pounds	1000
Corn	Mar, May, Jul, Sep, Dec	5,000 bushels	1250
Wheat	Mar, May, Jul, Sep, Dec	5,000 bushels	1250
Soybeans	Jan, Mar, May, Jul, Aug, Sep, Nov	5,000 bushels	1250
E-mini S&P 500	Mar, Jun, Sep, Dec	$50 × S&P 500 Index	1250

Table 4.2 Nearby contracts for all the futures contracts

	Contracts – Expiration	Days before rolling
	December – 18 Dec. 2015	23 Nov. 2015 – 10 Dec. 2015
E-min S&P 500	March – 18 Mar. 2016	11 Dec. 2015 – 10 Mar. 2016
	June – 17 Jun. 2016	11 Mar. 2016 – 31 Mar. 2016
	February – 12 Feb. 2016	23 Nov. 2015 – 20 Jan. 2015
Lean Hogs	April – 14 Apr. 2016	21 Jan. 2016 – 22 Mar. 2016
	June – 14 Jun. 2016	23 Mar. 2016 – 31 Mar. 2016
	February – 29 Feb. 2016	23 Nov. 2015 – 18 Jan. 2016
Live Cattle	April – 30 Apr. 2016	19 Jan. 2016 – 16 Mar. 2016
	June – 30 Jun. 2016	17 Mar. 2016 – 31 Mar. 2016
	January – 14 Jan. 2016	23 Nov. 2015 – 20 Dec. 2015
Soybeans	March – 14 Mar. 2016	21 Dec. 2015 – 21 Feb. 2016
	May – 13 May 2016	22 Feb. 2016 – 31 Mar. 2016
Corn	March – 14 Mar. 2016	23 Nov. 2015 – 21 Feb. 2016
	May – 13 May 2016	22 Feb. 2016 – 31 Mar. 2016
Wheat	March – 14 Mar. 2016	23 Nov. 2015 – 18 Feb. 2016
	May – 13 May 2016	19 Feb. 2016 – 31 Mar. 2016

Table 4.3 Mean and Standard Deviation of the Full LOB

	Lean Hogs	Live Cattle	Corn	Wheat	Soybeans	E-mini S&P 500
Obs.(1)	6,176,794	6,961,908	25,305,597	21,285,007	42,625,431	386,421,232
Price(2)	66835.90 (6666.22)	132277.90 (4498.3)	366.09 (7.23)	471.54 (11.44)	880.52 (14.79)	195664.50 (7608.52)
Volume (contract)(3)	(2.06) (2.82)	2.19 (2.78)	12.07 (32.25)	4.72 (9.19)	5.32 (10.32)	10.13 (25.99)
Number of Orders	2.08 (1.06)	2.03 (0.98)	5.78 (8.01)	3.69 (3.77)	4.06 (4.31)	4.86 (7.64)
Bid 1	66816.08 (6667.63)	132255.10 (4499.03)	365.97 (7.23)	471.41 (11.44)	880.39 (14.79)	195651.70 (7608.56)
Ask 1	66856.39 (6664.52)	132300.90 (4497.35)	366.23 (7.23)	471.68 (11.44)	880.66 (14.79)	195677.30 (7608.50)
Bid 2	66790.74 (6667.82)	132229.50 (4499.21)	365.72 (7.23)	471.16 (11.44)	880.14 (14.79)	195626.70 (7608.56)
Ask 2	66881.76 (6664.30)	132326.60 (4497.20)	366.48 (7.23)	471.93 (11.44)	880.91 (14.79)	195702.30 (7608.50)
Bid 3	66765.45 (6667.99)	132203.80 (4499.40)	365.47 (7.23)	470.91 (11.44)	879.89 (14.79)	195601.70 (7608.56)
Ask 3	66907.11 (6664.14)	132352.20 (4497.12)	366.73 (7.23)	472.18 (11.44)	881.16 (14.79)	195727.30 (7608.50)
Bid 4	66740.16 (6668.19)	132178.20 (4499.57)	365.22 (7.23)	470.66 (11.44)	879.64 (14.79)	195576.70 (7608.56)
Ask 4	66932.39 (6664.02)	132377.70 (4497.04)	366.98 (7.23)	472.43 (11.44)	881.41 (14.79)	195752.30 (7608.50)
Bid 5	66714.76 (6668.41)	132152.40 (4499.83)	364.97 (7.23)	470.41 (11.44)	879.39 (14.79)	195551.70 (7608.56)
Ask 5	66957.75 (6663.83)	132403.30 (4496.99)	367.23 (7.23)	472.68 (11.44)	881.66 (14.79)	195777.30 (7608.50)

(1)Is the total number of LOB updates or the total number of books for the nearby contracts.
(2)Is the average transaction price for the nearby contracts. The price unit is 0.001 cent per pound for livestock, cent per bushel for grains, and cent per contract for E-mini S&P 500.
(3)Is the average transaction volume for the nearby contracts.
(4)Is the average number of orders per transaction for the nearby contracts.

Table 4.3 continued

	Lean Hogs	Live Cattle	Corn	Wheat	Soybeans	E-mini S&P 500
Bid 6			364.72 (7.23)	470.16 (11.44)	879.14 (14.79)	195526.70 (7608.56)
Ask 6			367.48 (7.23)	472.93 (11.44)	881.91 (14.79)	195802.30 (7608.50)
Bid 7			364.47 (7.23)	469.91 (11.44)	878.89 (14.79)	195501.70 (7608.56)
Ask 7			367.73 (7.23)	473.18 (11.44)	882.16 (14.79)	195827.30 (7608.50)
Bid 8			364.22 (7.23)	469.66 (11.44)	878.64 (14.79)	195476.70 (7608.56)
Ask 8			367.98 (7.23)	473.43 (11.44)	882.41 (14.79)	195852.30 (7608.50)
Bid 9			363.97 (7.23)	469.41 (11.44)	878.39 (14.79)	195451.70 (7608.56)
Ask 9			368.23 (7.23)	473.68 (11.44)	882.66 (14.79)	195877.30 (7608.50)
Bid 10			363.72 (7.23)	469.16 (11.44)	878.14 (14.79)	195426.70 (7608.56)
Ask 10			368.48 (7.23)	473.93 (11.44)	882.91 (14.79)	195902.30 (7608.50)
Quant.1 buy (contract)	6.33 (8.67)	5.91 (7.80)	377.69 (431.07)	45.26 (47.32)	62.45 (66.55)	160.35 (139.51)
Quant.1 sell (contract)	6.48 (10.66)	5.56 (6.99)	375.27 (414.80)	43.92 (47.31)	64.00 (68.54)	159.31 (140.88)
Quant.2 buy (contract)	11.12 (10.95)	10.44 (10.97)	716.52 (467.46)	98.47 (61.80)	147.00 (90.48)	314.07 (163.47)
Quant.2 sell (contract)	12.40 (15.27)	10.16 (10.19)	682.75 (408.51)	95.02 (61.09)	150.04 (101.81)	313.77 (169.32)
Quant.3 buy (contract)	11.09 (10.95)	10.47 (11.06)	538.92 (379.75)	79.01 (64.52)	119.31 (86.04)	365.46 (178.83)

Table 4.3 continued

	Lean Hogs	Live Cattle	Corn	Wheat	Soybeans	E-mini S&P 500
Quant.3 sell (contract)	12.20 (16.45)	9.88 (10.83)	484.61 (329.01)	76.67 (66.42)	120.68 (102.06)	365.88 (184.22)
Quant.4 buy (contract)	9.48 (11.60)	8.95 (11.19)	419.09 (313.07)	62.15 (64.76)	88.90 (71.83)	388.33 (187.62)
Quant.4 sell (contract)	10.86 (16.77)	8.28 (10.71)	387.64 (279.37)	59.10 (62.31)	93.46 (95.33)	389.95 (193.41)
Quant.5 buy (contract)	8.72 (12.06)	8.46 (12.33)	401.01 (306.12)	63.44 (73.51)	90.66 (79.50)	402.50 (191.85)
Quant.5 sell (contract)	10.90 (19.80)	7.98 (12.19)	371.72 (285.90)	59.79 (62.09)	98.29 (109.71)	404.79 (199.81)
Quant.6 buy (contract)			369.64 (284.56)	63.41 (74.08)	88.44 (82.84)	416.85 (194.19)
Quant.6 sell (contract)			350.73 (301.49)	59.39 (63.00)	95.88 (111.69)	419.54 (202.98)
Quant.7 buy (contract)			343.95 (276.23)	61.49 (72.41)	83.53 (83.83)	423.42 (194.46)
Quant.7 sell (contract)			321.98 (305.87)	57.89 (65.23)	89.62 (109.35)	426.40 (202.03)
Quant.8 buy (contract)			323.65 (261.35)	57.76 (70.05)	80.67 (82.89)	427.13 (193.24)
Quant.8 sell (contract)			310.74 (297.76)	54.98 (65.41)	86.58 (102.85)	430.61 (200.79)
Quant.9 buy (contract)			312.04 (260.15)	55.74 (70.88)	82.27 (89.39)	424.55 (189.48)
Quant.9 sell (contract)			304.45 (308.39)	54.56 (68.26)	89.06 (107.74)	429.22 (202.42)
Quant.10 buy (contract)			302.25 (249.49)	56.05 (74.46)	83.82 (92.80)	426.65 (187.98)
Quant.10 sell (contract)			298.57 (303.45)	54.53 (69.90)	91.66 (115.24)	433.34 (207.77)

The standard deviation is between parentheses.
Ask (Bid) x is the mean ask (bid) price in the x^{th} step of the LOB across all reconstructed LOBs in the sample period. Quant. x is the mean number of contracts in the x^{th} step of the LOB.

Table 4.4 Price Event Durations

	Average Price Event Duration (Second)	Standard Deviation	Min. Price Event Duration (Second)	Max. Price Event Duration (Second)
Live Cattle	7.40	2.43	2.08	14.60
Lean Hogs	11.97	3.72	6.68	26.51
Corn	8.63	2.51	2.48	16.51
Wheat	11.94	4.07	3.87	25.70
Soybeans	7.60	2.12	1.84	14.70
E-mini S&P	1.12	0.65	0.35	4.12

Note. Price event is defined as a price change. And price event duration is the time between two price changes. In constructing average price event durations for each product in table 4.4, the mean of each day price durations is computed for the sample period and averaged across all days. Minimum and maximum price event durations in the table refer to the minimum and maximum average durations for all days in the sample period.

Table 4.5 Summary Statistics of the shape of the average sample LOB, Nov. 23, 2015 – Mar. 31, 2016

	Length (%)		Height (%)		Length (number of contracts)		Height (Cents)	
Steps	Buy	Sell	Buy	Sell	Buy	Sell	Buy	Sell
Live Cattle								
1	14.39	14.25	18.22	18.28	6.20	5.74	23.51	23.51
2	24.52	24.98	20.38	20.44	10.95	10.45	27.52	26.25
3	23.96	23.60	20.40	20.42	10.80	10.08	25.81	25.53
4	19.43	19.12	20.45	20.41	8.95	8.28	26.25	25.42
5	17.70	18.06	20.55	20.46	8.52	8.13	26.83	25.52
Number of observations: 176,142; mean price: 132498; mean volume: 1.74; mean number of orders: 1.95								
Lean Hogs								
1	14.87	13.57	16.78	16.79	6.44	6.29	21.07	21.07
2	24.37	24.11	20.75	20.73	10.78	11.70	25.86	25.26
3	23.77	23.11	20.74	20.88	10.73	11.55	25.20	26.30
4	19.46	20.02	20.88	20.78	9.02	10.39	26.27	25.38
5	17.52	19.19	20.84	20.81	8.34	10.73	25.50	25.42
Number of observations: 116,082; mean price: 66282.95; mean volume: 1.62; mean number of orders: 1.99								
Corn								
1	9.38	10.12	5.32	5.30	407.20	401.17	0.13	0.13
2	17.72	18.09	10.54	10.52	760.14	712.05	0.25	0.25
3	12.88	12.09	10.54	10.52	557.94	477.20	0.25	0.25
4	10.04	9.85	10.51	10.50	443.41	401.16	0.25	0.25
5	9.75	9.57	10.51	10.59	429.93	392.65	0.25	0.25
6	8.84	8.96	10.52	10.52	390.11	372.34	0.25	0.25
7	8.41	8.20	10.51	10.52	366.82	334.70	0.25	0.25
8	7.78	7.84	10.51	10.52	335.03	320.76	0.25	0.25
9	7.78	7.71	10.51	10.50	328.54	319.11	0.25	0.25
10	7.41	7.56	10.51	10.50	315.21	312.85	0.25	0.25
Number of observations: 175,463; mean price: 365.90; mean volume: 4.93; mean number of orders: 3.98								

Table 4.5 Continued

	Length (%)		Height (%)		Length (number of contracts)		Height (Cents)	
Steps	Buy	Sell	Buy	Sell	Buy	Sell	Buy	Sell
				Wheat				
1	7.79	8.36	5.57	5.54	47.94	47.22	0.13	0.13
2	16.25	16.90	10.53	10.50	103.35	97.98	0.25	0.25
3	12.54	12.81	10.49	10.53	81.31	77.12	0.25	0.25
4	9.33	9.26	10.49	10.50	64.54	59.07	0.25	0.25
5	9.42	9.34	10.51	10.48	68.04	61.48	0.25	0.25
6	9.56	9.34	10.48	10.53	68.79	61.83	0.25	0.25
7	9.36	9.01	10.48	10.50	66.76	59.76	0.25	0.25
8	8.66	8.36	10.48	10.46	61.68	56.32	0.25	0.25
9	8.55	8.37	10.49	10.49	60.67	56.76	0.25	0.25
10	8.55	8.25	10.49	10.46	60.84	56.10	0.25	0.25
Number of observations: 126,789; Price mean: 471.69; mean volume: 2.92; mean number of orders: 3.03								
				Soybeans				
1	6.90	6.92	5.48	5.47	63.73	64.19	0.13	0.13
2	16.58	16.34	10.50	10.59	153.24	154.03	0.25	0.26
3	13.32	12.88	10.52	10.50	123.06	121.91	0.25	0.25
4	9.41	9.36	10.50	10.51	91.42	94.19	0.25	0.25
5	9.62	9.75	10.50	10.52	95.19	101.99	0.25	0.25
6	9.26	9.42	10.52	10.51	93.57	98.70	0.25	0.25
7	8.79	8.77	10.50	10.48	89.37	91.13	0.25	0.25
8	8.55	8.61	10.50	10.48	85.59	88.46	0.25	0.25
9	8.67	8.91	10.48	10.48	88.09	92.24	0.25	0.25
10	8.90	9.03	10.50	10.48	90.04	93.51	0.25	0.25
Number of observations: 201,377; mean price: 879.08; mean volume: 3.40; mean number of orders: 3.35								

Table 4.5 Continued

	Length (%)		Height (%)		Length (number of contracts)		Height (Cents)	
Steps	Buy	Sell	Buy	Sell	Buy	Sell	Buy	Sell
				E-mini S&P 500				
1	4.27	4.08	5.71	5.72	158.94	157.85	14.05	14.05
2	8.31	8.18	10.68	10.65	311.12	311.61	25.91	25.66
3	9.53	9.67	10.47	10.44	356.51	359.31	25.11	25.00
4	10.39	10.14	10.44	10.47	378.33	382.38	25.01	25.11
5	10.46	10.58	10.53	10.44	392.24	397.86	25.28	25.00
6	11.15	11.22	10.43	10.44	407.05	414.61	25.00	25.00
7	11.26	11.51	10.43	10.44	412.87	420.85	25.00	25.00
8	11.59	11.40	10.43	10.44	417.89	425.06	25.00	25.00
9	11.44	11.53	10.43	10.44	413.79	422.93	25.00	25.00
10	11.61	11.68	10.43	10.52	414.48	426.24	25.00	25.27

Number of observations: 2,263,729; mean price: 197,931.20; mean volume: 4.42; mean number of orders: 3.03

Table 4.6 Summary Statistics of the Average Information Share Measures; Live Cattle (%)

		Price	WP^1	WP^{2-5}
	Mean	77.67	63.18	55.14
	Median	76.18	60.48	51.11
IS_H	Sd	10.99	17.27	18.19
	Min	57.70	29.79	29.62
	Max	98.05	96.52	95.33
	Mean	11.69	8.66	5.36
	Median	7.59	5.23	2.84
IS_L	Sd	11.53	8.46	5.95
	Min	0.11	0.00	0.00
	Max	43.46	31.56	24.32
IS_M	Mean(N)	**40.31**	**32.40**	**27.29**
	Mean	**26.83**	**37.96**	**35.21**
	Median	20.69	31.36	32.61
PT	Sd	20.27	22.07	23.51
	Min	2.13	0.49	0.14
	Max	81.41	86.97	82.28
	Mean	**28.54**	**36.53**	**34.92**
	Median	23.73	32.31	34.16
MIS	Sd	13.34	12.36	13.25
	Min	12.32	10.49	13.23
	Max	71.30	63.00	62.72

Note. The information share metrics in the table are estimated for each day and averaged over all days in the sample period. IS_M is calculated by averaging the IS_H and IS_L for each day and then averaging over all days. IS_M for the variables does not necessarily add up to 100 percent. Thus, we normalized IS_M for the three variables to add up to 100 percent, and its mean is referred to as Mean(N), to be comparable to the other measures.

Table 4.7 Summary Statistics of the Average Information Share Measures; Lean Hogs (%)

		P	WP^1	WP^{2-5}
	Mean	79.59	58.55	52.79
	Median	79.46	54.70	49.63
IS_H	Sd	11.37	18.24	16.15
	Min	44.45	30.37	30.93
	Max	100.00	99.28	95.74
	Mean	13.80	8.08	5.47
	Median	11.22	3.92	3.11
IS_L	Sd	11.07	8.88	5.89
	Min	0.04	0.00	0.00
	Max	44.26	42.07	21.11
IS_M	Mean(N)	**42.78**	**30.53**	**26.69**
	Mean	**32.20**	**35.04**	**32.76**
	Median	27.34	31.69	29.19
PT	Sd	21.06	23.23	20.81
	Min	1.25	0.18	0.66
	Max	98.73	91.30	86.54
	Mean	**31.49**	**35.26**	**33.25**
	Median	28.30	33.35	31.40
MIS	Sd	13.58	13.55	12.70
	Min	10.12	11.51	11.97
	Max	75.28	71.31	62.61

Table 4.8 Summary Statistics of the Average Information Share Measures; Corn (%)

		P	WP^1	$WP^{2\text{-}10}$
	Mean	53.84	62.87	50.38
	Median	49.01	64.76	46.14
IS_H	Sd	20.75	17.87	23.38
	Min	17.30	18.22	8.66
	Max	96.87	96.98	95.83
	Mean	16.87	16.09	12.21
	Median	11.24	13.21	9.68
IS_L	Sd	17.12	15.11	10.02
	Min	0.00	0.11	0.00
	Max	75.03	60.13	40.57
IS_M	Mean(N)	**33.31**	**37.20**	**29.49**
	Mean	**20.87**	**26.23**	**52.90**
	Median	18.98	24.50	55.40
PT	Sd	15.80	17.95	21.99
	Min	0.08	1.98	1.33
	Max	74.78	84.72	91.13
	Mean	**24.91**	**32.60**	**42.49**
	Median	20.86	31.90	39.95
MIS	Sd	18.17	14.41	16.11
	Min	2.26	7.70	9.61
	Max	82.69	71.35	76.48

Table 4.9 Summary Statistics of the Average Information Share Measures; Wheat (%)

		P	WP^1	WP^{2-10}
	Mean	68.69	59.75	58.41
	Median	69.67	58.60	57.70
IS_H	Sd	15.00	14.97	16.36
	Min	33.82	30.75	26.41
	Max	99.45	93.82	94.32
	Mean	12.75	8.98	9.08
	Median	10.18	7.36	7.54
IS_L	Sd	11.09	8.11	7.42
	Min	0.00	0.00	0.00
	Max	52.38	38.65	29.30
IS_M	Mean(N)	**37.42**	**31.58**	**31.01**
	Mean	**28.52**	**29.22**	**42.26**
	Median	26.06	27.29	42.98
PT	Sd	18.19	16.61	20.14
	Min	0.58	0.12	0.07
	Max	89.51	81.54	81.11
	Mean	**27.49**	**32.42**	**40.10**
	Median	25.61	32.46	40.31
MIS	Sd	14.13	10.78	13.18
	Min	7.44	11.27	11.56
	Max	74.15	63.73	66.17

Table 4.10 Summary Statistics of the Average Information Share Measures; Soybeans (%)

		P	WP^{1}	WP^{2-10}
	Mean	66.92	64.50	57.60
	Median	66.28	63.62	56.93
IS_H	Sd	13.97	13.08	17.85
	Min	31.18	34.06	26.18
	Max	99.60	92.38	99.39
	Mean	11.44	10.22	8.49
	Median	8.01	8.63	6.94
IS_L	Sd	10.27	8.25	7.84
	Min	0.05	0.03	0.02
	Max	48.08	32.80	34.75
IS_M	Mean(N)	**35.75**	**34.09**	**30.16**
	Mean	**26.12**	**30.16**	**43.72**
	Median	21.73	30.71	42.93
PT	Sd	16.96	16.48	22.09
	Min	1.71	1.22	4.44
	Max	83.32	68.22	95.08
	Mean	**25.48**	**33.86**	**40.66**
	Median	22.42	33.51	40.69
MIS	Sd	13.06	10.38	14.01
	Min	4.60	13.45	16.39
	Max	65.60	57.46	72.39

Table 4.11 Summary Statistics of the Average Information Share Measures; E-mini S&P 500 (%)

		P	WP^1	$WP^{2\text{-}10}$
	Mean	77.30	74.06	58.00
	Median	81.75	74.10	59.17
IS_H	Sd	14.23	12.69	9.95
	Min	42.29	49.77	26.52
	Max	96.01	95.93	79.63
	Mean	10.16	6.26	3.81
	Median	8.92	3.35	3.87
IS_L	Sd	7.68	7.03	1.56
	Min	0.01	0.00	0.02
	Max	31.79	30.28	8.21
IS_M	Mean(N)	**38.09**	**34.98**	**26.92**
	Mean	**23.56**	**17.00**	**59.44**
	Median	23.30	15.39	63.46
PT	Sd	12.37	10.76	14.04
	Min	0.71	0.49	4.17
	Max	51.11	57.22	81.11
	Mean	**22.59**	**32.22**	**45.19**
	Median	22.22	31.73	47.44
MIS	Sd	10.06	5.82	6.43
	Min	4.98	21.98	25.99
	Max	45.01	45.56	53.32

Table 4.12 The Information Share Measures for Four-Variable Model (%)

		IS_H	IS_L	IS_M(N)	PT	MIS
Live Cattle	Price	79.65	8.66	37.53	23.92	24.20
	WP^1	57.12	5.45	26.60	30.15	28.90
	WP^{2-3}	42.91	3.75	19.83	28.79	28.26
	WP^{4-5}	34.45	3.30	16.04	17.14	18.64
Lean Hogs	Price	80.80	9.83	39.10	28.43	26.36
	WP^1	53.01	5.05	25.04	28.46	28.40
	WP^{2-3}	40.30	3.29	18.80	26.05	26.48
	WP^{4-5}	35.70	3.83	17.06	17.06	18.77
Corn	Price	51.37	11.01	28.08	15.69	18.17
	WP^1	61.68	9.95	32.25	19.06	25.09
	WP^{2-3}	36.88	8.00	20.21	34.34	29.61
	WP^{4-10}	35.59	7.65	19.47	30.91	27.13
Wheat	Price	70.01	8.52	34.12	22.80	21.52
	WP^1	59.22	6.62	28.61	24.43	26.56
	WP^{2-3}	33.06	3.40	15.84	27.16	25.77
	WP^{4-10}	43.84	5.46	21.42	25.38	26.14
Soybeans	Price	65.81	6.44	31.21	18.42	18.23
	WP^1	63.68	7.32	30.67	25.04	27.28
	WP^{2-3}	33.31	4.00	16.12	28.20	26.28
	WP^{4-10}	44.94	6.02	22.01	28.34	28.21
E-mini S&P	Price	73.23	4.46	31.61	14.48	13.51
	WP^1	82.00	8.19	36.69	21.05	28.57
	WP^{2-5}	44.26	2.04	18.84	45.85	34.46
	WP^{6-10}	30.72	0.90	12.86	18.62	23.46

Note. The measures in the table were calculated for each day and averaged over all days. IS_M is calculated by averaging the IS_H and IS_L for each day and then averaging over all days. IS_M for the variables does not necessarily add up to 100 percent. Thus, we normalized IS_M for the three variables, denoted by IS_M(N), to add to 100 percent to be comparable to the other measures.

Appendix 4.1 Daily Diagnostic Tests and Information Share Measures and robustness checks of 60-second snapshot and MID cases.

Table 4.A1 Unit Root Test Results of the Price Series; Live Cattle Nov. - Dec. 2015

	Dickey-Fuller Test P-Value					Dickey-Fuller Test P-Value				
	Price	WP^{1}	WP^{2-5}	WP^{2-3}	WP^{4-5}	ΔPrice	ΔWP^{1}	ΔWP^{2-5}	ΔWP^{2-3}	ΔWP^{4-5}
23-11-2015	0.155	0.185	0.155	0.155	0.135	<0.000	<0.000	<0.000	<0.000	<0.000
24-11-2015	0.360	0.383	0.318	0.313	0.175	<0.000	<0.000	<0.000	<0.000	<0.000
25-11-2015	0.000	0.001	0.001	0.000	0.000	<0.000	<0.000	<0.000	<0.000	<0.000
30-11-2015	0.370	0.377	0.401	0.353	0.179	<0.000	<0.000	<0.000	<0.000	<0.000
01-12-2015	0.990	0.992	0.992	0.990	0.979	<0.000	<0.000	<0.000	<0.000	<0.000
02-12-2015	0.910	0.936	0.892	0.862	0.707	<0.000	<0.000	<0.000	<0.000	<0.000
03-12-2015	0.275	0.312	0.276	0.228	0.145	<0.000	<0.000	<0.000	<0.000	<0.000
04-12-2015	0.035	0.043	0.046	0.036	0.014	<0.000	<0.000	<0.000	<0.000	<0.000
07-12-2015	0.023	0.047	0.038	0.027	0.016	<0.000	<0.000	<0.000	<0.000	<0.000
08-12-2015	0.513	0.562	0.549	0.539	0.287	<0.000	<0.000	<0.000	<0.000	<0.000
09-12-2015	0.654	0.672	0.637	0.620	0.513	<0.000	<0.000	<0.000	<0.000	<0.000
10-12-2015	0.049	0.040	0.052	0.048	0.067	<0.000	<0.000	<0.000	<0.000	<0.000
11-12-2015	0.445	0.468	0.421	0.385	0.334	<0.000	<0.000	<0.000	<0.000	<0.000
14-12-2015	0.662	0.740	0.712	0.621	0.461	<0.000	<0.000	<0.000	<0.000	<0.000
15-12-2015	0.319	0.314	0.317	0.296	0.263	<0.000	<0.000	<0.000	<0.000	<0.000
16-12-2015	0.009	0.019	0.021	0.008	0.008	<0.000	<0.000	<0.000	<0.000	<0.000
17-12-2015	0.264	0.305	0.245	0.207	0.170	<0.000	<0.000	<0.000	<0.000	<0.000
22-12-2015	0.563	0.595	0.590	0.518	0.389	<0.000	<0.000	<0.000	<0.000	<0.000
23-12-2015	0.433	0.453	0.376	0.431	0.285	<0.000	<0.000	<0.000	<0.000	<0.000
24-12-2015	0.755	0.806	0.790	0.782	0.742	<0.000	<0.000	<0.000	<0.000	<0.000
28-12-2015	0.025	0.044	0.030	0.020	0.007	<0.000	<0.000	<0.000	<0.000	<0.000
29-12-2015	0.050	0.050	0.064	0.036	0.019	<0.000	<0.000	<0.000	<0.000	<0.000
30-12-2015	0.453	0.468	0.457	0.427	0.404	<0.000	<0.000	<0.000	<0.000	<0.000
31-12-2015	0.035	0.031	0.043	0.012	0.008	<0.000	<0.000	<0.000	<0.000	<0.000

BIC and HQIC stand for Schwarz Bayesian Information Criterion and Hannan and Quinn Information Criterion, respectively. Missing ranks in the Johansen's trace cointegration test in the table is due to stationarity of the price series.

Table 4.A1 continued - Unit Root Test Results of the Price Series; Live Cattle Jan. 2016

	Dickey-Fuller Test P-Value					Dickey-Fuller Test P-Value				
	Price	WP^{1}	WP^{2-5}	WP^{2-3}	WP^{4-5}	ΔPrice	ΔWP^{1}	ΔWP^{2-5}	ΔWP^{2-3}	ΔWP^{4-5}
04-01-2016	0.585	0.596	0.589	0.555	0.510	<0.000	<0.000	<0.000	<0.000	<0.000
05-01-2016	0.448	0.474	0.521	0.457	0.419	<0.000	<0.000	<0.000	<0.000	<0.000
06-01-2016	0.204	0.213	0.230	0.191	0.127	<0.000	<0.000	<0.000	<0.000	<0.000
07-01-2016	0.938	0.943	0.919	0.917	0.877	<0.000	<0.000	<0.000	<0.000	<0.000
08-01-2016	0.666	0.654	0.621	0.591	0.481	<0.000	<0.000	<0.000	<0.000	<0.000
11-01-2016	0.139	0.141	0.137	0.121	0.058	<0.000	<0.000	<0.000	<0.000	<0.000
12-01-2016	0.743	0.753	0.733	0.717	0.605	<0.000	<0.000	<0.000	<0.000	<0.000
13-01-2016	0.257	0.285	0.272	0.224	0.156	<0.000	<0.000	<0.000	<0.000	<0.000
14-01-2016	0.342	0.341	0.315	0.283	0.170	<0.000	<0.000	<0.000	<0.000	<0.000
15-01-2016	0.528	0.556	0.535	0.509	0.444	<0.000	<0.000	<0.000	<0.000	<0.000
19-01-2016	0.411	0.411	0.389	0.361	0.262	<0.000	<0.000	<0.000	<0.000	<0.000
20-01-2016	0.217	0.197	0.228	0.198	0.163	<0.000	<0.000	<0.000	<0.000	<0.000
21-01-2016	0.929	0.939	0.938	0.929	0.918	<0.000	<0.000	<0.000	<0.000	<0.000
22-01-2016	0.195	0.149	0.207	0.137	0.092	<0.000	<0.000	<0.000	<0.000	<0.000
25-01-2016	0.002	0.004	0.006	0.004	0.003	<0.000	<0.000	<0.000	<0.000	<0.000
26-01-2016	0.351	0.323	0.426	0.307	0.384	<0.000	<0.000	<0.000	<0.000	<0.000
27-01-2016	0.496	0.483	0.417	0.375	0.296	<0.000	<0.000	<0.000	<0.000	<0.000
28-01-2016	0.044	0.036	0.063	0.036	0.042	<0.000	<0.000	<0.000	<0.000	<0.000
29-01-2016	0.766	0.759	0.774	0.752	0.718	<0.000	<0.000	<0.000	<0.000	<0.000

Table 4.A1 continued - Unit Root Test Results of the Price Series; Live Cattle Feb. 2016

	Dickey-Fuller Test P-Value					Dickey-Fuller Test P-Value				
	Price	WP^{1}	WP^{2-5}	WP^{2-3}	WP^{4-5}	ΔPrice	ΔWP^{1}	ΔWP^{2-5}	ΔWP^{2-3}	ΔWP^{4-5}
01-02-2016	0.296	0.266	0.299	0.247	0.194	<0.000	<0.000	<0.000	<0.000	<0.000
02-02-2016	0.095	0.083	0.163	0.095	0.074	<0.000	<0.000	<0.000	<0.000	<0.000
03-02-2016	0.403	0.386	0.396	0.351	0.178	<0.000	<0.000	<0.000	<0.000	<0.000
04-02-2016	0.196	0.171	0.212	0.171	0.086	<0.000	<0.000	<0.000	<0.000	<0.000
05-02-2016	0.083	0.063	0.064	0.059	0.015	<0.000	<0.000	<0.000	<0.000	<0.000
10-02-2016	0.223	0.203	0.211	0.178	0.113	<0.000	<0.000	<0.000	<0.000	<0.000
11-02-2016	0.276	0.275	0.260	0.227	0.140	<0.000	<0.000	<0.000	<0.000	<0.000
12-02-2016	0.436	0.454	0.475	0.451	0.365	<0.000	<0.000	<0.000	<0.000	<0.000
16-02-2016	0.995	0.995	0.992	0.993	0.977	<0.000	<0.000	<0.000	<0.000	<0.000
17-02-2016	0.211	0.212	0.185	0.183	0.055	<0.000	<0.000	<0.000	<0.000	<0.000
18-02-2016	0.289	0.303	0.297	0.264	0.179	<0.000	<0.000	<0.000	<0.000	<0.000
19-02-2016	0.259	0.263	0.232	0.203	0.124	<0.000	<0.000	<0.000	<0.000	<0.000
22-02-2016	0.531	0.578	0.560	0.537	0.415	<0.000	<0.000	<0.000	<0.000	<0.000
23-02-2016	0.360	0.361	0.335	0.337	0.228	<0.000	<0.000	<0.000	<0.000	<0.000
24-02-2016	0.389	0.394	0.394	0.380	0.259	<0.000	<0.000	<0.000	<0.000	<0.000
25-02-2016	0.311	0.295	0.297	0.252	0.182	<0.000	<0.000	<0.000	<0.000	<0.000
26-02-2016	0.414	0.401	0.314	0.331	0.121	<0.000	<0.000	<0.000	<0.000	<0.000
29-02-2016	0.041	0.055	0.044	0.032	0.006	<0.000	<0.000	<0.000	<0.000	<0.000

Table 4.A1 continued - Unit Root Test Results of the Price Series; Live Cattle Mar. 2016

	Dickey-Fuller Test P-Value					Dickey-Fuller Test P-Value				
	Price	WP^{1}	WP^{2-5}	WP^{2-3}	WP^{4-5}	ΔPrice	ΔWP^{1}	ΔWP^{2-5}	ΔWP^{2-3}	ΔWP^{4-5}
01-03-2016	0.297	0.312	0.276	0.305	0.105	<0.000	<0.000	<0.000	<0.000	<0.000
02-03-2016	0.467	0.424	0.371	0.418	0.180	<0.000	<0.000	<0.000	<0.000	<0.000
03-03-2016	0.067	0.096	0.091	0.092	0.034	<0.000	<0.000	<0.000	<0.000	<0.000
04-03-2016	0.646	0.626	0.692	0.675	0.532	<0.000	<0.000	<0.000	<0.000	<0.000
07-03-2016	0.217	0.230	0.282	0.238	0.150	<0.000	<0.000	<0.000	<0.000	<0.000
08-03-2016	0.735	0.742	0.740	0.739	0.656	<0.000	<0.000	<0.000	<0.000	<0.000
09-03-2016	0.016	0.021	0.028	0.023	0.003	<0.000	<0.000	<0.000	<0.000	<0.000
10-03-2016	0.036	0.041	0.046	0.047	0.008	<0.000	<0.000	<0.000	<0.000	<0.000
11-03-2016	0.242	0.220	0.197	0.219	0.141	<0.000	<0.000	<0.000	<0.000	<0.000
14-03-2016	0.166	0.153	0.180	0.159	0.055	<0.000	<0.000	<0.000	<0.000	<0.000
15-03-2016	0.448	0.415	0.355	0.355	0.186	<0.000	<0.000	<0.000	<0.000	<0.000
16-03-2016	0.314	0.316	0.286	0.299	0.100	<0.000	<0.000	<0.000	<0.000	<0.000
17-03-2016	0.559	0.554	0.590	0.542	0.417	<0.000	<0.000	<0.000	<0.000	<0.000
18-03-2016	0.444	0.455	0.449	0.426	0.116	<0.000	<0.000	<0.000	<0.000	<0.000
21-03-2016	0.167	0.130	0.198	0.110	0.070	<0.000	<0.000	<0.000	<0.000	<0.000
22-03-2016	0.463	0.456	0.502	0.454	0.458	<0.000	<0.000	<0.000	<0.000	<0.000
23-03-2016	0.427	0.471	0.464	0.442	0.349	<0.000	<0.000	<0.000	<0.000	<0.000
24-03-2016	0.470	0.486	0.536	0.474	0.266	<0.000	<0.000	<0.000	<0.000	<0.000
28-03-2016	0.077	0.062	0.121	0.076	0.024	<0.000	<0.000	<0.000	<0.000	<0.000
29-03-2016	0.512	0.508	0.530	0.505	0.359	<0.000	<0.000	<0.000	<0.000	<0.000
30-03-2016	0.130	0.145	0.115	0.141	0.118	<0.000	<0.000	<0.000	<0.000	<0.000
31-03-2016	0.651	0.665	0.664	0.661	0.505	<0.000	<0.000	<0.000	<0.000	<0.000

Table 4.A1 continued - Unit Root Test Results of the Price Series; Lean Hogs Nov. – Dec. 2015

	Dickey-Fuller Test P-Value					Dickey-Fuller Test P-Value				
	Price	WP^{1}	WP^{2-5}	WP^{2-3}	WP^{4-5}	ΔPrice	ΔWP^{1}	ΔWP^{2-5}	ΔWP^{2-3}	ΔWP^{4-5}
23-11-2015	0.444	0.475	0.290	0.297	0.047	<0.000	<0.000	<0.000	<0.000	<0.000
24-11-2015	0.546	0.504	0.522	0.479	0.308	<0.000	<0.000	<0.000	<0.000	<0.000
25-11-2015	0.085	0.039	0.052	0.039	0.009	<0.000	<0.000	<0.000	<0.000	<0.000
30-11-2015	0.089	0.088	0.055	0.065	0.022	<0.000	<0.000	<0.000	<0.000	<0.000
01-12-2015	0.494	0.474	0.492	0.432	0.394	<0.000	<0.000	<0.000	<0.000	<0.000
02-12-2015	0.072	0.070	0.095	0.075	0.025	<0.000	<0.000	<0.000	<0.000	<0.000
03-12-2015	0.344	0.359	0.316	0.299	0.234	<0.000	<0.000	<0.000	<0.000	<0.000
04-12-2015	0.841	0.825	0.876	0.789	0.710	<0.000	<0.000	<0.000	<0.000	<0.000
07-12-2015	0.030	0.023	0.028	0.010	0.005	<0.000	<0.000	<0.000	<0.000	<0.000
08-12-2015	0.320	0.300	0.320	0.299	0.263	<0.000	<0.000	<0.000	<0.000	<0.000
09-12-2015	0.406	0.348	0.364	0.302	0.242	<0.000	<0.000	<0.000	<0.000	<0.000
10-12-2015	0.004	0.002	0.007	0.001	0.001	<0.000	<0.000	<0.000	<0.000	<0.000
11-12-2015	0.383	0.382	0.377	0.343	0.270	<0.000	<0.000	<0.000	<0.000	<0.000
14-12-2015	0.139	0.166	0.157	0.149	0.040	<0.000	<0.000	<0.000	<0.000	<0.000
15-12-2015	0.182	0.179	0.156	0.159	0.082	<0.000	<0.000	<0.000	<0.000	<0.000
16-12-2015	0.499	0.476	0.378	0.340	0.253	<0.000	<0.000	<0.000	<0.000	<0.000
17-12-2015	0.088	0.110	0.098	0.102	0.075	<0.000	<0.000	<0.000	<0.000	<0.000
18-12-2015	0.324	0.344	0.232	0.240	0.117	<0.000	<0.000	<0.000	<0.000	<0.000
21-12-2015	0.470	0.489	0.475	0.432	0.268	<0.000	<0.000	<0.000	<0.000	<0.000
22-12-2015	0.014	0.011	0.009	0.003	0.002	<0.000	<0.000	<0.000	<0.000	<0.000
23-12-2015	0.246	0.250	0.199	0.170	0.099	<0.000	<0.000	<0.000	<0.000	<0.000
24-12-2015	0.003	0.042	0.082	0.114	0.045	<0.000	<0.000	<0.000	<0.000	<0.000
28-12-2015	0.174	0.127	0.072	0.060	0.062	<0.000	<0.000	<0.000	<0.000	<0.000
29-12-2015	0.012	0.011	0.010	0.010	0.002	<0.000	<0.000	<0.000	<0.000	<0.000
30-12-2015	0.324	0.300	0.304	0.245	0.143	<0.000	<0.000	<0.000	<0.000	<0.000
31-12-2015	0.002	0.004	0.006	0.003	0.000	<0.000	<0.000	<0.000	<0.000	<0.000

Table 4.A1 continued - Unit Root Test Results of the Price Series; Lean Hogs Jan. 2016

	Dickey-Fuller Test P-Value					Dickey-Fuller Test P-Value				
	Price	WP^{1}	WP^{2-5}	WP^{2-3}	WP^{4-5}	ΔPrice	ΔWP^{1}	ΔWP^{2-5}	ΔWP^{2-3}	ΔWP^{4-5}
04-01-2016	0.013	0.011	0.008	0.008	0.003	<0.000	<0.000	<0.000	<0.000	<0.000
05-01-2016	0.220	0.242	0.203	0.253	0.164	<0.000	<0.000	<0.000	<0.000	<0.000
06-01-2016	0.037	0.038	0.023	0.026	0.003	<0.000	<0.000	<0.000	<0.000	<0.000
07-01-2016	0.857	0.867	0.792	0.810	0.651	<0.000	<0.000	<0.000	<0.000	<0.000
08-01-2016	0.413	0.375	0.428	0.357	0.284	<0.000	<0.000	<0.000	<0.000	<0.000
11-01-2016	0.183	0.142	0.117	0.114	0.015	<0.000	<0.000	<0.000	<0.000	<0.000
12-01-2016	0.107	0.098	0.097	0.080	0.061	<0.000	<0.000	<0.000	<0.000	<0.000
13-01-2016	0.291	0.283	0.300	0.267	0.136	<0.000	<0.000	<0.000	<0.000	<0.000
14-01-2016	0.185	0.124	0.124	0.111	0.045	<0.000	<0.000	<0.000	<0.000	<0.000
15-01-2016	0.285	0.204	0.284	0.257	0.166	<0.000	<0.000	<0.000	<0.000	<0.000
19-01-2016	0.068	0.036	0.024	0.024	0.004	<0.000	<0.000	<0.000	<0.000	<0.000
20-01-2016	0.208	0.160	0.196	0.173	0.092	<0.000	<0.000	<0.000	<0.000	<0.000
21-01-2016	0.684	0.694	0.691	0.688	0.643	<0.000	<0.000	<0.000	<0.000	<0.000
22-01-2016	0.051	0.056	0.146	0.052	0.026	<0.000	<0.000	<0.000	<0.000	<0.000
25-01-2016	0.148	0.165	0.148	0.108	0.071	<0.000	<0.000	<0.000	<0.000	<0.000
26-01-2016	0.753	0.624	0.747	0.620	0.572	<0.000	<0.000	<0.000	<0.000	<0.000
27-01-2016	0.016	0.006	0.023	0.007	0.002	<0.000	<0.000	<0.000	<0.000	<0.000
28-01-2016	0.787	0.779	0.803	0.794	0.744	<0.000	<0.000	<0.000	<0.000	<0.000
29-01-2016	0.001	0.001	0.001	0.001	0.000	<0.000	<0.000	<0.000	<0.000	<0.000

Table 4.A1 continued - Unit Root Test Results of the Price Series; Lean Hogs Feb. 2016

	Dickey-Fuller Test P-Value					Dickey-Fuller Test P-Value				
	Price	WP^1	WP^{2-5}	WP^{2-3}	WP^{4-5}	ΔPrice	ΔWP^1	ΔWP^{2-5}	ΔWP^{2-3}	ΔWP^{4-5}
01-02-2016	0.203	0.186	0.225	0.213	0.102	<0.000	<0.000	<0.000	<0.000	<0.000
02-02-2016	0.420	0.390	0.462	0.385	0.232	<0.000	<0.000	<0.000	<0.000	<0.000
03-02-2016	0.040	0.027	0.047	0.017	0.012	<0.000	<0.000	<0.000	<0.000	<0.000
04-02-2016	0.151	0.120	0.158	0.118	0.060	<0.000	<0.000	<0.000	<0.000	<0.000
05-02-2016	0.082	0.053	0.075	0.053	0.018	<0.000	<0.000	<0.000	<0.000	<0.000
08-02-2016	0.621	0.593	0.604	0.581	0.426	<0.000	<0.000	<0.000	<0.000	<0.000
10-02-2016	0.382	0.362	0.363	0.396	0.294	<0.000	<0.000	<0.000	<0.000	<0.000
11-02-2016	0.265	0.270	0.248	0.255	0.200	<0.000	<0.000	<0.000	<0.000	<0.000
12-02-2016	0.359	0.331	0.299	0.343	0.183	<0.000	<0.000	<0.000	<0.000	<0.000
16-02-2016	0.016	0.013	0.012	0.007	0.002	<0.000	<0.000	<0.000	<0.000	<0.000
17-02-2016	0.818	0.784	0.738	0.798	0.448	<0.000	<0.000	<0.000	<0.000	<0.000
18-02-2016	0.876	0.852	0.691	0.799	0.428	<0.000	<0.000	<0.000	<0.000	<0.000
19-02-2016	0.328	0.296	0.296	0.310	0.224	<0.000	<0.000	<0.000	<0.000	<0.000
22-02-2016	0.491	0.455	0.455	0.517	0.272	<0.000	<0.000	<0.000	<0.000	<0.000
23-02-2016	0.827	0.819	0.836	0.838	0.718	<0.000	<0.000	<0.000	<0.000	<0.000
24-02-2016	0.938	0.938	0.934	0.926	0.905	<0.000	<0.000	<0.000	<0.000	<0.000
25-02-2016	0.140	0.096	0.108	0.098	0.040	<0.000	<0.000	<0.000	<0.000	<0.000
26-02-2016	0.132	0.089	0.074	0.081	0.013	<0.000	<0.000	<0.000	<0.000	<0.000
29-02-2016	0.107	0.108	0.099	0.106	0.016	<0.000	<0.000	<0.000	<0.000	<0.000

Table 4.A1 continued - Unit Root Test Results of the Price Series; Lean Hogs Mar. 2016

	Dickey-Fuller Test P-Value					Dickey-Fuller Test P-Value				
	Price	WP^{1}	WP^{2-5}	WP^{2-3}	WP^{4-5}	ΔPrice	ΔWP^{1}	ΔWP^{2-5}	ΔWP^{2-3}	ΔWP^{4-5}
01-03-2016	0.077	0.058	0.128	0.129	0.019	<0.000	<0.000	<0.000	<0.000	<0.000
02-03-2016	0.000	0.000	0.000	0.000	0.000	<0.000	<0.000	<0.000	<0.000	<0.000
03-03-2016	0.896	0.885	0.895	0.904	0.723	<0.000	<0.000	<0.000	<0.000	<0.000
04-03-2016	0.225	0.163	0.226	0.186	0.059	<0.000	<0.000	<0.000	<0.000	<0.000
07-03-2016	0.002	0.001	0.001	0.000	0.000	<0.000	<0.000	<0.000	<0.000	<0.000
08-03-2016	0.000	0.000	0.000	0.000	0.000	<0.000	<0.000	<0.000	<0.000	<0.000
09-03-2016	0.969	0.959	0.946	0.949	0.893	<0.000	<0.000	<0.000	<0.000	<0.000
10-03-2016	0.149	0.213	0.132	0.171	0.031	<0.000	<0.000	<0.000	<0.000	<0.000
11-03-2016	0.101	0.072	0.080	0.081	0.016	<0.000	<0.000	<0.000	<0.000	<0.000
14-03-2016	0.000	0.000	0.000	0.000	0.000	<0.000	<0.000	<0.000	<0.000	<0.000
15-03-2016	0.023	0.010	0.040	0.023	0.006	<0.000	<0.000	<0.000	<0.000	<0.000
16-03-2016	0.649	0.610	0.606	0.609	0.508	<0.000	<0.000	<0.000	<0.000	<0.000
17-03-2016	0.094	0.063	0.090	0.078	0.019	<0.000	<0.000	<0.000	<0.000	<0.000
18-03-2016	0.271	0.128	0.124	0.118	0.038	<0.000	<0.000	<0.000	<0.000	<0.000
21-03-2016	0.248	0.204	0.197	0.210	0.069	<0.000	<0.000	<0.000	<0.000	<0.000
22-03-2016	0.656	0.418	0.418	0.414	0.165	<0.000	<0.000	<0.000	<0.000	<0.000
23-03-2016	0.016	0.008	0.048	0.022	0.016	<0.000	<0.000	<0.000	<0.000	<0.000
24-03-2016	0.722	0.713	0.708	0.701	0.662	<0.000	<0.000	<0.000	<0.000	<0.000
28-03-2016	0.018	0.020	0.016	0.018	0.019	<0.000	<0.000	<0.000	<0.000	<0.000
29-03-2016	0.005	0.005	0.001	0.006	0.000	<0.000	<0.000	<0.000	<0.000	<0.000
30-03-2016	0.601	0.599	0.604	0.608	0.561	<0.000	<0.000	<0.000	<0.000	<0.000
31-03-2016	0.144	0.225	0.205	0.227	0.130	<0.000	<0.000	<0.000	<0.000	<0.000

Table 4.A1 continued - Unit Root Test Results of the Price Series; Corn Nov. – Dec. 2015

	Dickey-Fuller Test P-Value					Dickey-Fuller Test P-Value				
	Price	WP^{1}	WP^{2-10}	WP^{2-3}	WP^{4-10}	ΔPrice	ΔWP^{1}	ΔWP^{2-10}	ΔWP^{2-3}	ΔWP^{4-10}
23-11-2015	0.186	0.283	0.586	0.472	0.551	<0.000	<0.000	<0.000	<0.000	<0.000
24-11-2015	0.000	0.003	0.120	0.083	0.017	<0.000	<0.000	<0.000	<0.000	<0.000
25-11-2015	0.000	0.000	0.000	0.000	0.000	<0.000	<0.000	<0.000	<0.000	<0.000
27-11-2015	0.028	0.059	0.116	0.071	0.129	<0.000	<0.000	<0.000	<0.000	<0.000
30-11-2015	0.007	0.021	0.018	0.080	0.009	<0.000	<0.000	<0.000	<0.000	<0.000
01-12-2015	0.003	0.027	0.356	0.203	0.266	<0.000	<0.000	<0.000	<0.000	<0.000
02-12-2015	0.000	0.000	0.002	0.007	0.000	<0.000	<0.000	<0.000	<0.000	<0.000
03-12-2015	0.203	0.241	0.148	0.231	0.183	<0.000	<0.000	<0.000	<0.000	<0.000
04-12-2015	0.000	0.001	0.042	0.058	0.028	<0.000	<0.000	<0.000	<0.000	<0.000
07-12-2015	0.194	0.285	0.455	0.490	0.438	<0.000	<0.000	<0.000	<0.000	<0.000
08-12-2015	0.000	0.000	0.015	0.001	0.008	<0.000	<0.000	<0.000	<0.000	<0.000
09-12-2015	0.380	0.476	0.696	0.651	0.664	<0.000	<0.000	<0.000	<0.000	<0.000
10-12-2015	0.082	0.256	0.396	0.471	0.336	<0.000	<0.000	<0.000	<0.000	<0.000
11-12-2015	0.001	0.004	0.005	0.011	0.004	<0.000	<0.000	<0.000	<0.000	<0.000
14-12-2015	0.000	0.000	0.001	0.015	0.000	<0.000	<0.000	<0.000	<0.000	<0.000
15-12-2015	0.002	0.034	0.245	0.372	0.156	<0.000	<0.000	<0.000	<0.000	<0.000
16-12-2015	0.342	0.478	0.504	0.376	0.562	<0.000	<0.000	<0.000	<0.000	<0.000
17-12-2015	0.927	0.945	0.993	0.981	0.991	<0.000	<0.000	<0.000	<0.000	<0.000
18-12-2015	0.189	0.287	0.696	0.525	0.670	<0.000	<0.000	<0.000	<0.000	<0.000
21-12-2015	0.016	0.022	0.047	0.108	0.027	<0.000	<0.000	<0.000	<0.000	<0.000
22-12-2015	0.612	0.760	0.889	0.864	0.860	<0.000	<0.000	<0.000	<0.000	<0.000
23-12-2015	0.000	0.000	0.000	0.000	0.000	<0.000	<0.000	<0.000	<0.000	<0.000
24-12-2015	0.000	0.007	0.094	0.021	0.053	<0.000	<0.000	<0.000	<0.000	<0.000
28-12-2015	0.000	0.003	0.009	0.002	0.008	<0.000	<0.000	<0.000	<0.000	<0.000
29-12-2015	0.210	0.699	0.972	0.932	0.939	<0.000	<0.000	<0.000	<0.000	<0.000
30-12-2015	0.000	0.000	0.006	0.008	0.006	<0.000	<0.000	<0.000	<0.000	<0.000
31-12-2015	0.000	0.000	0.000	0.001	0.000	<0.000	<0.000	<0.000	<0.000	<0.000

Table 4.A1 continued - Unit Root Test Results of the Price Series; Corn Jan. 2016

	Dickey-Fuller Test P-Value					Dickey-Fuller Test P-Value				
	Price	WP^{1}	WP^{2-10}	WP^{2-3}	WP^{4-10}	ΔPrice	ΔWP^{1}	ΔWP^{2-10}	ΔWP^{2-3}	ΔWP^{4-10}
04-01-2016	0.031	0.059	0.093	0.070	0.117	<0.000	<0.000	<0.000	<0.000	<0.000
05-01-2016	0.001	0.030	0.130	0.208	0.071	<0.000	<0.000	<0.000	<0.000	<0.000
06-01-2016	0.008	0.054	0.347	0.302	0.296	<0.000	<0.000	<0.000	<0.000	<0.000
07-01-2016	0.006	0.051	0.450	0.322	0.370	<0.000	<0.000	<0.000	<0.000	<0.000
08-01-2016	0.000	0.000	0.006	0.006	0.002	<0.000	<0.000	<0.000	<0.000	<0.000
11-01-2016	0.006	0.073	0.242	0.156	0.254	<0.000	<0.000	<0.000	<0.000	<0.000
12-01-2016	0.463	0.540	0.548	0.523	0.504	<0.000	<0.000	<0.000	<0.000	<0.000
13-01-2016	0.000	0.002	0.053	0.043	0.018	<0.000	<0.000	<0.000	<0.000	<0.000
14-01-2016	0.000	0.014	0.200	0.175	0.119	<0.000	<0.000	<0.000	<0.000	<0.000
15-01-2016	0.090	0.241	0.310	0.378	0.258	<0.000	<0.000	<0.000	<0.000	<0.000
19-01-2016	0.002	0.074	0.382	0.307	0.285	<0.000	<0.000	<0.000	<0.000	<0.000
20-01-2016	0.000	0.007	0.160	0.127	0.110	<0.000	<0.000	<0.000	<0.000	<0.000
21-01-2016	0.347	0.603	0.904	0.799	0.880	<0.000	<0.000	<0.000	<0.000	<0.000
22-01-2016	0.000	0.004	0.233	0.087	0.189	<0.000	<0.000	<0.000	<0.000	<0.000
25-01-2016	0.000	0.003	0.119	0.087	0.094	<0.000	<0.000	<0.000	<0.000	<0.000
26-01-2016	0.001	0.033	0.445	0.304	0.418	<0.000	<0.000	<0.000	<0.000	<0.000
27-01-2016	0.001	0.006	0.133	0.165	0.077	<0.000	<0.000	<0.000	<0.000	<0.000
28-01-2016	0.034	0.253	0.395	0.400	0.332	<0.000	<0.000	<0.000	<0.000	<0.000
29-01-2016	0.007	0.039	0.030	0.087	0.013	<0.000	<0.000	<0.000	<0.000	<0.000

Table 4.A1 continued - Unit Root Test Results of the Price Series; Corn Feb. 2016

	Dickey-Fuller Test P-Value					Dickey-Fuller Test P-Value				
	Price	WP^{1}	WP^{2-10}	WP^{2-3}	WP^{4-10}	ΔPrice	ΔWP^{1}	ΔWP^{2-10}	ΔWP^{2-3}	ΔWP^{4-10}
01-02-2016	0.000	0.048	0.641	0.570	0.522	<0.000	<0.000	<0.000	<0.000	<0.000
02-02-2016	0.023	0.103	0.358	0.319	0.356	<0.000	<0.000	<0.000	<0.000	<0.000
03-02-2016	0.003	0.051	0.283	0.365	0.208	<0.000	<0.000	<0.000	<0.000	<0.000
04-02-2016	0.073	0.100	0.092	0.140	0.086	<0.000	<0.000	<0.000	<0.000	<0.000
05-02-2016	0.000	0.000	0.000	0.036	0.000	<0.000	<0.000	<0.000	<0.000	<0.000
08-02-2016	0.073	0.272	0.878	0.643	0.892	<0.000	<0.000	<0.000	<0.000	<0.000
10-02-2016	0.000	0.000	0.005	0.000	0.010	<0.000	<0.000	<0.000	<0.000	<0.000
11-02-2016	0.017	0.061	0.283	0.262	0.231	<0.000	<0.000	<0.000	<0.000	<0.000
12-02-2016	0.006	0.060	0.676	0.453	0.583	<0.000	<0.000	<0.000	<0.000	<0.000
16-02-2016	0.004	0.038	0.846	0.740	0.707	<0.000	<0.000	<0.000	<0.000	<0.000
17-02-2016	0.000	0.005	0.130	0.085	0.088	<0.000	<0.000	<0.000	<0.000	<0.000
18-02-2016	0.000	0.000	0.056	0.083	0.016	<0.000	<0.000	<0.000	<0.000	<0.000
19-02-2016	0.000	0.009	0.295	0.163	0.266	<0.000	<0.000	<0.000	<0.000	<0.000
22-02-2016	0.000	0.000	0.097	0.036	0.031	<0.000	<0.000	<0.000	<0.000	<0.000
23-02-2016	0.046	0.220	0.543	0.489	0.608	<0.000	<0.000	<0.000	<0.000	<0.000
24-02-2016	0.000	0.004	0.388	0.189	0.289	<0.000	<0.000	<0.000	<0.000	<0.000
25-02-2016	0.000	0.002	0.000	0.001	0.000	<0.000	<0.000	<0.000	<0.000	<0.000
26-02-2016	0.002	0.031	0.448	0.504	0.280	<0.000	<0.000	<0.000	<0.000	<0.000
29-02-2016	0.000	0.008	0.007	0.024	0.005	<0.000	<0.000	<0.000	<0.000	<0.000

Table 4.A1 continued - Unit Root Test Results of the Price Series; Corn Mar. 2016

	Dickey-Fuller Test P-Value					Dickey-Fuller Test P-Value				
	Price	WP^{1}	WP^{2-10}	WP^{2-3}	WP^{4-10}	ΔPrice	ΔWP^{1}	ΔWP^{2-10}	ΔWP^{2-3}	ΔWP^{4-10}
01-03-2016	0.000	0.000	0.073	0.041	0.015	<0.000	<0.000	<0.000	<0.000	<0.000
02-03-2016	0.000	0.000	0.036	0.009	0.004	<0.000	<0.000	<0.000	<0.000	<0.000
03-03-2016	0.000	0.015	0.133	0.183	0.068	<0.000	<0.000	<0.000	<0.000	<0.000
04-03-2016	0.001	0.011	0.070	0.039	0.070	<0.000	<0.000	<0.000	<0.000	<0.000
07-03-2016	0.000	0.015	0.470	0.276	0.399	<0.000	<0.000	<0.000	<0.000	<0.000
08-03-2016	0.182	0.473	0.481	0.554	0.473	<0.000	<0.000	<0.000	<0.000	<0.000
09-03-2016	0.000	0.000	0.006	0.014	0.002	<0.000	<0.000	<0.000	<0.000	<0.000
10-03-2016	0.000	0.003	0.001	0.006	0.001	<0.000	<0.000	<0.000	<0.000	<0.000
11-03-2016	0.000	0.005	0.146	0.143	0.075	<0.000	<0.000	<0.000	<0.000	<0.000
14-03-2016	0.000	0.006	0.152	0.083	0.127	<0.000	<0.000	<0.000	<0.000	<0.000
15-03-2016	0.000	0.000	0.000	0.000	0.000	<0.000	<0.000	<0.000	<0.000	<0.000
16-03-2016	0.000	0.100	0.621	0.612	0.408	<0.000	<0.000	<0.000	<0.000	<0.000
17-03-2016	0.095	0.261	0.634	0.581	0.570	<0.000	<0.000	<0.000	<0.000	<0.000
18-03-2016	0.000	0.018	0.068	0.150	0.014	<0.000	<0.000	<0.000	<0.000	<0.000
21-03-2016	0.000	0.000	0.000	0.000	0.000	<0.000	<0.000	<0.000	<0.000	<0.000
23-03-2016	0.000	0.029	0.749	0.456	0.710	<0.000	<0.000	<0.000	<0.000	<0.000
24-03-2016	0.000	0.074	0.132	0.256	0.105	<0.000	<0.000	<0.000	<0.000	<0.000
28-03-2016	0.004	0.081	0.214	0.249	0.170	<0.000	<0.000	<0.000	<0.000	<0.000
29-03-2016	0.000	0.029	0.180	0.054	0.186	<0.000	<0.000	<0.000	<0.000	<0.000
30-03-2016	0.042	0.542	0.623	0.792	0.593	<0.000	<0.000	<0.000	<0.000	<0.000
31-03-2016	0.766	0.790	0.813	0.815	0.803	<0.000	<0.000	<0.000	<0.000	<0.000

Table 4.A1 continued - Unit Root Test Results of the Price Series; Wheat Nov. – Dec. 2015

	Dickey-Fuller Test P-Value					Dickey-Fuller Test P-Value				
	Price	WP^{1}	WP^{2-10}	WP^{2-3}	WP^{4-10}	ΔPrice	ΔWP^{1}	ΔWP^{2-10}	ΔWP^{2-3}	ΔWP^{4-10}
23-11-2015	0.023	0.018	0.018	0.014	0.018	<0.000	<0.000	<0.000	<0.000	<0.000
24-11-2015	0.527	0.436	0.651	0.598	0.603	<0.000	<0.000	<0.000	<0.000	<0.000
25-11-2015	0.005	0.001	0.010	0.013	0.004	<0.000	<0.000	<0.000	<0.000	<0.000
27-11-2015	0.001	0.001	0.040	0.000	0.085	<0.000	<0.000	<0.000	<0.000	<0.000
30-11-2015	0.028	0.025	0.139	0.111	0.097	<0.000	<0.000	<0.000	<0.000	<0.000
01-12-2015	0.063	0.086	0.107	0.080	0.087	<0.000	<0.000	<0.000	<0.000	<0.000
02-12-2015	0.017	0.027	0.076	0.085	0.063	<0.000	<0.000	<0.000	<0.000	<0.000
03-12-2015	0.016	0.020	0.016	0.011	0.023	<0.000	<0.000	<0.000	<0.000	<0.000
04-12-2015	0.046	0.067	0.251	0.175	0.195	<0.000	<0.000	<0.000	<0.000	<0.000
07-12-2015	0.601	0.584	0.761	0.744	0.667	<0.000	<0.000	<0.000	<0.000	<0.000
08-12-2015	0.025	0.021	0.037	0.079	0.016	<0.000	<0.000	<0.000	<0.000	<0.000
09-12-2015	0.038	0.023	0.020	0.056	0.010	<0.000	<0.000	<0.000	<0.000	<0.000
10-12-2015	0.044	0.041	0.020	0.026	0.019	<0.000	<0.000	<0.000	<0.000	<0.000
11-12-2015	0.107	0.111	0.197	0.158	0.157	<0.000	<0.000	<0.000	<0.000	<0.000
14-12-2015	0.002	0.001	0.015	0.006	0.009	<0.000	<0.000	<0.000	<0.000	<0.000
15-12-2015	0.631	0.598	0.621	0.678	0.572	<0.000	<0.000	<0.000	<0.000	<0.000
16-12-2015	0.488	0.495	0.394	0.540	0.370	<0.000	<0.000	<0.000	<0.000	<0.000
17-12-2015	0.943	0.945	0.947	0.965	0.920	<0.000	<0.000	<0.000	<0.000	<0.000
18-12-2015	0.548	0.558	0.541	0.547	0.531	<0.000	<0.000	<0.000	<0.000	<0.000
21-12-2015	0.446	0.424	0.537	0.489	0.520	<0.000	<0.000	<0.000	<0.000	<0.000
22-12-2015	0.448	0.486	0.556	0.498	0.522	<0.000	<0.000	<0.000	<0.000	<0.000
23-12-2015	0.129	0.146	0.176	0.339	0.101	<0.000	<0.000	<0.000	<0.000	<0.000
24-12-2015	0.033	0.053	0.151	0.115	0.104	<0.000	<0.000	<0.000	<0.000	<0.000
28-12-2015	0.144	0.140	0.301	0.184	0.270	<0.000	<0.000	<0.000	<0.000	<0.000
29-12-2015	0.900	0.888	0.944	0.943	0.928	<0.000	<0.000	<0.000	<0.000	<0.000
30-12-2015	0.191	0.185	0.298	0.184	0.285	<0.000	<0.000	<0.000	<0.000	<0.000
31-12-2015	0.000	0.000	0.000	0.001	0.000	<0.000	<0.000	<0.000	<0.000	<0.000

Table 4.A1 continued - Unit Root Test Results of the Price Series; Wheat Jan. 2016

	Dickey-Fuller Test P-Value					Dickey-Fuller Test P-Value				
	Price	WP^{1}	WP^{2-10}	WP^{2-3}	WP^{4-10}	ΔPrice	ΔWP^{1}	ΔWP^{2-10}	ΔWP^{2-3}	ΔWP^{4-10}
04-01-2016	0.000	0.000	0.000	0.001	0.000	<0.000	<0.000	<0.000	<0.000	<0.000
05-01-2016	0.001	0.000	0.011	0.006	0.007	<0.000	<0.000	<0.000	<0.000	<0.000
06-01-2016	0.376	0.321	0.273	0.385	0.204	<0.000	<0.000	<0.000	<0.000	<0.000
07-01-2016	0.355	0.300	0.337	0.404	0.256	<0.000	<0.000	<0.000	<0.000	<0.000
08-01-2016	0.024	0.023	0.097	0.040	0.091	<0.000	<0.000	<0.000	<0.000	<0.000
11-01-2016	0.207	0.199	0.218	0.202	0.216	<0.000	<0.000	<0.000	<0.000	<0.000
12-01-2016	0.813	0.807	0.822	0.825	0.810	<0.000	<0.000	<0.000	<0.000	<0.000
13-01-2016	0.142	0.111	0.284	0.317	0.193	<0.000	<0.000	<0.000	<0.000	<0.000
14-01-2016	0.008	0.004	0.079	0.033	0.049	<0.000	<0.000	<0.000	<0.000	<0.000
15-01-2016	0.187	0.129	0.124	0.227	0.093	<0.000	<0.000	<0.000	<0.000	<0.000
19-01-2016	0.231	0.190	0.480	0.430	0.450	<0.000	<0.000	<0.000	<0.000	<0.000
20-01-2016	0.140	0.087	0.291	0.238	0.218	<0.000	<0.000	<0.000	<0.000	<0.000
21-01-2016	0.379	0.330	0.665	0.461	0.656	<0.000	<0.000	<0.000	<0.000	<0.000
22-01-2016	0.096	0.062	0.310	0.168	0.264	<0.000	<0.000	<0.000	<0.000	<0.000
25-01-2016	0.171	0.129	0.223	0.260	0.175	<0.000	<0.000	<0.000	<0.000	<0.000
26-01-2016	0.010	0.009	0.233	0.039	0.277	<0.000	<0.000	<0.000	<0.000	<0.000
27-01-2016	0.477	0.437	0.471	0.502	0.434	<0.000	<0.000	<0.000	<0.000	<0.000
28-01-2016	0.002	0.002	0.006	0.010	0.003	<0.000	<0.000	<0.000	<0.000	<0.000
29-01-2016	0.003	0.003	0.021	0.032	0.010	<0.000	<0.000	<0.000	<0.000	<0.000

Table 4.A1 continued - Unit Root Test Results of the Price Series; Wheat Feb. 2016

	Dickey-Fuller Test P-Value					Dickey-Fuller Test P-Value				
	Price	WP^{1}	WP^{2-10}	WP^{2-3}	WP^{4-10}	ΔPrice	ΔWP^{1}	ΔWP^{2-10}	ΔWP^{2-3}	ΔWP^{4-10}
01-02-2016	0.036	0.103	0.816	0.443	0.842	<0.000	<0.000	<0.000	<0.000	<0.000
02-02-2016	0.426	0.411	0.556	0.512	0.511	<0.000	<0.000	<0.000	<0.000	<0.000
03-02-2016	0.002	0.003	0.056	0.013	0.055	<0.000	<0.000	<0.000	<0.000	<0.000
04-02-2016	0.379	0.336	0.377	0.399	0.371	<0.000	<0.000	<0.000	<0.000	<0.000
05-02-2016	0.000	0.000	0.001	0.001	0.001	<0.000	<0.000	<0.000	<0.000	<0.000
08-02-2016	0.731	0.713	0.799	0.792	0.757	<0.000	<0.000	<0.000	<0.000	<0.000
10-02-2016	0.004	0.002	0.002	0.019	0.001	<0.000	<0.000	<0.000	<0.000	<0.000
11-02-2016	0.701	0.610	0.821	0.763	0.807	<0.000	<0.000	<0.000	<0.000	<0.000
12-02-2016	0.128	0.060	0.321	0.185	0.274	<0.000	<0.000	<0.000	<0.000	<0.000
16-02-2016	0.340	0.220	0.497	0.575	0.320	<0.000	<0.000	<0.000	<0.000	<0.000
17-02-2016	0.000	0.000	0.000	0.000	0.000	<0.000	<0.000	<0.000	<0.000	<0.000
18-02-2016	0.226	0.069	0.302	0.374	0.153	<0.000	<0.000	<0.000	<0.000	<0.000
19-02-2016	0.006	0.000	0.005	0.027	0.001	<0.000	<0.000	<0.000	<0.000	<0.000
22-02-2016	0.058	0.076	0.365	0.154	0.276	<0.000	<0.000	<0.000	<0.000	<0.000
23-02-2016	0.435	0.497	0.565	0.538	0.527	<0.000	<0.000	<0.000	<0.000	<0.000
24-02-2016	0.421	0.318	0.457	0.486	0.310	<0.000	<0.000	<0.000	<0.000	<0.000
25-02-2016	0.015	0.012	0.253	0.071	0.276	<0.000	<0.000	<0.000	<0.000	<0.000
26-02-2016	0.164	0.146	0.248	0.199	0.249	<0.000	<0.000	<0.000	<0.000	<0.000
29-02-2016	0.001	0.001	0.003	0.003	0.001	<0.000	<0.000	<0.000	<0.000	<0.000

Table 4.A1 continued - Unit Root Test Results of the Price Series; Wheat Mar. 2016

	Dickey-Fuller Test P-Value					Dickey-Fuller Test P-Value				
	Price	WP^{1}	WP^{2-10}	WP^{2-3}	WP^{4-10}	ΔPrice	ΔWP^{1}	ΔWP^{2-10}	ΔWP^{2-3}	ΔWP^{4-10}
01-03-2016	0.003	0.005	0.025	0.010	0.019	<0.000	<0.000	<0.000	<0.000	<0.000
02-03-2016	0.196	0.188	0.325	0.233	0.306	<0.000	<0.000	<0.000	<0.000	<0.000
03-03-2016	0.634	0.639	0.697	0.683	0.630	<0.000	<0.000	<0.000	<0.000	<0.000
04-03-2016	0.097	0.120	0.323	0.172	0.303	<0.000	<0.000	<0.000	<0.000	<0.000
07-03-2016	0.522	0.560	0.857	0.866	0.811	<0.000	<0.000	<0.000	<0.000	<0.000
08-03-2016	0.282	0.317	0.526	0.405	0.521	<0.000	<0.000	<0.000	<0.000	<0.000
09-03-2016	0.189	0.238	0.526	0.331	0.444	<0.000	<0.000	<0.000	<0.000	<0.000
10-03-2016	0.024	0.019	0.000	0.013	0.000	<0.000	<0.000	<0.000	<0.000	<0.000
11-03-2016	0.101	0.086	0.236	0.178	0.176	<0.000	<0.000	<0.000	<0.000	<0.000
14-03-2016	0.129	0.153	0.277	0.247	0.255	<0.000	<0.000	<0.000	<0.000	<0.000
15-03-2016	0.135	0.096	0.385	0.279	0.216	<0.000	<0.000	<0.000	<0.000	<0.000
16-03-2016	0.000	0.000	0.000	0.001	0.000	<0.000	<0.000	<0.000	<0.000	<0.000
17-03-2016	0.484	0.455	0.504	0.484	0.497	<0.000	<0.000	<0.000	<0.000	<0.000
18-03-2016	0.481	0.473	0.589	0.666	0.448	<0.000	<0.000	<0.000	<0.000	<0.000
21-03-2016	0.128	0.102	0.156	0.181	0.086	<0.000	<0.000	<0.000	<0.000	<0.000
22-03-2016	0.042	0.025	0.052	0.069	0.029	<0.000	<0.000	<0.000	<0.000	<0.000
23-03-2016	0.003	0.000	0.008	0.011	0.002	<0.000	<0.000	<0.000	<0.000	<0.000
24-03-2016	0.006	0.017	0.192	0.163	0.086	<0.000	<0.000	<0.000	<0.000	<0.000
28-03-2016	0.005	0.007	0.004	0.005	0.006	<0.000	<0.000	<0.000	<0.000	<0.000
29-03-2016	0.187	0.193	0.297	0.274	0.253	<0.000	<0.000	<0.000	<0.000	<0.000
30-03-2016	0.014	0.015	0.020	0.010	0.024	<0.000	<0.000	<0.000	<0.000	<0.000
31-03-2016	0.839	0.834	0.793	0.839	0.665	<0.000	<0.000	<0.000	<0.000	<0.000

Table 4.A1 continued - Unit Root Test Results of the Price Series; Soybeans Nov. – Dec. 2015

	Dickey-Fuller Test P-Value					Dickey-Fuller Test P-Value				
	Price	WP^{1}	WP^{2-10}	WP^{2-3}	WP^{4-10}	ΔPrice	ΔWP^{1}	ΔWP^{2-10}	ΔWP^{2-3}	ΔWP^{4-10}
23-11-2015	0.820	0.809	0.811	0.830	0.772	<0.000	<0.000	<0.000	<0.000	<0.000
24-11-2015	0.000	0.000	0.007	0.002	0.005	<0.000	<0.000	<0.000	<0.000	<0.000
25-11-2015	0.253	0.230	0.172	0.244	0.138	<0.000	<0.000	<0.000	<0.000	<0.000
27-11-2015	0.047	0.014	0.156	0.122	0.098	<0.000	<0.000	<0.000	<0.000	<0.000
30-11-2015	0.010	0.007	0.023	0.018	0.012	<0.000	<0.000	<0.000	<0.000	<0.000
01-12-2015	0.125	0.078	0.147	0.233	0.065	<0.000	<0.000	<0.000	<0.000	<0.000
02-12-2015	0.423	0.334	0.471	0.478	0.401	<0.000	<0.000	<0.000	<0.000	<0.000
03-12-2015	0.154	0.134	0.142	0.228	0.100	<0.000	<0.000	<0.000	<0.000	<0.000
04-12-2015	0.681	0.582	0.671	0.743	0.533	<0.000	<0.000	<0.000	<0.000	<0.000
07-12-2015	0.824	0.819	0.807	0.855	0.758	<0.000	<0.000	<0.000	<0.000	<0.000
08-12-2015	0.552	0.474	0.529	0.583	0.450	<0.000	<0.000	<0.000	<0.000	<0.000
09-12-2015	0.538	0.486	0.550	0.531	0.500	<0.000	<0.000	<0.000	<0.000	<0.000
10-12-2015	0.262	0.192	0.238	0.279	0.198	<0.000	<0.000	<0.000	<0.000	<0.000
11-12-2015	0.021	0.017	0.039	0.020	0.045	<0.000	<0.000	<0.000	<0.000	<0.000
14-12-2015	0.105	0.044	0.090	0.092	0.046	<0.000	<0.000	<0.000	<0.000	<0.000
15-12-2015	0.017	0.005	0.031	0.026	0.019	<0.000	<0.000	<0.000	<0.000	<0.000
16-12-2015	0.238	0.220	0.242	0.263	0.206	<0.000	<0.000	<0.000	<0.000	<0.000
17-12-2015	0.955	0.936	0.962	0.961	0.948	<0.000	<0.000	<0.000	<0.000	<0.000
18-12-2015	0.016	0.010	0.029	0.015	0.029	<0.000	<0.000	<0.000	<0.000	<0.000
21-12-2015	0.020	0.011	0.023	0.015	0.009	<0.000	<0.000	<0.000	<0.000	<0.000
22-12-2015	0.621	0.487	0.731	0.660	0.624	<0.000	<0.000	<0.000	<0.000	<0.000
23-12-2015	0.000	0.000	0.005	0.003	0.001	<0.000	<0.000	<0.000	<0.000	<0.000
24-12-2015	0.006	0.010	0.023	0.010	0.029	<0.000	<0.000	<0.000	<0.000	<0.000
28-12-2015	0.033	0.024	0.025	0.025	0.016	<0.000	<0.000	<0.000	<0.000	<0.000
29-12-2015	0.011	0.007	0.009	0.027	0.002	<0.000	<0.000	<0.000	<0.000	<0.000
30-12-2015	0.182	0.169	0.492	0.296	0.447	<0.000	<0.000	<0.000	<0.000	<0.000
31-12-2015	0.011	0.006	0.019	0.021	0.007	<0.000	<0.000	<0.000	<0.000	<0.000

Table 4.A1 continued - Unit Root Test Results of the Price Series; Soybeans Jan. 2016

	Dickey-Fuller Test P-Value					Dickey-Fuller Test P-Value				
	Price	WP^{1}	WP^{2-10}	WP^{2-3}	WP^{4-10}	ΔPrice	ΔWP^{1}	ΔWP^{2-10}	ΔWP^{2-3}	ΔWP^{4-10}
04-01-2016	0.049	0.046	0.145	0.123	0.110	<0.000	<0.000	<0.000	<0.000	<0.000
05-01-2016	0.461	0.370	0.669	0.571	0.612	<0.000	<0.000	<0.000	<0.000	<0.000
06-01-2016	0.520	0.496	0.463	0.577	0.429	<0.000	<0.000	<0.000	<0.000	<0.000
07-01-2016	0.009	0.005	0.008	0.007	0.006	<0.000	<0.000	<0.000	<0.000	<0.000
08-01-2016	0.192	0.131	0.342	0.374	0.231	<0.000	<0.000	<0.000	<0.000	<0.000
11-01-2016	0.507	0.482	0.599	0.631	0.492	<0.000	<0.000	<0.000	<0.000	<0.000
12-01-2016	0.758	0.749	0.705	0.752	0.676	<0.000	<0.000	<0.000	<0.000	<0.000
13-01-2016	0.002	0.001	0.001	0.015	0.000	<0.000	<0.000	<0.000	<0.000	<0.000
14-01-2016	0.369	0.293	0.537	0.641	0.396	<0.000	<0.000	<0.000	<0.000	<0.000
15-01-2016	0.118	0.048	0.213	0.158	0.147	<0.000	<0.000	<0.000	<0.000	<0.000
19-01-2016	0.000	0.000	0.002	0.002	0.000	<0.000	<0.000	<0.000	<0.000	<0.000
20-01-2016	0.073	0.031	0.073	0.098	0.043	<0.000	<0.000	<0.000	<0.000	<0.000
21-01-2016	0.281	0.191	0.477	0.383	0.437	<0.000	<0.000	<0.000	<0.000	<0.000
22-01-2016	0.621	0.589	0.678	0.665	0.638	<0.000	<0.000	<0.000	<0.000	<0.000
25-01-2016	0.723	0.648	0.822	0.786	0.784	<0.000	<0.000	<0.000	<0.000	<0.000
26-01-2016	0.001	0.000	0.009	0.007	0.004	<0.000	<0.000	<0.000	<0.000	<0.000
27-01-2016	0.360	0.277	0.506	0.565	0.331	<0.000	<0.000	<0.000	<0.000	<0.000
28-01-2016	0.442	0.425	0.470	0.477	0.459	<0.000	<0.000	<0.000	<0.000	<0.000
29-01-2016	0.693	0.661	0.776	0.781	0.714	<0.000	<0.000	<0.000	<0.000	<0.000

Table 4.A1 continued - Unit Root Test Results of the Price Series; Soybeans Feb. 2016

	Dickey-Fuller Test P-Value					Dickey-Fuller Test P-Value				
	Price	WP^{1}	WP^{2-10}	WP^{2-3}	WP^{4-10}	ΔPrice	ΔWP^{1}	ΔWP^{2-10}	ΔWP^{2-3}	ΔWP^{4-10}
01-02-2016	0.042	0.017	0.174	0.114	0.132	<0.000	<0.000	<0.000	<0.000	<0.000
02-02-2016	0.438	0.422	0.570	0.588	0.519	<0.000	<0.000	<0.000	<0.000	<0.000
03-02-2016	0.233	0.186	0.234	0.248	0.214	<0.000	<0.000	<0.000	<0.000	<0.000
04-02-2016	0.487	0.366	0.533	0.571	0.480	<0.000	<0.000	<0.000	<0.000	<0.000
05-02-2016	0.128	0.078	0.176	0.156	0.136	<0.000	<0.000	<0.000	<0.000	<0.000
08-02-2016	0.050	0.009	0.180	0.136	0.135	<0.000	<0.000	<0.000	<0.000	<0.000
09-02-2016	0.001	0.000	0.007	0.008	0.003	<0.000	<0.000	<0.000	<0.000	<0.000
10-02-2016	0.000	0.000	0.000	0.000	0.000	<0.000	<0.000	<0.000	<0.000	<0.000
11-02-2016	0.035	0.024	0.036	0.048	0.031	<0.000	<0.000	<0.000	<0.000	<0.000
12-02-2016	0.042	0.017	0.224	0.177	0.178	<0.000	<0.000	<0.000	<0.000	<0.000
16-02-2016	0.151	0.103	0.438	0.335	0.361	<0.000	<0.000	<0.000	<0.000	<0.000
17-02-2016	0.000	0.000	0.001	0.001	0.000	<0.000	<0.000	<0.000	<0.000	<0.000
18-02-2016	0.000	0.000	0.013	0.006	0.007	<0.000	<0.000	<0.000	<0.000	<0.000
19-02-2016	0.003	0.000	0.050	0.034	0.023	<0.000	<0.000	<0.000	<0.000	<0.000
22-02-2016	0.385	0.337	0.728	0.669	0.663	<0.000	<0.000	<0.000	<0.000	<0.000
23-02-2016	0.010	0.009	0.003	0.005	0.003	<0.000	<0.000	<0.000	<0.000	<0.000
24-02-2016	0.018	0.008	0.114	0.124	0.061	<0.000	<0.000	<0.000	<0.000	<0.000
25-02-2016	0.044	0.040	0.105	0.085	0.088	<0.000	<0.000	<0.000	<0.000	<0.000
26-02-2016	0.040	0.023	0.133	0.095	0.104	<0.000	<0.000	<0.000	<0.000	<0.000
29-02-2016	0.000	0.001	0.040	0.022	0.022	<0.000	<0.000	<0.000	<0.000	<0.000

Table 4.A1 continued - Unit Root Test Results of the Price Series; Soybeans Mar. 2016

	Dickey-Fuller Test P-Value					Dickey-Fuller Test P-Value				
	Price	WP^{1}	WP^{2-10}	WP^{2-3}	WP^{4-10}	ΔPrice	ΔWP^{1}	ΔWP^{2-10}	ΔWP^{2-3}	ΔWP^{4-10}
01-03-2016	0.233	0.289	0.295	0.334	0.259	<0.000	<0.000	<0.000	<0.000	<0.000
02-03-2016	0.119	0.117	0.405	0.311	0.335	<0.000	<0.000	<0.000	<0.000	<0.000
03-03-2016	0.347	0.452	0.754	0.654	0.721	<0.000	<0.000	<0.000	<0.000	<0.000
04-03-2016	0.030	0.036	0.178	0.117	0.134	<0.000	<0.000	<0.000	<0.000	<0.000
07-03-2016	0.192	0.411	0.449	0.775	0.305	<0.000	<0.000	<0.000	<0.000	<0.000
08-03-2016	0.401	0.349	0.718	0.567	0.694	<0.000	<0.000	<0.000	<0.000	<0.000
09-03-2016	0.040	0.055	0.107	0.138	0.071	<0.000	<0.000	<0.000	<0.000	<0.000
10-03-2016	0.030	0.046	0.034	0.078	0.033	<0.000	<0.000	<0.000	<0.000	<0.000
11-03-2016	0.078	0.224	0.322	0.376	0.214	<0.000	<0.000	<0.000	<0.000	<0.000
14-03-2016	0.001	0.017	0.063	0.063	0.029	<0.000	<0.000	<0.000	<0.000	<0.000
15-03-2016	0.096	0.227	0.381	0.386	0.296	<0.000	<0.000	<0.000	<0.000	<0.000
16-03-2016	0.642	0.711	0.894	0.893	0.821	<0.000	<0.000	<0.000	<0.000	<0.000
17-03-2016	0.466	0.492	0.597	0.580	0.544	<0.000	<0.000	<0.000	<0.000	<0.000
18-03-2016	0.004	0.023	0.057	0.099	0.019	<0.000	<0.000	<0.000	<0.000	<0.000
21-03-2016	0.001	0.003	0.007	0.005	0.007	<0.000	<0.000	<0.000	<0.000	<0.000
22-03-2016	0.066	0.087	0.230	0.164	0.191	<0.000	<0.000	<0.000	<0.000	<0.000
23-03-2016	0.000	0.000	0.001	0.002	0.000	<0.000	<0.000	<0.000	<0.000	<0.000
24-03-2016	0.004	0.004	0.030	0.015	0.029	<0.000	<0.000	<0.000	<0.000	<0.000
28-03-2016	0.059	0.085	0.231	0.241	0.140	<0.000	<0.000	<0.000	<0.000	<0.000
29-03-2016	0.016	0.032	0.050	0.068	0.021	<0.000	<0.000	<0.000	<0.000	<0.000
30-03-2016	0.213	0.302	0.326	0.472	0.194	<0.000	<0.000	<0.000	<0.000	<0.000
31-03-2016	0.001	0.000	0.000	0.000	0.000	<0.000	<0.000	<0.000	<0.000	<0.000

Table 4.A1 continued - Unit Root Test Results of the Price Series; E-mini S&P 500 Nov. – Dec. 2015

	Dickey-Fuller Test P-Value					Dickey-Fuller Test P-Value				
	Price	WP^{1}	WP^{2-10}	WP^{2-5}	WP^{6-10}	ΔPrice	ΔWP^{1}	ΔWP^{2-10}	ΔWP^{2-5}	ΔWP^{6-10}
23-11-2015	0.047	0.066	0.332	0.272	0.351	<0.000	<0.000	<0.000	<0.000	<0.000
24-11-2015	0.275	0.309	0.418	0.421	0.405	<0.000	<0.000	<0.000	<0.000	<0.000
25-11-2015	0.000	0.000	0.000	0.000	0.000	<0.000	<0.000	<0.000	<0.000	<0.000
27-11-2015	0.001	0.001	0.036	0.008	0.038	<0.000	<0.000	<0.000	<0.000	<0.000
30-11-2015	0.010	0.026	0.097	0.075	0.101	<0.000	<0.000	<0.000	<0.000	<0.000
01-12-2015	0.046	0.076	0.483	0.393	0.493	<0.000	<0.000	<0.000	<0.000	<0.000
02-12-2015	0.569	0.624	0.763	0.745	0.754	<0.000	<0.000	<0.000	<0.000	<0.000
03-12-2015	0.396	0.375	0.393	0.391	0.388	<0.000	<0.000	<0.000	<0.000	<0.000
04-12-2015	0.511	0.501	0.521	0.523	0.501	<0.000	<0.000	<0.000	<0.000	<0.000
07-12-2015	0.110	0.096	0.209	0.187	0.198	<0.000	<0.000	<0.000	<0.000	<0.000
08-12-2015	0.010	0.004	0.033	0.030	0.026	<0.000	<0.000	<0.000	<0.000	<0.000
09-12-2015	0.717	0.658	0.759	0.738	0.753	<0.000	<0.000	<0.000	<0.000	<0.000
10-12-2015	0.113	0.056	0.170	0.142	0.158	<0.000	<0.000	<0.000	<0.000	<0.000
11-12-2015	0.220	0.119	0.236	0.217	0.226	<0.000	<0.000	<0.000	<0.000	<0.000
14-12-2015	0.058	0.019	0.056	0.047	0.041	<0.000	<0.000	<0.000	<0.000	<0.000
15-12-2015	0.004	0.002	0.007	0.006	0.006	<0.000	<0.000	<0.000	<0.000	<0.000
16-12-2015	0.569	0.449	0.582	0.519	0.543	<0.000	<0.000	<0.000	<0.000	<0.000
17-12-2015	0.811	0.761	0.894	0.869	0.875	<0.000	<0.000	<0.000	<0.000	<0.000
18-12-2015	0.581	0.488	0.737	0.685	0.694	<0.000	<0.000	<0.000	<0.000	<0.000
21-12-2015	0.136	0.065	0.380	0.345	0.341	<0.000	<0.000	<0.000	<0.000	<0.000
22-12-2015	0.519	0.409	0.771	0.754	0.724	<0.000	<0.000	<0.000	<0.000	<0.000
23-12-2015	0.084	0.078	0.251	0.241	0.200	<0.000	<0.000	<0.000	<0.000	<0.000
24-12-2015	0.034	0.025	0.349	0.298	0.245	<0.000	<0.000	<0.000	<0.000	<0.000
28-12-2015	0.023	0.018	0.289	0.227	0.233	<0.000	<0.000	<0.000	<0.000	<0.000
29-12-2015	0.006	0.007	0.086	0.077	0.065	<0.000	<0.000	<0.000	<0.000	<0.000
30-12-2015	0.035	0.017	0.492	0.341	0.488	<0.000	<0.000	<0.000	<0.000	<0.000
31-12-2015	0.155	0.123	0.547	0.396	0.535	<0.000	<0.000	<0.000	<0.000	<0.000

Table 4.A1 continued - Unit Root Test Results of the Price Series; E-mini S&P 500 Jan. 2016

	Dickey-Fuller Test P-Value					Dickey-Fuller Test P-Value				
	Price	WP^{1}	WP^{2-10}	WP^{2-5}	WP^{6-10}	ΔPrice	ΔWP^{1}	ΔWP^{2-10}	ΔWP^{2-5}	ΔWP^{6-10}
04-01-2016	0.324	0.270	0.570	0.532	0.521	<0.000	<0.000	<0.000	<0.000	<0.000
05-01-2016	0.030	0.017	0.170	0.112	0.178	<0.000	<0.000	<0.000	<0.000	<0.000
06-01-2016	0.060	0.047	0.125	0.114	0.098	<0.000	<0.000	<0.000	<0.000	<0.000
07-01-2016	0.664	0.624	0.755	0.751	0.723	<0.000	<0.000	<0.000	<0.000	<0.000
08-01-2016	0.766	0.734	0.829	0.807	0.797	<0.000	<0.000	<0.000	<0.000	<0.000
11-01-2016	0.198	0.158	0.247	0.233	0.225	<0.000	<0.000	<0.000	<0.000	<0.000
12-01-2016	0.244	0.192	0.336	0.301	0.324	<0.000	<0.000	<0.000	<0.000	<0.000
13-01-2016	0.900	0.886	0.921	0.913	0.918	<0.000	<0.000	<0.000	<0.000	<0.000
14-01-2016	0.568	0.526	0.597	0.590	0.580	<0.000	<0.000	<0.000	<0.000	<0.000
15-01-2016	0.025	0.017	0.030	0.028	0.019	<0.000	<0.000	<0.000	<0.000	<0.000
19-01-2016	0.284	0.253	0.321	0.311	0.314	<0.000	<0.000	<0.000	<0.000	<0.000
20-01-2016	0.754	0.722	0.758	0.753	0.730	<0.000	<0.000	<0.000	<0.000	<0.000
21-01-2016	0.098	0.065	0.071	0.076	0.051	<0.000	<0.000	<0.000	<0.000	<0.000
22-01-2016	0.006	0.003	0.025	0.017	0.022	<0.000	<0.000	<0.000	<0.000	<0.000
25-01-2016	0.474	0.411	0.662	0.612	0.640	<0.000	<0.000	<0.000	<0.000	<0.000
26-01-2016	0.100	0.080	0.160	0.152	0.151	<0.000	<0.000	<0.000	<0.000	<0.000
27-01-2016	0.692	0.648	0.734	0.709	0.707	<0.000	<0.000	<0.000	<0.000	<0.000
28-01-2016	0.057	0.032	0.071	0.056	0.063	<0.000	<0.000	<0.000	<0.000	<0.000
29-01-2016	0.402	0.420	0.446	0.445	0.429	<0.000	<0.000	<0.000	<0.000	<0.000

Table 4.A1 continued - Unit Root Test Results of the Price Series; E-mini S&P 500 Feb. 2016

	Dickey-Fuller Test P-Value					Dickey-Fuller Test P-Value				
	Price	WP^{1}	WP^{2-10}	WP^{2-5}	WP^{6-10}	ΔPrice	ΔWP^{1}	ΔWP^{2-10}	ΔWP^{2-5}	ΔWP^{6-10}
01-02-2016	0.152	0.120	0.269	0.256	0.250	<0.000	<0.000	<0.000	<0.000	<0.000
02-02-2016	0.128	0.110	0.227	0.222	0.201	<0.000	<0.000	<0.000	<0.000	<0.000
03-02-2016	0.666	0.621	0.652	0.659	0.617	<0.000	<0.000	<0.000	<0.000	<0.000
04-02-2016	0.043	0.022	0.041	0.034	0.035	<0.000	<0.000	<0.000	<0.000	<0.000
05-02-2016	0.181	0.157	0.158	0.179	0.132	<0.000	<0.000	<0.000	<0.000	<0.000
08-02-2016	0.380	0.306	0.361	0.360	0.312	<0.000	<0.000	<0.000	<0.000	<0.000
09-02-2016	0.192	0.135	0.169	0.164	0.143	<0.000	<0.000	<0.000	<0.000	<0.000
10-02-2016	0.104	0.043	0.058	0.058	0.039	<0.000	<0.000	<0.000	<0.000	<0.000
11-02-2016	0.020	0.009	0.009	0.009	0.005	<0.000	<0.000	<0.000	<0.000	<0.000
12-02-2016	0.191	0.164	0.203	0.203	0.160	<0.000	<0.000	<0.000	<0.000	<0.000
16-02-2016	0.156	0.148	0.264	0.224	0.249	<0.000	<0.000	<0.000	<0.000	<0.000
17-02-2016	0.117	0.125	0.166	0.156	0.159	<0.000	<0.000	<0.000	<0.000	<0.000
18-02-2016	0.010	0.009	0.038	0.031	0.033	<0.000	<0.000	<0.000	<0.000	<0.000
19-02-2016	0.008	0.005	0.036	0.031	0.026	<0.000	<0.000	<0.000	<0.000	<0.000
22-02-2016	0.000	0.000	0.002	0.001	0.001	<0.000	<0.000	<0.000	<0.000	<0.000
23-02-2016	0.266	0.295	0.503	0.493	0.482	<0.000	<0.000	<0.000	<0.000	<0.000
24-02-2016	0.931	0.918	0.955	0.955	0.944	<0.000	<0.000	<0.000	<0.000	<0.000
25-02-2016	0.675	0.642	0.860	0.821	0.848	<0.000	<0.000	<0.000	<0.000	<0.000
26-02-2016	0.143	0.129	0.284	0.238	0.258	<0.000	<0.000	<0.000	<0.000	<0.000
29-02-2016	0.597	0.576	0.709	0.735	0.654	<0.000	<0.000	<0.000	<0.000	<0.000

Table 4.A1 continued - Unit Root Test Results of the Price Series; E-mini S&P 500 Mar. 2016

	Dickey-Fuller Test P-Value					Dickey-Fuller Test P-Value				
	Price	WP^{1}	WP^{2-10}	WP^{2-5}	WP^{6-10}	ΔPrice	ΔWP^{1}	ΔWP^{2-10}	ΔWP^{2-5}	ΔWP^{6-10}
01-03-2016	0.683	0.692	0.753	0.753	0.736	<0.000	<0.000	<0.000	<0.000	<0.000
02-03-2016	0.016	0.012	0.120	0.084	0.115	<0.000	<0.000	<0.000	<0.000	<0.000
03-03-2016	0.114	0.162	0.479	0.399	0.460	<0.000	<0.000	<0.000	<0.000	<0.000
04-03-2016	0.057	0.052	0.172	0.172	0.141	<0.000	<0.000	<0.000	<0.000	<0.000
07-03-2016	0.107	0.073	0.262	0.226	0.265	<0.000	<0.000	<0.000	<0.000	<0.000
08-03-2016	0.019	0.016	0.105	0.070	0.107	<0.000	<0.000	<0.000	<0.000	<0.000
09-03-2016	0.000	0.000	0.001	0.000	0.001	<0.000	<0.000	<0.000	<0.000	<0.000
10-03-2016	0.260	0.218	0.260	0.245	0.251	<0.000	<0.000	<0.000	<0.000	<0.000
11-03-2016	0.121	0.047	0.213	0.181	0.212	<0.000	<0.000	<0.000	<0.000	<0.000
14-03-2016	0.006	0.001	0.049	0.021	0.066	<0.000	<0.000	<0.000	<0.000	<0.000
15-03-2016	0.002	0.001	0.057	0.023	0.071	<0.000	<0.000	<0.000	<0.000	<0.000
16-03-2016	0.368	0.292	0.485	0.446	0.436	<0.000	<0.000	<0.000	<0.000	<0.000
17-03-2016	0.257	0.261	0.338	0.334	0.334	<0.000	<0.000	<0.000	<0.000	<0.000
18-03-2016	0.000	0.000	0.003	0.001	0.004	<0.000	<0.000	<0.000	<0.000	<0.000
21-03-2016	0.002	0.002	0.060	0.038	0.067	<0.000	<0.000	<0.000	<0.000	<0.000
22-03-2016	0.064	0.106	0.293	0.239	0.300	<0.000	<0.000	<0.000	<0.000	<0.000
23-03-2016	0.004	0.008	0.042	0.031	0.040	<0.000	<0.000	<0.000	<0.000	<0.000
24-03-2016	0.085	0.137	0.597	0.481	0.617	<0.000	<0.000	<0.000	<0.000	<0.000
28-03-2016	0.000	0.003	0.040	0.018	0.050	<0.000	<0.000	<0.000	<0.000	<0.000
29-03-2016	0.777	0.794	0.899	0.882	0.901	<0.000	<0.000	<0.000	<0.000	<0.000
30-03-2016	0.000	0.002	0.072	0.033	0.087	<0.000	<0.000	<0.000	<0.000	<0.000
31-03-2016	0.001	0.003	0.047	0.032	0.042	<0.000	<0.000	<0.000	<0.000	<0.000

Table 4.A2 Cointegration Test Results ($\boldsymbol{r}$) of the Daily Regressions; Live Cattle Nov. – Dec. 2015

	Cointegration Test (3-Var. Model)			Cointegration Test (4-Var. Model)		
	Johansen's Trace (99%)	BIC	HQIC	Johansen's Trace (99%)	BIC	HQIC
23-11-2015	2	2	2	3	3	3
24-11-2015	2	2	2	3	3	3
25-11-2015	.	2	2	.	3	3
30-11-2015	2	2	2	3	3	3
01-12-2015	2	2	2	3	3	3
02-12-2015	2	2	2	3	3	3
03-12-2015	2	2	2	3	3	3
04-12-2015	.	2	2	.	3	3
07-12-2015	2	2	2	.	3	3
08-12-2015	2	2	2	3	3	3
09-12-2015	2	2	2	3	3	3
10-12-2015	.	2	2	.	3	3
11-12-2015	2	2	2	3	3	3
14-12-2015	2	2	2	3	3	3
15-12-2015	2	2	2	3	3	3
16-12-2015	.	2	2	.	3	3
17-12-2015	2	2	2	3	3	3
22-12-2015	2	2	2	3	3	3
23-12-2015	2	2	2	3	3	3
24-12-2015	2	2	2	3	3	3
28-12-2015	.	2	2	.	3	3
29-12-2015	2	2	2	3	3	3
30-12-2015	2	2	2	3	3	3
31-12-2015	.	2	2	.	3	3

Table 4.A2 continued - Cointegration Test Results (r) of the Daily Regressions; Live Cattle Jan. 2016

	Cointegration Test (3-Var. Model)			Cointegration Test (4-Var. Model)		
	Johansen's Trace (99%)	BIC	HQIC	Johansen's Trace (99%)	BIC	HQIC
04-01-2016	2	2	2	3	3	3
05-01-2016	2	2	2	3	3	3
06-01-2016	2	2	2	3	3	3
07-01-2016	2	2	2	3	3	3
08-01-2016	2	2	2	3	3	3
11-01-2016	2	2	2	3	3	3
12-01-2016	2	2	2	3	3	3
13-01-2016	2	2	2	3	3	3
14-01-2016	2	2	2	3	3	3
15-01-2016	2	2	2	3	3	3
19-01-2016	2	2	2	3	3	3
20-01-2016	2	2	2	3	3	3
21-01-2016	2	2	2	3	3	3
22-01-2016	2	2	2	3	3	3
25-01-2016	.	2	2	.	3	3
26-01-2016	2	2	2	3	3	3
27-01-2016	2	2	2	3	3	3
28-01-2016	.	2	2	.	3	3
29-01-2016	2	2	2	3	3	3

Table 4.A2 continued - Cointegration Test Results (r) of the Daily Regressions; Live Cattle Feb. 2016

	Cointegration Test (3-Var. Model)			Cointegration Test (4-Var. Model)		
	Johansen's Trace (99%)	BIC	HQIC	Johansen's Trace (99%)	BIC	HQIC
01-02-2016	2	2	2	3	3	3
02-02-2016	2	2	2	3	3	3
03-02-2016	2	2	2	3	3	3
04-02-2016	2	2	2	3	3	3
05-02-2016	2	2	2	3	3	3
10-02-2016	2	2	2	3	3	3
11-02-2016	2	2	2	3	3	3
12-02-2016	2	2	2	3	3	3
16-02-2016	2	2	2	3	3	3
17-02-2016	2	2	2	3	3	3
18-02-2016	2	2	2	3	3	3
19-02-2016	2	2	2	3	3	3
22-02-2016	2	2	2	3	3	3
23-02-2016	2	2	2	3	3	3
24-02-2016	2	2	2	3	3	3
25-02-2016	2	2	2	3	3	3
26-02-2016	2	2	2	3	3	3
29-02-2016	2	2	2	3	3	3

Table 4.A2 continued - Cointegration Test Results (r) of the Daily Regressions; Live Cattle Mar. 2016

	Cointegration Test (3-Var. Model)			Cointegration Test (4-Var. Model)		
	Johansen's Trace (99%)	BIC	HQIC	Johansen's Trace (99%)	BIC	HQIC
01-03-2016	2	2	2	3	3	3
02-03-2016	2	2	2	3	3	3
03-03-2016	2	2	2	3	3	3
04-03-2016	2	2	2	3	3	3
07-03-2016	2	2	2	3	3	3
08-03-2016	2	2	2	3	3	3
09-03-2016	.	2	2	.	3	3
10-03-2016	2	2	2	3	3	3
11-03-2016	2	2	2	3	3	3
14-03-2016	2	2	2	3	3	3
15-03-2016	2	2	2	3	3	3
16-03-2016	2	2	2	3	3	3
17-03-2016	2	2	2	3	3	3
18-03-2016	2	2	2	3	3	3
21-03-2016	2	2	2	3	3	3
22-03-2016	2	2	2	3	3	3
23-03-2016	2	2	2	3	3	3
24-03-2016	2	2	2	3	3	3
28-03-2016	2	2	2	3	3	3
29-03-2016	2	2	2	3	3	3
30-03-2016	2	2	2	3	3	3
31-03-2016	2	2	2	3	3	3

Table 4.A2 continued - Cointegration Test Results (r) of the Daily Regressions; Lean Hogs Nov. - Dec. 2015

	Cointegration Test (3-Var. Model)			Cointegration Test (4-Var. Model)		
	Johansen's Trace (99%)	BIC	HQIC	Johansen's Trace (99%)	BIC	HQIC
23-11-2015	2	2	2	3	3	3
24-11-2015	2	2	2	3	3	3
25-11-2015	2	2	2	3	3	3
30-11-2015	.	2	2	.	3	3
01-12-2015	2	2	2	3	3	3
02-12-2015	2	2	2	.	3	3
03-12-2015	2	2	2	3	3	3
04-12-2015	2	2	2	3	3	3
07-12-2015	.	2	2	.	3	3
08-12-2015	2	2	2	3	3	3
09-12-2015	2	2	2	3	3	3
10-12-2015	.	2	2	.	3	3
11-12-2015	2	2	2	3	3	3
14-12-2015	2	2	2	3	3	3
15-12-2015	2	2	2	3	3	3
16-12-2015	2	2	2	3	3	3
17-12-2015	2	2	2	3	3	3
18-12-2015	2	2	2	3	3	3
21-12-2015	2	2	2	3	3	3
22-12-2015	.	2	2	.	3	3
23-12-2015	2	2	2	3	3	3
24-12-2015	1	1	2	2	2	3
28-12-2015	2	2	2	3	3	3
29-12-2015	.	2	2	.	3	3
30-12-2015	2	2	2	3	3	3
31-12-2015	.	2	2	.	3	3

Table 4.A2 continued - Cointegration Test Results (r) of the Daily Regressions; Lean Hogs Jan. 2016

	Cointegration Test (3-Var. Model)			Cointegration Test (4-Var. Model)		
	Johansen's Trace (99%)	BIC	HQIC	Johansen's Trace (99%)	BIC	HQIC
04-01-2016	.	2	2	.	3	3
05-01-2016	2	2	2	3	3	3
06-01-2016	2	2	2	3	3	3
07-01-2016	2	2	2	3	3	3
08-01-2016	2	2	2	3	3	3
11-01-2016	2	2	2	3	3	3
12-01-2016	2	2	2	3	3	3
13-01-2016	2	2	2	3	3	3
14-01-2016	2	2	2	3	3	3
15-01-2016	2	2	2	3	3	3
19-01-2016	.	2	2	.	3	3
20-01-2016	2	2	2	3	3	3
21-01-2016	2	2	2	3	3	3
22-01-2016	2	2	2	3	3	3
25-01-2016	2	2	2	3	3	3
26-01-2016	2	2	2	3	3	3
27-01-2016	.	2	2	.	3	3
28-01-2016	2	2	2	3	3	3
29-01-2016	.	2	2	.	3	3

Table 4.A2 continued - Cointegration Test Results (r) of the Daily Regressions; Lean Hogs Feb. 2016

	Cointegration Test (3-Var. Model)			Cointegration Test (4-Var. Model)		
	Johansen's Trace (99%)	BIC	HQIC	Johansen's Trace (99%)	BIC	HQIC
01-02-2016	2	2	2	3	3	3
02-02-2016	2	2	2	3	3	3
03-02-2016	2	2	2	3	3	3
04-02-2016	2	2	2	3	3	3
05-02-2016	2	2	2	3	3	3
08-02-2016	2	2	2	3	3	3
10-02-2016	2	2	2	3	3	3
11-02-2016	2	2	2	3	3	3
12-02-2016	2	2	2	3	3	3
16-02-2016	.	2	2	.	3	3
17-02-2016	2	2	2	3	3	3
18-02-2016	2	2	2	3	3	3
19-02-2016	2	2	2	3	3	3
22-02-2016	2	2	2	3	3	3
23-02-2016	2	2	2	3	3	3
24-02-2016	2	2	2	3	3	3
25-02-2016	2	2	2	3	3	3
26-02-2016	2	2	2	3	3	3
29-02-2016	2	2	2	3	3	3

Table 4.A2 continued - Cointegration Test Results (r) of the Daily Regressions; Lean Hogs Mar. 2016

	Cointegration Test (3-Var. Model)			Cointegration Test (4-Var. Model)		
	Johansen's Trace (99%)	BIC	HQIC	Johansen's Trace (99%)	BIC	HQIC
01-03-2016	2	2	2	3	3	3
02-03-2016	.	2	2	.	3	3
03-03-2016	2	2	2	3	3	3
04-03-2016	2	2	2	3	3	3
07-03-2016	2	2	2	.	3	3
08-03-2016	.	2	2	.	3	3
09-03-2016	2	2	2	3	3	3
10-03-2016	2	2	2	3	3	3
11-03-2016	2	2	2	3	3	3
14-03-2016	2	2	2	3	3	3
15-03-2016	.	2	2	.	3	3
16-03-2016	2	2	2	3	3	3
17-03-2016	2	2	2	3	3	3
18-03-2016	2	2	2	3	3	3
21-03-2016	2	2	2	3	3	3
22-03-2016	2	2	2	3	3	3
23-03-2016	2	2	2	3	3	3
24-03-2016	2	2	2	3	3	3
28-03-2016	.	2	2	.	3	3
29-03-2016	.	2	2	.	3	3
30-03-2016	2	2	2	3	3	3
31-03-2016	2	2	2	3	3	3

Table 4.A2 continued - Cointegration Test Results (r) of the Daily Regressions; Corn Nov. – Dec. 2015

	Cointegration Test (3-Var. Model)			Cointegration Test (4-Var. Model)		
	Johansen's Trace (99%)	BIC	HQIC	Johansen's Trace (99%)	BIC	HQIC
23-11-2015	2	2	2	3	3	3
24-11-2015	2	2	2	3	3	3
25-11-2015	.	2	2	.	3	3
27-11-2015	.	2	2	.	2	3
30-11-2015	2	2	2	3	3	3
01-12-2015	2	2	2	3	3	3
02-12-2015	.	2	2	.	3	3
03-12-2015	2	2	2	3	3	3
04-12-2015	.	2	2	3	3	3
07-12-2015	2	2	2	3	2	3
08-12-2015	.	2	2	.	3	3
09-12-2015	2	2	2	3	3	3
10-12-2015	2	2	2	3	3	3
11-12-2015	.	2	2	.	3	3
14-12-2015	.	2	2	.	3	3
15-12-2015	2	2	2	3	3	3
16-12-2015	2	2	2	3	3	3
17-12-2015	2	2	2	3	3	3
18-12-2015	2	2	2	3	3	3
21-12-2015	.	2	2	3	3	3
22-12-2015	2	2	2	3	3	3
23-12-2015	.	2	2	.	3	3
24-12-2015	1	1	1	2	1	2
28-12-2015	.	2	2	.	3	3
29-12-2015	2	2	2	3	3	3
30-12-2015	.	2	2	.	3	3
31-12-2015	.	2	2	.	3	3

Table 4.A2 continued - Cointegration Test Results (r) of the Daily Regressions; Corn Jan. 2016

	Cointegration Test (3-Var. Model)			Cointegration Test (4-Var. Model)		
	Johansen's Trace (99%)	BIC	HQIC	Johansen's Trace (99%)	BIC	HQIC
04-01-2016	.	2	2	.	3	3
05-01-2016	2	2	2	3	3	3
06-01-2016	2	2	2	3	3	3
07-01-2016	2	2	2	3	3	3
08-01-2016	.	2	2	.	3	3
11-01-2016	2	2	2	3	3	3
12-01-2016	2	2	2	3	3	3
13-01-2016	.	2	2	.	3	3
14-01-2016	2	2	2	3	3	3
15-01-2016	2	2	2	3	3	3
19-01-2016	2	2	2	3	3	3
20-01-2016	2	2	2	3	3	3
21-01-2016	2	2	2	3	3	3
22-01-2016	2	2	2	3	3	3
25-01-2016	2	2	2	3	3	3
26-01-2016	2	2	2	3	3	3
27-01-2016	2	2	2	3	3	3
28-01-2016	2	2	2	3	3	3
29-01-2016	.	2	2	3	3	3

Table 4.A2 continued - Cointegration Test Results (r) of the Daily Regressions; Corn Feb. 2016

	Cointegration Test (3-Var. Model)			Cointegration Test (4-Var. Model)		
	Johansen's Trace (99%)	BIC	HQIC	Johansen's Trace (99%)	BIC	HQIC
01-02-2016	2	2	2	3	3	3
02-02-2016	2	2	2	3	3	3
03-02-2016	2	2	2	3	3	3
04-02-2016	2	2	2	3	3	3
05-02-2016	.	2	2	2	2	3
08-02-2016	2	2	2	3	3	3
10-02-2016	.	2	2	.	3	3
11-02-2016	2	2	2	3	3	3
12-02-2016	2	2	2	3	3	3
16-02-2016	2	2	2	3	3	3
17-02-2016	2	2	2	3	3	3
18-02-2016	2	2	2	3	3	3
19-02-2016	2	2	2	3	3	3
22-02-2016	2	2	2	3	3	3
23-02-2016	2	2	2	3	3	3
24-02-2016	2	2	2	3	3	3
25-02-2016	.	2	2	.	3	3
26-02-2016	2	2	2	3	3	3
29-02-2016	.	2	2	.	3	3

Table 4.A2 continued - Cointegration Test Results (r) of the Daily Regressions; Corn Mar. 2016

	Cointegration Test (3-Var. Model)			Cointegration Test (4-Var. Model)		
	Johansen's Trace (99%)	BIC	HQIC	Johansen's Trace (99%)	BIC	HQIC
01-03-2016	2	2	2	3	3	3
02-03-2016	.	2	2	3	3	3
03-03-2016	2	2	2	3	3	3
04-03-2016	2	2	2	3	3	3
07-03-2016	2	2	2	3	3	3
08-03-2016	2	2	2	3	3	3
09-03-2016	.	2	2	.	3	3
10-03-2016	.	2	2	.	3	3
11-03-2016	2	2	2	3	3	3
14-03-2016	2	2	2	3	3	3
15-03-2016	.	2	2	.	3	3
16-03-2016	2	2	2	3	3	3
17-03-2016	2	2	2	3	3	3
18-03-2016	2	2	2	3	3	3
21-03-2016	.	2	2	.	3	3
23-03-2016	2	2	2	2	2	3
24-03-2016	2	2	2	3	3	3
28-03-2016	2	2	2	3	3	3
29-03-2016	2	2	2	.	3	3
30-03-2016	2	2	2	3	3	3
31-03-2016	2	2	2	3	3	3

Table 4.A2 continued - Cointegration Test Results (r) of the Daily Regressions; Wheat Nov. - Dec. 2015

	Cointegration Test (3-Var. Model)			Cointegration Test (4-Var. Model)		
	Johansen's Trace (99%)	BIC	HQIC	Johansen's Trace (99%)	BIC	HQIC
23-11-2015	.	2	2	.	3	3
24-11-2015	2	2	2	3	3	3
25-11-2015	.	2	2	.	3	3
27-11-2015	2	1	2	3	3	3
30-11-2015	2	2	2	3	3	3
01-12-2015	2	2	2	3	3	3
02-12-2015	2	2	2	3	3	3
03-12-2015	.	2	2	.	3	3
04-12-2015	2	2	2	3	3	3
07-12-2015	2	2	2	3	3	3
08-12-2015	.	2	2	.	3	3
09-12-2015	.	2	2	.	3	3
10-12-2015	.	2	2	.	3	3
11-12-2015	2	2	2	3	2	3
14-12-2015	.	2	2	.	3	3
15-12-2015	2	2	2	3	3	3
16-12-2015	2	2	2	3	3	3
17-12-2015	2	2	2	3	3	3
18-12-2015	2	2	2	3	3	3
21-12-2015	2	2	2	3	3	3
22-12-2015	2	2	2	3	3	3
23-12-2015	2	2	2	3	3	3
24-12-2015	1	1	1	2	2	2
28-12-2015	2	2	2	3	3	3
29-12-2015	2	2	2	3	3	3
30-12-2015	2	2	2	3	3	3
31-12-2015	.	2	2	.	3	3

Table 4.A2 continued - Cointegration Test Results (r) of the Daily Regressions; Wheat Jan. 2016

	Cointegration Test (3-Var. Model)			Cointegration Test (4-Var. Model)		
	Johansen's Trace (99%)	BIC	HQIC	Johansen's Trace (99%)	BIC	HQIC
04-01-2016	.	2	2	.	3	3
05-01-2016	.	2	2	.	3	3
06-01-2016	2	2	2	3	3	3
07-01-2016	2	2	2	3	3	3
08-01-2016	2	2	2	.	3	3
11-01-2016	2	2	2	3	3	3
12-01-2016	2	2	2	3	3	3
13-01-2016	2	2	2	3	3	3
14-01-2016	2	2	2	3	3	3
15-01-2016	2	2	2	3	3	3
19-01-2016	2	2	2	3	3	3
20-01-2016	2	2	2	3	3	3
21-01-2016	2	2	2	3	3	3
22-01-2016	2	2	2	3	3	3
25-01-2016	2	2	2	3	3	3
26-01-2016	2	1	2	3	2	3
27-01-2016	2	2	2	3	3	3
28-01-2016	.	2	2	.	3	3
29-01-2016	.	2	2	.	3	3

Table 4.A2 continued - Cointegration Test Results (r) of the Daily Regressions; Wheat Feb. 2016

	Cointegration Test (3-Var. Model)			Cointegration Test (4-Var. Model)		
	Johansen's Trace (99%)	BIC	HQIC	Johansen's Trace (99%)	BIC	HQIC
01-02-2016	2	2	2	3	3	3
02-02-2016	2	2	2	3	3	3
03-02-2016	2	2	2	3	3	3
04-02-2016	2	2	2	3	3	3
05-02-2016	.	2	2	.	3	3
08-02-2016	2	2	2	3	3	3
10-02-2016	.	2	2	.	3	3
11-02-2016	2	2	2	3	3	3
12-02-2016	2	2	2	3	3	3
16-02-2016	2	2	2	3	3	3
17-02-2016	.	2	2	.	3	3
18-02-2016	2	2	2	3	3	3
19-02-2016	.	2	2	3	3	3
22-02-2016	2	2	2	3	3	3
23-02-2016	2	2	2	3	3	3
24-02-2016	2	2	2	3	3	3
25-02-2016	2	2	2	3	3	3
26-02-2016	2	2	2	3	3	3
29-02-2016	.	2	2	.	3	3

Table 4.A2 continued - Cointegration Test Results (r) of the Daily Regressions; Wheat Mar. 2016

	Cointegration Test (3-Var. Model)			Cointegration Test (4-Var. Model)		
	Johansen's Trace (99%)	BIC	HQIC	Johansen's Trace (99%)	BIC	HQIC
01-03-2016	.	2	2	.	3	3
02-03-2016	2	2	2	3	3	3
03-03-2016	2	2	2	3	3	3
04-03-2016	2	2	2	3	3	3
07-03-2016	2	2	2	3	3	3
08-03-2016	2	2	2	3	3	3
09-03-2016	2	2	2	3	3	3
10-03-2016	.	2	2	3	3	3
11-03-2016	2	2	2	3	3	3
14-03-2016	2	2	2	3	3	3
15-03-2016	2	2	2	3	3	3
16-03-2016	.	2	2	.	3	3
17-03-2016	2	2	2	3	3	3
18-03-2016	2	2	2	3	3	3
21-03-2016	2	2	2	3	3	3
22-03-2016	2	2	2	3	3	3
23-03-2016	.	2	2	.	3	3
24-03-2016	2	2	2	3	3	3
28-03-2016	.	2	2	.	2	3
29-03-2016	2	2	2	3	3	3
30-03-2016	.	2	2	.	3	3
31-03-2016	2	2	2	3	3	3

Table 4.A2 continued - Cointegration Test Results (r) of the Daily Regressions; Soybeans Nov. - Dec. 2015

	Cointegration Test (3-Var. Model)			Cointegration Test (4-Var. Model)		
	Johansen's Trace (99%)	BIC	HQIC	Johansen's Trace (99%)	BIC	HQIC
23-11-2015	2	2	2	3	3	3
24-11-2015	.	2	2	.	3	3
25-11-2015	2	2	2	3	3	3
27-11-2015	2	2	2	3	3	3
30-11-2015	.	2	2	.	3	3
01-12-2015	2	2	2	3	3	3
02-12-2015	2	2	2	3	3	3
03-12-2015	2	2	2	3	3	3
04-12-2015	2	2	2	3	3	3
07-12-2015	2	2	2	3	3	3
08-12-2015	2	2	2	3	3	3
09-12-2015	2	2	2	3	3	3
10-12-2015	2	2	2	3	3	3
11-12-2015	.	2	2	.	3	3
14-12-2015	2	2	2	3	3	3
15-12-2015	.	2	2	.	3	3
16-12-2015	2	2	2	3	3	3
17-12-2015	2	2	2	3	3	3
18-12-2015	.	2	2	.	3	3
21-12-2015	.	2	2	.	3	3
22-12-2015	2	2	2	3	3	3
23-12-2015	.	2	2	.	3	3
24-12-2015	1	1	1	2	2	2
28-12-2015	.	2	2	.	3	3
29-12-2015	.	2	2	.	3	3
30-12-2015	2	2	2	3	3	3
31-12-2015	2	2	2	3	3	3

Table 4.A2 continued - Cointegration Test Results (r) of the Daily Regressions; Soybeans Jan. 2016

	Cointegration Test (3-Var. Model)			Cointegration Test (4-Var. Model)		
	Johansen's Trace (99%)	BIC	HQIC	Johansen's Trace (99%)	BIC	HQIC
04-01-2016	2	2	2	3	3	3
05-01-2016	2	2	2	3	3	3
06-01-2016	2	2	2	3	3	3
07-01-2016	.	2	2	.	3	3
08-01-2016	2	2	2	3	3	3
11-01-2016	2	2	2	3	3	3
12-01-2016	2	2	2	3	3	3
13-01-2016	.	2	2	.	3	3
14-01-2016	2	2	2	3	3	3
15-01-2016	2	2	2	3	3	3
19-01-2016	.	2	2	.	3	3
20-01-2016	.	2	2	.	3	3
21-01-2016	2	2	2	3	3	3
22-01-2016	2	2	2	3	3	3
25-01-2016	2	2	2	3	3	3
26-01-2016	.	2	2	.	3	3
27-01-2016	2	2	2	3	3	3
28-01-2016	2	2	2	3	3	3
29-01-2016	2	2	2	3	3	3

Table 4.A2 continued - Cointegration Test Results (r) of the Daily Regressions; Soybeans Feb. 2016

	Cointegration Test (3-Var. Model)			Cointegration Test (4-Var. Model)		
	Johansen's Trace (99%)	BIC	HQIC	Johansen's Trace (99%)	BIC	HQIC
01-02-2016	2	2	2	3	3	3
02-02-2016	2	2	2	3	3	3
03-02-2016	2	2	2	3	3	3
04-02-2016	2	2	2	3	3	3
05-02-2016	2	2	2	3	3	3
08-02-2016	2	2	2	3	3	3
09-02-2016	.	2	2	.	3	3
10-02-2016	.	2	2	.	3	3
11-02-2016	.	2	2	.	3	3
12-02-2016	2	2	2	3	3	3
16-02-2016	2	2	2	3	3	3
17-02-2016	.	2	2	.	3	3
18-02-2016	.	2	2	.	3	3
19-02-2016	2	2	2	3	3	3
22-02-2016	2	2	2	3	3	3
23-02-2016	.	2	2	.	3	3
24-02-2016	2	2	2	3	3	3
25-02-2016	2	2	2	3	3	3
26-02-2016	2	2	2	3	3	3
29-02-2016	.	2	2	.	3	3

Table 4.A2 continued - Cointegration Test Results (r) of the Daily Regressions; Soybeans Mar. 2016

	Cointegration Test (3-Var. Model)			Cointegration Test (4-Var. Model)		
	Johansen's Trace (99%)	BIC	HQIC	Johansen's Trace (99%)	BIC	HQIC
01-03-2016	2	2	2	3	3	3
02-03-2016	2	2	2	3	3	3
03-03-2016	2	2	2	3	3	3
04-03-2016	2	2	2	3	3	3
07-03-2016	2	2	2	3	3	3
08-03-2016	2	2	2	3	3	3
09-03-2016	2	2	2	3	3	3
10-03-2016	.	2	2	.	3	3
11-03-2016	2	2	2	3	3	3
14-03-2016	.	2	2	.	3	3
15-03-2016	2	2	2	3	3	3
16-03-2016	2	2	2	3	3	3
17-03-2016	2	2	2	3	3	3
18-03-2016	2	2	2	3	3	3
21-03-2016	.	2	2	.	3	3
22-03-2016	2	2	2	3	3	3
23-03-2016	.	2	2	.	3	3
24-03-2016	.	2	2	.	3	3
28-03-2016	2	2	2	3	3	3
29-03-2016	2	2	2	3	3	3
30-03-2016	2	2	2	3	3	3
31-03-2016	.	2	2	.	3	3

Table 4.A2 continued - Cointegration Test Results (r) of the Daily Regressions; E-mini S&P 500 Nov. - Dec. 2015

	Cointegration Test (3-Var. Model)			Cointegration Test (4-Var. Model)		
	Johansen's Trace (99%)	BIC	HQIC	Johansen's Trace (99%)	BIC	HQIC
23-11-2015	2	2	2	3	3	3
24-11-2015	2	2	2	3	3	3
25-11-2015	.	2	2	.	3	3
27-11-2015	2	2	2	3	3	3
30-11-2015	2	2	2	3	3	3
01-12-2015	2	2	2	3	3	3
02-12-2015	2	2	2	3	3	3
03-12-2015	2	2	2	3	3	3
04-12-2015	2	2	2	3	3	3
07-12-2015	2	2	2	3	3	3
08-12-2015	2	2	2	3	3	3
09-12-2015	2	2	2	3	3	3
10-12-2015	2	2	2	3	3	3
11-12-2015	2	2	2	3	3	3
14-12-2015	2	2	2	3	3	3
15-12-2015	.	2	2	.	3	3
16-12-2015	2	2	2	3	3	3
17-12-2015	2	2	2	3	3	3
18-12-2015	2	2	2	3	3	3
21-12-2015	2	2	2	3	3	3
22-12-2015	2	2	2	3	3	3
23-12-2015	2	2	2	3	3	3
24-12-2015	2	2	2	3	3	3
28-12-2015	2	2	2	3	3	3
29-12-2015	2	2	2	3	3	3
30-12-2015	2	2	2	3	3	3
31-12-2015	2	2	2	3	3	3

Table 4.A2 continued - Cointegration Test Results (r) of the Daily Regressions; E-mini S&P 500 Jan. 2016

	Cointegration Test (3-Var. Model)			Cointegration Test (4-Var. Model)		
	Johansen's Trace (99%)	BIC	HQIC	Johansen's Trace (99%)	BIC	HQIC
04-01-2016	2	2	2	3	3	3
05-01-2016	2	2	2	3	3	3
06-01-2016	2	2	2	3	3	3
07-01-2016	2	2	2	3	3	3
08-01-2016	2	2	2	3	3	3
11-01-2016	2	2	2	3	3	3
12-01-2016	2	2	2	3	3	3
13-01-2016	2	2	2	3	3	3
14-01-2016	2	2	2	3	3	3
15-01-2016	.	2	2	.	3	3
19-01-2016	2	2	2	3	3	3
20-01-2016	2	2	2	3	3	3
21-01-2016	2	2	2	3	3	3
22-01-2016	.	2	2	.	3	3
25-01-2016	2	2	2	3	3	3
26-01-2016	2	2	2	3	3	3
27-01-2016	2	2	2	3	3	3
28-01-2016	2	2	2	3	3	3
29-01-2016	2	2	2	3	3	3

Table 4.A2 continued - Cointegration Test Results (r) of the Daily Regressions; E-mini S&P 500 Feb. 2016

	Cointegration Test (3-Var. Model)			Cointegration Test (4-Var. Model)		
	Johansen's Trace (99%)	BIC	HQIC	Johansen's Trace (99%)	BIC	HQIC
01-02-2016	2	2	2	3	3	3
02-02-2016	2	2	2	3	3	3
03-02-2016	2	2	2	3	3	3
04-02-2016	2	2	2	.	3	3
05-02-2016	2	2	2	3	3	3
08-02-2016	2	2	2	3	3	3
09-02-2016	2	2	2	3	3	3
10-02-2016	2	2	2	3	3	3
11-02-2016	.	2	2	.	3	3
12-02-2016	2	2	2	3	3	3
16-02-2016	2	2	2	3	3	3
17-02-2016	2	2	2	3	3	3
18-02-2016	.	2	2	.	3	3
19-02-2016	2	2	2	3	3	3
22-02-2016	.	2	2	.	3	3
23-02-2016	2	2	2	3	3	3
24-02-2016	2	2	2	3	3	3
25-02-2016	2	2	2	3	3	3
26-02-2016	2	2	2	3	3	3
29-02-2016	2	2	2	3	3	3

Table 4.A2 continued - Cointegration Test Results (r) of the Daily Regressions; E-mini S&P 500 Mar. 2016

	Cointegration Test (3-Var. Model)			Cointegration Test (4-Var. Model)		
	Johansen's Trace (99%)	BIC	HQIC	Johansen's Trace (99%)	BIC	HQIC
01-03-2016	2	2	2	3	3	3
02-03-2016	2	2	2	3	3	3
03-03-2016	2	2	2	3	3	3
04-03-2016	2	2	2	3	3	3
07-03-2016	2	2	2	3	3	3
08-03-2016	2	2	2	3	3	3
09-03-2016	.	2	2	.	3	3
10-03-2016	2	2	2	3	3	3
11-03-2016	2	2	2	3	3	3
14-03-2016	2	2	2	3	3	3
15-03-2016	2	2	2	3	3	3
16-03-2016	2	2	2	3	3	3
17-03-2016	2	2	2	3	3	3
18-03-2016	.	2	2	.	3	3
21-03-2016	2	2	2	3	3	3
22-03-2016	2	2	2	3	3	3
23-03-2016	.	2	2	.	3	3
24-03-2016	2	2	2	3	3	3
28-03-2016	2	2	2	3	3	3
29-03-2016	2	2	2	3	3	3
30-03-2016	2	2	2	3	3	3
31-03-2016	2	2	2	3	3	3

BIC and HQIC stand for Schwarz Bayesian information criterion and Hannan Quinn information criterion, respectively. The missing ranks reported for Johansen's trace rank is due to staitionarity of the price series.

Table 4.A3 Daily Information Share Measures; Live Cattle Nov. – Dec. 2015 (%)

	Price			WP^1			$WP^{2\text{-}5}$		
	IS_M	PT	MIS	IS_M	PT	MIS	IS_M	PT	MIS
23-11-2015	46.73	32.11	32.78	45.66	62.22	50.79	16.57	5.67	16.42
24-11-2015	39.15	22.11	24.91	48.24	59.83	50.83	21.57	18.06	24.26
25-11-2015	32.13	20.28	21.21	57.98	67.61	60.28	17.48	12.11	18.51
30-11-2015	33.37	0.11	13.74	22.48	15.60	23.54	59.05	82.28	62.72
01-12-2015	40.57	11.29	22.38	52.31	74.79	52.77	19.93	13.93	24.84
02-12-2015	36.89	7.78	19.59	52.69	70.20	53.10	23.04	22.02	27.31
03-12-2015	62.34	57.65	46.66	24.45	26.28	29.20	19.71	16.07	24.14
04-12-2015	36.39	7.31	16.33	27.60	19.65	27.05	52.21	73.04	56.62
07-12-2015	63.87	62.73	49.60	20.34	14.04	24.03	23.47	23.23	26.36
08-12-2015	35.56	3.98	16.58	42.85	45.31	40.11	37.52	50.72	43.30
09-12-2015	42.95	18.84	23.43	29.54	28.38	31.57	38.88	52.79	45.00
10-12-2015	56.23	36.34	34.33	21.94	16.79	27.09	28.75	46.87	38.58
11-12-2015	52.35	37.61	33.96	28.41	29.78	32.31	26.60	32.61	33.73
14-12-2015	35.01	7.03	17.31	42.33	46.05	40.42	36.79	46.92	42.27
15-12-2015	46.16	16.04	24.48	31.73	31.17	33.33	34.73	52.79	42.19
16-12-2015	40.51	19.62	22.68	33.16	29.29	32.24	37.50	51.09	45.08
17-12-2015	61.84	60.68	49.04	26.68	29.74	29.78	19.43	9.58	21.19
22-12-2015	45.74	25.00	27.29	36.20	41.51	38.11	26.98	33.49	34.60
23-12-2015	57.92	43.14	38.72	23.31	27.87	30.53	24.60	28.99	30.75
24-12-2015	39.29	14.45	21.71	43.87	52.87	43.05	29.80	32.68	35.25
28-12-2015	69.26	77.86	63.50	20.97	14.78	20.20	18.07	7.36	16.30
29-12-2015	41.35	23.55	25.07	45.70	55.99	46.32	22.09	20.46	28.61
30-12-2015	45.31	26.29	27.94	38.57	47.91	40.90	24.91	25.80	31.16
31-12-2015	50.25	42.37	38.48	38.35	46.53	41.45	18.11	11.09	20.07

Table 4.A3 continued - Daily Information Share Measures; Live Cattle Jan. 2016 (%)

	Price			WP^1			WP^{2-5}		
	IS_M	PT	MIS	IS_M	PT	MIS	IS_M	PT	MIS
04-01-2016	38.27	4.03	16.11	28.91	17.54	27.53	52.95	78.43	56.36
05-01-2016	31.02	6.22	15.29	58.88	71.80	55.63	22.39	21.98	29.08
06-01-2016	62.35	63.08	52.50	27.15	29.39	28.18	18.25	7.54	19.33
07-01-2016	31.90	7.29	15.70	43.62	46.54	41.26	37.56	46.17	43.04
08-01-2016	40.38	5.63	18.14	32.77	24.21	30.94	47.08	70.15	50.92
11-01-2016	45.97	24.00	26.63	33.53	35.66	35.39	30.13	40.35	37.98
12-01-2016	38.44	9.13	16.58	27.90	11.37	25.24	52.88	79.50	58.18
13-01-2016	39.92	20.69	23.73	45.08	54.62	45.72	24.65	24.69	30.55
14-01-2016	44.07	26.14	27.51	48.80	68.96	50.20	19.40	4.90	22.30
15-01-2016	33.88	14.54	18.78	43.78	45.71	41.92	33.16	39.75	39.30
19-01-2016	55.93	47.32	40.05	17.92	5.75	19.51	34.47	46.93	40.44
20-01-2016	38.56	23.66	24.69	49.85	60.86	50.52	20.55	15.48	24.79
21-01-2016	38.72	6.85	17.91	25.05	16.24	25.69	52.43	76.91	56.40
22-01-2016	38.45	14.26	19.53	32.29	25.46	30.88	42.30	60.29	49.59
25-01-2016	34.00	10.47	17.84	62.42	86.97	61.24	15.36	2.56	20.91
26-01-2016	32.62	3.32	13.65	39.93	33.93	36.11	43.47	62.75	50.23
27-01-2016	44.80	26.20	27.27	36.37	42.43	38.57	27.24	31.37	34.16
28-01-2016	60.17	57.58	48.04	28.84	31.36	29.69	17.66	11.06	22.27
29-01-2016	45.35	9.85	22.31	26.91	16.60	28.56	44.98	73.54	49.12

Table 4.A3 continued - Daily Information Share Measures; Live Cattle Feb. 2016 (%)

	Price			WP^1			WP^{2-5}		
	IS_M	PT	MIS	IS_M	PT	MIS	IS_M	PT	MIS
01-02-2016	51.20	34.04	32.10	27.42	23.95	29.93	28.57	42.02	37.97
02-02-2016	41.65	19.91	22.84	30.45	23.34	29.75	39.15	56.76	47.42
03-02-2016	29.56	4.56	13.82	42.44	44.46	40.77	39.79	50.98	45.41
04-02-2016	53.61	43.09	37.26	20.81	10.35	22.10	33.96	46.56	40.64
05-02-2016	54.55	51.82	43.97	37.45	45.65	39.55	16.08	2.54	16.48
10-02-2016	36.41	11.84	19.24	51.57	62.49	48.93	24.45	25.67	31.83
11-02-2016	41.42	11.39	22.41	46.24	61.51	45.82	26.35	27.10	31.77
12-02-2016	56.99	46.23	40.03	17.89	2.57	18.43	34.53	51.20	41.54
16-02-2016	40.87	12.52	20.48	31.43	29.17	32.13	42.34	58.31	47.38
17-02-2016	60.80	62.25	50.86	27.03	26.99	28.66	20.93	10.76	20.48
18-02-2016	34.56	6.10	15.54	38.18	35.22	35.52	43.54	58.68	48.94
19-02-2016	31.52	3.64	14.99	51.42	59.97	48.43	30.63	36.40	36.59
22-02-2016	51.86	38.34	35.34	25.06	26.55	29.81	28.59	35.11	34.84
23-02-2016	56.46	45.83	40.46	23.46	22.31	27.25	25.92	31.86	32.29
24-02-2016	29.14	5.67	12.32	26.44	20.39	25.19	57.81	73.94	62.49
25-02-2016	42.89	27.82	28.21	50.28	68.27	53.37	17.70	3.90	18.42
26-02-2016	38.38	20.19	23.60	55.65	75.60	58.16	17.78	4.21	18.24
29-02-2016	39.96	18.04	19.99	27.53	14.06	25.57	47.11	67.90	54.44

Table 4.A3 continued - Daily Information Share Measures; Live Cattle Mar. 2016 (%)

	Price			WP^1			WP^{2-5}		
	IS_M	PT	MIS	IS_M	PT	MIS	IS_M	PT	MIS
01-03-2016	55.26	47.19	41.56	33.23	42.80	37.61	19.24	10.01	20.84
02-03-2016	31.52	11.79	17.10	62.38	84.34	62.20	19.68	3.87	20.70
03-03-2016	40.18	27.37	25.99	53.61	72.49	54.41	18.50	0.14	19.60
04-03-2016	33.92	8.25	16.45	43.62	42.87	40.81	35.42	48.88	42.73
07-03-2016	30.50	6.52	15.47	58.88	70.24	57.75	20.60	23.24	26.78
08-03-2016	41.01	16.58	21.57	30.08	25.23	30.27	41.32	58.19	48.16
09-03-2016	43.88	33.71	30.70	48.52	62.04	50.54	16.50	4.26	18.76
10-03-2016	35.53	17.03	18.93	24.51	16.04	23.22	51.40	66.93	57.85
11-03-2016	44.09	29.39	29.90	42.56	54.69	47.04	21.19	15.93	23.05
14-03-2016	37.83	23.99	22.03	21.61	11.10	19.96	51.08	64.91	58.00
15-03-2016	70.76	81.41	71.30	14.91	1.68	10.49	21.76	16.91	18.20
16-03-2016	39.70	31.94	29.41	40.70	45.21	42.88	25.41	22.85	27.71
17-03-2016	68.66	71.94	65.71	22.42	20.77	21.06	14.94	7.30	13.23
18-03-2016	67.01	69.16	58.58	19.63	12.21	19.46	20.73	18.64	21.96
21-03-2016	57.91	51.20	44.70	29.07	33.19	31.28	18.40	15.61	24.03
22-03-2016	52.01	37.61	34.46	25.94	25.88	30.15	27.79	36.51	35.39
23-03-2016	33.50	9.95	17.61	54.49	67.04	53.20	23.89	23.00	29.19
24-03-2016	30.61	8.86	16.24	63.62	81.74	63.00	16.39	9.40	20.76
28-03-2016	37.21	16.28	19.48	26.78	16.63	25.10	48.17	67.09	55.43
29-03-2016	55.98	44.48	39.39	22.07	14.88	23.70	29.47	40.63	36.90
30-03-2016	41.75	6.38	19.05	29.13	16.50	28.17	49.03	77.13	52.78
31-03-2016	61.47	56.48	46.06	17.20	0.49	18.71	30.02	43.03	35.23

Table 4.A3 continued - Daily Information Share Measures; Lean Hogs Nov. – Dec. 2015 (%)

	Price			WP^1			WP^{2-5}		
	IS_M	PT	MIS	IS_M	PT	MIS	IS_M	PT	MIS
23-11-2015	37.02	19.54	22.95	49.83	60.38	52.83	21.04	20.08	24.23
24-11-2015	32.71	8.69	17.17	57.03	71.21	56.59	21.76	20.10	26.24
25-11-2015	35.11	10.72	19.23	53.11	67.21	53.97	23.32	22.07	26.80
30-11-2015	44.24	22.47	26.25	36.58	43.66	39.91	27.37	33.87	33.84
01-12-2015	57.05	46.83	40.10	20.33	14.82	24.79	29.00	38.35	35.11
02-12-2015	29.99	1.25	13.88	54.36	63.57	52.20	27.99	35.19	33.92
03-12-2015	36.48	5.70	19.07	56.58	77.97	57.01	19.39	16.32	23.91
04-12-2015	56.51	45.90	39.74	18.38	6.50	20.28	33.20	47.59	39.98
07-12-2015	49.44	29.00	29.57	25.01	24.91	29.87	32.80	46.10	40.56
08-12-2015	48.09	22.93	28.14	34.18	44.15	39.18	25.92	32.92	32.69
09-12-2015	33.55	7.16	17.58	53.45	66.68	53.72	24.69	26.17	28.70
10-12-2015	49.70	43.83	37.35	15.48	5.78	16.01	41.31	50.39	46.64
11-12-2015	64.41	64.22	52.01	23.15	21.46	27.34	19.88	14.32	20.65
14-12-2015	47.31	28.20	29.16	27.04	26.22	29.84	33.14	45.58	41.00
15-12-2015	55.29	44.65	37.47	19.18	10.30	22.83	33.48	45.05	39.70
16-12-2015	59.14	54.37	44.27	19.83	14.11	23.82	28.18	31.52	31.91
17-12-2015	64.79	70.66	55.06	18.63	6.40	19.85	25.71	22.94	25.09
18-12-2015	44.12	21.33	26.38	46.06	67.49	49.20	21.72	11.19	24.41
21-12-2015	40.89	15.48	21.24	27.95	24.02	29.17	43.71	60.50	49.59
22-12-2015	47.38	33.59	28.94	19.11	4.01	19.57	44.77	62.40	51.49
23-12-2015	45.78	30.54	30.39	39.37	49.08	43.48	21.72	20.37	26.14
24-12-2015	29.04	10.19	16.52	57.06	68.39	60.28	21.73	21.42	23.20
28-12-2015	42.67	25.09	26.30	31.39	32.40	33.63	33.38	42.51	40.08
29-12-2015	40.07	22.85	24.98	43.99	55.57	46.99	24.99	21.57	28.03
30-12-2015	22.27	2.64	10.12	70.68	91.30	71.31	17.09	6.07	18.57
31-12-2015	37.96	27.58	26.60	56.06	71.75	60.31	15.47	0.66	13.09

Table 4.A3 continued - Daily Information Share Measures; Lean Hogs Jan. 2016 (%)

	Price			WP[1]			WP[2-5]		
	IS_M	PT	MIS	IS_M	PT	MIS	IS_M	PT	MIS
04-01-2016	45.70	26.10	26.22	20.23	8.07	21.52	45.35	65.83	52.26
05-01-2016	35.71	10.74	18.33	20.72	23.94	25.33	53.01	65.32	56.34
06-01-2016	45.23	34.89	28.46	15.19	1.13	16.03	49.46	63.98	55.51
07-01-2016	48.13	30.10	29.71	22.79	22.54	26.96	35.99	47.36	43.33
08-01-2016	43.41	24.91	26.31	42.49	53.26	44.51	22.98	21.83	29.18
11-01-2016	38.21	7.43	19.97	55.60	79.20	54.83	20.71	13.38	25.20
12-01-2016	46.24	25.97	29.10	45.69	65.50	50.33	18.57	8.53	20.57
13-01-2016	44.52	20.76	25.67	33.15	38.42	36.72	30.95	40.82	37.61
14-01-2016	43.65	22.47	26.02	36.89	46.47	40.92	27.92	31.06	33.05
15-01-2016	42.99	27.09	26.65	46.77	58.88	48.58	18.73	14.03	24.76
19-01-2016	32.11	12.59	17.54	41.36	45.50	41.44	35.70	41.91	41.02
20-01-2016	37.80	13.71	19.84	36.74	36.07	36.07	37.19	50.22	44.10
21-01-2016	61.33	59.98	52.22	21.87	15.20	22.58	23.66	24.82	25.21
22-01-2016	37.38	20.60	21.33	23.46	12.98	21.75	49.52	66.42	56.92
25-01-2016	66.64	74.52	59.51	19.70	4.87	17.75	22.88	20.61	22.74
26-01-2016	30.04	13.51	17.06	59.44	65.17	58.88	17.37	21.32	24.06
27-01-2016	52.36	40.61	36.96	23.70	19.22	25.92	30.02	40.17	37.13
28-01-2016	40.01	12.32	20.43	22.55	16.62	24.82	49.39	71.06	54.75
29-01-2016	40.56	13.19	20.67	32.20	29.81	32.63	40.74	57.01	46.70

Table 4.A3 continued - Daily Information Share Measures; Lean Hogs Feb. 2016 (%)

	Price			WP[1]			WP[2-5]		
	IS_M	PT	MIS	IS_M	PT	MIS	IS_M	PT	MIS
01-02-2016	34.33	8.41	17.73	43.29	48.71	43.02	33.76	42.88	39.25
02-02-2016	56.43	46.60	40.01	20.61	15.94	25.18	28.90	37.47	34.81
03-02-2016	56.23	56.04	48.91	31.45	34.06	33.41	19.95	9.90	17.68
04-02-2016	41.48	21.81	24.44	27.06	26.54	29.35	39.51	51.65	46.21
05-02-2016	47.69	35.03	32.02	21.53	15.95	23.30	37.88	49.02	44.68
08-02-2016	39.17	16.92	23.26	52.35	69.68	55.78	17.96	13.39	20.97
10-02-2016	42.81	19.20	24.93	43.47	56.95	46.25	23.04	23.84	28.82
11-02-2016	43.60	17.62	24.96	44.71	61.87	47.98	21.12	20.51	27.05
12-02-2016	36.97	6.66	15.70	21.76	6.80	21.70	58.22	86.54	62.61
16-02-2016	36.33	24.93	24.59	55.99	69.83	58.61	17.65	5.24	16.80
17-02-2016	52.05	39.65	36.44	36.88	49.22	42.29	19.11	11.13	21.26
18-02-2016	59.76	63.91	50.89	19.11	11.52	21.39	29.68	24.57	27.71
19-02-2016	63.97	64.96	54.70	27.78	30.98	33.13	15.70	4.06	12.16
22-02-2016	63.06	66.06	54.46	19.55	8.97	19.09	26.09	24.97	26.45
23-02-2016	37.18	2.03	16.05	22.71	16.85	25.16	56.29	81.12	58.79
24-02-2016	49.31	31.76	31.45	41.82	59.90	45.70	18.86	8.34	22.85
25-02-2016	66.39	75.48	58.22	19.40	5.65	19.24	23.91	18.87	22.54
26-02-2016	52.62	40.17	35.66	26.65	25.94	30.51	26.71	33.88	33.82
29-02-2016	43.87	32.45	30.47	49.65	65.62	53.38	16.73	1.93	16.15

Table 4.A3 continued - Daily Information Share Measures; Lean Hogs Mar. 2016 (%)

	Price			WP[1]			WP[2-5]		
	IS_M	PT	MIS	IS_M	PT	MIS	IS_M	PT	MIS
01-03-2016	32.72	13.37	18.60	59.62	76.24	60.57	18.84	10.40	20.83
02-03-2016	36.79	18.87	21.08	35.66	35.68	35.96	36.67	45.45	42.95
03-03-2016	34.79	4.96	14.92	25.37	16.82	25.10	55.87	78.23	59.98
04-03-2016	58.59	52.14	44.23	25.70	25.50	29.58	21.58	22.36	26.20
07-03-2016	55.49	44.01	37.62	21.11	14.61	24.84	30.89	41.39	37.54
08-03-2016	36.21	21.17	21.46	39.72	38.67	38.89	32.37	40.16	39.65
09-03-2016	55.61	42.87	36.83	26.09	34.64	33.90	23.52	22.48	29.27
10-03-2016	58.33	55.78	45.83	27.70	29.78	31.40	21.78	14.45	22.77
11-03-2016	43.54	23.21	23.59	17.65	2.73	19.34	51.39	74.07	57.06
14-03-2016	47.94	35.31	32.71	33.38	36.81	36.40	24.41	27.88	30.90
15-03-2016	71.80	88.51	73.58	19.78	3.25	14.44	17.07	8.24	11.97
16-03-2016	57.46	47.55	40.64	27.96	33.29	34.17	19.96	19.16	25.19
17-03-2016	72.13	98.73	75.28	19.32	0.18	11.51	19.10	1.09	13.20
18-03-2016	44.87	30.77	28.61	37.19	38.74	38.27	24.73	30.49	33.12
21-03-2016	42.95	36.47	29.95	25.84	21.40	27.08	38.06	42.12	42.98
22-03-2016	49.76	50.08	42.96	35.91	38.14	36.39	21.31	11.78	20.65
23-03-2016	31.33	12.00	15.99	29.06	21.65	26.79	50.46	66.35	57.22
24-03-2016	56.55	38.63	35.29	20.09	8.72	23.80	32.30	52.65	40.91
28-03-2016	50.29	22.17	27.84	29.33	30.86	33.29	29.95	46.96	38.87
29-03-2016	56.51	53.84	47.16	33.66	37.58	35.87	15.93	8.58	16.97
30-03-2016	66.31	71.90	55.93	24.25	19.95	23.98	17.80	8.15	20.09
31-03-2016	49.25	30.24	30.47	30.46	34.80	34.99	27.09	34.96	34.54

Table 4.A3 continued - Daily Information Share Measures; Corn Nov. – Dec. 2016 (%)

	Price			WP^1			WP^{2-10}		
	IS_M	PT	MIS	IS_M	PT	MIS	IS_M	PT	MIS
23-11-2015	20.14	7.01	9.16	21.52	1.98	14.36	68.20	91.01	76.48
24-11-2015	46.73	25.14	34.87	21.28	12.14	17.96	36.76	62.72	47.17
25-11-2015	21.90	12.61	12.36	48.22	30.07	40.57	35.56	57.32	47.07
27-11-2015	13.02	6.83	6.09	45.65	26.20	36.53	46.62	66.96	57.38
30-11-2015	43.08	32.93	32.80	41.79	37.01	37.25	20.35	30.06	29.95
01-12-2015	25.64	10.96	13.06	37.66	23.67	31.86	46.07	65.37	55.08
02-12-2015	16.14	3.62	5.34	34.44	12.02	26.02	59.49	84.36	68.64
03-12-2015	73.69	53.87	64.54	15.16	3.76	11.05	14.12	42.37	24.41
04-12-2015	59.08	44.92	50.55	33.06	34.57	30.23	11.07	20.52	19.22
07-12-2015	50.62	30.16	38.74	37.08	26.21	32.16	15.40	43.63	29.10
08-12-2015	26.49	13.19	13.71	44.32	25.19	35.42	38.13	61.63	50.87
09-12-2015	50.64	40.74	39.25	37.59	40.11	36.78	16.12	19.16	23.97
10-12-2015	10.42	0.83	3.66	73.75	57.43	61.25	18.96	41.74	35.09
11-12-2015	68.74	58.08	63.57	27.16	35.65	24.84	5.27	6.27	11.59
14-12-2015	14.10	10.62	8.75	78.55	77.62	68.02	10.38	11.76	23.23
15-12-2015	70.31	52.25	62.42	15.53	10.19	12.59	17.07	37.55	24.99
16-12-2015	46.77	30.84	37.24	45.51	39.19	38.73	10.40	29.97	24.03
17-12-2015	41.44	18.59	24.07	24.62	4.38	18.17	46.77	77.02	57.76
18-12-2015	16.68	2.65	6.16	39.20	22.67	33.31	52.10	74.69	60.53
21-12-2015	16.76	0.89	4.61	34.47	14.29	26.88	59.97	84.82	68.51
22-12-2015	79.56	59.77	72.41	12.46	8.62	9.99	9.82	31.61	17.60
23-12-2015	49.42	40.91	38.56	20.33	6.65	15.46	35.98	52.44	45.98
24-12-2015	17.60	13.00	13.78	55.00	34.47	49.76	28.90	52.54	36.46
28-12-2015	30.01	15.98	22.11	56.46	38.18	47.06	16.00	45.84	30.83
29-12-2015	14.93	5.47	6.08	34.05	15.12	26.31	59.01	79.40	67.60
30-12-2015	32.51	18.76	20.18	28.79	12.44	22.37	46.73	68.80	57.45
31-12-2015	40.49	21.55	27.73	24.27	8.74	17.79	42.33	69.72	54.48

Table 4.A3 continued - Daily Information Share Measures; Corn Jan. 2016 (%)

	Price			WP^1			$WP^{2\text{-}10}$		
	IS_M	PT	MIS	IS_M	PT	MIS	IS_M	PT	MIS
04-01-2016	15.79	1.61	5.01	53.09	31.71	42.63	39.00	66.68	52.36
05-01-2016	16.45	12.62	11.03	65.18	63.70	59.18	23.62	23.68	29.79
06-01-2016	23.27	15.90	15.38	62.61	61.48	57.79	19.86	22.62	26.83
07-01-2016	40.51	22.97	24.90	23.16	2.50	16.38	47.09	74.53	58.72
08-01-2016	21.12	10.04	10.33	42.96	26.98	34.82	44.54	62.98	54.84
11-01-2016	14.90	6.11	7.94	72.75	58.71	64.24	15.24	35.19	27.82
12-01-2016	39.25	3.88	15.14	32.49	13.55	28.23	52.61	82.57	56.63
13-01-2016	55.82	36.42	42.79	27.43	21.91	24.76	21.74	41.66	32.44
14-01-2016	27.00	17.41	17.65	57.66	45.32	47.96	20.30	37.28	34.39
15-01-2016	15.86	11.18	9.75	76.01	84.72	71.35	12.74	4.10	18.90
19-01-2016	36.25	23.27	26.46	45.46	39.19	40.66	23.38	37.54	32.88
20-01-2016	41.28	30.39	30.53	42.13	35.20	36.92	22.21	34.41	32.56
21-01-2016	18.38	1.01	5.26	30.54	7.86	23.13	63.50	91.13	71.61
22-01-2016	14.04	3.23	4.72	48.55	29.97	38.67	45.12	66.80	56.61
25-01-2016	36.71	21.42	21.16	26.65	6.56	19.52	48.15	72.02	59.32
26-01-2016	20.67	7.90	8.54	48.09	27.81	37.62	41.13	64.28	53.84
27-01-2016	26.68	19.21	16.97	53.18	44.50	45.00	26.93	36.30	38.04
28-01-2016	45.33	21.31	30.82	22.78	3.03	15.01	39.27	75.66	54.17
29-01-2016	56.49	28.54	43.91	21.13	8.95	16.73	26.27	62.51	39.36

Table 4.A3 continued - Daily Information Share Measures; Corn Feb. 2016 (%)

	Price			WP^1			WP^{2-10}		
	IS_M	PT	MIS	IS_M	PT	MIS	IS_M	PT	MIS
01-02-2016	29.09	20.09	21.52	54.47	46.70	46.09	21.11	33.21	32.38
02-02-2016	29.78	20.39	20.43	36.20	24.34	30.12	39.89	55.27	49.46
03-02-2016	68.47	48.51	59.39	14.97	5.82	10.95	19.42	45.67	29.66
04-02-2016	29.02	20.68	19.03	38.64	23.78	31.93	38.40	55.53	49.04
05-02-2016	43.81	27.80	36.19	45.73	37.11	41.23	12.47	35.10	22.58
08-02-2016	20.26	10.75	11.18	62.50	42.01	50.47	21.77	47.24	38.36
10-02-2016	16.91	5.48	8.33	33.66	11.63	26.52	56.12	82.88	65.15
11-02-2016	85.95	74.78	82.69	9.98	13.54	7.70	5.67	11.68	9.61
12-02-2016	56.25	44.43	50.59	40.13	41.49	35.23	5.15	14.07	14.18
16-02-2016	27.28	17.16	16.70	53.10	35.87	43.60	25.21	46.97	39.69
17-02-2016	24.69	26.74	21.07	71.91	71.93	66.72	4.33	1.33	12.21
18-02-2016	60.49	37.33	46.84	20.86	2.23	12.96	24.31	60.43	40.20
19-02-2016	24.22	11.19	11.30	40.84	15.45	29.89	45.01	73.36	58.81
22-02-2016	23.01	19.45	16.62	58.56	40.10	50.84	21.18	40.46	32.55
23-02-2016	8.65	0.08	2.26	46.04	20.59	35.77	50.22	79.33	61.97
24-02-2016	38.45	26.57	27.59	48.73	35.91	39.83	17.25	37.52	32.58
25-02-2016	58.44	25.02	45.42	24.19	12.50	18.58	20.41	62.48	36.01
26-02-2016	40.90	23.89	29.28	42.40	24.66	33.01	20.79	51.45	37.71
29-02-2016	21.60	10.55	12.67	56.26	37.07	44.47	27.47	52.38	42.86

Table 4.A3 continued - Daily Information Share Measures; Corn Mar. 2016 (%)

	Price			WP^1			$WP^{2\text{-}10}$		
	IS_M	PT	MIS	IS_M	PT	MIS	IS_M	PT	MIS
01-03-2016	60.32	22.89	48.32	22.99	15.44	19.26	19.12	61.68	32.42
02-03-2016	61.97	28.27	47.08	23.91	9.18	17.82	17.65	62.55	35.09
03-03-2016	29.62	19.26	21.35	58.09	48.08	48.00	16.24	32.66	30.65
04-03-2016	53.52	31.41	37.16	23.90	5.04	18.29	30.24	63.55	44.54
07-03-2016	49.73	28.62	36.22	37.46	28.33	30.87	17.99	43.05	32.91
08-03-2016	35.05	15.90	20.81	41.66	26.61	34.34	31.75	57.49	44.85
09-03-2016	68.75	60.00	62.22	19.62	23.52	19.89	15.35	16.48	17.89
10-03-2016	46.71	27.79	35.01	36.88	25.46	30.02	20.79	46.75	34.98
11-03-2016	25.35	10.11	13.18	28.50	6.92	20.01	56.39	82.97	66.81
14-03-2016	24.20	10.27	15.41	24.82	10.72	19.77	57.35	79.01	64.81
15-03-2016	23.08	7.84	10.94	47.11	22.35	36.15	38.17	69.81	52.90
16-03-2016	32.09	15.25	20.91	24.69	6.50	17.46	49.88	78.25	61.63
17-03-2016	56.04	36.00	40.56	21.77	3.41	15.69	30.28	60.59	43.75
18-03-2016	34.33	24.05	25.18	45.66	33.76	37.10	25.02	42.19	37.72
21-03-2016	15.82	7.45	7.28	60.14	39.13	47.67	29.51	53.42	45.05
23-03-2016	34.78	15.76	21.09	40.04	18.14	30.47	31.96	66.11	48.43
24-03-2016	12.46	3.98	4.80	48.77	30.43	38.34	45.40	65.59	56.86
28-03-2016	12.99	3.07	4.71	39.13	22.42	31.31	55.06	74.51	63.98
29-03-2016	18.57	5.93	7.96	39.98	16.95	30.69	50.35	77.12	61.35
30-03-2016	43.30	22.76	31.51	42.80	33.28	35.32	18.47	43.96	33.18
31-03-2016	31.63	0.90	11.54	28.50	15.20	25.48	57.98	83.90	62.99

Table 4.A3 continued - Daily Information Share Measures; Wheat Nov. – Dec. 2015 (%)

	Price			WP^1			WP^{2-10}		
	IS_M	PT	MIS	IS_M	PT	MIS	IS_M	PT	MIS
23-11-2015	47.57	40.28	36.26	35.79	38.79	37.71	22.01	20.93	26.03
24-11-2015	30.50	7.84	13.01	25.76	11.05	21.71	58.97	81.11	65.28
25-11-2015	27.30	5.77	11.60	39.54	33.06	35.49	45.79	61.17	52.91
27-11-2015	27.93	22.00	18.00	31.74	25.78	29.73	46.77	52.22	52.27
30-11-2015	27.29	11.01	12.85	43.34	33.47	37.40	40.59	55.52	49.75
01-12-2015	52.91	48.36	43.70	37.66	42.17	37.80	14.34	9.47	18.50
02-12-2015	29.53	4.26	11.37	28.56	18.12	24.91	58.35	77.62	63.72
03-12-2015	41.80	27.09	26.99	36.19	40.37	38.39	29.71	32.54	34.62
04-12-2015	34.64	11.19	16.74	28.66	20.87	26.90	50.41	67.94	56.37
07-12-2015	61.65	59.76	50.85	26.52	27.29	27.41	18.52	12.95	21.75
08-12-2015	37.71	26.06	25.04	49.41	62.85	51.45	24.51	11.09	23.51
09-12-2015	50.06	46.93	38.36	30.59	35.30	33.81	27.94	17.77	27.82
10-12-2015	24.47	1.73	10.59	52.93	55.28	47.57	34.54	42.98	41.84
11-12-2015	55.88	52.90	43.58	18.57	7.99	19.72	33.09	39.11	36.71
14-12-2015	28.00	13.84	15.07	41.20	38.44	38.55	40.07	47.71	46.39
15-12-2015	29.07	12.63	15.94	58.14	64.87	54.86	22.73	22.50	29.19
16-12-2015	42.21	30.18	28.64	40.71	44.02	41.77	23.39	25.80	29.59
17-12-2015	56.36	50.20	42.14	20.20	12.42	22.37	30.77	37.38	35.48
18-12-2015	50.45	30.65	31.01	21.49	9.31	22.12	37.98	60.04	46.87
21-12-2015	53.16	43.68	38.18	22.39	12.09	22.70	32.49	44.22	39.13
22-12-2015	55.08	49.87	45.41	32.54	36.19	32.97	17.53	13.94	21.62
23-12-2015	62.96	67.61	59.99	25.07	26.10	25.17	20.37	6.28	14.84
24-12-2015	41.46	40.52	36.09	44.26	56.32	45.39	25.53	3.16	18.51
28-12-2015	50.73	42.99	41.54	33.77	31.25	32.92	19.61	25.76	25.54
29-12-2015	36.75	16.34	19.37	27.90	13.47	23.50	48.41	70.18	57.12
30-12-2015	51.48	43.41	39.59	29.45	28.54	29.96	24.39	28.05	30.44
31-12-2015	20.37	0.58	7.44	29.98	26.03	26.39	60.38	73.38	66.17

Table 4.A3 continued - Daily Information Share Measures; Wheat Jan. 2016 (%)

	Price			WP[1]			WP[2-10]		
	IS_M	PT	MIS	IS_M	PT	MIS	IS_M	PT	MIS
04-01-2016	32.37	18.39	20.10	62.59	81.54	63.73	14.84	0.07	16.17
05-01-2016	52.32	47.86	40.44	25.28	18.88	24.55	30.07	33.26	35.01
06-01-2016	60.39	64.03	52.98	19.10	9.25	17.77	29.40	26.72	29.25
07-01-2016	37.28	19.47	21.27	36.93	37.70	36.95	35.52	42.83	41.78
08-01-2016	37.45	16.98	20.39	33.25	30.77	33.08	39.81	52.25	46.53
11-01-2016	49.09	34.84	32.73	32.86	34.90	35.10	24.57	30.26	32.18
12-01-2016	59.28	50.49	40.39	19.80	13.69	25.90	27.78	35.82	33.71
13-01-2016	72.60	89.51	74.15	18.41	6.54	14.29	17.62	3.95	11.56
14-01-2016	48.20	38.13	33.09	26.03	16.99	25.25	34.30	44.88	41.66
15-01-2016	42.16	29.56	27.33	42.13	49.57	43.82	23.53	20.86	28.85
19-01-2016	34.58	17.11	17.66	31.91	21.18	28.79	45.77	61.71	53.55
20-01-2016	46.62	33.98	28.97	20.70	2.50	18.15	45.33	63.51	52.88
21-01-2016	38.95	20.06	21.98	33.76	24.58	31.23	37.16	55.36	46.79
22-01-2016	38.36	29.87	24.86	27.63	22.71	27.36	41.69	47.42	47.77
25-01-2016	33.50	19.09	19.11	37.19	37.60	36.28	39.19	43.31	44.61
26-01-2016	28.48	11.72	13.47	34.51	24.79	30.33	48.84	63.50	56.20
27-01-2016	41.25	29.95	26.66	39.27	37.01	37.46	27.66	33.04	35.88
28-01-2016	26.73	17.81	16.74	53.55	50.62	48.60	26.79	31.56	34.66
29-01-2016	44.59	35.16	31.46	44.88	51.08	44.66	16.45	13.76	23.87

Table 4.A3 continued - Daily Information Share Measures; Wheat Feb. 2016 (%)

	Price			WP^1			WP^{2-10}		
	IS_M	PT	MIS	IS_M	PT	MIS	IS_M	PT	MIS
01-02-2016	73.73	61.68	65.87	15.88	9.86	12.88	13.98	28.46	21.25
02-02-2016	28.07	7.83	12.54	47.47	38.73	41.31	36.10	53.44	46.15
03-02-2016	23.50	9.59	12.36	47.57	46.27	44.26	37.09	44.15	43.37
04-02-2016	24.72	1.39	7.89	39.69	23.19	32.83	50.70	75.42	59.28
05-02-2016	43.01	27.06	31.11	16.89	0.12	11.27	47.20	72.82	57.63
08-02-2016	50.71	43.17	39.01	35.67	38.73	36.81	18.36	18.10	24.18
10-02-2016	34.06	25.21	21.45	44.55	34.00	38.64	28.73	40.79	39.91
11-02-2016	48.94	37.08	35.13	28.82	16.55	24.66	29.84	46.37	40.21
12-02-2016	43.08	25.45	26.17	23.42	9.36	19.70	45.20	65.19	54.13
16-02-2016	23.10	13.38	12.42	45.23	37.38	40.24	39.08	49.24	47.34
17-02-2016	17.67	10.13	8.50	40.83	26.32	33.41	48.59	63.55	58.08
18-02-2016	45.27	39.89	34.86	36.43	25.47	32.46	23.76	34.64	32.68
19-02-2016	45.51	46.94	39.03	26.57	19.99	24.35	33.37	33.07	36.62
22-02-2016	39.72	23.40	25.96	27.40	13.57	22.15	41.05	63.03	51.88
23-02-2016	35.11	19.98	21.64	29.34	18.25	26.37	43.49	61.77	51.99
24-02-2016	45.75	40.76	35.54	36.39	35.72	37.08	22.71	23.52	27.38
25-02-2016	27.64	4.85	10.61	44.00	28.96	37.23	42.04	66.18	52.16
26-02-2016	18.55	2.15	7.63	66.24	60.69	59.04	21.15	37.16	33.33
29-02-2016	32.76	22.08	19.59	37.20	35.83	35.60	39.10	42.09	44.81

Table 4.A3 continued - Daily Information Share Measures; Wheat Mar. 2016 (%)

	Price			WP^1			WP^{2-10}		
	IS_M	PT	MIS	IS_M	PT	MIS	IS_M	PT	MIS
01-03-2016	38.33	16.93	20.44	30.66	15.92	26.00	43.88	67.15	53.56
02-03-2016	53.16	41.68	39.14	18.73	2.76	15.81	36.68	55.56	45.04
03-03-2016	63.73	59.37	52.68	20.64	13.44	20.81	21.89	27.19	26.50
04-03-2016	38.97	23.97	25.61	39.34	42.22	40.72	28.34	33.81	33.68
07-03-2016	46.08	38.02	35.21	34.79	40.74	36.76	25.09	21.24	28.03
08-03-2016	32.56	17.19	18.86	44.50	34.27	39.69	30.76	48.53	41.46
09-03-2016	27.11	6.48	13.32	54.82	59.33	50.70	28.96	34.19	35.98
10-03-2016	57.61	50.02	47.81	31.43	34.63	30.53	14.41	15.36	21.66
11-03-2016	34.88	21.58	19.97	27.78	20.24	26.06	47.16	58.18	53.97
14-03-2016	24.32	3.02	9.30	30.67	19.73	26.54	57.77	77.25	64.16
15-03-2016	37.34	29.98	25.20	22.15	6.93	17.06	48.68	63.09	57.74
16-03-2016	31.66	15.12	16.67	45.87	30.28	38.69	31.45	54.60	44.64
17-03-2016	59.41	53.30	46.39	22.90	19.12	25.56	23.73	27.58	28.05
18-03-2016	25.75	13.54	14.69	55.87	62.32	53.54	28.38	24.14	31.77
21-03-2016	40.88	22.67	22.63	28.59	17.54	26.10	42.90	59.79	51.27
22-03-2016	51.40	47.95	39.19	17.46	4.41	16.19	39.23	47.64	44.62
23-03-2016	28.09	1.60	9.23	37.60	19.99	30.56	52.35	78.41	60.22
24-03-2016	46.05	32.89	33.73	38.54	34.05	35.12	20.84	33.06	31.16
28-03-2016	30.32	14.89	15.95	36.71	27.09	32.89	42.94	58.02	51.16
29-03-2016	23.16	11.95	13.05	60.58	56.96	54.83	22.53	31.09	32.12
30-03-2016	52.63	38.79	34.13	21.15	7.77	21.90	36.51	53.44	43.97
31-03-2016	46.81	26.50	27.80	27.09	30.44	31.90	34.27	43.07	40.31

Table 4.A3 continued - Daily Information Share Measures; Soybeans Nov. – Dec. 2015 (%)

	Price			WP[1]			WP[2-10]		
	IS_M	PT	MIS	IS_M	PT	MIS	IS_M	PT	MIS
23-11-2015	52.90	48.82	41.64	37.48	43.69	37.99	16.54	7.49	20.37
24-11-2015	25.97	9.33	12.98	50.99	48.21	45.92	32.98	42.46	41.10
25-11-2015	43.23	31.27	27.99	32.79	27.60	32.28	31.81	41.13	39.72
27-11-2015	31.88	19.48	18.80	47.38	46.11	43.83	29.72	34.41	37.37
30-11-2015	28.40	7.63	13.01	50.31	46.40	44.11	33.72	45.97	42.89
01-12-2015	32.91	17.52	18.50	43.69	42.25	41.00	33.43	40.23	40.51
02-12-2015	53.36	42.03	35.84	22.07	3.46	20.04	36.47	54.51	44.12
03-12-2015	48.51	42.18	36.92	37.84	41.64	38.69	19.81	16.18	24.39
04-12-2015	55.08	53.09	46.28	35.49	38.28	36.44	15.48	8.64	17.28
07-12-2015	38.65	19.38	21.84	47.44	47.06	44.26	22.57	33.56	33.90
08-12-2015	44.76	33.77	29.16	35.84	34.37	35.59	27.14	31.85	35.25
09-12-2015	42.21	19.29	22.81	29.57	24.80	30.16	39.62	55.90	47.03
10-12-2015	61.89	62.80	52.26	25.89	18.53	23.93	20.52	18.67	23.81
11-12-2015	35.57	15.85	17.90	35.90	23.63	31.63	40.88	60.51	50.47
14-12-2015	51.75	48.18	40.43	32.02	29.60	31.97	22.95	22.22	27.61
15-12-2015	25.54	3.69	10.45	44.13	40.67	39.03	43.69	55.64	50.52
16-12-2015	41.67	24.92	24.93	33.35	24.15	31.03	33.68	50.93	44.04
17-12-2015	42.74	15.92	22.03	32.20	22.17	30.49	38.17	61.91	47.48
18-12-2015	52.45	41.63	37.03	25.72	17.29	25.92	29.28	41.08	37.05
21-12-2015	31.94	15.12	17.89	43.58	45.57	42.70	33.27	39.32	39.41
22-12-2015	42.01	29.73	25.90	20.56	2.43	16.45	49.25	67.85	57.65
23-12-2015	32.79	23.06	20.73	44.29	38.08	40.39	30.15	38.86	38.87
24-12-2015	29.68	16.64	18.47	50.75	49.52	50.48	24.88	33.84	31.05
28-12-2015	26.60	14.34	13.03	19.96	1.65	14.58	64.33	84.01	72.39
29-12-2015	44.99	43.20	36.61	33.28	32.79	33.85	27.47	24.01	29.53
30-12-2015	29.88	6.05	11.72	27.87	11.35	23.48	58.43	82.60	64.80
31-12-2015	29.91	22.16	19.74	49.33	49.70	47.38	27.77	28.14	32.88

Table 4.A3 continued - Daily Information Share Measures; Soybeans Jan. 2016 (%)

	Price			WP^1			$WP^{2\text{-}10}$		
	IS_M	PT	MIS	IS_M	PT	MIS	IS_M	PT	MIS
04-01-2016	30.43	19.29	16.77	25.75	12.85	21.20	54.22	67.86	62.03
05-01-2016	50.64	40.34	36.45	23.34	9.28	20.28	34.87	50.38	43.27
06-01-2016	28.97	5.38	13.96	57.56	68.22	53.71	26.60	26.40	32.33
07-01-2016	30.23	9.43	14.96	46.08	46.14	42.59	35.75	44.42	42.45
08-01-2016	40.45	36.52	30.53	49.71	57.45	49.24	18.04	6.03	20.23
11-01-2016	41.05	34.00	30.53	43.35	44.76	43.01	21.15	21.25	26.46
12-01-2016	47.58	18.20	26.49	33.51	47.39	38.43	29.24	34.40	35.09
13-01-2016	29.27	17.26	17.44	51.07	59.51	50.52	30.72	23.23	32.04
14-01-2016	27.64	19.31	17.08	60.50	64.71	57.46	20.02	15.98	25.46
15-01-2016	31.94	10.81	14.03	31.97	18.42	27.57	51.10	70.77	58.41
19-01-2016	30.98	6.27	11.69	27.73	8.52	22.53	59.34	85.21	65.78
20-01-2016	46.90	38.96	33.28	35.50	30.08	33.10	24.61	30.97	33.62
21-01-2016	57.71	43.60	42.13	22.29	4.64	17.94	29.59	51.76	39.93
22-01-2016	28.37	1.71	8.64	27.08	3.21	20.46	63.65	95.08	70.90
25-01-2016	51.09	39.77	36.85	29.20	18.45	25.95	27.29	41.79	37.20
26-01-2016	19.78	2.30	7.12	53.48	44.22	44.85	37.24	53.48	48.02
27-01-2016	49.34	40.32	34.52	23.36	9.52	20.51	37.00	50.15	44.98
28-01-2016	36.12	18.16	18.84	39.22	23.64	32.86	36.13	58.19	48.30
29-01-2016	55.40	45.88	42.19	29.25	24.62	27.56	21.57	29.50	30.25

Table 4.A3 continued - Daily Information Share Measures; Soybeans Feb. 2016 (%)

	Price			WP[1]			WP^{2-10}		
	IS_M	PT	MIS	IS_M	PT	MIS	IS_M	PT	MIS
01-02-2016	25.09	5.63	8.61	27.06	6.10	20.52	63.47	88.26	70.87
02-02-2016	42.43	29.11	28.50	33.85	23.00	30.02	30.57	47.89	41.48
03-02-2016	47.61	39.60	36.34	38.76	33.89	35.09	18.66	26.51	28.57
04-02-2016	64.05	72.32	62.73	26.28	23.24	20.88	17.96	4.44	16.39
05-02-2016	49.65	44.14	39.10	36.25	31.89	33.17	19.40	23.96	27.73
08-02-2016	33.45	13.24	15.19	42.98	27.56	35.64	37.50	59.20	49.17
09-02-2016	34.64	14.43	17.71	37.88	31.46	34.27	39.71	54.10	48.02
10-02-2016	28.53	21.27	15.86	39.35	29.22	34.21	41.47	49.51	49.93
11-02-2016	29.86	9.01	13.55	44.16	34.03	38.55	37.99	56.96	47.89
12-02-2016	32.97	17.18	17.25	40.23	26.02	34.23	37.20	56.81	48.52
16-02-2016	40.74	24.25	24.76	36.10	23.48	31.69	31.36	52.27	43.56
17-02-2016	70.71	64.85	65.60	18.06	13.61	15.03	15.34	21.54	19.37
18-02-2016	43.37	28.57	26.48	33.51	20.07	28.47	33.42	51.36	45.05
19-02-2016	15.61	1.79	4.60	54.59	32.63	43.06	37.89	65.59	52.34
22-02-2016	31.72	21.31	19.39	33.34	21.19	27.97	43.18	57.51	52.64
23-02-2016	30.92	22.54	21.30	53.75	42.48	46.14	20.16	34.98	32.56
24-02-2016	47.15	34.59	31.69	26.96	14.24	23.67	35.14	51.17	44.64
25-02-2016	37.42	28.91	25.51	43.07	31.92	37.40	25.72	39.18	37.09
26-02-2016	47.55	31.87	30.98	23.23	2.58	17.05	40.83	65.55	51.97
29-02-2016	34.05	18.50	17.50	36.46	18.21	29.32	41.95	63.29	53.18

Table 4.A3 continued - Daily Information Share Measures; Soybeans Mar. 2016 (%)

	Price			WP^1			WP^{2-10}		
	IS_M	PT	MIS	IS_M	PT	MIS	IS_M	PT	MIS
01-03-2016	23.09	13.12	12.99	51.51	43.25	44.76	32.77	43.64	42.25
02-03-2016	60.46	55.99	52.21	30.30	32.47	28.30	13.26	11.54	19.49
03-03-2016	23.10	7.71	9.44	44.85	28.01	36.42	43.29	64.29	54.13
04-03-2016	24.73	8.22	10.47	30.58	20.61	26.38	56.79	71.16	63.15
07-03-2016	54.99	53.16	50.98	30.73	37.95	31.82	20.75	8.89	17.19
08-03-2016	58.92	36.77	44.87	20.70	1.22	13.45	27.72	62.01	41.68
09-03-2016	39.37	20.86	23.05	36.51	35.73	36.07	33.67	43.40	40.88
10-03-2016	47.75	33.77	35.65	34.52	27.45	31.03	22.93	38.78	33.32
11-03-2016	36.50	29.27	28.46	49.00	54.31	47.63	20.71	16.42	23.92
14-03-2016	31.56	20.91	21.09	48.99	40.85	42.09	26.02	38.23	36.82
15-03-2016	49.18	37.51	36.94	33.86	31.34	31.88	23.31	31.14	31.18
16-03-2016	33.10	29.23	24.92	56.30	59.57	53.08	15.78	11.20	22.00
17-03-2016	33.70	7.09	14.51	42.60	32.89	36.99	39.82	60.03	48.50
18-03-2016	41.19	27.56	27.45	41.14	35.55	36.97	25.15	36.90	35.58
21-03-2016	27.30	4.89	11.16	45.72	36.20	39.07	40.64	58.92	49.77
22-03-2016	32.69	19.68	20.13	49.75	45.39	45.47	24.94	34.93	34.40
23-03-2016	30.37	7.92	11.56	33.84	13.99	27.13	53.37	78.09	61.32
24-03-2016	31.79	8.75	13.35	29.47	9.87	23.64	55.35	81.38	63.00
28-03-2016	26.00	9.85	9.95	26.14	3.63	18.92	62.79	86.52	71.12
29-03-2016	43.42	36.69	34.81	47.14	55.24	48.32	15.37	8.06	16.87
30-03-2016	33.82	28.76	26.22	54.57	63.49	55.06	19.22	7.75	18.72
31-03-2016	65.95	83.32	51.23	23.77	11.64	25.48	23.26	5.03	23.30

Table 4.A3 continued - Daily Information Share Measures; E-mini S&P 500 Nov. – Dec. 2015(%)

	Price			WP^1			WP^{2-10}		
	IS_M	PT	MIS	IS_M	PT	MIS	IS_M	PT	MIS
23-11-2015	53.98	28.35	29.31	34.85	3.12	25.50	22.89	68.54	45.18
24-11-2015	35.12	13.26	12.48	46.57	17.10	35.80	35.23	69.64	51.72
25-11-2015	52.56	28.03	27.79	34.50	1.61	24.81	25.50	70.36	47.40
27-11-2015	49.52	45.38	42.47	40.98	37.14	31.33	13.40	17.48	26.20
30-11-2015	42.25	17.01	16.54	42.51	9.51	32.34	31.74	73.48	51.13
01-12-2015	30.01	10.54	9.59	52.60	21.21	39.58	31.14	68.24	50.83
02-12-2015	43.81	19.24	18.86	41.46	11.99	32.13	31.58	68.77	49.01
03-12-2015	35.62	3.66	11.14	48.89	26.72	38.98	38.05	69.61	49.89
04-12-2015	32.60	7.54	11.07	50.28	28.28	39.75	34.73	64.17	49.18
07-12-2015	54.44	33.32	31.57	32.27	3.61	24.98	28.00	63.08	43.44
08-12-2015	50.40	34.61	30.71	35.64	17.69	29.97	25.43	47.70	39.32
09-12-2015	45.43	12.57	17.25	39.82	6.32	31.15	42.48	81.11	51.61
10-12-2015	52.85	33.39	30.40	31.76	4.98	25.29	31.27	61.63	44.31
11-12-2015	40.19	12.76	16.70	46.23	26.28	37.60	31.39	60.96	45.70
14-12-2015	55.83	39.77	35.18	27.60	10.55	26.09	28.82	49.68	38.73
15-12-2015	30.10	2.79	7.98	52.12	26.39	40.64	36.27	70.82	51.38
16-12-2015	54.86	40.20	35.84	27.27	12.45	25.07	29.07	47.35	39.09
17-12-2015	43.99	19.95	20.49	37.02	11.36	29.30	37.44	68.69	50.22
18-12-2015	48.76	28.71	27.07	35.06	15.11	29.45	29.95	56.18	43.49
21-12-2015	36.29	10.22	12.09	46.54	17.70	36.10	37.12	72.09	51.81
22-12-2015	53.88	35.29	33.68	31.70	8.03	24.49	26.58	56.68	41.83
23-12-2015	44.50	37.66	33.49	42.87	32.86	34.21	18.71	29.48	32.29
24-12-2015	25.85	12.85	10.98	49.62	23.70	37.62	34.76	63.45	51.40
28-12-2015	45.33	20.62	20.19	37.83	4.87	27.71	34.64	74.51	52.10
29-12-2015	29.84	12.83	10.88	47.68	17.51	35.80	35.95	69.66	53.32
30-12-2015	45.17	38.48	34.50	44.50	32.07	33.49	15.73	29.45	32.01
31-12-2015	31.84	8.27	10.84	46.93	20.52	36.39	38.30	71.21	52.77

Table 4.A3 continued - Daily Information Share Measures; E-mini S&P 500 Jan. 2016 (%)

	Price			WP[1]			WP^{2-10}		
	IS_M	PT	MIS	IS_M	PT	MIS	IS_M	PT	MIS
04-01-2016	40.50	13.62	16.12	41.84	16.19	33.26	37.91	70.19	50.62
05-01-2016	37.56	13.38	14.80	47.49	23.10	37.40	31.55	63.52	47.80
06-01-2016	60.51	48.73	45.01	26.29	10.75	22.34	22.22	40.52	32.65
07-01-2016	47.28	18.71	21.19	36.26	6.70	29.12	38.98	74.59	49.69
08-01-2016	42.43	12.29	17.58	41.20	18.90	33.85	37.72	68.81	48.57
11-01-2016	57.74	41.29	37.55	26.23	0.99	22.25	29.80	57.72	40.20
12-01-2016	46.06	20.45	21.92	39.00	16.57	32.38	31.50	62.99	45.69
13-01-2016	51.95	28.45	28.07	32.20	8.07	27.82	32.61	63.47	44.11
14-01-2016	46.03	26.44	25.52	39.84	31.08	35.68	25.97	42.47	38.80
15-01-2016	53.19	31.32	29.60	26.52	0.49	24.55	38.00	68.19	45.85
19-01-2016	46.05	22.94	23.56	40.50	25.36	34.84	27.45	51.70	41.60
20-01-2016	54.08	33.41	31.35	28.59	11.64	27.93	30.47	54.95	40.72
21-01-2016	55.74	37.42	33.01	25.29	2.33	25.22	34.39	60.25	41.76
22-01-2016	41.51	13.58	16.68	43.17	18.81	34.74	35.74	67.60	48.59
25-01-2016	43.50	16.92	18.52	40.99	15.67	33.11	34.94	67.42	48.37
26-01-2016	41.09	38.74	30.73	46.83	49.18	39.59	18.13	12.08	29.68
27-01-2016	52.22	33.60	31.06	31.33	15.81	28.56	28.68	50.58	40.38
28-01-2016	42.63	11.88	17.74	42.51	21.79	35.15	36.15	66.33	47.11
29-01-2016	54.92	36.05	34.16	28.08	2.19	21.98	30.76	61.76	43.87

Table 4.A3 continued - Daily Information Share Measures; E-mini S&P 500 Feb. 2016 (%)

	Price			WP[1]			WP[2-10]		
	IS_M	PT	MIS	IS_M	PT	MIS	IS_M	PT	MIS
01-02-2016	50.20	34.46	31.15	36.75	20.70	30.58	23.56	44.85	38.27
02-02-2016	47.80	23.67	23.25	35.65	7.51	28.18	35.23	68.83	48.57
03-02-2016	57.58	42.53	36.57	25.30	0.93	23.62	31.67	56.54	39.80
04-02-2016	55.96	40.07	34.67	28.89	9.61	26.91	28.55	50.31	38.42
05-02-2016	57.49	51.11	41.93	26.29	22.11	27.61	24.23	26.78	30.46
08-02-2016	48.55	24.31	24.31	35.82	15.10	31.30	32.44	60.60	44.39
09-02-2016	46.63	22.88	23.70	38.26	24.52	34.19	30.19	52.60	42.11
10-02-2016	54.19	35.46	31.33	28.51	4.94	26.28	33.78	59.59	42.39
11-02-2016	54.27	41.58	35.08	28.64	24.28	30.50	25.59	34.14	34.42
12-02-2016	54.00	41.33	35.78	29.43	13.45	25.92	28.02	45.22	38.31
16-02-2016	46.37	19.50	19.27	37.59	3.69	28.65	39.79	76.81	52.08
17-02-2016	45.20	24.35	22.51	38.06	12.61	29.83	32.26	63.04	47.67
18-02-2016	58.15	40.43	38.27	28.74	4.46	22.58	24.98	55.12	39.15
19-02-2016	47.17	24.87	22.72	36.96	8.56	28.88	33.80	66.57	48.40
22-02-2016	39.51	17.92	15.94	42.95	13.12	32.84	34.26	68.96	51.22
23-02-2016	49.40	30.06	27.47	36.61	13.02	29.03	27.35	56.93	43.49
24-02-2016	38.86	18.94	17.93	44.68	25.30	36.26	31.48	55.76	45.81
25-02-2016	46.11	25.09	23.01	38.61	12.84	30.37	30.83	62.07	46.62
26-02-2016	48.14	27.45	24.85	36.01	10.02	28.57	32.00	62.53	46.58
29-02-2016	51.92	35.50	31.66	30.89	9.20	25.30	30.32	55.30	43.03

Table 4.A3 continued - Daily Information Share Measures; E-mini S&P 500 Mar. 2016 (%)

	Price			WP[1]			WP[2-10]		
	IS_M	PT	MIS	IS_M	PT	MIS	IS_M	PT	MIS
01-03-2016	49.15	27.35	25.74	33.95	5.55	25.96	33.14	67.10	48.30
02-03-2016	45.99	23.68	21.91	38.99	11.65	30.59	31.73	64.67	47.49
03-03-2016	49.65	32.81	30.95	36.20	16.62	28.51	24.27	50.57	40.55
04-03-2016	28.27	3.84	8.39	54.02	32.35	42.28	33.63	63.81	49.33
07-03-2016	21.64	0.71	4.98	60.13	35.45	45.56	29.97	63.83	49.46
08-03-2016	34.02	11.61	12.30	49.25	24.61	38.56	33.41	63.79	49.14
09-03-2016	39.78	14.21	14.00	44.54	13.94	34.67	36.15	71.85	51.32
10-03-2016	38.05	10.06	14.48	46.42	26.60	37.65	36.08	63.33	47.88
11-03-2016	46.00	24.76	21.74	39.45	9.34	29.81	31.08	65.90	48.45
14-03-2016	38.81	16.58	13.06	45.09	10.38	34.39	34.20	73.05	52.55
15-03-2016	30.18	13.41	10.60	52.21	22.58	39.39	30.80	64.01	50.01
16-03-2016	30.24	7.19	10.55	52.38	32.90	41.41	33.18	59.90	48.04
17-03-2016	36.32	13.84	12.64	44.76	13.29	34.06	37.14	72.87	53.30
18-03-2016	21.46	4.72	5.48	58.09	28.10	43.11	31.84	67.18	51.41
21-03-2016	24.91	10.82	8.20	55.74	25.61	41.36	30.59	63.57	50.45
22-03-2016	21.66	7.27	6.61	58.42	30.46	43.34	30.47	62.27	50.05
23-03-2016	50.68	34.40	32.99	37.28	19.02	29.12	20.75	46.59	37.88
24-03-2016	38.90	17.98	15.76	44.08	13.36	33.54	31.80	68.66	50.70
28-03-2016	25.28	6.84	6.94	55.41	25.27	41.66	32.61	67.89	51.40
29-03-2016	40.75	18.95	17.02	44.16	14.32	33.89	30.08	66.73	49.09
30-03-2016	21.83	5.85	5.84	57.74	27.28	42.77	31.70	66.86	51.40
31-03-2016	37.13	38.60	32.92	51.89	57.22	41.09	15.38	4.17	25.99

IS_M, PT, and MIS stand for Hasbrouck midpoint information share, permanent transitory information share, and modified information share, respectively.

Table 4.A4 Daily Information Share Measures for the Four-variable model; Live Cattle Nov. – Dec. 2015 (%)

	Price			WP[1]			WP[2-3]			WP[4-5]		
	IS_M	PT	MIS	IS_M	PT	MIS	IS_M	PT	MIS	IS_M	PT	MIS
23-11-2015	40.66	19.50	22.36	38.07	47.67	38.65	22.99	22.91	25.43	15.67	9.93	13.56
24-11-2015	36.18	16.47	18.71	37.27	41.34	35.71	18.79	20.37	23.44	23.21	21.82	22.14
25-11-2015	29.96	14.66	16.63	47.75	54.25	47.07	18.84	16.66	20.90	18.31	14.42	15.40
30-11-2015	37.59	3.04	13.46	30.51	23.65	26.35	35.00	51.25	40.81	17.68	22.05	19.38
01-12-2015	42.93	18.60	22.60	48.34	73.08	46.34	16.31	3.40	18.59	16.74	4.92	12.47
02-12-2015	34.15	1.43	14.20	52.32	73.57	47.80	16.13	4.03	17.95	21.55	20.98	20.06
03-12-2015	58.11	53.80	40.75	23.74	26.07	25.49	16.91	9.43	18.98	16.10	10.69	14.78
04-12-2015	38.72	0.91	12.40	34.36	23.78	26.84	36.85	54.90	41.67	15.39	20.41	19.09
07-12-2015	60.80	64.29	47.20	23.66	22.56	23.58	20.34	10.73	19.28	14.25	2.42	9.94
08-12-2015	43.22	12.32	17.58	26.56	12.14	22.52	42.46	66.19	47.10	8.91	9.35	12.80
09-12-2015	46.30	22.39	22.06	21.52	11.55	21.32	19.13	35.83	29.03	25.85	30.23	27.59
10-12-2015	49.04	18.00	22.31	29.13	31.42	28.92	22.60	32.87	29.95	14.54	17.71	18.82
11-12-2015	49.75	34.84	28.39	24.52	24.49	25.09	13.86	13.60	20.02	23.59	27.07	26.50
14-12-2015	43.18	15.05	17.74	26.64	13.53	23.12	47.15	68.75	51.10	4.11	2.67	8.03
15-12-2015	47.68	14.95	20.29	24.05	5.66	21.57	38.54	68.88	44.29	7.46	10.51	13.86
16-12-2015	48.70	31.47	27.99	19.21	7.75	17.90	17.84	28.96	25.58	25.03	31.82	28.53
17-12-2015	53.97	40.77	32.80	22.53	23.35	25.14	16.34	16.96	22.53	17.61	18.91	19.53
22-12-2015	46.47	24.93	24.38	34.08	40.09	33.28	21.31	23.15	26.73	14.71	11.82	15.61
23-12-2015	60.30	45.34	37.99	21.60	41.03	27.53	14.92	7.41	19.58	17.26	6.23	14.91
24-12-2015	39.97	18.72	20.70	41.36	58.01	38.51	14.24	0.07	16.23	27.47	23.20	24.56
28-12-2015	58.80	54.50	44.18	23.61	23.06	23.70	18.50	13.67	20.73	13.65	8.78	11.38
29-12-2015	40.00	23.31	22.40	42.41	55.50	40.68	16.72	6.56	19.23	18.73	14.62	17.70
30-12-2015	44.51	25.45	24.48	35.64	46.51	35.16	19.95	14.82	23.27	16.77	13.23	17.09
31-12-2015	41.80	26.61	24.79	40.76	48.19	41.12	23.78	18.42	25.06	10.44	6.78	9.03

Table 4.A4 continued - Daily Information Share Measures for the Four-variable model; Live Cattle Jan. 2016 (%)

	Price			WP[1]			WP[2-3]			WP[4-5]		
	IS_M	PT	MIS	IS_M	PT	MIS	IS_M	PT	MIS	IS_M	PT	MIS
04-01-2016	40.66	6.72	15.11	33.48	25.77	26.99	26.41	40.93	33.18	23.15	26.59	24.72
05-01-2016	31.08	5.31	12.88	56.41	68.65	48.50	22.05	17.53	25.36	13.74	8.51	13.26
06-01-2016	60.94	66.84	52.20	22.83	19.44	20.39	16.84	5.63	15.03	18.10	8.09	12.39
07-01-2016	34.35	2.02	11.05	29.75	16.38	22.61	47.06	65.63	49.03	15.26	15.97	17.31
08-01-2016	42.32	2.23	13.98	32.47	15.19	23.59	21.43	46.65	32.45	27.93	35.93	29.97
11-01-2016	50.01	29.57	26.82	28.10	29.61	28.38	21.46	28.80	28.18	14.68	12.02	16.61
12-01-2016	40.55	12.18	15.55	24.78	6.29	19.09	19.75	40.42	29.90	35.04	41.11	35.46
13-01-2016	45.91	22.49	21.86	22.61	11.29	20.63	24.75	39.94	32.99	20.75	26.29	24.52
14-01-2016	40.88	20.41	21.64	45.77	65.64	43.20	18.04	4.59	19.05	19.58	9.37	16.11
15-01-2016	35.84	19.02	19.35	37.30	41.17	35.15	16.87	18.09	22.41	24.79	21.72	23.08
19-01-2016	53.81	54.99	40.43	16.46	7.89	15.77	12.51	4.48	13.16	31.43	32.64	30.63
20-01-2016	34.39	11.05	15.16	41.71	41.53	35.68	23.61	29.21	29.65	19.49	18.21	19.51
21-01-2016	39.05	7.36	15.56	26.01	22.21	23.76	18.69	27.57	25.98	35.00	42.86	34.70
22-01-2016	31.72	5.76	12.19	24.99	23.57	22.53	7.88	17.48	17.60	47.81	53.19	47.69
25-01-2016	40.68	21.21	21.57	35.75	45.04	34.20	11.00	4.05	16.32	26.94	29.70	27.91
26-01-2016	34.24	3.30	11.45	45.86	41.83	36.63	30.13	37.38	34.64	12.82	17.48	17.28
27-01-2016	46.07	24.41	23.46	36.09	41.50	34.44	26.09	29.49	30.70	11.06	4.60	11.40
28-01-2016	51.30	34.29	29.49	21.70	14.07	21.09	20.12	28.31	27.39	18.26	23.33	22.04
29-01-2016	48.68	15.13	20.81	23.11	8.66	22.32	25.39	51.90	34.77	18.67	24.31	22.09

Table 4.A4 continued - Daily Information Share Measures for the Four-variable model; Live Cattle Feb. 2016 (%)

	Price			WP[1]			WP^{2-3}			WP^{4-5}		
	IS_M	PT	MIS	IS_M	PT	MIS	IS_M	PT	MIS	IS_M	PT	MIS
01-02-2016	44.28	13.84	18.81	35.64	31.97	31.50	32.14	46.46	38.37	9.25	7.73	11.32
02-02-2016	44.30	25.15	23.47	25.13	21.34	24.19	13.57	20.95	21.87	26.76	32.56	30.47
03-02-2016	30.50	4.66	12.47	50.33	55.23	45.24	18.74	22.99	25.11	19.29	17.11	17.18
04-02-2016	50.34	36.91	30.40	18.81	5.06	18.06	26.55	38.96	32.77	18.91	19.07	18.77
05-02-2016	49.26	36.15	30.76	27.16	27.25	27.90	19.11	20.76	24.33	16.55	15.84	17.01
10-02-2016	41.32	19.34	20.37	34.03	40.95	31.70	15.42	11.91	21.19	25.14	27.80	26.74
11-02-2016	40.91	11.44	19.40	48.73	68.61	42.89	22.37	15.36	25.69	13.68	4.60	12.01
12-02-2016	49.09	37.63	30.42	16.11	10.20	16.91	11.37	13.44	16.60	33.28	38.72	36.07
16-02-2016	49.72	23.21	23.73	25.08	18.12	25.07	24.84	43.34	34.74	14.07	15.33	16.46
17-02-2016	57.48	61.50	47.48	27.23	28.26	26.29	18.75	6.92	17.59	16.58	3.33	8.64
18-02-2016	33.83	1.03	11.62	41.57	39.53	33.04	22.21	33.57	30.23	26.44	25.87	25.11
19-02-2016	33.56	12.70	15.75	38.22	50.78	35.72	11.68	2.94	16.09	34.89	33.58	32.44
22-02-2016	44.81	21.07	22.57	29.89	28.97	29.43	28.76	38.83	35.05	13.60	11.13	12.95
23-02-2016	55.59	47.79	37.60	17.72	1.30	16.60	33.36	48.40	37.52	10.93	2.51	8.27
24-02-2016	30.77	4.15	10.42	21.88	9.92	17.75	13.51	43.89	28.01	46.35	42.05	43.81
25-02-2016	44.78	24.72	24.46	36.20	45.09	36.70	21.69	18.88	25.10	14.81	11.31	13.74
26-02-2016	39.29	9.88	16.68	41.26	45.56	37.64	27.43	32.97	32.30	13.25	11.59	13.38
29-02-2016	39.75	14.68	16.26	23.47	5.56	18.74	20.66	44.43	32.70	31.87	35.33	32.31

Table 4.A4 continued - Daily Information Share Measures for the Four-variable model; Live Cattle Mar. 2016 (%)

	Price			WP[1]			WP[2-3]			WP[4-5]		
	IS_M	PT	MIS	IS_M	PT	MIS	IS_M	PT	MIS	IS_M	PT	MIS
01-03-2016	50.61	34.22	29.19	22.07	11.88	21.46	33.02	49.28	39.27	12.24	4.62	10.08
02-03-2016	28.09	3.11	10.86	58.15	79.83	52.48	11.84	1.49	15.29	27.26	15.57	21.37
03-03-2016	38.48	21.81	20.97	43.77	55.16	40.90	20.03	14.97	23.01	18.24	8.06	15.12
04-03-2016	40.66	13.04	17.23	31.63	22.26	26.84	30.14	47.50	38.49	16.24	17.20	17.44
07-03-2016	42.46	18.24	20.56	25.48	19.29	24.05	34.00	48.72	41.19	12.61	13.75	14.20
08-03-2016	40.07	8.12	15.64	33.81	27.94	28.84	31.59	48.28	38.45	15.60	15.66	17.06
09-03-2016	36.94	9.00	14.60	33.05	27.21	28.29	43.44	59.06	47.60	8.25	4.72	9.52
10-03-2016	42.80	27.00	23.68	18.69	6.08	16.48	17.86	36.86	28.28	30.00	30.07	31.57
11-03-2016	46.05	28.63	27.33	37.01	45.44	38.62	23.08	22.28	26.37	10.72	3.65	7.68
14-03-2016	33.73	14.68	15.47	18.96	3.16	14.06	51.63	70.50	56.87	12.53	11.66	13.61
15-03-2016	62.39	72.92	60.55	15.27	2.00	10.47	15.85	9.50	12.81	23.62	15.57	16.18
16-03-2016	42.07	38.20	33.30	42.87	52.36	44.85	16.13	7.30	15.59	15.56	2.14	6.26
17-03-2016	62.23	59.35	53.92	20.64	15.93	19.21	19.96	22.04	21.43	9.74	2.68	5.43
18-03-2016	63.12	64.16	52.92	16.72	5.03	15.40	23.59	26.58	25.38	10.53	4.23	6.30
21-03-2016	57.46	52.33	43.25	23.25	22.44	23.01	18.36	15.35	20.68	15.02	9.87	13.06
22-03-2016	56.75	59.34	44.21	21.75	17.47	21.07	13.83	1.81	13.42	24.96	21.37	21.29
23-03-2016	30.40	3.01	12.32	56.58	70.92	50.46	18.87	15.14	22.30	18.10	10.93	14.92
24-03-2016	36.19	5.37	13.70	37.00	34.35	32.44	40.13	53.12	44.26	8.67	7.16	9.60
28-03-2016	38.04	16.77	17.64	22.65	10.62	19.31	51.21	68.39	56.23	4.48	4.22	6.81
29-03-2016	52.41	43.09	35.52	24.54	25.66	25.41	14.29	12.49	18.58	20.17	18.76	20.48
30-03-2016	44.60	9.49	17.67	28.86	16.39	24.43	29.51	51.15	37.09	17.78	22.97	20.81
31-03-2016	44.19	12.25	18.36	30.75	23.08	27.26	36.15	54.48	42.42	8.87	10.19	11.96

Table 4.A4 continued - Daily Information Share Measures for the Four-variable model; Lean Hogs Nov. – Dec. 2015 (%)

	Price			WP[1]			WP[2-3]			WP[4-5]		
	IS_M	PT	MIS	IS_M	PT	MIS	IS_M	PT	MIS	IS_M	PT	MIS
23-11-2015	35.74	14.91	18.75	46.15	54.72	46.27	19.87	18.95	23.03	15.15	11.43	11.96
24-11-2015	34.95	1.71	11.99	25.62	12.89	21.31	52.52	74.10	54.37	10.55	11.30	12.33
25-11-2015	40.95	19.55	20.59	29.88	29.45	29.78	27.10	35.02	32.98	17.63	15.97	16.65
30-11-2015	38.73	16.49	19.46	34.75	49.41	35.61	9.21	1.87	13.43	33.36	32.23	31.50
01-12-2015	46.32	22.58	22.69	24.74	18.43	24.97	38.62	54.97	44.03	7.52	4.03	8.31
02-12-2015	35.39	7.71	13.64	22.20	7.58	18.58	51.97	73.38	54.57	11.42	11.33	13.21
03-12-2015	45.32	19.37	22.71	36.59	46.68	37.01	29.54	33.15	32.37	7.75	0.80	7.90
04-12-2015	53.95	44.05	35.27	15.58	1.95	16.04	20.90	28.85	25.53	20.78	25.15	23.16
07-12-2015	53.51	36.40	30.83	23.74	23.95	26.75	27.16	35.74	33.15	8.76	3.91	9.27
08-12-2015	40.65	5.56	16.45	26.78	28.94	26.54	17.89	28.78	26.20	32.02	36.72	30.81
09-12-2015	38.33	14.62	19.06	41.84	51.56	40.90	20.04	17.87	23.77	17.71	15.95	16.27
10-12-2015	49.49	42.31	35.54	13.74	2.84	13.73	20.65	27.68	25.02	24.28	27.18	25.71
11-12-2015	60.48	60.07	45.75	20.54	16.21	22.32	18.50	12.95	18.56	17.02	10.77	13.38
14-12-2015	43.74	25.08	24.61	31.10	40.43	33.09	14.17	12.96	19.26	22.89	21.53	23.05
15-12-2015	53.84	52.87	37.48	14.80	2.52	15.50	13.82	14.43	16.89	30.64	30.18	30.13
16-12-2015	60.01	62.43	46.73	20.17	12.63	19.70	22.69	18.31	21.69	16.95	6.62	11.87
17-12-2015	62.50	72.97	53.17	17.72	1.84	15.93	24.98	23.95	23.03	15.73	1.24	7.87
18-12-2015	38.53	5.53	15.76	42.95	50.71	35.46	23.00	24.13	26.80	22.16	19.63	21.98
21-12-2015	42.22	12.84	17.98	29.87	26.90	27.29	19.93	34.08	28.90	23.81	26.18	25.83
22-12-2015	37.97	17.67	19.09	34.46	39.80	33.12	18.95	19.08	23.61	24.89	23.45	24.18
23-12-2015	48.48	31.98	28.88	33.16	39.32	34.81	23.72	24.14	27.54	9.90	4.56	8.76
24-12-2015	39.70	10.55	15.08	43.30	40.04	37.68	26.38	31.71	32.70	9.83	17.71	14.54
28-12-2015	43.51	25.32	24.18	27.92	29.51	28.71	18.85	23.81	25.05	21.04	21.36	22.07
29-12-2015	33.94	14.99	16.94	32.42	45.68	32.31	11.26	3.23	14.19	38.38	36.10	36.56
30-12-2015	25.65	0.30	8.78	55.32	60.82	48.45	27.21	29.80	30.66	12.53	9.07	12.11
31-12-2015	28.44	9.64	14.26	60.96	80.24	60.33	17.62	3.11	16.67	13.65	7.00	8.74

Table 4.A4 continued - Daily Information Share Measures for the Four-variable model; Lean Hogs Jan. 2016 (%)

	Price			WP^1			WP^{2-3}			WP^{4-5}		
	IS_M	PT	MIS	IS_M	PT	MIS	IS_M	PT	MIS	IS_M	PT	MIS
04-01-2016	44.26	14.29	19.28	28.09	23.63	26.82	33.45	47.69	40.10	10.65	14.38	13.80
05-01-2016	43.49	25.56	23.08	15.23	13.71	18.97	11.90	25.08	20.59	36.24	35.65	37.36
06-01-2016	45.28	29.77	25.68	21.49	16.27	21.52	30.36	41.77	36.61	18.28	12.19	16.19
07-01-2016	44.38	17.88	20.48	30.58	32.62	30.03	29.86	37.84	34.79	13.04	11.67	14.71
08-01-2016	44.33	18.35	19.63	20.15	1.55	17.26	26.53	47.81	34.82	27.28	32.28	28.30
11-01-2016	44.59	16.90	19.74	18.53	10.32	19.91	13.80	36.31	26.19	33.14	36.46	34.16
12-01-2016	43.79	22.29	23.94	44.90	65.66	44.99	17.80	6.30	19.92	15.07	5.76	11.15
13-01-2016	36.87	8.79	16.61	30.18	42.22	31.15	6.74	9.99	15.04	38.15	39.00	37.19
14-01-2016	42.88	18.60	21.37	39.63	49.11	38.38	24.15	26.10	28.36	13.09	6.19	11.90
15-01-2016	43.76	31.52	26.01	43.17	55.87	41.30	16.29	3.65	18.46	16.28	8.95	14.23
19-01-2016	40.69	18.84	18.54	25.94	17.18	23.20	38.87	52.59	45.15	12.05	11.39	13.12
20-01-2016	34.04	5.44	13.53	46.61	50.17	39.59	20.45	25.43	26.26	19.86	18.96	20.62
21-01-2016	58.21	53.13	44.52	22.05	16.28	22.44	25.78	28.60	28.63	7.73	1.98	4.41
22-01-2016	37.61	18.08	19.15	32.29	28.72	30.50	28.49	34.39	34.83	15.39	18.81	15.51
25-01-2016	53.23	38.92	32.20	23.83	18.41	24.48	26.54	33.18	31.70	9.81	9.48	11.62
26-01-2016	34.89	16.09	17.01	50.90	55.04	48.34	25.09	26.64	29.08	5.04	2.24	5.57
27-01-2016	51.02	48.60	38.40	22.50	21.34	22.26	11.20	1.93	12.00	27.57	28.13	27.35
28-01-2016	38.43	7.76	15.66	18.32	8.97	18.31	21.32	42.94	31.55	37.13	40.33	34.48
29-01-2016	44.29	19.92	21.15	27.41	24.14	26.27	21.02	34.06	29.60	22.19	21.88	22.98

Table 4.A4 continued - Daily Information Share Measures for the Four-variable model; Lean Hogs Feb. 2016 (%)

	Price			WP[1]			WP^{2-3}			WP^{4-5}		
	IS_M	PT	MIS	IS_M	PT	MIS	IS_M	PT	MIS	IS_M	PT	MIS
01-02-2016	41.62	10.80	16.63	27.40	14.57	24.11	42.83	63.98	49.12	7.68	10.65	10.14
02-02-2016	57.74	53.81	41.50	19.86	13.62	21.08	15.19	12.51	18.07	20.44	20.07	19.35
03-02-2016	54.77	56.27	46.65	29.57	30.96	28.61	19.80	10.01	18.03	13.90	2.76	6.71
04-02-2016	49.31	45.91	35.54	15.65	14.69	16.94	9.65	5.56	11.91	35.03	33.84	35.62
05-02-2016	42.35	17.70	19.77	23.83	15.47	22.59	39.44	54.61	46.27	8.96	12.21	11.37
08-02-2016	48.65	36.28	30.93	28.38	33.87	31.82	13.23	12.51	18.45	20.50	17.34	18.80
10-02-2016	47.10	17.53	21.54	35.73	39.98	34.69	28.66	35.81	34.15	6.97	6.68	9.61
11-02-2016	39.93	11.14	18.95	41.75	62.53	41.48	14.47	4.87	19.07	21.81	21.47	20.50
12-02-2016	42.78	10.69	17.11	35.04	27.54	30.09	40.22	59.01	44.10	7.78	2.76	8.70
16-02-2016	34.29	21.99	20.64	55.33	72.64	55.15	17.65	2.96	16.76	14.76	2.41	7.44
17-02-2016	52.55	46.10	37.25	35.04	47.17	36.69	16.42	5.50	17.97	14.89	1.23	8.09
18-02-2016	48.94	30.15	27.65	24.49	24.13	26.62	22.58	32.46	30.31	17.34	13.26	15.43
19-02-2016	59.14	60.54	47.87	27.64	31.83	29.98	16.39	4.29	15.84	13.75	3.34	6.30
22-02-2016	59.53	62.23	49.00	20.71	13.62	18.55	20.07	17.36	21.16	18.43	6.79	11.29
23-02-2016	37.34	0.78	12.49	17.82	0.28	15.94	20.36	54.69	33.43	42.32	44.24	38.15
24-02-2016	50.77	34.59	29.81	31.25	42.51	33.87	20.91	19.73	25.26	12.61	3.18	11.06
25-02-2016	62.46	78.04	55.22	19.72	5.97	15.91	16.46	0.87	12.72	23.97	15.11	16.15
26-02-2016	46.52	33.46	26.91	23.42	22.81	24.22	10.48	12.49	17.94	29.09	31.24	30.93
29-02-2016	40.71	13.65	17.75	31.16	28.12	28.61	27.15	40.79	35.19	18.15	17.44	18.46

Table 4.A4 continued - Daily Information Share Measures for the Four-variable model; Lean Hogs Mar. 2016 (%)

	Price			WP^{1}			WP^{2-3}			WP^{4-5}		
	IS_M	PT	MIS	IS_M	PT	MIS	IS_M	PT	MIS	IS_M	PT	MIS
01-03-2016	32.31	7.13	14.48	46.50	52.13	41.51	22.61	30.15	28.33	19.89	10.60	15.68
02-03-2016	39.86	32.08	22.92	13.34	0.31	12.00	7.39	18.16	14.21	47.71	49.45	50.87
03-03-2016	38.30	10.86	15.91	25.69	18.38	22.96	17.97	37.49	28.41	33.23	33.27	32.72
04-03-2016	52.39	37.43	32.35	24.08	21.94	26.09	26.49	35.91	33.13	10.02	4.72	8.43
07-03-2016	52.77	51.12	35.07	15.23	3.73	15.59	10.90	8.56	14.91	34.59	36.60	34.42
08-03-2016	39.91	26.17	23.26	36.86	35.65	34.14	19.62	27.38	26.51	17.75	10.80	16.09
09-03-2016	52.30	36.33	30.18	25.64	35.78	30.79	21.02	21.40	25.65	14.38	6.49	13.38
10-03-2016	55.32	52.52	38.72	15.73	2.89	16.45	20.54	25.13	23.93	23.35	19.46	20.90
11-03-2016	46.75	24.69	23.48	19.04	9.69	20.07	24.35	44.74	34.41	21.89	20.88	22.04
14-03-2016	45.98	27.92	25.63	35.75	38.49	34.80	26.23	32.94	31.96	9.52	0.64	7.60
15-03-2016	50.79	43.09	35.21	16.50	2.80	14.85	26.21	34.89	31.03	19.28	19.22	18.91
16-03-2016	44.98	26.49	25.01	33.91	50.51	37.10	9.69	1.09	14.81	26.01	21.91	23.07
17-03-2016	61.89	68.47	52.15	20.50	10.05	16.83	22.89	19.85	21.93	14.71	1.63	9.08
18-03-2016	41.13	24.64	22.18	34.71	35.50	32.32	20.45	26.33	26.76	18.21	13.53	18.74
21-03-2016	40.45	36.67	27.52	25.67	23.73	25.28	13.20	14.31	17.29	31.74	25.29	29.91
22-03-2016	46.57	51.09	40.28	35.97	40.53	33.82	15.02	0.02	12.07	21.92	8.35	13.84
23-03-2016	33.99	16.45	16.92	27.06	20.26	23.32	24.67	33.02	30.70	27.46	30.27	29.05
24-03-2016	52.77	37.73	30.30	17.60	14.56	20.48	11.58	12.78	18.38	26.91	34.94	30.84
28-03-2016	51.57	20.96	24.28	29.16	32.15	29.98	23.39	36.14	31.58	10.29	10.74	14.17
29-03-2016	49.49	43.05	36.96	34.60	39.37	35.75	14.55	11.13	16.67	14.35	6.44	10.62
30-03-2016	47.69	24.19	24.03	20.59	10.83	20.16	23.05	38.98	31.50	21.96	26.00	24.31
31-03-2016	45.05	25.90	25.04	30.39	39.50	33.01	14.35	11.87	19.65	22.15	22.72	22.30

Table 4.A4 continued - Daily Information Share Measures for Four-variable model; Corn Nov. – Dec. 2015 (%)

	Price			WP[1]			WP^{2-3}			WP^{4-10}		
	IS_M	PT	MIS	IS_M	PT	MIS	IS_M	PT	MIS	IS_M	PT	MIS
23-11-2015	12.50	0.22	3.42	21.97	8.40	14.24	65.85	73.10	66.10	10.16	18.28	16.24
24-11-2015	44.46	22.55	31.00	18.87	8.36	14.46	32.37	46.94	40.14	11.39	22.15	14.39
25-11-2015	10.68	1.08	2.99	43.53	27.57	33.99	10.14	18.15	15.12	43.04	53.20	47.89
27-11-2015	13.79	7.67	5.97	46.02	26.65	34.89	7.99	21.20	14.65	36.95	44.47	44.49
30-11-2015	70.82	59.71	63.64	17.50	15.35	12.70	12.22	24.20	17.62	6.54	0.74	6.04
01-12-2015	25.90	14.80	13.44	31.18	20.72	23.48	6.06	11.60	13.88	46.03	52.89	49.19
02-12-2015	17.74	0.11	3.10	43.57	16.69	29.93	19.75	42.18	34.68	28.17	41.02	32.30
03-12-2015	61.70	38.16	45.69	20.53	7.04	14.53	17.20	37.37	27.47	7.43	17.42	12.31
04-12-2015	44.11	23.94	26.99	32.11	16.52	22.92	15.36	28.22	22.95	19.55	31.32	27.14
07-12-2015	52.98	28.90	39.42	23.66	12.52	16.85	9.93	11.49	15.59	20.77	47.10	28.14
08-12-2015	33.22	18.88	18.47	40.92	24.63	28.93	13.60	23.11	22.90	24.03	33.38	29.70
09-12-2015	49.56	32.10	31.81	28.48	19.56	22.26	26.88	47.22	35.67	9.45	1.12	10.26
10-12-2015	12.44	3.03	4.24	66.77	54.11	50.86	10.90	9.51	20.33	17.49	33.35	24.57
11-12-2015	46.73	23.71	29.37	29.41	13.44	20.25	24.44	42.63	34.32	10.31	20.22	16.06
14-12-2015	13.10	1.47	3.33	65.31	43.76	48.91	16.46	36.21	28.46	10.95	18.56	19.30
15-12-2015	41.68	23.82	27.19	31.95	17.94	22.72	19.67	41.15	30.96	16.99	17.09	19.13
16-12-2015	35.23	14.13	16.87	44.03	21.76	31.32	23.47	39.42	35.54	9.16	24.69	16.28
17-12-2015	43.53	20.54	24.00	22.25	1.60	13.57	18.76	31.51	27.37	29.56	46.35	35.07
18-12-2015	30.39	10.92	12.49	47.10	26.32	35.35	21.03	34.66	33.17	14.16	28.10	18.99
21-12-2015	33.15	13.01	15.41	27.24	3.16	15.67	45.80	66.99	52.64	12.63	16.83	16.28
22-12-2015	69.93	49.23	60.20	13.75	9.57	9.49	17.32	39.45	24.68	3.94	1.75	5.63
23-12-2015	51.02	48.05	40.93	18.36	7.17	12.46	2.49	3.70	7.60	33.79	41.08	39.01
24-12-2015	33.26	20.39	30.02	21.36	18.16	18.08	7.49	3.99	8.82	40.65	57.46	43.07
28-12-2015	16.87	4.47	5.25	34.39	10.56	21.16	58.01	75.35	62.92	3.87	9.63	10.68
29-12-2015	25.48	9.86	11.27	47.55	26.46	34.63	30.11	53.42	42.50	9.15	10.26	11.60
30-12-2015	17.35	11.19	8.31	23.78	9.71	15.68	1.88	5.71	7.39	63.95	73.39	68.61
31-12-2015	16.68	0.33	2.85	44.44	18.14	29.76	31.51	48.51	41.63	19.55	33.01	25.75

Table 4.A4 continued - Daily Information Share Measures for Four-variable model; Corn Jan. 2016 (%)

	Price			WP[1]			WP^{2-3}			WP^{4-10}		
	IS_M	PT	MIS	IS_M	PT	MIS	IS_M	PT	MIS	IS_M	PT	MIS
04-01-2016	46.36	24.19	29.75	34.89	27.04	25.96	26.22	47.94	36.45	4.24	0.84	7.84
05-01-2016	20.17	17.36	13.93	58.04	59.39	50.59	9.27	6.67	13.13	23.11	16.58	22.35
06-01-2016	29.30	9.12	12.43	24.23	3.17	14.38	56.68	78.94	61.34	8.16	8.77	11.84
07-01-2016	40.96	21.23	23.36	23.58	3.37	14.01	29.60	48.79	36.83	22.75	26.60	25.80
08-01-2016	21.42	12.27	10.91	43.77	29.04	32.94	9.00	19.90	16.77	34.84	38.79	39.38
11-01-2016	28.06	7.84	10.91	38.71	17.13	27.60	30.77	43.02	39.35	17.13	32.01	22.14
12-01-2016	36.67	0.94	11.58	43.59	35.39	30.60	16.26	27.83	26.66	29.57	35.84	31.15
13-01-2016	54.34	37.41	40.13	22.89	16.44	18.15	6.65	8.96	12.76	23.49	37.18	28.97
14-01-2016	17.97	7.97	7.66	56.12	39.21	42.15	8.04	15.93	15.96	25.63	36.89	34.23
15-01-2016	27.51	6.71	8.96	34.15	11.74	22.13	44.60	63.31	50.79	12.35	18.24	18.12
19-01-2016	42.91	25.63	28.60	41.36	34.90	32.82	15.20	25.94	24.80	11.35	13.53	13.77
20-01-2016	36.06	16.37	16.05	35.41	13.60	23.10	20.05	37.71	30.74	24.86	32.32	30.11
21-01-2016	20.24	0.01	3.98	43.94	18.61	31.11	24.02	34.51	34.93	26.12	46.86	29.98
22-01-2016	16.95	5.24	5.18	52.25	31.31	36.68	16.29	32.49	27.46	24.20	30.97	30.69
25-01-2016	30.04	12.59	12.31	31.17	9.21	19.14	21.38	36.30	28.46	36.58	41.90	40.09
26-01-2016	21.23	13.35	10.49	45.36	31.69	31.99	4.55	0.70	11.13	39.71	54.26	46.39
27-01-2016	28.57	14.38	12.80	41.45	24.00	28.41	14.42	28.47	24.28	30.04	33.16	34.51
28-01-2016	35.59	17.27	20.96	28.63	9.71	17.78	9.18	16.98	17.31	36.46	56.05	43.95
29-01-2016	50.41	24.62	35.91	20.82	6.88	14.16	9.72	21.56	19.38	25.13	46.94	30.56

Table 4.A4 continued - Daily Information Share Measures for Four-variable model; Corn Feb. 2016 (%)

	Price			WP[1]			WP^{2-3}			WP^{4-10}		
	IS_M	PT	MIS	IS_M	PT	MIS	IS_M	PT	MIS	IS_M	PT	MIS
01-02-2016	17.92	6.88	6.79	46.00	25.42	31.19	14.51	25.73	22.52	33.95	41.96	39.49
02-02-2016	34.86	18.12	18.97	25.87	4.57	14.57	24.46	41.54	33.74	28.74	35.78	32.72
03-02-2016	29.58	20.65	18.40	35.92	19.44	24.63	9.93	22.64	18.22	33.51	37.27	38.76
04-02-2016	27.72	22.37	18.68	49.49	37.77	38.22	9.53	13.25	18.21	20.88	26.61	24.89
05-02-2016	26.91	8.75	13.15	24.76	0.49	13.54	46.00	59.06	54.73	13.72	31.69	18.59
08-02-2016	16.31	1.17	3.84	45.26	23.43	30.95	40.18	55.55	45.41	11.33	19.85	19.79
10-02-2016	12.01	4.95	5.89	17.17	4.00	9.37	9.34	4.72	10.98	70.58	86.33	73.76
11-02-2016	38.45	19.49	22.62	29.02	10.66	17.81	30.62	49.76	38.83	15.39	20.09	20.74
12-02-2016	58.44	45.49	52.59	33.90	35.52	27.34	7.00	4.37	11.76	4.16	14.61	8.30
16-02-2016	15.60	1.06	4.03	27.34	7.93	17.12	65.20	85.72	68.76	4.66	5.29	10.08
17-02-2016	19.78	18.29	14.66	70.21	57.69	61.42	8.45	11.93	13.43	5.58	12.09	10.49
18-02-2016	28.05	11.59	12.12	31.50	6.58	17.77	36.32	49.92	39.22	21.87	31.91	30.89
19-02-2016	25.04	12.20	11.75	37.47	14.45	22.64	32.29	42.29	34.73	20.46	31.06	30.89
22-02-2016	21.47	19.40	14.37	52.62	35.80	43.16	2.65	5.38	4.25	28.18	39.42	38.22
23-02-2016	15.50	5.16	5.72	35.83	11.57	23.04	14.19	18.69	17.15	47.25	64.58	54.09
24-02-2016	59.17	37.68	44.49	24.97	13.93	17.38	7.96	12.93	13.83	14.92	35.45	24.30
25-02-2016	54.00	22.77	38.35	26.16	11.41	16.70	9.89	18.12	17.00	17.29	47.70	27.95
26-02-2016	24.91	13.99	13.49	51.41	27.41	35.33	19.69	36.19	28.02	12.89	22.41	23.16
29-02-2016	12.94	2.25	3.24	46.64	21.25	30.59	16.11	24.82	22.13	35.85	51.68	44.05

Table 4.A4 continued - Daily Information Share Measures for Four-variable model; Corn Mar. 2016 (%)

	Price			WP[1]			WP^{2-3}			WP^{4-10}		
	IS_M	PT	MIS	IS_M	PT	MIS	IS_M	PT	MIS	IS_M	PT	MIS
01-03-2016	16.30	4.67	6.54	32.53	9.97	19.80	46.11	48.69	46.49	16.97	36.67	27.18
02-03-2016	54.88	27.69	38.37	33.01	19.79	23.72	13.27	26.47	22.64	6.49	26.05	15.27
03-03-2016	16.81	1.99	3.69	33.88	7.35	18.74	48.05	55.05	46.05	21.48	35.60	31.52
04-03-2016	26.26	10.25	12.10	30.74	11.83	19.77	49.85	72.58	55.09	10.48	5.35	13.04
07-03-2016	25.96	7.13	8.56	33.14	6.93	19.06	49.26	65.68	52.51	10.17	20.27	19.88
08-03-2016	36.86	17.25	20.63	37.09	22.54	26.61	11.46	19.86	19.57	26.92	40.35	33.19
09-03-2016	69.54	63.41	61.66	13.70	7.82	10.82	7.12	6.69	10.55	17.34	22.08	16.97
10-03-2016	32.42	12.78	15.85	26.15	0.24	13.10	28.90	46.41	36.59	28.26	40.57	34.46
11-03-2016	15.74	1.47	3.33	41.85	14.54	27.52	35.11	52.13	43.64	20.23	31.85	25.51
14-03-2016	11.53	0.48	2.53	47.11	23.21	34.81	24.68	39.58	35.42	24.75	36.72	27.23
15-03-2016	38.51	15.42	23.89	29.29	13.84	18.71	33.45	50.36	37.25	10.00	20.38	20.14
16-03-2016	15.72	5.44	7.09	24.02	4.49	14.20	55.98	67.41	59.04	13.25	22.65	19.68
17-03-2016	25.85	10.12	12.16	21.88	7.71	13.31	60.46	78.73	63.53	6.16	3.45	11.01
18-03-2016	30.34	22.67	20.65	43.36	31.31	31.22	4.04	7.75	11.81	28.95	38.27	36.33
21-03-2016	13.61	6.06	5.18	59.06	40.71	43.49	11.15	16.64	18.28	23.71	36.60	33.05
23-03-2016	43.72	18.48	26.45	31.95	12.02	20.32	15.85	29.09	24.08	18.91	40.41	29.14
24-03-2016	9.66	1.68	2.64	52.46	33.11	36.56	12.90	28.17	23.31	32.68	37.03	37.49
28-03-2016	13.81	1.97	3.63	52.99	32.44	39.12	23.84	43.01	35.74	18.75	22.59	21.51
29-03-2016	14.72	3.69	4.72	39.45	16.81	25.97	10.29	20.80	19.14	45.80	58.70	50.17
30-03-2016	62.02	34.55	49.06	25.75	24.29	19.56	13.69	34.98	21.73	5.46	6.18	9.65
31-03-2016	40.24	13.09	17.52	32.58	20.96	25.36	31.78	47.75	37.83	15.96	18.20	19.29

Table 4.A4 continued - Daily Information Share Measures for Four-variable model; Wheat Nov. – Dec. 2015 (%)

	Price			WP^1			WP^{2-3}			WP^{4-10}		
	IS_M	PT	MIS	IS_M	PT	MIS	IS_M	PT	MIS	IS_M	PT	MIS
23-11-2015	44.55	35.89	29.35	29.76	30.63	28.20	11.32	12.19	18.81	23.92	21.29	23.64
24-11-2015	35.08	15.23	15.64	31.84	20.82	24.37	18.88	29.66	26.92	30.88	34.29	33.07
25-11-2015	27.56	3.64	9.26	44.01	35.14	33.32	14.63	29.48	25.14	31.25	31.74	32.28
27-11-2015	37.74	12.87	14.85	31.32	11.12	22.18	32.51	54.01	44.22	12.11	22.00	18.76
30-11-2015	27.62	8.90	10.15	45.67	34.66	33.71	13.53	23.43	23.27	28.25	33.01	32.88
01-12-2015	34.06	13.08	14.55	42.37	32.43	32.53	25.57	39.06	33.54	16.44	15.43	19.38
02-12-2015	35.50	10.71	13.99	35.68	25.73	26.87	16.61	35.08	27.72	30.75	28.47	31.42
03-12-2015	41.66	4.11	24.24	34.02	42.37	32.93	10.39	5.89	17.24	27.36	22.97	25.60
04-12-2015	34.81	9.03	13.99	37.03	30.73	29.54	16.01	29.05	25.38	29.60	31.18	31.10
07-12-2015	55.84	53.75	41.66	25.65	26.70	23.64	11.42	4.26	15.26	20.93	15.28	19.44
08-12-2015	43.76	24.91	23.81	32.19	26.68	27.64	22.27	39.62	32.38	20.11	8.79	16.18
09-12-2015	47.61	46.83	33.30	30.36	36.30	28.66	10.55	2.46	15.57	29.79	14.41	22.47
10-12-2015	28.52	2.33	9.36	44.26	38.66	32.77	12.49	19.79	21.06	34.62	39.22	36.82
11-12-2015	55.59	52.81	40.42	18.08	6.84	16.10	11.03	14.10	16.67	28.20	26.25	26.81
14-12-2015	25.87	14.58	12.95	39.53	43.16	34.46	6.33	4.47	13.06	39.75	37.79	39.53
15-12-2015	32.58	0.92	9.48	44.55	30.53	31.79	23.69	45.56	33.97	22.68	22.99	24.76
16-12-2015	37.74	16.27	17.53	36.72	31.52	30.72	18.25	28.48	26.91	22.64	23.73	24.84
17-12-2015	54.06	41.16	34.25	22.13	14.96	20.79	19.92	30.95	27.71	18.11	12.93	17.24
18-12-2015	42.79	18.73	19.76	19.00	5.29	16.34	12.84	23.17	21.21	40.60	52.80	42.69
21-12-2015	48.36	27.07	25.25	22.30	3.85	17.66	23.65	44.07	33.80	20.38	25.01	23.30
22-12-2015	52.11	49.04	41.41	30.40	33.42	27.20	12.79	8.47	15.75	17.35	9.08	15.65
23-12-2015	59.56	62.02	51.85	19.68	14.08	16.41	15.46	14.37	17.50	22.30	9.53	14.24
24-12-2015	37.66	36.78	28.87	40.67	50.58	37.22	17.07	5.73	16.49	27.90	6.91	17.42
28-12-2015	26.54	11.91	11.99	51.98	44.99	43.24	23.35	31.14	30.63	12.57	11.96	14.14
29-12-2015	36.15	17.11	16.81	28.81	16.38	21.43	13.63	20.94	21.40	36.28	45.58	40.36
30-12-2015	55.93	52.25	45.12	24.25	22.55	21.65	12.00	11.85	16.37	19.94	13.34	16.86
31-12-2015	19.05	2.60	6.94	45.52	43.70	37.01	13.09	22.17	20.87	35.42	31.53	35.18

Table 4.A4 continued - Daily Information Share Measures for Four-variable model; Wheat continued Jan. 2016 (%)

	Price			WP[1]			WP[2-3]			WP[4-10]		
	IS_M	PT	MIS	IS_M	PT	MIS	IS_M	PT	MIS	IS_M	PT	MIS
04-01-2016	41.87	16.54	18.79	31.60	20.53	25.28	21.81	39.03	31.87	21.43	23.90	24.07
05-01-2016	53.82	47.08	36.63	17.96	0.45	12.80	14.05	23.69	21.49	28.31	28.77	29.08
06-01-2016	53.55	44.38	36.98	20.79	10.86	17.41	31.61	44.61	37.30	13.10	0.15	8.32
07-01-2016	35.80	24.90	19.19	33.31	40.48	31.44	6.74	0.13	13.61	36.87	34.49	35.76
08-01-2016	40.17	7.21	14.31	35.30	26.47	28.75	43.38	63.50	48.17	3.56	2.82	8.77
11-01-2016	51.56	32.35	29.18	19.49	2.64	16.27	22.19	43.36	32.03	21.65	21.65	22.52
12-01-2016	54.07	43.52	30.70	19.43	15.92	21.05	11.03	6.20	18.51	27.99	34.36	29.74
13-01-2016	44.06	24.22	23.79	34.70	31.16	30.58	22.47	36.57	32.04	15.70	8.05	13.59
14-01-2016	54.57	42.37	36.83	20.32	4.66	15.58	20.66	36.72	28.78	19.18	16.25	18.81
15-01-2016	42.93	19.72	19.91	31.84	24.63	26.70	18.79	35.25	29.69	22.35	20.39	23.71
19-01-2016	34.99	15.04	15.60	35.67	25.27	27.93	18.14	32.74	28.26	27.55	26.96	28.21
20-01-2016	45.46	30.34	24.29	21.19	6.21	16.81	13.71	25.42	22.55	33.82	38.03	36.35
21-01-2016	40.73	17.67	18.57	37.02	27.98	30.14	18.12	26.95	27.06	18.50	27.40	24.23
22-01-2016	42.80	26.20	22.99	30.02	20.56	24.58	24.74	39.39	34.02	19.15	13.85	18.41
25-01-2016	40.74	15.63	17.15	28.60	15.63	21.01	26.13	53.55	37.32	25.52	19.93	24.52
26-01-2016	28.26	10.08	10.43	30.16	17.53	21.20	5.18	11.42	14.73	50.55	60.96	53.64
27-01-2016	44.15	40.04	30.12	35.08	37.96	31.08	9.24	0.39	13.91	24.45	21.61	24.89
28-01-2016	28.10	18.74	15.14	48.13	45.56	38.33	12.16	9.94	18.96	25.40	25.76	27.57
29-01-2016	41.37	15.24	18.00	27.87	10.40	20.17	44.03	69.12	49.24	8.11	5.23	12.58

Table 4.A4 continued - Daily Information Share Measures for Four-variable model; Wheat Feb. 2016 (%)

	Price			WP[1]			WP^{2-3}			WP^{4-10}		
	IS_M	PT	MIS	IS_M	PT	MIS	IS_M	PT	MIS	IS_M	PT	MIS
04-02-2016	33.56	17.95	15.47	28.80	12.99	19.92	6.05	4.83	12.47	46.48	64.23	52.13
05-02-2016	57.49	40.11	43.94	24.06	16.89	18.25	11.34	12.36	16.61	15.44	30.64	21.20
08-02-2016	47.04	24.94	24.55	24.87	5.92	17.94	39.77	64.82	47.06	8.13	4.32	10.44
10-02-2016	28.40	24.17	16.72	43.14	37.52	35.03	6.26	2.69	12.37	32.02	35.62	35.88
11-02-2016	35.87	29.28	22.50	42.43	36.03	35.17	10.40	4.65	15.76	21.97	30.04	26.57
12-02-2016	45.46	29.59	26.47	18.44	3.83	13.44	13.09	25.41	20.92	34.93	41.17	39.17
16-02-2016	20.79	12.02	9.86	44.66	37.63	36.90	7.92	15.98	15.02	35.60	34.36	38.22
17-02-2016	30.79	20.72	17.39	36.72	23.34	28.60	22.83	35.75	31.19	19.12	20.19	22.81
18-02-2016	34.93	21.90	18.54	22.55	4.59	14.22	26.28	37.21	32.25	32.22	36.31	34.99
19-02-2016	24.24	13.53	11.02	20.10	5.98	13.22	25.46	45.06	31.74	44.29	35.43	44.01
22-02-2016	34.79	16.70	17.46	35.72	23.11	28.35	22.93	28.85	30.54	19.10	31.34	23.65
23-02-2016	29.91	3.90	9.17	40.19	23.94	31.99	24.43	39.48	35.39	19.53	32.69	23.45
24-02-2016	38.75	24.53	22.18	38.96	34.34	34.25	23.43	33.65	31.98	13.71	7.48	11.59
25-02-2016	27.49	5.47	9.06	46.83	33.26	34.51	12.99	15.75	19.29	29.85	45.52	37.13
26-02-2016	21.91	10.42	10.18	60.07	55.12	50.66	9.28	5.85	13.54	19.63	28.60	25.62
29-02-2016	33.79	7.35	11.41	30.56	11.82	20.91	22.37	50.90	33.37	33.06	29.93	34.30

Table 4.A4 continued - Daily Information Share Measures for Four-variable model; Wheat Mar. 2016 (%)

	Price			WP^1			WP^{2-3}			WP^{4-10}		
	IS_M	PT	MIS	IS_M	PT	MIS	IS_M	PT	MIS	IS_M	PT	MIS
01-03-2016	34.13	12.56	14.41	43.54	33.87	33.49	16.81	23.03	24.82	20.90	30.55	27.29
02-03-2016	49.53	34.22	31.87	28.04	20.22	24.02	28.59	45.53	36.93	8.32	0.03	7.18
03-03-2016	55.15	42.33	36.10	19.33	7.66	17.08	16.31	24.94	23.92	19.84	25.07	22.91
04-03-2016	30.52	3.45	11.14	45.37	39.49	37.27	21.76	37.44	31.43	21.03	19.61	20.16
07-03-2016	36.10	12.06	14.81	27.57	9.69	18.79	36.48	60.18	42.79	24.54	18.06	23.62
08-03-2016	56.16	38.66	38.52	23.06	10.94	17.95	25.93	41.96	34.79	6.29	8.45	8.74
09-03-2016	25.82	0.52	8.40	56.75	58.64	44.64	21.12	28.58	27.77	17.12	12.26	19.19
10-03-2016	47.81	27.77	27.36	22.24	7.65	16.18	28.31	41.57	35.12	16.11	23.01	21.35
11-03-2016	30.75	7.45	11.97	40.00	30.93	31.70	22.03	39.78	31.85	24.53	21.85	24.47
14-03-2016	36.88	21.05	20.18	40.71	35.07	33.86	22.38	28.48	29.35	14.10	15.40	16.61
15-03-2016	31.68	16.39	14.13	34.34	17.09	24.88	18.00	37.33	30.05	28.63	29.19	30.95
16-03-2016	30.59	12.32	12.81	34.04	16.70	24.24	14.02	16.33	20.14	36.16	54.66	42.80
17-03-2016	63.40	69.35	54.49	16.57	0.07	12.62	17.09	14.64	17.06	19.43	15.94	15.83
18-03-2016	27.34	17.20	14.36	47.51	55.16	41.90	9.34	3.95	14.50	31.72	23.68	29.24
21-03-2016	41.58	21.20	20.11	32.08	24.14	26.23	19.87	35.27	30.09	21.83	19.39	23.57
22-03-2016	41.71	33.97	25.34	22.83	17.98	20.24	8.91	12.37	16.88	36.31	35.68	37.55
23-03-2016	35.59	10.33	12.93	31.54	11.40	20.83	37.60	54.79	43.00	17.75	23.48	23.24
24-03-2016	27.57	4.33	8.60	35.21	15.28	23.76	31.64	48.77	38.38	24.60	31.62	29.26
28-03-2016	29.58	16.98	14.62	34.73	26.94	28.64	9.39	12.40	15.13	37.94	43.68	41.60
29-03-2016	35.07	24.26	21.02	40.95	37.68	34.80	13.49	12.22	18.36	21.97	25.84	25.83
30-03-2016	46.41	26.02	24.13	26.39	21.41	24.35	15.08	26.96	24.95	24.03	25.61	26.57
31-03-2016	47.13	29.40	25.00	24.07	28.16	26.40	9.64	12.97	18.49	28.62	29.47	30.11

Table 4.A4 continued - Daily Information Share Measures for Four-variable model; Soybeans Nov. – Dec. 2015 (%)

	Price			WP[1]			WP^{2-3}			WP^{4-10}		
	IS_M	PT	MIS	IS_M	PT	MIS	IS_M	PT	MIS	IS_M	PT	MIS
23-11-2015	47.58	39.59	31.86	35.68	40.81	33.09	18.35	17.69	23.56	12.75	1.91	11.50
24-11-2015	31.91	16.46	15.61	45.72	41.85	37.21	13.96	19.89	22.57	22.83	21.80	24.61
25-11-2015	34.99	11.97	14.88	41.06	32.94	32.47	23.01	38.92	32.32	19.80	16.18	20.32
27-11-2015	26.23	2.68	8.96	52.00	45.41	39.82	16.35	32.73	26.41	23.41	19.18	24.82
30-11-2015	27.41	12.89	12.52	51.58	56.15	41.49	10.95	3.69	17.26	27.78	27.27	28.73
01-12-2015	28.56	5.32	10.03	41.07	33.13	31.35	9.99	24.23	20.30	36.74	37.32	38.32
02-12-2015	51.72	36.90	31.34	21.84	7.50	17.28	29.57	45.60	36.23	14.05	10.00	15.16
03-12-2015	47.65	27.48	25.37	26.47	13.56	21.32	25.75	43.77	35.37	14.93	15.19	17.94
04-12-2015	42.91	19.91	20.85	26.18	14.23	21.62	39.87	58.03	47.69	6.85	7.83	9.84
07-12-2015	35.48	18.83	17.61	47.14	49.75	40.19	11.04	5.44	16.55	21.53	25.99	25.66
08-12-2015	43.67	22.47	20.17	27.30	12.92	21.22	18.46	34.05	28.05	27.92	30.56	30.57
09-12-2015	36.77	11.78	14.53	26.81	21.39	23.02	8.28	10.37	16.23	45.15	56.46	46.21
10-12-2015	56.08	59.83	45.51	29.49	27.22	24.51	15.76	8.49	17.25	16.30	4.46	12.73
11-12-2015	34.80	15.13	14.95	37.94	27.46	29.44	15.99	22.49	23.40	27.03	34.92	32.21
14-12-2015	40.43	32.22	23.96	34.10	31.83	29.79	12.14	10.23	19.18	25.69	25.72	27.06
15-12-2015	37.40	12.97	14.97	28.57	9.77	19.83	33.32	57.04	41.42	22.08	20.22	23.78
16-12-2015	39.82	21.04	20.08	34.51	26.67	29.34	15.62	23.93	23.74	22.05	28.36	26.84
17-12-2015	39.03	4.90	14.48	36.62	26.30	28.08	20.93	38.45	29.72	24.97	30.36	27.71
18-12-2015	36.97	14.20	15.75	25.25	13.20	20.70	16.04	28.18	23.78	37.55	44.42	39.77
21-12-2015	25.31	2.55	9.41	39.32	39.58	32.99	12.28	17.71	17.79	39.56	40.15	39.82
22-12-2015	31.40	17.63	13.70	20.61	4.47	14.57	7.77	13.68	13.36	54.55	64.22	58.38
23-12-2015	34.10	22.96	20.13	36.45	31.36	30.52	32.93	43.89	38.74	11.01	1.78	10.60
24-12-2015	23.40	0.44	7.52	53.00	49.15	46.76	20.13	25.59	27.56	17.13	24.82	18.15
28-12-2015	24.70	5.48	7.73	29.67	12.36	20.88	12.33	28.70	22.10	46.58	53.46	49.30
29-12-2015	44.37	42.50	33.89	30.92	28.98	27.85	12.26	13.58	17.90	24.63	14.94	20.36
30-12-2015	31.44	8.08	11.21	26.24	9.49	18.56	12.15	25.26	21.58	48.18	57.17	48.65
31-12-2015	28.41	21.62	16.83	45.05	45.90	40.08	8.66	6.37	13.08	29.25	26.12	30.01

Table 4.A4 continued - Daily Information Share Measures for Four-variable model; Soybeans Jan. 2016 (%)

	Price			WP^{1}			WP^{2-3}			WP^{4-10}		
	IS_M	PT	MIS	IS_M	PT	MIS	IS_M	PT	MIS	IS_M	PT	MIS
04-01-2016	22.66	9.01	8.90	41.05	31.03	30.88	10.09	17.80	18.02	38.43	42.16	42.19
05-01-2016	57.08	55.06	45.86	17.82	2.98	11.87	9.99	6.86	12.99	27.37	35.10	29.29
06-01-2016	33.92	10.82	14.72	45.51	45.00	36.71	16.56	26.05	25.48	22.84	18.14	23.08
07-01-2016	26.86	9.21	10.88	42.75	46.36	34.82	6.66	1.61	14.43	39.92	42.81	39.87
08-01-2016	40.13	38.34	28.10	43.19	49.62	38.28	11.82	1.44	15.43	21.45	10.59	18.19
11-01-2016	42.31	39.00	31.29	38.87	41.77	35.43	9.68	4.19	14.04	20.37	15.04	19.24
12-01-2016	49.80	19.63	22.75	29.35	38.86	30.05	16.55	26.30	26.35	18.02	15.22	20.85
13-01-2016	29.88	16.18	14.41	41.29	42.16	34.90	10.04	16.67	19.54	33.32	24.98	31.15
14-01-2016	39.51	16.81	17.82	28.68	11.08	20.14	44.50	67.66	51.54	7.88	4.44	10.50
15-01-2016	30.58	3.20	9.24	36.96	22.21	26.51	12.69	31.53	24.67	38.68	43.06	39.57
19-01-2016	32.05	3.66	9.79	32.07	12.37	21.63	23.76	45.46	32.85	35.11	38.51	35.73
20-01-2016	42.83	34.44	25.67	33.57	27.14	27.29	10.73	7.62	16.91	25.99	30.80	30.12
21-01-2016	48.39	27.41	26.17	24.30	7.75	17.55	28.06	44.48	36.11	14.68	20.36	20.16
22-01-2016	28.47	0.66	7.02	33.40	12.63	21.76	12.79	33.73	24.23	47.16	52.98	46.99
25-01-2016	46.54	32.44	27.83	30.18	20.46	24.24	16.38	23.50	25.06	18.27	23.59	22.87
26-01-2016	21.37	4.91	6.71	50.61	38.89	36.43	11.43	21.65	21.90	30.62	34.55	34.96
27-01-2016	63.41	68.75	57.88	17.56	6.18	10.89	12.09	6.87	13.48	22.16	18.19	17.75
28-01-2016	27.48	0.64	6.91	47.76	30.20	33.66	21.47	38.19	31.15	22.27	30.97	28.29
29-01-2016	49.36	28.74	27.10	23.39	3.26	15.79	22.93	41.28	32.10	20.41	26.73	25.01

Table 4.A4 continued - Daily Information Share Measures for Four-variable model; Soybeans Feb. 2016 (%)

	Price			WP[1]			WP^{2-3}			WP^{4-10}		
	IS_M	PT	MIS	IS_M	PT	MIS	IS_M	PT	MIS	IS_M	PT	MIS
01-02-2016	25.86	6.73	7.93	28.14	8.48	18.40	5.91	20.89	16.71	55.56	63.90	56.95
02-02-2016	38.12	27.56	23.30	32.55	24.05	26.28	6.15	7.71	12.88	31.95	40.67	37.54
03-02-2016	40.43	18.04	18.32	28.33	4.96	17.39	25.62	44.21	35.02	25.85	32.79	29.28
04-02-2016	37.02	11.31	14.13	29.77	7.98	18.47	38.47	60.37	42.88	22.05	20.34	24.52
05-02-2016	46.65	29.49	26.51	27.66	12.61	19.80	21.88	35.37	31.24	17.95	22.53	22.45
08-02-2016	27.99	0.73	7.32	49.65	32.84	33.64	25.36	47.59	35.03	19.12	18.83	24.02
09-02-2016	28.56	7.52	10.49	35.89	31.94	28.13	5.26	3.77	12.94	46.57	56.78	48.45
10-02-2016	28.31	20.93	14.00	38.40	28.31	29.40	9.79	18.71	19.86	34.17	32.05	36.74
11-02-2016	32.67	10.26	12.53	42.86	31.33	32.37	16.66	26.54	26.06	24.24	31.86	29.04
12-02-2016	28.30	6.91	9.57	43.09	25.92	30.82	23.14	38.47	31.78	23.24	28.69	27.83
16-02-2016	34.53	17.35	16.29	34.45	21.46	26.44	10.45	13.92	17.77	33.05	47.27	39.50
17-02-2016	62.19	52.58	51.77	15.38	5.49	10.80	14.23	19.74	19.05	16.36	22.19	18.37
18-02-2016	40.79	28.07	21.57	32.36	19.67	24.45	9.57	8.18	15.28	32.35	44.07	38.70
19-02-2016	13.70	3.75	3.72	51.83	33.17	37.59	6.13	10.26	13.02	37.12	52.82	45.68
22-02-2016	35.42	32.33	25.41	33.57	27.88	27.78	6.07	1.68	9.28	33.21	38.11	37.52
23-02-2016	23.15	13.34	11.82	55.15	41.15	42.96	14.87	24.00	22.22	16.17	21.51	22.99
24-02-2016	38.69	23.47	19.85	28.48	15.18	21.76	12.14	22.26	20.66	33.54	39.09	37.73
25-02-2016	36.91	19.25	17.58	37.52	20.11	26.55	24.54	40.98	34.85	15.65	19.66	21.02
26-02-2016	34.24	12.56	14.80	25.99	6.81	16.27	49.75	69.11	54.55	8.38	11.52	14.38
29-02-2016	31.12	16.59	13.56	36.20	17.71	24.17	12.51	19.23	20.15	36.73	46.48	42.12

Table 4.A4 continued - Daily Information Share Measures for Four-variable model; Soybeans Mar. 2016 (%)

	Price			WP^1			WP^{2-3}			WP^{4-10}		
	IS_M	PT	MIS	IS_M	PT	MIS	IS_M	PT	MIS	IS_M	PT	MIS
01-03-2016	16.70	8.92	7.77	62.45	60.68	51.31	16.84	19.04	23.17	16.80	11.36	17.74
02-03-2016	32.44	2.48	9.80	31.20	9.87	20.07	48.22	66.77	51.70	11.10	20.88	18.43
03-03-2016	24.34	8.39	8.75	46.42	30.61	32.86	17.34	24.97	25.93	26.83	36.02	32.46
04-03-2016	36.64	19.65	18.23	31.87	19.89	24.64	15.60	31.83	26.28	29.39	28.63	30.86
07-03-2016	41.78	22.06	21.90	24.85	5.12	16.49	36.71	62.28	45.64	16.28	10.53	15.97
08-03-2016	39.15	16.78	18.04	35.37	16.27	24.82	28.85	39.52	37.13	12.00	27.44	20.02
09-03-2016	36.00	17.86	17.58	36.93	36.81	31.45	10.03	10.80	17.68	31.41	34.53	33.29
10-03-2016	32.02	10.26	11.61	36.75	16.86	25.18	33.52	47.95	41.46	16.34	24.92	21.75
11-03-2016	42.79	31.65	30.80	37.28	37.98	32.34	17.91	23.24	24.27	13.85	7.14	12.59
14-03-2016	32.63	17.17	15.33	24.58	1.51	14.03	5.87	12.27	13.58	51.12	69.06	57.06
15-03-2016	48.63	31.46	29.13	27.21	14.38	20.45	13.52	24.32	23.01	22.54	29.85	27.41
16-03-2016	33.50	27.12	23.65	48.86	47.94	42.42	15.93	22.60	21.54	12.61	2.35	12.39
17-03-2016	33.06	2.58	10.34	43.58	31.92	31.41	16.96	29.22	25.67	28.26	36.28	32.59
18-03-2016	34.87	16.86	16.36	38.29	26.18	28.74	13.48	20.43	21.22	27.68	36.53	33.67
21-03-2016	27.54	5.69	9.70	45.48	36.12	33.67	13.73	21.29	22.08	30.28	36.90	34.55
22-03-2016	46.09	24.21	24.88	26.89	10.91	19.89	30.48	51.54	40.66	10.75	13.34	14.56
23-03-2016	39.77	17.56	18.03	38.12	23.92	28.25	23.39	40.89	34.57	15.73	17.63	19.14
24-03-2016	36.40	13.91	15.34	35.51	18.96	25.88	19.53	30.78	27.43	25.49	36.35	31.35
28-03-2016	31.76	12.99	14.05	23.32	4.00	14.67	44.65	62.50	49.85	16.04	20.50	21.43
29-03-2016	41.73	21.61	21.40	38.98	30.68	31.86	25.83	39.33	35.28	10.29	8.38	11.45
30-03-2016	25.57	5.68	9.54	31.51	19.36	23.38	50.23	67.72	55.16	10.87	7.23	11.92
31-03-2016	45.80	0.87	18.30	42.54	43.54	30.83	22.67	38.12	29.00	18.11	17.47	21.86

Table 4.A4 continued - Daily Information Share Measures for Four-variable model; E-mini S&P 500 Nov. –Dec. 2015 (%)

	Price			WP^1			WP^{2-5}			WP^{6-10}		
	IS_M	PT	MIS	IS_M	PT	MIS	IS_M	PT	MIS	IS_M	PT	MIS
23-11-2015	36.22	16.08	11.60	47.31	16.64	28.05	29.80	66.29	39.15	12.24	0.99	21.19
24-11-2015	25.37	4.79	5.07	56.11	30.21	34.38	27.37	56.13	39.29	13.51	8.86	21.26
25-11-2015	33.13	13.14	8.86	50.98	20.78	30.87	27.86	59.16	40.97	10.38	6.92	19.29
27-11-2015	35.92	28.48	21.20	50.90	37.69	32.15	16.02	22.40	27.89	9.71	11.43	18.75
30-11-2015	34.05	11.37	8.84	50.55	20.15	30.14	25.74	53.91	38.67	11.95	14.57	22.35
01-12-2015	24.02	5.69	4.71	57.32	29.22	34.35	28.75	61.81	40.38	10.93	3.29	20.56
02-12-2015	31.28	7.61	7.30	54.13	29.08	33.54	26.74	55.21	39.11	11.83	8.10	20.05
03-12-2015	34.76	0.55	7.38	51.85	31.87	32.49	25.21	49.02	35.58	16.83	18.56	24.55
04-12-2015	32.28	5.96	8.16	51.45	30.87	32.16	18.36	30.93	30.53	20.34	32.23	29.15
07-12-2015	42.84	17.58	14.38	44.57	18.88	28.47	25.47	54.86	37.60	11.93	8.67	19.54
08-12-2015	44.39	18.36	15.63	42.83	16.42	27.84	28.62	61.44	38.74	12.26	3.77	17.78
09-12-2015	44.05	7.31	11.42	43.70	11.66	26.44	27.19	53.93	35.43	20.19	27.10	26.71
10-12-2015	38.49	13.45	12.11	47.21	25.69	30.72	28.82	55.39	37.89	13.27	5.46	19.28
11-12-2015	37.93	7.71	10.97	49.41	31.25	31.62	21.37	38.32	31.98	17.20	22.73	25.43
14-12-2015	50.45	24.11	21.86	32.43	13.59	24.28	21.50	46.02	32.48	15.45	16.28	21.38
15-12-2015	29.27	0.13	5.04	54.52	30.97	33.70	21.90	40.00	33.95	17.57	28.90	27.31
16-12-2015	52.58	35.68	28.92	23.64	6.09	17.82	15.38	20.39	22.62	24.01	37.84	30.65
17-12-2015	37.17	6.97	9.66	48.72	25.86	31.76	24.25	49.02	37.23	14.40	18.15	21.35
18-12-2015	45.68	16.18	15.69	39.23	12.57	25.70	28.78	58.60	39.71	11.48	12.65	18.89
21-12-2015	30.84	4.28	6.44	53.03	26.98	32.93	26.63	56.88	38.43	15.18	11.86	22.20
22-12-2015	39.81	15.07	12.92	45.73	18.89	29.14	26.94	58.08	39.64	12.54	7.96	18.30
23-12-2015	54.61	31.98	29.70	31.16	2.73	18.54	17.60	47.37	32.57	11.90	17.92	19.19
24-12-2015	19.36	4.00	3.95	59.47	33.11	38.94	23.01	48.01	40.05	11.59	14.88	17.05
28-12-2015	44.36	17.51	15.13	40.14	6.31	23.34	22.83	50.25	36.26	16.56	25.93	25.27
29-12-2015	22.21	5.67	4.59	56.92	26.63	34.61	19.84	45.83	36.98	16.22	21.87	23.83
30-12-2015	50.07	36.61	32.29	38.02	21.82	23.34	14.05	25.60	25.33	10.74	15.97	19.03
31-12-2015	31.12	5.30	7.31	51.16	25.64	33.02	23.45	43.80	36.42	16.92	25.25	23.25

Table 4.A4 continued - Daily Information Share Measures for Four-variable model; E-mini S&P 500 Jan. 2016 (%)

	Price			WP[1]			WP[2-5]			WP[6-10]		
	IS_M	PT	MIS	IS_M	PT	MIS	IS_M	PT	MIS	IS_M	PT	MIS
04-01-2016	35.74	5.50	8.94	49.89	27.15	31.72	23.43	46.78	35.39	17.60	20.57	23.95
05-01-2016	34.38	9.04	9.49	50.91	28.26	31.52	21.46	39.04	32.84	17.04	23.66	26.15
06-01-2016	46.92	23.73	19.85	40.12	19.56	27.10	27.11	53.26	37.48	9.90	3.45	15.57
07-01-2016	41.77	8.76	12.27	44.75	20.73	28.41	24.12	49.18	34.69	18.33	21.33	24.63
08-01-2016	41.20	9.88	13.24	42.59	22.72	27.67	17.04	30.68	28.31	24.71	36.72	30.78
11-01-2016	48.29	22.55	20.12	36.66	17.24	25.82	21.63	46.09	33.59	13.90	14.11	20.47
12-01-2016	43.57	15.84	15.76	41.83	21.97	27.70	19.50	36.69	30.77	18.25	25.49	25.77
13-01-2016	46.50	18.12	17.83	38.57	19.32	26.52	22.41	45.06	32.84	15.84	17.50	22.81
14-01-2016	50.21	21.09	20.20	33.28	1.76	22.18	31.12	66.77	38.06	13.67	10.38	19.56
15-01-2016	52.70	31.29	25.74	24.28	3.87	19.84	15.11	28.43	24.78	24.72	36.41	29.64
19-01-2016	47.47	14.74	16.45	38.41	4.73	23.78	39.14	78.11	40.69	12.15	2.43	19.09
20-01-2016	48.73	15.92	18.59	36.33	16.80	26.35	26.37	56.36	35.89	12.74	10.93	19.17
21-01-2016	49.39	20.78	20.62	32.61	18.64	25.40	18.91	38.49	29.75	18.52	22.09	24.23
22-01-2016	36.64	5.71	9.53	49.88	29.06	31.51	24.37	47.86	35.04	16.97	17.37	23.92
25-01-2016	40.30	12.20	12.64	44.86	22.51	28.37	20.74	37.45	31.46	19.98	27.85	27.52
26-01-2016	48.39	24.64	20.28	37.13	10.94	23.57	23.64	51.49	34.16	15.19	12.93	22.00
27-01-2016	50.85	24.96	22.43	30.49	5.27	21.44	23.92	48.73	33.40	17.19	21.04	22.73
28-01-2016	40.75	6.80	12.21	46.45	28.03	29.82	21.46	39.28	31.56	20.08	25.89	26.41
29-01-2016	46.56	24.42	20.76	36.46	15.44	24.33	17.12	34.68	29.65	18.85	25.46	25.26

Table 4.A4 continued - Daily Information Share Measures for Four-variable model; E-mini S&P 500 Feb. 2016 (%)

	Price			WP[1]			WP^{2-5}			WP^{6-10}		
	IS_M	PT	MIS	IS_M	PT	MIS	IS_M	PT	MIS	IS_M	PT	MIS
01-02-2016	41.28	11.39	11.69	45.01	16.06	28.04	30.45	64.49	39.88	13.79	8.05	20.39
02-02-2016	43.51	16.93	15.36	41.34	16.23	26.25	19.27	40.03	31.84	19.00	26.81	26.56
03-02-2016	48.82	22.72	20.49	34.87	18.90	25.79	21.41	44.70	32.12	15.98	13.69	21.59
04-02-2016	52.18	29.42	23.96	30.65	9.73	22.76	22.06	45.26	31.34	16.04	15.60	21.95
05-02-2016	47.97	21.86	20.13	37.31	20.32	26.87	30.66	56.72	37.32	12.34	1.09	15.68
08-02-2016	44.14	14.11	15.40	42.24	25.17	28.49	21.70	42.77	32.67	16.72	17.95	23.44
09-02-2016	44.12	16.91	17.04	40.67	29.45	28.71	18.30	31.37	28.99	18.73	22.28	25.27
10-02-2016	45.42	15.00	16.31	40.79	24.77	28.30	22.88	44.71	33.07	16.09	15.53	22.32
11-02-2016	53.26	30.51	25.27	27.18	5.03	21.87	27.04	52.66	34.62	13.59	11.79	18.25
12-02-2016	45.59	21.35	17.81	39.25	18.01	26.52	28.77	53.96	38.43	12.16	6.69	17.24
16-02-2016	40.35	8.89	9.85	45.47	15.77	27.86	30.24	58.86	39.56	14.73	16.48	22.72
17-02-2016	40.47	12.78	11.37	44.49	15.26	27.53	25.64	51.98	38.14	15.12	19.99	22.96
18-02-2016	49.00	28.15	22.99	35.76	13.21	22.87	19.77	39.76	30.78	15.96	18.89	23.36
19-02-2016	35.41	11.50	10.20	48.36	24.24	30.03	23.42	46.25	35.53	17.16	18.01	24.24
22-02-2016	34.10	12.98	9.89	48.72	20.54	29.25	23.53	46.83	36.21	16.40	19.65	24.64
23-02-2016	29.45	10.18	8.50	53.35	31.46	33.06	30.79	57.64	38.70	13.99	0.71	19.74
24-02-2016	31.65	6.20	8.14	53.10	35.06	34.18	28.24	51.85	37.82	13.90	6.89	19.86
25-02-2016	40.55	18.64	14.77	44.40	20.79	27.93	21.90	42.49	34.09	15.19	18.08	23.22
26-02-2016	39.22	16.81	13.71	44.67	21.72	28.12	22.17	42.41	33.93	17.07	19.06	24.23
29-02-2016	34.81	9.13	9.33	50.09	27.91	32.53	29.98	56.74	40.17	13.21	6.21	17.97

Table 4.A4 continued - Daily Information Share Measures for Four-variable model; E-mini S&P 500 Mar. 2016 (%)

	Price			WP^{1}			$WP^{2\text{-}5}$			$WP^{6\text{-}10}$		
	IS_M	PT	MIS	IS_M	PT	MIS	IS_M	PT	MIS	IS_M	PT	MIS
01-03-2016	41.21	20.81	16.83	40.33	17.33	25.19	15.63	27.74	27.83	22.29	34.11	30.15
02-03-2016	38.25	15.43	12.54	46.72	21.82	29.09	23.37	48.01	35.47	15.74	14.74	22.91
03-03-2016	48.25	25.37	21.26	38.50	11.47	24.11	23.95	54.71	36.93	11.20	8.45	17.70
04-03-2016	27.00	0.50	5.18	56.21	36.08	35.30	21.58	44.37	34.98	16.83	19.06	24.53
07-03-2016	21.85	1.25	3.87	58.54	35.72	34.97	18.39	30.84	31.11	18.99	32.20	30.05
08-03-2016	31.06	7.63	7.88	52.50	29.90	32.24	22.09	40.32	33.81	17.37	22.15	26.08
09-03-2016	47.32	24.70	20.25	34.74	5.55	19.70	12.48	13.23	22.10	29.34	56.52	37.95
10-03-2016	35.69	4.93	9.48	49.92	32.19	31.45	22.22	40.23	32.58	19.76	22.65	26.49
11-03-2016	41.53	21.01	15.33	42.77	14.44	25.29	21.52	38.66	32.23	17.75	25.89	27.15
14-03-2016	36.08	14.81	9.61	47.92	14.72	27.67	23.27	43.92	34.87	17.13	26.56	27.86
15-03-2016	24.46	8.24	5.62	56.85	29.60	33.47	21.04	42.34	35.38	14.96	19.83	25.54
16-03-2016	29.52	4.11	7.05	53.97	35.66	34.19	18.97	34.50	31.88	18.58	25.73	26.87
17-03-2016	26.21	5.84	5.32	54.58	26.20	33.12	26.73	56.17	39.51	14.58	11.79	22.05
18-03-2016	19.96	2.96	3.44	58.49	30.77	34.33	21.19	36.81	33.72	17.15	29.46	28.51
21-03-2016	23.97	10.24	6.42	55.48	27.04	31.88	20.07	34.51	32.56	18.27	28.21	29.14
22-03-2016	19.76	4.85	4.06	59.23	33.94	35.09	21.20	40.37	35.01	15.40	20.84	25.84
23-03-2016	56.53	32.80	30.94	31.10	1.03	17.54	14.10	40.29	28.29	12.91	25.88	23.24
24-03-2016	26.48	8.90	6.32	55.08	26.57	33.00	24.39	50.09	38.03	13.54	14.44	22.66
28-03-2016	28.04	8.59	6.92	52.47	23.62	30.34	18.66	27.43	30.21	20.96	40.36	32.53
29-03-2016	33.81	13.67	10.14	50.31	21.89	29.92	21.42	44.31	34.72	16.10	20.13	25.22
30-03-2016	22.43	6.20	4.86	56.83	28.39	33.19	19.31	33.75	32.71	18.07	31.66	29.24
31-03-2016	45.20	17.95	15.08	40.17	3.21	22.88	25.53	57.99	38.32	4.21	20.85	23.73

Table 4.A5 The Information Share Measures (%) – 60 second snapshots

		IS_L	IS_H	IS_M	PT	MIS
	Price	16.28	93.29	54.78	32.43	32.52
Lean Hogs	WP^{1}	2.12	50.44	26.16	33.60	33.75
	WP^{2-5}	2.33	53.61	27.97	33.97	33.72
	Price	16.60	95.65	56.12	32.02	32.77
Live Cattle	WP^{1}	1.40	52.68	26.93	33.73	33.46
	WP^{2-5}	1.29	53.09	27.19	34.25	33.77
	Price	15.08	79.95	47.52	26.69	29.78
Corn	WP^{1}	6.52	59.74	33.02	30.63	32.82
	WP^{2-10}	6.35	51.62	28.98	42.68	37.41
	Price	12.19	87.01	49.60	27.10	29.52
Wheat	WP^{1}	2.81	49.69	26.20	29.24	31.46
	WP^{2-10}	5.50	62.78	34.14	43.66	39.02
	Price	12.35	89.69	51.02	25.49	29.39
Soybeans	WP^{1}	2.97	53.28	28.17	32.57	33.43
	WP^{2-10}	3.42	58.91	31.16	41.94	37.18
	Price	16.44	97.67	57.06	23.07	31.12
E-mini S&P	WP^{1}	0.99	57.38	29.06	40.06	34.61
	WP^{2-10}	0.29	48.42	24.36	36.87	34.27

Table 4.A6 The Information Share Measures for the model with MID (%)

		IS_L	IS_H	IS_M	PT	MIS
	Price	9.88	78.97	44.42	23.76	27.36
Lean Hogs	MID	6.90	65.94	36.42	44.55	38.55
	WP^{2-5}	4.19	61.40	32.80	31.69	34.27
	Price	6.84	75.19	41.02	17.24	23.59
Live Cattle	MID	9.18	75.38	42.28	51.40	41.43
	WP^{2-5}	3.18	61.98	32.58	31.36	34.98
	Price	8.73	43.50	26.11	12.26	15.95
Corn	MID	19.49	77.16	48.32	39.71	40.81
	WP^{2-10}	8.44	58.48	33.46	48.02	43.24
	Price	8.22	64.64	36.43	20.30	22.35
Wheat	MID	9.95	70.25	40.10	41.45	38.38
	WP^{2-10}	6.72	63.75	35.23	38.25	39.27
	Price	5.10	59.67	32.39	14.87	17.78
Soybeans	MID	12.74	77.45	45.10	45.63	41.50
	WP^{2-10}	6.05	65.74	35.90	39.50	40.72
	Price	2.86	52.30	27.58	11.34	14.42
E-mini S&P	MID	21.67	92.34	57.01	61.96	45.87
	WP^{2-10}	0.61	57.46	29.04	26.70	39.34

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Chapter 5. Conclusion

This dissertation investigates three important issues in agricultural sector. In particular, this dissertation examines the evolution of intellectual property rights, the increase in market concentration, and the emergence of electronic trading in agricultural sector in three papers. The first two papers focus on the effect of policies on R&D and through R&D on welfare. The first paper compares three main IPRs with regard to their effect on product R&D investment through the R&D channel on farmers and breeders surplus. The second paper explains how, as a result of different trade and merger policies when firms undertake process R&D, international merger waves can emerge and market concentration increase. The third paper sheds light on the informativeness of the bid and ask price levels beyond the best bid and ask spread in price discovery of agricultural commodity electronic markets.

In the symmetric variation of the model, chapter 2 shows that breeders invest less in R&D with a researcher's exemption if variety differentiation is low or knowledge spillover is high. This chapter also shows that farmers prefer a farmer's exemption in the short run to other IPRs but favor a researcher's exemption or patent in the long run. Moreover, the social planner for most ranges of variety differentiation and knowledge spillover prefers the research exemption over the patent and prefers the patent to the farmer's exemption. The asymmetric variation of the model show that both situations where the researcher's exemption can resolve the common pool problem and increase R&D investment and the case where the researcher's exemption creates free riding problems and lowers R&D investment can arise depending on the level of asymmetry and knowledge spillover. This chapter shows that the more efficient/more endowed breeder invests more in R&D under the researcher's exemption than patents if variety differentiation is high and cost/knowledge endowment dispersion is low. On the other hand, the less efficient/less endowed breeder, generally, invests less in R&D under a researcher's exemption if variety differentiation or cost/knowledge endowment differences are low. Importantly, the results show that for most of the possible range of parameters where the researcher's exemption encourages R&D more than a patent, asymmetric firms *voluntarily* cooperate in research and a social planner intervention may not be required to increase R&D. These findings suggest new gains for society from adopting the 1991version of the UPOV convention.

The second paper (chapter 3) compares two different merger policies when firms are merging *endogenously* and engage in research and development (R&D). In the benchmark model, countries set optimal tariff levels but do not have merger policy. If ex-ante identical firms merge internationally, they have an ex-post cost advantage over the outsiders due to tariff savings. This gives the merger an incentive to increase its R&D investment, which increases the cost dispersion further; therefore, the merger paradox, where each firm wants to be an outsider, disappears when R&D is efficient. As a result, different equilibrium market structures depending on the efficiency of R&D are found. In the second part of this chapter, two different merger policies, one roughly the Canadian merger policy and another one roughly the European Union's merger policy, are compared. The results show that under the "welfare-increasing" merger policy, monopoly is the equilibrium market structure when R&D is very efficient. This explains why a merger, which created a monopoly, was approved in Canada. As R&D becomes less efficient, the equilibrium market structures become less concentrated under the two different merger policies. Each merger policy can be global welfare maximizing depending on the efficiency of R&D; however, the "consumer-surplus-increasing" merger policy is optimal for a wider range of parameters.

The second paper of this thesis fills a gap in the literature since different merger policies have not been compared to our best knowledge. Given that billions of dollars of mergers occur each year, we believe that finding an optimal merger policy has practical implications that will raise the welfare of countries.

The third paper investigate the information share of the price steps beyond the BAS in price discovery for futures markets. The literature on the price discovery in agricultural commodity markets relies on the transaction price and at most to the price steps at the best bid and ask. Chapter 4 of this dissertation fills this gap by reconstructing the LOB that is available to traders in futures markets in real time in order to draw a more accurate picture of the information contained in the steps beyond the BAS. These results provide a better understanding of how the traders utilize the steps farther from the top of the book by submitting limit order in their trading algorithms and strategies.

This is done for five major agricultural commodities namely lean hogs, live cattle, corn, wheat, and soybeans as well as the CME E-mini S&P 500 to examine the informativeness of the LOB across the agricultural commodities and relative to stocks. I find that there is a large number of contracts existing on the bids and asks beyond the best bid and ask for all the products. For agricultural commodities, most contracts exist at the step two and three compared to the BAS and the steps farther from the top of the book. For E-mini S&P 500, we find that the contracts are uniformly distributed along the LOB steps. The results of three information share metrics used show a substantial contribution by over 27% for the steps of the LOB beyond the BAS to price discovery in futures markets, higher than what the literature finds for the stock markets (i.e. Cao et al., 2009). Moreover, the information contained in the BAS and Price is higher for the meats than the rest of the products studied.

Along the LOB steps, the results show that the steps closer to the top of the book have more information relative to the steps farther from the best bid and ask. This contrasts the finding by Cao et al. (2009) and suggests that faked and spoofing trades are less present in the futures markets relative to the stock markets. Considering the daily estimates of the information share metrics, the results show that the steps beyond the BAS but closer to the top of the book contain more information during the early and late weekdays and less information in the middle of the week, mainly Wednesdays creating a V-shaped pattern for the LOB information share for E-mini S&P 500. On the other hand, the steps beyond the BAS but farther from the top of the book have the opposite behaviour and start the week with less information, the information increases and reaches its peak in the middle of the week, and finishes the week with lower information. This means that informed traders in the E-mini S&P 500 futures markets use the steps closer to the top of the book more on the early and late days of the week and the steps farther in the middle of the week. The behaviour of the LOB steps for agricultural commodities appears to be less systematic.

These findings indicate that informed traders in agricultural commodity electronic markets actively use limit orders with price levels beyond the BAS and show the importance of studying the LOB when analyzing different aspects of electronic markets for agricultural commodities.